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Wisconsin Focus on Energy 2022 Technical Reference Manual

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Executive Summary

Under its contract with the Public Service Commission of Wisconsin (the PSC) to evaluate the Wisconsin Focus on Energy programs, the Evaluation Team[1]—in coordination with the Program Administrator, the Program Implementers, and PSC staff—compiled this Technical Reference Manual (TRM). The information contained in this document summarizes the consensus calculations of the electric and natural gas energy savings, and the electric demand reductions, achieved from installing energy efficiency and renewable energy measures that are supported by Focus on Energy programs. This TRM is publicly available online at http://www.focusonenergy.com/about/evaluation-reports.

The values presented in this TRM fall into one of two categories:

- ***Deemed Savings*** are specific per-unit saving or demand reduction values that have been accepted by the Program Administrator, Program Implementers, Evaluator, and the PSC because the measures and the uses for the measures are consistent, and sound research supports the savings achieved.
- ***Savings Algorithms*** are equations for calculating savings or demand reductions based on project- and measure-specific details. This TRM makes these calculations transparent by identifying and justifying all relevant formulas, variables, and assumptions.

This TRM is also a reference guide as to how measures are classified in Focus on Energy's tracking database, SPECTRUM. This document is revised annually to account for changes to programs and measures.

The Evaluation Team leveraged many different primary and secondary sources to derive the calculation algorithms, variable assumptions, and measure descriptions contained in this TRM. These sources include available best practices and industry standards; on-site evaluation, measurement, and verification (EM&V) of savings from Focus on Energy projects; engineering reviews; and reviews of practices used in other jurisdictions. To best represent the Wisconsin climates and demographics, as well as program implementation practices, these energy-savings calculations account for state-specific factors such as climate zones, building codes, and market penetrations.

Update Process

The TRM is updated on a working basis throughout the year, and published once per year. The present edition presents deemed savings and inputs effective beginning April 2021.

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[1] The Evaluation Team consists of Cadmus, Apex Analytics, and Resource Innovations.

Annual updates keep the TRM relevant and useful by:

- Presenting validated savings calculations for any new measures Focus on Energy has begun offering through its programs since the last update;
- Eliminating measures that are no longer being offered through Focus on Energy programs; and
- Updating information on existing measures to reflect new research findings and technology changes.

Two processes are in place for updating the TRM and ensuring that those updates are timely, comprehensive, and accurate. All content updates are integrated into the existing document, with changes indicated in the Revision History table included for each measure entry.

As part of the annual impact evaluation, the Evaluation Team identifies whether measures' recommended savings could be informed by evaluation findings and/or the presence of new research. The Evaluation Team works with the Program Administrator and the PSC to determine whether the findings are significant enough to merit a full review of the measure savings. Further review is typically pursued for those measure(s) that make a significant contribution to overall program savings, as well as when a lengthy period of time has elapsed since the measure was last reviewed, and/or if there is uncertainty regarding the accuracy of the existing savings calculations.

In summer of each year, the Evaluation Team issues the results of its review, including any proposed revisions to savings calculations or other aspects of the existing TRM content. Program Implementation staff, the Program Administrator, and PSC staff review the proposed updates to achieve consensus on final revisions for publication in the TRM.

Focus on Energy Program Implementers may propose adding new measures or revising the entries for existing measures at any time during the year, by preparing a workpaper that follows the structure of a TRM entry. These workpapers are reviewed by members of the Evaluation Team, the Program Administrator, and PSC staff to ensure that the proposed savings calculations are fully and adequately justified. Workpapers that meet this standard must have the following key criteria:

a. A clear definition of the measure;
b. A clear description of how the measure saves energy;
c. A complete description of the calculation algorithms used to calculate savings, which identifies all variables and, where relevant, identifies the standard values to be used as inputs; and
d. Citation of all data to valid sources.

The initial workpaper may be revised to ensure that all criteria are met and to achieve consensus on a final savings recommendation. Workpapers that pass all levels of the review receive formal approval from the PSC.

New measures and revised savings calculations take effect for the programs immediately after the workpaper is approved. Similarly, existing measures are deactivated as soon as they are no longer offered. As a result, the published TRM does not have details for all active measures or savings calculations at every point during the year.

Navigating the TRM

Focus on Energy savings and demand reductions are calculated, and incentives are paid, by measure. Measures are defined as a specific product, technology, or service offered through one or more Focus on Energy programs, for which definable savings can be identified. Some TRM entries describe the savings for a single measure. Other entries address a group of related measures whose savings are calculated in a consistent way, such as measures that offer the same type of lighting product in different wattages.

TRM entries are grouped by technology and function, based on the group designations used to classify measures in SPECTRUM. Most groups are based on technology, including a lighting group with subcategories addressing CFLs, LEDs, and other specific lighting technologies. Some measures are grouped by technology end use, such as laundry or food service. These classifications are used for planning purposes and to categorize savings outcomes in evaluation reports.

Measure Detail Structure

Each entry describes the measure and its savings using the following format:

1. An introductory **Measure Detail Table** summarizes the measure savings and characteristics, including the formal measure name and any information necessary to include the measure in SPECTRUM. The measure detail table also identifies two key characteristics that guide how savings are calculated.

   First, the detail table identifies all sectors in which the measure is offered, which include:[2]

   a. Residential single-family homes;
   b. Residential multifamily dwellings (such as apartment buildings and condominiums);
   c. Commercial facilities;
   d. Industrial facilities;
   e. Agriculture facilities; and
   f. School and government facilities.

   In many cases, the energy savings calculated for a measure will be the same for each sector in which it is used. However, this can vary for measures that are used differently by different customer sectors. For example, research has confirmed that, on average, homeowners, commercial businesses, and industrial facilities use the same lighting product for different

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[2] Because measures that are incented through a markdown on the retail price at the store cannot be clearly assigned to a sector, they are assigned to the “upstream” sector based on the program design.

amounts of time and at different times of the day, resulting in different annual electricity savings and demand reductions.

2. Second, the table documents the measure type, which identifies the process by which savings are calculated. Each Focus on Energy measure is one of the following three measure types:
    a. *Prescriptive* measures have a specific deemed savings value that can be applied to each project within a given sector where the measure is used. This measure type is most commonly used for products that are manufactured and used consistently by all participants, such as light bulbs and appliances.
    b. *Custom* measure savings vary by project. This applies to more complex, multifaceted measures with different energy-use factors for each project, such as changes to industrial processes. TRM entries for custom measures do not identify savings values, but instead specify the savings algorithm that should be used to calculate savings and the source and calculation method used for algorithm inputs.
    c. *Hybrid* measure savings, like custom measure savings, vary by project, and are treated like custom measures in the TRM. The distinction between hybrid and custom measures is that the value of custom incentives also varies by project, while hybrid incentives are the same for each project.

The next three sections describe the measure(s) and how they achieve energy savings. The **Measure Description** defines the product, technology, or service. The **Description of Baseline Condition** identifies the less efficient product or service the customer could purchase in absence of Focus on Energy programs and incentives, while the **Description of Efficient Condition** identifies how the measure incented through Focus on Energy is more efficient than the baseline. Measures achieve energy savings and/or demand reductions based on the difference in energy use and demand between the baseline and efficient conditions.

Formulas are provided to specify the energy savings and demand reduction calculations. The **Annual Energy-Savings Algorithm** identifies how to calculate the electricity and/or natural gas savings achieved per year. The **Summer Coincident Peak Savings Algorithm** identifies the formula used to calculate reductions in electric demand, under the assumption that peak electric demand in Wisconsin occurs weekday afternoons from 1:00 p.m. to 4:00 p.m. in the months of June, July, and August. The **Lifecycle Energy-Savings Algorithm** identifies the formula used to convert annual electricity and/or natural gas savings to the lifecycle savings achieved over the expected useful life (EUL) of the measure. In addition to describing the algorithms used, all three sections specify the values of variables used in the calculation. These inputs may include assumptions about usage behavior or other details obtained through research. For custom and hybrid measures, the algorithms also note which inputs should be calculated on a project-by-project basis, from sources such as engineering reviews, modeling inputs, or on-site measurements. Electricity and natural gas savings are rounded to the nearest integer if their calculated value is 10 kWh or therms or greater, and rounded to two decimals if lower. Demand reduction in kilowatts is always rounded to four decimals.

Savings calculated through those formulas are often reported in the Measure Detail Table. However, in some cases—such as when there are calculations for multiple related measures—there is too much detail to concisely include in the Measure Detail Table. In those cases, a **Deemed Savings** section describes all completed savings calculations. In some cases, an **Assumptions** section may also be added to describe the process of selecting and/or calculating algorithm inputs in greater detail.

All factual statements and figures throughout the measure description include a superscript citation. The **Sources** section lists those citations numerically. For public sources such as published studies, hyperlinks and publication information are provided for the original source. More details on data cited to internal sources, such as historical Focus on Energy data or measure-specific market research, can be obtained from program staff. Initial inquiries can be directed to Mitch Horrie at the PSC, (608) 267-3206, mitch.horrie@wisconsin.gov.

The **Revision History** section has a table with all the revision dates for that TRM entry and briefly describes the changes.

Acknowledgements

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Business (Nonresidential) Measures

Through the Business Portfolio, Wisconsin Focus on Energy delivers energy efficiency and renewable energy programs to nonresidential utility customers in the state. Customers who are eligible to participate in these programs include commercial and industrial firms, agricultural producers, schools, and local governments. With the programs, Focus on Energy aims to help nonresidential customers meet their unique and complex electricity and natural gas needs as efficiently as possible. Focus on Energy accomplishes this by providing information, financial incentives, and support for implementing energy-efficient technologies. These technologies include, but are not limited to, efficient lighting, heating and cooling systems, motors and drives, appliances, renewable energy systems, and custom products specific to key industries, such as food service and agricultural production.

Agriculture

Agriculture Water Heaters

	Measure Details
Measure Master ID	Natural Gas to Natural Gas Commercial Water Heater Storage, 4937 Propane Commercial Water Heater Storage, 4938
Workpaper ID	W0029
Measure Unit	Per water heater
Measure Type	Hybrid
Measure Group	Agriculture
Measure Category	Water Heater
Sector(s)	Agriculture
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Annual Propane Savings (Gallons)	Varies by measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Lifecycle Propane Savings (Gallons)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Natural gas to natural gas or propane = $3,521.92 (MMIDs 4937 and 4938);[2,6]

Measure Description

This measure is replacing a less efficient water heater with a newer high-efficiency model that is code-compliant and delivers hot water at the same temperature and flow rate as the baseline water heater, using less energy. Dairy farms require a commercial-sized water heater to meet the farming hot water needs. This does not include measures for switching to an electric tankless water heater. AHRI listings are used as the valid form of third-party verification to ensure water heater quality and efficiency standards.

Description of Baseline Condition

New water heater units are intended to be installed when the existing unit has failed or is judged to have reached its end of life. Therefore, the baseline unit is a new conventional electric, natural gas, or propane storage water heater intended for service in a commercial and industrial building. Per an ACEEE report,[3] the following baseline efficiency energy factor ratings are assumed:

- Electric water heater: 0.90 EF
- Natural gas water heater: 0.59 EF

Description of Efficient Condition

The minimum requirements for the new high-efficiency replacement water heaters are as follows:

- ***Gas Storage to High-Efficiency Gas Storage or High-Efficiency Tankless Gas:*** New natural gas or propane water heater must have a thermal efficiency of ≥90% as rated by AHRI.
- ***Electric Storage to High-Efficiency Electric Storage:*** Electric commercial-rated water heater must have a thermal efficiency of ≥98% and a standby loss of ≤0.64% per hour as rated by AHRI.

Annual Energy-Savings Algorithm

Electric Water Heaters

$kWh_{SAVED} = Btu_{SAVED} / 3{,}412$

Where:

Btu_{SAVED} = Calculated as shown below for natural gas and propane water heaters

3,412 = Conversion factor from Btu to kWh

Natural Gas and Propane Water Heaters

$Gas_{SAVED} = Btu_{SAVED} / ConvF$

$Btu_{SAVED} = GPY * \rho_{WATER} * C_{P,H2O} * \Delta T * [(1 / EF_{BASELINE}) - (1 / EF_{EFFICIENT})]$

Where:

Gas_{SAVED} = Therms of natural gas or gallons of propane saved

GPY = Annual hot water usage (= GPD * 365)

GPD = Average gallons of hot water usage per day (= 2.75 gallons per cow per day * number of milking cows being served by water heater (as defined by user), or * maximum amount of hot water that can be supplied by the total number of purchased water heaters during two one-hour milking sessions;[2] see Assumptions; Note that for hybrid calculations, use the lesser of these two approaches to determine the annual water usage)

365 = Number of days in a year

ρ_{WATER} = Density of water (= 8.33 lbs/gallon)

$C_{P,H2O}$ = Specific heat of water (=1 Btu/lb-°F)

ΔT = Change in temperature (= $Temp_{HOT\_H20} – Temp_{COLD\_H20}$)

$Temp_{HOT\_H20}$ = Average dairy farm water heater setpoint temperature (= 170°F)[2]

$Temp_{COLD\_H20}$ = Assumed starting water temperature (= 103°F; see Assumptions)

$EF_{BASELINE}$ = Efficiency metric for baseline water heater (= 0.90 EF for electric storage, = 0.59 EF for natural gas storage;[3] see Assumptions)

$EF_{EFFICIENT}$ = Efficiency metric for efficient water heater (for commercial-rated water heaters = $M * C_{P,H2O} * \Delta T / Q_{in}$)[4]

M = Mass of hot water being used per day (= GPD * 8.34 lbs/gal)

Q_{in} = Daily Btu consumption of water heater (= $GPD * \rho_{WATER} * C_{P,H2O} * \Delta T / \eta_{RE} * (1 - \text{Standby Loss} / P_{in}) + 24 * \text{Standby Loss}$)[4]

η_{RE} = Recovery efficiency of water heater (%), assumed to be equivalent to the AHRI-rated thermal efficiency of the new commercial water heater

Standby Loss = Standby heat loss value (Btu/hour = % / hr * P_{in}) as rated by the AHRI certificate of the new commercial water heater (conversion for commercial electric water heater ratings must be performed based on the AHRI-stated percentage of loss per hour rating)

P_{in} = AHRI-rated input power of water heater (for commercial electric resistance conversion, Btu/hour = 3,412 * element kilowatt rating)

24 = Number of hours in a day

ConvF = Fuel conversion factor (= 100 MBtu per therm, = 91.3 MBtu per gallon of propane)[7]

Summer Coincident Peak Savings Algorithm

There are no peak coincident savings for these measures.

Lifecycle Energy-Savings Algorithm

$Gas_{LIFECYCLE} = Gas_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

- The actual water heater unit volume rating will be used, or a default of approximately 100 gallons[2] if unknown. This is the amount of water that is ready and at full hot water capacity prior to the start of each milking session.
- It is assumed that the cleaning of dairy pipeline equipment takes place within one hour after the milking session is complete to prevent the growth of bacteria. It is also assumed that the main water heating demand will take place within one hour after each milking session.
- Savings are based on a flat assumption (based on field experience from AgSG program Energy Advisors) that approximately 75% of Wisconsin dairy farms use a refrigeration heat recovery unit that pre-heats well water from the refrigeration system's waste heat and feeds that well water to the main water heater. Preheated refrigeration heat recovery output water is around a conservative 120°F and average well water temperature is 52.3°F,[5] and a 75/25 split of those two temperatures is assumed to determine a mixed deemed average of approximately 103°F incoming water heater temperature.
- Estimating the actual dairy hot water usage on a farm is quite volatile depending heavily on farm management and farm size. Several sources were evaluated and through engineering judgement, a realistic estimated average of 2.75 gallons of hot water per cow per day was used for this analysis.[2]
- A user-defined input is provided for the number of milking cows, assumed to be the average number of animals being milked throughout the entire year that are being served by the water heaters.
- This entry includes measures for gas-fired equipment eligible to both natural gas and propane customers. The Code of Federal Regulations,[8] upon which federal efficiency standards are based, defines *gas* as either natural gas or propane (§430.2 for consumer appliances, and §431.2 for commercial and industrial equipment). Thus, it is assumed that equipment efficiencies, costs, etcetera are equal for both fuel types. Any infrastructure or maintenance costs unique to each particular fuel were ignored.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. "Historical Data for Ag HW Measures.xls"
The Water Heater Costs tab shows historical SPECTRUM data of 59 agricultural water heater project costs for the two workpaper measures. Project dates ranges from June 2012 through August 2016. The water heater size in gallons of past projects is also reported in this file.
The HW Use tab shows sample data of 33 refrigeration heat recovery per water heater projects entered in SPECTRUM from April 2015 through July 2016. These projects were hybrid in nature

and the hybrid calculations provided an estimated hot water usage in gallons per day, hot water temperature, and number of milking cows per farm. The projects' hot water usage was combined with the recorded number of milking cows on the farm to estimate the amount of water usage per cow per day. Six additional sources also provided estimates of hot water usage per cow per day, ranging between 0.73 gallons and 4.75 gallons. A conservative engineering judgement of 2.75 gallons of hot water per cow per day was used. The projects' recorded hot water temperatures averaged close to 170°F.

The Water Recharge Calculation tab has additional support about the hybrid method to determine the maximum water supply provided for specific water heaters purchased for individual milking session cleaning needs.

3. Talbot, Jacob (American Council for an Energy-Efficient Economy). "Market Transformation Efforts for Water Heating Efficiency." ACEEE Report A121. January 2012. http://aceee.org/sites/default/files/publications/researchreports/a121.pdf
4. Lawrence Berkeley National Laboratory and Pacific Northwest National Laboratory. "WHAM: A Simplified Energy Consumption Equation for Water Heaters." p. 2–4. http://aceee.org/files/proceedings/1998/data/papers/0114.PDF
5. U.S. Department of Energy. "Domestic Hot Water Scheduler."
   Average water main temperature of all locations measured in Wisconsin by scheduler, weighted by city populations.
6. Wisconsin Focus on Energy historical project data obtained from SPECTRUM.
   Average cost of six units over five projects from 2017 to 2018 was $5,248.13. August 2018 online lookups of five baseline models on www.homeperfect.com, www.afsupply.com, and www.homedepot.com show an average baseline price of $1,726.21. The incremental cost is therefore $5,248.13 - $1,726.21 = $3,521.92.
7. U.S. Energy Information Administration. "Energy Units and Calculators Explained." Accessed December 2018. https://www.eia.gov/energyexplained/?page=about_energy_units
8. Electronic Code of Federal Regulations. §430-431. Accessed February 2019. https://www.ecfr.gov/cgi-bin/text-idx?gp=&SID=92c3f99c51e1124fcc790d11c93e04af&mc=true&tpl=/ecfrbrowse/Title10/10CIIsubchapD.tpl

Revision History

Version Number	Date	Description of Change
01	10/27/2016	Initial release
02	12/2018	Updated incremental cost
03	3/2019	Added propane measure
04	12/2019	Removed residential-type references, added new MMIDs for natural gas and propane measures
05	04/2021	Removed electric measures

Horticultural Lighting, Agriculture

	Measure Details
Measure Master ID	Horticultural Lighting, Non-Stacked Indoor, Agriculture: <700 W LED, Replacing 1,000 W HID, 5024 <400 W LED, Replacing 600 W HID, 5025 Horticultural Lighting, Supplemented Greenhouse, Agriculture: <700 W LED, Replacing 1,000 W HID, 5026 <400 W LED, Replacing 600 W HID, 5027 <250 W LED, Replacing 400 W HID, 5028
Workpaper ID	W0253
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Non-Stacked = 10 (MMIDs 5024 and 5025), Supplemented = 20 (MMIDs 5026, 5027, and 5028)[1,3]
Incremental Cost ($/unit)	1,000 W Replacement = $700.58 (MMIDs 5024 and 5026), 600 W Replacement = $492.34 (MMIDs 5025 and 5027), 400 W Replacement = $513.69 (MMID 5028)[2]

Measure Description

These prescriptive measures, part of the horticultural lighting offerings developed in 2020, are replacing 400 watt to 1,000 watt HID lighting with LED horticultural lighting fixtures. A mix of non-stacked indoor and supplemented greenhouses is anticipated. Supplemented greenhouses use electric lighting to extend the hours of daylight, supplement low levels of sunlight on cloudy days, or disrupt periods of darkness to alter plant growth. Non-stacked indoor greenhouses grow plants in a single layer along the floor, under ceiling-mounted lighting.[3]

Large-scale lighting upgrades, for new construction or existing buildings, are better suited to using the wattage-reduction-based hybrid measures (MMIDs 5032 and 5033).

Description of Baseline Condition

The baseline equipment is HID lighting ranging from 400 watts to 1,000 watts.[3]

Description of Efficient Condition

The efficient condition is a DLC–listed fixture in the Horticultural Lighting category or a fixture that meets three requirements:

- Fixture photosynthetic photon efficacy ≥2.0 µmol/J (DLC requirement is ≥1.9 µmol/J)[4]
- Five-year minimum warranty
- Appropriate Horticultural Lighting designation by OSHA NRTL or SCC-recognized body

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Power consumption of baseline equipment (= 1,079 watts for MMIDs 5024 and 5026; = 663 watts for MMIDs 5025 and 5027; = 455 watts for MMID 5028)[5]

$Watts_{EE}$ = Power consumption of efficient equipment (= 625 watts for MMIDs 5024 and 5026; = 361 watts for MMIDs 5025 and 5027; = 184 watts for MMID 5028)[5]

HOU = Hours of use (= 5,475 for non-stacked indoor [MMIDs 5024 and 5025], = 2,120 for supplemented [MMIDs 5026, 5027, and 5028])[3]

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= 1.0 for non-stacked indoor [MMIDs 5024 and 5025], = 0 for supplemented [MMIDs 5026, 5027, and 5028]; see Assumptions)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years for non-stacked indoor [MMIDs 5024 and 5025], = 20 years for supplemented [MMIDs 5026, 5027, and 5028][1]

Deemed Savings

Average Annual Deemed Savings for Horticultural Lighting

Measure		MMID	Agriculture	
			kWh	kW
Non-Stacked Indoor	<700 watt LED, replacing 1,000 watt HID	5024	2,486	0.454
	<400 watt LED, replacing 600 watt HID	5025	1,653	0.302
Supplemented Greenhouse	<700 watt LED, replacing 1,000 watt HID	5026	962	0
	<400 watt LED, replacing 600 watt HID	5027	640	0
	<250 watt LED, replacing 400 watt HID	5028	575	0

Average Lifecycle Deemed Savings for Horticultural Lighting

Measure		MMID	Agriculture
Non-Stacked Indoor	<700 watt LED, replacing 1,000 watt HID	5024	24,860
	<400 watt LED, replacing 600 watt HID	5025	16,530
Supplemented Greenhouse	<700 watt LED, replacing 1,000 watt HID	5026	19,240
	<400 watt LED, replacing 600 watt HID	5027	12,800
	<250 watt LED, replacing 400 watt HID	5028	11,500

Assumptions

The EUL for horticultural lighting fixtures is different than the EUL for non-horticultural lighting and is limited by the current test procedures. There are several methods for determining how many hours a fixture will remain viable for users.

- The most common way to measure non-horticultural LED fixtures is the L_{70} measurement, which determines how many hours a fixture will maintain 70% of the total original lumen output.
- For horticultural lighting, the industry standard is either the L_{90} or Q_{90} measurement, or the number of hours a fixture can maintain 90% of its original output.

Since most horticultural lighting fixtures are relatively new to the market and it is generally not possible to complete a full life-cycle output test before bringing to market, the accepted method of calculating the L_{90} and Q_{90} values is the TM-21 test procedure.[4] This procedure requires a test period of up to 10,000 hours (and sometimes 12,000 hours) to predict the L_{90} and Q_{90} values, but with a maximum L_{90} and Q_{90} value of six times the test period. Horticultural lighting fixtures therefore may perform with outputs at higher than 90% of their original rate for much longer than established by the TM-21 test method, but the company can only list six times the test period as their L_{90} or Q_{90}.

In determining the EUL for new LED horticultural measures per the TM-21 test procedure,[4] manufacturer specification sheets for numerous DLC-listed horticultural lighting fixtures were reviewed. Some manufacturers list that their fixtures maintain L_{90} or Q_{90} requirements for greater than the value listed because they could only project out to six times their testing period. For horticultural lighting, the Q_{90} values are a better indicator of fixture effectiveness, but L_{90} were used when Q_{90} values were unavailable. (Only specification sheets for 600 watt and 1,000 watt replacement LED fixtures were available, so a similar average lifetime hours for the 400 watt replacement fixtures was assumed.)

The coincidence factor for a supplemented greenhouse is assumed to be zero because incident light levels during peak demand periods are typically adequate aside from cloudy days. Non-stacked indoor greenhouses with 100% artificial lighting will use 100% of their lights during peak hours in the summer.

The DLC list of products is expanding rapidly. At the time of this workpaper development, only five 400 watt replacement fixtures were listed to determine the incremental cost of MMID 5028. This workpaper will be reviewed in one year to update the incremental costs for all measures.

Sources

1. MaxLite. Website. Accessed March 2020. https://www.maxlite.com/products/photonmax-horticulture-led-spot-light
   Osram. Website. Accessed March 2020. https://fluence.science/
   Illumitex. Website. Accessed March 2020. https://illumitex.com/products/neopar/
   The average specification sheet rated a Q_{90} or L_{90} of 57,433 hours for 600 watt and 1,000 watt replacement LED fixtures. With an HOU of 5,475 for non-stacked indoor units, their EUL is 10 years. With an HOU of 2,120 for supplemented units, their EUL is capped at 20 years.
2. HTG Supply. Website. Accessed March 2020. www.htgsupply.com
   LEDlighting Wholesale Inc. Website. Accessed March 2020. www.ledlightingwholesaleinc.com
   BGHydro. Website. Accessed March 2020. www.bghydro.com
   Amazon. Website. Accessed March 2020. www.amazon.com
   Illumitex. Website. Accessed March 2020. www.illumitex.com
   Fluence. Website. Accessed March 2020. www.fluence.com
   Maxlite. Website. Accessed March 2020. www.maxlite.com
3. U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. “Energy Savings Potential of SSL in Horticultural Applications.” p. ii (HOU), 2 (definitions), and 5 (baseline condition). December 2017.
   https://www.energy.gov/sites/prod/files/2017/12/f46/ssl_horticulture_dec2017.pdf
4. DesignLights Consortium. “Technical Requirements for Horticultural Lighting.” Accessed March 2020. https://www.designlights.org/horticultural-lighting/technical-requirements/
5. Wisconsin Focus on Energy. “Hort Lighting Analysis 051120.xlsx.”

Revision History

Version Number	Date	Description of Change
01	03/2020	Initial release

Grow Light System, Agriculture

	Measure Details
Measure Master ID	Grow Light System, Non-Stacked Indoor, Agriculture, 5032 Grow Light System, Supplemented Greenhouse, Agriculture, 5033
Workpaper ID	W0254
Measure Unit	Per system
Measure Type	Hybrid
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Non-Stacked = 10 (MMID 5032), Supplemented = 20 (MMID 5033)[1,3]
Incremental Cost ($/unit)	Varies[2]

Measure Description

These hybrid measures, part of the horticultural lighting offerings developed in 2020, involve installing LED horticultural lighting either instead of (for new construction) or to replace (for retrofit) existing HID and/or fluorescent fixtures. A mix of non-stacked indoor and supplemented greenhouses is anticipated. Customer inputs and lighting design details will be used to calculate savings (see Assumptions). Non-stacked indoor greenhouses grow plants in a single layer on the floor under ceiling-mounted lighting. Supplemented greenhouses use electric lighting to extend the hours of daylight, to supplement low levels of sunlight on cloudy days, or to disrupt periods of darkness—all intended to alter plant growth. Vertical farms, which include shelving from floor to ceiling (and where lighting is typically mounted within the shelving units and is much closer to the plants), are not included in this offering.[3]

The design and baseline photosynthetic photon flux density must be comparable and established by a lighting design.

Smaller-scale lighting upgrades, in existing buildings only, are better-suited to using the one-for-one prescriptive measures (MMIDs 5024 through 5028).

Description of Baseline Condition

The baseline system is a lighting design using HID and/or fluorescent fixtures with typical wattages (400 watts to 1,000 watts) that result in an equivalent photosynthetic photon flux density to the proposed design system. The baseline design must be a practical and viable alternative for the customer.

Description of Efficient Condition

The efficient condition must be comprised of either DLC-listed horticultural lighting fixtures, in the Horticultural Lighting category, or fixtures that meet three requirements:

- Fixture photosynthetic photon efficacy ≥2.0 µmol/J (DLC requirement is ≥1.9 µmol/J)[4]
- Five-year minimum warranty
- Appropriate Horticultural Lighting designation by OSHA NRTL or SCC-recognized body

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Power consumption of baseline lighting system (= customer input)
$Watts_{EE}$ = Power consumption of efficient lighting system (= customer input)
HOU = Hours of use (= customer input)
1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= customer input; see Assumptions)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years for non-stacked [MMID 5032], = 20 years for supplemented [MMID 5033])[1,3]

Assumptions

The EUL for horticultural lighting fixtures is different than the EUL for non-horticultural lighting and is limited by the current test procedures. There are several methods for determining how many hours a fixture will remain useful.

- The most common way to measure non-horticultural LED fixtures is the L_{70} measurement, which determines how many hours a fixture will maintain 70% of the total original lumen output.
- For horticultural lighting, the industry standard is either the L_{90} or Q_{90} measurement, or the number of hours a fixture can maintain 90% of its original output.

Since most horticultural lighting fixtures are relatively new to the market and it is not possible to have completed a full life cycle output test, the accepted method of calculating the L_{90} and Q_{90} values is the TM-21 test procedure.[4] This test procedure requires that a test period of up to 10,000 hours (and sometimes 12,000 hours) to predict the L_{90} and Q_{90} values, but with a maximum L_{90} and Q_{90} value of six times the test period. Horticultural lighting fixtures therefore may perform with outputs at a higher than 90% of their original rate for much longer than established by the TM-21 test method, but the company can only list six times the test period as their L_{90} or Q_{90}.

In determining the EUL for horticultural measures per the TM-21 test procudure,[4] manufacturer specification sheets for numerous DLC-listed horticultural lighting fixtures were reviewed. Some manufacturers list that their fixtures maintain L_{90} or Q_{90} requirements for greater than the value listed because they could only project out to six times their testing period. For horticultural lighting, the Q_{90} values are a better indicator of fixture effectiveness, but when Q_{90} values were unavailable, L_{90} values were used instead. (Only specification sheets for 600 watt and 1,000 watt replacement LED fixtures were available, so a similar average lifetime hours for the 400 watt replacement fixtures was assumed.)

The hours of use will vary for each project based on customer input. Default hours of 5,475 for non-stacked indoor applications and 2,120 for supplemented greenhouses should be used.[3] With greater potential for energy savings in non-stacked indoor applications, more LED lighting upgrades in this type of facility are anticipated.

The coincidence factor for a non-stacked indoor greenhouse with 100% artificial lighting will be 1.0, since it will use 100% of the lights during peak hours in the summer. A supplemented greenhouse that uses natural sunlight as their primary light source will use a fraction of their lights during peak hours (cloudy days only). For these cases, use the customer input regarding what percentage of the time the artificial lighting will be on during peak times.

Sources

1. MaxLite. Website. Accessed March 2020. https://www.maxlite.com/products/photonmax-horticulture-led-spot-light
   Osram. Website. Accessed March 2020. https://fluence.science/

Illumitex. Website. Accessed March 2020. https://illumitex.com/products/neopar/
Average specification sheet rated Q_{90} or L_{90} of 57,433 hours for 600 watt and 1,000 watt replacement LED fixtures. With an HOU of 5,475 for non-stacked indoor units, their EUL is 10 years. With an HOU of 2,120 for supplemented units, their EUL is capped at 20 years.

2. Incremental measure costs to be manually calculated and entered for each project individually. The following information details how costs were derived for the related prescriptive measures (MMIDs 5024-5028) and can serve as a reference for these hybrid measures as well.

   HTG Supply Website. Accessed March 2020. www.HTGsupply.com
   LEDlighting Wholesale Inc. Website. Accessed March 2020. www.ledlightingwholesaleinc.com
   BGHydro. Website. Accessed March 2020. www.bghydro.com
   Amazon. Website. Accessed March 2020. www.amazon.com
   Illumitex. Website. Accessed March 2020. www.illumitex.com
   Fluence. Website. Accessed March 2020. www.fluence.com
   MaxLite. Website. Accessed March 2020. www.maxlite.com
   A blended incremental cost is based on a 40/40/20 split of 1,000 watt/600 watt/400 watt fixtures for a baseline mix. 1,000-watt replacement = $700.58, 600-watt replacement = $492.34, 400-watt replacement = $366.68. Refer to supporting document 'Hort Lighting Analysis 031020'.
3. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. "Energy Savings Potential of SSL in Horticultural Applications." p. ii (HOU) and 2 (definitions). December 2017. https://www.energy.gov/sites/prod/files/2017/12/f46/ssl_horticulture_dec2017.pdf
4. DesignLights Consortium. "Technical Requirements for Horticultural Lighting." Accessed March 2020. https://www.designlights.org/horticultural-lighting/technical-requirements/

Revision History

Version Number	Date	Description of Change
01	03/2020	Initial release

Agriculture High Volume Low Speed Fans

	Measure Details
Measure Master ID	Fans, High Volume Low Speed (HVLS), General, 3998
Workpaper ID	W0053
Measure Unit	Per foot, fan diameter
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Fan
Sector(s)	Agriculture
Annual Energy Savings (kWh)	815
Peak Demand Reduction (kW)	0.2110
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	12,225
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$51.48[2]

Measure Description

Keeping livestock cool during the summer months is an important factor in breeding, milk production, and general good health. Traditionally, farmers use several high-speed circulation fans (typically less than 54 inches in diameter) with a 1 hp to 1.5 hp motor per fan that move approximately 29,000 cubic feet of air per minute (CFM) to keep the livestock cool. High volume low speed (HVLS) fans with diameters of eight to 24 feet typically use 1 hp to 2 hp motors per fan and move between 140,000 CFM and 300,000 or more CFM.[3] HVLS fans between 16-feet and 24-feet are eligible for incentives.

Description of Baseline Condition

Dairy farms typically have a freestall barn with one or two rows of high speed fans per group of animals, where one row is along the feed alley blowing over the animals' backs and one row is over the cow beds in the center of the group. Usually, 48-inch to 50-inch high speed fans are installed every 30 feet to 40 feet. The baseline condition for other livestock barns is similar, in that multiple high-speed fans are placed to keep the animals cool.

Description of Efficient Condition

For dairy farms, a freestall barn would generally have one row of HVLS fans installed down the center of the barn over the feed alley to meet the air circulation needs of the barn livestock. The efficient condition for other types of livestock barns is similar, in that fewer HVLS fans will be installed compared to baseline to achieve the same or similar amount of circulating air flow.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{HIGH\ SPEED} – Watts_{HVLS}) / 1,000 * HOU$

Where:

$Watts_{HIGH\ SPEED}$ = Power consumption of baseline high speed fan system (= varies by fan diameter; see table below)

$Watts_{HVLS}$ = Power consumption of HVLS fan (= varies by fan diameter; see table below)

Default Values for High Speed and HVLS Fan Wattages

HVLS Fan Diameter Size	One HVLS Fan is Equivalent to 48-inch High Speed Circulation Fan[5]	$W_{HIGH\ SPEED}$*	W_{HVLS}[5]
16 feet	4.0	4,124	761
18 feet	4.5	4,640	850
20 feet	5.0	5,155	940
22 feet	5.5	5,670	940
24 feet	6.0	6,186	1,119

* A 48-inch diameter circulation fan average uses 1,031 watts.[4] Therefore, a 16-foot HVLS fan has a $W_{HIGH\ SPEED}$ equivalent to 4.0 * 1,031 watts = 4,124 watts.

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 3,864)[6]

Deemed HVLS Fan kWh Savings

HVLS Fan Diameter Size	kWh_{SAVED}	kWh_{SAVED}/foot	Fan Size Distribution[2]
16 feet	12,995	812	5%
18 feet	14,645	814	5%
20 feet	16,287	814	53%
22 feet	18,277	831	2%
24 feet	19,579	816	35%
Weighted Average		**815 kWh_{SAVED}/foot**	

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{HIGH\ SPEED} - Watts_{HVLS}) / 1,000 * CF$

Where:

CF = Coincidence factor (= 1.0; see Assumptions)

Deemed HVLS Fan kW Savings

HVLS Fan Diameter Size	kW_{SAVED}	kW_{SAVED}/foot	Fan Size Distribution[2]
16 feet	3.3631	0.2102	5%
18 feet	3.7901	0.2106	5%
20 feet	4.2151	0.2108	53%
22 feet	4.7301	0.2150	2%
24 feet	5.0670	0.2111	35%
Weighted Average		**0.2110 kW_{SAVED}/foot**	

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

This measure is based on the assumption that HVLS fans have wider applications than just dairy barns, and that savings will be similar in other livestock barns such as those for poultry or swine. HVLS fans are most likely to be used in dairy barn applications based on Agriculture, Schools, and Government Program experience.

As the HVLS fan diameter increases, more 48-inch diameter circulation fans would be required to meet the same circulation needs of the facility (see the Default Values for High Speed and HVLS Fan Wattages table).

According to professional experience of program subject matter expert Terry Laube, farmers in Wisconsin typically turn their circulation fans on when it is 50°F or warmer to improve cow comfort. This HOU holds most true for dairy barn applications; however, the HOU rating is deemed reasonable to hold true for uses other than dairy barns, as well for control of animal comfort.

The fan size distribution was determined by analyzing historical program data from January 2012 through August 2016: it is estimated that the 22-foot fans will account for 2% of total, and that the newly eligible 16-foot and 18-foot fan options will account for 10% (5% each) of the total. Since the deemed savings is based on fan diameter foot, this is a conservative estimate. It is also estimated that the 20-foot and 24-foot fans will account for 53% and 35% of the total, respectively. These percentages were adjusted to reflect the historical split between the two fan sizes. Fan distribution will be re-evaluated in a couple of years and deemed savings will be adjusted as needed.

The coincidence factor equals 1.0, as all hours during the peak window are assumed to be above 50°F.

Sources

1. Cadmus. Database. March 2013.
   PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 17 units over eight projects from 2017 to 2018 is $332.36/foot. Base cost of $280.88 is also based on historical data, examining MMID 3768 (Circulation Fan, HS/HE, 48"-52", Ag), average cost of 122 units over 12 projects from 2016 to 2018 and normalizing per foot. Incremental cost is $332.36 - $280.88 = $51.48.
3. Kammel, D.W., M.E. Raabe, and J.J. Kappelman (University of Wisconsin-Madison). "Design of High Volume Low Speed Fan Supplemental Cooling System in Dairy Free Stall Barns." Accessed September 29, 2015. http://www.uwex.edu/energy/pubs/HVLSFreestallDesign.pdf
4. Bioenvironmental and Structural System Laboratory at The University of Illinois at Urbana-Champaign. "Fan Database." http://bess.illinois.edu/
5. KEMA. "2009 Evaluation of IPL Energy Efficiency Programs." Appendix H, Group I Programs, Volume 2. Tables H-16 and H-17. http://www.alliantenergy.com/wcm/groups/wcm_internet/@int/documents/document/mdaw/mtix/~edisp/121605.pdf
6. Appendix B: Common Variables, 'Outside Air Temperature Bin Analysis' average number of hours in Wisconsin at or above 50°F.

Revision History

Version Number	Date	Description of Change
01	10/01/2015	Initial TRM entry
02	10/01/2016	Changed measure unit from per fan to per fan diameter (foot) and updated deemed savings source
03	12/2018	Updated incremental cost

Agricultural Fans, Dairy

	Measure Details
Measure Master ID	Circulation Fan, HS/HE, Fixed Speed: 36-47 inches, Ag, Dairy, 5086 ≥ 48 inches, Ag, Dairy, 5087 Ventilation Fan, HS/HE, Fixed Speed: ≥ 48 inches, Ag, Dairy, 5088 Ventilation Fan, HS/HE, Variable Speed: ≥ 48 inches, Ag, Dairy, Variable Speed, 5089
Workpaper ID	W0265
Measure Unit	Per fan
Measure Type	Prescriptive
Measure Group	Agriculture
Measure Category	Fan
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies per fan size
Peak Demand Reduction (kW)	Varies per fan size
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies per fan size
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Circulation fan = 15 (MMIDs 5086-5087)[1], Ventilation fan = 16 (MMIDs 5088)[1], Ventilation fan with variable speed = 15 (MMID 5089)[2]
Incremental Cost ($/unit)	MMIDs 5086-5088 = $150.00[3] MMID 5089 = $384.18[4]

Measure Description

Agriculture ventilation and circulation fans are intended to provide minimum ventilation rates and maintain indoor air quality for dairy cows. Dairy circulation fans are designed to help provide animal comfort, control insects in summer, and maintain indoor air quality conditions. This measure is based on dairy barn fan installations and their operational characteristics, but can be applied to fan use in other livestock housing areas with similar uses as well.

Each fan grouping is divided into two levels of energy efficiency based on size and whether a variable speed drive (VSD) or other method of varying the speed such as an electronically commutated motor (ECM) is integral to the fan. Program incentives vary based on fan type, size, and capacity to vary speed.

Description of Baseline Condition

The baseline condition is a ventilation or circulation fan used within an agricultural building of standard efficiency without the ability to vary the speed of the motor. The baseline values for each fan grouping are based on a comparison of actual and certified fan performance information supplied from the BESS labs website as of August 27, 2020.[5]

The results of compiling the fan performance data were sorted into fan size groupings, with single- and three-phase fans combined. The fan baseline (standard) efficiency and energy consumption values are an average of all non-qualifying fans tested by BESS for each respective fan size grouping. The baseline comparison performance criteria for each of the fan size groupings is listed in the Fan Average Power Ratings table.

Description of Efficient Condition

To qualify for a prescriptive incentive, each circulation or ventilation fan must undergo third-party testing and be rated by BESS labs, an accredited Air Movement and Control Association testing facility, or other third party lab in accordance with AMCA/ANSI 210 or 230 test procedures.

The 75th percentile or higher is used as the minimum energy efficiency qualifying standard. Minimum efficiency for fans are listed in the 75th Percentile Efficiency Threshold column of the Deemed Inputs and Savings table below.

Annual Energy-Savings Algorithm

Fixed Speed Fans (MMIDs 5086-5088):

$kWh_{SAVED} = (Fan_{kW\_BASE} – Fan_{kW\_EFF}) * HOURS$

Where:

Fan_{kW_BASE} = Baseline efficiency fan average kilowatt rating for non-qualifying equipment (= see Fan Average Power Ratings table below)[3]

Fan_{kW_EFF} = High-efficiency fan average kilowatt rating (= see Power Rating columns of Deemed Inputs and Savings table below)[3]

HOURS = Annual hours of operation (= 6,570 for ventilation fans;[4] = 3,864 for circulation fans, see Assumptions)

Circulation fan baseline power ratings are the average kilowatts for fans below minimum qualifying efficiencies reported from BESS lab tested fans[5] in stated fan size groupings. Circulation fan efficient power ratings are the average kilowatts at or above the minimum qualifying efficiencies, stated in the Fan Average Power Ratings tables above, from BESS lab tested fans[5] in applicable fan size groupings.

Ventilation/Exhaust fan power ratings are determined by the same method as circulation fans, but at 0.10-inches of static pressure, since this is a critical variable in rating ventilation/exhaust fans.

Variable Speed Fans (MMID 5089):

Energy savings for this measure are custom calculated using a spreadsheet tool,[6] which is based on an engineering bulletin[7] and savings calculators from two different VFD manufacturers.[8,9]

For the energy savings analysis, this tool uses power curves developed from data obtained by measuring the operating characteristics of various fans and pumps. The curves are representative of typical VFD operation.

The spreadsheet tool uses this equation:

$$\text{Power at Design GPM [CFM]} = \text{Controlled Horsepower} * \text{Conversion Constant [kW/hp]} * \text{Motor Load at Design GPM [CFM]} / \text{Nameplate Efficiency}$$

These equations determine energy usage for each capacity level:

$$\text{Percentage of Design kW} = A1 + (A2 * \text{Capacity}) + (A3 * (\text{Capacity})^2) + (A4 * (\text{Capacity})^3)$$

$$\text{Percentage of Design kW for VFD} = A1 + (A2 * \text{Capacity}) + (A3 * (\text{Capacity})^2) + (A4 * (\text{Capacity})^3)$$

In the equations above, A1, A2, A3, and A4 are variables unique to each “before VFD” control type that allows for a quadratic equation to be created to represent the load profile. The table below shows values for A1, A2, A3, and A4.

Equation Variables: Before VFD

Control	A1	A2	A3	A4
On/Off	100.00000	0.00000	0.00000	0.00000
VFD Fan	5.90000	-0.19567	0.00766	0.00004

Since this is a prescriptive measure with deemed savings, the following inputs were entered into the VFD hybrid calculator. Deemed savings are in the table below.

VFD Calculator Inputs:

Nameplate Horsepower = 1.8249 (see Assumptions)

Motor Nameplate Efficiency= 86.5% (see Assumptions)

Annual Operating Hours = 6,570

Type of Flow Control (Controls before VFD) = On/Off

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Fan_{kW\_BASE} – Fan_{kW\_EFF}) * CF$

Where:

CF = Coincidence factor (= 1.0)

The coincidence factor for the fixed speed fans is based on the assumption that the outdoor air temperature is above the desired temperature in barns and therefore ventilation fans are running during an overwhelming majority of peak hours for cooling purposes.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years for circulation fans[1], = 16 years for ventilation/exhaust fans[1], = 15 years for variable speed fans[2]

Deemed Savings

Deemed Inputs and Savings

Fan Type	Diameter	MMID	75th Percentile Efficiency Threshold*	Power Rating (kW)[3]		Savings		
						Annual		Lifecycle kWh
				Base	Efficient	kWh	kW	
Circulation	36”-47”	5086	20.0	0.6050	0.5141	526	0.1362	7,894
	48”+	5087	24.5	1.1643	1.0034	621	0.1608	9,321
Ventilation / Exhaust	48”+	5088	21.0	1.4382	1.0821	2,340	0.3561	37,433
	Variable Speed 48”+	5089	n/a	n/a	n/a	6,054	0.9215	90,810

*Circulation fans have units of lbf/kW, ventilation fans have units of cfm/watt at 0.10” of static

Assumptions

The hours for ventilation fans are 8,760 * 0.75 = 6,570 hours[10]. This is based on the assumption that

dairy farms require mechanical ventilation for about three-quarters of the year to meet the needs of the facility. This is a conservative approach to account for barns designed with tunnel ventilation, side-wall curtains, and typical control schedules that incorporate the numbers of fans, stages, and temperature setpoints throughout the year.

According to Agriculture, Schools, and Government program subject matter expert, Terry Laube, dairy farmers in Wisconsin typically turn their circulation fans on when it is 50°F or warmer to improve cow comfort; this equates to 3,864 hours per year. This HOU assumption holds most true for dairy barn applications, and is assumed to reasonably hold true for other uses and for controlling animal comfort.

The variable speed fan calculations were run using the approved VFD savings calculation spreadsheet and motor speed profiles for agricultural ventilation/exhaust fans. The variable speed ventilation/exhaust fan measure uses the average kilowatt fan power ratings for all fans in the fan diameter range as shown in the BESS lab reports which is 1.3614.[5] The constant 0.746 kW/HP is used to convert the average fan kW to HP. The standard motor efficiency rating for a 1.5 HP motor of 86.5% was used as a conservative estimate since the average motor size was fractionally larger than 1.5 HP (1.8249 HP).

High-speed, high-efficiency fans can come with or without guards. Installing a guard on a fan that was originally tested and sold without a guard will decrease the performance of that fan. The deemed savings for fans are based on actual test performance data, assuming fans are sold and used as tested.

For peak savings, it was assumed that the temperature is above 50°F and fans are running during the majority of peak demand hours although the savings algorithm accounts for the fans running at lower than peak speeds during those peak hours.

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Revision History

Version Number	Date	Description of Change
01	01/2016	Initial version
02	08/03/2016	Corrected table headings and typos, added details to Assumptions
03	10/02/2017	Created tiered structure for multiple levels of efficiency
04	10/09/2019	Updated ventilation fan HOU, efficiencies, and savings figures; added new MMIDs to reflect the change in incentive structure from fan diameter (per inch) to a flat rate per fan
05	10/2020	Removed Tier structure, added variable-speed measure

Agricultural Fans, Other

	Measure Details
Measure Master ID	Circulation Fan, HS/HE, Fixed Speed: 24-35 inches, non-Dairy, 5090 36-47 inches, non-Dairy, 5091 ≥ 48 inches, non-Dairy, 5092 Ventilation Fan, HS/HE, Fixed Speed: 36-47 inches, non-Dairy, 5093 ≥ 48 inches, non-Dairy, 5094 Ventilation Fan, HS/HE, Variable Speed: ≥ 48 inches, non-Dairy, Variable Speed, 5095
Workpaper ID	W0266
Measure Unit	Per fan
Measure Type	Prescriptive
Measure Group	Agriculture
Measure Category	Fan
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies per fan size
Peak Demand Reduction (kW)	Varies per fan size
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies per fan size
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Circulation Fan = 15 (MMIDs 5090-5092) [1], Ventilation Fan = 16 (MMID 5093-5094)[1] Ventilation Fan with Variable Speed Drive = 15 (MMID 5095)[2]
Incremental Cost ($/unit)	MMIDs 5090-5094 = $150.00[3] MMID 5095 = $210.52 per HP[4]

Measure Description

Agriculture ventilation and circulation fans are intended to provide minimum ventilation rates and maintain indoor air quality for a variety of applications including, but not limited to poultry, swine, greenhouses, and produce storage. Agricultural circulation fans are designed to help provide animal comfort, control insects in summer, maintain relative humidity levels and maintain indoor air quality conditions.

Each fan grouping is divided into three levels of energy efficiency based on size and whether a variable speed drive (VSD) or other method of varying the speed such as an ECM is integral to the fan. Program incentives vary based on fan type, size and capacity to vary speed.

Description of Baseline Condition

The baseline condition is a ventilation or circulation fan used within an agricultural building of standard efficiency and 4,000 or more hours of operation per year without the ability to vary the speed of the motor. The baseline values for each fan grouping are based on a comparison of actual and certified fan performance information supplied from the BESS labs website as of August 27, 2020.[5]

The results of compiling the fan performance data were sorted into fan size groupings, with single- and three-phase fans combined. The fan baseline (standard) efficiency and energy consumption values are an average of all non-qualifying fans tested by BESS for each respective fan size grouping. The baseline comparison performance criteria for each of the fan size groupings is listed in the Fan Average Power Ratings table.

Description of Efficient Condition

To qualify for a prescriptive incentive, each circulation or ventilation fan must undergo third-party testing and be rated by BESS labs, an accredited Air Movement and Control Association testing facility, or other tried party lab in accordance with AMCA/ANSI 210 or 230 test procedures.

The 75th percentile or higher is used as the minimum energy efficiency qualifying standard. Minimum efficiency for fans are listed in the 75th Percentile Efficiency Threshold column of the Deemed Inputs and Savings table below.

Annual Energy-Savings Algorithm

Fixed Speed Fans (MMIDs 5090 - 5094):

$kWh_{SAVED} = (Fan_{kW\_BASE} – Fan_{kW\_EFF}) * HOURS$

Where:

Fan_{kW_BASE} = Baseline efficiency fan average kilowatt rating for non-qualifying equipment (= see Fan Average Power Ratings table below)[3]

Fan_{kW_EFF} = High-efficiency fan average kilowatt rating (= see Power Rating columns of Deemed Inputs and Savings table below)[3]

HOURS = Annual hours of operation (= 4,000, minimum requirement)

Circulation fan baseline power ratings are the average kilowatts for fans below minimum qualifying efficiencies reported from BESS lab tested fans[5] in stated fan size groupings. Circulation fan efficient power ratings are the average kilowatts at or above the minimum qualifying efficiencies, stated in the Fan Average Power Ratings tables above, from BESS lab tested fans[5] in applicable fan size groupings.

Ventilation/Exhaust fan power ratings are determined by the same method as the circulation fans, but at 0.10-inches of static pressure, since this is a critical variable in rating ventilation/exhaust fans.

For Variable Speed Fans (MMID 5095):

Energy savings for these measures are custom calculated using a spreadsheet tool,[6] which is based on an engineering bulletin[7] and savings calculators from two different VFD manufacturers.[8,9]

For the energy savings analysis, this tool uses power curves developed from data obtained by measuring the operating characteristics of various fans and pumps. The curves are representative of typical VFD operation.

The spreadsheet tool uses this equation:

$$\text{Power at Design GPM [CFM]} = \text{Controlled Horsepower} * \text{Conversion Constant [kW/hp]} * \text{Motor Load at Design GPM [CFM]} / \text{Nameplate Efficiency}$$

These equations determine energy usage for each capacity level:

$$\text{Percentage of Design kW} = A1 + (A2 * \text{Capacity}) + (A3 * (\text{Capacity})^2) + (A4 * (\text{Capacity})^3)$$

$$\text{Percentage of Design kW for VFD} = A1 + (A2 * \text{Capacity}) + (A3 * (\text{Capacity})^2) + (A4 * (\text{Capacity})^3)$$

In the equations above, A1, A2, A3, and A4 are variables unique to each “before VFD” control type that allows for a quadratic equation to be created to represent the load profile. The table below shows values for A1, A2, A3, and A4.

Equation Variables: Before VFD

Control	A1	A2	A3	A4
On/Off	100.00000	0.00000	0.00000	0.00000
VFD Fan	5.90000	-0.19567	0.00766	0.00004

Since this is a prescriptive measure with deemed savings, the following inputs were entered into the VFH hybrid calculator. Deemed savings are in the table below.

VFD Calculator Inputs:

Nameplate Horsepower = 1.8249 (see assumptions)
Motor Nameplate Efficiency= 86.5% (see assumptions)

Annual Operating Hours = 4,000

Type of Flow Control (Controls before VFD) = On/Off

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Fan_{kW\_BASE} - Fan_{kW\_EFF}) * CF$

Where:

CF = Coincidence factor (= 1.0)

The coincidence factor for the fixed speed fans is based on the assumption that the outdoor air temperature is above the desired temperature in barns, greenhouses, and crop storage areas and therefore ventilation fans are running during an overwhelming majority of peak hours for cooling purposes.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years for circulation fans[1], = 16 years for ventilation/exhaust fans[1], = 15 years for variable speed fans[2])

Deemed Savings

Deemed Inputs and Savings

Fan Type	Diameter	MMID	75th Percentile Efficiency Threshold*	Power Rating (kW)[3]		Savings		
						Annual		Lifecycle kWh
				Base	Efficient	kWh	kW	
Circulation	24”-35”	5090	15.8	0.479460	0.397576	328	0.0819	4,913
	36”-47”	5091	20.0	0.650350	0.514149	545	0.1362	8,172
	48”+	5092	24.5	1.164257	1.003434	643	0.1608	9,649
Ventilation / Exhaust	36”-47”	5093	17.0	0.793860	0.549116	979	0.2447	15,664
	48”+	5094	21.0	1.438194	1.082097	1,424	0.3561	22,790
	Variable Speed 48”+	5095	n/a	n/a	n/a	3,686	0.9215	55,288

*Circulation fans have units of lbf/kW, ventilation fans have units of cfm/watt at 0.10” of static

Assumptions

High-speed, high-efficiency fans can come with or without guards. Installing a guard on a fan that was originally tested and sold without a guard will decrease the performance of that fan. The deemed savings for fans are based on actual test performance data, assuming fans are sold and used as tested.

The variable speed fan calculations were run using the approved VFD savings calculation spreadsheet and motor speed profiles for agricultural ventilation/exhaust fans. The variable speed ventilation/exhaust fan measure uses the average kilowatt fan power ratings for all fans in the fan diameter range as shown in the BESS lab reports which is 1.3614.[5] The constant 0.746 kW/HP is used to convert the average fan kW to HP. The standard motor efficiency rating for a 1.5 HP motor of 86.5% was used as a conservative estimate since the average motor size was fractionally larger than 1.5 HP (1.8249 HP).

For peak savings, it was assumed that the temperature is above 50°F and fans are running during the majority of peak demand hours although the savings algorithm accounts for the fans running at lower than peak speeds during those peak hours.

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Revision History

Version Number	Date	Description of Change
01	10/2020	Initial version

Agriculture, VFD, Milk Pump

	Measure Details
Measure Master ID	VFD, Dairy Milk Pump, Agriculture, 3988
Workpaper ID	W0153
Measure Unit	Per milking cow
Measure Type	Prescriptive
Measure Group	Motors & Drives
Measure Category	VFD
Sector(s)	Agriculture
Annual Energy Savings (kWh)	20.7688 kWh
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	311.532 kWh
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$3,004[2]

Measure Description

Milk pumps in dairy milking operations move the milk into a well-water plate cooler before it flows to the mechanical cooling system. The milk flow is usually not consistent as it comes from the cows. Since the load on the milk pump changes as the flow of milk varies during the milking process, quite often milk may either surge or trickle into the well water plate cooler throughout the milking cycles, reducing the effectiveness of heat transfer across the plate cooler heater exchanger fins. By slowing the milk pump flow rate, a greater and more consistent water to milk flow ratio can be achieved, increasing heat transfer between the milk and well water. A VFD or other variable speed drive provides the necessary control of the milk pump for a slower, more consistent and more even flow of milk through the plate cooler. The well water being pumped through the plate cooler to serve as the milk coolant is assumed to be reused for other farm needs after its use in the plate cooler, typically for animal consumption.

Description of Baseline Condition

The baseline condition is a milk pump motor operating at full speed to transfer milk from the receiver jar to the plate cooler without any variable speed milk pump flow control.

Description of Efficient Condition

The efficient condition is to add a VFD to control the milk pump and slow the milk flow through the plate cooler, increasing effectiveness of the heat transfer between the milk and well water. Slowing down milk flow can achieve several additional degrees, up to a maximum of 15°F, of milk cooling out of the existing plate cooler. These few extra degrees of cooling equate to less energy that the refrigeration system compressor will need to cool the milk to its final storage temperature of around 38°F. The output milk temperature from the plate cooler, in conjunction with a VFD on the milk pump, can be within 4°F of well water temperature.[3]

Annual Energy-Savings Algorithm

The prescriptive deemed kWh savings are based on an average per pound of milk per day cooled on a dairy farm as calculated using the hybrid calculations on file with past applications.[2]

$kWh_{SAVED} = lbs\ of\ Milk * C_{P,MILK} * \Delta T_{MILK} * 365 / AEER_{COMPRESSOR} / 1{,}000$

Where:

lbs of Milk = Estimated daily pounds of milk produced by the dairy farm that needs to be cooled through use of a milk pre-cooler (= 68 pounds of milk per cow;[4] with the number of milking cows being user defined)

$C_{P,MILK}$ = Specific heat of milk (= 0.94 Btu/(lb-°F))[5]

ΔT_{MILK} = Temperature difference of the output of plate cooler milk before and after the use of variable speed control on the milk pump to slow milk pump and increase heat removed from milk through the plate cooler prior to mechanical refrigeration. The average plate cooler milk temperature without VFD control is 70°F (see Assumptions). VFD control on the milk pump can help decrease milk temperature in the plate cooler to within around 4°F of the well water temperature.[3] The plate cooler theoretical milk temperature with VFD control is 52.3°F + 4°F = 56.3°F (Final ΔT_{MILK} value= 70°F - 56.3°F = 13.7°F).

365 = Number of milking days per year[7]

$AEER_{COMPRESSOR}$ = Annual energy efficiency ratio of refrigeration compressor (= 15.39 Btu/watt * hr)[8]

1,000 = Conversion factor from watts to kilowatts

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for VFD dairy milk pumps. Through research of refrigeration compressor power demands, no substantial evidence has arisen that any notable kW demand reduction is possible in relation to using a VFD with a milk pre-cooler to pre-cool milk that would otherwise need to be chilled through mechanical refrigeration means.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

- The electric savings value does not account for the potential of electric savings on the milk pump itself due to the VFD usage since milk pumps are typically ≤ 2 hp and savings is deemed minimal compared to savings of the refrigeration compressor. The purpose of installing variable speed control on a milk pump is not aimed at achieving savings from the pump itself. As such, these savings are ignored.
- This measure refers to the use of a VFD to provide milk pump control, however other forms of variable speed drives are also eligible if they adequately reduce the speed of the milk pump to achieve higher well water to milk flow ratios (1:1 to 2:1 or 3:1).
- Assumes an even 50/50 split of farms using scroll versus reciprocating compressors to drive the milk cooling process.[8]
- Milk temperature from the output of a pre-cooler is based on a weighted percentage of single and double pass pre-cooler units. Single pass units roughly drop the milk temperature 25°F while double pass units drop the milk roughly 35°F.[9] Based on past project data analysis related to milk pre-cooler application submittals, the latest Wisconsin trend for new pre-cooler installations is 40% single pass pre-cooler and 60% double pass pre-coolers.[10] The estimated temperature drop for a farm with a pre-cooler = 25°F * 0.4 + 35°F * 0.6 = 31°F.
- Temperature of milk leaving cow is 101°F. Average plate cooler milk temperature without VFD control is 101°F – 31°F = 70°F. The measure savings are based on the assumption that a well water temperature of 52.3°F is used as milk coolant.[6] It is assumed the lowest milk temperature that could be achieve would be 56.3°F (or 4°F higher than well water coolant temperature).[3] The maximum additional cooling for any style of plate cooler in conjunction with a variable speed controlled milk pump would be up to 15°F of additional cooling.[9]
- The user-defined input provided for the number of milking cows is assumed to be the average number of animals being milked throughout the entire year.

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Revision History

Version Number	Date	Description of Change
01	09/30/2015	Original
02	10/28/2016	Updated measure to be based on number of milking cows. Updated algorithm inputs. Replaced MMID 3797 with MMID 3988.

Agriculture, VFD, Vacuum Pump

	Measure Details
Measure Master ID	VFD, Dairy Vacuum Pump, Small, Agriculture, 5231 VFD, Dairy Vacuum Pump, Large, Agriculture, 5232
Workpaper ID	W0154
Measure Unit	Per milking cow
Measure Type	Prescriptive
Measure Group	Motors & Drives
Measure Category	VFD
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/VFD)	Varies by measure[2]

Measure Description

Vacuum pumps in dairy milking operations create suction to extract milk from the cow and move the milk to the mechanical cooling system. The vacuum pump is also typically used to flush warm wash water through the milk pipeline to clean it between milkings to prevent bacteria growth. The load on the pump changes between attachments (moving milkers from one cow to the next), as one quarter is emptied and a teat cup drops off, and is affected by how much milk the system is moving at any given time. An alternate way to provide control of motor systems is to use VFDs, which physically slow the pump motors to achieve reduced flow rates at considerable energy savings when the suction load drops in the system.

Description of Baseline Condition

The baseline condition is a vacuum pump motor operating at full speed when in use to handle the demand of the vacuum pump for milking operation as well as the milk pipeline cleaning needs. The only control for the vacuum pump for the baseline condition is a conventional type of vacuum pump regulator that acts to throttle the flow of a vacuum pump to control the suction pressure.

Description of Efficient Condition

The efficient condition is to add a VFD or other variable speed drive to the motor to vary the electric frequency (Hertz) going to the motor, which allows the speed of the motor to be varied. The variable speed drive will be automatically controlled by a vacuum or pressure sensor/transducer that measures the changes in pressure in the milking suction system during milking and wash cycles. A customer can buy a variable speed vacuum pump from a manufacturer that includes the vacuum pump and all variable speed control components in one package ready to install in the dairy milk house. A customer may also retrofit an existing baseline vacuum pump set up by installing an appropriate off the shelf VFD and additional sensor/transducer components, if not already present, to achieve the variable speed control for the pump. Each variable speed vacuum pump setup is different. The VFD controlling the pump should have its control sequence (typically PID control) tuned to meet the appropriate suction needs of the milking operation as part of the equipment installation and commissioning process.

Annual Energy-Savings Algorithm

kWh savings are based on herd size. The Small measure includes pumps serving < 500 milking cows, and the Large measure includes pumps serving 500 - 2,000 milking cows. Based on historical project data, the average number of cows is 232 for a small herd and 864 for a large herd.[6] It is noted below where assumptions vary based on equipment used for small and large milking operations.

$kWh_{SAVED} = kWh_{BASE} - kWh_{VFD}$

$kWh_{BASE} = hp * 0.746 * \text{Motor Load} / \text{Motor Eff} * (HOURS_{MILK} + HOURS_{WASH})$

$HOURS_{MILK} = 365 * MD * HPM$

$HOURS_{WASH} = 365 * MD * HPW$

$kWh_{VFD} = kW_{MILKING} * HOURS_{MILK} + kW_{WASH} * HOURS_{WASH}$

$kW_{MILKING} = 0.05 * \%CFM_{MIN} * CFM_{TOT} + 1.7729$ (see Assumptions)

$kW_{WASH} = 0.05 * CFM_{TOT} + 1.7729$ (see Assumptions)

Where:

hp = Motor horsepower of the pump (= 9.8 hp for Small; = 13.6 hp for Large)[6]

0.746 = Constant to convert horsepower to kilowatts

Motor Load = Estimated percentage of full load the motor runs at (= 90%)

Motor Eff = Based on motor horsepower and NEMA Premium TEFC 1800 RPM full load motor efficiency ratings (= 91.7%)

365 = Days per year

MD = Milkings per day (= 2.39 for Small;[5] = 3 for Large, see Assumptions)

HPM = Hours per milking (= 4.73 for Small, = 4.85 for Large)[5]

HPW = Hours per washing (= 0.75)[5]

0.05 = Formula constant (see Assumptions)[4]

$\%CFM_{MIN}$ = Minimum percent speed required for the constant torque vacuum pump to not overheat (= 35% for Small; = 20% for Large, see Assumptions)

CFM_{TOT} = Total required suction for milking and washing needs (= 79 CFM for Small; = 119 CFM for Large, see Assumptions)

1.7729 = Formula constant (see Assumptions)[4]

Summer Coincident Peak Savings Algorithm

Small herd size will not have any kW savings because milkings are not likely to occur during peak hours.

For Large herd size:

$kW_{SAVED} = kWh_{SAVED} / (HOURS_{MILK} + HOURS_{WASH}) / 864$

Where:

864 = Number of cows for the large herd size (see above)

It is assumed that the same demand power requirements for the vacuum pump are needed during every milking operation time of day. The three or more times per day operations are assumed to have one of their milking times occur during the peak hour of 1:00 p.m. to 4:00 p.m. every day.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=15 years)[1]

Deemed Savings

Description	MMID	kWh/cow		kW/cow	$/VFD
		Annual	Lifecycle		
VFD, Dairy Vacuum Pump, Small	5231	85	1275	0	$3,737.53
VFD, Dairy Vacuum Pump, Large	5232	54	810	0.0074	$6,159.50

Assumptions

- For Small herd sizes (< 500 milking cows), if the total CFM demand of vacuum pump falls below 35% of rated pump speed, the pump motor will start to overheat. Therefore, the pump CFM produced for milking or washing needs will have to be greater than or equal to 35% of rated CFM of the pump.[3] Milking operations need a minimum CFM for kick offs and/or system leaks.

For Large herd sizes (500 - 2,000 milking cows), it is assumed the motor speed can be reduced down to the point at which it will overheat (20%) and still have adequate CFM capacity.

- Large farms milk three times a day for maximum production and milking will take place during peak hours.
- Number of milking units for Small herds is based on an average of SPECTRUM project data (= 14.57)[6]. For Large herds, a 2 x 14 milking parlor (28 milking units) was estimated to correspond to the average cow herd size by an industry expert.
- This measure assumes that the vacuum pump is large enough to produce the total required suction in CFM needed for all the milking and washing operational needs. Sizing in UW publication states 3 CFM per milking unit + 35 CFM reserve up to a maximum of 120 CFM. For Small herds, (14.57 milking units * 3 CFM) + 35 CFM = 78 CFM. For Large herds, (28 milking units * 3 CFM) + 35 CFM = 119 CFM.[3,4]
- It is assumed that a correct-sized VFD is installed to control the vacuum pump properly across its operating range.
- A 2003 paper[4] measured energy usage for variable speed vacuum pumps at four farms with 12 to 32 milking cows each. The measured usage was [pump kW] = 0.0018 * [liters per minute air flow] + 1.7729. Converting liters to cubic feet yields [pump kW] = 0.05 * CFM + 1.7729
- Savings based on 365 days per year of milking operations.
- User defined input provided for milking units is assumed to be the average number of animals being milked throughout the entire year, including dry cows, but excludes heifers not yet fresh.

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Revision History

Version Number	Date	Description of Change
01	09/30/2015	Initial TRM entry
02	10/28/2016	Updated to be based on number of milking cows using new sources and replaced MMID 3798 with MMID 3987
03	12/2020	Updated cost
04	10/2021	Restructured measure into small and large herd size and updated costs, replacing MMID 3987 with MMIDs 5231 and 5232.

Swine Farrowing Crate Heater

	Measure Details
Measure Master ID	Swine Farrowing Crate Heater w/Controls, Single, 4939 Swine Farrowing Crate Heater w/Controls, Double, 4940
Workpaper ID	W0249
Measure Unit	Per heater
Measure Type	Prescriptive
Measure Group	Agriculture
Measure Category	Controls
Sector(s)	Agriculture
Annual Energy Savings (kWh)	828 kWh for MMID 4939, 1,656 kWh for MMID 4940
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	4,140 kWh for MMID 4939, 8,280 kWh for MMID 4940
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1,2]
Incremental Cost ($/unit)	Single Farrowing Crate Heater = $205.00 (MMID 4939), Double Farrowing Crate Heater = $360.00 (MMID 4940)[3]

Measure Description

This measure involves installing a swine farrowing crate heater with controls to keep piglets warm after birth. The use of heaters reduces mortality rates and increases piglet growth rates. Heaters are designed to keep the piglets at around 100°F while the sow, adjacent to the piglets, is kept at around 70°F to maximize comfort and milk production.

The heaters come in a few different styles: one type consists of mats with heating elements. When placed under the piglets, these mats allow for better control of heating temperatures and more precise placement of heat. Other models have the heaters placed above the piglets, mounted on the crate wall. These incorporate a plastic curtain to create a microclimate within that can be controlled at a set temperature. As they grow or as the ambient air temperature rises, the piglets need less heat. The heating controls modulate to lower the electrical consumption of the heating elements due to this reduced need for heat.

Description of Baseline Condition

The baseline condition is heat lamps or ceramic heaters that generate radiant heat and only adjust due to changes in ambient air temperature. The electrical usage for a baseline single crate unit is typically 175 watts to 250 watts[4,7] and for a baseline double crate unit is typically 350 watts to 500 watts.[4,7]

Description of Efficient Condition

The efficient condition is an energy-efficient swine farrowing heater that is in a farrowing crate directly under or over the piglets. Qualifying farrowing crate heaters have thermostatic controls. Studies have shown the average energy consumption per crate for both mats and overarching microclimate heaters, such as the FarrPro Haven units, is 60 watts[6,7] for a single crate and 120 watts[6,7] for a double crate when used with a controller that automatically varies the heat output according to piglet needs.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Average power consumption of baseline heat lamp per crate (single crate = 175 watts, double crate = 350 watts)[4,7]

$Watts_{EE}$ = Average power consumption of energy-efficient measure equipment retrofit per crate (single crate = 60 watts, double crate = 120 watts)[6,7]

1,000 = Kilowatt conversion factor

HOU = Average annual run hours of farrowing heater (= 7,200)[5]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1,2]

Deemed Savings

Average Annual Deemed Savings

Type	MMID	Annual kWh	Lifecycle kWh
Single Farrowing Crate Heater	4939	828	4,140
Double Farrowing Crate Heater	4940	1,656	8,280

Assumptions

No peak demand reduction is associated with this measure because farrowing heaters are not guaranteed to be operating during peak demand times.

All costs were gathered from the manufacturers' (Kane and Osborne-Stanfield) websites[3] and are assumed to be representative of industry-wide costs. FarrPro Haven costs are very similar to Kane and Osborne-Stanfield costs for both single crate and double crate heaters.

Annual operation estimates for the number of hours are based on a 20-day average farrowing cycle and an average of 15 turns (litters of piglets per year) per farrowing stall.[5] This is a conservative estimate of the number of turns per stall compared with other published farm data.

The Internal Revenue Service methodology for depreciation of assets that fit the swine farrowing crate heater[1] were assumed to be conservative estimates of the equipment EUL. The manufacturer also recommended five years as a conservative estimate for the EUL of equipment included in this measure.[2]

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Revision History

Version Number	Date	Description of Change
01	12/2019	Initial release
02	2/28/2020	Added to TRM

Energy Efficient Grain Dryer

	Measure Details
Measure Master ID	Energy Efficient Grain Dryer, 3386 Energy Efficient Grain Dryer, Propane-Fueled, 4868
Workpaper ID	W0004
Measure Unit	Bushels per hour
Measure Type	Hybrid
Measure Group	Agriculture
Measure Category	Dryer
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies
Annual Propane Savings (Gallons)	Varies
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	Varies
Lifecycle Propane Savings (Gallons)	Varies
Water Savings (gal/yr)	0
Effective Useful Life (years)	20[1,4,7]
Measure Incremental Cost ($/unit)	$160.78[3]

Measure Description

This incentive offering is for agricultural operations that replace their existing grain drying systems with a more energy-efficient batch or continuous flow grain drying system. Although still operational, the efficiency of older equipment becomes obsolete in comparison to newer technology and can be more expensive to operate. Newer grain dryers generally have larger drying capacities, and can process loads faster and at a greater efficiency. Installing a new and more efficient grain dryer will effectively reduce the annual hours of operation by allowing for faster processing of grain through increased efficiency. The purpose of drying grain is to reduce the amount of water contained in the crop after harvest to an acceptable level for marketing, storage, or processing. This incentive will be provided based on the bushel per hour processing capacity of the new grain dryer.

While this measure can apply to all types of grain, the focus of this workpaper is on corn, which is the main use of grain dryers in the state of Wisconsin. This measure is not eligible for new construction, which should be handled as a custom project.

Description of Baseline Condition

The grain dryer's baseline efficiency (in Btu per pound of water removed) is either provided by the trade ally or a default value is used based on USDA literature[4].

Most trade ally's grain dryer analyses are propriety in nature, but they help determine an estimate of efficiency based on normal weather temperature/humidity data at the location of grain dryer installation during the time of harvest/drying. Their analysis should also account for the past harvested grain moisture contents, pre- and post-installation, as recorded by the customer, as well as the capacity ratings of the respective dryer (or a dryer similar to the existing dryer if specific information on the actual existing dryer cannot be obtained).

If a trade ally analysis cannot be provided, a default grain dryer efficiency value will be used (refer to Baseline Grain Dryer Efficiency Table).

The efficiency of grain dryers is very dependent on the weather conditions and time of harvest for each year. Unfortunately, there is no simple way to depict this information for each individual project and many assumptions must be made. The options for providing information to arrive at a baseline efficiency value are provided below to help ensure that the most accurate savings are calculated for Wisconsin Focus on Energy on a project-by-project basis.

Description of Efficient Condition

Since this measure is hybrid, the actual drying efficiency will be calculated for the specific efficient grain dryer installed, and to the best level possible based on the information provided by the customer and grain dryer specification sheet. To ensure that the efficient grain dryer is in fact more efficient than the previous dryer before providing the incentive, Wisconsin Focus on Energy requires that the efficient grain dryer use at least 250 Btu/lb H_2O less than the baseline dryer.

The efficiency of a new grain dryer (Btu/lb H_2O removed) can be calculated using the formulas provided in the Annual Energy-Savings Algorithm section, or the efficiency can be provided as trade ally analysis showing all the inputs and outputs used.

The efficient grain dryer is also required to have at least one of the following features specific to being more energy efficient than the previous dryer:

- Staged temperature (higher temperature for wettest grain, lower for nearly dry grain)
- Grain turners or inverters (rotate mostly dry grain away from to wetter grain toward plenum)
- Differential grain speed (column designed to move grain next to the drying plenum faster to reduce excessive grain temperatures and provide a more uniform moisture content)
- Varied width of the drying column (narrower at top where the grain is wettest, allowing humid air to vent to the atmosphere faster)
- Some form of heat recovery (captures excess heat from cooling section of a grain dryer, where applicable, and redirects it to help preheat the incoming burner intake air)
- Advanced grain dryer operation controls

Annual Energy-Savings Algorithm

Energy-Savings Calculations:

kWh_{SAVED} = Acres * Bsh/Acre * Lbs_{BUSHEL} * MS% * (Eff_{BASE} - Eff_{EE}) / 3,412 * %Elec

Gas_{SAVED} = Acres * Bsh/Acre * Lbs_{BUSHEL} * MS% * (Eff_{BASE} - Eff_{EE}) / ConvF * %Gas

MS% = Moisture shrink percent, % weight reduction of wet grain as it is dried
= (MC_{INIT} - MC_{FINAL}) / (100% - MC_{FINAL})
= 9.51% (see inputs below)

Eff_{EE} = Proposed grain dryer efficiency in Btu per pound of water removed[5]
= [(CAP / Eff_{BURN} * ConvF) + (hp * 0.746 * LF / Eff_{MOT} * 3,412)] / [Bushels/hr * (Lbs_{BUSHEL} - lbs_{FINAL})]

CAP = Grain dryer burner capacity[5]
= 1.08 * CFM * (T_P - T_A)

Where:

Acres = Number of acres planted that will be dried using the proposed grain dryer (= user-defined input)

Bsh/Acre = Average number of bushels per acre based on crop type (= 172.8)[7]

Lbs_{BUSHEL} = Initial bushel weight determined from grain moisture content percentage and weight per bushel reference tables (= 61.37)[8]

MC_{INIT} = Harvested grain moisture content percentage (= 22.9%)[6]

MC_{FINAL} = Dried grain moisture content percentage (= 14.8%)[6]Eff_{BASE} = Existing grain dryer efficiency, Btu per pound of water removed (= can be user-defined input from trade ally, or deemed by dryer type, see Grain Dryer Type Efficiency and Energy Savings Splits table below)

Grain Dryer Type Efficiency and Energy Savings Splits[4]

Dryer Type	Eff_{BASE}*	$Gas_{\%}$	$Electric_{\%}$
Continuous Cross Flow Dryer (Tower Dryer)	2,800	98%	2%
Combination High/Low Temperature	1,475	75%	25%
Ambient-Air Bin Dryer (No Heat)	1,500	0%	100%
Low Temperature Bin Dryer	1,650	0%	100%
Continuous Flow In-Bin Dryer	2,000	98%	2%
Mixed Flow Dryer	2,050	98%	2%
Recirculating Cross-Flow Batch Dryer	2,200	98%	2%
High Temperature Batch Bin Dryer	2,430	98%	2%
Batch Cross Flow Dryer	2,450	98%	2%

* Assuming 10% moisture removed

CFM = Rated blower CFM (= derived from dryer specification sheet or user-defined if spec sheet not available)

T_P = Plenum temperature inside dryer at normal operation (= derived from dryer specification sheet or user-defined if spec sheet not available)

T_A = Average ambient temperature of outside air during typical drying times (= varies by city; see Average Fall Ambient Temperatures table below)

Average Fall Ambient Temperatures[9]

City	October	November	Total
Eau Claire	46°F	33°F	40°F
Green Bay	47°F	34°F	41°F
LaCrosse	48°F	36°F	42°F
Madison	47°F	34°F	40.5°F
Milwaukee	50°F	38°F	44°F

Eff_{BURN} = Combustion efficiency of grain dryer burner (= assumed to be 95%)[5]

ConvF = Fuel conversion factor (= 100,000 Btu per therm, = 91,333 Btu per gallon of propane)[10]

hp = Main grain dryer blower fan horsepower rating (= derived from dryer specification sheet or user-defined if spec sheet not available)

0.746 = Constant to convert horsepower to kilowatts

LF = Assumed load factor of blower fan (= estimated to be 85%)

Eff_{MOT} = Efficiency of motor, derived from NEMA-rated fan efficiency tables based on motor horsepower[11]

3,412 = Constant to convert Btu to kilowatt-hours

Bushels/hr = Bushels per hour of dryer capacity at 100% operation based on manufacturer rated capacities for a 5% moisture removal and a 10% moisture removal, with a finishing moisture of 15% (= user-defined, or derived from dryer specification sheet)

lbs_{FINAL} = Final bushel weight determined from grain moisture content percentage and weight per bushel reference tables (= 55.54)[8]

%Elec = Percentage of total energy consumed that is electric (= see Grain Dryer Type Efficiency and Energy Savings Splits table above)

%Gas = Percentage of total energy consumed that is gas (= see Grain Dryer Type Efficiency and Energy Savings Splits table above)

Summer Coincident Peak Savings Algorithm

Grain drying does not occur during the summer peak time periods, therefore no peak demand savings can be claimed.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years, see Assumptions)[4,7]

Assumptions

The amount of energy savings from grain dryers is based on production, so farms that grow and dry more grain achieve more savings. The amount of grain harvested can be affected by the weather and the number of acres of grain planted in a particular year. The need for drying is also dependent on the weather at the time of harvest, with drier weather requiring less grain drying. To attempt to control for these variables, the number of acres planted for the upcoming harvest is collected on the application and will be used along with Wisconsin historical crop yields per acre to determine future grain drying output.

The measure assumes that all grain drying takes place in the late fall months after grain harvest, typically around October and November.[13] While latent heat has a role in the grain drying process, for purposes of simplification the air ‘sensible’ heat transfer formula is used for grain dryer efficiency calculations. The savings assume that blower/dryer fans are running at their full rated speed throughout the entire drying period, as well as that the burner plenum temperature stays constant throughout entire drying period. Specific electric use for grain dryer conveyors or augers/stirrers is not included in the calculation. This is accounted for in the Energy Savings Split Between Gas and Electric table. Finally, grain dryer pricing is based on newer style grain dryers from one manufacturer that are more energy efficient than older models.

The incentive amount is based on the bushels per hour of drying capacity at an 10% moisture content reduction for corn.

This entry includes measures for gas–fired equipment eligible to both natural gas and propane customers. The Code of Federal Regulations,[14] upon which federal efficiency standards are based, defines *gas* as either natural gas or propane (§430.2 for consumer appliances, and §431.2 for commercial and industrial equipment). Thus, it is assumed that equipment efficiencies, costs, etcetera are equal for both fuel types. Any infrastructure or maintenance costs unique to each fuel are ignored.

Sources for EUL list a measure life of 30 years[1] and 10 to 12 years.[4,7] An EUL of 20 years is deemed.

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Version Number	Date	Description of Change
01	10/8/2015	Initial release
02	3/2018	Added propane measure
03	11/2019	Minor changes to requirements
04	11/2020	Updated cost
05	7/2021	Added baseline efficiencies table for various dryers, updated moisture content reference, replaced input value of annual bushels with annual acres dried, removed reference to utility bill method for determining baseline efficiency

Grain Dryer Tune-Up

	Measure Details
Measure Master ID	Grain Dryer Tune-Up, 4901 Grain Dryer Tune-Up, Propane-Fueled, 5085
Workpaper ID	W0248
Measure Unit	Per grain dryer
Measure Type	Hybrid
Measure Group	Agriculture
Measure Category	Tune-Up / Repair / Commissioning
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	Varies
Water Savings (gal/year)	0
Effective Useful Life (years)	1[1]
Incremental Cost ($/unit)	Standard = $276.18 (MMID 4901); Propane-Fueled = $355.40 (MMID 5085)[2]

Measure Description

This incentive offering is for agricultural operations that service their existing grain drying systems to improve energy efficiency. Although still operational, the efficiency of grain drying equipment drops as its components become clogged, dirty, or out of calibration. Cleaning all fans and screens to allow for increased airflow will effectively reduce the annual hours of operation by allowing for faster process of grain and increased capacity.[3] All temperature and moisture sensors will also need to be cleaned and calibrated to ensure that the equipment controls are functioning properly and at peak efficiencies.[1] This incentive will be provided annually as a hybrid measure with a fixed incentive rate and savings based on the number of acres planted that will be dried in the grain dryer receiving a tune-up.

While this measure can apply to all types of grain, the focus of this workpaper is on corn, which is the main use of grain dryers in the state of Wisconsin. Also, certain types of grain dryers will benefit more from the listed tune-up items than others. For this reason, only grain dryers with the highest potential for savings have been included: tower-style continuous flow dryers, mixed flow dryers, high-temperature batch dryers, and other styles of dryers with heat recovery capabilities. Low temperature bin style dryers are not eligible for this incentive.

This measure is not eligible for new construction.

Description of Baseline Condition

The baseline condition is grain drying equipment associated with a commercial-grade farm facility that has not been inspected or tuned up by a trade ally in the current calendar year.

The efficiency of grain dryers is very dependent on the weather conditions and time of harvest for each year. Unfortunately, there is no simple way to depict this information for each individual project and many assumptions must be made. The grain dryer efficiencies used for this measure are estimates made using normal weather temperature and humidity data at the location of grain dryer installation during the time of harvest and drying. Baseline conditions and efficiencies were established using USDA literature[4] as well as an industry fact sheet:[5] the analysis also states that the overall efficiency of grain dryers does not change with increases in the capacity of the dryer.

Grain dryer capacities vary considerably from a few hundred bushels per hour up to 10,000 bushels per hour for the largest units. Since the corn harvest season only lasts a few weeks in the fall, run time on the grain dryers can be from a few hundred hours up to almost 1,000 hours depending on the total amount of corn that needs to be dried and the starting moisture content. Many dryers will handle a few hundred thousand bushels of corn each year.

Description of Efficient Condition

The efficient condition is grain drying equipment associated with a commercial-grade farm facility that has been inspected, cleaned, and tuned up by a Focus on Energy trade ally. The trade ally must abide by all rules and regulations related to grain dryer testing and safety protocols and must conduct the following tasks: inspect and clean screens, inspect and clean fans, clean and calibrate all temperature sensors, clean and calibrate moisture sensors if applicable, inspect and adjust grain dryer controls including temperature setpoint for maximum efficiency, and lubricate bearings.

These tune-up items are low-cost activities that will improve the grain drying equipment efficiency and performance[1,6] and are useful system checks, as regular maintenance keeps the equipment operating as specified.[3]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Acres * Bsh/Acre * Lbs_{BUSHEL} * MS\% * Eff_{GD} / 3{,}412 * \%Elec * SF$

$Gas_{SAVED} = Acres * Bsh/Acre * Lbs_{BUSHEL} * MS\% * Eff_{GD} / ConvF * \%Gas * SF$

MS% = Moisture shrink percent, % weight reduction of wet grain as it is dried

= $(MC_{INIT} - MC_{FINAL}) / (100\% - MC_{FINAL})$

= 9.51% (see inputs below)

Where:

Acres = Number of acres planted that will be dried using the grain dryer (= user-defined input)

Bsh/Acre = Average number of bushels of corn per acre (= 172.8)[7]

Lbs_{BUSHEL} = Initial bushel weight determined from grain moisture content percentage and weight per bushel reference tables (= 61.37)[10]

MC_{INIT} = Harvested grain moisture content percentage (= 22.9%)[11]

MC_{FINAL} = Dried grain moisture content percentage (= 14.8%)[11]

Eff_{GD} = Existing grain dryer efficiency, Btu per pounds water removed (= varies by type of dryer; see Grain Dryer Table – Common Types table below)

3,412 = Constant to convert Btu to kilowatt-hours

%Elec = Percentage of total energy consumed that is electric (= varies by type of dryer; see Grain Dryer Table – Common Types table below)

ConvF = Fuel conversion factor (= 100,000 Btu per therm, = 91,333 Btu per gallon propane)[8]

Gas% = Existing natural gas usage (= 1 - Elec%)

SF = Savings factor (= 0.05; see Assumptions)

Grain Dryer Table – Common Types

Grain Dryer Type	Eff_{GD}* (Btu/Lbs_{H2O})[4,5]	kWh%[9]	kWh_{SAVED}/ Acre	$Therm_{SAVED}$/ Acre (MMID 4901)	$Gallons_{SAVED}$/ Acre (MMID 5085)
Continuous Cross Flow Dryer (includes Tower Dryers)	2,800	2%	0.83	1.38	1.51
Continuous Flow In-Bin Dryer	2,000	2%	0.59	1.00	1.08
Mixed Flow Dryer	2,050	2%	0.61	1.01	1.11
Recirculating Cross-Flow Batch Dryer	2,200	2%	0.65	1.09	1.19
High Temperature Batch Bin Dryer	2,430	2%	0.72	1.20	1.31
Batch Cross Flow Dryer	2,450	2%	0.72	1.21	1.32

* Assuming 10% moisture removed

Summer Coincident Peak Savings Algorithm

Grain drying does not occur during the summer peak time periods; therefore, no peak demand reduction can be claimed.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life = (1 year)[1]

Assumptions

The savings factor of 5% is a conservative estimate based on a whole grain dryer equipment and controls tune up according to Kerry Hartwig, the Sukup dryer sales director.[6] Mr. Hartwig made two notable comments:

- Dirty screens essentially reduce airflow through the dryer. This means it is burning the same amount of electricity but accomplishing less, which significantly decreases the dryer's capacity by generally well over 5%.
- Moisture sensor cleaning and calibration can make a big difference. If a customer is over-drying grain because of a dirty or uncalibrated sensor, they are wasting a lot of energy (both heating fuel and electricity) and costing themselves grain weight they can sell. A potential gain of 5% or more would be very reasonable here.

The amount of energy savings from grain dryers is based on production, so farms that grow and dry more grain achieve more savings. The amount of grain harvested can be affected by the weather and the number of acres of grain planted in a particular year. The number of planted acres serviced by the grain dryer is a user input, and is multiplied by the Wisconsin state average yield for bushels of corn harvested per acre from the last five years to produce the bushels per year dried by the dryer. This accounts for the variability of productivity based on weather from year to year, and is a change from the previous approach for this measure which required users to estimate upcoming bushels per year.

The measure assumes that all grain drying takes place in the late fall months after grain harvest, typically around October and November. While latent heat effects the grain drying process, for purposes of simplification, the air sensible heat transfer formula is used for grain dryer efficiency calculations. The measure assumes that blower/dryer fans are running at their full rated speed throughout the entire drying period. It also assumes that the dryer rated capacity is decreased as screens and fans build up with debris due to a reduction in airflow and constant burner plenum temperatures. Specific electric use for grain dryer conveyors or augers/stirrers is not included in the calculation.

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Revision History

Version Number	Date	Description of Change
01	7/2019	Initial TRM entry
02	9/2020	Added propane measure and removed low temperature bin style dryers
03	9/2021	Replaced input value of annual bushels with annual acres dried, updated dryer efficiencies, moisture content references, and lbs water removed

Heat Recovery Tank, No Heating Element, Electric or Natural Gas

	Measure Details
Measure Master ID	Refrigeration Heat Recovery: Natural Gas WH With Milk Pre-Cooler & Milk Pump VFD, 3989 Natural Gas WH With Milk Pre-Cooler, 3990 Natural Gas WH Without Milk Pre-Cooler, 3991 Electric WH With Milk Pre-Cooler & Milk Pump VFD, 3992 Electric WH With Milk Pre-Cooler, 3993 Electric WH Without Milk Pre-Cooler, 3994 Propane WH With Milk Pre-Cooler & Milk Pump VFD, 4874 Propane WH With Milk Pre-Cooler, 4875 Propane WH Without Milk Pre-Cooler, 4876
Workpaper ID	W0002
Measure Unit	Per milking cow
Measure Type	Hybrid
Measure Group	Domestic Hot Water
Measure Category	Energy Recovery
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies by number of milking cows and tank size
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Annual Propane Savings (Gallons)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by number of milking cows and tank size
Annual Propane Savings (Gallons)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$3,441.45[2]

Measure Description

A refrigeration heat recovery (RHR) unit captures waste heat from the refrigeration system and transfers some of that heat into incoming well water. That captured waste heat preheats ground water before it enters the main water heater unit to be heated up to the desired final temperature needed for farm equipment cleaning. The most popular RHR units are comprised of a water tank with a heat exchanger wrapped around the outside of the tank. The hot compressed refrigerant flows through the heat exchanger on its way to the condenser unit. The heat from the refrigerant is transferred through the tank wall into the water. Thermal buoyancy causes the warmest water to rise to the top of the tank. When hot water is used, water flows from the RHR tank into the water heater, while well water flows into the heat recovery tank. These units can typically assist in reducing the water heating energy use by approximately 50%.[3]

It is important to note that if a dairy farm installs a RHR unit and a milk plate cooler, with or without the use of milk pump VFD control, the plate cooler will impact the savings potential of the RHR unit. The use of a plate cooler will reduce the total milk mechanical refrigeration load. Due to this refrigeration load reduction, the amount of heat rejection possible to the RHR system is diminished. Note that there are three different measures listed for each water heater source.

Description of Baseline Condition

The baseline condition is an existing dairy farm with refrigeration equipment and a water heater unit without the use of an RHR unit to feed preheated water to the water heater. Water heater is fed directly with ground water.

Description of Efficient Condition

The efficient condition is farm refrigeration equipment where an RHR tank (without additional heating element) is installed and captures waste refrigerant heat from the refrigeration system compressor and transfers that waste refrigerant heat into an RHR tank, supplied with cool ground water, through a heat exchanger before continuing through the refrigeration system condensing unit. The newly preheated water in the RHR tank is used as input into the farm’s main water heater unit, which now has a smaller temperature differential to overcome to be fully heated, compared to direct ground water.

Annual Energy-Savings Algorithm

The kWh savings are for MMIDs 3992-3994 (RHR unit paired with electric water heater). The therm savings are for MMIDs 3989-3991 (RHR unit paired with natural gas water heater). The propane savings are for MMIDs 4874-4876 (RHR unit paired with propane water heater).

$kWh_{SAVED} = Btu_{SAVED} / 3{,}412$

$Gas_{SAVED} = Btu_{SAVED} / ConvF$

$Btu_{SAVED} = (Btu_{RECOVERED} / Day * 365) / EF$

$Btu_{RECOVERED}/Day$ = Lesser of: $Btu_{MILK\_POTENTIAL}$ or $Btu_{RHR\_STORAGE}$

$Btu_{MILK\_POTENTIAL} = \text{Lbs of Milk} * C_{P,MILK} * \Delta T_{MILK} * SF$

$Btu_{RHR\_STORAGE} = \text{RHR tank size} * \text{\# of milking's per day} * C_{P,H2O} * P_{WATER} * \Delta T_{H20}$

Where:

3,412 = Btu per kWh conversion factor

ConvF = Fuel conversion factor (= 100 MBtu per therm, = 91.3 MBtu per gallon propane)[14]

365 = Days of milking per year[4]

EF = Energy factor (= 90% for electric standard water heater; = 59% for natural gas standard water heater)[5]

Lbs of Milk = The pounds of milk produced per day that needs to be cooled (= 68 lbs of milk per cow; note that the number of milking cows is user defined)[6]

$C_{P,MILK}$ = Specific heat of milk (= 0.94 Btu/(lb-°F))[8]

ΔT_{MILK} = Change in milk temperature (= $°F_{IN}$ - $°F_{FINAL}$)

  $°F_{IN}$ = Temperature of supplied milk that needs to be mechanically cooled (= 98°F if no pre-cooler is used in operation;[7] = 67°F if a milk pre-cooler unit is used; = 56.3°F if a milk pre-cooler unit and VFD milk pump are used; see Assumptions)

  $°F_{FINAL}$ = Final stored temperature of cooled milk (= 38°F)[7]

SF = Savings factor, the percentage of energy able to be captured from the milk cooling process (= 50%; see Assumptions)[9]

RHR tank size = Size in gallons the RHR tank(s) can hold preheated water per wash cycle (= this is a customer-provided input found on the project invoice; a default value of 100 gallons should be used if RHR tank size cannot be determined from the invoice)

# of milking's per day = Number of times cows are milked per day (= 2.1125; this is based on 11.25%[10] of Wisconsin farms milking more than twice per day. Note that typically, the number of milking's equals the number of equipment wash cycles)

$C_{P,H2O}$ = Specific heat of water (= 1 Btu/lb-°F)

P_{WATER} = Density of water (= 8.34 lbs/gallon)

ΔT_{H20} = Temperature difference (= $Temp_{WARM\_H20}$ – $Temp_{COLD\_H20}$)

  $Temp_{WARM\_H20}$ = Expected temperature an RHR unit can preheat well water up to (= 120 °F)[9]

  $Temp_{COLD\_H20}$ = Average well water temperature (= 52.3 °F)[11]

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for RHR units. It is assumed that electric water heaters have a single element and will still be used to heat water up to full temperature, and that the kW rating is unchanged when a RHR unit is added in the water heating loop (resulting in no demand reduction).

Lifecycle Energy-Savings Algorithm

There are kWh savings for measures using electric water heaters, and therm savings for measures using natural gas water heaters.

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Gas_{LIFECYCLE} = Gas_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

- The percentage range of heat recoverable from milk is 20% to 60%.[9] This workpaper is based on 50% as the deemed savings percentage of recoverable Btus from the milk cooling/heat recovery process, based on engineering judgment.
- This measure assumes that at a minimum, all the preheated water captured in a full RHR tank is ultimately used for cleaning during at least one milk equipment cleaning cycle.
- The RHR unit is assumed to consume no energy itself in order to function (no heating element).
- Based on past project data submitted for the plate-coolers measure, there is roughly a 40%/60% split of single vs. double pass plate coolers,[6] assumed to provide ~25°F/35°F of milk cooling, respectively.[12] This results in a 31°F deemed drop in milk temperature from the inclusion of a pre-cooler to the milk refrigeration system (= [40% * 25°F] + [60% * 35°F]).
- Savings may also result from an increased efficiency of the refrigeration system due to the increased capacity to dissipate heat; however, this workpaper does not account for those savings due to lack of documentation to support the size of those values and claim savings that are conservative in nature.
- The savings are based on the assumption that the maximum hot water temperature from the output of the water heater is 170°F. Therefore, the RHR unit will most likely not achieve total water heating needs on its own.[9]
- The measure savings are based on a well water temperature of 52.3°F for milk coolant.[11] It is assumed that the lowest milk temperature that could be achieved is 56.3°F (or 4°F higher than the well water coolant temperature).[13] The maximum additional cooling for any style of plate cooler in conjunction with a variable speed controlled milk pump would be up to 15°F of additional cooling.[12]
- The user-defined input provided for the number of milking cows is assumed to be the average number of animals being milked throughout the entire year, associated with the refrigeration system(s) using the heat recovery unit.

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Revision History

Version Number	Date	Description of Change
01	10/01/2015	Initial release
02	10/28/2016	Adjusted to include more assumptions and require less customer data, changed unit measure to per milking cow
03	12/2018	Updated cost based on new historical data
04	02/2021	Added propane measures

Plate Heat Exchanger and Well Water Pre-Cooler

	Measure Details
Measure Master ID	Plate Heat Exchanger and Well Water Pre-Cooler (< 135 Milking Cows), 3982 Plate Heat Exchanger and Well Water Pre-Cooler (≥ 135 Milking Cows), 3983
Workpaper ID	W0005
Measure Unit	Per milking cow
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Heat Exchanger
Sector(s)	Agriculture
Annual Energy Savings (kWh)	47 kWh
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	705 kWh
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$14.44[2]

Measure Description

A well water pre-cooler is a heat exchanger device used to partially cool milk without the need for energy intensive mechanical refrigeration. Cold well water and groundwater, which is around 52.3°F, is pumped through one side of a heat exchanger while cow's milk, at about 98°F, is pumped through the other side of the heat exchanger. Energy savings are calculated based on the amount of milk temperature reduction achieved from the heat exchanger, defined as heat energy that does not have to be removed via mechanical refrigeration. This measure is only eligible for new pre-cooler installations and is not applicable for replacement pre-cooler units. It is assumed that the warmed output water from the plate cooler is reused elsewhere on the farm for either general farm equipment washing or most likely for reuse as animal watering. Little to no water waste should occur of the pre-cooler water output. It is in the farmer's best interest to reuse this output water for general farm use water needs to avoid pumping additional water for farm use.

Description of Baseline Condition

The baseline condition is a dairy operation without the use of a milk pre-cooler. Baseline milk cooling is achieved by using mechanical refrigeration compressors/chillers. Typically scroll or hermetically sealed reciprocating compressors are used to drive the cooling process.

Description of Efficient Condition

The efficient condition is a dairy operation that installs a milk pre-cooler unit to use colder well water as a coolant to pre-cool milk by several degrees prior to the mechanical refrigeration that cools the milk down to a final storage temperature of around 38°F.

Annual Energy-Savings Algorithm

kWh_{SAVED} = lbs of Milk * $C_{P,MILK}$ * ΔT_{MILK} * Milking Days per year / $AEER_{COMPRESSOR}$ / 1,000

Where:

lbs of Milk = Estimated daily pounds of milk produced by the dairy farm that needs to be cooled through use of a milk pre-cooler (= # of milking cows * 68 lbs of milk per day per cow[2,3] / 365 days)

$C_{P,MILK}$ = Specific heat of milk (= 0.94 Btu/(lb-°F))[4]

ΔT_{MILK} = Temperature difference between warm milk incoming into the plate cooler and the cooled milk leaving the plate cooler (= 31°F; see Assumptions)

Milking Days per year = Number of milking days per year (= 365)[5]

$AEER_{COMPRESSOR}$ = Annual energy efficiency ratio of compressor (= 15.39 Btu/watt-hr; see Assumptions)[6]

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for well water pre-coolers.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

The savings calculation does not account for the pump energy needed to pump the cold well water through the plate cooler; since the plate cooler output of warmed well water is then used for animal watering, this water pumping would normally occur anyway for animal watering needs. The savings are based on the assumption that all plate cooler water output is reused elsewhere on the farm.

The following assumptions also apply to the savings calculations:

- Milking operations are assumed to occur 365 days per year.[5]

- Savings associated with the reduced runtime of mechanical refrigeration system condenser fans are not included (thus the savings from the measure is conservative).
- A typical water to milk flow ratios of 3:1 or 2:1 is assumed.
- It is assumed that there is a 25°F of milk temperature difference for a single pass plate cooler and a 35°F of temperature difference for a double/multi-pass plate cooler.[7] Recent program trends of plate heat exchanger measures applying for incentives in Wisconsin shows a 40%/60% split[2] of single and double pass plate coolers, respectively. The estimated deemed temperature drop for a farm with a pre-cooler is 31°F (25°F * 0.4 + 35°F * 0.6).
- An even 50/50 split of farms using scroll versus reciprocating compressors to drive the milk cooling process is assumed, using an annual EER of compressor usage based on changing annual ambient temperature conditions.[6]
- Assumes all second-use warmed water from the output of the well water plate cooler will be reused as general wash water to clean farm equipment or help fulfill animal watering needs due to the basis that a dairy cow consumes at least three times more water than they produce as milk.[8]
- User defined input provided for the number of milking cows value is assumed to be the average number of animals being milked throughout the entire year.

Sources

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4. Hu, Jin. “Determination of Specific Heat of Milk at Different Fat Content Between 1°C and 59°C Using Micro DSC.” Journal of Food Engineering (February 2009): 90(3). p. 395-399.· http://www.researchgate.net/publication/234102534_Determination_of_specific_heat_of_milk_at_different_fat_content_between_1C_and_59C_using_micro_DSC
Table 1 Units converted from J/(g*K) to Btu/(lb-°F).
5. Wisconsin Milk Marketing Board. “Did You Know? Website: Milking Every Day.” Accessed December 21, 2015. http://www.dairydoingmore.org/economicimpact/dairyfacts
6. “Dairy Pre-Cooler Supplemental Data.”
Compressor Modeling Tab created by CESA10 using compressor model data from past projects submitted to Focus on Energy and Compressor Performance Data sheets from Copeland scroll compressors.

7. Sanford, Scott (University of Wisconsin–Madison). "Energy Efficiency for Dairy Enterprises." Presentation to Agricultural and Life Sciences Program staff. December 2014. http://farmenergymedia.extension.org/sites/default/files/Dairy%20Energy%20Conservation-2013.pdf
8. Sanford, Scott (University of Wisconsin–Madison). "Well Water Precoolers." Publication A3784-3. October 2003. http://learningstore.uwex.edu/Assets/pdfs/A3784-03.pdf

Revision History

Version Number	Date	Description of Change
01	09/22/2015	Initial release
02	10/28/2016	Added additional assumptions, updated sources, changed to prescriptive based on number of milking cows
03	12/2020	Updated cost

Energy Efficient or Energy Free Livestock Waterer

	Measure Details
Measure Master ID	Waterer, Livestock: < 250 Watts, 2660 Energy Free, 3018
Workpaper ID	W0006
Measure Unit	Per waterer
Measure Type	Prescriptive
Measure Group	Agriculture
Measure Category	Livestock Waterer
Sector(s)	Agriculture
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	0 (winter use only)
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	< 250 watts = $575.35 for retrofit, $566.73 for new construction (MMID 2660);[3] Energy free = $562.89 (MMID 3018)[4]

Measure Description

Electrically heated waterers are commonly used to provide clean water for livestock during winter months when temperatures may drop below freezing. Baseline efficiency waterers typically have no insulation and require large heating elements to prevent water from freezing. Energy-efficient livestock waterers have at least two inches of insulation, which allows for the use of much smaller heating elements (less than 250 watts). Energy-free waterers have at least two inches of insulation and no heating element, as they use ground source water to prevent freezing.

Description of Baseline Condition

The heating element for a baseline unit is typically at least 750 watts, but may be 1,500 watts or larger. Retrofit waterer installations, both energy efficient and energy free, use a baseline of 1,100 watts. New construction waterer calculations use a baseline of 500 watts.

Description of Efficient Condition

Efficient or low energy livestock waterers must have a minimum of two inches of insulation. The heating element for an efficient unit will be a maximum of 250 watts. The energy-free unit may not have an electric heating element installed, but instead uses ground source heating. The new waterer must be able to serve the same herd size as the existing equipment. For new construction, the livestock waterer must be energy free.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * HOU$

Where:

$Watts_{BASE}$ = Power consumption of baseline measure equipment (= 1,100 watts for retrofit; = 500 watts for new installation)[2]

$Watts_{EE}$ = Power consumption of efficient measure equipment (= 250 watts for energy-efficient retrofit; = 0 watts for energy-free installation)

1,000 = Kilowatt conversion factor

HOU = Average annual run hours of heater (= 3,040; annual operation is used as a conservative estimate of the number of hours below 32°F annually throughout the state of Wisconsin, consistent with TMY3 bin data)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (= 0)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Average Annual Deemed Savings

Type	MMID	Sector	kWh
Energy Efficient Livestock Waterer	2660	Agriculture	2,584
Energy Free Retrofit Livestock Waterer	3018	Agriculture	3,344
Energy Free New Construction Livestock Waterer	3018	Agriculture	1,520

Lifecycle Energy Savings

Type	MMID	Sector	kWh
Energy Efficient Livestock Waterer	2660	Agriculture	25,840
Energy Free Retrofit Livestock Waterer	3018	Agriculture	33,440
Energy Free New Construction Livestock Waterer	3018	Agriculture	15,200

Deemed Peak Demand Reduction

Type	MMIDs	kWh
All Livestock Waterers	2660 and 3018	0

Assumptions

No peak demand (kW) reduction is associated with this measure because heaters are generally only used during winter months.

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. EnSave. Energy Efficient Stock Waterers. http://www.usdairy.com/~/media/usd/public/ensaveenergyefficientstockwaterers.pdf
3. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 131 units over 30 projects from 2016 to 2018 is $788.41. Retrofit baseline cost of $213.06 reflects cost of standard small waterer and 1,000-watt de-icer, derived from five product lookups on www.farmandfleet.com and amazon.com. Retrofit incremental cost is $788.41 - $213.06 = $575.35. New construction baseline cost of $221.68 reflects cost of standard small waterer and 500-watt de-icer, derived from five product lookups on www.chewy.com and amazon.com. Retrofit incremental cost is $788.41 - $221.68 = $566.73.
4. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 306 units over 49 projects from 2017 to 2018 is $921.46. Baseline cost of $358.57 reflects cost of standard large waterer and 1,000-watt de-icer, derived from five product lookups on www.farmandfleet.com and amazon.com. Incremental cost is $921.46 - $358.57 = $562.89.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	12/2018	Updated cost based on historical program data

Dairy Refrigeration Tune-Up

	Measure Details
Measure Master ID	Refrigeration System Tune-Up, Agriculture, 4403
Workpaper ID	W0008
Measure Unit	Per milking cow
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Agriculture
Annual Energy Savings (kWh)	2.5637
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	2.5637
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	1[1]
Incremental Cost ($/unit)	$194.05[2]

Measure Description

This tune-up is designed to assess all refrigeration equipment associated with a commercial-grade dairy farm facility with the intention of reducing electrical consumption.

Description of Baseline Condition

The baseline condition is refrigeration equipment associated with a commercial-grade dairy farm facility that has not been inspected or tuned up in more than 12 months.

Description of Efficient Condition

The efficient condition is refrigeration equipment associated with a commercial-grade dairy farm facility that has been inspected and tuned up by a U.S. EPA 608 Certified Service Provider. The Service Provider must abide by all rules and regulations related to refrigerant testing and safety protocol and must conduct the following tasks: clean and inspect condenser and evaporator coils; clean drain pan; inspect/clean fans, screens, grills, filters, and drier cores; inspect/adjust heat reclaim operation; tighten all line voltage connections; inspect/replace relays and capacitors as needed; and add/remove refrigerant charge as needed.

Annual Energy-Savings Algorithm

Energy savings from the refrigeration equipment tune up/maintenance is 5%.[4]

$kWh_{SAVED} = kWh_{SAVED}/day * 365\ days$

$kWh_{SAVED}/day = [lbs\ milk/day * C_{P,MILK} * (°F_{IN} - °F_{FINAL}) / AEER_{COMPRESSOR} / 1{,}000] * SF$

Where:

365 = Number of days per year cows are milked[5]

lbs milk/day = Pounds of milk produced at farm facility per day (= 68 pounds of milk per cow;[3,5] the number of milking cows is a user-defined input)

$C_{P,MILK}$ = Specific heat of milk (= 0.94 Btu/lb-°F)[6]

$°F_{IN}$ = Temperature of supplied milk that needs to be mechanically cooled (= 71.8°F, or = 98°F if no pre-cooler used in operation;[7] = 67°F if a milk pre-cooler unit is used; = 56.3°F if a milk pre-cooler unit and VFD milk pump are used; see Assumptions)

$°F_{FINAL}$ = Final stored temperature of cooled milk (= 38°F)[7]

$AEER_{COMPRESSOR}$ = Annual energy efficiency ratio of refrigeration compressor (= 15.39 Btu/watt-hour;[4] see Assumptions)

1,000 = Kilowatt conversion factor

SF = Energy savings factor (= 0.05)[4]

Summer Coincident Peak Savings Algorithm

There are no peak coincident savings claimed for this measure. While some level of kilowatt savings is likely to result from a refrigeration system tune up, the amount is anticipated to be small. Also, a large majority of farms in Wisconsin do not actively milk during Focus on Energy–defined peak time periods, due to having only two milking periods per day: this would create a low coincidence factor for any kilowatt savings. Lastly, there is a lack of concrete data readily available on the amount of kilowatt savings that could realistically ensue from a system tune up.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 1 year)[1]

Assumptions

The savings factor is a conservative estimate based on a whole refrigeration system tune up. According to Scott Sanford from the University of Wisconsin–Madison, between 3% and 5% electrical savings can be achieved from just cleaning the condenser on an annual basis.[4] In addition to cleaning the condenser, the refrigeration system tune up involves cleaning the evaporator coils, fans, filters, screens, and grills, and inspecting and adjusting or replacing relays, capacitors, and refrigerant charge.

Milk temperature from the output of a pre-cooler is based on a weighted percentage of single and double pass pre-cooler units. Single pass units drop the milk temperature roughly 25°F while double pass units drop the milk temperature roughly 35°F.[9] Based on past project data analysis related to milk pre-cooler application submittals, new pre-cooler installations in Wisconsin are 40% single pass pre-cooler and 60% double pass pre-coolers; therefore, the estimated temperature drop for a farm with a pre-cooler is 31°F (= [25°F * 0.4] + [35°F * 0.6]).[4]

The AEER value is based on an even 50/50 split of farms using scroll versus reciprocating compressors to drive the milk cooling process.[4]

The savings are based on a well water temperature of 52.3°F being used as milk coolant.[4] It is assumed that the lowest milk temperature that could be achieved is 56.3°F (or 4°F higher than the well water coolant temperature).[10] The maximum additional cooling for any style of plate cooler in conjunction with a variable speed controlled milk pump would add up to 15°F of cooling.[4]

The 2017 Focus on Energy Potential Study Site Surveys[4] provide a breakdown of Wisconsin dairy farms with the existing milking equipment scenarios shown in the table below.

Installed Equipment Populations

Existing Milking Equipment Scenario	Percentage of Sites Surveyed
Operation with Milk Pre-Cooler and VFD on Milk Pump	48.4
Operation with Milk Pre-Cooler Only	19.4
Operation without Milk Pre-Cooler	32.3

The user-defined input provided for the number of milking cows is assumed to be the average number of animals being milked throughout the entire year.

Sources

1. Engineering judgement. It is recommended that tune-ups be completed annually.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 35 units over 31 projects in 2018.
3. U.S. Department of Agriculture. “Milk Production Per Cow, Wisconsin.” WI Dairy Statistics tab. https://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Dairy/Historical_Data_Series/mkpercow.pdf
4. “Dairy Refrigeration Tune-up, Agriculture Potential Study Data.” Spreadsheet. Potential Study Survey Data tab shows the breakdown of Wisconsin dairy farms with existing

milking equipment scenarios based on 2017 Wisconsin Focus on Energy Potential Study results. Compressor Modeling tab created by CESA10 using compressor model data from past projects submitted to Focus on Energy and Compressor Performance Data sheets from Copeland scroll compress. Pre-cooler Measure Analysis tab showing sample data of 86 pre-cooler projects entered in Spectrum from January 2015 to July 2016. The split of single pass to double pass plate coolers installed on Wisconsin dairies was determined from the project inputs of these 86 sample projects.

5. Wisconsin Milk Marketing Board. "Did You Know? Milking Every Day." Accessed December 21, 2015. http://www.dairydoingmore.org/economicimpact/dairyfacts
6. Hu, Jin. "Determination of Specific Heat of Milk at Different Fat Content Between 1°C and 59°C Using Micro DSC." Journal of Food Engineering (February 2009): 90(3). p. 395–399.·http://www.researchgate.net/publication/234102534_Determination_of_specific_heat_of_milk_at_different_fat_content_between_1C_and_59C_using_micro_DSC
   Table 1 Units converted from J/(g*K) to Btu/(lb-°F).
7. Sanford, Scott (University of Wisconsin–Madison). "Well Water Precoolers." Publication A3784-3. October 2003. http://learningstore.uwex.edu/Assets/pdfs/A3784-03.pdf
8. Sanford, Scott (University of Wisconsin–Madison). "Energy Efficiency for Dairy Enterprises." Presentation to Agricultural and Life Sciences Program staff. Slides 16, 21, and 26. December 2014. http://farmenergymedia.extension.org/sites/default/files/Dairy%20Energy%20Conservation-2013.pdf
9. U.S. Department of Energy. "Domestic Hot Water Scheduler." http://energy.gov/eere/buildings/downloads/dhw-event-schedule-generator
   Average water main temperature of all locations measured in Wisconsin by scheduler, weighted by city populations.
10. EnSave. "Milk Pump Variable Speed Drive." Brochure. 2009. http://www.usdairy.com/~/media/usd/public/ensavemilkpumpvariablespeeddrive.pdf

Revision History

Version Number	Date	Description of Change
01	10/01/2015	Initial TRM entry
02	10/28/2016	Changed EUL and EER values, included three measures to address various system operations, changed unit measure to the number of milking cows
03	10/2017	Updated EUL
04	10/25/2017	Combined three measures into one using Potential Study[4] results to weight existing milking equipment scenarios
05	12/2018	Updated Incremental cost

Boilers and Burners

Boiler, Condensing, ≥90% AFUE

	Measure Details
Measure Master ID	Boiler, Hot Water, Modulating: ≥90% AFUE, <300 MBh, 2218 ≥90% AFUE, <300 MBh, Propane-Fueled, 4852 Boiler, Condensing: ≥90% AFUE, ≥300 MBh, 3276 ≥90% AFUE, ≥300 MBh, Propane-Fueled, 4866
Workpaper ID	W0009
Measure Unit	Per MBh
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Boiler
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Annual Propane Savings (Gallons)	Varies by measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Lifecycle Propane Savings (Gallons)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	25[1]
Incremental Cost ($/unit)	$10.98 for modulating (MMIDs 2218 and 4852)[2], $6.07 for condensing (MMIDs 3276 and 4866)[8]

Measure Description

High-efficiency sealed combustion, condensing, and modulating boilers operate by taking advantage of condensing to lower energy consumption. Condensing boilers are designed to capture the latent heat of condensation in the form of water vapor in the exhaust stream. Capturing this latent heat produces high-efficiency levels. For a boiler to operate in condensing mode, its return water temperature should be kept below 120°F. In order to capture as much latent heat as possible, condensing boilers are made from stainless steel or other corrosion-resistant materials. Chimney liners must be installed for boilers that are replacing a naturally drafting unit that was vented through the same flue as a water heater. Flue closure protocols must be followed when the chimney that will used by the replacement unit was not in use for the previous equipment.

Description of Baseline Condition

The baseline measure is an 82% AFUE boiler.[4]

Description of Efficient Condition

The efficient measure meets several requirements:

- Boiler must be ≥90% AFUE
- Boiler must be used in space heating applications
- Boiler must be natural gas– or propane-fueled and produce hot water (those using other fuel types or that generate steam do not qualify)
- Chimney liners must be installed where a high-efficiency natural gas or propane boiler replaces atmospherically drafted equipment that was vented through the same flue as a natural gas or propane water heater
- Redundant or backup boilers do not qualify
- The return water temperature must be cool enough to condense flue gases in order to provide maximum efficiency (if the heating system configuration cannot provide necessary operating conditions to the boiler, selection of a non-condensing or near-condensing boiler may be more appropriate)
- For MMIDs 2218 and 4852 (<300 MBh):
    - Must be a sealed combustion unit
    - Must be capable of firing rate modulation
    - Must include outdoor air reset control
    - MMID 4852 is only for when the existing boiler uses fuel oil or propane
- For MMIDs 3276 and 4866 (≥300 MBh):
    - Must be capable of capacity modulation
    - Must submit specification sheet with steady state boiler input and output ratings and AFUE
    - When replacing a natural gas–fueled boiler system with both condensing (>90% AFUE) and near-condensing (85% AFUE to 89% AFUE), use the Hybrid Hot Water Boiler Plant measure (MMID 3275)
    - MMID 4866 is only for when the existing boiler uses fuel oil or propane, and is not eligible for use with the Hybrid Hot Water Boiler Plan measure

Annual Energy-Savings Algorithm

$Gas_{SAVED} = BC * OF * EFLH * ISR * (1 / AFUE_{BASE} – 1 / AFUE_{EFF}) / ConvF$

Where:

BC = Boiler rated capacity (MBtu/hr)

OF = Oversizing factor (= varies by measure; see Oversize Factor table below)

Oversize Factor by Measure

Description	MMIDs	Sectors	Oversize Factor[6]
Boiler, Hot Water, Modulating, ≥90% AFUE, ≤300 MBh	2218	Residential- multifamily	174%
Boiler, Hot Water, Modulating, ≥90% AFUE, <300 MBh	2218, 4852	Agriculture, Commercial, Industrial, Schools & Government	217%
Boiler, Condensing, ≥90% AFUE, ≥300 MBh	3276	Residential- multifamily, Agriculture, Commercial, Industrial, Schools & Government	120%
Boiler, Condensing, ≥90% AFUE, ≥300 MBh	4866	Agriculture	119%

EFLH = Equivalent full-load hours (= 1,890)[5]

ISR = In-service rate (= 95% for MMIDs 3276 and 4866, = 100% for MMIDs 2218 and 4852)[7]

$AFUE_{BASE}$ = Boiler baseline thermal efficiency (= 82%)[4]

$AFUE_{EFF}$ = Boiler proposed thermal efficiency (= 95%)[7]

ConvF = Conversion factor (= 100 MBtu per therm, = 91.3 MBtu per gallon propane)[8]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Gas_{LIFECYCLE} = Gas_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 25 years)[1]

Deemed Savings

Natural Gas Savings (per MBh)

Description	MMID	Sector	therms		Gallons Propane	
			Annual	Lifecycle	Annual	Lifecycle
Boiler, Hot Water, Modulating						
≥90% AFUE, ≤300 MBh	2218	Residential- multifamily	5.22	130.5	-	-
≥90% AFUE, <300 MBh	2218	Agriculture, Commercial, Industrial, Schools & Government	6.50	162.5	-	-
≥90% AFUE, <300 MBh, Propane-Fueled	4852	Agriculture	-	-	7.12	178.0
Boiler, Condensing						
≥90% AFUE, ≥300 MBh	3276	Residential- multifamily, Agriculture, Commercial, Industrial, Schools & Government	3.42	85.5	-	-
≥90% AFUE, ≥300 MBh, Propane-Fueled	4866	Agriculture	-	-	3.75	93.75

Assumptions

This entry includes measures for gas-fired equipment eligible to both natural gas and propane customers. The Code of Federal Regulations,[9] upon which federal efficiency standards are based, defines *gas* as either natural gas or propane (§430.2 for consumer appliances, and §431.2 for commercial/industrial equipment). Thus, it is assumed that equipment efficiencies, costs, and other variables are equal for both fuel types. Any infrastructure or maintenance costs unique to each particular fuel are ignored.

Sources

1. U.S. Department of Energy. Technical Support Document: Energy Efficiency Program For Consumer Products and Commercial and Industrial Equipment: Commercial Packaged Boilers. December 9, 2016. Page 8F-4.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 321 projects, 440 boilers, and 109,151 MBh for MMIDs 2218, 4852 from January 2018 to July 2020 is $39.80. August 2018 online lookups of 18 baseline and 22 efficient boiler models less than 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 27.6% higher than the baseline cost. The incremental cost is therefore 27.6% * $39.80 = $10.98 per MBh.
3. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 400 projects, 741 boilers, and 1,017,865 MBh for MMIDs 3276, 4866 from January 2018 to July 2020 is $21.99. August 2018 online lookups of 18 baseline and 22 efficient boiler models

less than 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 27.6% higher than the baseline cost. The incremental cost is therefore 27.6% * $21.99 = $6.07 per MBh.

4. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Energy Efficiency and Renewable Energy Office. "2008-07-28 Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnaces and Boilers; Final Rule; Technical Amendment." Federal standard for residential boilers. Effective August 27, 2008. https://www.regulations.gov/document?D=EERE-2006-STD-0102-0009
5. U.S. Environmental Protection Agency and U.S. Department of Energy. "Life Cycle Cost Estimate for ENERGY STAR Qualified Air Source Heat Pump(s)." April 2009. https://www.energystar.gov/sites/default/uploads/buildings/old/files/ASHP_Sav_Calc.xls
   Several Cadmus metering studies have revealed that the ENERGY STAR calculator EFLH values are overestimated by 25%. The heating EFLH were adjusted by population-weighted heating degree days and typical meteorological year values, then averaged for the state of Wisconsin.
6. Cadmus. "Focus on Energy Boiler Measure Study." 2016.
   The study determined realized savings from billing data for sites that had applied for boiler incentives during the 2012 through 2014 program years. The oversize factors in this workpaper align each measure's calculated savings, in conjunction with assumed EFLH and AFUE values, with the savings calculated from billing data results for 26 sites for MMID 2218 and 33 sites for MMID 3276.
7. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
8. U.S. Energy Information Administration. "Energy Units and Calculators Explained." Accessed December 2018. https://www.eia.gov/energyexplained/?page=about_energy_units
9. Electronic Code of Federal Regulations. §430-431. Accessed February 2019. https://www.ecfr.gov/cgi-bin/text-idx?gp=&SID=92c3f99c51e1124fcc790d11c93e04af&mc=true&tpl=/ecfrbrowse/Title10/10CIIsubchapD.tpl

Revision History

Version Number	Date	Description of Change
01	01/2013	Updated baseline efficiency from 80% to 82% (MMID 2743).
02	08/2016	Added MMIDs 2218 and 3276, which were not previously documented. Merged boiler measures into one workpaper for consistency. Updated the oversizing factor based on the 2016 boiler measure study by Cadmus and consolidated EFLH to one value for the state of Wisconsin.
03	05/2018	Updated efficient AFUE and added ISR.
04	12/2018	Updated incremental cost, EFLH, and savings algorithm.
05	03/2019	Added propane measures.
06	02/2020	Revised to move multifamily MMID 2743 savings to multifamily sector savings under MMID 2218. Updated cost.

Boiler, Near Condensing, ≥ 85% AFUE

	Measure Details
Measure Master ID	Boiler, Hot Water, Near Condensing, ≥ 85% AFUE, ≥ 300 MBh, 3277 Boiler, Hot Water, Near Condensing, ≥ 85% AFUE, ≥ 300 MBh, Propane-Fueled, 4867
Workpaper ID	W0010
Measure Unit	Per MBh
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Boiler
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	1.60
Annual Propane Savings (Gallons)	1.75
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	40.0
Lifecycle Propane Savings (Gallons)	43.8
Water Savings (gal/year)	0
Effective Useful Life (years)	25[1]
Incremental Cost	$5.37[2]

Measure Description

Mid-efficiency boilers use forced draft or induced draft power burners, instead of atmospheric draft, to push or pull gases through the firebox and heat exchanger. Because these boilers have relatively high efficiencies and relatively low flue gas temperatures, they are often constructed with stainless steel or other corrosion-resistant materials to tolerate condensation in the boiler. These boilers are typically used in applications where high-efficiency sealed combustion, condensing, and modulating boilers cannot be vented or where they will not have low enough return water temperatures to condense the water vapor in the flue gas.

Description of Baseline Condition

The baseline measure is an 82% AFUE boiler.[3]

Description of Efficient Condition

The efficient condition is one that meets several requirements:

- Boiler must be ≥ 85% AFUE
- Boiler must be used in space heating applications

- Boiler must be natural gas– or propane-fired and must produce hot water (those using other fuels or to generate steam do not qualify)
- Chimney liners must be installed where a high-efficiency natural gas or propane boiler replaces atmospherically drafted equipment that was vented through the same flue as a natural gas or propane water heater
- Redundant or backup boilers do not qualify
- Condensing boilers (≥ 90% AFUE or thermal efficiency) will provide maximum efficiency only if the return water temperature is cool enough to condense flue gases (if the heating system configuration cannot provide necessary operating conditions to the boiler, the savings are calculated based on a non-condensing or near-condensing boiler)
- Boiler must be capable of capacity modulation
- Specification sheet must be submitted with steady state boiler input and output ratings and AFUE
- When replacing a natural gas–fueled boiler system with both condensing (≥ 90% AFUE) and near-condensing (85% AFUE to 89% AFUE), savings are calculated based on MMID 3275
- MMID 4867 is only used when the existing boiler uses fuel oil or propane. MMID 4867 is not eligible for use of the hybrid hot water boiler plant measure.

Annual Energy-Savings Algorithm

Gas_{SAVED} = BC * OF * EFLH * ($AFUE_{EE}$ / $AFUE_{BASE}$ – 1) / ConvF

Where:

BC = Boiler rated capacity (MBtu per hour)
OF = Oversizing factor (= 77%)[4]
EFLH = Equivalent full-load hours (= 1,890)[5]
$AFUE_{BASE}$ = Boiler baseline thermal efficiency (= 82%)[3]
$AFUE_{EFF}$ = Boiler proposed thermal efficiency (= 91%)[6]
ConvF = Fuel conversion factor (= 100 MBtu per therm, = 91.3 MBtu per gallon propane)[7]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Gas_{LIFECYCLE} = Gas_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 25 years)[1]

Assumptions

This entry includes measures for natural gas–fired equipment eligible to both natural gas and propane customers. The Code of Federal Regulations,[8] upon which federal efficiency standards are based, defines *gas* as either natural gas or propane (§430.2 for consumer appliances, and §431.2 for commercial and industrial equipment). Thus it is assumed that equipment efficiencies, costs, and the like are equal for both fuel types. Any infrastructure or maintenance costs unique to each particular fuel are ignored.

Sources

1. U.S. Department of Energy. Technical Support Document: Energy Efficiency Program For Consumer Products and Commercial and Industrial Equipment: Commercial Packaged Boilers. December 9, 2016. Page 8F-4.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 42 projects, 75 boilers, and 170,993 MBh for MMID 3277 from January 2018 to June 2020 is $14.09. August 2018 online lookups of 4 baseline and 19 efficient boiler models over 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 38.1% higher than the baseline cost. The incremental cost is therefore 38.1% * $14.09 = $5.37/MBh.
3. PA Consulting Group. *Focus on Energy Evaluation, ACES: Default Deemed Savings Review Final Report*. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Energy Efficiency and Renewable Energy Office. “2008-07-28 Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnaces and Boilers; Final Rule; Technical Amendment.” Federal standard for residential boilers. Effective August 27, 2008. https://www.regulations.gov/document?D=EERE-2006-STD-0102-0009
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3-2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. U.S. Environmental Protection Agency and U.S. Department of Energy. “Life Cycle Cost Estimate for ENERGY STAR Qualified Air Source Heat Pump(s).” April 2009. http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_ASHP.xls
   Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLH values are overestimated by 25%. The heating EFLH were adjusted by population-weighted HDD and TMY3 values, then averaged for the state of Wisconsin.

6. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
7. U.S. Energy Information Administration. “Energy Units and Calculators Explained.” Accessed December 2018. https://www.eia.gov/energyexplained/?page=about_energy_units
8. Electronic Code of Federal Regulations. §430-431. Accessed February 2019. https://www.ecfr.gov/cgi-bin/text-idx?gp=&SID=92c3f99c51e1124fcc790d11c93e04af&mc=true&tpl=/ecfrbrowse/Title10/10CIIsubchapD.tpl

Revision History

Version Number	Date	Description of Change
01	01/2013	Updated baseline efficiency from 80% to 82% AFUE (MMID 2743)
02	08/2016	Consolidated EFLH to one value for the state of Wisconsin
03	05/2018	Updated efficient AFUE, added ISR
04	12/2018	Updated incremental cost, EFLH, and savings algorithm
05	03/2019	Added propane measure
06	11/2020	Corrected listed savings, updated cost

Boiler Plant Retrofit

	Measure Details
Measure Master ID	Boiler Plant Retrofit, Hybrid Plant, ≥1 MMBh, 3275
Workpaper ID	W0011
Measure Unit	Per MBh
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Boiler
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	1.43 per MBh
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	28.63 per MBh
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost	$6.60[2]

Measure Description

High-efficiency sealed combustion, condensing, and modulating boilers operate by taking advantage of condensing in an effort to decrease energy consumption. Condensing boilers are designed to capture latent heat by condensing water vapor in the exhaust stream. For a boiler to properly condense, its return water temperature should be kept below 120°F. In order to capture as much latent heat as possible, condensing boilers are made from stainless steel or other corrosion-resistant materials.

Mid-efficiency boilers use forced draft or induced draft power burners, instead of atmospheric draft, to push or pull gases through the firebox and heat exchanger. Because these boilers have relatively high efficiencies and relatively low flue gas temperatures, they are often constructed with stainless steel or other corrosion-resistant materials to tolerate condensation in the boiler.

This measure applies to the entire boiler plant. The summation of the capacity for all heating equipment must be greater than 1,000 MBh. This measure combines high- and mid-efficiency boilers in a boiler plant to take advantage of both condensing boilers (when return water temperatures are low enough for condensing) and mid-efficiency boilers (when return water temperatures do not allow for condensing). The upgraded plant must have at least 50% high-efficiency boilers.

Description of Baseline Condition

The baseline measure is an 82% AFUE boiler.[3]

Description of Efficient Condition

The efficient condition is one which meets the following requirements:

- Boiler must be ≥ 85% AFUE
- Boiler must be used in space heating applications
- Boiler must be natural gas (those using other fuels or to generate steam do not qualify)
- Chimney liners must be installed where a high-efficiency natural gas boiler replaces atmospherically drafted equipment that was vented through the same flue as a gas water heater
- Redundant or backup boilers do not qualify
- Condensing boilers (≥ 90% AFUE or thermal efficiency) will provide maximum efficiency only if the return water temperature is cool enough to condense flue gases (if the heating system configuration cannot provide necessary operating conditions to the boiler, calculate the savings based on a non-condensing or near-condensing boiler)
- Summation of plant heating capacity must be ≥ 1,000 MBh excluding backup and redundant boilers
- Must include both condensing (≥90% AFUE) and near-condensing (≥85% AFUE) boilers, and be capable of capacity modulation
- Plant must have at a minimum 50% of total heating capacity served by ≥ 90% AFUE boilers
- Plant must have controls to operate condensing boilers when return water temperature allows condensing operation
- Plant must have indoor/outdoor reset and staging controls
- Specification sheet must exist with steady state boiler input and output ratings and AFUE

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{BC} * \text{OF} * \text{EFLH} * (\text{AFUE}_{\text{EE}} / \text{AFUE}_{\text{BASE}} – 1)/ 100$

Where:

BC = Boiler rated input capacity (MBtu per hour)
OF = Oversizing factor (= 124%)[4]
EFLH = Equivalent full-load hours (= 1,890)[5]
$\text{AFUE}_{\text{BASE}}$ = Boiler baseline thermal efficiency (= 82%)[3]
AFUE_{EFF} = Boiler proposed thermal efficiency (= 87%)
100 = Conversion factor from MBtu to therm

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE}$ = DS * EUL

Where:

EUL = Effective useful life (= 20 years)[1]

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 20 boilers over 11 projects from 2016 to 2018 is $17.33/MBh. August 2018 online lookups of four baseline and 19 efficient boiler models over 300 MBh on www.supplyhouse.com and www.grainger.com reveal an efficient cost that is 38.1% higher than the baseline cost. The incremental cost is therefore 38.1% * $17.33 = $6.60/MBh.
3. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation ACES: Default Deemed Savings Review." Final Report. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Energy Efficiency and Renewable Energy Office. "2008-07-28 Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnaces and Boilers; Final rule; technical amendment." Federal standard for residential boilers. Effective August 27, 2008. https://www.regulations.gov/document?D=EERE-2006-STD-0102-0009
4. Cadmus. "Focus on Energy Boiler Measure Study." 2016.
   In this study, Cadmus determined realized savings from billing data for sites that had applied for boiler incentives during the 2012-2014 program years. The oversize factor in this workpaper aligns the calculated savings, in conjunction with assumed EFLH and AFUE values, with the savings calculated from billing data results. Billing data was analyzed for a total of nine sites.
5. U.S. Environmental Protection Agency and U.S. Department of Energy. "Life Cycle Cost Estimate for ENERGY STAR Qualified Air Source Heat Pump(s)." April 2009. https://www.energystar.gov/sites/default/uploads/buildings/old/files/ASHP_Sav_Calc.xls
   Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLH values are over-estimated by 25%. The heating EFLH were adjusted by population-weighted HDD and TMY3 values, then they were averaged for the state of Wisconsin.

Revision History

Version Number	Date	Description of Change
01	1/2013	Updated baseline efficiency from 80% to 82% (MMID 2743)
02	8/2016	Updated oversizing factor based on the 2016 boiler measure study by Cadmus. Consolidated EFLH to one value for the state of Wisconsin.
03	12/2018	Updated incremental cost, EFLH, and savings algorithm

Boiler Control, Outside Air Temperature Reset/Cutout Control

	Measure Details
Measure Master ID	Boiler, Outside Temperature Reset/Cutout Control, 2221
Workpaper ID	W0012
Measure Unit	Per MBh
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, and Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by sector and location
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by sector and location
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$612.00[2]

Measure Description

Boiler reset controls automatically control the boiler water temperature based on outdoor temperature. This allows the water to run a little cooler during the fall and spring, and a little hotter during the coldest parts of the winter, improving boiler efficiency and indoor comfort by providing a better match between boiler output and space heating needs. Boiler cutout controls prevent a boiler from firing at a predetermined outside temperature setpoint to prevent overheating.

Description of Baseline Condition

The baseline condition is no input/output reset with an 84% boiler.

Description of Efficient Condition

Outside air temperature reset or cutout control incentives are for existing space heating boilers only. A new boiler with integrated boiler reset controls is not eligible. New boilers not equipped with these controls are eligible for retrofit. The system must be set so that the minimum temperature is not more than 10°F above the manufacturer’s recommended minimum return temperature, unless unusual circumstances require a higher setting. The system must have an outdoor air temperature sensor in a shaded location on the north side of the building. For controls on multiple boilers to qualify, a control strategy must stage the lag boiler(s) only after the first boiler stage(s) fail to maintain the boiler water temperature called for by the reset control.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{BC} * \text{EFLH}_{\text{HEAT}} / (\text{Eff} * 100) * \text{SF}$

Where:

BC = Boiler input capacity in MBh (= 1)

$\text{EFLH}_{\text{HEAT}}$ = Equivalent full-load heating hours (= 1,890)

Equivalent Full-Load Heating and Cooling Hours by City

City	$\text{EFLH}_{\text{HEAT}}$[3]
Green Bay	1,852
La Crosse	1,966
Madison	1,934
Milwaukee	1,883
Wisconsin Average	1,909
Weighted Average	**1,890**

Eff = Combustion efficiency of the boiler (= 84%)[4]

100 = Conversion factor from therm to MBtu

SF = Savings factor (= 8%)[5]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 5 years)[1]

Deemed Savings

Evaluated Therm Savings

Measure Name	MMID	Sector, City	Energy Savings (therms per MBh)	
			Annual	Lifetime
Boiler, Outside Temperature Reset/Cutout Control	2221	Commercial Industrial Agriculture Schools & Gov Multifamily	1.800	9.000

Sources

1. Average of Cadmus database March 2013 and Fannie Mae Estimated Useful Life Table: https://www.fanniemae.com/content/guide_form/4099f.pdf
2. *Illinois Technical Reference Manual*. p. 187. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf
   Boiler outside air reset/cutout controls cost is $612.00 per set of controls.
3. Several Cadmus metering studies revealed that the ENERGY STAR calculator EFLH values are overestimated by 25%. The heating EFLH were adjusted by population-weighted heating degree days and typical meteorological year values, then averaged for the state of Wisconsin.
4. Cadmus. *2016 Potential Study for Focus on Energy.*
   Data maintained by Cadmus and Wisconsin PSC.
   Based on 43 boilers at school, office, restaurant, and retail sites.
5. Michigan Energy Measures Database. http://www.michigan.gov/mpsc/0,1607,7-159-52495_55129---,00.html

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2015	Changed savings from per unit to per MBh
03	05/2018	Updated based on Potential Study data
04	12/2018	Updated multifamily EFLH
05	12/2020	Corrected EFLH text and sectors

Boiler Burner, 10:1 High Turndown

	Measure Details
Measure Master ID	HVAC Boiler Burner, Retrofit, 10:1 High Turndown, 2203 HVAC Boiler Burner, New Boiler, 10:1 High Turndown, 5237 Process Boiler Burner, Retrofit, 10:1 High Turndown, 4760 Process Boiler Burner, New Boiler, 10:1 High Turndown, 5238
Workpaper ID	W0013-T020
Measure Unit	Per boiler horsepower
Measure Type	2203, 5237: Prescriptive 4760, 5238: Hybrid
Measure Group	Boilers & Burners
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	Install on New Boilers = 21 (MMIDs 5237, 5238)[1] Retrofit on Existing Boiler = 15 (MMIDs 2203, 4760) [2]
Incremental Cost ($/unit)	$65.22[3]

Measure Description

Boilers typically have an operating turndown of 3:1 or 4:1. Installing a high turndown burner with 10:1 (or better) turndown capability reduces burner starts, provides better load control, saves wear and tear on the burner, reduces refractory wear, reduces purge-air requirements, and provides fuel savings. Boilers ≤ 1,000 horsepower are eligible; larger boilers may be eligible for a custom incentive.

Description of Baseline Condition

The baseline condition is a boiler burner with 3:1 or 4:1 turndown capability.

Description of Efficient Condition

The efficient condition is a burner system with 10:1 turndown capability. High turndown burners may be paired with linkageless and oxygen trim controls in order to further improve the boiler system efficiency.

Annual Energy-Savings Algorithm

Process boilers:

$Therm_{SAVED} = BHP * 33{,}476 * LF * HOU / 100{,}000 * (1 / Eff_{BASE} – 1 / Eff_{PROPOSED})$

HVAC boilers:

$Therm_{SAVED} = \Sigma_{TEMPBIN\text{-}HOURS} [BHP * 33{,}476 * LF * HOU_{BIN} / 100{,}000 * (1 / Eff_{BASE} – 1 / Eff_{PROPOSED})]$

Where:

BHP = Boiler horsepower (= user input)

33,476 = Conversion factor from BHP to Btu/h

LF = Boiler load factor (= single user input for process boilers, see Assumptions for HVAC boilers)

HOU = Annual hours of operation (= single user input for process boilers, see Assumptions for HVAC boilers)

100,000 = Conversion factor from Btu to therms

Eff_{BASE} = Boiler efficiency baseline (= user input for process boilers, = 85%[4] for HVAC boilers, see Assumptions)

$Eff_{PROPOSED}$ = Boiler efficiency with proposed burner (scales across load factors based on user-specified Eff_{BASE}; see Assumptions)

$\Sigma_{TEMPBIN\text{-}HOURS}$ = Summary of items across temperature bins

HOU_{BIN} = Hours of use within that temperature bin

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 21 years for install on new boilers, = 15 years for retrofit on existing boilers)[1,2]

Deemed Savings

For process boilers (MMIDs 4760 and 5238), savings vary by application. These hybrid measures use inputs from the application that are then entered into the savings algorithm above to generate the therm savings.

For HVAC boilers (MMIDs 2203 and 5237), savings are prescriptive (on a per-boiler horsepower basis) since HVAC boilers use average Wisconsin weather data. See the table below.

Annual Savings (per BHP) for High Turndown Burners for HVAC Boilers

Measure	MMID	Sector	Annual Therms	Lifecycle Therms
HVAC Boiler Burner, 10:1 High Turndown	2203	Commercial	13	195
		Industrial	13	195
		Agriculture	13	195
		Schools & Government	13	195
		Multifamily	13	195
HVAC Boiler Burner, 10:1 High Turndown	5237	Commercial	13	273
		Industrial	13	273
		Agriculture	13	273
		Schools & Government	13	273
		Multifamily	13	273

Assumptions

The boiler efficiency baseline uses the combustion efficiency provided by the end user on the application form (MMIDs 4760 and 5238) or 85%[4] (MMIDs 2203 and 5237). Based on a bulletin from Cleaver Brooks,[5] the calculations assume that boiler efficiency will remain at this baseline level at 80% load and above, that the boiler efficiency is 5% less than this at 10% load, and that the boiler efficiency varies linearly between 80% load and 10% load.

Boiler manufacturers claim that a high turndown burner can add savings of 2% to 3%.[5,6,7] It is assumed that a high turndown burner produces an efficiency gain of 0.5% at 80% load and 2% at 10% load and that the gain varies linearly between 80% load and 10% load.[5]

The value for the boiler efficiency with a proposed burner equals the boiler efficiency baseline plus the gain in efficiency at the specified average load factor. Typical gains in efficiency range from 0.6% to 1.4%.

For high turndown burners for HVAC boilers (MMIDs 2203 and 5237), a linear load profile was used with the boiler operating at 100% load at the design outside air temperature of -15°F[8] and ramping down to 10% load at a cut-out temperature of 55°F. A cut-out temperature of 55°F was used to get the estimated equivalent full load hours to closely match the 1,890 hours used for other heating measures..

Boiler horsepower, boiler load factor, and operating hours are all provided by the end user on the application form for MMIDs 4760 and 5238. The HOU value should reflect the yearly hours of use, with the load factor representing the average boiler load fraction throughout the hours of use.

Sources

1. American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. ASHRAE Handbook, HVAC Applications. Chapter 38 “Owning and Operating Costs”, Table 4. 2019.
2. Engineering judgement. A burner retrofit on an existing boiler should have a shorter EUL than a burner on a new boiler. A 15 year EUL also matches the EUL for linkageless controls (W0014).
3. Wisconsin Focus on Energy. Historical project data for MMID 2203 obtained from SPECTRUM. Average cost of 25 units over 19 projects from 2016 to 2018.
4. Cadmus. Focus on Energy Evaluated Deemed Savings Changes. p. 34. August 31, 2017. www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
5. Cleaver Brooks. *Discover How to Save Fuel with Turndown and High Efficiency across the Firing Range*. Accessed October 2018. http://cleaverbrooks.com/products-and-solutions/boilers/firetube/cbex-elite/Burner%20Efficiency%20and%20Firing%20rate.pdf
6. U.S. Department of Energy, Energy Efficiency and Renewable Energy Advanced Manufacturing Office. Steam Tip Sheet #24. *Upgrade Boilers with Energy-Efficiency Burners.* January 2012. https://www.energy.gov/sites/prod/files/2014/05/f16/steam24_burners.pdf
7. Missouri Division of Energy. *The Missouri Technical Reference Manua*l. *Volume 2: Commercial and Industrial Measures*. p. 110 and 111. March 31, 2017. https://energy.mo.gov/sites/energy/files/MOTRM2017Volume2.pdf
8. PA Consulting Group. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0. Section 3.4, p. 3–14. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	02/2019	Initial TRM entry
02	11/2020	Added HVAC high turndown burners

Boiler Control, Linkageless

	Measure Details
Measure Master ID	Boiler Control, Linkageless, 2205 Process Boiler Control, Linkageless, 4761
Workpaper ID	W0014
Measure Unit	Per boiler horsepower
Measure Type	Boiler Control = Prescriptive (MMID 2205) Process Boiler Control = Hybrid (MMID 4761)
Measure Group	Boilers & Burners
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure (see savings algorithms below)
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure (see savings algorithms below)
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$85.42[2]

Measure Description

Traditional boiler combustion controls consist of a single servo motor and a series of linkages to control the airflow and fuel flow into the combustion chamber. The linkage connections are susceptible to hysteresis, which limits the accuracy of the control. In addition, linkage controls are unable to match the combustion curve for airflow and fuel flow across a range of burn rates. Therefore, combustion efficiency is not optimized. Linkageless controls eliminate these issues and can improve the efficiency of the boiler.

Description of Baseline Condition

The baseline condition is a single servo motor with linkages to control airflow and fuel flow to the combustion chamber.

Description of Efficient Condition

The efficient condition is linkageless controls to control airflow and fuel flow to the combustion chamber.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{BHP} * 33{,}476 * \text{LF} * \text{HOU} / (\text{Eff} * 100{,}000) * \text{SF}$

Where:

BHP = Boiler horsepower (= user input)

33,476 = Conversion factor from BHP to Btu/h

LF = Boiler load factor (= 100% for MMID 2205, see Assumptions; = actual for MMID 4761)

HOU = Annual hours of operation (= 1,890 for MMID 2205;[3] = actual for MMID 4761)

Eff = Boiler efficiency (= 85% for MMID 2205;[4] = actual for MMID 4761)

100,000 = Conversion factor from Btu to therms

SF = Savings fraction (= 3%, see Assumptions)

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Savings for Linkageless Controls, Therms per Boiler Horsepower

Measure	MMID	Annual Savings	Lifecycle Savings
Boiler Control, Linkageless	2205	22	330
Process Boiler Control, Linkageless	4761	Varies	Varies

Assumptions

The savings above are based on linkageless controls only. Oxygen trim controls are a separate measure.

For the space heating boiler measure (MMID 2205), the HOU value of 1,890 reflects the equivalent full-load hours and the load factor is not needed and is therefore 100%. For the process boiler measure (MMID 4761), the HOU value should reflect the yearly hours of use, with the load factor representing the average boiler load fraction throughout the hours of use.

The savings fraction is deemed to be 3%, which is the value historically used for Focus on Energy, outlined in the 2010 *Deemed Savings Manual*.[5] The manual cites a number of sources that are now unavailable, showing savings factors ranging from 1% to 6%. The one currently available source[6] indicates roughly 3.3% (Figure 2). That source also indicates 5% to 15% in text, though this range is likely very optimistic and exists only for poorly tuned boiler burners and boilers normally operated at a small fraction of design load. A more recent case study[7] indicates 1.1% to 1.4%, though this was compared against well-tuned linkage burners that may not reflect the actual field baseline. Another recent case study[8] indicates roughly 1.1% for a single site, based on the average differences in efficiency (Table 5). Because the latter two studies may not represent the field as a whole, and engineering judgement indicates that savings are probably in fact higher than their findings on average, the savings fraction is deemed to remain at 3%. This percentage may merit further review as new data becomes available.

Sources

1. California Utilities Statewide Codes and Standards Team. *Codes and Standards Enhancement Initiative, Commercial Boilers*. p. 16. October 2011. http://title24stakeholders.com/wp-content/uploads/2017/10/2013_CASE-Report_Commercial-Boilers.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 41 boilers and 30,484 BHP over 28 projects from January 2020 to July 2021.
3. U.S. Environmental Protection Agency and U.S. Department of Energy. “Life Cycle Cost Estimate for ENERGY STAR Qualified Air Source Heat Pump(s).” April 2009. http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_ASHP.xls

   Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLH values are over-estimated by 25%. The heating EFLH were adjusted by population-weighted HDD and TMY3 values, then averaged for the state of Wisconsin.
4. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. p. 34. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
5. PA Consulting Group. *Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Cellucci, G. *Removing Guesswork*. Hydronics. September/October 2005. http://www.bizlink.com/HPAC_articles/September2005/38.pdf

7. Steven Winter Associates. *Linkageless Boiler Retrofits for Steam Boilers: Going Beyond Carburetor Technology in a Large Segment of the NYS Market*. December 2017. https://www.swinter.com/wp-content/uploads/Linkageless-Burner-Retrofits-for-Steam-Boilers-46932-SWA-Final-Report.pdf
8. Carpenter, K., C. Schmidt, and K. Kissock. *Common Boiler Excess Air Trends and Strategies to Optimize Efficiency*. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. https://aceee.org/files/proceedings/2008/data/papers/3_349.pdf

Revision History

Version Number	Date	Description of Change
01	02/2019	Initial TRM entry
02	1/2021	Updated cost

Boiler Oxygen Trim Controls

	Measure Details
Measure Master ID	Boiler Oxygen Trim Controls, 2206 Process Boiler, Oxygen Trim Combustion Controls, 4762
Workpaper ID	W0015
Measure Unit	Per boiler horsepower
Measure Type	Oxygen Trim Controls = Prescriptive (MMID 2206) Oxygen Trim Combustion Controls = Hybrid (MMID 4762)
Measure Group	Boilers & Burners
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure (see savings algorithms below)
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure (see savings algorithms below)
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$79.95[2]

Measure Description

Although boilers require some excess oxygen to ensure the complete combustion of fuel, too much excess oxygen decreases boiler efficiency. An increase in excess oxygen requires an increase in combustion air. The higher volume of combustion air will heat up during combustion and this heat energy is lost up the stack. Installing a system to monitor excess oxygen in the flue allows excess air to be reduced to optimal levels. This improves the efficiency of the boiler.

Description of Baseline Condition

The baseline condition is dual-point (linkageless) controls with no system in place to monitor oxygen levels in flue gases.

Description of Efficient Condition

The efficient condition is to install oxygen monitoring in the flue gas to control oxygen to optimal levels.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{BHP} * 33{,}476 * \text{LF} * \text{HOU} / (\text{Eff} * 100{,}000) * \text{SF}$

Where:

BHP = Boiler horsepower (= user input)

33,476 = Conversion factor from BHP to MBh

LF = Boiler load factor (= 100% for MMID 2206, see Assumptions; = actual for MMID 4762)

HOU = Annual hours of operation (= 1,890 for MMID 2206;[3] = actual for MMID 4762)

Eff = Boiler efficiency (= 85% for MMID 2206;[4] = actual for MMID 4762)

100,000 = Conversion factor from Btu to therms

SF = Savings fraction (= 1.1%, see Assumptions)

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Deemed Savings

Savings for Oxygen Trim Controls, Therms per Boiler Horsepower

Measure	MMID	Annual Savings	Lifecycle Savings
Boiler Oxygen Trim Controls	2206	8	40
Process Boiler, Oxygen Trim Combustion Controls	4762	Varies	Varies

Assumptions

For the space heating boiler measure (MMID 2206), the HOU value of 1,890 reflects the equivalent full-load hours and the load factor is not needed and is therefore 100%. For the process boiler measure (MMID 4762), the HOU value should reflect the yearly hours of use, with the load factor representing the average boiler load fraction throughout the hours of use.

The savings fraction is deemed to be 1.1%, which is the value historically used for Focus on Energy, outlined in the 2010 *Deemed Savings Manual*.[5] The manual refers to a 2002 report from Oak Ridge National Laboratory[6] and a 2001 Environmental Protection Agency brief,[7] and shows a short analysis based on these two reports.

Two additional studies suggest savings ranging from 0.5% to 5%[8] and 5%.[9] However, additional (January 2019) analysis was conducted using data from Table 5 of an ACEEE paper[10] and Table B.1 from the Oak Ridge National Laboratory report[6] supporting a savings fraction of around 1% for a linkageless controls baseline. Therefore, the existing 1.1% savings factor is maintained.

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. Appendix B. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 30 boilers and 27,536 BHP over 19 projects from January 2020 to July 2021.
3. U.S. Environmental Protection Agency and U.S. Department of Energy. "Life Cycle Cost Estimate for ENERGY STAR Qualified Air Source Heat Pump(s)." April 2009. http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_ASHP.xls

   Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLH values are over-estimated by 25%. The heating EFLH were adjusted by population-weighted HDD and TMY3 values, then averaged for the state of Wisconsin.
4. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. p. 34. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
5. PA Consulting Group. *Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Oak Ridge National Laboratory. *Steam Survey Guide*. ORNL/TM-2001/263. May 2002. https://www.energy.gov/sites/prod/files/2014/04/f15/steam_survey_guide.pdf
7. United States Environmental Protection Agency. *Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency*. EPA/625/R-99/003. June 2001. https://p2infohouse.org/ref/19/18351.pdf
8. United States Environmental Protection Agency. *Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Industrial, Commercial, and Institutional Boilers*. p. 15. October 2010. https://www.epa.gov/sites/production/files/2015-12/documents/iciboilers.pdf
9. Carpenter, K., C. Schmidt, and K. Kissock. *Common Boiler Excess Air Trends and Strategies to Optimize Efficiency*. 2008 ACEEE Summer Study on Energy Efficiency in Buildings. https://aceee.org/files/proceedings/2008/data/papers/3_349.pdf
10. Cooperative Extension Washington State University Energy Program. *Boiler Combustion Monitoring & Oxygen Trim Systems*. 2010. http://controltrends.org/wp-content/uploads/2010/11/boiler_comb.pdf

Revision History

Version Number	Date	Description of Change
01	02/2019	Initial TRM entry

Steam Fittings and Pipe Insulation

	Measure Details
Measure Master ID	Insulation, Steam Fitting, Removable, Natural Gas, 2429 Insulation, Steam Piping, Natural Gas, 2430
Workpaper ID	W0017
Measure Unit	Per linear foot (pipe insulation) Per fitting (fitting insulation)
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Insulation
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government Residential- Multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	11.38 (per linear foot pipe insulation) 40.44 (per fitting insulation)
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	113.8 (per linear foot pipe insulation) 404.4 (per fitting insulation)
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	Steam fitting = $37.63 (MMID 2429)[4] Steam piping = $8.40 (MMID 2430)[5]

Measure Description

Uninsulated steam lines and fittings are a constant source of wasted energy. Adding insulation can typically reduce energy losses by 90% and will help ensure proper steam pressure and temperatures where needed. This measure is only for steam pipes in unconditioned spaces, including unconditioned basements and crawlspaces that are insulated from the conditioned space of the building.

Description of Baseline Condition

The baseline measure is an existing, non-insulated steam pipe or fittings that is part of an HVAC steam distribution system, with 80% boiler efficiency.

Description of Efficient Condition

Insulation must meet all federal and local safety standards and be rated for the temperature of the pipe on which it will be applied. Incentives are not intended for replacing existing pipe, insulation but only for insulating existing bare pipe.

The pipe being insulated must be at least 0.5-inches in diameter and must carry steam as part of an HVAC steam distribution system. The insulation thickness must meet 2009 IECC standards,[2] as outlined in section 5.3.2.8. For steam pipe with a 1.5-inch NPS or smaller, insulation must be at least 1.5 inches thick. For steam pipe with an NPS greater than 1.5 inches, insulation must be at least 3.0-inches thick. This is based on insulation with a K-value that does not exceed 0.27 Btu per inch/h * foot^2*°F. Installation must include a protective jacket around the insulation.

Annual Energy-Savings Algorithm

Savings were calculated using the assumptions listed below and 3E Plus v4.0 software, distributed by NAIMA (North American Insulation Manufacturers Association).[3] The 3E Plus software was used to calculate heat loss rates for bare and insulated pipe thickness per foot. The difference in heat loss is multiplied by the assumed hours of operation and divided by the boiler efficiency and Btu to therm conversion to calculate annual natural gas therm savings.

$Therm_{SAVED\_PIPE} = PipeInsul_{SAVED} * LF$

$PipeInsul_{SAVED} = Pipe_{BARE} - Pipe_{INSUL}$

Where:

$PipeInsul_{SAVED}$ = Annual energy savings through insulating in therms per linear foot of pipe (= 11.38)

LF = Total linear feet of pipe (= 1)

$Pipe_{BARE}$ = Annual energy consumption for uninsulated pipe calculated with 3E Plus software

$Pipe_{INSUL}$ = Annual energy consumption for insulated pipe calculated with 3E Plus software

$Therm_{SAVED\_FITTING} = FittingInsul_{SAVED} * NF$

$FittingInsul_{SAVED} = Fitting_{BARE} - Fitting_{INSUL}$

Where:

$FittingInsul_{SAVED}$ = Annual energy savings through insulating in therms per fitting (= 40.44)

NF = Number of fittings (= 1)

$Fitting_{BARE}$ = Annual energy consumption for uninsulated fitting calculated with 3E Plus software

$Fitting_{INSUL}$ = Annual energy consumption for uninsulated fitting calculated with 3E Plus software

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Assumptions

The pipe or fitting will be hot for 4,000 hours per year.

The NPS is 2 inches. A fitting is equivalent to approximately 3.55 feet of 2-inch pipe.

The system application for this calculation is Pipe – Horizontal/Vertical, with the dimensional standard of ASTM C 585 Rigid/Flexible.

Sources

1. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3-2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/ sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
2. 2009 IECC standards.
3. This program is available through NAIMA (North American Insulation Manufacturers Association) at http://www.pipeinsulation.org/.
4. Actual Program Data, 2015-2016. 20 projects with average actual cost of $37.63 per fitting.
5. Actual Program Data, 2015-2016. 18 projects with average actual cost of $8.40 per foot

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/2016	Cost update
03	12/2020	Added multifamily sector, removed SBP MMIDs

Boiler Tune-Up

	Measure Details
Measure Master ID	Boiler Tune-Up, 2744, 4419
Workpaper ID	W0018
Measure Unit	Per MBh
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0.339
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	0.339
Water Savings (gal/year)	0
Effective Useful Life (years)	1[1]
Incremental Cost ($/unit)	$0.83[2]

Measure Description

Tune-ups are required for boilers to maintain optimal combustion efficiency. Boiler tune-ups must be completed according to the boiler tune-up checklist. This measure applies to non-process-related boilers. A boiler tune-up includes reducing excess air and stack temperature; cleaning burners, burner nozzles, combustion chamber, and boiler tubes; sealing the combustion chamber; and recalibrating boiler controls.

The inspector also checks combustion air intake. The proper combustion air-to-fuel ratio directly affects combustion efficiency. Inadequate air supply yields unburned combustibles (fuel, soot, smoke, and carbon monoxide) while excess air causes heat loss from increased flue gas flow, which lowers the boiler efficiency.

Description of Baseline Condition

The baseline measure is 84% boiler efficiency.

Description of Efficient Condition

The incentive is available once in a 12-month period. The service provider must perform before and after combustion efficiency tests and record the results on the boiler tune-up incentive application. The burner must be adjusted to improve combustion efficiency as needed. The incentives are only available for space and water heating equipment.

Annual Energy-Savings Algorithm

$Therm_{SAVED} = BOF * CAP * SF * HDD * 24 / [(T_{INDOOR} – T_{OUTDOOR}) * AFUE_{PRE} * 100]$

Where:

BOF = Boiler oversize factor (= 77%, deemed)
CAP = Size of the boiler being tuned (= 1 MBh)
SF = Savings factor (= 1.6%, deemed)[3]
HDD = Heating degree days (= 7,699)[3]
T_{INDOOR} = Indoor design temperature (= 65°F)[3]
$T_{OUTDOOR}$ = Outdoor design temperature (= -15°F)[3]
$AFUE_{PRE}$ = AFUE of boiler prior to tune-up (= 84% for multifamily; = 84% for small business)[4]
100 = Conversion factor from MBh to therm

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 1 year)[1]

Sources

1. PA Consulting Group. “Public Service Commission of Wisconsin Focus on Energy Evaluation: Business Programs Measure Life Study. Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Illinois Technical Reference Manual. p. 185. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf

3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Cadmus. *2016 Potential Study for Focus on Energy.*
Data maintained by Cadmus and Wisconsin PSC.
Based on 18 boilers at office, restaurant, and retail sites and 23 boilers at multifamily sites.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	04/2017	Added MMID 4058
03	05/2018	Updated based on *Potential Study* data
04	10/2018	Removed MMID 4058, added MMID 4419, changed EUL to one year, removed average boiler size

Building Shell

Spring-Loaded Garage Door Hinge

	Measure Details
Measure Master ID	Spring-Loaded Garage Door Hinge: 55 Degree Indoor Temperature Setpoint, 3680 60 Degree Indoor Temperature Setpoint, 3681 65 Degree Indoor Temperature Setpoint, 3682 70 Degree Indoor Temperature Setpoint, 3683
Workpaper ID	W0019
Measure Unit	Per garage door
Measure Type	Prescriptive
Measure Group	Building Shell
Measure Category	Air Sealing
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/Year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$228.00[9]

Measure Description

Overhead doors do not always seal well against weather stripping and gaps may occur that lead to the loss of energy if the inside space is heated. These gaps can be exacerbated by wind and/or deterioration of weather stripping with age.

Spring-loaded garage door hinges reduce air infiltration around overhead doors by employing spring-loaded assemblies that keep overhead door sections pressed tightly against the seals. This eliminates the loss of energy.

The heavy-duty 12-gauge steel hinges fit most existing commercial doors. Individual door panels can be custom-adjusted to overcome poor track positioning and warped walls. The measure can be installed as a retrofit or on new construction.

Description of Baseline Condition

Infiltration is the uncontrolled leakage of air into a building. Air leaking can increase both heating and cooling costs. The rate of infiltration is driven by how well a building is sealed, the difference in temperature between the inside of the building and outside air, and the wind speed. Generally, the greatest temperature differences and wind speeds occur in winter. Sealed leaks will produce heating savings. The calculations below estimate heating savings.

The baseline condition is a 1/8-inch gap between the door and the weather stripping on the two vertical dimensions and one horizontal dimension. The bottom of the door is assumed sealed.

Description of Efficient Condition

The efficient condition is having installed the spring-loaded hinges, and the gap is assumed to be zero resulting in a net sealed dimension of 1/8 inch.

Annual Energy-Savings Algorithm

Reduced Infiltration (CFM) = $A_L * [(C_s * \Delta T) + (C_w * W_s^2)]^{0.5}$

Where:

A_L = Effective leakage area reduced, in square inches (= 51; average door assumed to be 10 feet wide and 12 feet tall; perimeter of top and two sides is 408 inches; with 1/8-inch gap reduced)

C_s = Stack coefficient (= 0.0299 $CFM^2/(in^4 * °F$; determined from building height in stories with average of 2 stories assumed)[3]

ΔT = Indoor temperature setpoint minus average outside temperature during heating season (= 35°F; average outside temperature across Wisconsin during the heating season, for four locations)[4]

C_w = Wind coefficient (= 0.0086 $CFM^2/ in^4\ mph^2$; determined from how sheltered the building is from the wind)[5]

W_s = Average heating season wind speed (= 11 mph)[2,6]

Hourly Heat Load Reduced (Btu/hour) = Reduced Infiltration (CFM) * (60 Min/Hr) * (0.08 Lb/CF) * (0.24 Btu/lb) * ΔT

Where:

0.08 = Average heating season air density in Wisconsin (lb/CF)[7]

0.24 = Specific heat of air (Btu/lb)[8]

Hourly Natural Gas Reduced (therms/hour) = (Reduced Heat Load Btu/hour)/(Heating Efficiency)/(100,000 Btu/therm)

Where:

Heating Efficiency = Typical non-condensing heating efficiency (= 0.80)[9]

Annual Natural Gas Use Reduced (therms/year) = Hourly Natural Gas Reduced (therms/hour) * (Heating hours/year)

Where:

Heating Hr/Yr = Hours in typical September to April heating season (= 5,840)

Deemed Savings Results

MMID	Indoor Temperature Setpoint (°F)	Deemed Savings/Door (Therms/Year)
3680	55	110
3681	60	143
3682	65	179
3683	70	217

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}}$ = Therms/year * EUL

Where:

EUL = Effective useful life (= 20 years)[1]

Assumptions

The baseline condition is having a 1/8-inch gap between the garage door and the weather stripping on the two vertical dimensions and one horizontal dimension. The bottom of the door is assumed to be sealed. After installing the spring-loaded hinges, the gap is assumed to be zero resulting in a net sealed dimension of 1/8 inch. Interior space must be heated with natural gas.

The infiltration calculation is based on an ASHRAE model noted in the sources.

Infiltration in residential buildings has been studied extensively, and several calculation techniques have been produced to estimate annual infiltration rates. However, infiltration in commercial buildings has not been studied to the same detail, and standard calculations have not been developed for annual commercial infiltration rates. Therefore, the calculations assume residential-like infiltration.

The interior temperature setpoint is based on individual customer, and will be input by the customer who selects one of the four options (55°F, 60°F, 65°F, or 70°F). Deemed energy savings will vary according to the Deemed Savings Results table above. The incentive will not vary by setpoint, so there is no gain for a customer to report an inaccurate number.

The average garage door is 10 feet wide by 12 feet tall, based on Wisconsin Focus on Energy installations done to date.

The EUL is 20 years.[1] Initial installations of the Green Hinge product have been in the market for at least five years, and the trade ally claims there have been no failures in that time. The company provides a lifetime guarantee thus if there is a failure, the customer would likely replace it in kind. The spring supplier certifies that the spring is good for > 10,000,000 cycles. Conventional garage door hinges routinely last 20+ years.

The average installation cost is based on the average door size of 10 feet wide by 12 feet tall, with six panels and five sets of hinges at $28.00/set (trade ally website quote) plus an estimated installation of $200.00 per door.

Sources

1. Focus on Energy. Evaluation – Business Program: Measure Life Study. 2009.
2. 2009 ASHRAE Handbook – Fundamentals. p. 16.23.
3. 2001 ASHRAE Handbook – Fundamentals. p. 26.21 (40).
4. U.S. Climate Data. "U.S. climate data." Last updated 2016. http://www.usclimatedata.com.
5. Graphiq Inc. "Find Average Wind Speed for US Cities." Last updated 2016. http://average-wind-speed.findthebest.com/
6. The Engineering ToolBox. "Air Density and Specific Weight." http://www.engineeringtoolbox.com/air-density-specific-weight-d_600.html
7. The Engineering ToolBox. "Properties of Air - temperatures ranging -100 to 1000 °F." http://www.engineeringtoolbox.com/air-properties-viscosity-conductivity-heat-capacity-d_1509.html
8. The Engineering Toolbox. http://www.engineeringtoolbox.com/specific-heat-capacity-gases-d_159.html
9. 2015 Vendor Feedback. The average installation cost is based on the average door size of 10 feet wide by 12 feet tall, with six panels and five sets of hinges at $28.00 per set (trade ally feedback /web quote) plus an estimated installation of $200.00 per door.

Revision History

Version Number	Date	Description of Change
01	8/2016	Added workpaper

Loading Dock Door and Pit/Ramp Seals

	Measure Details
Measure Master ID	Dock Door Infiltration Reduction, New Install, 2300 Dock Door Infiltration Reduction, Replace Existing, 2301 Dock Pit/Ramp External Seal, Added to Existing “Brush” Barrier, 2302 Dock Pit/Ramp External Seal, No Brush Barrier Present, 2303
Workpaper ID	W0281
Measure Unit	Per door or pit sealed
Measure Type	Prescriptive
Measure Group	Building Shell
Measure Category	Air Sealing
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Electricity Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Natural Gas Savings (therms)	Varies by measure
Lifecycle Electricity Savings (kWh)	0
Lifecycle Natural Gas Savings (therms)	Varies by measure
Annual Water Savings (gallons)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	Varies by measure, see Incremental Cost table below[2]

Measure Description

Loading dock seals, also known as loading dock shelters, stop outside air from leaking into the building while the loading dock door is open to load or unload semi-trailers. Without a seal, there is a roughly 4-to-6-inch gap between the semi and the dock door opening. Adding seals, which are typically made of compressible foam and rubber, seals the gap between the semi and dock door and significantly reduced the amount of infiltration.

Additionally, facilities often have a built-in pit ramp that adjusts (up or down) to meet the height of the semi-trailer to allow access for a forklift. The pits below these ramps typically remain open, or just have a basic “brush” type barrier that allows year-round infiltration. Ramp pit seals can be added to fill these gaps.

Description of Baseline Condition

The baseline condition is a loading dock door or ramp that does not have seals (MMIDs 2300, 2303) or that has degraded or minimal seals (MMIDs 2301, 2302).

Description of Efficient Condition

The efficient condition is a dock door with a loading dock door seal (MMIDs 2300 and 2301) and/or a ramp with a pit seal (MMIDs 2302, 2303).

Annual Energy-Savings Algorithm

$Therm_{SAVED} = 1.08 * CFM_{INF} * HDD * 24 * HrsPerWk / (168 * EFF_{HEAT} * 100{,}000)$

$$CFM_{INF} = Area_{LEAKS} * \sqrt{C_{STACK} * (T_{IN} - T_{OUT}) + C_{WIND} * V_{WIND}^2}$$

For dock doors: $Area_{LEAKS} = GapSize * (2 * Height + 2 * Width)$

For pit seals: $Area_{LEAKS} = GapSize * (2 * Length + 2 * Width)$

Where:

1.08 = Constant for sensible heat load equation, Btu/CFM- °F-hr

HDD = Heating degree days (= 7,616)[3]

24 = Conversion, hours per day

HrsPerWk = Hours per week that the infiltration occurs (= 10 for dock doors,[4] = 168 for leveler seals, see Assumptions)

168 = Conversion, hours per week

EFF_{HEAT} = Heating efficiency (= 80%, see Assumptions)

100,000 = Conversion, Btu per therm

C_{STACK} = Stack coefficient (= 0.0225)[5]

T_{IN} = Indoor temperature setpoint (= 55°F, see Assumptions)

T_{OUT} = Average outdoor temperature during the heating season of October through April (= 33.0°F)[6]

C_{WIND} = Wind coefficient (= 0.006)[5]

V_{WIND} = Average winter wind speed (= 9.6 MPH)[7]

GapSize = Refer to Gap Size by MMID table below

Height = Height of the dock door (= 9 feet)[9]

Width = Width of the dock door or leveler ramp (= 8 feet)[9]

Length = Length of leveler ramp (= 8 feet, see Assumptions)

Gap Size by MMID

Measure	MMID	Gap (inches)	Source
Dock Door Infiltration Reduction:			
New Install	2300	4.21	8
Replace Existing	2301	2.105	8, see Assumptions
Dock/Pit Ramp External Seal:			
Added to Existing “Brush” Barrier	2302	0.1	see Assumptions
No Brush Barrier Present	2303	0.5	see Assumptions

Summer Coincident Peak Savings Algorithm

There are no peak coincident savings for these measures.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 10 years[1])

Deemed Savings

Savings for Loading Dock Door & Pit Seals

Measure	MMID	Annual Therms	Lifecycle Therms
Dock Door Infiltration Reduction:			
New Install	2300	258	2,580
Replace Existing	2301	129	1,290
Dock/Pit Ramp External Seal:			
Added to Existing “Brush” Barrier	2302	97	970
No Brush Barrier Present	2303	485	4,850

Assumptions

Heating systems for loading dock areas are assumed to primarily be unit heaters and infrared heaters, which typically have an efficiency of 80%.

The width of the leveler ramp was assumed to be the same as the dock door width (8 feet). Many manufacturer photos and spec sheets show the leveler ramp as square, so the length of the leveler ramp was assumed to be 8 feet.

The hours for leveler ramps are set to 168 hours per week, as these air leaks occur all the time, regardless of whether a truck is being loaded/unloaded or not.

The indoor temperature setpoint is assumed to be 55°F as the loading dock area would be minimally heated.

A wind coefficient[5] of 0.0138 would be appropriate if there were no sheltering. A 1.5 story building with typical sheltering would have a wind coefficient of 0.0076, or 0.0045 in a more urban environment. A wind coefficient of 0.006 is selected for this measure.

The gap size for replacing an existing loading dock seal (MMID 2301) is assumed to be 50% of the gap size for a new installation (MMID 2300), or 50% x 4.21 inches = 2.105 inches. The gap size for dock pit/ramp seals with an existing brush type barrier is assumed to be 0.1 inches and the gap for pit/ramp seals without a brush type barrier is assumed to be 0.5 inches, both of which are based on a historical Focus on Energy calculation derived from a manufacturer's calculator.

Incremental Cost

Efficient costs are derived from historical project data[2]. Baseline cost is zero (continue without a dock / pit seal).

Incremental Costs

Measure Name	MMID	SPECTRUM Data			Base Cost	Incremental Cost
		Projects	Units (each)	Average Unit Cost		
Dock Door Infiltration Reduction:						
New Install	2300	9	38	$3,947.41	$0	$3,947.41
Replace Existing	2301	45	243	$2,722.43	$0	$2,722.43
Dock/Pit Ramp External Seal:						
Added to Existing "Brush" Barrier	2302	9	30	$1,176.29	$0	$1,176.29
No Brush Barrier Present	2303	10	234	$624.47	$0	$624.47

Sources

1. Michaels Energy, "Final Report: Custom Measure Life Review (Michaels No.:O6717AAN)," Ontario Energy Board, Toronto, May 10, 2018. www.oeb.ca/sites/default/files/OEB-DSM-Custom-Measure-Life-Review.pdf
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. January 2018 through July 2021.
3. ASHRAE Estimation of Degree-Days: Fundamentals, Chapter 14.
   Calculated from TMY3 weather files of the seven Wisconsin locations using statewide weighted values calculated from 2010 U.S. Census data for Wisconsin.
4. Minnesota Department of Commerce Division of Energy Resources. *State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs*. Version 3.2. https://mn.gov/commerce-stat/pdfs/20210201_trm_cip_vers3.2.pdf

5. American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. *ASHRAE Handbook – Fundamentals*. Chapter 16 “Ventilation and Infiltration”, Tables 2 and 4, page 16.16. 2021.
   Both stack coefficient and wind coefficient are the averages of the values for one-story and two-story buildings. Wind coefficient is the average of typical shielding and urban environment.
6. National Renewable Energy Laboratory. “National Solar Radiation Data Base, 1991- 2005 Update: Typical Meteorological Year 3.” https://nsrdb.nrel.gov/data-sets/archives.html
   Average temperature for Eau Claire, La Crosse, Madison, Milwaukee, and Green Bay for October to April from 6:00 AM to 6:00 PM.
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8. Enbridge Gas Inc., "Technology Assessment-Dock Door Seals," OEB, Chatham, ON, 2019.
9. Material Handling Industry (MHI), “Frequently Asked Questions”, accessed December 2021. www.mhi.org/media/members/49652/129999849700821430.pdf
   Most common side of door is 8 foot wide by 9 foot tall. This aligns well (on the conservative side) of the door size options listed in the Ontario Natural Gas DSM TRM of 8x8, 8x9, 8x10, and 10x10.

Revision History

Version Number	Date	Description of Change
01	12/2021	Initial TRM entry

Compressed Air, Vacuum Pumps

Air Compressor, Variable Speed Drive

	Measure Details
Measure Master ID	Air Compressor, Variable Speed Drive, Constant Speed Replacement, 2196
Workpaper ID	W0264
Measure Unit	Per horsepower
Measure Type	Hybrid
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Compressor
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Electricity Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Natural Gas Savings (therms)	0
Lifecycle Electricity Savings (kWh)	Varies
Lifecycle Natural Gas Savings (therms)	0
Annual Water Savings (gallons)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	$100.93[2]

Measure Description

This measure is for replacing a fixed-speed air compressor with a variable speed drive (VSD) equipped air compressor, or for installing a VSD instead of a fixed-speed compressor in new construction applications. The VSD allows the air compressor to match the actual load within the plant, which varies throughout the day. VSD air compressors are best suited for single compressor systems with varying loads and for trim compressor operation in multiple compressor systems, as they provide efficient part-load performance but, due to the VSD efficiency, are slightly less efficient at 100% speed.

Description of Baseline Condition

The baseline is one or more fixed-speed compressors with load/no load, inlet air modulation, or variable displacement controls.

Description of Efficient Condition

The efficient condition is one or more VSD compressors. It is allowable to use more than one VSD compressor when pre-approval is obtained and both compressors are needed to satisfy the load (and one VSD is not a backup). Typically, two compressors allow for widely varying maximum versus minimum airflow during operation, where, for example, two 50 hp compressors can provide a better turndown ratio than one 100 hp compressor.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{BASE} - kWh_{EE}$

$kWh_{BASE} = \sum_{SHIFTS} [\sum_{BASECOMPS} (0.746 * HP_{BASE} * HOU * Weeks * LoadFactor_{BASE} * PresAdjust_{BASE} * Runtime\%)]$

$kWh_{EE} = \sum_{SHIFTS} [\sum_{EFFCOMPS} (0.746 * HP_{EE} * HOU * Weeks * LoadFactor_{EE} * PresAdjust_{EE} * Runtime\%)]$

Where:

$\sum_{SHIFTS}$ = Summary across shift 1, shift 2, shift 3, and weekends

$\sum_{BASECOMPS}$ = Summary across each baseline compressor

0.746 = Conversion from horsepower to kilowatts

HP_{BASE} = Horsepower of the baseline air compressor (= user input)

HOU = Hours of use per week for the given shift (= User input for shift 1, shift 2, shift 3, and weekends, as applicable)

Weeks = Weeks of operation per year (= 52 unless lower value provided by user)

$LoadFactor_{BASE}$ = varies as follows based on base compressor control method[3]
= -0.4513 * %Load^2 + 1.1965 * %load + 0.2631 (for load/no load controls)
= 0.3 * %Load + 0.7 (for inlet modulation controls)
= 0.7164 * %Load + 0.2782 (for variable displacement controls)

where:

%Load = CFM_{SHIFT} / CFM_{MAX}

CFM_{SHIFT} = The CFM assigned to the compressor for the given shift (see Assumptions)

CFM_{MAX} = Maximum CFM for the given compressor capability (= user input if existing compressor, = 4.55 CFM/hp[4] * HP_{EE} if no existing compressor)

$PresAdjust_{BASE}$ = $1 + 0.01 * (PSI_{OPERATING} - PSI_{RATED,BASE}) / 2$ (see Assumptions)

where:

$PSI_{OPERATING}$ = Actual operating pressure of air compressor (= user input)

$PSI_{RATED,BASE}$ = Pressure for performance data of baseline air compressor (= user input)

Runtime% = Percentage of time that the given compressor runs (= 100% for baseload compressor and VSD compressor, = user input for baseline trim compressors)

$\sum_{EFFCOMPS}$ = Summary across each VSD compressor

HP_{EE} = Horsepower of VSD air compressor (= user input)

$LoadFactor_{EE}$ = Percentage of load (for VSD controls)

$PresAdjust_{EE}$ = $1 + 0.01 * (PSI_{OPERATING} - PSI_{RATED,EE}) / 2$ (see Assumptions)

$PSI_{RATED, EE}$ = Pressure for performance data of VSD air compressor (= user input)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (kW_{BASE} - kW_{EE}) * CF$

Where:

kW_{BASE} = $\sum_{BASECOMPS} (0.746 * HP_{BASE} * LoadFactor_{BASE} * PresAdjust_{BASE} * Runtime\%)$

kW_{EE} = $\sum_{EFFCOMPS} (0.746 * HP_{EE} * LoadFactor_{EE} * PresAdjust_{EE} * Runtime\%)$

CF = Coincidence factor (= 1.0; see Assumptions)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years)[1]

Assumptions

The average CFM per shift provided on the incentive application is split between the various existing compressors. The lead compressor is assigned up to 60% of its maximum CFM (this is CFM_{SHIFT} in the savings algorithm above). If there is a second existing compressor, it is then assigned the remaining average CFM per shift up to 60% of its maximum, and similarly for the third existing compressor. This process is repeated for shift 1, shift 2, shift 3, and weekends (which encompasses all weekend hours on Saturday and Sunday). The 60% limit is based on engineering judgement to provide conservative savings since, over the course of one year, most compressors will run at well under 100% capacity.

Existing air compressor performance data, new VSD air compressor performance, and actual operating pressure are often provided at different pressures. In order to try to match the performance data to the actual operating pressure, an assumption that power changes by 1% for every 2 PSI pressure change is used.[5]

Shift 1 operation is assumed to occur during the Focus on Energy definition of on-peak (1 p.m. to 4 p.m., Monday to Friday from June through August). Therefore, the demand reduction is based on the average first shift CFM (user input). Since the kilowatt demand is already based on actual average airflow during first shift operation, the coincidence factor is assumed to be 1.0.

Sources

1. U.S. Department of Energy. Technical Support Document: Energy Efficiency Program For Consumer Products and Commercial and Industrial Equipment: Air Compressors. December 2016. Page 8-12. http://www.energy.gov/sites/prod/files/2019/09/f66/crac-doas-noda-tsd.pdf

2. Wisconsin Focus on Energy historical project data obtained from SPECTRUM. Average cost of 175 VSD air compressors over 169 projects from January 2019 to November 2020 was $403.93. November 2020 online lookups of 34 models from 20 hp to 200 hp on www.northerntool.com, www.aircompressorsdirect.com, www.compressorworld.com, and www.store.industrialairpower.com show an average baseline price of $303.77 per horsepower.
3. Compressed Air Challenge. "Best Practices for Compressed Air Systems - Second Edition." www.airbestpractices.com/article/best-practices-compressed-air-systems Appendix 2, Figures A.2.o., A.2.p., A.2.q., and A2.r used to determine the average percentage power. Table A.2.o, 2 gallons per CFM receiver volume curve is used. Typical compressed air systems are in the 1 to 3 gallons per CFM range.
4. U.S. Department of Energy, Office of Industrial Technologies. "Compressed Air Systems Fact Sheet #8: Packaged Compressor Efficiency Ratings." p. 2. April 1998. www.compressedairchallenge.org/data/sites/1/media/library/factsheets/factsheet08.pdf This reference shows 22 bhp/100acfm, making the inverse (cfm per hp) equal to 4.55 cfm/hp.
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Revision History

Version Number	Date	Description of Change
01	12/2020	Initial TRM entry

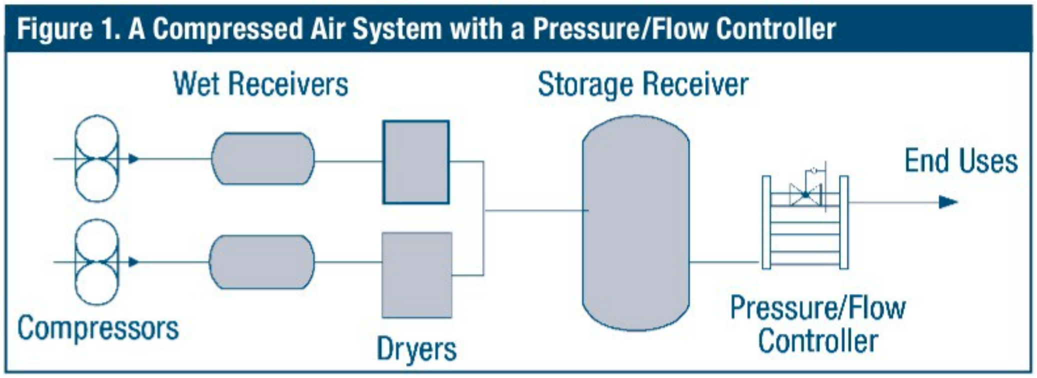
Compressed Air Controller, Pressure/Flow Controller

	Measure Details
Measure Master ID	Compressed Air Controller, Pressure/Flow Controller, 2255
Workpaper ID	W0020
Measure Unit	Per horsepower
Measure Type	Prescriptive
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	199
Peak Demand Reduction (kW)	0.035
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	2,989
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$26.46/hp[7]

Measure Description

A pressure/flow controller can greatly increase the control of an air storage system. These units, also called demand valves, precision flow controllers, or pilot-operated regulators, are precision pressure regulators that allow the airflow to fluctuate while maintaining a constant pressure to the facility's air distribution piping network.

Compressed Air System with a Pressure/Flow Controller[2]



Installing a pressure/flow controller on the downstream side of an air storage receiver creates a pressure differential entering and leaving the vessel. This pressure differential stores energy in the form of readily available compressed air, which can be used to supply the peak air demand for short-duration events, in place of using more compressor horsepower to feed this peak demand.

The benefits of having a pressure/flow controller include:

- Reducing the kilowatts of peak demand, especially with multiple compressor configurations.
- Saving kilowatt-hours by allowing the compressor to run at most efficient loads, then turn itself off in low demand and no demand periods.
- Saving kilowatt-hours by reducing plant air pressure to the minimum allowable. This leads to reduced loads on the electric motors and greater system efficiency. For every 2 psi reduced in the system, 1% of energy is saved.
- Maintaining a reduced, constant pressure in the facility wastes less air due to leakage, and less volume is required by the compressor.
- Ensuring quality control of the process by the constant pressure: machines can produce an enhanced product quality when the pressure is allowed to fluctuate.

Description of Baseline Condition

The baseline condition is having no existing pressure/flow controller and an existing compressed air system with a total compressor motor capacity ≥ 50 hp.

Description of Efficient Condition

To qualify for an incentive, the facility must have a compressed air system with motor capacity ≥ 50 hp and a pressure/flow controller must be installed on the main pressure header. This measure is not replacing drop-line regulators or filter-regulator lubricators.

Annual Energy-Savings Algorithm

kWh_{SAVED} = hp * 0.746 / Motor Eff. * Load Factor * HOU * % decrease

Where:

hp = Compressor motor size in horsepower

0.746 = Conversion factor from kilowatts to horsepower

Motor Eff. = Compressor motor efficiency (= 95%)[3]

Load Factor = Average load on compressor motor (= 89%)[3]

HOU = Average annual run hours (= 5,702)[4]

% decrease = Percentage decrease in power input (= 5%)[5]

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = hp * 0.746 / Motor Eff. * Load Factor * % decrease * CF

Where:

CF = Coincidence factor (= 1)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Sources

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4. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
5. United States Department of Energy. *Improving Compressed Air System Performance: A Sourcebook for Industry.* p. 20. November 2003.
6. Army Corps of Engineers. *Compressed Air System Survey at Sierra Army Depot, CA*. Mike C.J. Lin, Ahmad R. Ganji, Shy-Sheng Liou, and Bryan Hackett. November 2000. www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA384166
7. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 309 units over 31 projects from 2016 to 2018.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	05/2018	Updated HOU
03	12/2018	Updated incremental cost

Compressed Air, Cycling Thermal Mass Air Dryers

	Measure Details
Measure Master ID	Compressed Air, Cycling Thermal Mass Air Dryers, 2264
Workpaper ID	W0021
Measure Unit	Per CFM
Measure Type	Prescriptive
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Dryer
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	28.11 per CFM
Peak Demand Reduction (kW)	0.0049 per CFM
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	421.65 per CFM
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$6.00[7]

Measure Description

When air is compressed, it is typically saturated with moisture, which may cause corrosion or contamination if it condenses in a compressed air system. Compressed air dryers remove moisture from the compressed air system. Refrigerated dryers are the most common,[2] which remove moisture by cooling the air and causing water vapor to condense. Cycled refrigerated dryers turn on and off or use a VFD to operate only as needed. Non-cycling dryers will continue to consume energy when drying is not needed.

Description of Baseline Condition

The baseline for this measure is a non-cycling refrigerated thermal mass air dryer.

Description of Efficient Condition

New dryers must be properly sized to meet the needs of the compressed air system in order to qualify. New dryers must be cycling or VFD-controlled refrigerated dryers. This measure is only for the replacement of non-cycled refrigerated dryers with cycled refrigerated dryers. The addition of controls to existing dryers does not qualify. The replacement of desiccant, deliquescent, heat-of-compression, membrane, or other types of dryers does not qualify.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = SF * LF * CFM * HOU$

Where:

SF = Savings factor in kilowatts per CFM (= 0.00554)[3]
LF = Load factor (= 89%)[4]
CFM = Cubic feet per minute; the actual rated capacity of air dryer
HOU = Average annual run hours (= 5,702)[5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = SF * LF * CFM * CF$

Where:

CF = Coincidence factor (= 1)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Sources

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2. United States Department of Energy. Compressed Air Challenge, Improving Compressed Air System Performance: A Sourcebook for Industry. p. 11. November 2003.
3. DNV GL. *Impact Evaluation of Prescriptive Chiller and Compressed Air Installations.* October 26, 2015. Table 1-10. https://ma-eeac.org/wp-content/uploads/MA30-Prescriptive-Chiller-and-CAIR-Report_FINAL_151026.pdf
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Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	05/2018	Updated HOU
03	12/2020	Updated Savings Factor value and reference to root source. Updated savings to per cfm.

Dew Point Controls for Desiccant Dryers

	Measure Details
Measure Master ID	Dew Point Controls for Desiccant Dryers, 4363
Workpaper ID	W0022
Measure Unit	Per CFM
Measure Type	Hybrid
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Dryer
Sector(s)	Commercial, Industrial
Annual Energy Savings (kWh)	Varies by air compressor type, horsepower, and air dryer type
Peak Demand Reduction (kW)	Varies by air compressor type, horsepower, and air dryer type
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by air compressor type, horsepower, and air dryer type
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$4,000 per system[2]

Measure Description

Desiccant dryers are used in compressed air systems where air needs to be dried to a lower dew point (down to -40°F) than refrigerated-type dryers can provide (35–39°F). A desiccant dryer consists of two towers containing a desiccant medium. One of these towers dries the air, while the other purges compressed air to regenerate the desiccant medium. When the drying tower is saturated, the towers swap functions. This regeneration is typically accomplished by one of several mechanisms: compressed air purging, heated compressed air purging, or heated blower air.

Desiccant dryers that use compressed air purging to regenerate the desiccant towers typically operate by purging a fixed amount of compressed air at regular intervals, regardless of the amount of air being dried at the time. This situation leads to over-purging compressed air, increasing the energy consumption of the air compressor. Installing dewpoint-dependent switching controls will monitor the dewpoint within the dryer and only purge compressed air when necessary, potentially reducing the annual operating costs of the desiccant dryer by up to 60%.[3]

Description of Baseline Condition

The baseline equipment is a desiccant air dryer that purges periodically based on a timer control. Modulation-controlled air compressor systems are not qualified for this measure.

Description of Efficient Condition

The efficient condition is a dew-point sensor control, which can measure the amount of humidity within the desiccant tower and will purge only when required. This control will reduce the amount of purge energy (compressed air, heater and blower power) required by the air dryer during part-load operation.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = CFM * (PR_{BASE} - PR_{EE}) * HOURS$

$PR_{BASE} = Eff * \%Power_{BASE} + HD_{BASE} + BD_{BASE}$

$PR_{EE} = Eff * \%Power_{EE} + HD_{EE} + BD_{EE}$

Where:

CFM = Cubic feet per minute; the actual rated capacity of air compressor that the air dryer serves

PR_{BASE} = Power requirement of baseline system in kW/cfm

PR_{EE} = Power consumption of efficient dew-point sensor controlled system in kW/cfm

HOURS = Average annual run hours (= 5,702)[4]

Eff = Efficiency of standard air compressor (varies by air compressor type; see table below)[5]

$\%Power_{BASE}$ = Percentage of rated power at baseline condition (= varies by air compressor control type and dryer type; see table below)

HD_{BASE} = Heater demand of the dryer at baseline condition (= varies by dryer type; see table below)

BD_{BASE} = Blower demand of the dryer at baseline condition (= varies by dryer type; see table below)

$\%Power_{EE}$ = Percentage of rated power with dew point control (= varies by air compressor control type and dryer type; see table below)

HD_{EE} = Heater demand of the dryer with dew point control (= varies by dryer type; see table below)

BD_{EE} = Blower demand of the dryer with dew point control (= varies by dryer type; see table below)

Efficiency of Standard Air Compressor (Eff)

Air Compressor Type	Eff (kW/cfm)[5]
Single-acting, air-cooled reciprocating	0.22
Double-acting, water-cooled reciprocating	0.15
Single-stage, lubricant-injected rotary screw	0.18
Two-stage, lubricant-injected rotary screw	0.16
Lubricant-free rotary screw	0.18
Centrifugal	0.16
Other	0.18

Power by Air Compressor Control Type and Dryer Type[6,8]

Air Compressor Control Type	Dryer Type	$\%Power_{BASE}$	$\%Power_{EE}$
Variable Speed Drive	Heatless	65.0%	57.5%
	Heated	57.0%	53.5%
	Blower Purge	50.8%	50.8%
Load/Unload	Heatless	83.2%	78.3%
	Heated	78.0%	75.5%
	Blower Purge	72.9%	72.9%
Variable Displacement	Heatless	73.1%	67.3%
	Heated	66.9%	64.2%
	Blower Purge	61.5%	61.5%
Inlet Modulation	Heatless	89.5%	87.3%
	Heated	87.1%	86.1%
	Blower Purge	85.0%	85.0%

Heater Demand and Blower Demand by Dryer Type

Dryer Type	Heater Demand (kW/CFM)[6]		Blower Demand (kW/CFM)[6]	
	HD_{BASE}	HD_{EE}	BD_{BASE}	BD_{EE}
Heatless Dryer	0	0	0	0
Heated Dryer	0.012	0.006	0	0
Blower Purge Dryer	0.019	0.010	0.003	0.0015

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = CFM * (PR_{BASE} - PR_{EE}) * CF$

Where:

CF = Coincidence factor (= 1)[7]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

The %Power depends on air compressor control type and load factor. The total load of the air compressor is the sum of loads from end uses and the amount of purge air required by dryer. The average load factor of air compressor end uses was obtained through a survey of 12 custom compressed air projects (within Michigan and Ohio) where older, traditional controlled air compressors were replaced with similar sized VSD air compressors. The total power consumption was metered over a seven-day period both before and after replacement, and the average power draw (kW) for each project was analyzed. Using this data, the percentage volume flow rate (CFM) loading of all the VSD compressors was found using the manufacturer's specification sheets. The study revealed that, on average, these compressors were loaded to 47% of their full-load CFM. The post-replacement data was analyzed because the profile with these compressors gives the most accurate prediction of the facility's actual air demand, assuming the facility's air demand did not change from pre- to post-replacement.

The purge air demands were obtained through a survey of 82 dryers from the following manufacturers: Ingersoll Rand, Quincy, Parker-AIRTEK, and Parker-DOMNICK HUNTER.[6] The heatless dryers and heated dryers require 15% and 7% capacity respectively for purge air, respectively. Blower purge dryers do not need purge air from the air compressor: with the help of dew point control, the purge air demand can be reduced to match the compressed air demand at end use. Because the average load factor from end use is close to 50%, we assumed the dew point controls can reduce purge air by 50% for all cases. The baseline total load factors and dew point control total load factors are summarized in the following table. Finally, the %Powers were determined for different types of air compressors using typical air compressor performance curves.[9]

Total Load Factors of Different System Types

Dryer Types	Baseline	Dew Point Control
Heatless Dryer	65%	57.5%
Heated Dryer	57%	53.5%
Blower Purge Dryer	50%	50%

The baseline average power demands for heaters and blowers was obtained based on a survey of 76 dryers from the following manufacturers: Ingersoll Rand, Quincy, Parker-AIRTEK and Parker-DOMNICK HUNTER. With the help of dew point control, the heater demand and blower demand can be reduced to match the compressed air demand at end use. Because the average load from end use is close to 50%, it is assumed both heater demand and blower demand can be reduced by 50% for all cases with dew point controls.

Sources

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Revision History

Version Number	Date	Description of Change
01	10/11/2017	Initial TRM entry

Compressed Air and Vacuum Pump Heat Recovery, Space Heating

	Measure Details
Measure Master ID	Compressed Air Heat Recovery, Space Heating, 2257 Compressed Air Heat Recovery, Space Heating, Propane, 4853 Vacuum Pump Heat Recovery, Space Heating, 3928
Workpaper ID	W0023
Measure Unit	Per horsepower
Measure Type	Prescriptive
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Energy Recovery
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Electricity Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Natural Gas Savings (therms)	76
Annual Propane Savings (Gallons)	83
Lifecycle Electricity Savings (kWh)	0
Lifecycle Natural Gas Savings (therms)	988
Lifecycle Propane Savings (Gallons)	1,079
Annual Water Savings (gallons)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	$141.56[6]

Measure Description

The majority of the energy consumed by industrial air compressors and vacuum pumps is converted to heat, which can be recovered. Air compressor and vacuum pump heat recovery systems are designed to capture waste heat and use it for space heating, water heating, or process heating. These systems can be installed on both air- and water-cooled compressors and vacuum pumps. For air-cooled compressors and vacuum pumps, ductwork and fans may be installed to send cool air across the unit's after-cooler and oil cooler. The cool air absorbs heat from the compressor or vacuum pump and gets ducted to where it is needed. For water-cooled compressors and vacuum pumps, a water-to-air or water-to-water heat exchanger may be used.

Heat recovery systems installed for backup or redundant air compressors and vacuum pumps do not qualify. The project must result in an estimated net reduction in facility Btus to be eligible. The static pressure in the area where the compressor or vacuum pump is enclosed must remain the same, since a reduction in static pressure may reduce compressor efficiency. If outside air is used, anti-freeze protection must be considered.

Description of Baseline Condition

The baseline condition is a compressor or vacuum pump without a heat recovery system, but with natural gas or propane space heating.

Description of Efficient Condition

The efficient condition is a compressor or vacuum pump with a heat recovery system for natural gas or propane space heating.

Annual Energy-Savings Algorithm

Gas_{SAVED} = hp * Load Factor * 2,545 * HR * HOU / (ConvF * EFF_{HEAT})

Where:

Gas_{SAVED} = Therms of natural gas or gallons of propane saved
hp = Compressor or vacuum pump motor horsepower size
Load Factor = Average load on compressor or vacuum pump motor (= 89%)[2]
2,545 = Conversion factor from horsepower to Btu/hr
HR = Heat recoverable as a percentage of brake horsepower (= 70%, see Assumptions)
HOU = Average annual run hours of the compressor or vacuum pump (= 3,812)[4]
ConvF = Fuel conversion factor (= 100,000 Btu per therm, = 91,300 Btu per gallon propane)[5]
EFF_{HEAT} = Efficiency of building heating system (= 80%, see Assumptions)[9]

Summer Coincident Peak Savings Algorithm

There are no peak coincident savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE}$ = $Therm_{SAVED}$ * EUL

Where:

EUL = Effective useful life (= 13 years)[1]

Assumptions

Historical project data for Focus on Energy indicates that all or nearly all heat recovery projects have been for air-cooled air compressors. Several references claim differing amounts of heat are recoverable from air cooled air compressors. One reference from the Compressed Air Challenge[3] claims 80% to 90%, but another[7] claims 50% to 90%. A research paper review[8] claims 50% to 80%. A conservative estimate of 70% is used here.

Based on engineering judgement, the heating season is assumed to be October through March, which is six months or 50% of the year.

The heating system efficiency is deemed to be 80%. This reflect data for rooftop units from the 2016 Potential study[9] and the 80% value assumed for unit heaters in workpaper W0048.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf Roberts, John, B. Tso. "Do Savings from Retrocommissioning Last? Results from an Effective Useful Life Study." 2010 ACEEE Summer Study on Energy Efficiency in Buildings. (2010). http://aceee.org/files/proceedings/2010/data/papers/1990.pdf
2. Cascade Energy. "Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors." Table 6: Load Factor by Nameplate hp and End Use. November 5, 2012. https://rtf.nwcouncil.org/meeting/rtf-meeting-november-14-2012
3. Moskowitz, Frank. "Compressed Air Challenge™, Heat Recovery and Compressed Air Systems." September 2010. www.compressedairchallenge.org/library/articles/2010-09-CABP.pdf
4. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
5. U.S. Energy Information Administration. "Energy Units and Calculators Explained." Accessed December 2018. https://www.eia.gov/energyexplained/?page=about_energy_units
6. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 74 projects and 77 units from January 2018 to July 2020 is $141.56.
7. Compressed Air Challenge. *Heat Recovery with Compressed Air Systems*. *Fact Sheet #10*. https://www.compressedairchallenge.org/data/sites/1/media/library/factsheets/factsheet10.pdf
8. R. Saidur, N.A. Rahim, and M. Hasanuzzaman. *A review on compressed-air energy use and energy savings*. Renewable and Sustainable Energy Reviews. Volume 14, Issue 4, page 1135-1153. May 2010. https://www.sciencedirect.com/science/article/abs/pii/S1364032109002755
9. Cadmus. *2016 Potential Study for Focus on Energy.* Data maintained by Cadmus and Public Service Commission of Wisconsin. Commercial site visits from the summer of 2016 to retail, restaurant, and small office sites. 80.3% value observed for 121 rooftop units.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	09/2016	Expanded scope to include compressed air and vacuum pump heat recovery
03	10/2017	Updated EUL
04	05/2018	Updated HOU
05	09/2020	Heat recovery fraction updated, updated cost
06	10/2021	Added propane measure, building heating efficiency factor

Compressed Air Mist Eliminators

	Measure Details
Measure Master ID	Compressed Air Mist Eliminators, 2258
Workpaper ID	W0024
Measure Unit	Per horsepower
Measure Type	Prescriptive
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Filtration
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	80
Peak Demand Reduction (kW)	0.014
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	New construction = 400; retrofit = 240
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	New construction = 5; retrofit= 3[1]
Incremental Cost ($/unit)	$28.24[7]

Measure Description

Large compressed air systems require air filtration for proper operation. These filters remove oil mist from the supply air of lubricated compressors, protecting the distribution system and end-use devices. While these filters are important to the operation of the system, they do have a pressure drop across them, and thus require a slightly higher operating pressure. Typical coalescing oil filters will operate with a 2 psig to 10 psig pressure drop. Mist eliminator air filters operate at a 0.5 psig pressure drop that increases to 3 psig over time before replacement is recommended.

This reduction in pressure drop allows the compressed air system to operate at a reduced pressure and, in turn, reduces the energy consumption of the system. In general, the energy consumption will decrease by 1% for every 2 psig the operating pressure is reduced.[2] Lowering the operating pressure has the secondary benefit of decreasing the demand of all unregulated usage, such as leaks and open blowing.

The equipment is mist eliminator air filters. The compressed air system must be greater than 50 hp to qualify, and the mist eliminator must have less than a 1 psig pressure drop and replace a coalescing filter.

Description of Baseline Condition

The baseline measure is a standard coalescing filter.

Description of Efficient Condition

The efficient condition is a mist eliminator air filter that replaces a standard coalescing filter.

Annual Energy-Savings Algorithm

kWh_{SAVED} = hp * 0.746 / Motor Eff. * Load Factor * HOU * % Savings

% Savings = $Total_{PR}$ * RS

Where:

hp = Compressor motor size horsepower
0.746 = Conversion factor from horsepower to kilowatts
Motor Eff. = Compressor motor efficiency (= 95%)[2]
Load Factor = Average load on compressor motor (= 89%)[2]
HOU = Average annual run hours (= 5,702)[3]
% Savings = Percentage of energy saved (= 2%)[4]
$Total_{PR}$ = Total pressure reduction from replacing filter (= 4 psig)[4]
RS = Percentage of energy saved for each psig reduced (= 0.5%)[5]

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = hp * 0.746 / Motor Eff. * Load Factor * % Savings * CF

Where:

CF = Coincidence factor (= 1; compressed air systems run during peak demand)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 5 years for new construction; = 3 years for retrofit)[1]

Sources

1. *Massachusetts Technical Reference Manual*. 2013. http://ma-eeac.org/wordpress/wp-content/uploads/TRM_PLAN_2013-15.pdf
   Savings based on low pressure mist eliminator filters and on typical replacement schedules for low pressure filters (NSTAR staff estimates)
2. Cascade Energy. *Proposed Standard Savings Estimation Protocol for Ultra-Premium Efficiency Motors.* November 5, 2012.
3. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf

4. Sullair Corporation. *Compressed Air Filtration and Mist Eliminators Datasheet*. http://www.amcompair.com/products/brochures/sullair_brochures/_Sullair%20filtration.pdf.
5. United States Department of Energy. *Improving Compressed Air System Performance: A Sourcebook for Industry*. p. 20. November 2003.
6. Army Corps of Engineers. *Compressed Air System Survey at Sierra Army Depot, CA.* Mike C.J. Lin, Ahmad R. Ganji, Shy-Sheng Liou, and Bryan Hackett. November 2000. www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA384166
7. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 135 units over 59 projects from 2016 to 2018.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	05/2018	Updated HOU
03	12/2018	Updated incremental cost

Compressed Air Nozzles, Air Entraining

	Measure Details
Measure Master ID	Compressed Air Nozzles, Air Entraining, 2259
Workpaper ID	W0025
Measure Unit	Per nozzle
Measure Type	Prescriptive
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Nozzle
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	4,800
Peak Demand Reduction (kW)	1.8
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	72,000
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$35.49[6]

Measure Description

Engineered nozzles, also known as air entraining nozzles, reduce the amount of compressed air required for cleaning, cooling, drying, and blowoff applications. These nozzles use the coanda effect to pull in free air and accomplish tasks with up to 70% less compressed air. Engineered nozzles often replace simple copper tubes, and have the added benefits of reducing noise due to the use of laminar airflow and producing a safer workplace due to the elimination of potential skin contact with high pressure air.

Description of Baseline Condition

The baseline condition is a standard efficiency compressed air system operating at an efficiency of 0.16 kW/scfm[2] for a minimum of 2,000 hours per year. Compressed air pipe flow rates are standard.[3]

Description of Efficient Condition

Nozzles must be engineered and usage must be 2,000 hours or greater to qualify.

Annual Energy-Savings Algorithm

kWh_{SAVED} = Eff * (Open Flow – Eng. Flow) * HOU

Where:

Eff = Efficiency of standard air compressor (= 0.16 kW/scfm)

Open Flow = Flow of copper pipe nozzle (= 21 scfm)

Eng. Flow = Flow of engineered nozzle (= 6 scfm)

HOU = Average annual run hours (= 2,000)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Eff * (Open\ Flow - Eng.\ Flow) * CF$

Where:

CF = Coincidence factor (= 0.75)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

The nozzle flow rates are averages based on available published data from engineered nozzle manufacturers. The savings assume a 1/8-inch diameter open tube.[3]

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. United States Department of Energy. *Improving Compressed Air System Performance*. Pgs. 48-49.
3. Franklin Energy Services, LLC. Personal communications regarding engineering approximation based on field observation.
4. Technical Reference Manual for Ohio Senate Bill 221 Energy Efficiency and Conservation Program and 09-512-GE-UNC. October 15, 2009.
5. The 2,000 hours is the minimum (and most conservative) run hours needed to qualify for this measure and agreed upon by the PSC, Cadmus, Administrator, and Implementers.
6. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 228 units over 16 projects from 2012 to 2017.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	12/2018	Updated incremental cost

Compressed Air System Leak Survey and Repair

	Measure Details
Measure Master ID	Compressed Air System Leak Survey and Repair, 4766 Compressed Air System Leak Survey and Repair-Agriculture, 4767
Workpaper ID	W0026
Measure Unit	Per horsepower
Measure Type	Hybrid
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by capacity and leak size
Peak Demand Reduction (kW)	Varies by capacity and leak size
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by capacity and leak size
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	2[1]
Incremental Cost ($/unit)	$4.83[2]

Measure Description

For the compressed air system survey and repair measure, the facility's compressed air system is analyzed and areas are identified with opportunity to reduce leakage and energy consumption and gain efficiency through an improved equipment control strategy or equipment replacement.

Description of Baseline Condition

The baseline condition is determined by surveying the existing compressed air system. This involves identifying the number and types of compressors used; their nominal hp, scfm, or psig; and the controls associated with each compressor. The most common method of surveying the compressed air system is a leak survey with an ultrasonic instrument.

Description of Efficient Condition

To qualify for an incentive, the customer must repair one leak for every five connected compressor horsepower. If less than one leak per every five horsepower is identified, then all identified leaks must be repaired. The customer can provide a written explanation for a leak that cannot be repaired and may still qualify for an incentive. The customer must provide a leak log in the form of a spreadsheet so that the number of repairs and associated savings can verified using the algorithm provided below. Customers must leave leak tags in place for at least four months after submitting an application to allow for verification if needed.

Annual Energy-Savings Algorithm

kWh_{SAVED} = CFM Reduction / (CFM/BHP) * 0.746 * HOU / Eff

Where:

CFM Reduction = Total CFM reduction in entire compressed air system (= directly from the leak log survey (preferred) or estimated using other reported leak log data the table below

CFM/BHP = Average amount of CFM per brake horsepower (= 4.2)[3]

0.746 = Motor brake horsepower to kilowatt conversion factor

HOU = Average annual compressor run hours (= user input)

Eff = Air compressor deemed motor efficiency (= 90%)

CFM Discharge Rates by Leak Decibel Readings and Pressure Levels[3,4]

Digital Reading	System Air Pressure						
	10 PSIG	25 PSIG	50 PSIG	75 PSIG	100 PSIG	125 PSIG	150 PSIG
	Estimated CFM Equivalent Values						
10 dB	0.05	0.10	0.20	0.30	0.40	0.40	0.60
20 dB	0.20	0.30	0.50	0.70	0.90	1.10	1.30
30 dB	0.50	0.70	1.00	1.30	1.60	1.90	2.20
40 dB	0.80	1.20	1.60	2.10	2.50	2.80	3.20
50 dB	1.30	1.80	2.30	2.90	3.40	3.80	4.30
60 dB	2.00	2.60	3.10	3.80	4.30	4.80	5.40
70 dB	2.70	3.50	4.00	4.80	5.40	5.90	6.60
80 dB	3.60	4.50	5.00	5.80	6.50	7.10	7.80
90 dB	4.60	5.60	6.10	6.90	7.60	8.30	9.10
100 dB	5.70	6.90	7.30	8.10	8.80	9.60	10.40

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 2 years)[1]

Assumptions

The savings assume that the air compressor unit is not variable speed controlled.

Historical project data from January 2016 through June 30, 2018 was used to determine the incremental cost. Data from all sectors was included in the analysis. There were 97 projects for MMID 2261, 43 projects for MMID 2262, 50 projects for MMID 2263, and 111 projects for MMID 3598. The average actual measure cost and average actual unit of measure (hp) across all four MMIDs was used to calculate the average dollar per horsepower incremental cost.

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
   Each tune-up should last two years.
2. Historical Focus on Energy project data, January 1, 2016 to June 30, 2018.
   For 301 projects across previous compressed air leak survey and repair measures MMID 2261, MMID 2262, MMID 2263, and MMID 3598, the average cost is $4.83/hp.
3. UE Systems, Inc. *Compressed Air Ultrasonic Leak Detection Guide*. http://www.uesystems.com/wp-content/uploads/2012/08/compressed_air_guide.pdf
4. UE Systems, Inc. "Compressed Air Loss Guesstimator for Digital Ultraprobes." Accessed January 30, 2017. http://www.uesystems.com/resources/charts-and-graphs/compressed-air-loss-guesstimator-for-digital-ultraprobes

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/14/2016	Updated savings algorithm
03	10/17/2018	Updated to one measure rather than separate measures for years 1 through 4

Compressed Air Condensate Drains, No Loss Drain

	Measure Details
Measure Master ID	Compressed Air Condensate Drains, No Loss Drain, 2254
Workpaper ID	W0027
Measure Unit	Per drain
Measure Type	Prescriptive
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Other
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	1,711
Peak Demand Reduction (kW)	0.24
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	34,200
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	$448.93[5]

Measure Description

Air condensate drains, also referred to as traps, allow for water in the form of condensation to be removed from compressed air systems. Undrained water may interfere with the flow of compressed air and may also corrode the piping or tank.

Manual or automatic drains may be used. A manual drain is typically a simple valve that is opened by an operator. Level-operated mechanical drains are automatic and should not waste air if properly maintained, but they do require maintenance. Electrically operated solenoid drains use a timing device to open an orifice for a programmed amount of time, regardless of the level of condensate. Each of these types of drains may waste compressed air, and each can be replaced with no air-loss drains that automatically remove condensate without waste.

Description of Baseline Condition

The baseline measure is a timed solenoid drain.

Description of Efficient Condition

The efficient condition is a no loss air drain used in a system with load/no-load, variable speed, variable displacement, or centrifugal compressors. Load/no-load compressors must have adequate storage for drains to be eligible. Manual drains, lever-operated mechanical drains, and solenoid drains are not eligible for incentives. No loss drains must be rated to remove the necessary amount of condensate without any loss of compressed air.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = SF * HOU$

Where:

SF = Saving factor in kilowatts per drain (= 0.3)[2]
HOU = Average annual run hours (= 5,702)[3]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = SF * CF$

Where:

CF = Coincidence factor (= 0.80)[2]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Sources

1. *2011 Xcel Colorado DSM Plan*. https://www.xcelenergy.com/staticfiles/xe/Regulatory/Regulatory%20PDFs/2011-CO-DSM-Plan.pdf.
2. TecMarket Works. *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs*. pp. 193 and 194. October 15, 2010.
3. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf
4. TecMarket Works. *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs*. p. 13. October 15, 2010.
5. Historical project data from 2016 and 2017. Average cost for 118 projects is $448.93 per drain.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	05/2018	Updated HOU

Compressed Air Process Load Shifting

	Measure Details
Measure Master ID	Compressed Air Process Load Shifting, 2848
Workpaper ID	W0282
Measure Unit	Per horsepower of load shifted
Measure Type	Hybrid
Measure Group	Compressed Air, Vacuum Pumps
Measure Category	Reconfigure Equipment
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$330.94 per horsepower of load shifted[2]

Measure Description

Compressed air is a necessary operation for most industrial facilities, but it may not be the most effective or efficient use of energy for a certain process. For example, to run a 1 hp air motor, 7 hp at the air compressor is needed.[3] Many applications that use air motors, open blowing, etc. can also be accomplished using an electric motor or a blower with considerably less energy use.

Description of Baseline Condition

The baseline condition is using compressed air when a less energy-intensive solution could be used instead. Potentially inappropriate uses of compressed air can be identified from a walk-through or a system audit performed by a compressed air specialist, the customer themselves, or an energy advisor. These audits will typically identify the amount of compressed air, in CFM, needed to perform the end use function. During the audit, the efficiency of the air compressor (in CFM/hp) is noted.

Description of Efficient Condition

The efficient solution involves installing an electric motor or a blower to accomplish the task that the compressed air was performing, and uses considerably less horsepower. The horsepower for the efficient condition is based on the specification sheet for the equipment being installed. The use of technologies other than a blower or electric motor are not covered by this measure and would need to be evaluated for a custom incentive.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = [(CFM_{BASE} / (CFM_{COMP} / HP_{COMP}) * 0.746 / Eff_{BASE}) – (HP_{EFF} * 0.746 / Eff_{EE})] * HOURS$

Where:

CFM_{BASE} = Baseline CFM of compressed air use that is being shifted (= user input)
CFM_{COMP} = Maximum CFM of air compressor (= user input, see Assumptions)
HP_{COMP} = Horsepower of air compressor (= user input, see Assumptions)
0.746 = Conversion from horsepower to kilowatts
Eff_{BASE} = Efficiency of the air compressor motor (= NEMA Premium efficiency[4] for HP_{COMP})
HP_{EE} = Horsepower of the efficient technology, i.e., electric motor or blower (= user input)
Eff_{EE} = Motor efficiency of the efficient technology (= NEMA Premium efficiency[4] for HP_{EE})
HOURS = Average annual run hours (= user input)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = [(CFM_{BASE} / (CFM_{COMP} / HP_{COMP}) * 0.746 / Eff_{BASE}) – (HP_{EFF} * 0.746 / Eff_{EE})] * CF$

Where:

CF = Coincidence factor (= 1.0)[5]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} / HOURS * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

If the air compressor hp and CFM are not known, use 4.55 CFM/HP[6] in place of CFM_{COMP} / HP_{COMP} in the kWh_{SAVED} equation.

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. Used EUL for NEMA Premium motor (similar to efficient technology). https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 16 projects from January 1, 2018 to November 30, 2021 = $330.94/hp shifted. Excludes two outlier projects with costs of $2.10/hp shifted and $2,646.81/hp shifted.
3. Zolkowski, Jerry. "Pneumatic vs. Electric Tool Calculations and Considerations", *Compressed Air Best Practices*. Accessed December 2021. www.airbestpractices.com/technology/pneumatics/pneumatic-vs-electric-tool-calculations-and-considerations
4. Washington State University – Extension Energy Program. "Induction Motor Efficiency Standards." October 2005 www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/motor_efficiency_standards.pdf
5. Army Corps of Engineers. Compressed Air System Survey at Sierra Army Depot, CA. Mike C.J. Lin, Ahmad R. Ganji, Shy-Sheng Liou, and Bryan Hackett. November 2000.
6. U.S. Department of Energy, Office of Industrial Technologies. "Compressed Air Systems Fact Sheet #8: Packaged Compressor Efficiency Ratings." p. 2. April 1998. www.compressedairchallenge.org/data/sites/1/media/library/factsheets/factsheet08.pdf This reference shows 22 bhp/100acfm, making the inverse (cfm per hp) equal to 4.55 cfm/hp.

Revision History

Version Number	Date	Description of Change
01	12/9/2021	Initial TRM entry

Domestic Hot Water

Water Heater, High Usage, ≥90% TE Gas Storage / ≥2 COP Electric Heat Pump

	Measure Details
Measure Master ID	Water Heater, High Usage: ≥95% TE, K-12 School, Natural Gas, 5083 ≥90% TE, Natural Gas, 3045 ≥90% TE, Indirect, Natural Gas, 5084 ≥90% TE, Tankless, Natural Gas, 4942 ≥2.0 COP, Heat Pump Storage, Electric, 4941
Workpaper ID	W0030
Measure Unit	Per heater
Measure Type	Hybrid
Measure Group	Domestic Hot Water
Measure Category	Water Heater
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by facility type
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by facility type
Lifecycle Energy Savings (kWh)	Varies by facility type
Lifecycle Therm Savings (Therms)	Varies by facility type
Water Savings (gal/year)	0
Effective Useful Life (years)	Varies by measure, see EUL and Incremental Costs by Measure table
Incremental Cost ($/unit)	Varies by measure, see EUL and Incremental Costs by Measure table

Measure Description

This measure is installing a new high-efficiency water heater unit in new construction or in place of an older existing water heater. The new high-efficiency water heater delivers the same amount of hot water at the same temperature as the existing or baseline unit.

Description of Baseline Condition

The baseline condition is a new conventional electric resistance or natural gas storage water heater intended for service in a commercial or industrial building (as new DHW heaters are only installed when the existing unit has failed or has reached its end of life). The fuel type is the same as the water heater being replaced.

Water heaters defined as commercial have certain input capacities:[7]

- >75 MBh for storage natural gas
- >300 MBh for indirect natural gas
- >200 MBh for tankless natural gas
- ≥12 kW for electric resistance and heat pump with supplemental electric resistance heaters (hybrid)

Several efficiency ratings are assumed:

- Natural gas storage DHW heater: 80% thermal efficiency[8]
- Natural gas indirect DHW heater: 80% thermal efficiency[8]
- Natural gas tankless DHW heater: ≥80% thermal efficiency[8]
- Electric DHW heater: 0.95 COP[9]

High-usage applications are required to meet the annual operation and usage requirements for one or more of the categories shown in the table below.

Annual Operation and Usage in High Usage Applications

Category	Subcategory	Annual Operation (Minimum Days/Year)	Usage (Minimum)
Fitness	Fitness Center	≥300	Sq Ft (≥3,000)
Food Service	Full Service Restaurant Fast Food	≥300	Meals/Day (≥300)
	Cafeteria	≥175	Meals/Day (≥300)
Lodging	Dormitory	≥200	Beds (≥50)
	Hotel/Motel	≥300	Rooms or Beds (≥30)
Healthcare	Hospital	≥300	Beds (≥30)
	Nursing Home	≥300	Beds (≥30)
Laundry	Laundromat	≥300	Washes/Day (≥30)
Food Sales	Super Market	≥300	N/A
Education	K-12 Schools	≥250	Students/Building (≥600)
Prisons	Housing	≥200	Housed Inmates (≥50)
Multifamily	Housing	≥300	Mutifamily Units (≥10)

Description of Efficient Condition

The efficient condition is one of the following types of new energy-efficient DHW heaters:

Qualifying Natural Gas Equipment

- ***95% Thermal Efficiency Condensing Natural Gas Storage Water Heaters (K-12 School)***

- ***90% Thermal Efficiency Condensing Natural Gas Storage Water Heaters:*** Condensing natural gas storage water heaters are designed to capture the latent heat from water vapor created when natural gas is burned. Conventional natural gas storage water heaters allow water vapor to leave the device, and therefore the latent heat is not captured (meaning condensing natural gas heaters have a higher efficiency). Because flue gases have been significantly cooled, condensing natural gas water heaters require the use of a fan to propel combustion products gases through the exhaust flue.
- ***90% Thermal Efficiency Condensing Natural Gas Indirect Water Heaters:*** These operate similarly to natural gas storage water heaters but are heated by a separate hot water supply boiler and storage tank. This allows for different combinations of heat source capacity versus storage capacity and is often used to have the same heat source serve both space heating and water heating needs.
- ***90% Thermal Efficiency Condensing Natural Gas Tankless Water Heaters:*** To be able to heat water to 70°F or higher virtually instantaneously, most natural gas tankless water heaters have an input of 200,000 Btu/hour or higher. Their major advantage is having no standby heat losses, in which the heater fires whenever the water temperature drops below a set temperature. In addition, these heaters are typically installed close to the location where hot water is needed, which minimizes losses from the hot water delivery piping.

<u>Qualifying Electric Equipment</u>

- ***Minimum 2.0 COP Heat Pump Water Heaters***

Heat pump water heaters may have supplemental electric resistance heating elements (hybrid heat pump water heater).

Annual Energy-Savings Algorithm

For a new natural gas water heater replacing a natural gas water heater:

$$\text{Therms}_{\text{SAVED}} = \frac{\text{GPY} * 8.33 * \text{C}_{\text{P}} * (\text{T}_{\text{OUT}} - \text{T}_{\text{IN}}) * \left(\frac{1}{\text{TE}_{\text{BASE}}} - \frac{1}{\text{TE}_{\text{EE}}}\right) + (\text{Q}_{\text{LOSS-BASE}} - \text{Q}_{\text{LOSS-EE}}) * 24 * 365}{100{,}000}$$

Where:

GPY = Gallons per year of DHW usage (= derived from days per year of operation and gallons per day shown in Average Daily Gallons by Facility Type table below)

8.33 = Density of water in pounds per gallon

C_{P} = Specific heat of water (=1.0 Btu/(lb * °F))

T_{OUT} = Water temperature leaving the DHW heater (= user input, or 130°F as default)[10]

T_{IN} = Water temperature entering the DHW heater (= 52.3°F)[11]

TE_{BASE} = Thermal efficiency for baseline DHW heater (= 80%)[8]

TE_{EE} = Thermal efficiency for efficient DHW heater (= user input)

$Q_{LOSS\text{-}BASE}$ = Standby heat losses for the baseline DHW heater (= 1,292 Btu/h for storage water heaters, = $Q_{LOSS\text{-}INDIRECT}$ for indirect water heaters, = 0 for tankless water heaters; see Assumptions)

$Q_{LOSS\text{-}EE}$ = Standby heat losses for the efficient DHW heater (= user input or if unknown = 1,089 Btu/h for storage water heaters, = $Q_{LOSS\text{-}INDIRECT}$ for indirect water heaters, = 0 for tankless water heaters; see Assumptions)

24 = Number of hours per day

365 = Number of days per year

100,000 = Conversion factor for Btu per therm

For indirect water heaters:

$$Q_{LOSS\text{-}BASE} = Q_{LOSS\text{-}INDIRECT} = [(\pi * D * H) + (2 * \pi * D^2 / 4)] / R * (T_{OUT} – T_{ROOM})$$

Where:

D = Diameter of storage tank (= user input, feet)

H = Height of the storage tank (= user input, feet)

R = R-value of tank insulation (= 12.5 for baseline, = actual for efficient storage tank)

T_{ROOM} = Ambient temperature surrounding tank (= 75°F; see Assumptions)

For a new heat pump water heater replacing electric resistance water heater:

$$kWh_{SAVED} = GPY * 8.33 * 1.0 * (T_{OUT} – T_{IN}) * [1 / COP_{BASE} – (1 + ERF) / COP_{EE}] / 3{,}412$$

Where:

COP_{BASE} = Coefficient of performance for baseline DHW heater (= 0.95)[9]

ERF = Electric resistance fraction, or fraction of electrical energy of hybrid heat pump water heaters attributed to electric resistance heater (= 0% for heat pump water heaters without supplemental electric resistance heating elements [not hybrid], = 14.6% for heat pump water heaters with supplemental electric resistance heating elements [hybrid]; see Assumptions)

COP_{EE} = Coefficient of performance for efficient DHW heater (= user input)

3,412 = Conversion factor for Btu per kilowatt-hour

Average Daily Gallons by Facility Type

Facility Type	Average Daily Gallons	Source
Schools Elementary School Junior/Senior High School	 0.6 gal/student 1.8 gal/student	ASHRAE HVAC Applications 2019, Chapter 51, Table 6[12]
Motels and Hotels ≤20 rooms/suites 21 to 99 rooms/suites ≥100 rooms/suites	 20 per room 14 per room 10 per room	ASHRAE HVAC Applications 2019, Chapter 51, Table 6[12]
Dormitories	12.7 per student	ASHRAE HVAC Applications 2019, Chapter 51, Table 6[12] (average of 13.1 for male dormitory and 12.3 for female dormitory)
Prison Housing	12.7 per housed inmate	ASHRAE HVAC Applications 2019, Chapter 51, Table 6[12] (average of 13.1 for male dormitory and 12.3 for female dormitory; *prison housing water usage is assumed to be similar to the dormitories category)*
Hospital	50 per bed	Sacremento Municipal Utility District[13] (lists a range of 25 to 90 gallons per day per bed; this workpaper used 50, which is conservative of 57.5 midpoint)[13]
Nursing Homes	18.4 per bed	ASHRAE HVAC Applications 2019, Chapter 51, Table 6[12]
Food Service Full Service Restaurant or Cafeteria Fast Food	 2.4 per meal 350 per day	Full service and cafeteria: ASHRAE HVAC Applications 2019, Chapter 51, Table 6[12] Fast food: ASHRAE HVAC Applications 2019, Chapter 51, page 51.15 (lists range of 250 to 500, used 350 as under midpoint of the range)[12]
Supermarket	650 per day	ASHRAE HVAC Applications 2019, Chapter 51, page 51.15 (lists range of 300 to 1,000, used average of 650)[12]
Fitness Center	0.1387 per sq ft per day	Calculated using data from eQuest Schematic Design Wizard, including: 13.1 gal/person/day (per ASHRAE HVAC Applications 2019, Chapter 51, Table 6[12] for male dormitories), sq ft per person (80% of space at 50 sq ft per person, 15% of space at 100 sq ft per person, and 5% of space at 333.3 sq ft per person) and average occupancy % (60%) as defined in eQuest.
Laundry	21 per wash	ASHRAE HVAC Applications 2019, Chapter 51, page 51.13, Table 3 (for low-flow clothes washer)[12]
Multifamily	34.14 per unit	Florida Solar Energy Center. *Estimating Daily Domestic Hot-Water Use in North American Homes.* June 30, 2015.[13] and U.S. Energy Information Administration. *Residential Energy Consumption Survey*. 2009.[15]

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for a natural gas water heater.

For a heat pump water heater:

$$kW_{SAVED} = CF * FUF * kW_{BASE} * [1 / COP_{BASE} - (1 + ERF) / COP_{EE}]$$

Where:

CF = Coincidence factor, or ratio of expected power demand at utility peak system demand to maximum connected load of an item of equipment (= varies by facility type, see Coincidence Factors and Facility Utilization Factors table below)

FUF = Facility utilization factor, or ratio of facility usage at the time of utility peak system demand to the maximum facility usage as a function of facility type. For dormitories, it should reflect summer occupancy relative to maximum occupancy. Similarly for other facility types, it should account for summer weekday occupancy factors that affect DHW usage (= project-specific values; otherwise use set of typical FUF values shown in Coincidence Factors and Facility Utilization Factors table below)

kW_{BASE} = Power rating of the baseline DHW heater

Coincidence Factors and Facility Utilization Factors[16]

Facility Type	CF	FUF
Dormitories	0.25	0.30
Schools		
Elementary	0.10	0.10
Junior / Middle / High	0.25	0.40
Motels and Hotels*	0.25	1.00
Nursing Homes	0.35	1.00
Hospital (assume same values as nursing home)	0.35	1.00
Food Service	0.40	1.00
Apartment Houses	0.25	0.90
Supermarkets	0.15	1.00
Fitness Center**	0.25	1.00
Laundry	0.50	1.00

* Excludes restaurants, kitchens, and laundries.

** Matches dormitories

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years for natural gas storage and freestanding water heaters, = 20 years for natural gas tankless water heaters, = 10 years for electric heat pump)[1]

Assumptions

For heat pump water heaters, the effect of room temperature on COP and on heating and cooling energy are assumed to be small and are neglected. Program history shows installations in commercial kitchens, where the year-round cooling was beneficial.

The electric resistance factor was determined from a U.S. Department of Energy study on hybrid heat pump water heaters.[17] The study measured the percentage of the kilowatt-hour consumption that was attributed to the water heater's electric resistance heater instead of the heat pump. For three models across 14 units and sites, the average of the values (32.7%, 5.6%, and 5.5%) is 14.6%.

The default standby heat loss values for the natural gas baseline storage water heaters were calculated using the formulas from the federal standard for commercial water heaters.[18]

$$Q_{LOSS\text{-}BASE} = (\text{Rated Btu / h Input}) / 800 + 110 * \sqrt{(\text{Rated Gallons})}$$

Based on an 90-gallon water heater with 199,000 Btu/h input:

$$Q_{LOSS\text{-}BASE} = 199{,}000 / 800 + 110 * \sqrt{90} = 1{,}292 \text{ Btu/h}$$

The default standby heat loss value for the efficient storage water heater is the average standby loss of AHRI-rated commercial water heaters[19] with 80 to 100 gallon storage tanks, a thermal efficiency of at least 90%, and heating capacities less than or equal to 300 MBh. Based on data available in October 2019, there are 153 water heaters that meet the above criteria. However, 26 of those water heaters have a very low standby loss (<700 Btu/hr) compared to what Focus on Energy historical data has observed on actual projects (typically around 1,000 Btu/hr). Therefore, water heaters with a 700 Btu/hr or less standby loss were excluded, leaving 127 water heaters with an average standby loss of 1,089 Btu/hr.

To determine the standby heat loss for the baseline storage water heater, 90 gallons was used as the storage capacity (midpoint of the 80 to 100 gallon range used for the efficient water heater) and 199 MBh was used as the heating capacity (data for efficient water heater standby loss was limited to a heating capacity of 300 MBh, and the minimum size in the AHRI data was about 100 MBh).

Indirect water heater storage tanks are required to have R-12.5 insulation.[7] The heat loss in Btus per hour is calculated based on known or estimated storage tank dimensions and applying a U * A * ΔT heat loss formula with R-12.5 insulation for the baseline and actual insulation for the proposed. When calculating the heat loss, the average annual mechanical room temperature where the storage tank is located was assumed to be 75°F. Residential water heater MMID 4271 uses 65°F, but assumes the water heater is in a semi-conditioned space like a basement: this workpaper uses 75°F for commercial settings where the water heater is likely to be located in a warm mechanical room.

EUL and Incremental Costs by Measure

Measure	MMID	EUL[1]	Incremental Cost
≥95% TE, K-12 School, Natural Gas	5083	15	$1,660.25[2]
≥90% TE, Natural Gas	3045	15	$1,176.21[3]
≥90% TE, Indirect, Natural Gas	5084	15	$988.50[4]
≥90% TE, Tankless, Natural Gas	4942	20	$605.00[5]
≥2.0 COP, Heat Pump Storage, Electric	4941	10	$2,253.00[6]

Sources

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2. Wisconsin Focus on Energy historical project data for MMID 3684 obtained from SPECTRUM. Average cost of 61 water heaters ≥95% TE in over 31 projects from January 2018 to September 2020 was $10,185.59. August 2018 online lookups of 43 baseline and 29 efficient water heater models on www.grainger.com and www.supplyhouse.com allow for a linear fit of cost to MBh for baseline and efficient models. This fit was applied to the spread of water heater sizes in Focus on Energy program data, revealing an efficient cost that was 16.3% higher than the baseline cost. Therefore, the incremental cost is 16.3% * $10,185.59 = $1,660.25.
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    Average water heater setpoint recorded at 132 school, office, restaurant, and retail sites.
11. U.S. Department of Energy. "Domestic Hot Water Scheduler." http://energy.gov/eere/buildings/downloads/dhw-event-schedule-generator
    Average water main temperature of all locations measured in Wisconsin by scheduler, weighted by city populations.
12. American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. *ASHRAE Handbook, HVAC Applications.* Chapter 51 "Service Water Heating." 2019.
13. Sacramento Municipal Utility District. "Energy Library / Facility Types / Healthcare / Hospitals." Accessed November 12, 2014. http://smud.apogee.net/comsuite/content/ces/?id=971,
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Revision History

Version Number	Date	Description of Change
01	01/01/2013	Revised measure
02	11/07/2014	Added building categories
03	09/25/2015	Added categories for K-12 schools and prisons
04	12/29/2015	Updated incremental cost data
05	10/2017	Updated EUL for MMIDs 3045 and 3046
06	10/2017	Updated EUL for MMID 3047
07	05/2018	Updated based on Potential Study data
08	12/2018	Updated costs for MMIDs 3045 and 3047
09	10/2019	Added factor for hybrid heat pump water heaters and changed efficiency units and EUL for MMID 3046
10	12/2019	Add multifamily eligibility and retired MMID 2760 for only multifamily properties
11	2/2020	Revised baseline COP
12	09/2020	Removed MMID 3684 for K-12 schools, added indirect natural gas water heater
13	11/2021	Add fitness centers as an eligible building type

Natural Gas Storage Water Heater

	Measure Details
Measure Master ID	Water Heater, NG, ≤55 gal, UEF of 0.68 or Greater, 4943
Workpaper ID	W0250
Measure Unit	Per water heater
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Water Heater
Sector(s)	Commercial, Industrial, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies
Water Savings (gal/year)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	$400.00[2]

Measure Description

This measure is residential-sized (55 gallons or smaller) tank-type storage domestic water heaters, defined as equipment with an input rating ≤75,000 Btuh and a storage volume from 20 gallons to 50 gallons. The measure is an upgrade from a water heater with a minimum allowed UEF to 0.68 UEF or greater.

Description of Baseline Condition

The base case is a natural gas–fueled residential-duty commercial storage water heater with a 0.58 UEF (see the Assumptions section for more details).

Description of Efficient Condition

The efficient condition is a natural gas–fueled residential-duty commercial storage water heater that is 55 gallons or smaller with a ≥0.68 UEF.

Annual Energy-Savings Algorithm

$Therm_{SAVED} = [(GPD * 365 * 8.33 * C_{P,WATER} * \Delta T_{w}) / 100{,}000] * [(1 / UEF_{BASE}) - (1 / UEF_{EE})]$

Where:

GPD = Average daily hot water consumption (= 55 gallons per day for business,[3] = 34.14 gallons per day for multifamily[4,5])

365 = Days per year

8.33 = Density of water (pounds per gallon)

$C_{P,WATER}$ = Specific heat of water (= 1 Btu/lb °F)

ΔT_w = Difference between the average cold water inlet temperature and the hot water delivery temperature (= T_{OUT} - T_{IN})

T_{IN} = Average cold water inlet temperature (= 52.3°F)[6]

T_{OUT} = Hot water delivery temperature (= 130°F for business,[8] = 125°F for multifamily[7])

100,000 = Conversion factor from Btu to therm

UEF_{BASE} = Energy factor of the baseline water heater (= 0.58; see Assumptions)

UEF_{EE} = Energy factor of the efficient water heater (= 0.68; see Assumptions)[9]

Summer Coincident Peak Savings Algorithm

Natural gas–fired storage water heaters consume no electrical energy, aside from a combustion air fan; therefore, they have a negligible impact on demand reduction.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years)[1]

Deemed Savings

Deemed Natural Gas Savings

Measure	MMID	Sector	Annual Therms	Lifecycle Therms
Water Heater, NG, ≤55 gal, UEF of 0.68 or Greater	4943	Multifamily	19	247
		Commercial, Industrial, School and Government	33	429

Assumptions

Based on data of available products and as defined in the federal standard,[10] water heaters are assumed to have a medium or high draw pattern. Reviewing water heater models with a tank size ≤55 gallons in the AHRI database[11] shows 12 low-use models, 435 medium-use models, and 583 high-use models. It also shows a majority of units between 40 gallons and 50 gallons. For simplicity and to match with the previously available measure, the UEF for the high draw pattern (0.68) was selected as the efficient condition (which is slightly higher than the medium draw pattern requirement of 0.64 UEF). However, to be conservative, the 24-hour water usage for the medium draw pattern test was used for business sectors.

The baseline efficiency was derived from federal standard for water heaters[10] and generally follows the form UEF = 0.6597 – (0.0009 * V), where V is the tank size volume. Several sets of coefficients exist across water heater types, tank size ranges, and draw patterns, as shown in the Baseline UEF Values table below. Therefore, for the baseline UEF, a value of 0.58—which is the average for medium and high draw for 50 gallons—was chosen. This reflects an average of 40 gallons to 50 gallons, with medium- and high-draw pattern values.

Baseline UEF Values

Tank Size	Fuel	Draw Pattern	UEF Formula	UEF Value for Tank Size (Gallons)			
				30	40	50	55
≥20 gallons and ≤55 gallons	Natural gas	Very Small	0.2674 – (0.0009 * V)	0.2404	0.2314	0.2224	0.2179
		Low	0.5362 – (0.0012 * V)	0.5002	0.4882	0.4762	0.4702
		Medium	0.6002 – (0.0011 * V)	0.5672	0.5562	0.5452	0.5397
		High	0.6597 – (0.0009 * V)	0.6327	0.6237	0.6147	0.6102

The gallons per day for multifamily use was calculated by fitting a polynomial equation to data from Table 3 of the Florida Solar Energy Center study.[4] An average value of 1.9 occupants per home was used for Wisconsin, based on 2009 RECS data.[5] The fitted equation is GPD = $-0.0089 * x^2 + 16.277 * x + 3.25$, where x is the average number of occupants per home.

Sources

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5. U.S. Energy Information Administration. *Residential Energy Consumption Survey*. 2009. https://www.eia.gov/consumption/residential/index.php
6. United States Department of Energy. *DHW Scheduler*.
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7. The water heater setpoint is assumed to be 125°F. Wisconsin building code 704.06 requires landlords to set water heaters to 125°F: https://docs.legis.wisconsin.gov/statutes/statutes/704/06. Water heater setpoints typically range from 120°F to 140°F, because temperatures below 120°F are susceptible to Legionella bacteria (which leads to Legionnaires Disease) and heaters set to temperatures above 140°F can quickly scald users: http://www.nrel.gov/docs/fy12osti/55074.pdf. Most TRMs assume water heater setpoints of 120°F, 125°F, or 130°F, though most of those are using unsourced engineering assumptions.
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Revision History

Version Number	Date	Description of Change
01	12/11/2019	Initial TRM entry
02	2/2020	Added to TRM

Kitchen and Bathroom Aerators, Business, Electric or Natural Gas, Pack Based

	Measure Details
Measure Master ID	Kitchen Aerator: 1.5 GPM, Small Office, Electric or Natural Gas, Pack Based, 4688 1.5 GPM, Restaurant, Electric or Natural Gas, Pack Based, 4689 Bathroom Aerator: 1.0 GPM, Small Office, Electric or Natural Gas, Pack Based, 4690 1.0 GPM, Restaurant, Electric or Natural Gas, Pack Based, 4691 1.0 GPM, Retail, Electric or Natural Gas, Pack Based, 4692
Workpaper ID	W0032
Measure Unit	Per aerator
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Aeration
Sector(s)	Commercial, Industrial
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	Varies by measure
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	Kitchen Aerator: $1.44 (MMID 4688, 4689)[2] Bathroom Aerator: $1.46 (MMID 4690, 4691, 4692)[2]

Measure Description

This measure is the installation of low-flow aerators in the kitchens and bathrooms of small offices, restaurants, and retail commercial buildings. These low-flow aerators conserve water by reducing the flow rate as compared to the 2.2 gallons per minute (gpm) standard aerators. Not only are there savings in water consumption, but also in electricity and natural gas usage because low-flow aerators reduce the demand to heat and transport as much water. These devices are an affordable, easily installed, long-lasting solution to save water and energy.

Description of Baseline Condition

The baseline condition is a standard aerator with a flow rate of 2.2 gpm.[3]

Description of Efficient Condition

The efficient condition is replacing a standard aerator with a low-flow aerator with a flow rate of 1.5 gpm for kitchen aerators and 1.0 gpm for bathroom aerators.[4]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Gallons_{SAVED} * 8.33 * C * (T_{POINT\ OF\ USE} – T_{ENTERING}) / (EF_{ELECTRIC} * 3{,}412) * WFS_{ELECTRIC}$

$Therm_{SAVED} = Gallons_{SAVED} * 8.33 * C * (T_{POINT\ OF\ USE} – T_{ENTERING}) / (EF_{GAS} * 100{,}000) * WFS_{GAS}$

$Gallons_{SAVED} = (GPM_{EXISTING} – GPM_{NEW}) / GPM_{EXISTING} * Usage * ISR$

Where:

$Gallons_{SAVED}$ = First-year water savings in gallons
8.33 = Density of water, lbs/gallon
C = Specific heat of water (= 1 Btu/lb °F)
$T_{POINT\ OF\ USE}$ = Temperature of water at point of use (= 86°F for bathrooms,[11] = 93°F for office and retail kitchens,[11] = 101°F for restaurant kitchens;[10] see Assumptions)
$T_{ENTERING}$ = Temperature of water entering water heater (= 52.3°F)[7]
$EF_{ELECTRIC}$ = Energy factor of electric water heater (= 93%)[9]
3,412 = Conversion factor for Btus per kilowatt-hour
$WFS_{ELECTRIC}$ = Assumed fraction of participating sites with electric hot water (= 60%)[8]
EF_{GAS} = Energy factor of natural gas water heater (= 77%)[9]
100,000 = Conversion factor for Btus per therm
WFS_{GAS} = Assumed fraction of participating sites with natural gas hot water (= 40%)[8]
$GPM_{EXISTING}$ = Baseline flow rate (= 2.2 gpm)[3]
GPM_{NEW} = Efficient flow rate (= 1.5 gpm for kitchens, = 1.0 gpm for bathrooms)[4]
Usage = Estimated usage of mixed water (= 2,500 gallons per year for small office, = 3,650 gallons per year for retail, = 12,675 gallons per year for restaurants; see Assumptions)[5]
ISR = In-service rate (= varies, see table below)

Aerator In-Service Rates

Facility Type	In-Service Rate[6]	
	Bath Aerator	Kitchen Aerator
Small Office	41%	39%
Restaurant	81.5%	81.5%
Retail	69%	N/A

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Deemed Savings for Aerators

Facility Type	Aerator Location	MMID	Annual Gallons	Lifecycle Gallons	Annual kWh	Lifecycle kWh	Annual Therms	Lifecycle Therms
Small Office	Bathroom	4690	559	5,590	30	300	0.82	8.2
	Kitchen	4688	310	3,100	20	200	0.55	5.5
Restaurants	Bathroom	4691	5,634	56,340	299	2,990	8.22	82.2
	Kitchen	4689	3,287	32,870	252	2,520	6.93	69.3
Retail	Bathroom	4692	1,374	13,740	73	730	2.00	20.0

Assumptions

The average end-use temperature for bathrooms is assumed to be 86°F and the average end-use temperature for kitchens at small office and retail sites is assumed to be 93°F. This matches the assumptions for residential sites.[11] The average restaurant kitchen end-use is assumed to be 101°F. This matches the assumption for pre-rinse sprayers (MMID 4693) and is an equally weighted average of cold (72.3°F), mixed (105.0°F), and hot (125.6°F) water temperatures obtained from a study on pre-rinse sprayers.[10]

For restaurant usage, a 50/50 average of sit-down and fast food values, from the Illinois TRM,[5] is used (the average of 9,581 and 15,768 is 12,675).

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Revision History

Version Number	Date	Description of Change
01	03/2018	Initial TRM entry

Food Service

Salamander Broiler, Infrared

	Measure Details
Measure Master ID	Salamander Broiler, Infrared, Nautral Gas, Per input MBh, 4359
Workpaper ID	W0033
Measure Unit	Per input MBh of efficient broiler
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Broiler
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	5.82
Lifecycle Electricity Savings (kWh)	0
Lifecycle Therm Savings (Therms)	69.84
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$1,000.00[2]

Measure Description

A salamander broiler is a self-contained appliance intended for a range of culinary functions such as toasting, finishing, or browning of dishes and melting cheese to intense searing of food products. Salamanders are an efficient alternative to broiling in a standard oven as the smaller heating element in a salamander broiler can provide more precise control of the cooking compared to a broiler oven that heats a larger amount of air.

Radiant broilers typically have cast-iron burners that heat ceramic bricks to cook food product with a mix of radiant and convective heat transfer. Infrared broilers use a different burner and ceramic brick design that increases radiant heat transfer and reduces convective heat transfer for a given Btu of input. This not only increases the effectiveness of the broiler for certain tasks, but also increases the overall efficiency of the broiler in terms of heat delivered to food per Btu of input.

Description of Baseline Condition

The baseline condition is a natural gas–fired radiant salamander broiler.

Description of Efficient Condition

This incentive applies toward the installation of newly purchased natural gas–fired salamander broiler with infrared burners.

Annual Energy-Savings Algorithm

$\text{Therms}_{\text{SAVED}} = \text{MBh}_{\text{INPUT}} * [(1 / \text{EffRatio}) - 1] * \text{DC} * \text{HOU} / 100$

Where:

$\text{MBh}_{\text{INPUT}}$ = Input capacity in MBh of the efficient salamander broiler (= actual capacity of the efficient salamander broiler)
EffRatio = Ratio of radiant to infrared broiler efficiency (= 75%, see Assumptions)
DC = Duty cycle (= 70%)[4]
HOU = Annual hours of use based on eight hours per day, six days per week, 52 weeks per year (= 2,496 hours)[4]
100 = MBh to therms conversion factor

Lifecycle Energy-Savings Algorithm

$\text{Therms}_{\text{LIFECYCLE}} = \text{Therms}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 12 years)[1]

Assumptions

An infrared broiler is assumed to consume 25% less energy per unit of food cooked than a radiant broiler. This mimics the assumption used in the Missouri TRM,[3] which assumes that the difference in baseline and efficient consumption for a salamander broiler matches that of a char broiler, and therefore it receives typical char broiler values from the Food Service Technology Center's Life-Cycle Cost Calculator.[5] This also matches information from a Food Arts magazine article,[6] which mentions that radiant broilers typically consume "roughly 25 to 30 percent less heat-on-meat per BTU."

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Revision History

Version No.	Date	Description of Change
01	09/29/2017	Initial TRM entry

Dishwasher, ENERGY STAR Commercial

	Measure Details
Measure Master ID	Dishwasher: Low Temp: Door Type, ENERGY STAR, 2280 (Electric) and 2293 (Natural Gas) Multi Tank Conveyor, ENERGY STAR, 2294 (Electric), 2295 (Natural Gas) Single Tank Conveyor, ENERGY STAR, 2296 (Electric), 2297 (Natural Gas) Under Counter, ENERGY STAR, 2298 (Electric) and 2299 (Natural Gas) Pots/Pans Type, ENERGY STAR, 3139 (Electric) and 3140 (Natural Gas) High Temp, Electric Booster: Door Type, ENERGY STAR, 2281 (Electric) and 2282 (Natural Gas) Multi Tank Conveyor, ENERGY STAR, 2283 (Electric) and 2284 (Natural Gas) Single Tank Conveyor, ENERGY STAR, 2285 (Electric) and 2286 (Natural Gas) Under Counter, ENERGY STAR, 2287 (Electric) and 2288 (Natural Gas) Pots/Pans Type, ENERGY STAR, 3136 (Electric) and 3137 (Natural Gas) High Temp, Natural Gas Booster: Door Type, ENERGY STAR, 2289 (Natural Gas) Multi Tank Conveyor, ENERGY STAR, 2290 (Natural Gas) Single Tank Conveyor, ENERGY STAR, 2291 (Natural Gas) Under Counter, ENERGY STAR, 2292, (Natural Gas) Pots/Pans Type, ENERGY STAR, 3138, (Natural Gas)
Workpaper ID	W0034
Measure Unit	Per dishwasher
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Dishwasher, Commercial
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	Varies by measure
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

On average, ENERGY STAR-qualified commercial dishwashers are 25% more efficient than conventional dishwashers in both energy and water use. The reduction in water use results in additional water-heating energy savings.

The ENERGY STAR rating applies to commercial under-counter dishwashers; single-tank door type dishwashers; pot, pan, and utensil dishwashers; single- and multiple-tank conveyor dishwashers; and flight-type dishwashers. To meet ENERGY STAR criteria, commercial dishwashers must meet certain idle energy use rates and volume of water consumed per rack.

Dishwasher measures are for higher temperature and lower temperature machines in door type, multitank conveyor, single-tank conveyor, and under-counter machines. Water heater configurations are for electric water heaters with an electric booster heater, natural gas water heaters with an electric booster heater, and natural gas water heaters with a natural gas booster heater. This measure does not apply to flight-type dishwashers, as these units are custom.

Description of Baseline Condition

The baseline condition for commercial dishwashers is based on values in the ENERGY STAR commercial kitchen equipment calculator;[2] these values were based on the U.S. EPA 2013 FSTC research on available commercial dishwasher models.[3]

Description of Efficient Condition

The efficient condition for commercial dishwashers is defined by the ENERGY STAR v2.0 *Requirements for Commercial Dishwashers*.[2]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \Delta kWh/yr_{WATER\ HEATER} + \Delta kWh/yr_{BOOSTER\ HEATER} + \Delta kWh/yr_{IDLE}$

$Therm_{SAVED} = \Delta Therms/yr_{WATER\ HEATER} + \Delta Therms/yr_{BOOSTER\ HEATER}$

$Gallons_{SAVED} = Gallons/yr_{BASE} - Gallons/yr_{EE}$

Energy-Savings Algorithms by Fuel and Machine Type

Fuel Type	Machine Type	Algorithm
Electric	Water Heater	$\Delta kWh/yr_{WATER\ HEATER} = Gallons_{SAVED} * kWh/gallon_{WATER\ HEATER}$
	Booster Heater	$\Delta kWh/yr_{BOOSTER\ HEATER} = Gallons_{SAVED} * kWh/gallon_{BOOSTER\ HEATER}$
Natural Gas	Water Heater	$\Delta Therms/yr_{WATER\ HEATER} = Gallons_{SAVED} * Therms/gallon_{WATER\ HEATER}$
	Booster Heater	$\Delta Therms/yr_{BOOSTER\ HEATER} = Gallons_{SAVED} * Therms/gallon_{BOOSTER\ HEATER}$

Energy Usage by Fuel and Machine Type

Fuel Type	Machine Type	Energy Use
Electric	Water Heater	$\text{kWh/gallon}_{\text{WATER HEATER}} = \Delta T_{\text{WH}} * C_{\text{WATER}} * \rho_{\text{WATER}} / \eta_{\text{ELECTRIC}} / 3{,}412$
	Booster Heater	$\text{kWh/gallon}_{\text{WATER HEATER}} = \Delta T_{\text{BH}} * C_{\text{WATER}} * \rho_{\text{WATER}} / \eta_{\text{ELECTRIC}} / 3{,}412$
Natural Gas	Water Heater	$\text{Therms/gallon}_{\text{WATER HEATER}} = \Delta T_{\text{WH}} * C_{\text{WATER}} * \rho_{\text{WATER}} / \eta_{\text{GAS}} / 100{,}000$
	Booster Heater	$\text{Therms/gallon}_{\text{BOOSTER HEATER}} = \Delta T_{\text{WH}} * C_{\text{WATER}} * \rho_{\text{WATER}} / \eta_{\text{GAS}} / 100{,}000$

Where:

ΔT_{WH} = Temperature rise delivered by water heater (= 70°F)[2]

C_{WATER} = Specific heat of water (= 1 Btu/pound/°F)

ρ_{WATER} = Density of water (= 8.33 lbs/cubic foot)

η_{ELECTRIC} = Electric conversion efficiency (= 98%)[4]

3,412 = Conversion factor from Btu to kWh

ΔT_{BH} = Temperature rise delivered by booster heater (= 40°F)[2]

η_{GAS} = Natural gas conversion efficiency (= 76%)[4]

100,000 = Conversion factor from Btu to therms

$$\Delta \text{kWh/yr}_{\text{IDLE}} = (\text{kW}_{\text{BASE IDLE}} * \text{DY} * (\text{HD} - \text{RD} * \text{WT}_{\text{BASE}} / 60)) - (\text{kW}_{\text{EE IDLE}} * \text{DY} * (\text{HD} - \text{RD} * \text{WT}_{\text{EE}} / 60))$$

$$\text{Gallons/yr}_{\text{BASE}} = \text{GPR}_{\text{BASE}} * \text{DY} * \text{RD}$$

$$\text{Gallons/yr}_{\text{EE}} = \text{GPR}_{\text{EE}} * \text{DY} * \text{RD}$$

Where:

$\text{kW}_{\text{BASE IDLE}}$ = Baseline consumption when on but not in wash cycle (= varies by measure; see table below)[2]

DY = Days per year of dishwasher operation (= 365)[2]

HD = Hours per day of dishwasher operation (= 18)[2]

RD = Number of racks of dishes washed each day (= varies by measure; see table below)[2]

WT_{BASE} = Wash time (= length of wash cycles in minutes; varies by measure, see table below)[2]

60 = Minutes per hour

$\text{kW}_{\text{EE IDLE}}$ = Efficient equipment consumption when on but not in wash cycle (= varies by measure; see table below)[2]

WT_{EE} = Wash time efficient equipment (= varies by measure; see table below)

GPR_{BASE} = Gallons per rack of baseline equipment (= varies by measure; see table below)[2]

GPR_{EE} = Gallons per rack of ENERGY STAR equipment (= varies by measure; see table below)[2]

Variable Values by Measure Type

Measure Type	GPR_{BASE}	GPR_{EE}	$kW_{BASE\ IDLE}$	$kW_{EE\ IDLE}$	WT_{BASE}	WT_{EE}	RD
Low Temperature							
Under Counter	1.73	1.19	0.50	0.50	2.0	2.0	75
Stationary Single-Tank Door	2.10	1.18	0.60	0.60	1.5	1.5	280
Single-Tank Conveyor	1.31	0.79	1.60	1.50	0.3	0.3	400
Multiple Tank Conveyor	1.04	0.54	2.00	2.00	0.3	0.3	600
Pot, Pan, and Utensil							
High Temperature							
Under Counter	1.09	0.86	0.76	0.50	2.0	2.0	75
Stationary Single-Tank Door	1.29	0.89	0.87	0.70	1.0	1.0	280
Single-Tank Conveyor	0.87	0.70	1.93	1.50	0.3	0.3	400
Multiple Tank Conveyor	0.97	0.54	2.59	2.25	0.2	0.2	600
Pot, Pan, and Utensil	0.70	0.58	1.20	1.20	3.0	3.0	280

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / (DY * HD) * CF$

Where:

kWh_{SAVED} = Total kWh saved, as calculated above

DY = Days per year of dishwasher operation (= 365)[2]

HD = Hours per day of dishwasher operation (= 18)[2]

CF = Coincident factor (= 0.32, see Assumptions)[5]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

$Gallons_{LIFECYCLE} = Gallons_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Savings with Electric Water Heater and Booster Heater

	MMIDs	Baseline		ENERGY STAR		Savings		
		kWh	Therms	kWh	Therms	kWh	Therms	kW
Low Temperature								
Under Counter	2298	11,085	0	8,508	0	2,577	0	0.1255
Stationary Single-Tank Door	2280	39,824	0	23,433	0	16,392	0	0.7984
Single-Tank Conveyor	2296	42,687	0	28,868	0	13,819	0	0.6731
Multitank Conveyor	2294	50,656	0	31,567	0	19,090	0	0.9298
Pot, Pan, and Utensil	3139					8,002	0	0.3897
High Temperature (with electric booster heater)								
Under Counter	2287	12,474	0	9,278	0	3,196	0	0.1557
Stationary Single-Tank Door	2281	40,351	0	28,325	0	12,027	0	0.5858
Single-Tank Conveyor	2285	46,069	0	36,758	0	9,311	0	0.4535
Multitank Conveyor	2283	73,321	0	45,538	0	27,784	0	1.3533
Pot, Pan, and Utensil	3136	21,351	0	17,991	0	3,360	0	0.1637

Savings with Natural Gas Water Heater and Booster Heater

	MMIDs	Baseline		ENERGY STAR		Savings		
		kWh	Therms	kWh	Therms	kWh	Therms	kW
Low Temperature								
Under Counter	2299	2,829	363	2,829	250	0	113	0
Stationary Single-Tank Door	2293	2,409	1,647	2,409	925	0	721	0
Single-Tank Conveyor	2297	9,344	1,467	8,760	885	584	582	0.0284
Multitank Conveyor	2295	10,950	1,747	10,950	907	0	840	0
Pot, Pan, and Utensil	3140					0	312	0
High Temperature (with electric booster heater)								
Under Counter	2288	7,272	229	5,174	181	2,098	48	0.1022
Stationary Single-Tank Door	2282	17,368	1,012	12,468	698	4,900	314	0.2387
Single-Tank Conveyor	2286	23,925	975	18,941	784	4,984	190	0.2428
Multitank Conveyor	2284	36,288	1,630	24,921	907	11,367	723	0.5536
Pot, Pan, and Utensil	3137	8,879	549	7,657	455	1,222	94	0.0595
High Temperature (with natural gas booster heater)								
Under Counter	2292	4,300	360	2,829	284	1,471	76	0.0716
Stationary Single-Tank Door	2289	4,234	1,590	3,407	1,097	827	493	0.0403
Single-Tank Conveyor	2291	11,271	1,531	8,760	1,232	2,511	299	0.1223
Multitank Conveyor	2290	15,126	2,561	13,140	1,426	1,986	1,135	0.0967
Pot, Pan, and Utensil	3138	1,752	863	1,752	715	0	148	0

Annual Water Savings

	MMIDs	Baseline (Gallons/yr)	ENERGY STAR (Gallons/yr)	Savings (Gallons/yr)
Low Temperature				
Under Counter	2298, 2299	47,359	32,576	14,783
Stationary Single-Tank Door	2280, 2293	214,620	120,596	94,024
Single-Tank Conveyor	2296, 2297	191,260	115,340	75,920
Multitank Conveyor	2294, 2295	227,760	118,260	109,500
Pot, Pan, and Utensil	3139, 3140			
High Temperature				
Under Counter	2287, 2288, 2292	29,839	23,543	6,296
Stationary Single-Tank Door	2281, 2282, 2289	131,838	90,958	40,880
Single-Tank Conveyor	2285, 2286, 2291	127,020	102,200	24,820
Multitank Conveyor	2283, 2284, 2290	212,430	118,260	94,170
Pot, Pan, and Utensil	3136, 3137, 3138	71,540	59,276	12,264

Assumptions

The coincidence factor comes from estimates found in a 1985 research paper.[5] Coincidence factors derived from this paper are used for ovens in the Minnesota TRM,[6] and applied to dishwashers in the Illinois TRM.[7] They vary based on building type, ranging from 0.32 to 0.51. A conservative value of 0.32 is used here.

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Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2019	Removed MMIDs 2295, 2297, 3139, and 3140
03	02/2020	Altered demand savings, removed deactivated MMIDs, added previously missing MMIDs

Fryer, ENERGY STAR

	Measure Details
Measure Master ID	Fryer, ENERGY STAR, Electric, 2337 Fryer, ENERGY STAR, NG, 2338
Workpaper ID	W0035
Measure Unit	Per fry pot
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Fryer
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1,2]
Measure Incremental Cost ($/unit)	MMID 2337: $1,500[2] MMID 2338: $1,000[2]

Measure Description

This measure is installing a standard ENERGY STAR electric or natural gas fryer (with a vat that measures ≥14 inches and <18 inches wide, and a shortening capacity of ≥25 pounds and <60 pounds). One fry pot unit is considered as one unit.

Description of Baseline Condition

Baseline equipment is assumed to be a new electric or natural gas fryer that does not meet ENERGY STAR performance specification.

Description of Efficient Condition

The efficient condition is an electric or natural gas fryer that is on the ENERGY STAR Fryer qualified products list. ENERGY STAR fryers include advanced burner and heat exchanger designs to achieve savings while cooking, as well as insulation to achieve savings when idle or during periods of low use.

ENERGY STAR lists individual units with one fry pot as fryers on their qualified products list, and essentially treats one fry pot as one fryer. In practice, manufacturers will often take two or three individual fry pots and package them together as one unit.

Annual Energy-Savings Algorithm

Energy savings result from installing a more efficient unit than the standard efficiency on the market. The amount of savings depends on the type of unit install: ENERGY STAR electric or ENERGY STAR natural gas.

Savings estimates are based on savings equations and assumptions provided to Pacific Gas and Electric by the Food Service Technology Center and shared with Focus on Energy through the Consortium on Energy Efficiency. Fryer performance is determined by applying ASTM F1361-05, the Standard Test Method for the Performance of Open Deep Fat Fryers. The savings estimates are reported per fry pot. Therefore, if a fryer has more than one fry pot, savings should be multiplied accordingly.

The energy consumption equation for electric fryers (kWh) and natural gas fryers (Btu) is of the same form, with only the units of the variables changed. The form of the equation shows that the energy consumption of a fryer is equal to the sum of energy used for cooking, energy used at idle, and energy used to preheat.

$$E_{DAY} = \frac{LB_{FOOD} * E_{FOOD}}{Efficiency} + IdleRate * \left(OpHrs - \frac{LB_{FOOD}}{PC} - \frac{T_{PreHt}}{60}\right) + E_{PreHt}$$

Where:

E_{DAY} = Daily energy consumption per fry pot, in kWh for electric and in Btu for natural gas (= calculated)

LB_{FOOD} = Pounds of food cooked per day (= 150 lb/day)[3,4,5]

E_{FOOD} = ASTM energy to (= 0.167 kWh/lb for electric; 570 Btu/lb for nautral gas)[6]

Efficiency = ASTM heavy load cooking energy efficiency percentage (= varies by measure and sector; see table in Assumptions section)[3]

IdleRate = Idle energy rate, in kW for electric and in Btu/hr for natural gas; see table in Assumptions section)[4,5]

OpHrs = Operating hours per day (= 12 hours for the commercial, industrial, and agriculture sectors;[3] = 9 hours for the schools/government sector; see the Assumptions section[8])

PC = Production capacity in lb/hr (= varies by measure and sector; see table in Assumptions section)[4,5]

T_{PreHt} = Preheat time (= 15 minutes)[6]

60 = Minute to hour conversion factor

E_{PreHt} = Preheat energy in kWh for electric and in Btu for natural gas (= varies by measure and sector; see table in Assumptions section)[4,5]

In order to estimate annual savings, the daily energy consumption baseline and qualifying units are calculated using the above equation, and the latter is subtracted from the former. The resulting daily savings value is multiplied by operating days per year to yield annual savings.

$kWh_{SAVED} = (E_{DAY,B} - E_{DAY,Q}) * OpDay$

$Therm_{SAVED} = (E_{DAY,B} - E_{DAY,Q}) * OpDay / 100{,}000$

Where:

$E_{DAY,B}$ = Daily energy use of a baseline unit in kWh or Btu

$E_{DAY,Q}$ = Daily energy use of a qualifying unit in kWh or Btu

OpDay = Number of operating days per year (= 365 days for commercial, industrial, and agriculture sectors;[3,4,5] = 282.5 days for schools/government sector; see the Assumptions section[8])

100,000 = Btu to therm conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} * CF / (OpHrs * OpDay)$

Where:

CF = Coincidence factor (=0.9)[7]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therms_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (=12 years)[1]

Deemed Savings

Annual Deemed Savings

MMID	Measure	Sector	kW	kWh	Therms
2337	Fryer, ENERGY STAR, Electric	Agriculture, Commercial, Industrial	0.4223	2,055	-
		Schools & Government	0.4610	1,302	-
2338	Fryer, ENERGY STAR, NG	Agriculture, Commercial, Industrial	-	-	629
		Schools & Government	-	-	397

Lifecycle Deemed Savings

MMID	Measure	Sector	kWh	Therms
2337	Fryer, ENERGY STAR, Electric	Agriculture, Commercial, Industrial	24,660	-
		Schools & Government	15,628	-
2338	Fryer, ENERGY STAR, NG	Agriculture, Commercial, Industrial	-	7,548
		Schools & Government	-	4,765

Assumptions

Below is a discussion of each parameter and its basis, following by a table with the values for each parameter by fryer type. The preheat energy, idle energy rate, and production capacity are based on the Food Service Technology Calculators.[4,5]

Efficiency values for fryers are based on the ENERGY STAR Commercial Kitchen Equipment Calculator.[3] Electric fryers are deemed to be 75% efficient for the baseline and 80% efficient for the ENERGY STAR rated products. These are conservative values since this workpaper does not classify fryers as large or standard vat fryers, as ENERGY STAR lists. The ENERGY STAR efficiency values for electric fryers by vat size are outlined in the table below.

Efficiency Values for Electric Fryers[3]

Standard Vat		Large Vat		Assumed Efficiency	
Baseline	ENERGY STAR	Baseline	ENERGY STAR	Baseline	ENERGY STAR
75%	83%	70%	80%	75%	80%

Operating Hours (OpHrs). The operating hours per day is determined to be 12 hours for all fryers. The Food Service Technology Center lists annual operating hours at 14 hours.[4,5] The ENERGY STAR Commercial Kitchen Equipment Calculator lists 16 hours for standard vat fryers and 12 hours for large vat fryers.[3] The most conservative value was used in energy savings calculations.

Operating Days (OpDay). The calculation assumes that the fryers operate 365 days per year.[3,4,5]

For the schools and government sector, schools have a lower hours per day (6 hours)[8] and days per year (200 days).[8] Since school and government facilities are not broken out into their own sectors, a straight average (of 9 hours per day, 282.5 days per year) was used.

ASTM Parameters. ASTM parameters are those that were determined by Food Service Technology Center by applying ASTM F1361-05, the Standard Test Method for the Performance of Deep Fat Fryers.[6]

Pounds of Food per Day (LB_{Food}). This variable was determined to be 150 pounds of food cooked per day for all fryer types.[3,4,5]

Preheat Time (T_{PreHt}). A prefheat time of 15 minutes is used in the savings equation for each fryer.[6]

The assumed parameter values for electric fryers are presented in the table below.

Parameter Values for Electric Fryers

Parameter	Baseline Model	Energy Efficient Model
Preheat Energy (kWh)	2.4[5]	1.9[5]
Idle Energy Rate (kW)	1.2[5]	0.86[5]
Cooking Energy Efficiency	75%[3]	80%[3]
Production Capacity (lbs/hr)	65[5]	71[5]
ASTM Energy to Food (kWh/lb)	0.167[6]	0.167[6]
Pounds of Food Cooked per Day (lb/day)	150[3,4,5]	150[3,4,5]
Preheat Time (min)	15[6]	15[6]
Operating Hours (hr/day)	12[3]	12[3]
Operating Days (day/yr)	365[3,4,5]	365[3,4,5]

The assumed parameter values for natural gas fryers are presented in the table below.

Parameter Values for Natural Gas Fryers

Parameter	Baseline Model	Energy Efficient Model
Preheat Energy (kWh)	18,500[4]	16,000[4]
Idle Energy Rate (kW)	17,000[4]	6,371[4]
Cooking Energy Efficiency	35%[3]	50%[3]
Production Capacity (lbs/hr)	60[4]	67[4]
ASTM Energy to Food (kWh/lb)	570[6]	570[6]
Pounds of Food Cooked per Day (lb/day)	150[3,4,5]	150[3,4,5]
Preheat Time (min)	15[6]	15[6]
Operating Hours (hr/day)	12[3]	12[3]
Operating Days (day/yr)	365[3,4,5]	365[3,4,5]

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” EUL Table. 2014. http://www.deeresources.com
2. ENERGY STAR. “Savings Calculator for ENERGY STAR Commercial Food Service (CFS) Products.” Calculator. March 2021 Version. https://www.energystar.gov/sites/default/files/asset/document/CFS_calculator_03-02-2021.xlsx
3. ENERGY STAR Commercial Kitchen Equipment Calculator. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
4. Food Service Technology Center. “Gas Fryer Life-Cycle Cost Calculator.” https://fishnick.com/saveenergy/tools/calculators/gfryercalc.php

5. Food Service Technology Center. "Electric Fryer Life-Cycle Cost Calculator." https://fishnick.com/saveenergy/tools/calculators/efryercalc.php
6. Pacific Gas and Electric. "Commercial Fryers, Food Service Equipment." Workpaper PGECOFST102 R5. 2014. http://deeresources.net/workpapers
7. *2004-2005 Database for Energy Efficiency Resources (DEER) Update Study Final Report*. pp. 3-15 to 3-18, table 3-14. http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf
8. Engineering judgement from AgSG program for typical school operating hours per day (6 hours) and days per year (200 days).

Revision History

Version Number	Date	Description of Change
01	09/08/2017	Initial TRM entry

Griddle, ENERGY STAR

	Measure Details
Measure Master ID	Griddle, ENERGY STAR, Electric, 2371 Griddle, ENERGY STAR, NG, 2372
Workpaper ID	W0036
Measure Unit	Per linear foot
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Griddle
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Measure Incremental Cost ($/unit)	MMID 2371: $860[2] MMID 2372: $1,250[2]

Measure Description

This measure applies to electric- and natural gas–fired high-efficiency griddles installed in a commercial kitchen. Commercial griddles that are ENERGY STAR qualified are about 10% to 11% more energy efficient than standard models, due to the use of highly conductive or reflective plate materials, improved thermostatic controls, and strategic placement of thermocouples.[3]

Description of Baseline Condition

Baseline equipment is assumed to be a new electric or natural gas griddle that does not meet ENERGY STAR performance specification.

Description of Efficient Condition

The efficient condition is either an electric or natural gas griddle that is on the ENERGY STAR *Griddle Qualified Products List*.

Annual Energy-Savings Algorithm

Energy savings result from installing a more efficient unit than the standard efficiency on the market. Savings estimates are based on savings equations and assumptions provided to Pacific Gas and Electric by the Food Service Technology Center (FSTC) and shared with Focus on Energy through the Consortium on Energy Efficiency.

For electric griddles, kilowatt savings are not determined by a savings equation. Rather, they are reported based on metered data. All savings are per linear foot of griddle.

The equation for energy consumption for electric griddles is similar to the equation for natural gas griddles, with only the units of the variables changed. The form of the equation shows that the energy consumption of a griddle is equal to the sum of energy used for cooking, idle, and preheating.

$$E_{DAY} = \frac{LB_{FOOD} * E_{FOOD}}{Efficiency} + IdleRate * \left(OpHrs - \frac{LB_{FOOD}}{PC} - \frac{T_{PREHT}}{60}\right) + E_{PREHT}$$

Where:

E_{DAY} = Daily energy consumption in kWh/linear ft or Btu/linear ft

LB_{FOOD} = Pounds of food cooked per day per linear foot (= varies by sector; see table in the Assumptions section)

E_{FOOD} = ASTM energy to food in kWh/lb or Btu/lb (= varies by sector; see table in the Assumptions section)

Efficiency = ASTM heavy load cooking energy efficiency percentage (= varies by sector; see table in the Assumptions section)

IdleRate = Idle energy rate per linear foot in kW/ft or Btu/hr/ft (= varies by sector; see table in the Assumptions section)

OpHrs = Operating hours per day (= varies by sector; see Operating Schedule by Sector table below)

PC = Production capacity per linear foot in lb/hr/ft (= varies by sector; see table in the Assumptions section)

T_{PREHT} = Preheat time (= 15 minutes; see the Assumptions section)

60 = Minute to hour conversion

E_{PREHT} = Preheat energy per linear foot in kWh/ft or Btu/ft (= varies by sector; see table in the Assumptions section)

In order to estimate annual savings, the consumption of the baseline and qualifying units are calculated using the above equation, and the latter is subtracted from the former. The resulting daily savings value is multiplied by operating days per year to yield annual savings.

$kWh_{SAVED} = (E_{DAY,B} - E_{DAY,Q}) * OpDay$

Where:

$E_{DAY,B}$ = Daily energy use of baseline unit per linear foot in kWh/ft or Btu/ft

$E_{DAY,Q}$ = Daily energy use of qualifying unit per linear foot in kWh/ft or Btu/ft

OpDay = Number of operating days per year (see Operating Schedule by Sector table below)

$Therm_{SAVED} = (E_{Day,B} - E_{Day,Q}) * OpDay / 100{,}000$

Where:

$E_{Day,B}$ = Daily energy use of baseline unit per linear foot (kWh/ft or Btu/ft)

$E_{Day,Q}$ = Daily energy use of qualifying unit per linear foot (kWh/ft or Btu/ft)

OpDay = Number of operating days per year (= varies by sector; see Operating Schedule by Sector table below)

100,000 = Btu to therms conversion

Operating Schedule by Sector

Sector	Hours per Day (OpHrs)	Days per Year (OpDay)
Agriculture[4,5]	12	365
Commercial[4,5]	12	365
Industrial[4,5]	12	365
Schools & Government[10] (see the Assumptions section)	9	282.5

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} * CF / (OpDay * OpHrs)$

Where:

CF = Coincidence factor (= 0.9)[9]

OpDay = Number of operating days per year (= varies by sector; see Operating Schedule by Sector table above)

OpHrs = Operating hours per day (= varies by sector; see Operating Schedule by Sector table above)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (=12 years)[1]

Deemed Savings

Annual Deemed Kilowatt and Kilowatt-Hour Savings

MMID	Measure Description	Commercial		Industrial		Agriculture		Schools & Gov	
		kW	kWh	kW	kWh	kW	kWh	kW	kWh
2371	Griddle, ENERGY STAR, Electric	0.2384	1,160	0.2384	1,160	0.2384	1,160	0.2535	716

Annual Deemed Therm Savings

MMID	Measure Description	Commercial	Industrial	Agriculture	Schools & Gov
2372	Griddle, ENERGY STAR, Natural Gas	100	100	100	53

Lifecycle Deemed Kilowatt-Hour Savings

MMID	Measure Description	Commercial	Industrial	Agriculture	Schools & Gov
2371	Griddle, ENERGY STAR, Electric	13,920	13,920	13,920	8,592

Lifecycle Deemed Therm Savings

MMID	Measure Description	Commercial	Industrial	Agriculture	Schools & Gov
2372	Griddle, ENERGY STAR, Natural Gas	1,200	1,200	1,200	636

Assumptions

Many of the parameter values used in the savings estimate were determined by FSTC according to ASTM F1275, the Standard Test Method for Performance of Griddles.[6] These were originally prepared for Pacific Gas and Electric and were provided to the program through the Consortium on Energy Efficient Kitchens when the measure was deemed in 2007. ENERGY STAR subsequently began qualifying griddles, and savings estimates have been updated to match ENERGY STAR data and criteria. All values are discussed below, and summarized in the Griddle Parameters by Model and Fuel table below.

- ***Pounds of Food per Day, LB_{FOOD}.*** The deeming calculation assumes that 33.3 pounds of food are cooked per day per linear foot by natural gas and electric standard efficiency and ENERGY STAR griddles. The FSTC assumes that 100 lb/hr were cooked per day by each griddle. The deemed value is obtained by dividing 100 lb/hr by three feet, which is the rounded average length from ENERGY STAR *Qualified Products List*.[8]

- ***Energy to Food, E_{FOOD}.*** Energy to food is deemed to be 0.139 kWh/lb for electric griddles and 475 Btu/lb for natural gas griddles. These values are the original values provided by FSTC.[7]
- ***Efficiency.*** The deemed ASTM heavy load cooking energy efficiency values used in this calculation are the values provided by FSTC. For baseline units, deemed values are 30% for natural gas griddles and 60% for electric griddles.[7] For ENERGY STAR units, the deemed values are 38% for natural gas griddles and 70% for electric griddles. These values are the minimum efficiency values to be ENERGY STAR qualified.[3]
- ***Idle Energy Rate, IdleRate.*** The deemed idle energy rates for baseline models are 7,000 Btu/hr/ft for natural gas griddles and 0.800 kW/ft for electric griddles. These are based on FSTC provided values of 3,500 Btu/hr/ft^2 for natural gas griddles and 0.4 kW/ft^2 for electric griddles.[4,5] The deemed idle energy rate for ENERGY STAR models are 4,136 Btu/hr/ft for natural gas griddles and 0.586 kW/ft for electric griddles. These are based on FSTC provided values of 2,068 Btu/hr/ft^2 for natural gas griddles and 0.293 kW/hr/ft^2 for electric griddles.
- ***Production Capacity, PC.*** The deemed production capacity values for baseline models are 8.4 lb/hr/ft for natural gas griddles and 11.6 lb/hr/ft for electric griddles. These are based on FSTC provided values of 4.2 lb/hr/ft^2 for natural gas griddles and 5.8 lb/hr/ft^2 for electric griddles.[4,5] The deemed production capacity for ENERGY STAR models are 16.4 lb/hr/ft for natural gas griddles and 16.4 lb/hr/ft for electric griddles. These are based on FSTC provided values of 8.2 lb/hr/ft^2 for natural gas griddles and 8.2 lb/hr/ft^2 for electric griddles.[4,5]
- ***Preheat Time, T_{PREHT}.*** Preheat time is the deemed amount of time it takes a griddle to reach operating temperature after being turned on. This is deemed to be 15 minutes from an FSTC workpaper.[7]
- ***Preheat Energy, E_{PREHT}.*** The deemed preheat energy for baseline models are 7,000 Btu/ft for natural gas griddles and 1.33 kWh/ft for electric models. These are based on values from the FSTC provided values of 3,500 Btu/ft^2 for natural gas griddles and 0.667 kWh/ft^2 for electric gridles.[4,5] The deemed preheat energy for ENERGY STAR models are 5,000 Btu/ft for natural gas units and 0.667 kWh/ft^2 for electric units. These are based on FSTC provided values of 2,500 Btu/ft^2 for natural gas griddles and 0.333 kWh/ft^2 for electric griddles.[4,5]
- ***Idle Energy Rate, Production Capacity, and Preheat Energy.*** The base values for these variables were provided in terms of square feet. These base values were multiplied by two feet, as this was the rounded average depth from ENERGY STAR *Qualified Products List*.[8]
- ***Deemed Effective Useful Life***. This is 12 years, erring on a more conservative value from the FSTC calculator default value.[4,5]

Savings are based on the assumption that kilowatts were metered while the unit or units were firing. The peak period kilowatt savings are defined as the average kilowatts from 1 p.m. to 4 p.m., Monday through Friday, June through August. So, using these metered kilowatt values tacitly assumes that the unit is firing throughout the peak period.

For the schools and government sector, schools have a lower hours per day (six hours)[10] and days per year (200 days).[10] Since school and government facilities are not broken out into individual sectors, a straight average of the lower hours per day and days per year for schools and the values for government facilities[4,5] was used. These values are substituted into the savings equation to yield the savings values reported in the Annual Energy-Savings Algorithm and Lifecycle Energy-Savings Algorithm sections. The values are reported in the table below.

Griddle Parameters by Model and Fuel

Fuel Type	Parameter	Baseline Model	ENERGY STAR Model
Electric or Natural Gas	Preheat Time (min)	15	15
	Pounds of Food per Day (lb/day/ft)	33.3	33.3
Electric	Preheat Energy (kWh/ft)	1.33	0.67
	Idle Energy Rate (kW/ft)	0.8	0.586
	Efficiency	60%	70%
	Production Capacity (lb/h/ft)	11.6	16.4
	ASTM Energy to Food (kWh/lb)	0.139	0.139
Natural Gas	Preheat Energy (Btu/ft)	7,000	5,000
	Idle Energy Rate (Btu/h/ft)	7,000	4,136
	Efficiency	30%	38%
	Production Capacity (lb/h/ft)	8.4	16.4
	ASTM Energy to Food (Btu/lb)	475	475

Sources

1. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. EUL for commercial cooking equipment measure. http://www.deeresources.com
2. ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. October 2016 Version. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
3. ENERGY STAR. "Commercial Griddles." Energy Efficient Commercial Griddles. Accessed December 19, 2017. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_griddles
4. "Commercial Foodservice Equipment Life-cycle Cost Calculator - Electric Griddle." Accessed September 5, 2017. https://fishnick.com/saveenergy/tools/calculators/egridcalc.php
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6. ENERGY STAR. "Commercial Griddles Key Product Criteria." Products. Accessed September 5, 2017. https://www.energystar.gov/index.cfm?c=griddles.pr_crit_comm_griddles

7. Pacific Gas and Electric. "Commercial Griddle – Electric and Gas." Food Service Equipment Workpaper PGECOFST103 R7. 2016. http://deeresources.net/workpapers
8. "ENERGY STAR Commercial Griddles Qualified Product List." Accessed January 19, 2018. https://www.energystar.gov/productfinder/product/certified-commercial-griddles/results
9. *Database for Energy Efficiency Resources*. Update Study Final Report, p. 3-15 to 3-18, Table 3-14. http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf
10. Engineering judgement from AgSG program for typical school operating hours per day (six hours) and days per year (200 days).

Revision History

Version Number	Date	Description of Change
01	09/05/2017	Initial TRM entry
02	11/13/2017	Updated to address comments from other implementers

Hot Food Holding Cabinets

	Measure Details
Measure Master ID	Hot Food Holding Cabinet, V = 13-28 cu. ft., ENERGY STAR, 2677 Hot Food Holding Cabinet, V < 13 cu. ft., ENERGY STAR, 2678 Hot Food Holding Cabinet, V ≥ 28 cu. ft., ENERGY STAR, 2679
Workpaper ID	W0037
Measure Unit	Per cabinet
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Hot Holding Cabinet
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$902[2]

Measure Description

This measure is an ENERGY STAR hot food holding cabinet, which is designed to keep cooked or baked foods warm and fresh until ready for serving customers.

Description of Baseline Condition

The baseline equipment is an electric hot food holding cabinet that is not ENERGY STAR certified.

Description of Efficient Condition

The efficient condition is an electric hot food holding cabinet that is ENERGY STAR certified. ENERGY STAR certified hot food holding cabinets include better insulation to reduce heat loss, provide better temperature uniformity within the cabinet from top to bottom (less stratification), and may include magnetic door gaskets or auto-door closures.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * OpHrs * OpDays / 1,000$

Where:

$Watts_{BASE}$ = Power consumption of baseline cabinet (= varies by volume; see table below)

$Watts_{EE}$ = Power consumption of efficient cabinet (= varies by volume; see table below)

OpHrs = Average hours of operation per day (= varies by sector; see table below)

OpDays = Average days of operation per year (= varies by sector; see table below)

1,000 = Kilowatt conversion factor

$Watts_{BASE}$ and $Watts_{EE}$ are based on the cabinet’s interior volume, V. Interior volumes are referenced using the ENERGY STAR *Certified Commercial Products List,* then categorized as ½, ¾, or full size based on ENERGY STAR Version 2.0 *Requirements for Commercial Hot Food Holding Cabinets*.[6] The average volume, V_{AVG}, is determined by cabinet description and used in calculating $Watts_{BASE}$ and $Watts_{EE}$.

For $Watts_{BASE}$, the average volume is multiplied by the maximum idle energy rate to determine wattage. The maximum idle energy rate, 40 watts per cu. ft., is a manufacturer’s requirement for all hot food holding cabinets sold in California.[5]

For $Watts_{EE}$, the average volume is multiplied by the ENERGY STAR *Maximum Idle Energy Consumption Rate*.[6] The interior volume is an averaged value from the ENERGY STAR *Certified Commercial Hot Food Holding Cabinet List* as of September 14, 2017.[7]

Parameters by Cabinet Description

MMID	Cabinet Description	Interior Volume (cu ft)	Average Interior Volume (cu ft)	Maximum Idle Energy Consumption Rate (watts)
2677	¾ Size	$13 \leq V < 28$	21.14	$\leq 2.0 * V_{AVG} + 254.0$
2678	½ Size	$0 < V < 13$	7.78	$\leq 21.5 * V_{AVG}$
2679	Full Size	$28 \leq V$	53.40	$\leq 3.8 * V_{AVG} + 203.5$

Power Consumption by Cabinet Description

MMID	Cabinet Description	$Watts_{BASE}$	$Watts_{EE}$
2677	¾ Size	846	296
2678	½ Size	311	167
2679	Full Size	2,136	406

Operating Schedule by Sector

Sector	Hours per Day	Days per Year
Agriculture[2]	15	365
Commercial[2]	15	365
Industrial[2]	15	365
Schools & Government[2,3] (see the Assumptions section)	10.5	282.5

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= 0.9)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[1]

Assumptions

Schools operate for fewer hours per day (six hours)[3] and fewer days per year (200 days)[3] than other sectors. Since school and government facilities are part of a single sector, a straight average of the lower hours per day and days per year for schools (six hours/day and 200 days/year) and the values for government facilities (15 hours/day and 365 days/year)[2] was used to calculate savings for that sector.

Deemed Savings

Annual Deemed Savings

MMID	Measure Description	Commercial		Industrial		Agriculture		Schools & Gov	
		kW	kWh	kW	kWh	kW	kWh	kW	kWh
2677	Hot Food Holding Cabinet, V = 13-28 cu. ft., ENERGY STAR	0.495	3,011	0.495	3,011	0.495	3,011	0.495	1,631
2678	Hot Food Holding Cabinet, V < 13 cu. ft., ENERGY STAR	0.130	788	0.130	788	0.130	788	0.130	427
2679	Hot Food Holding Cabinet, V ≥ 28 cu. ft., ENERGY STAR	1.557	9,472	1.557	9,472	1.557	9,472	1.557	5,132

Lifecycle Deemed Savings (kWh)

MMID	Measure Description	Commercial	Industrial	Agriculture	Schools & Gov
2677	Hot Food Holding Cabinet, V = 13-28 cu. ft., ENERGY STAR	36,132	36,132	36,132	19,572
2678	Hot Food Holding Cabinet, V < 13 cu. ft., ENERGY STAR	9,456	9,456	9,456	5,124
2679	Hot Food Holding Cabinet, V ≥ 28 cu. ft., ENERGY STAR	113,664	113,664	113,664	61,584

Sources

1. *Database for Energy Efficiency Resources*. Version 2008.2.05. “Effective/Remaining Useful Life Values.” October 10, 2008. http://www.deeresources.com/files/deer0911planning/downloads/EUL_Summary_10-1-08.xls
2. ENERGY STAR. *Commercial Kitchen Equipment Calculator*. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
   Used for both incremental cost and calculation inputs (hours per day and days per year)
3. Engineering judgement from AgSG program for typical school operating hours per day (six hours) and days per year (200 days).
4. *Database for Energy Efficiency Resources Update Study Final Report*. p. 3-15 to 3-18, Table 3-14. 2004-2005. http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf
5. Pacific Gas & Electric. *Insulated Holding Cabinet*. Food Service Equipment Workpaper PGECOFST105 R5. 2016. http://deeresources.net/workpapers
6. “ENERGY STAR Version 2.0 Requirements for Commercial Hot Food Holding Cabinets.” https://www.energystar.gov/products/commercial_food_service_equipment/commercial_hot_food_holding_cabinets/partners
7. ENERGY STAR Commercial Hot Food Holding Cabinets. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_hot_food_holding_cabinets

Revision History

Version Number	Date	Description of Change
01	09/20/2017	Initial TRM entry
02	11/13/2017	Updated to address comments from other implementers

ENERGY STAR Commercial Combination Ovens (Natural Gas or Electric)

	Measure Details
Measure Master ID	Oven, Combination, ENERGY STAR, Electric, 3118 Oven, Combination, ENERGY STAR, Natural Gas, 3119
Workpaper ID	W0038
Measure Unit	Per oven
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Oven
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	15,096 (electric), 0 (gas)
Peak Demand Reduction (kW)	3.446 (electric), 0 (gas)
Annual Therm Savings (Therms)	0 (electric), 1,103 (gas)
Lifecycle Energy Savings (kWh)	181,146 (electric), 0 (gas)
Lifecycle Therm Savings (Therms)	0 (electric), 13,237 (gas)
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$0.00[6]

Measure Description

A combination oven is a self-contained device that functions as a hot air convection (oven mode), saturated and superheated steam heating (steam mode), and combination convection/steam mode for moist heating. The convection/stem mode performs steaming, baking, roasting, rethermalizing, and proofing of various food products. The combination oven can also be referred to as a combination oven/steamer, combi, or combo.

Description of Baseline Condition

Baseline equipment is assumed to be a new combination oven that does not meet ENERGY STAR v2.0 performance specification. Data analysis were provided by the CEE and a dataset was provided by the EPA FSTC and manufacturers from December 2011 through July 2012.

Description of Efficient Condition

The efficient condition is any commercial combination oven that is on the ENERGY STAR Commercial Combination Ovens qualified products list,[2] per the ENERGY STAR v2.0 performance specifications for natural gas and electric combination ovens.[2]

Annual Energy-Savings Algorithms

Electric Combination Oven:

$$\text{kWh}_{\text{SAVED}} = (\text{Wh/day}_{\text{BASELINE}} - \text{Wh/day}_{\text{EE}}) * \text{DPY} / 1{,}000$$

$$\text{Wh/day}_{\text{BASELINE}} = \text{Wh/day}_{\text{CONVECTION, BASELINE}} + \text{Wh/day}_{\text{STEAM, BASELINE}} + \text{Wh/day}_{\text{PREHEAT, BASELINE}}$$

$$\text{Wh/day}_{\text{CONVECTION, BASELINE}} = (1\text{-}\%_{\text{STEAM}}) *\{(\text{m} * \text{E}_{\text{CONVECTION}}) / \eta_{\text{CONVECTION, BASELINE}} + [\text{E}_{\text{IDLE-CONVECTION, BASELINE}} * (\text{t}_{\text{DAY}} - \text{m/PC}_{\text{CONVECTION, BASELINE}} - \text{nP} * \text{t}_{\text{PREHEAT}}/60)]\}$$

$$\text{Wh/day}_{\text{STEAM, BASELINE}} = \%_{\text{STEAM}} * \{(\text{m}* \text{E}_{\text{STEAM}}) / \eta_{\text{STEAM,BASELINE}} + [\text{E}_{\text{IDLE-STEAM, BASELINE}} * (\text{t}_{\text{DAY}} - \text{m/PC}_{\text{STEAM,BASELINE}} - \text{nP} * \text{t}_{\text{PREHEAT}}/60)]\}$$

$$\text{Wh/day}_{\text{PREHEAT, BASELINE}} = \text{E}_{\text{PREHEAT, BASELINE}} * \text{nP}$$

$$\text{Wh/day}_{\text{EE}} = \text{Wh/day}_{\text{CONVECTION, EE}} + \text{Wh/day}_{\text{STEAM, EE}} + \text{Wh/day}_{\text{PREHEAT, EE}}$$

$$\text{Wh/day}_{\text{CONVECTION, EE}} = (1\text{-}\%_{\text{STEAM}}) * \{(\text{m} * \text{E}_{\text{CONVECTION}}) / \eta_{\text{CONVECTION, EE}} + [\text{E}_{\text{IDLE-CONVECTION, EE}} * (\text{t}_{\text{DAY}} - \text{m/PC}_{\text{CONVECTION, EE}} - \text{nP} * \text{t}_{\text{PREHEAT}}/60)]\}$$

$$\text{Wh/day}_{\text{STEAM, EE}} = \%_{\text{STEAM}} * \{(\text{m} * \text{E}_{\text{STEAM}}) / \eta_{\text{STEAM,EE}} + [\text{E}_{\text{IDLE-STEAM, EE}} * (\text{t}_{\text{DAY}} - \text{m/PC}_{\text{STEAM, EE}} - \text{nP} * \text{t}_{\text{PREHEAT}}/60)]\}$$

$$\text{Wh/day}_{\text{PREHEAT, EE}} = \text{E}_{\text{PREHEAT, EE}} * \text{nP}$$

Natural Gas Combination Oven:

$$\text{Therm}_{\text{SAVED}} = (\text{Btu/day}_{\text{BASELINE}} - \text{Btu/day}_{\text{EE}}) * \text{DPY} / 100{,}000$$

$$\text{Btu/day}_{\text{BASELINE}} = \text{Btu/day}_{\text{CONVECTION, BASELINE}} + \text{Btu/day}_{\text{STEAM,BASELINE}} + \text{Btu/day}_{\text{PREHEAT, BASELINE}}$$

$$\text{Btu/day}_{\text{CONVECTION, BASELINE}} = (1\text{-}\%_{\text{STEAM}}) * \{(\text{m} * \text{E}_{\text{CONVECTION}}) / \eta_{\text{CONVECTION, BASELINE}} + [\text{E}_{\text{IDLE-CONVECTION, BASELINE}} * (\text{t}_{\text{DAY}} - \text{m/PC}_{\text{CONVECTION, BASELINE}} - \text{nP} * \text{t}_{\text{PREHEAT}}/60)]\}$$

$$\text{Btu/day}_{\text{STEAM, BASELINE}} = \%_{\text{STEAM}} * \{(\text{m}* \text{E}_{\text{STEAM}}) / \eta_{\text{STEAM, BASELINE}} + [\text{E}_{\text{IDLE-STEAM, BASELINE}} * (\text{t}_{\text{DAY}} - \text{m/PC}_{\text{STEAM,BASELINE}} - \text{nP} * \text{t}_{\text{PREHEAT}}/60)]\}$$

$$\text{Btu/day}_{\text{PREHEAT, BASELINE}} = \text{E}_{\text{PREHEAT,BASELINE}} * \text{nP}$$

$$\text{Btu/day}_{\text{EE}} = \text{Wh/day}_{\text{CONVECTION, EE}} + \text{Wh/day}_{\text{STEAM, EE}} + \text{Wh/day}_{\text{PREHEAT, EE}}$$

$$\text{Wh/day}_{\text{CONVECTION, EE}} = (1\text{-}\%_{\text{STEAM}}) * \{(\text{m}* \text{E}_{\text{CONVECTION}}) / \eta_{\text{CONVECTION, EE}} + [\text{E}_{\text{IDLE-CONVECTION, EE}} * (\text{t}_{\text{DAY}} - \text{m/PC}_{\text{CONVECTION, EE}} - \text{nP} * \text{t}_{\text{PREHEAT}}/60)]\}$$

$$\text{Wh/day}_{\text{STEAM, EE}} = \%_{\text{STEAM}} * \{(\text{m} * \text{E}_{\text{STEAM}}) / \eta_{\text{STEAM, EE}} + [\text{E}_{\text{IDLE-STEAM, EE}} * (\text{t}_{\text{DAY}} - \text{m/PC}_{\text{STEAM, EE}} - \text{nP} * \text{t}_{\text{PREHEAT}}/60)]\}$$

$$\text{Wh/day}_{\text{PREHEAT, EE}} = \text{E}_{\text{PREHEAT,EE}} * \text{nP}$$

Where:

DPY = Days of operation per year (= 365)[3]

1,000 = Kilowatt conversion factor

$\%_{STEAM}$ = Percentage of time in steam mode (= 50%)[3]

m = Estimated mass of food cooked per day, in pounds (= 250)[3]

$E_{CONVECTION}$ = Energy absorbed by food product: cooking by convection (= 73.2 Wh/lb; = 250 Btu/lb)[4]

$E_{IDLE\text{-}CONVECTION,\ BASELINE}$ = Baseline idle energy rate (= varies by unit type; see table below)[3]

t_{DAY} = Estimated operating time per day, in hours (= 12)[3]

$PC_{CONVECTION,\ BASELINE}$ = Production capacity of baseline equipment in pounds per hour (= varies by unit type; see table below)[3]

nP = Estimated number of preheats per day (= 1)[3]

$t_{PREHEAT}$ = Estimated preheat time in minutes per preheat (= 15)[3]

60 = Minutes in an hour

E_{STEAM} = Energy absorbed by food product: cooking by steam (= 30.8 Wh/lb; = 105 Btu/lb)[4]

100,000 = Conversion factor from Btu to therms

$\eta_{STEAM,BASELINE}$ = Cooking energy efficiency of baseline unit (= varies by unit type; see table below)[4]

$\eta_{CONVECTION,\ BASELINE}$ = Energy efficiency of baseline unit (= varies by unit type; see table below)[4]

$E_{IDLE\text{-}STEAM,\ BASELINE}$ = Baseline energy absorbed by food product: cooking by steam (= varies by unit type; see table below)[3]

$PC_{STEAM,BASELINE}$ = Production capacity of baseline cooking by steam

$E_{PREHEAT,\ BASELINE}$ = Measured energy used per preheat for baseline unit (= varies by unit type; see table below)[3]

$\eta_{CONVECTION,\ EE}$ = Cooking energy efficiency of efficient unit

$E_{IDLE\text{-}CONVECTION,\ EE}$ = ENERGY STAR idle rate of efficient equipment (= varies by unit type; see table below)[4]

$PC_{CONVECTION,\ EE}$ = Production capacity of efficient equipment in pounds per hour (= varies by unit type; see table below)[3]

$\eta_{STEAM,\ EE}$ = Cooking energy efficiency of efficient unit, cooking by steam (= varies by unit type; see table below)[4]

$E_{IDLE\text{-}STEAM, EE}$ = ENERGY STAR idle rate of efficient equipment, cooking by steam (= varies by unit type; see table below)[4]

$PC_{STEAM,EE}$ = Production capacity of energy efficient equipment, cooking by steam

$E_{PREHEAT, EE}$ = Measured energy used per preheat from efficient equipment (= varies by unit type; see table below)[3]

Production Capacity by Unit Type

	Baseline	EE
$PC_{CONVECTION}$	100	125
PC_{STEAM}	150	200

Cooking Energy Efficiency by Unit Type

	Electric		Natural Gas	
	Baseline	EE	Baseline	EE
$\eta_{CONVECTION}$	65%	70%	35%	44%
η_{STEAM}	40%	50%	20%	38%

Measured Energy Used per Preheat by Unit Type

	Baseline	EE
$E_{PREHEAT, ELECTRIC}$ (Watts)	3,750	2,000
$E_{PREHEAT, STEAM}$ (Btu)	22,000	16,000

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} * (CF / HOU)$

Where:

CF = Coincidence factor (= 1)[5]

HOU = Annual hours of use (= 4,380)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[1]

Assumptions

The default values given in calculators from the ENERGY STAR FSTC were used for savings calculation variables.

Sources

1. Similar MMIDs 2485-2488. EUL derived from Food Service Technology Center. Gas Convection Oven Life-Cycle Cost Calculator.
2. United States Department of Energy. ENERGY STAR Product Finder: Commercial Combination Ovens.
3. United States Department of Energy. Version 2.0 ENERGY STAR Performance Specification for Gas and Electric Combination Ovens.
4. Food Service Technology Center. “Life-Cycle & Energy Cost Calculator: Combination Ovens.” http://www.fishnick.com/saveenergy/tools/calculators/
5. The Summer Peak Coincidence Factor is assumed to equal 1.0, since the annual kWh savings is divided by the total annual hours (8760), effectively resulting in the average kW reduction during the peak period.
6. ENERGY STAR® Commercial Kitchen Savings Calculator. Accessed March 11, 2016. All Rack Ovens Incremental Cost=$0.00. https://www.energystar.gov/products/commercial_food_service_equipment

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry

Oven, Convection, ENERGY STAR, Electric

	Measure Details
Measure Master ID	Oven, Convection, ENERGY STAR, Electric, 2485
Workpaper ID	W0039
Measure Unit	Per oven
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Oven
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	2,083
Peak Demand Reduction (kW)	0.48
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	24,998
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$388.00[5]

Measure Description

A convection oven is a self-contained device that functions as a hot air convection (oven mode), saturated and superheated steam heating (steam mode), and combination convection/steam mode for moist heating. The convection/stem mode performs steaming, baking, roasting, rethermalizing, and proofing of various food products. Savings adjustment for existing active measure based on ENERGY STAR Version 2.1 specification taking effect January 1, 2014.[3]

Description of Baseline Condition

The baseline condition is an electric full-size convection ovens that has an average cooking energy efficiency of 65% and an average idle rate of 2 kW.[4]

Description of Efficient Condition

The efficient condition is the minimum cooking energy efficiency of an ENERGY STAR electric full-size convection ovens of 71%, with a maximum idle rate of 1.6 kW.[4]

Annual Energy-Savings Algorithm

Per the energy formula on page 4-48 of the Deemed Savings Manual 1.0:[2]

$$kWh_{SAVED} = (E_{DAY,\ BASELINE} - E_{DAY,\ ENERGY\ STAR}) * OpDay$$

$$E_{DAY} = [(LB_{FOOD} * E_{FOOD})/Efficiency] + IdleRate * [OpHrs - (LB_{FOOD}/PC) - (T_{PREHT}/60)] + E_{PREHT}$$

Where:

OpDay = Operating days per year (= varies by model and fuel type; see table below)

E_{DAY} = Daily energy consumption (kWh or Btu)

LB_{FOOD} = Pounds of food cooked per day (= varies by model and fuel type; see table below)

E_{FOOD} = ASTM Energy to Food (kWh/lb or Btu/lb; = varies by model and fuel type, see table below)

Efficiency = ASTM Heavy Load Cooking Energy Efficiency percentage (= varies by model and fuel type; see table below)

IdleRate = Idle energy rate (kW or Btu/hr; = varies by model and fuel type, see table below)

OpHrs = Operating hours per day (= varies by model and fuel type; see table below)

PC = Production capacity in pounds per hour (= varies by model and fuel type; see table below)

T_{PREHT} = Preheat time in minutes (= varies by model and fuel type; see table below)

60 = Conversion from minutes to hours

E_{PREHT} = Preheat energy (kWh or Btu; = varies by model and fuel type, see table below)

Parameter Values by Model and Oven Fuel

Oven Fuel	Parameter	Baseline Model	ENERGY STAR Model	Source
Electric or Natural Gas	Preheat Time (min)	15	15	Deemed
	Operating Hours/Day	12	12	4
	Operating Days/Year	365	365	4
	Pounds of Food Cooked per Day	100	100	4
Electric	Production Capacity (lb/h)	90	90	4
	Preheat Energy (kWh)	1.5	1	4
	Idle Energy Rate (kW)	2	1.6	4
	Cooking Energy Efficiency (%)	65%	71%	4
	ASTM Energy to Food (kWh/lb)	0.0732	0.0732	4
Natural Gas	Production Capacity (lb/h)	83	86	4
	Preheat Energy (Btu)	19,000	11,000	4
	Idle Energy Rate (Btu/h)	15,100	12,000	4
	Cooking Energy Efficiency (%)	44%	46%	4
	ASTM Energy to Food (Btu/lb)	250	250	4

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (E_{DAY,\ BASELINE} - E_{DAY,\ ENERGY\ STAR}) / OpHrs$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[4]

Sources

1. Food Service Technology Center. Convection Oven Life-Cycle Cost Calculator.
2. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3-2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/ sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
3. ENERGY STAR Commercial Ovens Program Requirements, Version 2.1.
4. ENERGY STAR Commercial Kitchen Equipment Calculator.
5. ENERGY STAR. “Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.” 2016. https://www.energystar.gov/sites/default/files/asset/

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	12/2018	Updated incremental cost

Oven, Convection, ENERGY STAR, Natural Gas

	Measure Details
Measure Master ID	Oven, Convection, ENERGY STAR, Natural Gas, 2486
Workpaper ID	W0040
Measure Unit	Per full size oven
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Oven
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	156
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	1,872
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$170.00[5]

Measure Description

A convection oven is a self-contained device that functions as a hot air convection (oven mode), saturated and superheated steam heating (steam mode), and combination convection/steam mode for moist heating. The convection/stem mode performs steaming, baking, roasting, rethermalizing, and proofing of various food products.

Description of Baseline Condition

The average cooking energy efficiency of a natural gas full-size convection oven is 44%, with an average idle rate of 15,100 Btu per hour.[4]

Description of Efficient Condition

The minimum cooking energy efficiency of ENERGY STAR full-size convection ovens is 46%, with a maximum idle rate of 12,000 Btu per hour.[4]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (E_{DAY,\ BASELINE} - E_{DAY,\ ENERGY\ STAR}) * OpDay * (1/100{,}000)$

$E_{DAY} = [(LB_{FOOD} * E_{FOOD})/Efficiency] + IdleRate * [OpHrs - (LB_{FOOD}/PC) - (T_{PREHT}/60)] + E_{PREHT}$

Where:

E_{DAY} = Daily energy consumption (kWh or Btu)

OpDays = Operating days per year (= varies by model and fuel type; see table below)

1/100,000 = Btu to therms conversion

LB_{FOOD} = Pounds of food cooked per day (= varies by model and fuel type; see table below)

E_{FOOD} = ASTM Energy to Food (kWh/lb or Btu/lb; = varies by model and fuel type, see table below)

Efficiency = ASTM Heavy Load Cooking Energy Efficiency percentage (= varies by model and fuel type; see table below)

IdleRate = Idle energy rate (kW or Btu/hr; = varies by model and fuel type, see table below)

OpHrs = Operating hours per day (= varies by model and fuel type; see table below)

PC = Production capacity (lb/hr; = varies by model and fuel type, see table below)

T_{PREHT} = Preheat time in minutes (= varies by model and fuel type; see table below)

60 = Conversion from minutes to hours

E_{PREHT} = Preheat energy (kWh or Btu; = varies by model and fuel type, see table below)

Parameter Values by Model and Oven Fuel

Oven Fuel	Parameter	Baseline Model	ENERGY STAR Model	Source
Electric or Natural Gas	Preheat Time (min)	15	15	Deemed
	Operating Hours/Day	12	12	3
	Operating Days/Year	365	365	3
	Pounds of Food Cooked per Day	100	100	3
Electric	Production Capacity (lb/h)	90	90	3
	Preheat Energy (kWh)	1.5	1	4
	Idle Energy Rate (kW)	2	1.6	3
	Cooking Energy Efficiency (%)	65%	71%	3
	ASTM Energy to Food (kWh/lb)	0.0732	0.0732	3
Natural Gas	Production Capacity (lb/h)	83	86	3
	Preheat Energy (Btu)	19,000	11,000	4
	Idle Energy Rate (Btu/h)	15,100	12,000	3
	Cooking Energy Efficiency (%)	44%	46%	3
	ASTM Energy to Food (Btu/lb)	250	250	3

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 12 years)[1]

Sources

1. Food Service Technology Center. Gas Convection Oven Life-Cycle Cost Calculator.
2. ENERGY STAR Commercial Ovens Program Requirements, Version 2.1.
3. ENERGY STAR Commercial Kitchen Equipment Calculator.
4. Food Service Technology Center. Electric Convection Oven Life-Cycle Cost Calculator.
5. ENERGY STAR. “Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.” 2016. https://www.energystar.gov/sites/default/files/asset/

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	12/2018	Updated incremental cost

Oven, Rack Type, ENERGY STAR, Natural Gas

	Measure Details
Measure Master ID	Oven, Rack Type, ENERGY STAR, Natural Gas: Single Compartment, 2488 Double Compartment, 2487
Workpaper ID	W0041
Measure Unit	Per oven
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Oven
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1,2]
Incremental Cost ($/unit)	$0.00[3]

Measure Description

Rack ovens have a high capacity, are able to produce steam internally, and are fitted with a motor-driven mechanism for rotating multiple pans inserted into one or more removable or fixed pan racks within the oven cavity. A single rack oven is able to accommodate one removable single rack of standard sheet pans measuring 18 x 26 x 1-inch, while a double rack oven is able to accommodate two removable single racks of standard sheet pans measuring 18 x 26 x 1-inch, or one removable double-width rack.

Description of Baseline Condition

The baseline condition is an average natural gas single rack oven with cooking energy efficiency of 43.5% and an average idle rate of 24,451 Btu per hour.[4]

The baseline condition could also be an average natural gas double rack oven with cooking energy efficiency of 50.5% and an average idle rate of 37,971 Btu per hour.[4]

Description of Efficient Condition

The minimum cooking energy efficiency for a single rack oven to qualify for ENERGY STAR is 48%, with a maximum idle rate of 25,000 Btu per hour.[5] The average cooking energy efficiency of available ENERGY STAR-qualified natural gas single rack ovens is 48.9% with an average idle rate of 21,009 Btu per hour.[4]

The minimum cooking energy efficiency for a double rack oven to qualify for ENERGY STAR is 52%, with a maximum idle rate of 30,000 Btu per hour.[5] The average cooking energy efficiency of available ENERGY STAR-qualified natural gas double rack ovens is 53.9% with an average idle rate of 24,128 Btu per hour.[4]

Annual Energy-Savings Algorithm

$Therm_{SAVED} = (E_{DAY,\ BASELINE} – E_{DAY,\ ENERGY\ STAR}) * OpDay * (1/100{,}000)$

$E_{DAY} = [(LB_{FOOD} * E_{FOOD})/Efficiency] + GasIdleRate * [OpHrs – (LB_{FOOD}/PC) – (T_{PREHT}/60)] + E_{PREHT}$

$kWh_{SAVED} = kWh_{ANNUAL,\ BASELINE} – kWh_{ANNUAL,\ ENERGY\ STAR}$

$kWh_{ANNUAL} = ElecIdleRate * OpDay * [OpHrs – (LB_{FOOD}/PC)]$

Where:

E_{DAY} = Daily energy consumption (Btu)
OpDays = Operating days per year (= varies by model; see table below)
1/100,000 = Btu to therms conversion
LB_{FOOD} = Pounds of food cooked per day (= varies by model; see table below)
E_{FOOD} = ASTM Energy to Food (Btu/lb; = varies by model, see table below)
Efficiency = ASTM Heavy Load Cooking Energy Efficiency (%; = varies by model, see table below)
GasIdleRate = Gas Idle energy rate (Btu/hr; = varies by model, see table below)
OpHrs = Operating hours per day (= varies by model; see table below)
T_{PREHT} = Preheat time in minutes (= varies by model; see table below)
60 = Conversion from minutes to hours
E_{PREHT} = Preheat energy (Btu; = varies by model, see table below)
ElecIdleRate = Electric Idle energy rate (kW; = varies by model, see table below)
PC = Production capacity (lb/hr; = varies by model, see table below)

Parameter Values by Model

Parameter	Single Rack		Double Rack		Source
	Baseline	ENERGY STAR	Baseline	ENERGY STAR	
Preheat Energy (Btu; E_{PREHT})	50,000	44,000	100,000	85,000	4
Gas Idle Energy Rate (Btu/hr; GasIdleRate)	24,451	21,009	37,971	24,128	4
Electric Idle Energy Rate (kW; ElecIdleRate)	0.80	0.51	1.55	1.14	4
Heavy-Load Energy Efficiency (%; Efficiency)	43.5%	48.9%	50.5%	53.9%	4
ASTM Energy to Food (Btu/lb; E_{FOOD})	250	250	250	250	6
Production Capacity (lbs/hr; PC)	141	137	268	281	4
Operating Hours per Day (OpHrs)	12	12	12	12	4
Operating Days per Year (OpDays)	365	365	365	365	4
Preheat time in minutes (T_{PREHT})	15	15	15	15	7
Lbs of Food Cooked per Day (LB_{FOOD})	600	600	1,200	1,200	4

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = ElecIdleRate_{BASELINE} – ElecIdleRate_{ENERGY\ STAR}$

Where:

$ElecIdleRate_{BASELINE}$ = Electric Idle energy rate (kW; = varies by model, see table above)

$ElecIdleRate_{ENERGY\ STAR}$ = Electric Idle energy rate (kW; = varies by model, see table above)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[1,2]

Deemed Savings

Natural Gas and Electricity Deemed Savings per ENERGY STAR, Natural Gas, Rack Type Oven

Measure	MMID	Annual kWh	Annual Therms	Peak kW	Lifecycle kWh	Lifecycle Therms
Single Compartment	2488	828	255	0.29	9,936	3,060
Double Compartment	2487	1,002	529	0.41	12,024	6,348

Sources

1. Food Service Technology Center. *Gas Rack Oven Life-Cycle Cost Calculator.* www.fishnick.com/saveenergy/tools/calculators/grackovencalc.php
2. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/
3. ENERGY STAR® Commercial Kitchen Savings Calculator. Accessed March 11, 2016. All Rack Ovens Incremental Cost = $0.00. https://www.energystar.gov/products/commercial_food_service_equipment
4. Commercial Ovens Draft 2 Version 2.2 Plots, ENERGY STAR website for development of Commercial Ovens Specification Version 2.2. http://www.energystar.gov/products/spec/commercial_ovens_specification_version_2_2_pd. *(Implementer had personal communication with Consortium for Energy Efficiency staff to obtain the data tables used to generate these public plots of rack oven performance).*
5. ENERGY STAR Commercial Ovens Program Requirements, Version 2.2. www.energystar.gov/sites/default/files/Commercial%20Ovens%20Final%20Version%202.2%20Specification.pdf
6. ENERGY STAR Commercial Kitchen Equipment Calculator (used convection ovens value since a separate value for rack ovens is not yet available). www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx
7. *Wisconsin Focus on Energy Technical Reference Manual.* October 22, 2015. (Preheat time listed as 15 minutes and “deemed” for convection ovens (MMID 2485, 2486) and combination ovens (MMID 3118, 3119).

Revision History

Version Number	Date	Description of Change
01	11/11/2015	Updated from Wisconsin Focus on Energy QPL to ENERGY STAR
02	01/22/2016	Updated per comments

Commercial Freezers, ENERGY STAR

	Measure Details
Measure Master ID	Freezer, Chest, Glass Door: 15-29 cu ft, ENERGY STAR, 2322 30-49 cu ft, ENERGY STAR, 2323 50+ cu ft, ENERGY STAR, 2324 Freezer, Chest, Solid Door: < 15 cu ft, ENERGY STAR, 2325 15-29 cu ft, ENERGY STAR, 2326 30-49 cu ft, ENERGY STAR, 2327 Freezer, Vertical, Glass Door: 15-29 cu ft, ENERGY STAR, 2330 30-49 cu ft, ENERGY STAR, 2331 50+ cu ft, ENERGY STAR, 2332 Freezer, Vertical, Solid Door: < 15 cu ft, ENERGY STAR, 2333 15-29 cu ft, ENERGY STAR, 2334 30-49 cu ft, ENERGY STAR, 2335 50+ cu ft, ENERGY STAR, 2336
Workpaper ID	W0042
Measure Unit	Per freezer
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Refrigerator / Freezer - Commercial
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by size and door type
Peak Demand Reduction (kW)	Varies by size and door type
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by size and door type
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$0 for solid door (MMIDs 2325–2327 and 2333–2336)[1] $1,240 for glass door (MMIDs 2322–2324 and 2330–2332)[1]

Measure Description

This measure is installing refrigeration equipment that meets ENERGY STAR Version 4.0 performance specification, effective March 27, 2017.[2] ENERGY STAR commercial solid door and glass door freezers are more energy efficient than standard units, and use higher efficiency ECM evaporator and condenser fan motors, a hot natural gas anti-sweat heater, or high-efficiency compressors.

Description of Baseline Condition

The baseline condition is a unit meeting U.S. Department of Energy commercial refrigeration equipment maximum energy usage standards for equipment sold in the United States, effective March 27, 2017.[3]

Description of Efficient Condition

The efficient condition is certified ENERGY STAR Version 4.0, effective March 27, 2017, for vertical and horizontal closed-door freezers.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (kWh_{BASELINE} - kWh_{ENERGY\ STAR}) * Days$

Where:

$kWh_{BASELINE}$ = Daily baseline unit consumption (= varies by unit; see table below)
$kWh_{ENERGY\ STAR}$ = Daily qualifying unit consumption (= varies by unit; see table below)
Days = Annual days of operation, deemed (= 365)

Parameter Values by Unit Type

Unit Type	Door Type	Size (cu. ft.)	Daily Baseline Consumption, DOE 2017	Daily Qualifying Consumption, ENERGY STAR Specification 4.0
Vertical Closed Freezers	Solid	0 < V < 15	0.22V + 1.38	0.21V + 0.9
		15 ≤ V < 30	0.22V + 1.38	0.12V + 2.428
		30 ≤ V < 50	0.22V + 1.38	0.285V - 2.703
		50 ≤ V	0.22V + 1.38	0.142V + 4.445
	Transparent	0 < V < 15	0.29V + 2.95	0.232V + 2.36
		15 ≤ V < 30	0.29V + 2.95	0.232V + 2.36
		30 ≤ V < 50	0.29V + 2.95	0.232V + 2.36
		50 ≤ V	0.29V + 2.95	0.232V + 2.36
Horizontal Closed Freezers	Solid	All volumes	0.06V + 1.12	0.057V + 0.55
	Transparent		0.75V + 4.10	

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / HOURS$

Where:

HOURS = Hours of use, deemed (= 8,760)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[1]

Deemed Savings

Deemed Savings Values by Measure

Measure Master Name	MMID	Average Volume Based on Measure	Daily Baseline Consumption, DOE 2017	Daily Qualifying Consumption, ENERGY STAR Specification 4.0	Deemed Savings		
					Annual kWh	LC kWh	kW
Freezer, Chest, Glass Door							
15-29 cu ft, ENERGY STAR	2322	22	0.08V + 1.23	0.057V + 0.55	433	5,196	0.049
30-49 cu ft, ENERGY STAR	2323	39.5	0.08V + 1.23	0.057V + 0.55	580	6,960	0.066
50+ cu ft, ENERGY STAR	2324	65	0.08V + 1.23	0.057V + 0.55	794	9,528	0.091
Freezer, Chest, Solid Door							
< 15 cu ft, ENERGY STAR	2325	7.5	0.06V + 1.12	0.057V + 0.55	216	2,592	0.025
15-29 cu ft, ENERGY STAR	2326	22	0.06V + 1.12	0.057V + 0.55	232	2,784	0.026
30-49 cu ft, ENERGY STAR	2327	39.5	0.06V + 1.12	0.057V + 0.55	251	3,012	0.029
Freezer, Vertical, Glass Door							
15-29 cu ft, ENERGY STAR	2330	22	0.29V + 2.95	0.232V + 2.36	681	8,172	0.078
30-49 cu ft, ENERGY STAR	2331	39.5	0.29V + 2.95	0.232V + 2.36	1,052	12,624	0.12
50+ cu ft, ENERGY STAR	2332	65	0.29V + 2.95	0.232V + 2.36	1,591	19,092	0.182
Freezer, Vertical, Solid Door							
< 15 cu ft, ENERGY STAR	2333	7.5	0.22V + 1.38	0.21V + 0.9	203	2,436	0.023
15-29 cu ft, ENERGY STAR	2334	22	0.22V + 1.38	0.12V + 2.428	420	5,040	0.048
30-49 cu ft, ENERGY STAR	2335	39.5	0.22V + 1.38	0.285V - 2.703	553	6,636	0.063
50+ cu ft, ENERGY STAR	2336	65	0.22V + 1.38	0.142V + 4.445	732	8,784	0.084

Assumptions

It is assumed that the smallest internal volume of freezers is one cubic foot and the greatest internal volume of freezers (per certified products in ENERGY STAR) is 80 cubic feet. These numbers are used to provide the average internal volume of the measures, specifically those under 15 cu ft and 50 or more cu ft.

Sources

1. ENERGY STAR. *Program Calculator for Commercial Refrigerators and Freezers*. October 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
2. ENERGY STAR. *Program Requirements for Commercial Refrigerators and Freezers*. Version 4.0. https://www.energystar.gov/sites/default/files/asset/document/Commercial%20Refrigerators%20and%20Freezers%20V4%20Spec%20Final%20Version_0.pdf
3. U.S. Department of Energy. *Commercial Refrigeration Equipment Standards.* Effective March 27, 2017. https://www.ecfr.gov/cgi-bin/text-idx?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431_166&rgn=div8

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	10/2017	Updated baseline and qualifying unit specifications
03	01/2019	Removed MMIDs 2321, 2328, and 2329

Commercial Refrigerator, ENERGY STAR

	Measure Details
Measure Master ID	Refrigerator, Chest, Glass Door: 15-29 cu ft, ENERGY STAR, 2522 30-49 cu ft, ENERGY STAR, 2523 50+ cu ft, ENERGY STAR, 2524 Refrigerator, Chest, Solid Door: < 15 cu ft, ENERGY STAR, 2525 15-29 cu ft, ENERGY STAR, 2526 30-49 cu ft, ENERGY STAR, 2527 50+ cu ft, ENERGY STAR, 2528 Refrigerator, Vertical, Glass Door: < 15 cu ft, ENERGY STAR, 2529 15-29 cu ft, ENERGY STAR, 2530 30-49 cu ft, ENERGY STAR, 2531 50+ cu ft, ENERGY STAR, 2532 Refrigerator, Vertical, Solid Door: < 15 cu ft, ENERGY STAR, 2533 15-29 cu ft, ENERGY STAR, 2534 30-49 cu ft, ENERGY STAR, 2535 50+ cu ft, ENERGY STAR, 2536
Workpaper ID	W0043
Measure Unit	Per refrigerator
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Refrigerator / Freezer - Commercial
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by size and door type
Peak Demand Reduction (kW)	Varies by size and door type
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by size and door type
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$1,440 for solid door (MMIDs 2525–2528 and 2533–2536); $470 for glass door (MMIDs 2522–2524 and 2529–2532)[1]

Measure Description

This measure is installing refrigeration equipment that meets ENERGY STAR Version 4.0 performance specification, effective March 27, 2017.[2] ENERGY STAR commercial solid and glass door refrigerators are designed to be more energy efficient than standard units and use higher-efficiency ECM evaporator and condenser fan motors, a hot natural gas anti-sweat heater, or high-efficiency compressors.

Description of Baseline Condition

The baseline condition is a unit meeting U.S. Department of Energy commercial refrigeration equipment maximum energy usage standards for equipment sold in the United States, effective March 27, 2017.[3]

Description of Efficient Condition

The efficient equipment is certified ENERGY STAR Version 4.0, effective March 27, 2017, for vertical and horizontal closed-door refrigerators.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (kWh_{BASELINE} – kWh_{ENERGY\ STAR})$ * Days

Where:

$kWh_{BASELINE}$ = Daily baseline unit consumption (= varies by unit; see table below)

$kWh_{ENERGY\ STAR}$ = Daily qualifying unit consumption (=varies by unit; see table below)

Days = Annual days of operation, deemed (= 365)

Parameter Values by Unit Type

Unit Type	Door Type	Size (cu. ft.)	Daily Baseline Consumption, DOE 2017	Daily Qualifying Consumption, ENERGY STAR Specification 4.0
Vertical Closed Refrigerators	Solid	$0 < V < 15$	0.05V + 1.36	0.022V + 0.97
		$15 \le V < 30$	0.05V + 1.36	0.066V + 0.31
		$30 \le V < 50$	0.05V + 1.37	0.04V + 1.09
		$50 \le V$	0.05V + 1.38	0.024V + 1.89
	Transparent	$0 < V < 15$	0.1V + 0.86	0.095V + 0.445
		$15 \le V < 30$	0.1V + 0.86	0.05V + 1.12
		$30 \le V < 50$	0.1V + 0.86	0.076V + 0.34
		$50 \le V$	0.1V + 0.86	0.105V - 1.111
Horizontal Closed Refrigerators	Solid	All volumes	0.05V + 0.91	0.05V + 0.28
	Transparent		0.06V + 0.37	

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / HOU$

Where:

HOU = Hours of use, deemed (= 8,760)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[4]

Deemed Savings

Deemed Savings Values by Measure

Measure Master Name	MMID	Average Volume Based on Measure	Daily Baseline Consumption	Daily Qualifying Consumption	Deemed Savings		
					Annual kWh	LC kWh	kW
Refrigerator, Chest, Glass Door							
15-29 cu ft, ENERGY STAR	2522	22	0.06V + 0.37	0.05V + 0.28	113	1,356	0.013
30-49 cu ft, ENERGY STAR	2523	39.5	0.06V + 0.37	0.05V + 0.28	177	2,124	0.02
50+ cu ft, ENERGY STAR	2524	65	0.06V + 0.37	0.05V + 0.28	270	3,240	0.031
Refrigerator, Chest, Solid Door							
< 15 cu ft, ENERGY STAR	2525	7.5	0.05V + 0.91	0.05V + 0.28	230	2,760	0.026
15-29 cu ft, ENERGY STAR	2526	22	0.05V + 0.91	0.05V + 0.28	230	2,760	0.026
30-49 cu ft, ENERGY STAR	2527	39.5	0.05V + 0.91	0.05V + 0.28	230	2,760	0.026
50+ cu ft, ENERGY STAR	2528	65	0.05V + 0.91	0.05V + 0.28	230	2,760	0.026
Refrigerator, Vertical, Glass Door							
< 15 cu ft, ENERGY STAR	2529	7.5	0.1V + 0.86	0.095V + 0.445	165	1,980	0.019
15-29 cu ft, ENERGY STAR	2530	22	0.1V + 0.86	0.05V + 1.12	307	3,684	0.035
30-49 cu ft, ENERGY STAR	2531	39.5	0.1V + 0.86	0.076V + 0.34	536	6,432	0.061
50+ cu ft, ENERGY STAR	2532	65	0.1V + 0.86	0.105V - 1.111	601	7,212	0.069
Refrigerator, Vertical, Solid Door							
< 15 cu ft, ENERGY STAR	2533	7.5	0.05V + 1.36	0.022V + 0.97	219	2,628	0.025
15-29 cu ft, ENERGY STAR	2534	22	0.05V + 1.36	0.066V + 0.31	255	3,060	0.029
30-49 cu ft, ENERGY STAR	2535	39.5	0.05V + 1.37	0.04V + 1.09	243	2,916	0.028
50+ cu ft, ENERGY STAR	2536	65	0.05V + 1.38	0.024V + 1.89	423	5,076	0.048

Assumptions

It is assumed that the smallest internal volume of refrigerators is one cubic foot and the greatest internal volume of refrigerators (per certified products in ENERGY STAR) is 80 cubic feet. These numbers are used to provide the average internal volume of the measures, specifically those less than 15 cu ft and 50 or more cu ft.

Sources

1. ENERGY STAR. *Program Calculator for Commercial Refrigerators and Freezers*. October 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
2. ENERGY STAR. *Program Requirements for Commercial Refrigerators and Freezers*. Version 4.0. https://www.energystar.gov/sites/default/files/asset/document/Commercial%20Refrigerators%20and%20Freezers%20V4%20Spec%20Final%20Version_0.pdf
3. U.S. Department of Energy. *Commercial Refrigeration Equipment Standards*. Effective March 27, 2017. https://www.ecfr.gov/cgi-bin/text-idx?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431_166&rgn=div8

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	10/2017	Updated baseline and qualifying unit specifications
03	01/2019	Removed MMID 2521

Steamer, ENERGY STAR

	Measure Details
Measure Master ID	Steamer, ENERGY STAR, Electric, 4710 Steamer, ENERGY STAR, NG, 4711
Workpaper ID	W0044
Measure Unit	Per pan
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Steamer
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	Varies by measure
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	Electric = $755.56 (MMID 4710), NG = $504.44 (MMID 4711)[2]

Measure Description

This measure consists of installing an ENERGY STAR electric or natural gas commercial steamer. ENERGY STAR steamers consume less energy than standard steamers because of improved insulation and a more efficient steam delivery system. To qualify, ENERGY STAR steamers must meet a minimum cooling efficiency and a maximum idle energy rate.

Description of Baseline Condition

The baseline condition is a non-ENERGY STAR commercial steamer.

Description of Efficient Condition

The efficient condition is an ENERGY STAR–certified commercial steamer.

Annual Energy-Savings Algorithm

Energy savings result from installing a more efficient unit than the standard efficiency on the market, and the amount of savings depends on the quantity of pans.

Savings estimates are based on savings equations and assumptions provided to Pacific Gas and Electric by the Food Service Technology Center (FSTC) and shared with Focus on Energy through the Consortium on Energy Efficiency. Steamer performance was determined by FSTC according to ASTM F1484, the Standard Test Method for Performance of Steam Cookers.

The energy consumption equation for electric steamers (kWh) and natural gas steamers (Btu) is of the same form, with only the units of the variables changed. The form of the equation shows that the daily energy consumption of a steamer is equal to the sum of cooking, idle, steam, and preheat energy:

$$E_{DAY}=\left(\frac{LB_{FOOD} * E_{FOOD}}{\text{Efficiency}}\right)+(1-\%\text{Steam}) * \text{IdleRate} * \left(\text{OpHrs}-\frac{LB_{FOOD}}{PC}-\frac{T_{PreHt}}{60}\right)+$$
$$\%\text{Steam} * \left(\text{OpHrs}-\frac{LB_{FOOD}}{PC}-\frac{T_{PreHt}}{60}\right) * \left(\frac{PC * E_{FOOD}}{\text{Efficiency}}\right)+E_{PreHt}$$

Where:

E_{DAY} = Daily energy consumption (kWh or Btu; calculated)

LB_{FOOD} = Pounds of food per day (lb/day; see table in Assumptions)[2]

E_{FOOD} = ASTM Energy to Food (= 0.0308 kWh/lb for electric; = 105 Btu/lb for natural gas)[2]

Efficiency = ASTM heavy load cooking energy efficiency (%; see table in Assumptions)[2]

%Steam = Percentage of time in constant steam mode (%; see table in Assumptions)[2]

IdleRate = Idle energy rate (kW or Btu/hr; see table in Assumptions)[3,4]

OpHrs = Operating hours per day (= 12 for the commercial, industrial, and agriculture sectors;[2] = 9 for the schools and government sector;[2,5] see Assumptions)

PC = Production capacity (lb/hr; see table in Assumptions)[2]

T_{PreHt} = Preheat time (= 15 minutes)[6]

60 = Minute to hour conversion

E_{PreHt} = Preheat energy (kWh or Btu; see table in Assumptions)[3,4]

To estimate annual savings, the consumption of the baseline and qualifying units are calculated using the above equation, and the latter is subtracted from the former. The resulting daily savings value is multiplied by operating days per year to yield annual savings:

$$kWh_{SAVED} = (E_{DAY,B} - E_{DAY,Q}) * \text{OpDay}$$

$$Therm_{SAVED} = (E_{DAY,B} - E_{DAY,Q}) * \text{OpDay} / 100{,}000$$

$$Gallons_{SAVED} = (GPH_{BASE} - GPH_{Q}) * \text{OpHrs} * \text{OpDay}$$

Where:

$E_{DAY,B}$ = Daily energy use of a baseline unit (kWh or Btu)

$E_{DAY,Q}$ = Daily energy use of a qualifying unit (kWh or Btu)

OpDay = Number of operating days per year (= 365 for the commercial, industrial, and agriculture sectors;[2] = 282.5 for the schools and government sector;[2,5] see Assumptions)

100,000 = Btu to therm conversion

GPH_{BASE} = Gallons per hour water use for a baseline unit (= varies by measure; see table below and Assumptions)

GPH_{Q} = Gallons per hour water use for a qualifying unit (= varies by measure; see table below)

Gallons of Water Use for Baseline and Qualifying Units

MMID	Fuel Source	Baseline Water Consumption Per Pan (Gallons/Hour)[7]	Average ENERGY STAR Model Water Consumption Per Pan (Gallons/Hour)[8]
4710	Electric	5.83	0.40
4711	Natural Gas	5.83	0.51

Annual Deemed Savings Per Pan

MMID	Sector	kW	kWh	Therms	Water Savings (gal)
Steamer, ENERGY STAR, Electric					
4710	Agriculture, Commercial, Industrial	4.34	2,827	--	24,445
	Schools & Government	4.34	1,663	--	14,190
Steamer, ENERGY STAR, Natural Gas					
4711	Agriculture, Commercial, Industrial	--	--	205	23,301
	Schools & Government	--	--	121	13,526

Summer Coincident Peak Savings Algorithm

The summer coincident peak savings for electric steamers are not determined using a savings equation, but are reported based on metered data.[6] Further details can be found in the Assumptions.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Gallons_{LIFECYCLE} = Gallons_{SAVED} * EUL$

Where:

EUL = Effective useful life (=12 years)[1]

Lifecycle Deemed Savings Per Pan

MMID	Sector	kWh	Therms	Water Savings (gal)
Steamer, ENERGY STAR, Electric				
4710	Agriculture, Commercial, Industrial	33,926	--	293,340
	Schools & Government	19,961	--	170,280
Steamer, ENERGY STAR, Natural Gas				
4711	Agriculture, Commercial, Industrial	--	2,464	279,612
	Schools & Government	--	1,457	162,312

Assumptions

Savings are based on the per-pan weighted average of the savings calculated from multiple pan steamers. Per-pan weighted averages were calculated with the weightings from the three, four, five, and six-pan electric steamers and five and six-pan natural gas steamers listed on the ENERGY STAR Qualified Product List as of January 23, 2018, as shown in the table below.

Weighting Per Pan

# of Pans	Weighting[8]
Steamer, ENERGY STAR, Electric, 4710	
3	26%
4	1%
5	10%
6	63%
Steamer, ENERGY STAR, Natural Gas, 4711	
5	12.5%
6	87.5%

Values for ASTM parameters for baseline and energy-efficient cases were determined by FSTC according to ASTM F1484, the Standard Test Method for Performance of Steam Cookers. These parameters are based on measured data under preheat, idle, and heavy-load cooking conditions:

- ***Pounds of Food per Day, LB_{FOOD}.*** An estimate of the average pounds of food steamed per day.
- ***Energy to Food, E_{FOOD}.*** The amount of energy absorbed by food during cooking, per pound of food.
- ***Heavy Load Cooking Efficiency.*** The minimum qualifying value for each steamer measure. This ASTM parameter value is not based on an average of tested steamers. The minimum qualifying values of 38% for natural gas steamers and 50% for electric steamers are used as the efficiencies of the qualifying steamers in the savings calculations.
- ***Percentage of Time in Constant Steam Mode, %Steam.*** The steamer's constant steam setting that keeps the steamer operating at maximum input even when not cooking. The setting is controlled by the operator.

- ***Idle Energy Rate, IdleRate.*** The energy rate consumed by the steamer when on but not cooking and not set to constant steam.
- ***Operating Hours, OpHrs.*** The number of hours the steamer is on per day, whether cooking or idle.
- ***Production Capacity, PC.*** The amount of food a given steamer can cook per hour.
- ***Preheat Time, T_{PreHt}.*** The amount of time for a steamer to reach operating temperature when turned on.
- ***Preheat Energy, E_{PreHt}.*** The amount of energy the steamer consumes daily to reach operating temperature.
- ***Operating Days, OpDay.*** The number of days the steamer is on per year, whether cooking or idle.

For the schools and government sector, schools have fewer hours per day (six hours)[5] and fewer days per year (200 days)[5] than government facilities. Since school and government facilities are not broken out into their own sectors, a straight average (nine hours per day, 282.5 days per year) of the lower hours per day and days per year for schools (six hours per day and 200 days per year) and the values for government facilities (12 hours per day and 365 days per year) was used.

The values used in the savings equations and the resulting consumptions and savings are presented in the tables below.

Electric Steamer Assumptions That Are Constant with Respect to Number of Pans

Parameter	Baseline Model	Energy-Efficient Model
Pounds of Food per Day (lb/day)[2]	100	100
ASTM Energy to Food (kWh/lb)[2]	0.0308	0.0308
Cooking Energy Efficiency (%)[2]	30	50
Constant Steam (%)[2]	40	40
Preheat Time (min)[6]	15	15
Preheat Energy (kWh)[3]	1.5	1.5
Operating Hours (hr/day) for Agriculture, Commercial, and Industrial Sectors[2]	12	12
Operating Hours (hr/day) for Schools & Government Sector[2,5]	9	9
Operating Days (day/yr) for Agriculture, Commercial, and Industrial Sectors[2]	365	365
Operating Days (day/yr) for Schools & Government Sector[2,5]	282.5	282.5

Electric Steamer Assumptions Per Pan

Fuel Source	Parameter	Baseline Model	Energy-Efficient Model
Electric	Idle Energy Rate per Pan (kW)[3]	0.17	0.04
	Production Capacity per Pan (lb/hr)[2]	23.3	16.7

Using the above values, daily kilowatt-hour consumptions for the baseline and energy-efficient models were calculated, and the difference between these was multiplied by annual operating days to yield the values in the Annual Deemed Savings Per Pan table.

Steamers were initially deemed as having a demand reduction of 6.201 kW. These initial findings were later reduced by 30%, as it was determined to be more representable of actual savings. Therefore, the savings are 4.341 kW for all electric steamers, as was shown in the Annual Deemed Savings Per Pan table above. These values are based on metering studies conducted by FSTC.[6]

Natural Gas Steamer Assumptions That Are Constant with Respect to Number of Pans

Parameter	Baseline Model	Energy-Efficient Model
Pounds of Food per Day (lb/day)[2]	100	100
ASTM Energy to Food (Btu/lb)[2]	105	105
Cooking Energy Efficiency (%)[2]	18	38
Constant Steam (%)[2]	40	40
Preheat Time (min)[6]	15	15
Preheat Energy (Btu)[4]	20,000	20,000
Operating Hours (hr/day) for Agriculture, Commercial, and Industrial Sectors[2]	12	12
Operating Hours (hr/day) for Schools & Government Sector[2,5]	9	9
Operating Days (day/yr) for Agriculture, Commercial, and Industrial Sectors[2]	365	365
Operating Days (day/yr) for Schools & Government Sector[2,5]	282.5	282.5

Natural Gas Steamer Assumptions Per Pan

Fuel Source	Parameter	Baseline Model	Energy-Efficient Model
Natural Gas	Idle Energy Rate per Pan (Btu/hr)[3]	2,500	486
	Production Capacity per Pan (lb/hr)[2]	23.3	20

Using the above values, the daily Btu consumptions for the baseline and energy-efficient models were calculated, and the difference between them was multiplied by annual operating days to yield deemed savings in Btu. That result was divided by 100,000 to convert deemed reduction estimates to the therm values shown in the Annual Deemed Savings per Pan table above.

For water savings, the baseline was set at 35 gallons per hour, which is the midpoint of the range (30 to 40 gallons per hour) provided by ENERGY STAR[7] for a six-pan steamer. Dividing 35 gallons per hour by six yields the baseline water use per pan of 5.83 gallons per hour.

For incremental cost, the ENERGY STAR savings calculator[2] lists $3,400 for electric steamers and $2,270 for gas steamers, but does not differentiate by number of pans. The cost is applied equally to 3, 4, 5, and 6 pan steamers. Therefore, to convert that cost to a per-pan cost, the cost was divided by the average of the number of pans (4.5).

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Revision History

Version Number	Date	Description of Change
01	09/08/2017	Initial TRM entry
02	09/21/2018	Updated unit of measure and condensed measures into two MMIDs

Demand Controlled Kitchen Ventilation

	Measure Details
Measure Master ID	Ventilation Controls, Kitchen Hood, Temp only, Adder for MUA, 2621 Ventilation Controls, Kitchen Hood, Temp only, Exhaust Only, 2623 Ventilation Controls, Kitchen Hood, with Optical, Adder for MUA, 2625 Ventilation Controls, Kitchen Hood, with Optical, Exhaust Only, 2627
Workpaper ID	W0287
Measure Unit	Per horsepower
Measure Type	Prescriptive
Measure Group	Food Service
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Electricity Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Natural Gas Savings (therms)	Varies by measure
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Natural Gas Savings (therms)	Varies by measure
Annual Water Savings (gallons)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	Varies by measure, see Incremental Cost table[2]

Measure Description

Traditional kitchen ventilation controls include a manual on/off switch for each hood, so that the exhaust and make-up air fans operate either at 100% speed or not at all. Cooking loads, and therefore exhaust requirements, vary throughout the day and typically peak at meal times. However, the fans are typically left on from open to close to accommodate customers at off times and food preparation. These measures add variable speed controls to the exhaust fan, with an option to also control the make-up air fan.

Description of Baseline Condition

The baseline condition is a kitchen hood with manual on/off controls for the kitchen exhaust and make-up air fans.

Description of Efficient Condition

The efficient condition is a kitchen hood where the exhaust fan is variable speed and is controlled based on effluent output from the cooking appliances under the hood. Two control options are available: temperature only sensing, and temperature plus optical sensing. Heating savings from reduced make-up air is captured under the exhaust fan measure.

Additional measures (MMIDs 2621 & 2625) are available to capture the fan energy savings from the make-up air (MUA) unit if it is also converted to variable speed.

Annual Energy-Savings Algorithm

$kWh_{SAVED,\ EXHAUST} = kW_{EXHAUST} / hp_{EXHAUST} * SF_{FAN} * HOU$

$kWh_{SAVED,\ MUA} = kW_{MUA} / hp_{MUA} * SF_{FAN} * HOU$

$Therm_{SAVED} = (1 / SpecificPower) * HeatLoad * 1{,}000 * SF_{CFM} / (100{,}000 * Eff_{HEAT})$

Where:

$kW_{EXHAUST}$ = Average measured kW of exhaust fan (= 3.20 for MMID 2623,[3,4] = 6.47 for MMID 2627[5,6])

kW_{MUA} = Average measured kW of make-up air unit fan (= 4.32,[5,6] see assumptions)

$hp_{EXHAUST}$ = Average rated exhaust fan horsepower (= 7.88 for MMID 2623,[3,4] = 9.55 for MMID 2627[5,6])

hp_{MUA} = Average rated exhaust fan horsepower (= 12.5,[5,6] see assumptions)

SF_{FAN} = Average fan power reduction (= 45.6% for MMIDs 2621 and 2623,[3,4] = 59.2% for MMIDs 2625 and 2627[5,6])

SF_{CFM} = Average airflow reduction (= 20.5% for MMID 2623,[3,4] = 31.9% for MMID 2627[5])

HOU = Annual hours of use (= 6,205, see Assumptions)

SpecificPower = Fan HP per 1,000 CFM (= 1.11 for MMID 2623,[3,4] = 0.586 for MMID 2627[5])

HeatLoad = Average annual heating load, MBtu per 1,000 CFM, see table below

Annual Heating Load[7]

WI Region	Heating Load, MBtu / 1000 CFM
Eau Claire	107,355
Green Bay	97,697
La Crosse	93,901
Madison	96,201
Milwaukee	92,609
Average	**92,609**

1,000 = Conversionfrom Btu to MBtu

100,000 = Conversion from Btu to Therms

Eff_{HEAT} = Heating efficiency of make-up air unit (= 80%, see assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED,\ EXHAUST} = kW_{EXHAUST} / HP_{EXHAUST} * SF_{FAN} * CF$

$kW_{SAVED,\ MUA} = kW_{MUA} / HP_{MUA} * SF_{FAN} * CF$

Where:

CF = Coincidence factor (= 1.0, see Assumptions)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE,\ EXHAUST} = kWh_{SAVED,\ EXHAUST} * EUL$

$kWh_{LIFECYCLE,\ MUA} = kWh_{SAVED,\ MUA} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years[1])

Deemed Savings

Savings for Kitchen Demand Controlled Ventilation

Measure	MMID	kW	kWh Savings		Therm Savings	
			Annual	Lifecycle	Annual	Lifecycle
Ventilation Controls, Kitchen Hood:						
Temp only, Adder for MUA	2621	0.1577	974	9,740	0	0
Temp only, Exhaust Only	2623	0.1850	1,148	11,480	226	2,260
with Optical, Adder for MUA	2625	0.2048	1,281	12,810	0	0
with Optical, Exhaust Only	2627	0.4013	2,490	24,900	664	6,640

Assumptions

The temperature only DCV measurement and verification reports[3,4] provided an average of 16.9 hours per day and 365 days per year for a total of 6,178 hours per year, while the temperature + optical DCV projects in the PG&E workpaper[5,6] provided an average of 18 hours per day and 348 days per year for a total of 6,256 hours per year. To standardize these values and for use in the annual heating load calculations, 17 hours per day for 365 days per year, or 6,205 hours per year, was used. This also eliminates the need to estimate average days off (holidays, 1 regular day closed per week, etc.) when performing the annual heating load calculation if less than 365 days per year is used.

For kW_{MUA} and hp_{MUA}, only data for temperature + optical systems was available, so the same data was used for temperature only systems.

For calculation of annual heating load, 17 hours of operation per day was assumed to occur between 6:00 AM and 9:00 PM.

Demand savings for kitchen demand control ventilation is calculated as an average savings over the course of the day. This technology will likely see less savings during peak meal times (such as 6 AM to 8 AM, 11 AM to 1 PM, and 5 PM to 7 PM) and more savings between typical meal times. Since the Focus definition for electric demand peak is 1-4 PM Monday to Friday which would be between typical meal times, savings should be at least equal to the average demand savings over the day. Therefore a coincidence factor of 1.0 was used.

Existing make-up air units are assumed to be indirect fired units, which would have a heating efficiency of approximately 80%.

Incremental Cost

Efficient costs are derived from historical project data[2]. Baseline cost is zero (continue with the current fixed speed kitchen ventilation system).

Incremental Costs

Measure Name	MMID	SPECTRUM Data			Base Cost	Incremental Cost
		Projects	Units (hp)	Average Unit Cost		
Ventilation Controls, Kitchen Hood:						
Temp only, Adder for MUA	2621	75	167.25	$4,211.53	$0	$4,211.53
Temp only, Exhaust Only	2623	82	186.03	$2,035.85	$0	$2,035.85
with Optical, Adder for MUA	2625	6	218.00	$413.31	$0	$413.31
with Optical, Exhaust Only	2627	7	167.50	$2,183.92	$0	$2,183.92

Sources

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7. Annual heating load calculated for the hours of 6 AM to 9 PM, a 60°F heating setpoint for make-up air using TMY3 weather data from: National Renewable Energy Laboratory "National Solar Radiation Data Base, 1991- 2005 Update: Typical Meteorological Year 3." http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html

Revision History

Version Number	Date	Description of Change
01	12/20/2021	Initial TRM entry

HVAC

Advanced Rooftop Unit Controller

	Measure Details
Measure Master ID	Advanced Rooftop Unit Controller, 3964
Workpaper ID	W0045
Measure Unit	Per ton
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	Varies
Lifecycle Electricity Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	Varies
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$509.08[3]

Measure Description

The Pacific Northwest National Laboratory estimates that 90% of the installed base of rooftop units are constant volume systems with single speed supply fans.[4] Advanced rooftop controllers convert these units to variable speed systems that can better optimize performance for varying loads and that incorporate additional features such as demand control ventilation (DCV) and improved economizer controls.

Description of Baseline Condition

The baseline condition is a rooftop unit with direct expansion cooling and natural gas heat, a constant speed supply fan, a functional economizer, and no carbon dioxide–based ventilation controls. The rooftop unit must also have ≥ 7 tons nominal cooling capacity and have a ≥ 1 hp supply fan.

Description of Efficient Condition

The efficient condition is an advanced rooftop controller, defined as a digital controller for retrofit applications that improves the rooftop unit's ability to optimize for heating, cooling, and ventilation load based on temperature, humidity, or occupancy through enhanced control of airflow and variable or multispeed control. The advanced rooftop unit controller must meet several characteristics to qualify for an incentive:

- Multi-speed or variable speed control of the supply fan with, at a minimum, reduced fan speed operation for first stage cooling and ventilation modes.
- Modulating outdoor air damper control to maintain proper ventilation rates according to ASHRAE Standard 62.1 under different fan speeds.
- DCV, in which the breathing zone airflow shall be reset in response to current occupancy and shall be no less than the building component of the DCV zone. The ventilation system shall be controlled such that at steady state it provides each zone with no less than the breathing zone outdoor airflow for the current zone population.
    - Carbon dioxide sensors shall be used as to determine occupancy; these sensors may be placed in either the return air ducts of the single zone systems or in the zones themselves. The outdoor air damper must adjust proportionally so that the ventilation rate varies continuously between the minimum ventilation setpoint and the design ventilation setpoint of the affected space based on the occupancy at any given time.
    - Time of day schedules may not be used to determine occupancy in the affected space.
    - Economizer operation should override DCV control.
- Integrated economizer, whereby the compressor will stage on and off as needed to make up the additional cooling load required when 100% outside air is not capable of providing the entire cooling load. When the outside air conditions are not suitable for free cooling or integrated economizer operation, the economizer dampers are positioned to provide only the required amount of ventilation airflow.

Annual Energy-Savings Algorithm

The amount of energy savings for advanced rooftop unit controllers is based on hourly calculations that compare baseline and proposed heating and cooling requirements and fan energy use while the building is designated as occupied. The difference between baseline and proposed is the resulting savings for this measure.[5,6]

$kWh_{SAVED} = (FanEnergy_{BASELINE} + CoolingEnergy_{BASELINE} + ElecHeatingEnergy_{BASELINE}) – (FanEnergy_{PROPOSED} + CoolingEnergy_{PROPOSED} + ElecHeatingEnergy_{PROPOSED})$

$FanEnergy_{BASELINE} = \Sigma\ (hp * 0.746 * LoadFactor / MotorEff * OccStatus * 1\ hour)$

$CoolingEnergy_{BASELINE} = \Sigma\ (1.08 * CFM * \Delta T / (1{,}000 * EER) * OccStatus * 1\ hour)$

$ElecHeatingEnergy_{BASELINE} = \Sigma\ (1.08 * CFM * \Delta T / (ElecHtgEff * 3{,}412) * OccStatus * 1\ hour)$

$FanEnergy_{PROPOSED} = \Sigma\ ([FanPower40\% + FanPower75\% + FanPower90\%] * OccStatus * 1\ hour)$

$$CoolingEnergy_{PROPOSED} = \Sigma\,(1.08 * CFM * \Delta T / (1{,}000 * EER) * OccStatus * 1\ hour)$$

$$ElecHeatingEnergy_{PROPOSED} = \Sigma\,(1.08 * CFM * \Delta T / (ElecHtgEff * 3{,}412) * OccStatus * 1\ hour)$$

$$Therm_{SAVED} = HeatingEnergy_{BASELINE} - HeatingEnergy_{PROPOSED}$$

$$HeatingEnergy_{BASELINE} = \Sigma\,(1.08 * CFM * \Delta T / (HtgEff * 100{,}000) * OccStatus * 1\ hour)$$

$$HeatingEnergy_{PROPOSED} = \Sigma\,(1.08 * CFM * \Delta T / (HtgEff * 100{,}000) * OccStatus * 1\ hour)$$

Where:

hp = Fan horsepower of the rooftop unit

0.746 = Conversion from horsepower to kilowatts

LoadFactor = Fan motor load factor (= actual if known, otherwise 75%)

MotorEff = Fan motor efficiency (= actual if known, otherwise 90%)

OccStatus = Indicator of whether the building is occupied at the specific hour for the calculation (= 0 if unoccupied, = 1 if occupied)

1.08 = Constant for sensible heat load equation

CFM = Airflow in CFM of the rooftop unit (= actual if known, otherwise 400 CFM/ton cooling capacity)

ΔT = Temperature difference (°F) between the outside air and either the building heating or cooling setpoint

1,000 = Conversion from watts to kilowatts (EER units are Btuh per watt)

EER = Cooling efficiency of the rooftop unit (= actual if known, otherwise use IECC 2006 minimum efficiency for retrofit projects and IECC 2009 minimum efficiency for new construction projects, see Assumptions)

3,412 = Conversion from Btu/h to kW

FanPower40% = Fan power while operating at 40% load (using fan laws with 2.5 exponent and $FanEnergy_{BASELINE}$)

FanPower75% = Fan power while operating at 75% load (using fan laws with 2.5 exponent and $FanEnergy_{BASELINE}$)

FanPower90% = Fan power while operating at 90% load (using fan laws with 2.5 exponent and $FanEnergy_{BASELINE}$)

HtgEff = Gas heating efficiency (= actual if known, otherwise 80%)

ElecHtgEff = Electric heating efficiency (= actual if known, otherwise 1.0 COP for electric resistance heating)

100,000 = Conversion from Btu to therms

Summer Coincident Peak Savings Algorithm

The amount of demand reduction is the reduction in fan power energy from operating at 100% speed (baseline) to operating at 90% speed (proposed). The cooling load for the baseline and proposed is assumed to be the same.

kW_{SAVED} = hp * 0.746 * LoadFactor / MotorEff * $(1 – 0.9^{2.5})$

Where:

0.9 = Maximum fan motor percentage of speed under the proposed conditions

2.5 = Fan affinity law exponent

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

$Therm_{LIFECYCLE}$ = $Therm_{SAVED}$ * EUL

Where:

EUL = Effective useful life (=10 years)[1]

Assumptions

- Customer cannot apply for a rebate for both this measure and for a DCV (MMID 3266) or a VFD (MMID 2643).
- If advanced rooftop unit controllers are installed on an existing rooftop unit that needs to be replaced within 10 years, it is expected that the advanced rooftop unit controller will be transferred and re-programmed to the new rooftop unit. The new rooftop unit under this scenario is not eligible for an additional advanced rooftop unit controller incentive.
- Rooftop unit equipment for this measure will usually have just a supply fan. If a rooftop unit has both a supply fan and a return fan, it is assumed that variable speed controls would also be added to the return fan to maintain appropriate building pressurization. In those cases, the supply and return fan horsepower would be added together and used as the horsepower in the savings calculation.
- The rooftop unit EER for retrofit projects is estimated to equal IECC 2006 minimum requirements, which are:
  - 10.3 EER for units ≥ 65,000 and < 135,000 Btu (≥ 5.42 and < 11.25 tons)
  - 9.7 EER for units ≥ 135,000 and < 240,000 Btu (≥ 11.25 and < 20 tons)
  - 9.5 EER for units ≥ 240,000 and < 760,000 Btu (≥ 20 and < 63.3 tons)
  - 9.2 EER for units ≥ 760,000 Btu (≥ 63.3 tons)

- The rooftop unit EER for new construction projects is estimated to equal IECC 2009 minimum requirements, which are:
    - 11.2 EER for units ≥ 65,000 to 135,000 Btu (≥5.42 < 11.25 tons)
    - 11.0 EER for units ≥ 135,000 to 240,000 Btu (≥ 11.25 < 20 tons)
    - 10.0 EER for units ≥ 240,000 to 760,000 Btu (≥ 20 < 63.3 tons)
    - 9.7 EER for units ≥ 760,000 Btu (≥ 63.3 tons)
- Advanced rooftop unit controls incorporate variable speed fans, DCV, and economizer improvements. Nearly all the savings comes from the variable speed fan and DCV. Therefore, the measure life for advanced rooftop unit controls was assumed to match that of the individual measures for variable speed fan (MMID 2643) and DCV (MMID 3266).
- Cadmus conducted a metering study over the summer of 2017[7] to examine 54 rooftop units across 16 Wisconsin sites, which were mostly convenience stores, drugstores, and supermarkets. This study revealed that rooftop units generally do not heat above 50°F or cool below 55°F. The calculation tool for this measure[5] therefore assumes no need for heating or cooling between 50°F and 55°F. To complete the load profile, it then allows the user to specify the heating and cooling design temperatures, and assumes 80% of heating load and 90% of cooling load at those temperatures.
- The workbook for these measures previously included 180 kWh per ton of "soft savings" reflecting improved user behavior as a result of the control upgrades that are difficult to quantify. That value came from a Bonneville Power Administration Rooftop Unit Servicing Program Report. The deemed algorithm above does not incorporate these savings, and they are removed from the workbook starting in the 2020 Focus program year.

Sources

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   Federal Energy Management Program. *Demand-Controlled Ventilation Using CO2 Sensors*. March 2004. http://infohouse.p2ric.org/ref/43/42844.pdf
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Revision History

Version Number	Date	Description of Change
01	11/2016	Initial TRM entry (measure was previously a special offer)
02	10/2017	Updated EUL
03	11/2018	Added electric heating savings
04	12/2019	Removed “soft” savings from workbook
05	2/2021	Updated cost

Demand Control Ventilation for Air Handling Units

Measure Master ID	Demand Control Ventilation for Air Handling Units, 2853
Workpaper ID	W0046
Measure Unit	Per CFM of outside air controlled
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Calculated
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Calculated
Lifecycle Energy Savings (kWh)	Calculated
Lifecycle Therm Savings (Therms)	Calculated
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$1.34/CFM[2]

Measure Description

Commercial spaces are required to provide ventilation based on a minimum flow rate of outside air, as calculated using the area of conditioned space and number of occupants. Standard systems are unable to measure the number of occupants and must default to a maximum occupancy based ventilation rate. Demand control ventilation measures that carbon dioxide is in the space as a proxy for occupants, and allows the occupant-based portion of ventilation to be reduced below the maximum, resulting in heating and cooling savings.

Description of Baseline Condition

The baseline equipment is a packaged, split, or built-up air handler with an economizer that does not provide ventilation during unoccupied operation. Heating is assumed to be provided by natural gas equipment with an operating efficiency of 80%. Cooling efficiencies are estimated at code requirements according to the table below.

Cooling Efficiency Code Requirements

IECC 2009 Table 503.2.3(1)	Minimum Efficiency
Standard AC Unit < 65 kBtu/h (5.42 tons)	13.0 SEER
Standard AC Unit ≥ 65 and < 135 kBtu/h (5.42 to 11.25 tons)	11.0 EER
Standard AC Unit ≥ 135 and < 239 KBtu/h (11.25 to 20 tons)	10.8 EER
Standard AC Unit ≥ 240 and < 759 kBtu/h (20 to 63.33 tons)	9.8 EER
Standard AC Unit ≥ 760 kBtu/h (63.33 tons)	9.5 EER

Description of Efficient Condition

The efficient equipment includes packaged, split, or built up air handlers that control outside air by monitoring carbon dioxide conditions in the space and adjusting ventilation to meet the occupancy based space requirement while not falling below the conditioned area requirement.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (4.5 * CFM * \Delta h) * (EFLH_{COOL} * 12 / EER) * SF_{COOL} / 3{,}412 * (HOU/HOU_{COOL})$

$Therm_{SAVED} = (1.08 * CFM) * HOU * HDD / \eta / 100{,}000 * SF_{HEAT}$

Where:

4.5 = Conversion factor for flow rate and specific volume of air for enthalpy based cooling calculation

CFM = Outside airflow in cubic feet per minute, provided by customer

Δh = Difference in enthalpy (Btu/lbm) between the design day outside air conditions and the return air conditions; lbm is pounds per mass.

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= varies by building type; see table below)[6]

12 = Conversion factor from EER to kW/ton

EER = Energy efficiency ratio of the existing equipment, assumed to be code (= varies by unit size; see table above)

SF_{COOL} = Deemed cooling savings factor (= varies by building type; see table below)[6]

3,412 = Conversion factor from Btu to kWh

HOU = Hours of operation per day, provided by customer

HOU_{COOL} = Default hours of operation per day used in $EFLH_{COOL}$ (= varies by building type; see table below)[6]

1.08 = Conversion factor for flow rate and specific volume of air for dry bulb heating calculation

HDD = Heating degree days (using base 65; = see table below)

η = Heating efficiency (= assumed to be 0.83)

SF_{HEAT} = Deemed heating savings factor (= varies by building type; see table below)[6]

Enthalpies, HDD, and Incremental Costs

	Design Cooling h (Btu/lbm)	Cooling Return h (Btu/lbm)	HDD
Weighted Wisconsin Average	32.15	28.86	7,616

Cooling and Heating Savings Factors and Equivalent Full-Load Hours by Building Type

Building Type	SF_{COOL}	SF_{HEAT}	$EFLH_{COOL}$	HOU_{COOL}
Food Sales	0.34	0.40	749	17.25
Food Service	0.34	0.40	578	11.50
Health Care	0.34	0.40	803	24.00
Hotel/Motel	0.15	0.18*	663	24.00
Office	0.15	0.18	578	11.50
Public Assembly	0.34	0.40	535	11.50
Public Services (non-food)	0.34	0.40	535	11.50
Retail	0.34	0.40	567	11.50
Warehouse	0.31	0.36	358	11.50
School	0.34	0.40	439	13.00
College	0.34	0.40	877	13.20
Other	0.15	0.18	589	11.50

* This value is applicable to common areas and conference rooms, but not to sleeping areas.

Summer Coincident Peak Savings Algorithm

There are no peak savings associated with this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Assumptions

$EFLH_{COOL}$ data based on DOE2/EQuest building simulation. The prototype building models are based on the California DEER study prototypes, modified for local construction practices and code. Simulations were run using TMY3 weather data.

Assumed ventilation rates complied following the requirements of ASHRAE standard 62.1 - 2004.

Incremental costs include controls and programming, and assumes a similar cost between Direct Expansion and water-cooled equipment.

Savings assume a constant volume air system.

Savings assume existing economizer operation, and that economizer operation is given preference over a demand control ventilation strategy.

Assumes savings in hospitals and clinics is limited to areas without a code required ACH of fresh air.

Sources

1. 2013 Connecticut TRM. http://www.energizect.com/sites/default/files/2013%20PSD_ProgramSavingsDocumentation-Final110112.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 23 projects from 2017 to 2018.
3. "ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment."
4. Trane. "Psychometric Chart at Barometric Pressure 29.921 Inches of Mercury." and ASHRAE 2009 Fundamentals. Cooling DB/MCWB @ 0.4% averaged for state.
5. Franklin Energy Services. Assumed cooling setpoint of 74°F with 50% relative humidity and a 2°F temperature rise in the return plenum.
6. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3-2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. Franklin Energy Services. Calculated through energy modeling with certain building type square footage modified based on economizer operation hours. Savings limited to 40% based on professional experience due to concerns for negative building pressurization and minimum outside air requirements per square footage of occupied facility. Higher values may be obtained, requiring custom calculations.

Revision History

Version Number	Date	Description of Change
01	01/01/2013	Revised measure
02	12/2018	Updated incremental cost
03	11/2019	Corrected 15-year EUL in text to 10 years

Demand Control Ventilation, RTU Optimization

	Measure Details
Measure Master ID	Demand Control Ventilation, RTU Optimization, 3266
Workpaper ID	W0290
Measure Unit	Per RTU
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Rooftop Unit / Split System AC
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by area of conditioned space and number of occupants
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by area of conditioned space and number of occupants
Lifecycle Energy Savings (kWh)	Varies by area of conditioned space and number of occupants
Lifecycle Therm Savings (Therms)	Varies by area of conditioned space and number of occupants
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$2,130.68/AHU[2]

Measure Description

Commercial spaces are required to provide ventilation based on a minimum flow rate of outside air, calculated using the area of conditioned space and number of occupants. Standard systems are unable to measure the number of occupants and must default to a maximum occupancy-based ventilation rate. Demand control ventilation controls measure the carbon dioxide in the space as a proxy for the number of occupants and allow the occupant-based portion of ventilation to be reduced below the maximum, resulting in heating and cooling savings.

Description of Baseline Condition

The baseline equipment is a packaged RTU with an air side economizer and a fixed minimum ventilation rate.

Description of Efficient Condition

The efficient equipment includes a sensor that measures the carbon dioxide level of the space and an economizer that can adjust the ventilation rate to maintain carbon dioxide levels within the space according to code.

Annual Energy-Savings Algorithm

Savings are calculated using the Honeywell Savings Estimator[4] tool for RTUs, with inputs given in the following table.

Honeywell Savings Estimator Inputs

Data Input	Demand Controlled Ventilation
Outdoor CO_2 Level	390 ppm
Building Type [3]	Space type
Area [3]	Tons * 400 cfm/ton * 1 sq.ft./cfm
Construction	Frame
Thermal Envelope	ASHRAE Standard 90.1 - 2007
City	Nearest to site address[3] in Eau Claire, Green Bay, La Crosse, or Madison, Milwaukee
Equipment Type	Unitary AC and heating[3]
Efficiency	Cooling EER = 10 Heating Natural Gas EER = 0.8 Heating Electric EER = 1.0
Damper Leakage	0%
Base Case	Unoccupied fan cycling
Set Points Heating	Occupied 70°F Unoccupied (70°F heating set back)
Set Points Cooling	Occupied 75°F Unoccupied (75°F cooling set up)
CO_2 Setpoint	1,100 ppm
Occupancy	Default occupancy
Utility Rates	\$0.70/therm; \$0.10/kWh

Savings from Honeywell Estimator:

$Therm_{SAVED}$ = Natural Gas Energy (DCV + DB) – Natural Gas Energy (Dry Bulb)

kWh_{SAVED} = Electric Energy (DCV + DB) – Electric Energy (Dry Bulb)

Where:

Natural Gas Energy = Model output from Honeywell Savings Estimator in therms[4]
DCV + DB = Demand control ventilation plus dry bulb economizer
Dry Bulb = Dry bulb economizer controls
Electric Energy = Model output from Honeywell Savings Estimator in kWh[4]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (10 years)[1]

Assumptions

The minimum ventilation is based on ASHRAE 62.1-2007, which is representative for building stock addressed by measure.

Sources

1. Engineering judgement. Most CO_2 sensors have a 5-year warranty and need periodic cleaning and calibration. When they fail, they read high CO_2 levels so outdoor air is brought in and DCV ceases to function. An EUL of 10 years is deemed.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 131 projects and 247 units from January 2018 to May 2020 is $2,130.68.
3. Inputs collected from customer in Focus on Energy application.
4. Honeywell Savings Estimator Model located at: https://customer.honeywell.com/Documents/setupFullSE4_2_0_1.zip

Revision History

Version Number	Date	Description of Change
01	03/11/2013	Initial measure entry
02	12/8/2021	Re-activate workpaper, update EUL and incremental cost

Parking Garage Ventilation Controls

	Measure Details
Measure Master ID	Parking Garage Ventilation Controls, 3016 Parking Garage Ventilation Controls with Heating, 3493
Workpaper ID	W0047
Measure Unit	Per exhaust fan system
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Controls = 0 (MMID 3016), Controls with Heating = Varies (MMID 3493)
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	Controls = 0 (MMID 3016), Controls with Heating = Varies (MMID 3493)
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$827.88[2]

Measure Description

The proposed measure requires controlling ventilation airflow in enclosed parking garages based on carbon monoxide concentrations, while maintaining code required run hours.[3] By controlling airflow based on need rather than running it constantly, the system will save energy and maintain a safe environment. The measure with heating applies only to garages with heated exhaust air—not to heated garages in general, which generally meet space heating needs via separate unit heaters.

Description of Baseline Condition

The baseline condition is 24-hour garage exhaust fan operation.

Description of Efficient Condition

The efficient condition is garage exhaust fan(s) that are controlled by carbon monoxide sensor(s) with a minimum five hours of daily operation.[3]

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = kWh_{BASE} - kWh_{EE}$$

$$kWh_{BASE} = hp_{FAN} * 0.746 * HOU_{BASE} * 365$$

$$kWh_{EE} = hp_{FAN} * 0.746 * HOU_{EE} * 365$$

$\text{Therm}_{\text{SAVED}} = \text{Therm}_{\text{BASE}} - \text{Therm}_{\text{EE}}$

$\text{Therm}_{\text{BASE}} = \text{CFM} * 1.08 * (T_{\text{IN}} - T_{\text{OUT}}) * \text{HOU}_{\text{BASE}} * \text{DAY}_{\text{HEAT}} / (100{,}000 * \text{Eff})$

$\text{Therm}_{\text{EE}} = \text{CFM} * 1.08 * (T_{\text{IN}} - T_{\text{OUT}}) * \text{HOU}_{\text{EE}} * \text{DAY}_{\text{HEAT}} / (100{,}000 * \text{Eff})$

Where:

kWh_{BASE} = Annual electricity consumption of baseline fan control system
kWh_{EE} = Annual electricity consumption of carbon monoxide fan control system
hp_{FAN} = Total horsepower of garage ventilation fan motor(s) (= user input)
0.746 = Kilowatts per horsepower
HOU_{EE} = Average daily exhaust fan run hours with carbon monoxide control system (= 7; see Assumptions)
365 = Days per year
$\text{Therm}_{\text{BASE}}$ = Annual natural gas consumption of baseline fan control system
Therm_{EE} = Annual natural gas consumption of efficient fan control system
CFM = Airflow in cubic feet per minute of air handling unit (= user input)
1.08 = Sensible heat constant in Btu/hr-CFM-°F
T_{IN} = Makeup air setpoint temperature (= user input; if unknown use 50°F)
T_{OUT} = Average outdoor heating temperature (= varies by location; see Assumptions)
HOU_{BASE} = Daily run hours for base case (= 24)
DAY_{HEAT} = Average days per year requiring heat (= varies by location; see Assumptions)
100,000 = Conversion from Btu to therms
Eff = Heating efficiency (user input; if unknown use 80%)

Summer Coincident Peak Savings Algorithm

There are no coincident peak savings associated with this measure.

Lifecycle Energy-Savings Algorithm

$\text{kWh}_{\text{LIFECYCLE}} = (\text{kWh}_{\text{BASE}} - \text{kWh}_{\text{EE}}) * \text{EUL}$

Where:

EUL = Effective useful life (= 5 years)[1]

Assumptions

General space heating needs for a heated garage are assumed to be met by separate unit heaters. The measure version with heating only applies to garages with heated makeup air. For these garages, the air is heated from the outside temperature to the makeup air setpoint.

It is assumed that the heating season for garages is from November 1 to March 31, and that heating only occurs when the outdoor temperature is under 50°F. Therefore, the average outdoor heating temperature is the average temperature below 50°F from November 1 to March 31 using TMY3 weather data[4] for the nearest city. Similarly, DAY_{HEAT} is the average number of days per year (hours / 24) meeting these conditions. The table below contains these values.

The average daily exhaust fan run hours with a carbon monoxide control system was set to seven hours to account for the five-hour minimum[3] plus additional carbon monoxide sensing run time based on engineering judgement.

The value for T_{IN} reflects the setpoint for the makeup air heat, if the makeup air is heated. This is a user input, but can be assumed to be 50°F if unknown.

Weather-Related Data by Location

City	DAY_{HEAT}[4]	T_{OUT}[4]	Weighting by Participant[5]
Green Bay	149.5	24.5°F	22%
La Crosse	146.6	25.5°F	3%
Madison	143.6	23.6°F	18%
Milwaukee	145.0	26.3°F	48%
Wisconsin Average	146.2	25.0°F	9%
Weighted Average	**145.9**	**25.3**	

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. Ventilation Controls Installed, p. 69. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 16 units over three projects from 2013 to 2014.
3. Wisconsin Legislature SPS 364.0404 - minimum enclosed garage ventilation. http://docs.legis.wisconsin.gov/code/admin_code/sps/safety_and_buildings_and_environment/361_366/364.pdf

4. National Renewable Energy Laboratory. “National Solar Radiation Data Base, 1991-2005 Update: Typical Meteorological Year 3.” https://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html
5. Cadmus. *Focus on Evaluated Energy Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Revision History

Version Number	Date	Description of Change
01	12/31/2012	Initial TRM entry
02	10/11/2018	Added MMID 3493 for heated garages, updated algorithm

Unit Heaters, ≥ 90% Thermal Efficiency

	Measure Details
Measure Master ID	Unit Heater, ≥ 90% Thermal Efficiency, Heating: Setpoint = 70°F, 4753 Setpoint = 65°F, 4754 Setpoint = 60°F, 4755 Setpoint = 55°F, 4756 Unit Heater, ≥ 90% Thermal Efficiency, Heating, Propane-Fueled: Setpoint = 70°F, 4878 Setpoint = 65°F, 4879 Setpoint = 60°F, 4880 Setpoint = 55°F, 4881
Workpaper ID	W0048
Measure Unit	Per MBh input capacity
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Unit Heater
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies
Annual Propane Savings (Gallons)	Varies
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies
Lifecycle Propane Savings (Gallons)	Varies
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$15.56[2]

Measure Description

Condensing natural gas– or propane-fired unit heaters with at least 90% thermal efficiency have higher thermal efficiencies than heaters with code-minimum efficiency and save energy by consuming less fuel.

Description of Baseline Condition

The baseline equipment is assumed to be any non-condensing unit heater with a thermal efficiency of 80%. The standard measures must be used when replacing a natural gas–fired heater. The propane measures must be used when replacing a fuel oil- or propane-fired heater.

Description of Efficient Condition

Qualified units must be condensing natural gas– or propane-fired unit heaters, with thermal efficiency of at least 90%. Higher efficiencies are achieved by passing the flue gas through a secondary heat exchanger to extract more heat.

Annual Energy-Savings Algorithm

$Gas_{SAVED} = CAP_{EE} * LF * (Eff_{EE} / Eff_{BASE} - 1) * EFLH_{HEAT} / ConvF$

Where:

- Gas_{SAVED} = Therms of natural gas or gallons of propane saved
- CAP_{EE} = Efficient unit heater input capacity in MBh (= user input)
- LF = Load factor (= 0.7245; see Assumptions)
- Eff_{EE} = Thermal efficiency of new unit heaters (= 0.93)[8]
- Eff_{BASE} = Thermal efficiency of baseline unit heaters (= 0.80)[3]
- $EFLH_{HEAT}$ = 24 * HDD / ΔT in hours
  - Where:
    - 24 = Conversion factor from days to hours
    - HDD = Heating degree days (= varies by balance point inside temperature; see Assumptions)
    - ΔT = $T_{INSIDE} – (T_{OUTSIDE} + T_{DR} / 2)$
      - Where:
        - T_{INSIDE} = Design balance point inside temperature (= varies with internal loads; see Assumptions)
        - $T_{OUTSIDE}$ = Design outside temperature (deemed; = -15°F)[4]
        - T_{DR} = Average winter diurnal temperature range (= 18°F; see Assumptions)
- ConvF = Fuel conversion factor (= 100 MBtu per therm, = 91.3 MBtu per gallon propane)[5]

There are no electrical savings for this measure.

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Gas_{LIFECYCLE} = Gas_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

The savings per MBh input is presented in the table below.

Gas Savings per MBh by Thermostat Setpoint

Thermostat Setpoint	Therms Savings per MBh Input		Gallons Propane Savings per MBh Input	
	Annual	Lifecycle	Annual	Lifecycle
≥ 70°F	3.07	46.05	3.36	50.47
65°F	2.71	40.65	2.97	44.55
60°F	2.38	35.7	2.61	39.15
≤ 55°F	2.05	30.75	2.24	33.6

Assumptions

Baseline equipment costs were obtained from an equipment supplier website[2] that sells non-condensing unit heaters from multiple manufacturers. Capacities ranged from 30 MBh to 400 MBh. The average baseline equipment cost was $7.08 per MBh for non-condensing unit heaters. Condensing unit heaters cost an average of $22.64 per MBh based on historical Focus on Energy project data from 2015 to June 2018. This resulted in an incremental cost of $15.56 per MBh input.

Heating degree days were calculated using temperature bin data (1-degree bins) from TMY3 weather files for 20 Wisconsin locations. This statewide bin dataset was created by averaging the hours for the 20 sites for each temperature bin.

To account for internal heat gains (lights, people, computers, machinery, etcetera), the base temperature for heating degree days was assumed to be 5°F below the thermostat setpoint.

The outside temperature associated with heating degree days is the average outside temperature for the day. The data in the table below show that during the winter in Wisconsin, the diurnal temperature range—the difference between the maximum temperature and the minimum temperature for the day—averages approximately 18 degrees.

Average Winter Diurnal Temperature in Wisconsin[6]

Location	Month	Temperature		
		Maximum	Minimum	Difference
Ashland	December	26.1	7.9	18.2
	January	22.1	0.1	22.0
	February	27.3	3.4	23.9
Green Bay	December	27.7	12.6	15.1
	January	22.8	5.7	17.1
	February	27.1	9.5	17.6
Madison	December	29.8	13.5	16.3
	January	24.8	7.2	17.6
	February	30.0	11.1	18.9
Medford	December	23.5	6.1	17.4
	January	19	-1.7	20.7
	February	24.6	1.2	23.4
Milwaukee	December	31.3	17.4	13.9
	January	26.1	11.7	14.4
	February	30.0	16.0	14.0
LaCrosse	December	28.0	12.6	15.4
	January	23.5	5.4	18.1
	February	29.7	10.0	19.7
Average				**18.0**

The design outside temperature associated with heating degree days is then -15°F + (18°F / 2) = -15°F + 9°F = -6°F.

The equivalent full-load heating hours are presented in the table below. A load factor of 0.7245 was selected, which brings the produces an overall $EFLH_{HEAT}$ of 1,890 hours at a 70°F setpoint. This is consistent with the average commercial $EFLH_{HEAT}$ used elsewhere in this technical manual.

Equivalent Full-Load Heating Hours by Thermostat Setpoint

Thermostat Setpoint Temperature	HDD Base Temperature, T_{INSIDE}	ΔT	HDD	$EFLH_{HEAT}$	$EFLH_{HEAT}$ * LF
70°F	65°F	77°F	7,718	2,609	1,890
65°F	60°F	66°F	6,342	2,306	1,671
60°F	55°F	61°F	5,136	2,021	1,464
55°F	50°F	56°F	4,058	1,739	1,260

This entry includes measures for natural gas–fired equipment eligible to both natural gas and propane customers. The Code of Federal Regulations,[8] upon which federal efficiency standards are based, defines *gas* as either natural gas or propane (§430.2 for consumer appliances, and §431.2 for commercial and industrial equipment). Thus, it is assumed that equipment efficiencies, costs, etcetera are equal for both fuel types. Any infrastructure or maintenance costs unique to each particular fuel were ignored.

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Historical Focus on Energy project data. 2015 to June 2018.
   For 29 projects and 100 total unit heaters, the average unit heater cost is $22.64/MBh, less the baseline unit heater cost of $7.08/MBh from review of www.supplyhouse.com pricing (Accessed June 2018) for Reznor and Modine unit heaters. See 2018 Focus on Energy *Incremental Measure Cost* study for details.
3. International Code Council. *2015 International Energy Conservation Code*. Table 403.2.3(4). https://codes.iccsafe.org/public/document/IECC2015/chapter-4-ce-commercial-energy-efficiency
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Section 3.4, p. 3–14. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. U.S. Energy Information Administration. "Energy Units and Calculators Explained." Accessed December 2018. https://www.eia.gov/energyexplained/?page=about_energy_units
6. Climatemps.com. Accessed May 2018. http://www.usa.climatemps.com/
7. Electronic Code of Federal Regulations. §430-431. Accessed February 2019. https://www.ecfr.gov/cgi-bin/text-idx?gp=&SID=92c3f99c51e1124fcc790d11c93e04af&mc=true&tpl=/ecfrbrowse/Title10/10CIIsubchapD.tpl
8. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average AFUE of 20 projects and 77 units from 1/2017 to 10/2019 is 93%.

Revision History

Version Number	Date	Description of Change
01	10/10/2018	Initial TRM entry
02	3/2019	Added propane measures
03	2/24/2020	Updated deemed savings to incorporate delivered efficiency

Infrared Heating Units, High or Low Intensity

	Measure Details
Measure Master ID	Infrared Heating Units, High or Low Intensity, 2422 Infrared Heating Units, High or Low Intensity, Propane, 4854
Workpaper ID	W0049
Measure Unit	Per MBh
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Infrared Heater
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Natural gas = 1.06 (MMID 2422)
Annual Propane Savings (Gallons)	Propane = 1.16 (MMID 4854)
Lifecycle Electricity Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Natural gas = 15.90 (MMID 2422)
Annual Propane Savings (Gallons)	Propane = 17.4 (MMID 4854)
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$15.56[2]

Measure Description

This measure applies to natural gas or propane–fired high- and low-intensity infrared heaters with an electronic ignition that uses non-conditioned air for combustion.

Description of Baseline Condition

The baseline condition is a natural gas or propane–fired unit heater with a code minimum thermal efficiency of 80%. Air in rooms with high ceilings is often stratified. Air near the roof is many degrees warmer than air at the thermostat level, so more heat is lost through roof conduction in rooms with stratified air than in rooms where the air is not as stratified.

Description of Efficient Condition

The efficient condition is a natural gas or propane–fired infrared radiant heater with electronic ignition that uses non-conditioned air for combustion. Energy is saved in three possible ways:

1. First, radiant heat provides the same level of comfort at lower air temperatures than non-radiant systems, so the thermostat is set lower and conduction heat transfer is lower.
9. Secondly, the radiant heat warms up the floor of a room which destratifies the air, so compared to non-radiant systems the air near the ceiling is cooler and conduction heat transfer through the roof is lower.
10. Third, the thermal efficiency of the radiant heater may be slightly higher than the thermal efficiency of the baseline unit heater.

Both high- and low-intensity units qualify.

Annual Energy-Savings Algorithm

$Gas_{SAVED} = Gas_{BASE} - Gas_{EE}$

$Gas_{BASE} = LF * (1{,}000 * Cap) * EFLH_{HEAT} * (T_{CEILING,BASE} – T_{OUTSIDE}) / [ConvF * Eff_{BASE} * (T_{INSIDE,BASE} – T_{OUTSIDE})]$

$Gas_{EE} = LF * (1{,}000 * Cap) * EFLH_{HEAT} * (T_{CEILING,EE} – T_{OUTSIDE}) / [ConvF * Eff_{EE} * (T_{INSIDE,EE} – T_{OUTSIDE})]$

Where:

LF = Load factor (= 0.77)[3]

Cap = Input capacity for new infrared radiant heater in MBh (= user input)

$EFLH_{HEAT}$ = Equivalent full-load heating hours (= 1,890; see Assumptions)

$T_{CEILING,BASE}$ = Inside air temperature near the ceiling with the baseline unit heater (= 75°F; see Assumptions)

$T_{OUTSIDE}$ = Design outside temperature (= -15°F)[3]

$ConvF$ = Fuel conversion factor (= 100 MBtu per therm, = 91.3 MBtu per gallon propane)[7]

Eff_{BASE} = Efficiency of baseline unit heater (= 0.80)[4]

$T_{INSIDE,BASE}$ = Inside air temperature, which is the thermostat setpoint, with the baseline unit heater (= 65°F; see Assumptions)

$T_{CEILING,EE}$ = Inside air temperature near the ceiling with the infrared radiant heater (= 65°F; see Assumptions)

Eff_{EE} = Efficiency of infrared radiant heater (= 0.80)[4]

$T_{INSIDE,EE}$ = Inside air temperature, which is the thermostat setpoint, with the infrared radiant heater (= 60°F; see Assumptions)

There are no electrical savings for this measure.

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak demand savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

The inside air temperature at the ceiling is assumed to be in contact with a majority of the building envelope, except the middle and lower sections of walls. This lower wall area is assumed to be small relative to the area of the roof and higher parts of walls.

The building envelope R-value and area are not explicitly in the savings calculation because the heater capacity is assumed to be sized for the envelope insulation and envelope area of the space being heated.

The inside air temperature near the roof is assumed to be 10°F warmer than the air at the thermostat in the baseline condition and is assumed to be 5°F warmer with the infrared heater, based on measured stratified temperatures with a 25-foot ceiling.[5]

The calculation methodology for this measure assumes, based on engineering judgment, that the space thermostat setpoint can be lowered by 5°F while maintaining occupant comfort levels.

Since the thermostat setting can be lower with an infrared heater, the heat load calculation with a lower inside temperature would result in a slightly smaller heater. However, this size difference is negligible. If the infrared radiant heater is sized for an inside design temperature of 60°F and the equivalent baseline heater is sized for an inside design temperature of 65°F, the baseline unit heater would be larger by 7% [(65° - -15°) / (60° - -15°) = 80 / 75 = 1.0667]

No electrical savings are claimed because the combustion air fans in the infrared radiant heaters have roughly equivalent power to the propeller fans in the baseline unit heaters. This is based on data from four infrared heater manufacturers (Modine, Reznor, Space-ray, and Schwank) and three unit heater manufacturers (Modine, Reznor, and Trane) in April 2018. Any difference is negligible.

The impact of whether most of the heating load is from infiltration versus conduction was considered. The savings for 100% infiltration was 7% larger than for 100% conduction. This difference is negligible. Even though the algorithm uses the conduction formula, the results are applicable to a system with no envelope exposure and sized for infiltration. The inputs for this comparison are shown in the table below.

Assumptions for Comparing Infiltration and Conduction

Value	Baseline	Proposed
Heater Efficiency	80%	80%
Inside Design Temperature	70°F	65°F
Balance Point Temperature	65°F	65°F
Ceiling Temperature	80°F	70°F

Data for determining the equivalent full-load heating hours are presented in the table below.

Supporting Inputs for Equivalent Full-Load Heating Hours by City for Business[6]

Location	$EFLH_{HEAT}$	Weighting by Participant
Green Bay	1,852	22%
Lacrosse	1,966	3%
Madison	1,934	18%
Milwaukee	1,883	48%
Wisconsin Average	1,909	9%
Weighted Average	**1,890**	**100%**

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. Appendix B. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Historical Focus on Energy project data. 2016 to June 2018.
   Eighty-nine projects, 262 total unit heaters. Average unit heater cost is $22.64/MBh, minus the baseline unit heater cost of $7.08/MBh (based on a review of www.supplyhouse.com pricing, accessed June 2018, for Reznor and Modine unit heaters. See the 2018 Focus on Energy *Incremental Measure Cost* study for details.
3. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. p. 4-12 for load factor, p. 4-133 for outside design temperature. March 22, 2010. https://www.focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
   Similar to MMIDs 2744, 3277, 4058, and 4659.

4. International Code Council. *2015 International Energy Conservation Code*. Table 403.2.3(4). https://codes.iccsafe.org/public/document/IECC2015/chapter-4-ce-commercial-energy-efficiency
5. Kosar, Doug. "1026: Destratification Fans – Public Project Report." Nicor Gas, Emerging Technology Program. October 6, 2014.https://www.nicorgasrebates.com/-/media/Files/NGR/PDFs/ETP/1026%20Thermal%20Equalizer%20Destratification%20Fans%20Public%20Project%20Report%20APPROVED%20FINAL%20to%20Nicor%20Gas%2010062014%20REV%202.pdf
6. Several Cadmus metering studies reveal that the ENERGY STAR EFLHs calculator are overestimated by 25%. $EFLH_{HEAT}$ was adjusted by population-weighted heating degree days and TMY3 values.
7. U.S. Energy Information Administration. "Energy Units and Calculators Explained." https://www.eia.gov/energyexplained/?page=about_energy_units

Revision History

Version Number	Date	Description of Change
01	10/10/2018	Initial TRM entry
02	02/2021	Propane measure added

Direct-Fired Make-Up Air Units

	Measure Details
Measure Master ID	Direct Fired Make-Up Air Unit, Natural Gas, 5081
Workpaper ID	W0260
Measure Unit	Per CFM
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Direct Fired Heating
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$0.99[1]

Measure Description

This measure is installing a direct-fired make-up air unit in place of a standard efficiency indirect-fired make-up air unit. Direct-fired make-up units heat with an open flame in the airstream, which sends the products of combustion into the space. As such, they are best used for spaces with high ventilation needs to ensure that products of combustion are vented to outdoors. Only constant speed units are eligible; variable speed units may be eligible for a custom incentive.

Description of Baseline Condition

The baseline condition is a make-up air unit with an indirect burner (flame separated from airstream), which is nominally 80% efficient.

Description of Efficient Condition

The efficient condition is a direct-fired make-up air unit, which is typically considered to have a 92% thermal efficiency rating.[2]

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \sum [1.08 * \text{CFM} * (T_{\text{SUPPLY}} - T_{\text{OUTSIDE}})] * (1 / \text{Eff}_{\text{BASE}} - 1 / \text{Eff}_{\text{EE}}) / 100{,}000$ * Each hour of operation across a typical meteorological year

Where:

1.08 = Constant for sensible heat load equation

CFM = Outside airflow provided by the make-up air unit (= user input)

T_{SUPPLY} = Supply air temperature from the make-up air unit (= user input; use 65°F if unknown)

$T_{OUTSIDE}$ = Outside air dry bulb from hourly TMY3 weather data file[3]

EFF_{BASE} = Thermal efficiency of indirect-fired make-up air unit (= 80%)[4]

$EFFE_{EE}$ = Thermal efficiency of direct-fired make-up air unit (= 92%)[2]

100,000 = Btus to therms conversion factor

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

The hours of operation will be provided as a start/stop time for weekdays, Saturdays, and Sundays on the incentive application. The calculation will assume that the operating schedule applies year-round without holidays unless specifically noted by the customer. If the hourly dry bulb temperature in the weather data is below the make-up air unit supply air temperature and the operating schedule indicates that the building is occupied, heating savings will be calculated.

A 92% Eff_{EE} value is used based on a reasonable estimate. After a year or more, this value will be updated based on actual application data.

Sources

1. Navigant Consulting (Young, Jim). *Field Demonstration of High Efficiency Gas Heaters.* Prepared for Better Buildings Alliance and U.S. DOE. 2014. www.energy.gov/sites/prod/files/2014/11/f19/gas_heater_demo_report_2.pdf
   EULs listed as approximately 15 to 20 years (15 years was selected as a conservative value). The field demonstration report lists a cost of $7.43 per MBh. Online lookups conducted in November 2019 of CFM and MBh from eight different manufacturers and 126 total models found a weighted average of 7.51 cfm per MBh, which results in an incremental cost of $0.99 per CFM.
2. Boeckermann, Thomas, et al. "Direct-Fired Technology." ASHRAE Journal. September 2015. www.ruppair.com/documents/news/ASHRAE%20Direct%20Fired%20Heating%20Article.pdf

3. National Renewable Energy Laboratory. “National Solar Radiation Data Base, 1991- 2005 Update: Typical Meteorological Year 3.” https://nsrdb.nrel.gov/data-sets/archives.html
4. International Code Council. *2015 International Energy Conservation Code*. Table 403.2.3(4). 2015. https://codes.iccsafe.org/public/document/IECC2015

Revision History

Version Number	Date	Description of Change
01	11/20/2020	Initial TRM entry

Smart Thermostats for Business

	Measure Details
Measure Master ID	Smart Thermostat: Natural Gas Boiler, 4375 Natural Gas Furnace with AC, 4376 Natural Gas Rooftop Unit, 4377 Unit Heater, Standard Efficiency, 5079 Unit Heater, ≥90% TE, 5080
Workpaper ID	W0050
Measure Unit	Per MBh for MMIDs 4375, 5079, and 5080 Per thermostat for MMIDs 4376 and 4377
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies
Lifecycle Electricity Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	Varies
Water Savings (gal/year)	0
Effective Useful Life (years)	9[1]
Incremental Cost ($/unit)	Per-thermostat unit = $298.45[2] (MMIDs 4376 and 4377) Per-MBh unit = $0.92[14] (MMIDs 4375, 5079, 5080)

Measure Description

Standard programmable thermostats allow customers to adjust temperature setpoints at different times of the day, changing temperatures during unoccupied periods to allow for energy savings. Compared to standard programmable thermostats, smart thermostats provide enhanced functionality:

- More simple use and programming, both on the thermostat and remotely via smartphone apps and web portals
- Occupancy sensing that enables energy savings from automatic setbacks during unoccupied periods (occupancy sensing may use sensors in the thermostat or a smartphone app’s capability to track the resident’s location)
- Learning capability or automatic schedule generation or modification by dynamically adjusting or constructing a program schedule based on actual occupancy patterns, eliminating the need for programming

- Intelligent control of HVAC equipment, including minimizing the amount of energy expended for recovery from setback, intelligent control of two-stage HVAC sources, and minimizing the use of inefficient electric-resistance heat associated with most heat pumps
- Use of outside temperature and other weather data to better ensure comfort and minimize energy use
- Encourage the use of more energy-efficient set temperatures, such as a leaf icon that appears when the set temperature is moved in the direction of less energy use
- Algorithms that make frequent, subtle set temperature changes to save energy

Description of Baseline Condition

The baseline condition is a manual or standard programmable thermostat installed in a business with a natural gas furnace with air conditioning, natural gas rooftop unit with air conditioning, or natural gas boiler (no cooling).

Description of Efficient Condition

The efficient condition is a smart thermostat installed in a small business to replace the existing thermostat.

To qualify as *smart*, the thermostat must be certified as an ENERGY STAR Connected Thermostat or be included on the Focus on Energy business smart thermostat qualified products list, which requires the thermostat to have occupancy sensing, learning capability, or other features above and beyond Wi-Fi connectivity, as outlined in the Measure Description section. The Focus on Energy qualified products list serves as an alternate to ENERGY STAR, since the list of ENERGY STAR-qualified thermostats includes 63 models from 17 manufacturers (as of September 14, 2020).

Annual Energy-Savings Algorithm

$Therm_{SAVED} = EFLH_{HEAT} * CAP_{HEAT} / (EFF_{HEAT} * 100) * ESF_{HEAT}$

$kWh_{SAVED} = EFLH_{COOL} * CAP_{COOL} / EFF_{COOL} * RLF_{COOL} * ESF_{COOL}$

Where:

$EFLH_{HEAT}$ = Equivalent full-load heating hours (= 1,663 for unit heaters, see Assumptions; = 1,890 average for other equipment in commercial buildings, see table below)

Equivalent Full-Load Heating Hours by City

Location	$EFLH_{HEAT}$[3]	Weighting by Participant
Green Bay	1,852	22%
Lacrosse	1,966	3%
Madison	1,934	18%
Milwaukee	1,883	48%
Wisconsin Average	1,909	9%
Weighted Average	**1,890**	**100%**

CAP_{HEAT} = Heating system capacity (= user input for boilers and unit heaters; see Heating Capacity Info table in Assumptions for furnaces and rooftop units)

EFF_{HEAT} = Efficiency of the heating system (= 89.6% for furnaces, = 80.3% for rooftop units, = 85.5% for boilers, = 80% for standard efficiency unit heaters, = 93% for ≥90% thermal efficiency unit heaters; see Efficiency Info table in Assumptions)

100 = Conversion factor from MBh to therms

ESF_{HEAT} = Heating energy savings fraction (for smart thermostats: = 4.6% for furnaces, rooftop units, and unit heaters; = 5.0% for boilers, see Assumptions)

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 599 average for Wisconsin commercial buildings, see table below)

Equivalent Full-Load Cooling Hours by Building Type

Building Type	$EFLH_{COOL}$[4]
College	877
Food Sales	749
Food Service	578
Healthcare	803
Hotel/Motel	663
Industrial	519
Office	578
Other	589
Public Assembly	535
Public Services (non-food)	535
Retail	567
School	439
Warehouse	358
Average	**599**

CAP_{COOL} = Cooling system capacity in MBh (= see Cooling Capacity Info table in Assumptions section)

EFF_{COOL} = Cooling system efficiency (= 0 for boilers, = 13 SEER for furnaces with AC,[5] = 11.4 EER for rooftop units;[6] see Efficiency Info table in Assumptions)

RLF_{COOL} = Rated load factor for cooling; the peak cooling load/nameplate capacity. This factor compensates for oversizing the air conditioning unit (= 0.90 for rooftop units, see Assumptions; = 1.0 for all other)

ESF_{COOL} = Cooling energy savings fraction (= 20.5% for smart thermostats, see Assumptions)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure. It is assumed that businesses will be occupied during this time, and therefore no programmed or automatic setbacks will be occurring.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 9 years)[1]

Deemed Savings

Annual and Lifecycle Savings by Measure

Measure	MMID	Peak kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms	Unit
Smart Thermostat, Business Heated by							
Natural Gas Boiler	4375	0	0	0	1.11	10.0	per MBh controlled
Natural Gas Furnace with AC	4376	0	418	3,762	84	756	per smart thermostat
Natural Gas Rooftop Unit	4377	0	1,417	12,753	184	1,656	
Natural Gas Unit Heater, Standard Efficiency	5079	0	0	0	0.96	8.6	per MBh controlled
Natural Gas Unit Heater, ≥90% Thermal Efficiency	5080	0	0	0	0.82	7.4	per MBh controlled

Assumptions

It is difficult to conduct billing analyses to derive advanced thermostat savings for commercial populations, and there is currently not a single standard method for calculating such savings. A 2017 examination of seven other programs (in Illinois, Iowa, Massachusetts, Minnesota, Montana, New York, and Rhode Island) reveals an array of approaches, but many of these programs employ savings fractions or fixed savings values derived from proprietary sources, and many use approaches or savings values that are not ideal for the Focus on Energy program. The New York program[7] simply applies the same savings fractions for commercial and residential thermostats. There are many reasons that savings fractions for residential and commercial thermostats may be different, such as different occupancy behavior, different manual and programmable setback practices, and different smart setback practices. However, with a lack of valid alternatives, this workpaper used the approach of the New York program.

For the 2016 Focus on Energy evaluation, Cadmus conducted a billing analysis to examine savings for participants who installed smart thermostats as part of MMIDs 3609, 3610, and 3611 (updated to MMIDs 4301, 4302, and 4303). The 2016 *Focus on Energy Evaluation Report*[8] discusses these findings, and results from that billing analysis are analyzed further in the updated workpaper for these MMIDs. This study provided savings factors for smart thermostats, as described in the workpaper for MMIDs 4301, 4302, and 4303.

Energy savings factors for smart thermostats from the 2016 Cadmus billing analysis are shown in the table below.

Energy Savings Factors

Parameter	Thermostat Type	Furnace	Boiler
ESF_{THERM}	Smart	4.6%	5.0%
ESF_{COOL}	Smart	20.5%	20.5%
ESF_{HEAT}	Smart	14.2%	N/A

Rooftop unit and unit heater energy savings factors are assumed to match furnace energy savings factors.

For unit heaters (workpaper W0048), $EFLH_{HEAT}$ varies with the space temperature setpoint to account for unit heaters being used in lower temperature applications like parking garages and warehouses that are not heated to typical setpoints for offices, schools, retail, and similar. Using historical project data[9] from Focus on Energy, the $EFLH_{HEAT}$ for unit heaters was determind to be 1,663. Details are shown in the table below.

Unit Heater Average EFLH

MMID	Setpoint Temperature (°F)	$EFLH_{HEAT}$ (including load factor adjustment)	MBh Participation	# of Projects	# of Unit Heaters
4753	70	1,890	735	2	5
4754	65	1,671	1,655	3	7
4755	60	1,464	900	3	5
4756	55	1,260	0	0	0
	Weighted Average:	**1,663**			

The heating and cooling efficiencies for boilers, furnaces, and rooftop units were obtained from *Potential Study* data,[6] which was from site visits to retail, restaurant, school, and small offices. Average efficiencies and site counts for each type of system are presented in the table below.

Efficiency Info

Parameter	System	Sites	Average Value
EFF_{HEAT}	Boilers	43	85.5%
	Furnaces	37	89.6%
	Rooftop Units	121	80.3%
EFF_{COOL}	Rooftop Units	68	11.4 SEER

The heating efficiencies for unit heaters were set to match the baseline and efficient condition values from workpaper W0048: 80%[10] and 93%[11].

The cooling capacities for the furnace and rooftop unit measures were obtained by examining system sizes for an existing measure in historical project data.[12] Results from this examination are shown in the table below. A default value of 0.90 was assumed for the rated load factor for rooftop unit cooling consumption, which aligns with MMIDs 4368 through 4371 for split systems greater than or equal to 5.42 tons. Boiler and unit heater systems were assumed to not have cooling capabililty.

Cooling Capacity Info

HVAC System	MMID	MMID of Measure Used to Derive Capacity	Programs Examined	Number of Projects	Average Cooling Capacity (MBh)
Furnace	4376	3022 (business AC split system)	BIP, CSF (≤ 5.4 tons)	141	44.3
Rooftop Unit	4377		BIP, CSF (> 5.4 tons, ≤ 20 tons)	151	146.2

The heating capacities for furnaces were also obtained by analyzing project data from other measures.[12] Heating capacity for rooftop units was obtained by examining common heating sizes matched to a cooling capacity of 146.2 MBh for three manufacturers.[13] Findings are presented in the table below.

Heating Capacity Info

HVAC System	MMID	MMIDs/Measures Used to Derive Capacity	Programs Examined	Number of Projects	Average Heating Capacity (MBh)
Boiler	4375	Boilers may have multiple zones, with each zone controlled by an individual thermostat			User input for MBh controlled by thermostat
Unit Heater	5079, 5080	Unit heaters vary considerably in size, and large spaces may have multiple units controlled by a single thermostat			User input for MBh controlled by thermostat
Furnace	4376	3491, 3492 (furnaces ranging from 39 to 331 MBh)	Commercial, Agriculture, Industrial, Schools & Government (includes new construction for each)	268	87
Rooftop Unit	4377	Analysis of three rooftop unit manufacturers to determine heating MBh for 146.2 MBh cooling capacity rooftop unit			170

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, HVAC Controls. June 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 6,350 projects and 7,163 units from May 2018 to July 2020 is $337.56 (MMIDs 3612 - 3615, 4054 - 4056, and 4301 - 4303, 4667, 4668, 4376, and 4377 in commercial and multifamily

sectors). Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.

3. Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLH are over-estimated by 25%. The $EFLH_{HEAT}$ were adjusted by population-weighted HDD and TMY3 values.
4. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
DEER model runs that were weather normalized for statewide use by population density.
5. Appliance Standards Awareness Project. "Central Air Conditioners and Heat Pumps." http://www.appliance-standards.org/product/central-air-conditioners-and-heat-pumps
6. Cadmus. *2016 Potential Study for Focus on Energy.* Data maintained by Cadmus and Public Service Commission of Wisconsin. Commercial site visits from the summer of 2016 to retail, restaurant, and small office sites.
7. New York State Department of Public Service. *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, Version 4*. April 29, 2016. http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1100671bdd/$FILE/ATTESQKL.pdf/TRM%20-%20Version%204.0-April%202016.pdf
8. Cadmus. *Focus on Energy Calendar Year 2016 Evaluation Report, Volume II*. May 19, 2017. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202016%20Volume%20II%20-%20%28Low%20Res%29.pdf
9. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. 8 projects and 17 heaters for MMIDs 4753, 4754, 4755, and 4756. January 1, 2019 to August 31, 2020.
10. International Code Council. *2015 International Energy Conservation Code*. Table 403.2.3(4). https://codes.iccsafe.org/public/document/IECC2015/chapter-4-ce-commercial-energy-efficiency
11. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average AFUE of 20 projects and 77 units from 1/2017 to 10/2019 is 93%.
12. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 1, 2016 through October 31, 2017.
13. Trane, model YH*150G3,4,W – 12.5 ton cooling capacity, 150 MBh heating capacity
Carrier, model 48HCDD14 – 12.5 ton cooling capacity, 180 MBh heating capacity
Johnson Controls, model J12ZF – 12.5 ton cooling capacity, 180 MBh heating capacity
Average heating capacity of 170 MBh.
14. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 17 projects, 60 boilers, and 12,457 MBh from August 2018 to June 2020 for MMIDs 4375 and 4666 in commercial and multifamily programs is $1.11/MBh. Minus the cost of a manual thermostat, which is $39.11 per unit based on online lookups from July 2018, therefore $0.19 per MBh. $1.11 - $0.19 = $0.92 per MBh.

Revision History

Version Number	Date	Description of Change
01	05/02/2018	Initial TRM entry
02	12/2018	Added communicating thermostats, updated costs
03	09/2020	Removed communicating thermostats, added smart thermostat for unit heaters, updated cost

Surgery Occupancy, HVAC Controls

	Measure Details
Measure Master ID	HVAC Controls, Surgery Occupancy, 3632
Workpaper ID	W0051
Measure Unit	Per upgrade
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Commercial, Schools & Government
Annual Energy Savings (kWh)	Varies by type of savings
Peak Demand Reduction (kW)	Varies by type of savings
Annual Therm Savings (Therms)	Varies by type of savings
Lifecycle Energy Savings (kWh)	Varies by type of savings
Lifecycle Therm Savings (Therms)	Varies by type of savings
Water Savings (gal/year)	0
Effective Useful Life (years)	5[7]
Incremental Cost ($/unit)	$5,500.00[6]

Measure Description

The savings expected to be realized in the business commercial sector, specifically within hospital air handlers serving surgery spaces. These air handlers currently operate continuously at a minimum of 20 Air Changes per Hour (ACH), and 4 ACH of outside air. After Building Automation Systems are upgraded to an extended architecture, the capability to reduce airflow to operating rooms when unoccupied may be obtained. However, space pressure relationships between an operating room and adjoining spaces are critical and steps must be taken to prevent an operating room from having negative pressure when airflow is reduced. Typically, these steps involve installing additional equipment on the return and/or supply ductwork serving the operating room. Once the equipment and controls changes have been made, an airflow reduction to 6 ACH, 1.6 ACH OA is feasible. The cost of these upgrades varies widely, depending on the existing equipment. However, if a base system of building automation system is present, the additional controls and possible VFD cost is within expected program range of one to 10 years.

Description of Baseline Condition

Baseline equipment includes an air handler with Supply/Return fans served by Variable Speed Drives, chilled water cooling coils, hot water heating coils, and economizer operation. Cooling energy is provided by a chilled water loop, typically served by a chiller paired with a cooling tower. Heating energy is provided by a hot water loop, typically served by an atmospheric boiler.

Air handlers typically serve multiple spaces, so the portion of air flow and supply/return fan horsepower energy that should be attributed to the surgery rooms is calculated by the following inputs:

- Number of surgery rooms
- Total square footage of surgery rooms
- Total square footage of non-surgery rooms served by associated AHU
- Average volume of rooms
- Reheat Type, Natural Gas or Electric
- Existing air changes per hour
- Surgery room temperature and humidity requirements during occupied and unoccupied modes
- Estimated schedule of unoccupied controls to be implemented (e.g. 6pm to 6am, 7 days/week)
- Surgery Room space pressure setpoint relative to adjacent spaces
- Proposed Control Strategy Type (described in description of efficient condition)

Based on these inputs, a baseline condition of Supply CFM, OA CFM, and Fan Power kW is calculated. CFM calculations are based on the size of the room and assumptions of 20 ACH Supply, 4 ACH OA Supply. Fan power is calculated as CFM*Static Pressure/(6,356*Total Fan Efficiency).

With these calculated values, BIN Data and typical AHU setpoints are used to calculate savings on cooling kWh, heating therms, reheat therms, and fan kWh. Assumptions are used for Cooling kW/Ton, Boiler efficiency, Return Air Temperature, Supply Air Temperature, Fan efficiency, fan static pressure, and return/exhaust fan load relative to supply fan.

Description of Efficient Condition

The Efficient Condition allows for operation in a similar manner to the proposed condition, except the total supply CFM has been reduced to 6 ACH with proportional OA cfm reduction. The Efficient Condition is expected to operate as one of the three possible controls strategies:

- A two-position (min/max) variable air volume (VAV) box is installed on the supply air source. Supply airflow is controlled to setpoint. Shut-off dampers are installed in the return ductwork equal to the amount of the setback volume. The VAV box and dampers are balanced to the maximum and minimum volumes for occupied and unoccupied modes. When the VAV box switches to the unoccupied mode, the return dampers (controlling the setback volume) close.
- Pressure-independent valves are placed on the supply and return ductwork (and potentially on ductwork serving surrounding spaces). The supply airflow is controlled to setpoint. The valves, calibrated to the maximum and minimum volumes for occupied and unoccupied modes, maintain the desired offset.
- A modulating control dampers is installed in the return duct and controlled by a room pressure sensor. The damper modulates to maintain a positive relative room pressure during both

occupied and unoccupied modes. A standard terminal box controls the supply airflow to setpoint for each sequence.

Annual Energy-Savings Algorithm

Heating Load Savings (therms/year)

If bin data recorded is between schedule of unoccupied controls: (Total CFM Existing - Total CFM Proposed) * Sensible Heat Constant * (T_supply - T_MA)

Cooling Load Savings (kWh/year)

Total Energy Cooling Load of outside Air: (Outside Air CFM Existing-Outside Air CFM Proposed) * Total Heat Constant * (Enthalpy_OA - Enthalpy_DA)

Sensible Energy Cooling Load of Return Air: If T_OA > T_supply: (Return Air CFM Existing - Return Air CFM Proposed) * Sensible Heat Constant * (T_return - T_supply)

Fan Power Savings (kWh/year)

(Total Air CFM Existing - Total AIR CFM Proposed) * (Pressure_fan static / 6,356 / Efficiency_fan) * kW/bhp * RF + EF_Multiplier * hours/yr unoccupied

Reheat Savings (therms/year)

Sensible Heat Constant * (Total CFM Existing - Total CFM Proposed) * (T_VAV_Supply_Existing - T_VAV_Supply_Proposed) * (Total Hours - Occupied Hours)

Where:

Total CFM Existing = Actual total building airflow

Total CFM Proposed = Proposed total building airflow

Sensible Heat Constant = (lb/cubic feet air * Btu/lb air * minute/hour = 1.08

T_supply = Supply temperature of air handling unit (= 52°F)

T_MA = Mixed air temperature, calculated based on percentage of outside air vs. return air (based on ideal economizer schedule)

Outside Air CFM Existing = Actual outside air supply airflow

Outside Air CFM Proposed = Proposed outside air supply airflow

Total Heat Constant = (60 min/hr) / (density of standard air = 0.075) = 4.5

Enthalpy_OA = Enthalpy of outside air= [A * RH_OA + B (Curve fit equation to psych chart, accurate within 0.7% between 40°F ≤ T_OA ≤ 80°F)]

A = 0.007468 * DB^2 - 0.4344 * DB + 11.1769

RH_OA = Outside air relative humidity, TMY3 bin data B = 0.2372 * DB + 0.1230

Enthalpy_DA = Enthalpy of discharge air, 52°F at saturated conditions in 0-foot elevation (= 21.45)

Return Air CFM Existing = Actual return air supply airflow

Return Air CFM Proposed = Proposed return air supply airflow

T_return = Return temperature of air handling unit (= assumed 3°F above T_setpoint)

Total Air CFM Existing = Actual total airflow

Total Air CFM Proposed = Proposed total airflow

Pressure_fan static = Total static pressure of supply fan (= assumed 4 inches Water Gauge)

6,356 = Horsepower conversion factor

Efficiency_fan = Overall supply fan efficiency (= assumed 75, including fan, motor, and VFD efficiencies)

kW/bhp = Conversion from horsepower to watts (= 0.746)

RF+ EF_Multiplier = Total energy consumption of all fans is 175% of the energy consumption of just the supply fan. (= assumed 1.75)

hours/yr unoccupied = Unoccupied hours per year (=6,140)

T_VAV_Supply_Existing = Actual supply temperature of the air after passing through the VAV box

T_VAV_Supply_Proposed = Proposed supply temperature of the air after passing through the VAV box

Total Hours = Number of hours per year, per bin

Occupied Hours = Number of hours facility is occupied

Summer Coincident Peak Savings Algorithm

There are no peak savings from this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)

Sources

1. Grumman Butkus. “Greening the OR Symposium.” Presentation. September 11, 2014.
2. The American Society for Healthcare Engineering. Operating Room HVAC Setback Strategies. 2011. http://www.ashe.org/resources/management_monographs/pdfs/mg2011love.pdf
3. ANSI/ASHRAE/ASHE 170-2008 Ventilation of Healthcare Facilities
4. ASHRAE 90.1-2007 Energy Standard for Buildings Except Low-Rise Residential Buildings
5. ASHRAE 62.1-2007 Ventilation for Acceptable Indoor Air Quality
6. Historical Program Data- four similar projects done under other measure names

Historical Focus on Energy Surgery HVAC Projects

App ID	Project Cost	Square Footage
249844	$29,980.00	1,800
74147	$25,050.00	3,912
118592	$29,514.00	3,600
199725	$75,640.00	4,520

7. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
8. Roberts, John, B. Tso. "Do Savings from Retrocommissioning Last? Results from an Effective Useful Life Study." 2010 ACEEE Summer Study on Energy Efficiency in Buildings. (2010). http://aceee.org/files/proceedings/2010/data/papers/1990.pdf

Revision History

Version Number	Date	Description of Change
01	03/2015	Initial TRM entry
02	10/2017	Updated EUL

Energy Recovery Ventilator

	Measure Details
Measure Master ID	Energy Recovery Ventilator, 2314 Energy Recovery Ventilator, Sensible Only, 5082
Workpaper ID	W0052
Measure Unit	Per CFM
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Energy Recovery
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	Varies
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	Varies
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$6.85[2]

Measure Description

This measure is installing an energy recovery ventilator (ERV) on an HVAC system that provides both heating and cooling to occupied space. ERV systems exchange heat (often both sensible heat and water vapor) between outgoing exhaust air and incoming ventilation air. Under appropriate conditions, this allows for reducing the capacity of the HVAC system, which creates energy savings. Heat and energy recovery wheels are the most commonly applied ERV systems.

Description of Baseline Condition

The baseline is an HVAC system with the same facility operating hours, heating and cooling equipment efficiencies, and supply airflow CFM but without an energy recovery ventilator installed.

Description of Efficient Condition

The efficient condition is an ERV installed on the HVAC system. MMID 2314 is for ERVs that recover both sensible and latent heat, while MMID 5082 is for ERVs that only recover sensible heat. The system must both heat and cool the space, with minimum cooling hours from 1:00 p.m. to 4:00 p.m., June through August, and with heating occurring in the winter. Three additional specifications must be met:

- The leaving supply airflow matches (or is less than) AHRI standard 1060-2005. If the supply airflow is less than AHRI rated value, use the 75% airflow effectiveness ratings or interpolate between 75% and 100% as appropriate.

- Equipment is AHRI certified to standard 1060-2005 and bears the AHRI certification symbol for the air-to-air recovery ventilation equipment certification program based on AHRI 106.
- Qualifying equipment is independently tested and reported per ASHRAE standard 84-1991.

Annual Energy-Savings Algorithm

Savings were calculated as the sum of iterations over the full range of temperatures (-30°F to 100°F), broken into five-degree intervals. The total savings account for the distribution of the number of hours for each temperature interval.

When in cooling, the savings for each temperature interval are calculated as:

$kWh_{SAVED} = \Sigma\ (\Delta kWh_{TEMP\text{-}INTERVAL})$

For sensible and latent energy recovery ventilators:

$\Delta kWh_{TEMP\text{-}INTERVAL} = [\rho_{AIR} * 60 * CFM_{SUPPLY} * \eta_{HX\text{-}SUMMER} * (h_{OUT} - h_{RETURN}) / (EFF_{COOL} * 1{,}000) - kW_{FAN}] * t_{TEMP\text{-}INTERVAL}$

For sensible only energy recovery ventilators:

$\Delta kWh_{TEMP\text{-}INTERVAL} = [\rho_{AIR} * 60 * 0.24 * CFM_{SUPPLY} * \eta_{HX\text{-}SUMMER} * (T_{COOLED} - T_{OUTSIDE}) / (EFF_{COOL} * 1{,}000) - kW_{FAN}] * t_{TEMP\text{-}INTERVAL}$

For sensible and latent energy recovery ventilators:

$kW_{FAN} = CFM_{SUPPLY} * \Delta P_{HX} * 0.746 * 5.202 / (33{,}013 * \eta_{FANMECH} * \eta_{FANMOTOR})$

When in heating, the savings for each temperature interval are calculated as:

$Therm_{SAVED} = \Sigma\ (\Delta Therms_{TEMP\text{-}INTERVAL})$

$\Delta Therm_{TEMP\text{-}INTERVAL} = \rho_{AIR} * 60 * 0.24 * CFM_{SUPPLY} * \eta_{HX\text{-}WINTER} * (T_{HEATED\ SPACE} - T_{OUTSIDE}) / (100{,}000 * EFF_{HEAT}) * t_{TEMP\text{-}INTERVAL}$

Where:

ρ_{AIR} = Specific volume of air (ρ_{AIR} = 0.075 lb/cubic foot at 1 atm and 68°F)
60 = Conversion factor from hours to minutes
CFM_{SUPPLY} = Volume of supply air (= user input)
$\eta_{HX\text{-}SUMMER}$ = Efficiency of summer heat exchanger (= user input from AHRI data sheet)
h_{OUT} = Enthalpy of outside air in Btu per pound (= based on temperature interval)
h_{RETURN} = Enthalpy of inside air at 75°F and 50% relative humidity (= 28.3 Btu/lb)
EFF_{COOL} = Efficiency of cooling system, MBh per kilowatt (= user input, if unknown use 11.4 EER)[3]
1,000 = Conversion from Btu per hour to MBh

$t_{TEMP\text{-}INTERVAL}$ = Number of hours the system operates in the particular temperature interval

0.24 = Specfic heat of air, lb/°F

T_{COOLED} = Temperature inside cooled space (= 74°F; see Assumptions)

$T_{OUTSIDE}$ = Midpoint of the temperature interval outside, in Fahrenheit

ΔP_{HX} = Pressure drop across heat exchanger (= user input from AHRI data sheet, if unknown use 0.76 inches of water; see Assumptions)

0.746 = Conversion factor from horsepower to kilowatts

5.202 = Conversion factor from inches of water to pounds per square foot

33,013 = Conversion factor from horsepower to foot pounds per minute

$\eta_{FANMECH}$ = Fan mechanical efficiency (= 65%; see Assumptions)

$\eta_{FANMOTOR}$ = Fan motor efficiency (= actual, otherwise use default value of 89.5% for 5 hp fan motor; see Assumptions)

$\eta_{HX\text{-}WINTER}$ = Efficiency of summer heat exchanger (= user input from AHRI data sheet)

$T_{HEATED\ SPACE}$ = Temperature inside heated space (= 68°F; see Assumptions)

100,000 = Btu to therm conversion

EFF_{HEAT} = Efficiency of heating system as a percentage (= user input, if unknown use 82.9%)[4]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / HOU_{COOLING}$

Where:

$HOU_{COOLING}$ = Number of operating hours during cooling (= 1,258; see Assumptions)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

The kilowatt-hour calculation may result in negative kilowatt-hour savings, as the fan pressure drop penalty is applied over all operating hours (in both heating and cooling mode), while the cooling savings from the ERV only apply to a small percentage of the annual hours of operation. A typical space heating temperature of 68°F and space cooling temperature of 74°F were selected, based on ASHRAE Standard

55-2017,[5] which recommends 67°F to 82°F to maintain thermal comfort, and based on values from ENERGY STAR,[6] which recommends 68°F to 78°F.

A fan efficiency of 65% was selected based on engineering judgement and the ASHRAE Pocket Guide for Air Conditioning Heating Ventilation and Refrigeration recommending 55% to 60% for fan efficiency. Fan motors for ERVs are typically small (under 10 hp) and are intended to overcome the pressure drop of the heat exchange media. An average value of 5 hp was assumed, which corresponds to an efficiency of 89.5% for a NEMA Premium 1,800 RPM totally enclosed, fan-cooled motor.

The default pressure drop across the heat exchanger was determind based on AHRI data for air-to-air energy recovery ventilators packages. The highest and lowest values (1.38 and 0.15 inches of water) were excluded. The next highest and lowest values are 1.30 and 0.22 inches of water, with 0.76 as the midpoint.

All the assumptions used in the savings calculations, as listed in the definition of terms, are from the Focus on Energy Program Energy Recovery Ventilator Calculation input.[7]

The weather intervals and corresponding operating hours in the following tables were used to calculate the deemed savings values.[7] The weather data bins identified as cooling mode in this table total 1,258 hours of operation in cooling mode. This value was used for calculating the kilowatt demand reduction.

Weather Intervals and Corresponding Operating Hours

Temperature Range (°F)	Range Midpoint (°F)	Hours Operating in each Temperature Interval (hours)	Enthalpy (Btu/lb)
Cooling			
95 to 100	97.5	4.18	42.12
90 to 95	92.5	20.56	40.57
85 to 90	87.5	70.72	39.45
80 to 85	82.5	266.68	35.13
75 to 80	77.5	421.24	32.40
70 to 75	72.5	474.69	30.69

Temperature Range (°F)	Range Midpoint (°F)	Hours Operating in each Temperature Interval (hours)	Enthalpy (Btu/lb)
Heating			
65 to 70	67.5	698.74	28.33
60 to 65	62.5	877.28	25.22
55 to 60	57.5	574.89	21.97
50 to 55	52.5	642.02	19.17
45 to 50	47.5	466.10	17.11
40 to 45	42.5	639.90	15.06
35 to 40	37.5	859.58	12.95
30 to 35	32.5	730.96	10.99
25 to 30	27.5	429.07	9.13
20 to 25	22.5	507.80	7.61
15 to 20	17.5	388.02	5.87
10 to 15	12.5	229.07	4.04
5 to 10	7.5	147.38	2.53
0 to 5	2.5	95.69	1.30
-5 to 0	-2.5	93.43	0.08
-10 to -5	-7.5	79.95	-1.39
-15 to -10	-12.5	27.69	-2.52
-20 to -15	-17.5	9.57	-3.90
-25 to -20	-22.5	3.49	-4.86
-30 to -25	-27.5	1.31	-6.22

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 170 projects from May 2018 to July 2020.
3. Cadmus. *2016 Potential Study for Focus on Energy.* Data maintained by Cadmus and Public Service Commission of Wisconsin. Commercial site visits from the summer of 2016 to retail, restaurant, and small office sites. Average installed roof-top unit efficiency is 11.4 EER.
4. Cadmus. *2016 Potential Study for Focus on Energy.* Data maintained by Cadmus and Public Service Commission of Wisconsin. Commercial site visits from the summer of 2016 to retail, restaurant, and small office sites. Average installed boiler efficiency is 85.5% and average installed roof-top unit heating efficiency is 80.3%. The midpoint of these two efficiencies is 82.9%.

5. American Society of Heating Refrigerating and Air-Cconditioning Engineers. *Standard 55: Thermal Environmental Conditions for Human Occupancy*. 2017. https://ashrae.iwrapper.com/ASHRAE_PREVIEW_ONLY_STANDARDS/STD_55_2017
6. U.S. Department of Energy. “Energy Saver Thermostat.” Accessed November 20, 2020. https://www.energy.gov/energysaver/thermostats
7. Franklin Energy. Focus on Energy Program Energy Recovery Ventilator Calculator.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	12/2018	Updated incremental cost
03	10/2020	Added sensible-only ERV measure

ECM HVAC Fan Motors

	Measure Details
Measure Master ID	ECM HVAC Fan Motors, Heating, 3910 ECM HVAC Fan Motors, Cooling, 3911 ECM HVAC Fan Motors, Occupied Ventilation, 3912 ECM HVAC Fan Motors, 24/7 Ventilation, 3913
Workpaper ID	W0054
Measure Unit	Per horsepower
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Motors and Drives
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	18[1,2]
Incremental Cost ($/unit)	$120.00 per motor[3]

Measure Description

This measure is for the installation of an electronically commutated motor (ECM) with ≥1 hp on air handling equipment such as exhaust fans, fan coil units, VAV boxes, and cabinet heaters. These are typically induction motors and are covered by NEMA standards. Residential type furnaces with an ECM are excluded from this measure, as they are covered by other measures (MMIDs 1981, 2764, 3491, and 3492). Single package vertical units for multifamily (MMIDs 3693, 3694) are also excluded.

Description of Baseline Condition

The baseline condition is an existing shaded pole (SP) or permanent split capacitor (PSC) motor that is 1 hp or less.

Description of Efficient Condition

The efficient condition is an ECM that is an equivalent size to the motor being replaced.

Annual Energy-Savings Algorithm

Savings are determined by converting the motor horsepower to kW, multiplying by inverse of the difference in motor efficiencies, and multiplying by the hours of use for the specific type of equipment.

This will allow a “units of measure” question to be used to enter the motor horsepower and generate accurate savings for the variety of motor sizes available for this technology.

$kWh_{SAVED} = hp * 0.746 * (1/Eff_{BASE} - 1/Eff_{EE}) * HOU$

Where:

hp = Horsepower of the motor being replaced (= customer provided)
0.746 = Conversion factor from horsepower to kW
Eff_{BASE} = Motor efficiency of baseline technology (= 36.25%)[3]
Eff_{EE} = Motor efficiency for the ECM (= 70.0%)[3]
HOU = Average annual hours of operation (= varies by motor application and sector; see table below)

Hours of Use by Fan Type and Sector

Fan Type	Sector	Hours of Use
Heating Fan[4]	All	2,285
Cooling Fan[4]	All	678
Occupied Ventilation	Commercial[5]	3,730
	Industrial[5]	4,745
	Agriculture[5]	4,698
	Schools and Government[5]	3,239
	Residential-Multifamily (common areas)[6]	5,950
24/7 Ventilation	All	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = hp * 0.746 * (1/Eff_{BASE} - 1/Eff_{EE}) * CF$

Where:

CF = Coincidence factor (= varies by fan type; see table below)

Coincidence Factor by Fan Type

Fan Type	Coincidence Factor
Heating Fan[7]	0.0
Cooling Fan[6]	0.8
Occupied Ventilation[8]	0.9
24/7 Ventilation[9]	1.0

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 18 years)[1,2]

Deemed Savings

For select standard fractional horsepower motors, the amount of savings from upgrading to an ECM are outlined in the following tables.

Demand Reduction by Fan Type

Baseline Horsepower	Proposed Horsepower	Heating Fan kW Reduced	Cooling Fan kW Reduced	Occupancy Vent kW Reduced	24/7 Vent kW Reduced
1.0	1.0	0.000	0.7938	0.8930	0.9922

Annual Energy Savings by Fan Type

Baseline hp	Proposed hp	Fan kWh Saved		Occupancy Vent kWh Saved					24/7 Vent kWh Saved
		Heating	Cooling	Comm	Indust	Ag	S&G	MF	
1.0	1.0	2,267	673	3,701	4,708	4,661	3,214	5,904	8,692

Lifecycle Energy Savings by Fan Type

Baseline hp	Proposed hp	Fan kWh Saved		Occupancy Vent kWh Saved					24/7 Vent kWh Saved
		Heating	Cooling	Comm	Indust	Ag	S&G	MF	
1.0	1.0	40,806	12,114	66,618	84,744	83,898	57,852	106,272	156,456

Assumptions

A 50%/50% average of SP efficiency (30%) and PSC efficiency (42.5%) was used for the baseline motor efficiency (i.e., 36.25%), based on engineering judgment. Program project data collection will include motor type and size, which will be used to adjust this assumption, if appropriate.

Heating fan includes cabinet heaters, unit heaters, and heating-only fan coil units.

Cooling fan includes cooling-only fan coil units.

Occupied ventilation includes any equipment that is normally on during occupied hours all year, regardless of season. This includes fan powered VAV boxes, fan coil units that provide both heating and cooling, and exhaust fans with timer controls to only run during occupied hours.

24/7 ventilation includes any items that run continuously year round. Typically this would be exhaust fans without controls, but may also include fan powered VAV boxes and fan coil units for facilities that operate 24/7.

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Sachs, Harvey and S. Smith. “Saving Energy with Efficient Residential Furnace Air Handlers: A Status Report and Program Recommendations.” ACEEE report A033. p. 9. May 1, 2003. http://aceee.org/research-report/a033
3. Navigant Consulting Inc. “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment.” Table 2.1, p. 5, Section 2.4.3, p. 16, and Table 4.10, p. 49. Prepared for U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. December 4, 2013. http://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
   SP efficiency is the midpoint of 20 – 40% range listed in Table 2.1.
   PSC efficiency is the midpoint of 35 – 50% range listed in Section 2.4.3.
   ECM efficiency is the fractional horsepower efficiency of 70% listed in Section 2.4.3.
4. Appendix B: Common Variables, Heating and Cooling Degree Days. Converted HDD to hours using process for MMID 3275, and CDD to hours using process for MMIDs 3494 to 3505.
5. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
   The savings are based on the assumption that lighting hours equal building occupancy hours when ventilation would also be needed.
6. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
7. Engineering judgement.
   By definition of the measure, the motor only operates during the heating season, making the peak demand coincidence factor = 0.
8. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/
   DEER model runs were weather normalized for statewide use by population density.

9. Engineering judgement.
   By definition of the measure, the motor operates continuously, making the peak demand coincidence factor = 1.0.

Revision History

Version Number	Date	Description of Change
01	09/13/2016	Initial TRM entry

A/C Split or Packaged System, High Efficiency

	Measure Details
Measure Master ID	A/C Split or Packaged System, High Efficiency: ≥ 5.42 to < 11.25 tons, 4368 ≥ 11.25 to < 20.00 tons, 4369 ≥ 20.00 to < 63.33 tons, 4370 ≥ 63.33 tons, 4371
Workpaper ID	W0055
Measure Unit	Per DX Cooling Unit
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Rooftop Unit / Split System AC
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$1,025.44 (MMID 4368)[2,8] $1,749.75 (MMID 4369)[2,8] $1,083.06 (MMID 4370)[2,8] $2,742.68 (MMID 4371)[2,8]

Measure Description

This measure is installing high-efficiency, unitary packaged, and split air conditioning equipment that is ≥ 65,000 Btu/hr (5.42 tons). This measure applies to replacing an existing unit at the end of its useful life or installing a new unit in a new or existing building.

Description of Baseline Condition

The baseline equipment for new construction or where new equipment is required by code is a standard efficiency packaged or split air conditioner that meets the 2015 IECC energy efficiency requirements. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

Baseline Equipment for New Construction

Size of Standard AC Unit	Minimum Efficiency[3]			
	Electric Resistance Heat		All Other Heat (including natural gas)	
≥ 65 and < 135 kBtu/hour (≥ 5.42 to < 11.25 tons)	11.2 EER	12.8 IEER	11.0 EER	12.6 IEER
≥ 135 and < 240 kBtu/hour (≥ 11.25 to < 20.00 tons)	11.0 EER	12.4 IEER	10.8 EER	12.2 IEER
≥ 240 and < 760 kBtu/hour (≥ 20.00 to < 63.33 tons)	10.0 EER	11.6 IEER	9.8 EER	11.4 IEER
≥ 760 kBtu/hour (≥ 63.33 tons)	9.7 EER	11.2 IEER	9.5 EER	11.0 IEER

The baseline equipment for existing buildings is a standard efficiency packaged or split air conditioner that meets the 2012 IECC energy efficiency requirements. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

Baseline Equipment for Existing Building

Size of Standard AC Unit	Minimum Efficiency[4]			
	Electric Resistance Heat		All Other Heat (including Natural Gas)	
≥ 65 and < 135 kBtu/hour (≥ 5.42 to < 11.25 tons)	11.2 EER	11.4 IEER	11.0 EER	11.2 IEER
≥ 135 and < 240 kBtu/hour (≥ 11.25 to < 20.00 tons)	11.0 EER	11.2 IEER	10.8 EER	11.0 IEER
≥ 240 and < 760 kBtu/hour (≥ 20.00 to < 63.33 tons)	10.0 EER	10.1 IEER	9.8 EER	9.9 IEER
≥ 760 kBtu/hour (≥ 63.33 tons)	9.7 EER	9.8 IEER	9.5 EER	9.6 IEER

Description of Efficient Condition

The efficient equipment is a high-efficiency packaged air conditioner that exceeds the CEE Tier 1 energy efficiency requirements listed in the table below.

Efficient Equipment Requirements

Size of High-Efficiency AC Unit	Minimum to Qualify[5]
≥ 65 and < 135 kBtu/hour (≥ 5.42 to < 11.25 tons)	12.0 EER and 13.8 IEER
≥ 135 and < 240 kBtu/hour (≥ 11.25 to < 20.00 tons)	12.0 EER and 13.0 IEER
≥ 240 and < 760 kBtu/hour (≥ 20.00 to < 63.33 tons)	10.3 EER and 12.1 IEER
≥ 760 kBtu/hour (≥ 63.33 tons)	9.7 EER and 11.4 IEER

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (CAP * 12) * (1 / IEER_{BASE} – 1 / IEER_{EE}) * EFLH_{COOL}$

Where:

CAP = Rated cooling capacity of the energy-efficient unit (tons)

12 = Conversion factor from tons to MBh

$IEER_{BASE}$ = Integrated energy efficiency ratio of standard efficiency code baseline unit in Btu/watt-hour

$IEER_{EE}$ = Integrated energy efficiency ratio of efficient unit in Btu/watt-hour

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410 for multifamily; = 599 for commercial, industrial, agriculture, and schools & government; see tables below)

Multifamily Equivalent Full-Load Cooling Hours by Location

Location	$EFLH_{COOL}$[6]	Weighting by Participant
Green Bay	344	22%
La Crosse	323	3%
Madison	395	18%
Milwaukee	457	48%
Wisconsin Average	380	9%
Overall	**410**	

Commercial, Industrial, Agriculture, and Schools & Government
Equivalent Full-Load Cooling Hours by Building Type

Building Type	$EFLH_{COOL}$[7]
College	877
Food Sales	749
Food Service	578
Healthcare	803
Hotel/Motel	663
Industrial	519
Office	578
Other	589
Public Assembly	535
Public Services (non-food)	535
Retail	567
School	439
Warehouse	358
Average	**599**

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (CAP * 12) * (1 / EER_{BASE} – 1 / EER_{EE}) * CF$

Where:

CF = Coincidence factor (= 80%)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=15 years)[1]

Deemed Savings

The measure is hybrid and savings will vary; the tables below list reference savings values for various capacities. The data below are based on the assumption that equipment has natural gas heat for baseline EER value. Actual savings will vary.

Reference Savings Values by Capacity: Multifamily New Construction, Natural Gas Heat

Capacity (Btu/hour)	EER$_{BASE}$	EER$_{EE}$	IEER$_{BASE}$	IEER$_{EE}$	MMID	kWh$_{SAVED}$	kW$_{SAVED}$	kWh$_{LIFECYCLE}$
100,000	11.0	12.0	12.6	13.8	4368	255	0.61	3,820
187,000	10.8	12.0	12.2	13.0	4369	349	1.39	5,235
500,000	9.8	10.3	11.4	12.1	4370	936	1.98	14,044
800,000	9.5	9.7	11.0	11.4	4371	942	1.39	14,124

Reference Savings Values by Capacity: Multifamily Retrofit, Natural Gas Heat

Capacity (Btu/hour)	EER$_{BASE}$	EER$_{EE}$	IEER$_{BASE}$	IEER$_{EE}$	MMID	kWh$_{SAVED}$	kW$_{SAVED}$	kWh$_{LIFECYCLE}$
100,000	11.0	12.0	11.2	13.8	4368	621	0.61	9,311
187,000	10.8	12.0	11.0	13.0	4369	968	1.39	14,515
500,000	9.8	10.3	9.9	12.1	4370	3,388	1.98	50,826
800,000	9.5	9.7	9.6	11.4	4371	4,855	1.39	72,829

Reference Savings Values by Capacity: Commercial, Industrial, Agriculture, and Schools & Government New Construction, Natural Gas Heat

Capacity (Btu/hour)	EER$_{BASE}$	EER$_{EE}$	IEER$_{BASE}$	IEER$_{EE}$	MMID	kWh$_{SAVED}$	kW$_{SAVED}$	kWh$_{LIFECYCLE}$
100,000	11.0	12.0	12.6	13.8	4368	372	0.61	5,581
187,000	10.8	12.0	12.2	13.0	4369	510	1.39	7,648
500,000	9.8	10.3	11.4	12.1	4370	1,368	1.98	20,518
800,000	9.5	9.7	11.0	11.4	4371	1,376	1.39	20,635

Reference Savings Values by Capacity: Commercial, Industrial, Agriculture, and Schools & Government Retrofit, Natural Gas Heat

Capacity (Btu/hour)	EER$_{BASE}$	EER$_{EE}$	IEER$_{BASE}$	IEER$_{EE}$	MMID	kWh$_{SAVED}$	kW$_{SAVED}$	kWh$_{LIFECYCLE}$
100,000	11.0	12.0	11.2	13.8	4368	907	0.61	13,603
187,000	10.8	12.0	11.0	13.0	4369	1,414	1.39	21,206
500,000	9.8	10.3	9.9	12.1	4370	4,950	1.98	74,256
800,000	9.5	9.7	9.6	11.4	4371	7,093	1.39	106,401

Assumptions

A default value of 0.90 was assumed for the rated load factor.

The reference savings values were calculated for hypothetical units with capacities equal to the midpoint of each interval found in the IECC 2012 or 2015 standard, except for units ≥ 760 kBtu/hour (which used 800 kBtu/hour). Business savings uses 599 average full load hours from the table above.

The efficient condition cooling performance criteria were set using the “All Other” Heating Section Type (i.e., not “Electric Resistance (or None)” performance rating), as most DX cooling measures are assumed to be rooftop units with gas heating.

These measures are set up in SPECTRUM with a unit of measure question of “Enter Total Unit Incentive”, which was done to facilitate the variable incentive that is based on the amount above the required minimum efficiency for the DX cooling unit. To convert the incremental cost per ton[2] to a per DX cooling unit incremental cost, the average tons per MMID from 2018 historical Focus on Energy data was used[8]. This results in the following incremental cost per DX Cooling unit:

Size Category	MMID	# of Applications	Average Capacity (tons)[8]	Incremental Cost ($/ton)[2]	Incremental Cost ($/DX Cooling Unit)
DX Cooling ≥ 5.42 to < 11.25 tons	4368	25	8.08	$126.84	$1,025.44
DX Cooling ≥ 11.25 to < 20.00 tons	4369	25	13.79	$126.84	$1,749.75
DX Cooling ≥ 20.00 to < 63.33 tons	4370	10	28.63	$37.83	$1,083.06
DX Cooling ≥ 63.33 tons	4371	1	72.50	$37.83	$2,742.68

Sources

1. PA Consulting Group. *State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study.* Final Report. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Northeast Energy Efficiency Partnerships and Navigant. *NEEP Incremental Cost Study Phase Three Final Report.* May 28, 2014. Table 10. http://www.neep.org/sites/default/files/resources/NEEP%20ICS3%20Report%20FINAL%202014%20June%2022_0.pdf
   Used CEE Tier 2 values.
3. International Code Council. *2015 International Energy Conservation Code*. Table C403.2.3(1). 2015. https://codes.iccsafe.org/content/IECC2015
4. International Code Council. *2012 International Energy Conservation Code*. Table 403.2.3(1). 2012. https://codes.iccsafe.org/content/IECC2012

5. Consortium for Energy Efficiency. *High Efficiency Commercial Air Conditioning and Heat Pump Initiative*. Appendix B, p. 40-41. May 30, 2018. https://library.cee1.org/system/files/library/13655/Final_2018_CEE_HECAC_Initiative_Description.pdf
   Values for "Heating Section Type" = "All Other."
6. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
7. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
   DEER model runs were weather normalized for statewide use by population density.
8. Historical Focus on Energy project data. SPECTRUM. January 1, 2018 to December 31, 2018. Business Incentive, Ag Schools and Government, and Large Energy User programs had 113 projects with 187 DX cooling units, of which 61 projects and 122 DX cooling units had capacity information entered in the Actual Capacity field in SPECTRUM.

Revision History

Version Number	Date	Description of Change
01	10/07/2015	Initial TRM entry
02	12/15/2015	Revised per evaluator comments
03	11/10/2017	Updated to standardize offer across business and multifamily programs
04	01/2019	Updated efficient EER requirements, measure unit, costs
05	10/2020	Corrected sources #3 and #4

A/C Split System, ≤ 65 MBh, SEER 16/17/18/19/20

	Measure Details
Measure Master ID	A/C Split System, ≤ 65 MBh: SEER 16, 4737 SEER 17, 4738 SEER 18, 4739 SEER 19, 5069 SEER 20, 5070 A/C Single Package, ≤ 65 MBh: SEER 16, 4741 SEER 17, 4742 SEER 18, 4743 SEER 19, 5071 SEER 20, 5072
Workpaper ID	W0056
Measure Unit	Per ton
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Rooftop Unit / Split System AC
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by SEER level and application type
Peak Demand Reduction (kW)	Varies by SEER level and application type
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by SEER level and application type
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure, see Incremental Costs by Measure table[2]

Measure Description

A split-system air conditioner has a compressor and condenser located outside the building, and has an evaporator mounted inside the building in an air handler or blower. The system is connected by pipes that cycle refrigerant between the two heat exchangers. Energy savings result from installing a more efficient unit than the market standard. Additional savings are incurred because the unit must be installed with proper refrigerant charge and airflow. Proper adjustment of the refrigerant charge and airflow results in more efficient operation. Installation by a qualified contractor and regular servicing are required to maintain proper refrigerant charge and airflow.

Description of Baseline Condition

For split system air conditioners, the baseline condition is a SEER 13 unit for new construction[3] and a SEER 13 unit for existing buildings.[3] For single package air conditioners, the baseline condition is a SEER 14 unit for new construction[3] and a SEER 13 unit for existing buildings.[4]

Description of Efficient Condition

The efficient condition for both a split system and single package units is an air conditioning split system ≤ 65 MBh (5.42 tons) with SEER 16 or greater. Split system air conditioners must have both the condenser and evaporator coils replaced.

The condenser model, evaporator model, and AHRI reference number are required for all installations.

All capacity and efficiency ratings will be verified using the AHRI database.[5]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (CAP * 12) * (1 / SEER_{BASE} – 1 / SEER_{EE}) * EFLH_{COOL}$

Where:

CAP = Rated cooling capacity of the energy-efficient unit (tons)

12 = Conversion factor from tons to MBh

$SEER_{BASE}$ = Seasonal energy efficiency rating of baseline unit (= 14 for single package new construction,[3] = 13 for single package retrofits and all split systems[4])

$SEER_{EE}$ = Seasonal energy efficiency rating of efficient unit (=16, 17, 18, 19, or 20)

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410 for multifamily, = 599 for business; see tables below)

Multifamily Equivalent Full-Load Cooling Hours by Location

Location	$EFLH_{COOL}$[6]	Weighting by Participant
Green Bay	344	22%
La Crosse	323	3%
Madison	395	18%
Milwaukee	457	48%
Wisconsin Average	380	9%
Overall	**410**	

Commercial, Industrial, Agriculture, and Schools & Government Equivalent Full-Load Cooling Hours by Building Type

Building Type	$EFLH_{COOL}$[7]
College	877
Food Sales	749
Food Service	578
Healthcare	803
Hotel/Motel	663
Industrial	519
Office	578
Other	589
Public Assembly	535
Public Services (non-food)	535
Retail	567
School	439
Warehouse	358
Average	**599**

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (CAP * 12) * (1 / EER_{BASE} – 1 / EER_{EE}) * CF$

Where:

EER_{BASE} = Energy efficiency rating of baseline unit (= 11.2 for SEER 13 unit, = 11.8 for 14 SEER unit)

EER_{EE} = Energy efficiency rating of efficient unit (= 12.8 for 16 SEER unit, = 13.1 for 17 SEER unit, = 13.7 for 18 SEER unit, = 14.1 for 19 SEER unit, = 14.4 for 20 SEER unit)

CF = Coincidence factor (= 0.80)[8]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Deemed Savings per Ton by MMID and Sector

Sector	Equipment Type	Retrofit or New Construction	SEER	MMID	Savings (kW)	Annual Savings (kWh)	Lifecycle Savings (kWh)
Multifamily	Split System	Both	16	4737	0.109	71	1,065
			17	4738	0.135	89	1,335
			18	4739	0.157	105	1,575
			19	5069	0.176	120	1,800
			20	5070	0.192	132	1,980
	Packaged System	Retrofit	16	4741	0.109	71	1,065
			17	4742	0.135	89	1,335
			18	4743	0.157	105	1,575
			19	5071	0.176	120	1,800
			20	5072	0.192	132	1,980
		New Construction	16	4741	0.066	44	660
			17	4742	0.092	62	930
			18	4743	0.115	78	1,170
			19	5071	0.134	92	1,380
			20	5072	0.150	105	1,575
Commercial, Industrial, Agriculture, Schools & Government	Split System	Both	16	4737	0.109	104	1,560
			17	4738	0.135	130	1,950
			18	4739	0.157	154	2,310
			19	5069	0.176	175	2,625
			20	5070	0.192	194	2,910
	Packaged System	Retrofit	16	4741	0.109	104	1,560
			17	4742	0.135	130	1,950
			18	4743	0.157	154	2,310
			19	5071	0.176	175	2,625
			20	5072	0.192	194	2,910
		New Construction	16	4741	0.066	64	960
			17	4742	0.092	91	1,365
			18	4743	0.115	114	1,710
			19	5071	0.134	135	2,025
			20	5072	0.150	154	2,310

Assumptions

The additional savings incurred from proper adjustment of the refrigerant charge and airflow is highly variable and was unaccounted for in the savings algorithm.

SEER values were converted to EER (for calculating kilowatt savings) based on EER = (-0.02 * SEER^2) + 1.12 * SEER.[9]

Incremental costs per ton for split systems was determined by using costs for 3-ton units in the Itron workbook, which shows installed costs for many SEER levels. Incremental costs per ton for packaged systems were determined by extrapolating cost increases for SEER levels from 12 to 14, and averaging between new construction and retrofit baselines.

The following table shows incremental costs for each measure.

Incremental Costs by Measure

Measure	MMID	Incremental Cost (per ton)[2]
A/C Split System, ≤ 65 MBh, SEER 16	4737	$276.38
A/C Split System, ≤ 65 MBh, SEER 17	4738	$368.51
A/C Split System, ≤ 65 MBh, SEER 18	4739	$460.63
A/C Split System, ≤ 65 MBh, SEER 19	5069	$552.76
A/C Split System, ≤ 65 MBh, SEER 20	5070	$644.89
A/C Single Package, ≤ 65 MBh, SEER 16	4741	$1,257.35
A/C Single Package, ≤ 65 MBh, SEER 17	4742	$1,789.32
A/C Single Package, ≤ 65 MBh, SEER 18	4743	$2,321.29
A/C Single Package, ≤ 65 MBh, SEER 19	5071	$2,853.26
A/C Single Package, ≤ 65 MBh, SEER 20	5072	$3,385.24

Sources

1. PA Consulting Group. *State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study*. Final Report. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Itron. *Ex Ante Measure Cost Study results Matrix, Volume I: Hedonic Model Estimates, Version 1.7*. Spreadsheet “NR HW Heater WA017 MCS Results Matrix Volume I August 2016.” https://energy.mo.gov/about/trm/supporting-documents
Equipment + Labor tab, rows 152 through 175 for split system costs and rows 224 through 235 for packaged system costs.
3. International Code Council. *2015 International Energy Conservation Code.* Table C403.2.3(1). 2015. https://codes.iccsafe.org/public/document/IECC2015/chapter-4-ce-commercial-energy-efficiency
4. International Code Council. *2012 International Energy Conservation Code*. Table C403.2.3(1). 2012. https://codes.iccsafe.org/public/document/IECC2012
5. Air-Conditioning, Heating, and Refrigeration Institute. “Directory of Certified Product Performance.” www.ahridirectory.org

6. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
7. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
   DEER model runs were weather normalized for statewide use by population density.
8. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
9. Robert Hendron and Cheryn Engebrecht, National Renewable Energy Lab. *Building America House Simulation Protocols.* October 2010. Page 7. https://www.nrel.gov/docs/fy11osti/49246.pdf

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	11/2017	Updated common structure across business, small business, and multifamily sectors
03	12/2018	Added separate baselines for split system and single package equipment. Updated incremental costs.
04	10/2020	Retired SEER 15, added SEER 19 and 20

A/C Split System, Condensing Unit Only, High Efficiency

	Measure Details
Measure Master ID	A/C Split System, Condensing Unit Only, High Efficiency, 3909
Workpaper ID	W0057
Measure Unit	Per ton
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Rooftop Unit / Split System AC
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by capacity
Peak Demand Reduction (kW)	Varies by capacity
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by capacity
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$82.34[7]

Measure Description

This measure is installing a high-efficiency condensing unit as part of a split system air conditioning system. This measure applies to replacing an existing unit at the end of its useful life or installing a new unit in a new or existing building. This measure covers "condensing unit only" replacements where the coil and air handling unit (AHU) are not replaced at the same time, and new installations of custom-built split system air conditioners that do have the AHU, coil, and condensing unit combination listed in AHRI. These types of systems are a better fit for IECC's condensing unit minimum efficiency requirements, as the manufacturer data is rated as "condensing unit only," and generally appears to be higher than a "complete system" or "matched air handler" rating that includes the condensing unit, AHU, and cooling coil together.

Description of Baseline Condition

The baseline equipment for existing buildings is a standard efficiency condensing unit that meets the 2006 IECC energy efficiency requirements. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

Standard air-cooled condensing unit ≥ 135,000 Btu/hr = 10.1 EER[2]

The baseline equipment for new construction or where new equipment is required by code is a standard efficiency condensing unit that meets the 2009 IECC energy efficiency requirements. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

Standard air-cooled condensing unit ≥ 135,000 Btu/hr = 10.1 EER[3]

Description of Efficient Condition

The efficient equipment is a high-efficiency condensing unit that exceeds energy efficiency requirements listed below. The efficient condition is set at CEE Tier 2 levels, which offer between 7.6% and 10.0% peak kW savings over current federal minimum EER requirements.[4] A value of 9% was used to determine the savings, so a baseline of 10.1 EER / (1 – 0.09) = 11.1 EER.

Efficient air-cooled condensing unit ≥ 135,000 Btu/hr = 11.1 EER

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Capacity * 12{,}000 * RLF * EFLH_C * (1 / 1{,}000) * (1/EER_{BASE} – 1/EER_{EE})$

Where:

Capacity = Capacity (size) of the condensing unit in tons

12,000 = Btuh to tons conversion factor

RLF = Rated load factor; the peak cooling load/nameplate capacity. This factor compensates for oversizing of the air conditioning unit (= 0.90)

$EFLH_C$ = Equivalent full-load cooling hours (= varies by building type; see table below for default values)

1,000 = Kilowatt conversion factor

EER_{BASE} = Energy efficiency ratio of baseline condensing unit in Btu/watt-hour (= 10.1 EER)

EER_{EE} = Energy efficiency ratio of efficient condensing unit in Btu/watt-hour (= 11.1 EER or actual)

Cooling Equivalent Full Load Hours by Building Type

Building Type	$EFLH_C$[5]
College	877
Food Sales	749
Food Service	578
Healthcare	803
Hotel/Motel	663
Industrial	519
Office	578
Other	589
Public Assembly	535
Public Services (non-food)	535
Retail	567
School	439
Warehouse	358
Average	**599**

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = Capacity * (1 / 1,000) * CF * ($1/EER_{BASE}$ – $1/EER_{EE}$)

Where:

CF = Coincidence factor (= 0.8)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Though the measure is hybrid, reference savings values for various capacities are listed in the table below. Actual savings will vary.

Reference Savings Values by Capacity

Capacity (Btuh)	EER_{BASE}	EER_{EE}	kWh_{BASE}	kWh_{EE}	kWh_{SAVED}	kW_{BASE}	kW_{EE}	kW_{SAVED}	$kWh_{LIFECYCLE}$
187,000	10.1	11.1	10,008	9,106	902	14.85	13.51	1.34	13,524
500,000	10.1	11.1	26,688	24,284	2,404	39.60	36.04	3.57	36,065
800,000	10.1	11.1	42,701	38,854	3,847	63.37	57.66	5.71	57,704

Assumptions

The average (mean) value for all building types was used to determine cooling EFLH.

A default value of 0.90 was assumed for the rated load factor.

The deemed savings values were calculated for hypothetical units with capacities equal to the midpoint of each interval found in the IECC 2009 standard, but the < 65,000 Btu/hr and 65,000 to 135,000 Btu/hr categories were excluded since the condensing unit only rating in the IECC only applies to ≥ 135,000 Btu/hr capacity.

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. International Energy Conservation Code. Table 503.2.3(6). 2006. https://law.resource.org/pub/us/code/ibr/icc.iecc.2006.pdf

3. International Energy Conservation Code. Table 503.2.3(6). 2009. http://codes.iccsafe.org/app/book/toc/2009/I-Codes/2009%20IECC%20HTML/index.html
4. Consortium for Energy Efficiency. “High Efficiency Commercial Air-conditioning and Heat Pumps Initiative.” Table 3, p. 26. January 12, 2016. https://library.cee1.org/sites/default/files/library/5347/CEE_2016_HECAC_Initiative_Description_and_Specification.pdf
5. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/
DEER model runs were weather normalized for statewide use by population density.
6. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. https://www.focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. Northeast Energy Efficiency Partnerships. “Incremental Cost Study Phase Three Final Report.” Table 10. May 2014. http://www.neep.org/incremental-cost-study-phase-3
Average of CEE Tier 2 values ($126.84 and $37.83)

Revision History

Version Number	Date	Description of Change
01	03/2017	Initial TRM entry

Air Source Heat Pump, ≤65 MBh

	Measure Details
Measure Master ID	Air-Source Heat Pump, ≤ 65 MBh: SEER 16 and 9.0 HSPF, 4745 SEER 17 and 9.0 HSPF, 4746 SEER 18 and 9.0 HSPF, 4747 SEER 19 and 9.0 HSPF, 5073 SEER 20 and 9.0 HSPF, 5074
Workpaper ID	W0058
Measure Unit	Per ton
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Other
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therms Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therms Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/ton)	Varies by measure, see Incremental Costs by Measure table[2]

Measure Description

A split-system air-source heat pump has a compressor and condenser/evaporator located outside the building and has an evaporator/condenser mounted inside the building in an air handler or blower. The outside unit and inside unit are connected by pipes that carry refrigerant between the two heat exchangers. Packaged units contain compressors, the condenser, and the evaporator in the same equipment. Heat pumps use reversing valves to switch the roles of the evaporator and condenser. In cooling mode the outside condenser/evaporator operates as a condenser. In heating mode the outside condenser/evaporator operates as an evaporator. Energy savings result from installing a more efficient unit than the market standard.

Description of Baseline Condition

The baseline condition is an air cooled heat pump with a cooling capacity of 5.42 tons or less, a cooling efficiency of 14 SEER, and a heating efficiency of 8.2 HSPF for split systems and 8.0 HSPF for packaged systems[3] for both new construction and retrofits.

Description of Efficient Condition

The efficient condition is an air cooled heat pump with a cooling capacity of 5.42 tons or less, a cooling efficiency of 16, 17, 18, 19, or 20 SEER, and a heating efficiency of at least 9.0 HSPF for both split systems and packaged systems.

All capacity and efficiency ratings should be verified using the AHRI database.[4] For split systems, the AHRI capacity and efficiency ratings must be with the matched evaporator. Condensing unit only applications are not eligible.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{COOL} + kWh_{HEAT}$

$kWh_{COOL} = (CAP * 12) * [(1 / SEER_{BASE}) – (1 / SEER_{EE})] * EFLH_{COOL}$

$kWh_{HEAT} = (CAP * 12) * [(1 / HSPF_{BASE}) – (1 / HSPF_{EE})] * EFLH_{HEAT}$

Where:

CAP = Rated cooling capacity of the energy-efficient unit (tons)

12 = Conversion factor from tons to MBh

$SEER_{BASE}$ = Cooling seasonal energy efficiency rating of baseline unit (= 14 MBh per kilowatt)[3]

$SEER_{EE}$ = Seasonal energy-efficiency rating of efficient unit (16, 17, 18, 19, or 20)

$EFLH_{COOL}$ = Equivalent full-load hours in cooling mode (= 410 average for Wisconsin multifamily buildings, = 599 average for Wisconsin commercial buildings; see tables below)

$HSPF_{BASE}$ = Heating seasonal performance factor of baseline unit (= 8.2 MBh per kilowatt; see Assumptions)

$HSPF_{EE}$ = Heating seasonal performance factor of efficient unit (= 9.0 MBh per kilowatt)

$EFLH_{HEAT}$ = Equivalent full-load hours in heating mode (= 1,158 for multifamily,[5] = 1,890 average for Wisconsin commercial buildings; see table below)

Multifamily Equivalent Full-Load Cooling Hours by Location

Location	$EFLH_{COOL}$[5]	Weighting by Participant
Green Bay	344	22%
La Crosse	323	3%
Madison	395	18%
Milwaukee	457	48%
Wisconsin Average	380	9%
Overall	**410**	

Commercial, Industrial, Agriculture, and Schools & Government Cooling Equivalent Full-Load Cooling Hours by Building Type

Building Type	$EFLH_{COOL}$[6]
College	877
Food Sales	749
Food Service	578
Healthcare	803
Hotel/Motel	663
Industrial	519
Office	578
Other	589
Public Assembly	535
Public Services (non-food)	535
Retail	567
School	439
Warehouse	358
Average	**599**

Supporting Inputs for Equivalent Full-Load Heating Hours by City for Business

Location	$EFLH_{HEAT}$[7]	Weighting by Participant
Green Bay	1,852	22%
Lacrosse	1,966	3%
Madison	1,934	18%
Milwaukee	1,883	48%
Wisconsin Average	1,909	9%
Weighted Average	**1,890**	**100%**

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (CAP * 12) * [(1 / EER_{BASE}) – (1 / EER_{EE})] * CF$

Where:

EER_{BASE} = $-0.02 * SEER_{BASE}$^2 + 1.12 * $SEER_{BASE}$ in MBh per kilowatt[8]

EER_{EE} = $-0.02 * SEER_{EE}$^2 + 1.12 * $SEER_{EE}$ in MBh per kilowatt[8]

CF = Coincidence factor (= 0.80)[9]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Deemed Savings per Ton

Type	MMID	Savings (kW)	Annual Savings (kWh)	Lifecycle Savings (kWh)
Multifamily				
16 SEER	4745	0.0663	195	2,925
17 SEER	4746	0.0923	213	3,195
18 SEER	4747	0.1146	229	3,435
19 SEER	5073	0.1335	243	3,645
20 SEER	5074	0.1497	256	3,840
Business				
16 SEER	4745	0.0663	310	4,650
17 SEER	4746	0.0923	336	5,040
18 SEER	4747	0.1146	360	5,400
19 SEER	5073	0.1335	381	5,715
20 SEER	5074	0.1497	400	6,000

Assumptions

Incremental costs per ton were determined by averaging incremental costs per ton for both split systems and packaged systems, across sizes specified in the Itron workbook.[2] Cost data was available up to 16 SEER for split systems and up to 15 SEER for packaged systems. Costs for higher SEER units for each system type were determined by linear extrapolation.

The heating seasonal performance factor of the baseline unit is 8.2 for split systems and 8.0 for packaged systems.[3] Since this measure does not distinguish between the two system types, the more conservative value (8.2) was used.

Incremental Costs by Measure

Measure	MMID	Incremental Cost (per ton)[2]
Air-Source Heat Pump, ≤ 65 MBh, SEER 16 and 9.0 HSPF	4745	$276.19
Air-Source Heat Pump, ≤ 65 MBh, SEER 17 and 9.0 HSPF	4746	$419.65
Air-Source Heat Pump, ≤ 65 MBh, SEER 18 and 9.0 HSPF	4747	$563.12
Air-Source Heat Pump, ≤ 65 MBh, SEER 19 and 9.0 HSPF	5073	$706.58
Air-Source Heat Pump, ≤ 65 MBh, SEER 20 and 9.0 HSPF	5074	$850.05

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Revision History

Version Number	Date	Description of Change
01	12/31/2018	Initial TRM entry
02	10/2020	Removed 15 SEER, add 19 and 20 SEER

HVAC Chiller

	Measure Details
Measure Master ID	Chiller, Air Cooled: < 150 tons, Path A, 4712 ≥ 150 tons, Path A, 4713 < 150 tons, Path B, 4714 ≥ 150 tons, Path B, 4715 Chiller, Water Cooled, Positive Displacement: < 75 tons, Path A, 4716 ≥ 75 and < 150 tons, Path A, 4717 ≥ 150 and < 300 tons, Path A, 4718 ≥ 300 and < 600 tons, Path A, 4719 ≥ 600 tons, Path A, 4720 < 75 tons, Path B, 4721 ≥ 75 and < 150 tons, Path B, 4722 ≥ 150 and < 300 tons, Path B, 4723 ≥ 300 and < 600 tons, Path B, 4724 ≥ 600 tons, Path B, 4725 Chiller, Water Cooled, Centrifugal: < 150 tons, Path A, 4726 ≥ 150 and < 300 tons, Path A, 4727 ≥ 300 and < 400 tons, Path A, 4728 ≥ 400 and < 600 tons, Path A, 4729 ≥ 600 tons, Path A, 4730 < 150 tons, Path B, 4731 ≥ 150 and < 300 tons, Path B, 4732 ≥ 300 and < 400 tons, Path B, 4733 ≥ 400 and < 600 tons, Path B, 4734 ≥ 600 tons, Path B, 4735
Workpaper ID	W0059
Measure Unit	Per ton
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Chiller
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure

	Measure Details
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Air Cooled and Water Cooled, Positive Displacement: 20[1] Water Cooled, Centrifugal = 23[8]
Incremental Cost ($/unit)	Varies by measure,[2] see Chiller Incremental Cost table

Measure Description

Chillers are used for commercial and industrial space cooling applications in order to provide adequate temperature control via chilled water. The proposed measure applies to the replacement of less efficient chillers with more efficient chillers that supply the same amount of cooling.

Description of Baseline Condition

The baseline condition is a chiller that meets the minimum efficiencies described by 2015 IECC.[3] It is assumed that new chillers are installed when the existing unit has failed or is at the end of its useful life.

Baseline Chiller Efficiency[3]

Size	MMIDs	kW / ton			
		Path A		Path B	
		Full	Part (IPLV)	Full	Part (IPLV)
Air Cooled					
< 150 tons	4712, 4714	1.190	0.880	1.240	0.760
≥150 tons	4713, 4715	1.190	0.860	1.240	0.750
Water Cooled, Positive Displacement					
< 75 tons	4716, 4721	0.750	0.600	0.780	0.500
≥ 75 and < 150 tons	4717, 4722	0.720	0.560	0.750	0.490
≥ 150 and < 300 tons	4718, 4723	0.660	0.540	0.680	0.440
≥ 300 and < 600 tons	4719, 4724	0.610	0.520	0.625	0.410
≥ 600 tons	4720, 4725	0.560	0.500	0.585	0.380
Water Cooled, Centrifugal					
< 150 tons	4726, 4731	0.610	0.550	0.695	0.440
≥ 150 and < 300 tons	4727, 4732	0.610	0.550	0.635	0.400
≥ 300 and < 400 tons	4728, 4733	0.560	0.520	0.595	0.390
≥ 400 and < 600 tons	4729, 4734	0.560	0.500	0.585	0.380
≥ 600 tons	4730, 4735	0.560	0.500	0.585	0.380

Chillers designed for Path A are optimized at full load, so the full-load efficiency is lower while the part-load efficiency remains at code level. Chillers designed for Path B are optimized at part load, so the part-load efficiency is lower while the full-load efficiency remains at code level. An efficiency reduction of 0.03 kW/ton was selected as the “better than code” amount based on review of 2018 chiller projects to date. Focus on Energy has historically offered incentives for a reduction of about 0.05 kW/ton or 0.06 kW/ton better than full-load efficiency of the old code, but this amount was reduced due to the baseline efficiency improvements in IECC's 2015 code update.

Chillers must be driven by an electric motor. Absorption chillers and engine or steam turbine driven chillers do not qualify.

Description of Efficient Condition

The efficient equipment is a chiller that meets or exceeds the full load efficiency and the part load efficiency listed in the table below.

Efficient Chiller Efficiency

Size	MMIDs	kW / ton			
		Path A		Path B	
		Full	Part (IPLV)	Full	Part (IPLV)
Air Cooled					
< 150 tons	4712, 4714	1.160	0.880	1.240	0.730
≥150 tons	4713, 4715	1.160	0.860	1.240	0.720
Water Cooled, Positive Displacement					
< 75 tons	4716, 4721	0.720	0.600	0.780	0.470
≥ 75 and < 150 tons	4717, 4722	0.690	0.560	0.750	0.460
≥ 150 and < 300 tons	4718, 4723	0.630	0.540	0.680	0.410
≥ 300 and < 600 tons	4719, 4724	0.580	0.520	0.625	0.380
≥ 600 tons	4720, 4725	0.530	0.500	0.585	0.350
Water Cooled, Centrifugal					
< 150 tons	4726, 4731	0.580	0.550	0.695	0.410
≥ 150 and < 300 tons	4727, 4732	0.580	0.550	0.635	0.370
≥ 300 and < 400 tons	4728, 4733	0.530	0.520	0.595	0.360
≥ 400 and < 600 tons	4729, 4734	0.530	0.500	0.585	0.350
≥ 600 tons	4730, 4735	0.530	0.500	0.585	0.350

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (IPLV_{BASE} – IPLV_{EE}) * LF * \text{Ton-hours}$

Where:

$IPLV_{BASE}$ = Integrated part-load value of baseline chiller in kW per ton (see Baseline Chiller Efficiency table above)

$IPLV_{EE}$ = Integrated part-load value of efficient chiller at AHRI conditions in kW per ton (= user input)

LF = Load factor (= 0.85)[4]

Ton-hours = Annual chiller load (= hours * efficient chiller capacity at AHRI conditions; see Assumptions)

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = (Full Load kW/ton_{BASE} – Full Load kW/ton_{EE}) * LF * Tons * CF

Where:

Full Load kW/ton_{BASE} = kW/ton full-load value of baseline chiller (see Baseline Chiller Efficiency table above)

Full Load kW/ton_{EE} = kW/ton full-load value of efficient chiller at AHRI conditions (= user input)

Tons = Capacity in tons of the efficient chiller at AHRI conditions (= user input)

CF = Coincidence factor (= 0.8)[5]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 20 years)[1]

Assumptions

The incremental measure cost was calculated in two steps. First, ratios of incremental costs to efficient costs are calculated from a 2013 incremental cost study from Northeast Energy Efficiency Partnership.[2] Second, these ratios are applied to actual costs recorded from historical Focus on Energy project data.

Based on a 2021 benchmarking effort, the EUL is deemed to be 20 years for Air Cooled chillers and and Water Cooled, Positive Displacement chillers. A preponderance of sources listed centrifugal chiller EUL as 25 years, and there may be some merit to this because of their generally larger size. An EUL of 23 years, from the Illionois TRM,[8] is deemed for these.

For developing the incremental to efficient cost ratios, the closest chiller efficiencies to the program baseline and efficient condition were selected, then the cost for sizes in the range for the MMID were used directly (or averaged if more than one size was available). For Path B, the baseline and efficient condition full-load kW/ton are the same (the part-load kW/ton varies). The cost reference, however, only has cost by varying full-load kW/ton, so the incremental cost for Path B was assumed to be the same as that for Path A. Results can be seen in the Chiller Cost Ratios table.

Chiller Cost Ratios

Measure	Path A MMID	Path B MMID	Closest IC Information					Incremental / Efficient Cost Ratio
			Tonnage of Chiller from Cost Source	Baseline kW/ton	Baseline $/ton	Efficient kW/ton	Efficient $/Ton	
Air Cooled								
< 150	4712	4714	Avg 50, 100	1.212	$172	1.141	$526	67.3%
≥ 150	4713	4715	Avg 150, 200, 400	1.212	$49	1.141	$149	67.3%
Water Cooled, Positive Displacement								
< 75	4716	4721	Avg 50, 100	0.78	$0	0.720	$57	39.7%
≥ 75 to < 150	4717	4722	100	0.72	$38	0.680	$63	37.7%
≥ 150 to < 300	4718	4723	200	0.68	$61	0.640	$122	50.0%
≥ 300 to < 600	4719	4724	400	0.64	$61	0.600	$92	33.7%
≥ 600	4720	4725	400	0.64	$61	0.600	$92	33.7%
Water Cooled, Centrifugal								
< 150	4726	4731	100	0.60	$73	0.580	$110	33.6%
≥ 150 to < 300	4727	4732	Avg 150, 200	0.60	$43	0.580	$64	32.8%
≥ 300 to < 400	4728	4733	300	0.58	$91	0.540	$152	40.1%
≥ 400 to < 600	4729	4734	600	0.58	$46	0.540	$76	39.5%
≥ 600	4730	4735	600	0.58	$46	0.540	$76	39.5%

These ratios were then applied to Focus on Energy cost data from January 2018 through July 2020.[7] For measures that did not have usage in this time period, an overall ratio of costs was applied. Results can be seen in the Chiller Incremental Costs table.

Chiller Incremental Costs

Measure	Path A MMID	Path B MMID	Incremental / Efficient Cost Ratio	SPECTRUM Data, January 2018 - July 2020		Incremental Cost
				Total Tons	Cost / Ton	
Air Cooled						
< 150	4712	4714	67.3%	2,657	$673	$453.12
≥ 150	4713	4715	67.3%	4,883	$482	$323.56
Water Cooled, Positive Displacement						
< 75	4716	4721	39.7%	0*	0*	$164.29*
≥ 75 to < 150	4717	4722	37.7%	0*	0*	$7.062*
≥ 150 to < 300	4718	4723	50.0%	2,852	$479	$239.52
≥ 300 to < 600	4719	4724	33.7%	13,290	$368	$123.86
≥ 600	4720	4725	33.7%	13,290	$368	$123.86

Measure	Path A MMID	Path B MMID	Incremental / Efficient Cost Ratio	SPECTRUM Data, January 2018 - July 2020		Incremental Cost
				Total Tons	Cost / Ton	
Water Cooled, Centrifugal						
< 150	4726	4731	33.6%	0*	0*	$106.65*
≥ 150 to < 300	4727	4732	32.8%	559	$747	$245.06
≥ 300 to < 400	4728	4733	40.1%	2,852	$479	$239.52
≥ 400 to < 600	4729	4734	39.5%	600	$400	$157.89
≥ 600	4730	4735	39.5%	600	$400	$157.89

*Because no recent data was available for these measures, a ratio of the total updated incremental costs to the total previous incremental costs, 288%, was applied to the previous incremental costs for these measures.

Ton-hours were calculated by first determining a linear load profile for the chiller, with 100% load occurring at 95°F, the design ambient temperature for chillers at their rated capacity, and with the low end point at 40% load occurring at an outside air temperature equal to the chiller lock-out temperature. Below this, it was assumed that the air-side economizer handles cooling load. Then, using Wisconsin population weighted bin weather data, the ton-hours for each weather bin were calculated by multiplying the calculated tons by the number of hours in that bin. For temperature bins over the 95°F design temperature, the tons were limited to the chiller maximum capacity.

Population Weighting Percentages

Location	Weighting by Location
Green Bay	22%
Lacrosse	3%
Madison	18%
Milwaukee	48%
Average	**9%**

Temperature bin hours, population weighted for the state of Wisconsin, are listed in the table below. The four cities account for 91% of the population. The hours used for the remaining 9% of the population are the average of the four cities.

Bin Hours[6]

Temperature Range	Green Bay	LaCrosse	Madison	Milwaukee	Average	Weighted Average
95°F to 100°F	0	7	0	5	3	**3**
90°F to 95°F	22	46	25	16	27	**21**
85°F to 90°F	62	121	86	59	82	**68**
80°F to 85°F	275	355	339	225	299	**267**

Temperature Range	Green Bay	LaCrosse	Madison	Milwaukee	Average	Weighted Average
75°F to 80°F	398	445	486	400	432	**419**
70°F to 75°F	445	489	447	497	470	**474**
65°F to 70°F	675	762	723	692	713	**698**
60°F to 65°F	871	746	770	936	831	**877**
55°F to 60°F	647	583	605	545	595	**584**
50°F to 55°F	543	615	597	679	609	**626**
45°F to 50°F	404	444	491	471	453	**457**
40°F to 45°F	579	597	510	723	602	**638**
35°F to 40°F	777	826	905	883	848	**859**
30°F to 35°F	820	719	741	720	750	**748**
25°F to 30°F	507	425	396	423	438	**438**
20°F to 25°F	579	457	439	531	502	**520**
15°F to 20°F	443	319	353	390	376	**392**
10°F to 15°F	265	227	212	228	233	**234**
5°F to 10°F	178	208	164	125	169	**150**
0°F to 5°F	90	110	105	88	98	**93**
-5°F to 0°F	81	106	157	61	101	**88**
-10°F to -5°F	83	109	105	57	89	**76**
-15°F to -10°F	9	23	70	6	27	**21**
-20°F to -15°F	7	9	21	0	9	**6**
-25°F to -20°F	0	6	9	0	4	**2**
-30°F to -25°F	0	6	4	0	3	**1**

Sources

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Revision History

Version Number	Date	Description of Change
01	10/31/2018	Initial TRM entry
02	2/2021	Updated incremental costs

Packaged Terminal Heat Pumps (PTHPs)

	Measure Details
Measure Master ID	PTHP <8,000 Btu/h, 2699 PTHP 8,000–9,999 Btu/h, 2702 PTHP 10,000–12,999 Btu/h, 2701 PTHP ≥13,000 Btu/h, 2700
Workpaper ID	W0060
Measure Unit	Per PTHP
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Packaged Terminal Unit (PTAC, PTHP)
Sector(s)	Commercial, Schools & Government, Industrial, Agriculture, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	<8,000 Btu/h = $58 (MMID 2699), 8,000–9,999 Btu/h = $69 (MMID 2702), 10,000–12,999 Btu/h = $77 (MMID 2701), ≥13,000 Btu/h = $49 (MMID 2700)[2]

Measure Description

Packaged terminal heat pumps (PTHPs) are self-contained heating and air conditioning units typically found in hotel rooms and multifamily dwellings. They have supplemental electric resistance heaters for when the heat pump cannot provide sufficient heat.

Description of Baseline Condition

The baseline condition is a packaged terminal air conditioner (PTAC) unit with electric resistance heat and a cooling EER meeting the minimum guidelines in the table below.

Minimum Cooling Efficiency Requirements for Packaged Terminal Air Conditioners[3]

New Construction / Retrofit	Minimum Efficiency
New Construction	$EER = 14.0 - (0.300 * Cap_{COOL} / 1,000)$
Retrofit	$EER = 10.9 - (0.213 * Cap_{COOL} / 1,000)$

Baseline EER requirements, using the equations from the table above and an assumed size for each measure, are shown in the table below.

Minimum PTAC Cooling Efficiencies (EER)[3]

Size Range	MMID	Size (Btu/h) for Minimum Efficiency	New Construction	Retrofit
< 8,000 Btu/h	2699	7,000	11.90	9.41
8,000–9,999 Btu/h	2702	9,000	11.30	8.98
10,000–12,999 Btu/h	2701	12,000	10.40	8.34
≥ 13,000 Btu/h	2700	15,000	9.50	7.71

Retrofit efficiencies only apply to units with existing sleeves that are less than 16-inches tall and less than 42-inches wide. Retrofit units are factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." (emphasis in original)

Description of Efficient Condition

The efficient condition is a PTHP meeting the Focus on Energy minimum efficiencies. See Assumptions for details.

Minimum Efficiencies for Qualifying Equipment

Cooling Capacity Range	MMID	New Construction		Retrofit	
		EER	COP	EER	COP
< 8,000 Btu/h	2699	12.7	3.1	10.7	3.1
8,000–9,999 Btu/h	2702	12.1	3.0	10.4	3.0
10,000–12,999 Btu/h	2701	10.9	2.9	9.9	2.9
≥ 13,000 Btu/h	2700	10.3	2.9	9.3	2.9

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{COOL} + kWh_{HEAT}$

$kWh_{COOL} = EFLH_{COOL} * (Cap_{COOL} / 1{,}000) * [(1 / EER_{BASE}) - (1 / EER_{EE})]$

$kWh_{HEAT} = EFLH_{HEAT} * Cap_{COOL} * [(1 / COP_{BASE}) - (1 / COP_{EE})] / 3{,}412$

Where:

$EFLH_{COOL}$ = Equivalent full-load hours during cooling mode (= 410[4] for multifamily, 599 for business; see Assumptions)

Cap_{COOL} = Nominal cooling capacity in Btu/h (= user input)

EER_{BASE} = Energy efficiency ratio of baseline unit (= see Assumptions)

EER_{EE} = Energy efficiency ratio of energy-efficient unit (= see Description of Efficient Condition)

$EFLH_{HEAT}$ = Equivalent full-load hours during heating mode (= 711 for multifamily, 1,161 for business; see Assumptions)

COP_{BASE} = Coefficient of performance of baseline equipment (= 1.0; see Assumptions)

COP_{EE} = Coefficient of performance of energy-efficient equipment (= see Description of Efficient Condition)

3,412 = Btu per kWh conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Cap_{COOL} / 1{,}000) * [(1 / EER_{BASE}) - (1 / EER_{EE})] * CF$

Where:

CF = Coincidence factor (= 0.80)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

The energy savings are presented in the tables below.

Annual, Summer Coincident Peak, and Lifecycle Savings for Retrofits

Size Range	MMID	Multifamily			Business		
		kW	Annual kWh	Lifecycle kWh	kW	Annual kWh	Lifecycle kWh
< 8,000 Btu/h	2699	0.0718	1,025	15,375	0.0718	1,667	25,005
8,000–9,999 Btu/h	2702	0.1092	1,306	19,590	0.1092	2,123	31,845
10,000–12,999 Btu/h	2701	0.1808	1,731	25,965	0.1808	2,810	42,150
≥ 13,000 Btu/h	2700	0.2671	2,185	32,775	0.2671	3,543	53,145

Annual, Summer Coincident Peak, and Lifecycle Savings for New Construction

Size Range	MMID	Multifamily			Business		
		kW	Annual kWh	Lifecycle kWh	kW	Annual kWh	Lifecycle kWh
< 8,000 Btu/h	2699	0.0252	1,003	15,045	0.0296	1,635	24,525
8,000–9,999 Btu/h	2702	0.0358	1,272	19,080	0.0421	2,072	31,080
10,000–12,999 Btu/h	2701	0.0360	1,660	24,900	0.0423	2,706	40,590
≥ 13,000 Btu/h	2700	0.0834	2,098	31,470	0.0981	3,416	51,240

Assumptions

Minimum EER values for new construction for each size range were determined by finding an EER that at least three major manufacturers can meet based on data from AHRI.[5]

Minimum COP values for new construction were determined by rounding up from code minimum values for new construction. The formulas to determine the code minimum efficiencies are shown in the tables below for reference.

Code Minimum Heating Efficiency Requirements[3]

New Construction / Retrofit	Minimum Efficiency
New Construction	$COP = 3.2 – (0.026 * Cap_{COOL} / 1,000)$
Retrofit	$COP = 2.9 – (0.026 * Cap_{COOL} / 1,000)$

Minimum Heating Efficiency for Qualifying Equipment

Size Range	MMID	Size (Btu/h) for Minimum Efficiency	Retrofit		New Construction	
			Code	Program	Code	Program
< 8,000 Btu/h	2699	7,000	2.72	3.1	3.02	3.1
8,000–9,999 Btu/h	2702	9,000	2.67	3.0	2.97	3.0
10,000–12,999 Btu/h	2701	12,000	2.59	2.9	2.89	2.9
≥ 13,000 Btu/h	2700	15,000	2.51	2.9	2.81	2.9

Minimum EER values for retrofits for 2019 are equal to those in the 2018 Focus on Energy incentive catalog.

Minimum COP values for retrofits are equal to those for new construction.

Since the heat source for the baseline PTAC is an electric resistance heater, its COP = 1.0.Data for determining the equivalent full-load hours are presented in the tables below.

Supporting Inputs for Equivalent Full-Load Cooling Hours for Business Buildings

Building Type	$EFLH_{COOL}$[6]
College	877
Food Sales	749
Food Service	578
Healthcare	803
Hotel/Motel	663
Industrial	519
Office	578
Other	589
Public Assembly	535
Public Services (non-food)	535
Retail	567
School	439
Warehouse	358
Average	**599**

Supporting Inputs for Equivalent Full-Load Cooling Hours by City for Multifamily[7]

Location	$EFLH_{COOL}$	Weighting by Participant
Green Bay	344	22%
Lacrosse	323	3%
Madison	395	18%
Milwaukee	457	48%
Wisconsin Average	380	9%
Weighted Average	**410**	**100%**

Supporting Inputs for Equivalent Full-Load Heating Hours by City for Business[8]

Location	$EFLH_{HEAT}$	Weighting by Participant
Green Bay	1,852	22%
Lacrosse	1,966	3%
Madison	1,934	18%
Milwaukee	1,883	48%
Wisconsin Average	1,909	9%
Weighted Average	**1,890**	**100%**

$EFLH_{HEAT}$ values were adjusted to account for electric resistance heat when the outside temperature is below 40°F. The controls are assumed to run only the electric heater when the outside temperature is below 25°F, to run both the heat pump and electric heater between 25°F and 40°F, and to run only the heat pump above 40°F.[9] No heating is assumed above 65°F, the common base for heating degree days. Using average bin weather data for 20 Wisconsin locations, the heat pump is expected to operate 61.4% (= 4,245 / 6,914) of the hours when the temperature is below 65°F. The adjusted $EFLH_{HEAT}$ values are 1,158 hours[5] * 61.4% = 711 hours for multifamily and 1,890 hours * 61.4% = 1,161 hours for business.

Supporting Calculation for Electric Heat Adjustment

Temperature Range	Hours in Temperature Range	Heat Control	% Heat Pump Hours	Total Heat Pump Hours	% of Hours Below 65°F
40°F–65°F	3,274	Heat pump only	100%	3,274	47%
25°F–40°F	1,943	Heat pump + electric heater	50%	971	14%
<25°F	1,697	Electric heater only	0%	0	0%
Total	**6,914**	**-**	**-**	**4,245**	**61%**

Summary of Equivalent Full-Load Cooling and Heating Hours

Building Type	$EFLH_{COOL}$	$EFLH_{HEAT}$
Multifamily	410	711
Business	599	1,161

Average costs were determined by the following method:

1. Prices were collected for each size from four manufacturers (Amana, LG, Friedrich, and GE) from two sources (Grainger and Total Home Supply).
2. The lowest cost was determined for each size category and each manufacturer.
3. The lowest costs from the four manufacturers were averaged for each size.

This procedure was followed for PTHPs that meet the minimum efficiencies for the energy-efficient case, and again for PTACs for the baseline case. The incremental cost for each size is the average PTHP cost minus the average PTAC cost.

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Revision History

Version Number	Date	Description of Change
01	11/2018	Updated for 2019 – Changed baseline system from PTHP to PTAC with electric resistance heat. Updated efficiencies due to new energy code. Updated costs. Updated EFLHs.

Data Center and Telecom Cooling, ≤65 MBh

	Measure Details
Measure Master ID	Split System: SEER 16, <5.4 tons, Data Center/Telecom, 4769 SEER 17, <5.4 tons, Data Center/Telecom, 4770 SEER 18, <5.4 tons, Data Center/Telecom, 4771 SEER 19, <5.4 tons, Data Center/Telecom, 5075 SEER 20, <5.4 tons, Data Center/Telecom, 5076 Single Package: SEER 16, <5.4 tons, Data Center/Telecom, 4773 SEER 17, <5.4 tons, Data Center/Telecom, 4774 SEER 18, <5.4 tons, Data Center/Telecom, 4775 SEER 19, <5.4 tons, Data Center/Telecom, 5077 SEER 20, <5.4 tons, Data Center/Telecom, 5078
Workpaper ID	W0061
Measure Unit	Per ton
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Other
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therms Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therms Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/ton)	Varies by measure, see Incremental Costs section[2]

Measure Description

This measure is an efficient air conditioner serving a data center, telecom, or similar facility. A split-system air conditioner has a compressor and condenser located outside the building, and has an evaporator mounted inside the building in an air handler or blower. The system is connected by pipes that cycle refrigerant between the two heat exchangers. In single package systems, all refrigeration system components are in a single unit. Energy savings result from installing a more efficient unit than the market standard.

Description of Baseline Condition

The baseline condition for split systems is an air conditioner with a cooling capacity of 5.4 tons or less and a cooling efficiency of 13 SEER for new construction[3] or existing buildings.[4] The baseline condition for packaged systems is an air conditioner with a cooling capacity of 5.4 tons or less and a cooling efficiency of 14 SEER for new construction[3] and of 13 SEER for existing buildings.[4]

Description of Efficient Condition

The efficient condition for both split systems and packaged systems is an air conditioner with a cooling capacity of 5.4 tons or less and a cooling efficiency of at least 16 SEER.

The condenser model, evaporator model, and AHRI reference number are required for all installations. All capacity and efficiency ratings will be verified using the AHRI database.[5] For mini-split/ductless systems, the AHRI capacity and efficiency ratings must be with the matched evaporator. Condensing unit only mini-split/ductless applications are not eligible.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (CAP * 12) * LF * [(1 / SEER_{BASE}) – (1 / SEER_{EE})] * EFLH_{COOL}$

Where:

CAP = Rated cooling capacity of the energy-efficient unit, in tons (= user input)

12 = Conversion factor from tons to MBh

LF = Load factor (= 0.65)[6]

$SEER_{BASE}$ = Cooling seasonal energy efficiency rating of baseline unit, in MBh per kilowatt (= 14 for single package new construction,[3] = 13 for single package retrofits[4] and all split systems[3,4])

$SEER_{EE}$ = Seasonal energy efficiency rating of efficient unit, in MBh per kilowatt = 16 SEER for MMIDs 4769 and 4773, = 17 SEER for MMIDs 4770 and 4774, = 18 SEER for MMIDs 4771 and 4775, = 19 SEER for MMIDs 5075 and 5077, = 20 SEER for MMIDs 5076 and 5078)

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 8760; see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (CAP * 12) * LF * [(1 / EER_{BASE}) – (1 / EER_{EE})] * CF$

Where:

EER_{BASE} = Energy efficiency rating of baseline unit (= 11.2 for SEER 13 unit, = 11.8 for 14 SEER; see Assumptions)

EER_{EE} = Energy efficiency rating of efficient unit = 12.8 for 16 SEER, = 13.1 for 17 SEER, = 13.7 for 18 SEER, 14.1 for 19 SEER, 14.4 for 20 SEER; see Assumptions)

CF = Coincidence factor (= 1.0)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Deemed Savings per Ton

Type	MMID	Savings (kW)	Annual Savings (kWh)	Lifecycle Savings (kWh)
Split Systems				
16 SEER	4769	0.0883	986	14,790
17 SEER	4770	0.1094	1,237	18,555
18 SEER	4771	0.1275	1,460	21,900
19 SEER	5075	0.1429	1,660	24,900
20 SEER	5076	0.1560	1,840	27,600
Packaged Systems, Existing Buildings				
16 SEER	4773	0.0883	986	14,790
17 SEER	4774	0.1094	1,237	18,555
18 SEER	4775	0.1275	1,460	21,900
19 SEER	5077	0.1429	1,660	24,900
20 SEER	5078	0.1560	1,840	27,600
Packaged Systems, New Construction				
16 SEER	4773	0.0539	610	9,150
17 SEER	4774	0.0750	861	12,915
18 SEER	4775	0.0931	1,085	16,275
19 SEER	5077	0.1085	1,284	19,260
20 SEER	5078	0.1216	1,464	21,960

Assumptions

Data centers, telecom, and similar facilities require cooling year round. Systems smaller than 5.42 tons typically do not have any air-side or water-side economizers, so the equivalent full load cooling hours ($EFLH_{COOL}$) is 8,760 hours per year. The load factor accounts for equipment oversizing.

SEER values were converted to EER (for calculating kilowatt savings) based on EER = (-0.02 * SEER^2) + 1.12 * SEER.[7]

The baseline cooling efficiencies are the current code (2015 IECC) for new construction and the previous code (2009 IECC) for retrofits.

The coincidence factor is assumed to be 1.0 because the cooling load is constant year round, so it does not change any during the peak period. The load factor accounts for equipment cycling due to oversizing.

Incremental Costs

The incremental costs per ton for split systems were determined by using costs for 3-ton units in the Itron workbook, which shows installed costs for many SEER levels. Incremental costs per ton for packaged systems were determined for higher SEER levels by extrapolating cost increases for SEER 12 to SEER 14. Incremental costs were relative to 13 SEER for split systems and packaged systems in existing buildings, and relative to 14 SEER for packaged systems in new construction. For packaged systems, incremental costs per ton were averaged between new construction and retrofit baselines.

Incremental Costs by Measure and Delivery

Measure	MMID	Incremental Cost (per ton)[2]
A/C Split System, ≤ 65 MBh, SEER 16	4769	$276.38
A/C Split System, ≤ 65 MBh, SEER 17	4770	$368.51
A/C Split System, ≤ 65 MBh, SEER 18	4771	$460.63
A/C Split System, ≤ 65 MBh, SEER 19	5075	$552.76
A/C Split System, ≤ 65 MBh, SEER 20	5076	$644.89
A/C Single Package, ≤ 65 MBh, SEER 16	4773	$1,257.35
A/C Single Package, ≤ 65 MBh, SEER 17	4774	$1,789.32
A/C Single Package, ≤ 65 MBh, SEER 18	4775	$2,321.29
A/C Single Package, ≤ 65 MBh, SEER 19	5077	$2,853.26
A/C Single Package, ≤ 65 MBh, SEER 20	5078	$3,385.24

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Revision History

Version Number	Date	Description of Change
01	12/2018	Initial TRM entry
02	10/2020	Retired 15 SEER measures, added 19 and 20 SEER measures.

Energy-Efficient Drycooler for Data Center

	Measure Details
Measure Master ID	Energy-Efficient Drycooler for Data Center, 2305
Workpaper ID	W0062
Measure Unit	Per ton
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Economizer
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Electricity Savings (kWh)	Varies by ton
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by ton
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$4,882.57[2]

Measure Description

This measure is installing a water-side economizer system that is automatically controlled to enable economizer (free cooling) operation based on outside air temperature. When the outdoor temperature is below a certain value, air conditioning compressors can be turned off.

Description of Baseline Condition

The baseline condition is direct expansion (DX) computer room air conditioning (CRAC) units with no water-side economizer. The system—including CRAC fan, compressor, and condenser fans—operates continuously the entire year to meet the continuous data center cooling load. DX CRAC units with existing economizers or non-functioning economizers do not qualify.

Description of Efficient Condition

The efficient condition is adding a water-side economizer to the DX CRAC unit, which consists of a fluid (typically glycol) loop with a cooling coil in the CRAC unit, a dry cooler outside, and a fluid loop circulating pump. The CRAC unit fan continues to circulate air through the data center. The pressure drop through the added fluid loop cooling coil adds to the static pressure requirement for the CRAC unit fan. The compressor and condenser fans do not operate when the temperature outside is below its enable/disable setpoint temperature (such as 35°F).

Above the drycooler’s enable/disable setpoint temperature (such as 65°F), the fluid loop does not operate and the DX system operates as in the baseline condition. Between these enable/disable setpoint temperatures, when both the drycooler and the compressor are allowed to operate, the fluid loop system provides as much cooling as it can, while the DX system makes up the difference. The fluid loop circulation pump and drycooler fans use less power than the DX system compressor, which saves energy.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{BASE} – kWh_{EE}$

kWh_{BASE} = Cap * Σ[(LF * $Eff_{COOL,BASE}$ + $P_{CRAC,BASE}$) * HOU] for each temperature bin

kWh_{EE} = Cap * Σ[(LF * $Eff_{COOL,EE}$ + $P_{CRAC,EE}$ + P_{PUMP} + P_{DC}) * HOU] for each temperature bin

$P_{CRAC,BASE} = HP_{CRAC} * 0.746 * MLF_{CRAC,BASE} / Eff_{CRAC}$

$P_{CRAC,EE} = HP_{CRAC} * 0.746 * MLF_{CRAC,EE} / Eff_{CRAC}$

$P_{PUMP} = HP_{PUMP} * 0.746 * MLF_{PUMP} / Eff_{PUMP}$

$P_{DC} = HP_{DC} * 0.746 * MLF_{DC} / Eff_{DC}$

Where:

Cap = Installed cooling capacity of DX split system serving CRAC unit in tons (= user input)

LF = Average load factor on DX cooling system (= 0.65)[3]

$Eff_{COOL,BASE}$ = Air cooled condensing unit efficiency in kilowatts per ton (= user input; otherwise use 1.64 kW/ton per Assumptions)

$P_{CRAC,BASE}$ = CRAC unit fan power per ton without the glycol coil in kW/ton

HP_{CRAC} = CRAC fan horsepower per ton (= user input; otherwise use 0.42 hp/ton per Assumptions)

0.746 = Conversion from horsepower to kilowatts

$MLF_{CRAC,BASE}$ = Motor load factor for CRAC fan without glycol cooling coil (= 0.8; see Assumptions)

EFF_{CRAC} = CRAC fan motor efficiency (= 0.91; see Assumptions)

HOU = Number of hours in temperature bin (= varies with temperature; see Assumptions)

$P_{CRAC,EE}$ = CRAC unit fan power per ton with the glycol coil in kW/ton

$MLF_{CRAC,EE}$ = Motor load factor for CRAC fan with glycol cooling coil (= 0.85; see Assumptions)

P_{PUMP} = Glycol pump power per ton in kW/ton

HP_{PUMP} = Glycol pump horsepower per ton (= user input; otherwise use 0.09 hp/ton per Assumptions)

MLF_{PUMP} = Glycol pump motor load factor (= 0.8; see Assumptions)

Eff_{PUMP} = Glycol pump motor efficiency (= 0.85; see Assumptions)

P_{DC} = Dry cooler fan power per ton in kW/ton

HP_{DC} = Drycooler total fan horsepower per ton (= user input; otherwise use 0.24 hp/ton per Assumptions below)

MLF_{DC} = Motor load factor for drycooler fans (= 0.80; see Assumptions)

Eff_{DC} = Drycooler fan motor efficiency (= 0.65; see Assumptions)

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

At temperatures other than rated condition, down to a minimum condenser temperature of 65°F,[5] the DX cooling system efficiency is calculated using standardized energy modeling equations published by COMNET,[4] a program to standardize building energy modeling that is managed by New Buildings Institute. The cooling system efficiency remains constand below 65°F. Greater detail of savings algorithm inputs can be found in the workbook associated with this workpaper. Motor load factors are assumed to be 0.85 for the CRAC fan in the energy-efficient case and 0.80[6] for other motors. The load factor for the CRAC fan is higher in the energy-efficient case compared to the baseline case to account for the pressure drop from the glycol coil. The value of 0.85 is based on engineering judgement.

The minimum outside air for ventilation is 0 CFM.

Fan and pump powers per ton and motor efficiency were determined from manufacturer data[7,8] and are presented in the table below. These will be used if the actual horsepower of the components are not provided on the application.

Fan and Pump Power per Ton and Efficiency

Equipment	Power	Power Units	Motor Efficiency
CRAC Supply Fan	0.42	hp/ton	95%
Compressor	1.64	kW/ton	-
Condenser Fans	0.15	kW/ton	-
Drycooler Fans	0.24	kW/ton	-
Glycol Pump	0.09	hp/ton	85%

Between 35°F and 65°F, the fraction of the cooling load met by the DX cooling system varies linearly from 0 (off) at 35°F and 1.0 (always on) at 65°F.

Weather data was population weighted using the weighting factors shown in the following table.

Population Weighting Percentages

Location	Weighting by Location
Green Bay	22%
Lacrosse	3%
Madison	18%
Milwaukee	48%
Other (4-City Average)	9%

The four cities account for 91% of the state's population. The values used for the remaining 9% of the state are the averages of the four cities.

Temperature bin hours, population weighted for the state of Wisconsin, are listed in the table below.

Temperature Bin Hours[9]

Temperature Range	Green Bay	LaCrosse	Madison	Milwaukee	Four-City Average	Weighted Average
95°F to 100°F	0	7	0	5	3	3
90°F to 95°F	22	46	25	16	27	21
85°F to 90°F	62	121	86	59	82	68
80°F to 85°F	275	355	339	225	299	267
75°F to 80°F	398	445	486	400	432	419
70°F to 75°F	445	489	447	497	470	474
65°F to 70°F	675	762	723	692	713	698
60°F to 65°F	871	746	770	936	831	877
55°F to 60°F	647	583	605	545	595	584
50°F to 55°F	543	615	597	679	609	626
45°F to 50°F	404	444	491	471	453	457
40°F to 45°F	579	597	510	723	602	638

Temperature Range	Green Bay	LaCrosse	Madison	Milwaukee	Four-City Average	Weighted Average
35°F to 40°F	777	826	905	883	848	**859**
30°F to 35°F	820	719	741	720	750	**748**
25°F to 30°F	507	425	396	423	438	**438**
20°F to 25°F	579	457	439	531	502	**520**
15°F to 20°F	443	319	353	390	376	**392**
10°F to 15°F	265	227	212	228	233	**234**
5°F to 10°F	178	208	164	125	169	**150**
0°F to 5°F	90	110	105	88	98	**93**
-5°F to 0°F	81	106	157	61	101	**88**
-10°F to -5°F	83	109	105	57	89	**76**
-15°F to -10°F	9	23	70	6	27	**21**
-20°F to -15°F	7	9	21	0	9	**6**
-25°F to -20°F	0	6	9	0	4	**2**
-30°F to -25°F	0	6	4	0	3	**1**

Sources

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Revision History

Version Number	Date	Description of Change
01	02/28/2019	Initial TRM entry

Steam Trap Repair, < 10 psig, General Heating

	Measure Details
Measure Name and ID	Steam Trap Repair, <10 psig, General Heating, Prescriptive: 7/32" or Smaller, 4004, 4648 1/4", 4005, 4649 5/16", 4006, 4650 3/8" or Larger, 4007, 4651
Workpaper ID	W0063
Measure Unit	Per steam trap
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Steam Trap
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure, see table below
Lifecycle Electricity Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure, see table below
Water Savings (gal/year)	0
Effective Useful Life (years)	6[1]
Incremental Cost ($/unit)	$102.28[2]

Measure Description

Steam distribution systems contain steam traps, which are automatic valves that remove condensate, air, and other non-condensable gases while preventing or minimizing steam loss. This measure is the repair of failed open and leaking steam traps on steam systems supplying space heating only.

Steam traps that fail in the open position allow steam to escape into the condensate lines before the available heat energy can be used for space heating, wasting the energy used to make the steam. By replacing or repairing traps that have failed in the open position, the wasted heating energy can be conserved.

The measure specifications are as follows:

- Boiler must be used for space heating, not process applications
- Repaired traps must be leaking steam, not be failed in the closed position or plugged
- The incentive is available once per year per system
- Municipal steam systems do not qualify
- When mass replacing steam traps, 20% of traps replaced will qualify
- System pressure must be < 10 psig

A steam trap survey and repair log must be completed. The information required to determine savings includes a trap identification tag number, location description, nominal steam pressure, trap type, trap condition (functioning, failed open, or failed closed), and trap orifice diameter.

Description of Baseline Condition

The measure baseline is a steam trap that has failed in the open position and is leaking steam into the condensate line in a steam system. The steam from the boiler must be used for space heating and not for process applications. It is important to note that the trap must be failed in the open position and not be failed in the closed position or plugged.

Description of Efficient Condition

The efficient condition is replacing or repairing traps that have failed in the open position, providing the ability to use steam heat that was previously wasted.

Annual Energy-Savings Algorithm

$\text{Therm}_{SAVED} = 1.9 * K * 60 * (\pi \ast D^2/4) * \surd([P_{ABS} - \{P_1 - P_2\}] * [P_1 - P_2]) * h_{FG} * HOU * DF / (100{,}000 * eff)$

Where:

1.9 = Constant based on units and fluid flow equation[3]

K = Discharge coefficient (= 0.55)[4]

60 = Conversion from minutes to hours

D = Steam trap orifice diameter (= 7/32-inches, 1/4-inches, 5/16-inches, or 3/8-inches)

P_{ABS} = System absolute pressure in pounds per square inch (= 20.7 psia; steam gage pressure at trap inlet (6 psig) + atmospheric pressure at sea level in pounds per square inch (14.7 psi))[5]

P_1 = Steam pressure at trap inlet (= 6 psig)[5]

P_2 = Steam pressure at trap outlet, condensate tank pressure (= 0 psig)

h_{FG} = Latent heat of steam at system absolute pressure (= 959 Btu/lb)[6]

HOU = Annual hours of operation the boiler is on and the system is at design pressure (= 5,510)[7]

DF = Derating factor to account for the average percentage of time the trap fails in the open position and actual versus theoretical energy loss (= 5.9%)[5]

100,000 = Conversion factor from Btu to therms

eff = Boiler efficiency (= 80%)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure, as it does not generate electric savings.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 6 years)[1]

Deemed Savings

Deemed Savings

Measure Name	MMID	Energy Savings (therms)	
		Annual	Lifecycle
Steam Trap Repair, < 10 psig, General Heating, 7/32-inches or Smaller	4004	86	517
Steam Trap Repair, < 10 psig, General Heating, 1/4-inches	4005	113	676
Steam Trap Repair, < 10 psig, General Heating, 5/16-inches	4006	176	1,056
Steam Trap Repair, < 10 psig, General Heating, 3/8-inches or Larger	4007	253	1,521

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 158 projects and 2,831 steam traps for MMIDs 4004, 4005, 4006, 4007, 4648, 4649, 4650, 4651 from March 2018 to July 2020 is $102.28.
3. Hornaday, William T. “Steam: Its Generation and Use.” Equation 50. Merchant Books, 2007. http://www.gutenberg.org/files/22657/22657-h/chapters/flow.html#page_321
   This formula applies for subsonic flow, which occurs when steam flows through an orifice where $P_2 \geq 58\%$ of P_1.
4. Manczyk Energy Consulting. “Estimating the Cost of Steam Loss Through the Orifice of a Steam Trap.” http://invenoinc.com/file/Estimating-the-Steam-Loss-through-a-Orifice-of-a-Steam-Trap.pdf
   The discharge coefficient was determined by converging flow rates with the Napier equation at $P_2 = 0.58 * P_1$. The Napier equation is used to determine flow rate through an orifice when $P_2 \leq 0.58 * P_1$. The Napier equation is in fact Equation 49 in source 3, with an added discharge coefficient of 0.6. Matching Equation 50 in source 3 to the Napier formula in the link above, at $P_2 = 0.58 * P_1$, produces this equality: $1.9 * (\pi/4 * D^2) * K * \sqrt{([P_1 - 0.42 * P_1] * 0.42 * P_1)} * 60 =$

24.24 * P_1 * D^2. Note that 60 is inserted to convert lb/min to lb/hr, and that P_1 and P_2 are treated as absolute pressures. Solving this produces K = 0.55.

5. Cadmus. “Focus on Energy Steam Trap Study.” 2016. Unpublished.
   The study determined realized savings from billing data for 35 sites that had applied for steam trap incentives during the 2012 to 2014 program years. This study revealed 6 psig as the weighted average pressure of < 10 psig steam traps surveyed.
   These sites had an overall realization rate of billing data results to calculated savings (using algorithms in this workpaper with site-specific values and the previous derating factor of 50%) of 11.8%, suggesting that a derating factor of 5.9% would be more appropriate. Note: the 50% derating factor came from: Enbridge Steam Saver Program. 2005.
6. The Engineering Toolbox. “Properties of Saturated Steam - Imperial Units.” http://www.engineeringtoolbox.com/saturated-steam-properties-d_273.html
7. Appendix B. Outside Air Temperature Bin Analysis table.
   PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
   Since HOU is dependent on trap type, a weighted average HOU was calculated for this measure. Approximately 10% of traps are float-and-thermostatic type traps (Wisconsin TRM v1.0). These are under pressure whenever the boiler is operating, an estimated nine months or 6,570 hours per year. The remaining 90% of traps are thermostatic and are under pressure only when the building is in heating, approximately 5,392 hours per year according to the Outside Air Temperature Bin Analysis table in Appendix B. These values produce a weighted average of 5,510 hours per year.

Revision History

Version Number	Date	Description of Change
01	1/2017	Initial workpaper
02	5/2018	Adjusted derating factor to 5.9%
03	12/2020	Updated costs

Steam Trap Repair, > 10 psig, General Heating

	Measure Details
Measure Master ID	Steam Trap Repair, 10-49 psig, General Heating, Prescriptive: 7/32” or Smaller, 4008 1/4”, 4009 5/16”, 4010 3/8” or Larger, 4011 Steam Trap Repair, 50-124 psig, General Heating, Prescriptive: 7/32” or Smaller, 4012 1/4”, 4013 5/16”, 4014 3/8” or Larger, 4015 Steam Trap Repair, >125psig, General Heating, Prescriptive: 7/32” or Smaller, 4944 1/4”, 4945 5/16”, 4946 3/8” or Larger, 4947
Workpaper ID	W0064
Measure Unit	Per system psi, absolute
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Steam Trap
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure, see algorithm below
Lifecycle Electricity Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure, see algorithm below
Water Savings (gal/year)	0
Effective Useful Life (years)	6[1]
Incremental Cost ($/unit)	Varies by measure, see table below

Measure Description

Steam distribution systems contain steam traps, which are automatic valves that remove condensate, air, and other non-condensable gases while preventing or minimizing steam loss. This measure is the repair of failed open and leaking steam traps on steam systems supplying space heating only.

Steam traps that fail in the open position allow steam to escape into the condensate lines before the available heat energy can be used for space heating, wasting the energy used to make the steam. By replacing or repairing traps that have failed in the open position, the wasted heating energy can be conserved.

There are several measure specifications:

- The boiler must be used for space heating, not process applications
- Repaired traps must be leaking steam, not be failed in the closed position or plugged
- The incentive is available once per year per system
- Municipal steam systems do not qualify
- When mass replacing steam traps, 20% of traps replaced will qualify
- System pressure must be greater than or equal to 10 psig

A steam trap survey and repair log must be completed. The information required to determine savings includes a trap identification tag number, location description, nominal steam pressure, trap type, trap condition (functioning, failed open, or failed closed), and trap orifice diameter. The implementer should record the absolute system steam pressure at trap inlet (psia = psig + 14.7) as a savings input.

Description of Baseline Condition

The measure baseline is a steam trap that has failed in the open position and is leaking steam into the condensate line in a high pressure (greater than or equal to 10 psig) steam system. The steam from the boiler must be used for space heating and not for process applications. The boiler is assumed to operate with 80% efficiency. It is important to note that the trap must be failed in the open position and not be failed in the closed position or plugged.

Description of Efficient Condition

The efficient condition is replacing or repairing traps that have failed in the open position, providing the ability to use steam heat that was previously wasted.

Annual Energy-Savings Algorithm

The steam leakage rate was determined following the Napier equation.[2]

$$\text{Therm}_{\text{SAVED}} = 24.24 * P_{\text{ABS}} * D^2 * h_{\text{FG}} * \text{HOU} * \text{DF} \;/\; (100{,}000 * \text{eff})$$

Where:

24.24 = Constant from Napier equation when units for absolute system pressure are in psia and units of diameter are in inches

P_{ABS} = System absolute pressure in pounds per square inch (= steam gauge pressure at trap inlet plus atmospheric pressure at sea level in pounds per square inch [= psig + 14.7]; system absolute pressure at steam trap inlet to be input by implementers)

D = Steam trap orifice diameter in inches (= 7/32-inches, 1/4-inches, 5/16-inches, or 3/8-inches)

h_{FG} = Latent heat of vaporization for water at P_{ABS} (= varies by measure; see Pressure, Latent Heat, and Savings Multipliers table below)

HOU = Annual hours of operation when the boiler is on and the system is at design pressure (= 5,510)[4]

DF = Derating factor to account for the average percentage a trap fails in the open position, and to account for actual versus theoretical energy loss (= 5.9%)[3]

100,000 = Conversion factor from Btu to therms

eff = Boiler efficiency (= 80%)

The amount of therms saved varies based on system pressure (the system absolute pressure at trap inlet is to be recorded by implementers) and orifice diameter.

The latent heat of vaporization value (h_{FG}) corresponds to the assumed system absolute pressures (P_{ABS}), as shown in the Pressure, Latent Heat, and Savings Multipliers table below. The latent heat of vaporization values for each measure’s pressure range was determined using assumed mid-range pressures. The implementers are to input the absolute system pressure at trap inlet when calculating savings. The following is a simplified algorithm to calculate annual savings:

$Therm_{SAVED}$ = System Absolute Pressure * Annual Savings Multiplier

= [System Gauge Pressure + 14.7] * Annual Savings Multiplier

Pressure, Latent Heat, and Savings Multipliers

Measure Name	MMID	Assumed P_{ABS} for h_{FG}[3]	Deemed h_{FG} Latent Heat of Steam (Btu/lb)[5]	Annual Savings Multiplier (therms/psia)	Lifetime Savings Multiplier (therms/psia)
Steam Trap Repair, 10-49 psig, General Heating					
7/32” or Smaller	4008	44.7	929.0	4.4	26.4
1/4”	4009		929.0	5.7	34.2
5/16”	4010		929.0	8.9	53.4
3/8” or Larger	4011		929.0	12.9	77.4
Steam Trap Repair, 50-124 psig, General Heating					
7/32” or Smaller	4012	102.2	887.5	4.2	25.2
1/4”	4013		887.5	5.5	33.0
5/16”	4014		887.5	8.5	51.0
3/8” or Larger	4015		887.5	12.3	73.8
Steam Trap Repair, >125 psig, General Heating					
7/32” or Smaller	4944	190.2	846.8	4.0	24.0
1/4”	4945		846.8	5.2	31.2
5/16”	4946		846.8	8.1	48.6
3/8” or Larger	4947		846.8	11.7	70.2

For example, for MMID 4008 (Steam Trap Repair, 10-49 psig, General Heating, 7/32-inches or Smaller), a steam trap repaired on a 11 psig system with an orifice diameter of 7/32-inches has an annual savings multiplier of 4.4 and would result in an annual savings of 113.1 therms:

$$\text{Therm}_{\text{SAVED}} = 24.24 * (11 + 14.7) * 0.21875^2 * 929 * 5{,}510 * 5.9\% / (100{,}000 * 80\%)$$

or

$$\text{Therm}_{\text{SAVED}} = (11 + 14.7) * 4.4 = 113.1$$

Summer Coincident Peak Savings Algorithm

There are no peak coincident savings for this measure, which does not generate electric savings.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 6 years)[1]

Incremental Cost

Incremental Cost and Source

Measure Name	MMID	Incremental Cost	Source
Steam Trap Repair, 10-49 psig, General Heating			
7/32” or Smaller	4008	$130.24	Average unit cost of 11 projects and 742 steam traps from January 2018 to March 2020 is $130.24.
1/4”	4009	$348.37	Average unit cost of 6 projects and 22 steam traps from January 2019 to June 2020 is $348.37.
5/16”	4010	$128.60	Average unit cost of 4 projects and 52 steam traps from June 2018 to June 2019 is $128.60.
3/8” or Larger	4011	$106.41	Average unit cost of 4 projects and 46 steam traps from June 2018 to October 2019 is $106.41.
Steam Trap Repair, 50-124 psig, General Heating			
7/32” or Smaller	4012	$256.39	Average unit cost of 18 projects and 62 steam traps from January 2018 to March 2020 is $256.39.
1/4”	4013		
5/16”	4014		
3/8” or Larger	4015		
Steam Trap Repair, >125 psig, General Heating			
7/32” or Smaller	4944	$196.87	Average unit cost of 2 projects and 15 steam traps from June 2020 to June 2020 is $196.87.
1/4”	4945		
5/16”	4946		
3/8” or Larger	4947		

Sources

1. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. “Steam Pressure Reduction: Opportunities and Issues.” November 2005. https://energy.gov/eere/amo/downloads/steam-pressure-reduction-opportunities-and-issues
3. Cadmus. “Focus on Energy Steam Trap Study.” 2016.
   The study determined realized savings from billing data for 35 steam trap sites during the 2012 to 2014 program years. These sites had an overall realization rate of billing data results to calculated savings of 11.8% (using algorithms in this workpaper with site-specific values and the previous derating factor of 50%), suggesting that a derating factor of 5.9% would be more appropriate. The 50% derating factor came from the Enbridge Steam Saver program, 2005.
4. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Appendix B. Outside Air Temperature Bin Analysis table. Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
   Since HOU is dependent on trap type, a weighted average HOU was calculated for this measure.

Approximately 10% of traps are float-and-thermostatic type traps (Wisconsin TRM v1.0). These are under pressure when the boiler is operating, which is an estimated nine months or 6,570 hours per year. The remaining 90% of traps are thermostatic and are under pressure only when the building is heating, approximately 5,392 hours per year according to the Outside Air Temperature Bin Analysis table in Appendix B. These values produce a weighted average of 5,510 hours per year.

5. The Engineering Toolbox. "Properties of Saturated Steam - Imperial Units." http://www.engineeringtoolbox.com/saturated-steam-properties-d_273.html
User must take the 'Assumed P_{ABS} for h_{FG}' value from the Pressure, Latent Heat, and Savings Multipliers table above and subtract 14.7 psi to correspond to the correct gauge pressure listed in this source's table when looking up corresponding h_{FG} value.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial release for system pressure <50 psig
02	01/2015	Initial release for system pressure >50 psig
03	07/2016	Included all MMIDs for pressure ≥15psi, corrected algorithm
04	02/2017	Changed assumptions for all measures
05	05/2018	Adjusted derating factor to 5.9%
06	01/2020	Deleted MMIDs 4020 to 4023 and renamed MMIDs 4016 to 4019 and 4944 to 4947 to include >225 psig
07	2/2021	Updated cost.

Steam Trap Repair, < 10 psig, Radiator

	Measure Details
Measure Name	Steam Trap Repair, < 10 psig, Radiator, 2772
Workpaper ID	W0065
Measure Unit	Per steam trap
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Steam Trap
Sector(s)	Commercial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	113
Lifecycle Electricity Savings (kWh)	0
Lifecycle Therm Savings (Therms)	676
Water Savings (gal/year)	0
Effective Useful Life (years)	6[1]
Incremental Cost ($/unit)	$42.17[2]

Measure Description

Steam distribution systems contain steam traps, which are automatic valves that remove condensate, air, and other non-condensable gases while preventing or minimizing steam loss. This measure is the repair of failed open and leaking steam traps on steam systems supplying space heating only.

Steam traps that fail in the open position allow steam to escape into the condensate lines before the available heat energy can be used for space heating, wasting the energy used to make the steam. By replacing or repairing traps that have failed in the open position, the wasted heating energy can be conserved.

The measure specifications are as follows:

- Steam trap must be for a space heating radiator
- Repaired traps must be leaking steam, not be failed in the closed position or plugged
- Incentive is available once per year per system
- Municipal steam systems do not qualify
- When mass replacing steam traps, 20% of traps replaced will qualify
- System pressure must be < 10 psig with a 1/4-inch diameter orifice

A steam trap survey and repair log must be completed. The information required to determine savings includes a trap identification tag number, location description, nominal steam pressure, trap type, trap condition (functioning, failed open, or failed closed), and trap orifice diameter.

Description of Baseline Condition

The measure baseline is a steam trap that has failed in the open position and is leaking steam into the condensate line in a steam system. The steam from the boiler must be used for space heating and not for process applications. It is important to note that the trap must be failed in the open position and not be failed in the closed position or plugged.

Description of Efficient Condition

The efficient condition is replacing or repairing traps that have failed in the open position, providing the ability to use steam heat that was previously wasted.

Annual Energy-Savings Algorithm

The steam trap is assumed to be failed in the open position in an HVAC steam distribution system operating with a boiler efficiency of 80%. The savings are calculated from the steam leakage rate according to the following formula:[3]

$$\text{Therm}_{\text{SAVED}} = 1.9 * K * 60 * (\pi * D^2/4) * \sqrt{([P_{\text{ABS}} - \{P_1 - P_2\}] * [P_1 - P_2])} * h_{\text{FG}} * \text{HOU} * \text{DF} / (100{,}000 * \text{eff})$$

Where:

1.9 = Constant based on units and fluid flow equation[3]

K = Discharge coefficient (= 0.55)[4]

60 = Unit conversion for minutes per hour

D = Steam trap orifice diameter (= 1/4-inches)

P_{ABS} = System absolute pressure in pounds per square inch (= 20.7 psia; steam gage pressure at trap inlet (6 psig) plus atmospheric pressure at sea level (14.7 psi)[5]

P_1 = Steam pressure at trap inlet (= 6 psig)[5]

P_2 = Steam pressure at trap outlet, condensate tank pressure (= 0 psig)

h_{FG} = Latent heat of steam at P_{ABS} (= 959 Btu/lb)[6]

HOU = Annual hours of operation the boiler is on and the system is at design pressure (= 5,510)[8]

DF = Derating factor to account for the average percentage of time a trap fails in the open position, and to account for actual versus theoretical energy loss (= 5.9%)[5]

100,000 = Conversion factor from Btu to therms

eff = Boiler efficiency (= 80%)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure, as it does not generate electric savings.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 6 years)[1]

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 9 projects and 643 steam traps from March 2018 to October 2019 is $42.17.
3. Hornaday, William T. "Steam: Its Generation and Use." Equation 50. Merchant Books, 2007. July 13, 2016. http://www.gutenberg.org/files/22657/22657-h/chapters/flow.html#page_321
   The equation applies to subsonic flow, which occurs when steam flows through an orifice where $P_2 \geq 58\%$ of P_1
4. Manczyk Energy Consulting. "Estimating the Cost of Steam Loss Through the Orifice of a Steam Trap." http://invenoinc.com/file/Estimating-the-Steam-Loss-through-a-Orifice-of-a-Steam-Trap.pdf
   The discharge coefficient was determined by converging flow rates with the Napier equation at $P_2 = 0.58 * P_1$. The Napier equation is used to determine flow rate through an orifice when $P_2 \leq 0.58 * P_1$. This is equation 49 from source 3, with an added discharge coefficient of 0.6. Matching equation 50 in source 3 to the Napier formula at $P_2 = 0.58 * P_1$ produces this equality: $1.9 * (\pi/4 * D^2) * K * \surd([P_1 - 0.42 * P_1] * 0.42 * P_1) * 60 = 24.24 * P_1 * D^2$. Note that 60 is inserted to convert lb/min to lb/hr, and that P_1 and P_2 are treated as absolute pressures. Solving this equation produces K = 0.55.
5. Cadmus. "Focus on Energy Steam Trap Study." 2016. Unpublished.
   The study determined realized savings from billing data for 35 sites that had applied for steam trap incentives during the 2012 to 2014 program years. This study revealed 6 psig as the weighted average pressure of < 10 psig steam traps surveyed.
   These sites had an overall realization rate of billing data results to calculated savings of 11.8% (using algorithms in this workpaper with site-specific values and the previous derating factor of

50%), suggesting that a derating factor of 5.9% would be more appropriate. The 50% derating factor came from the Enbridge Steam Saver Program, 2005.

6. “The Engineering Toolbox.” http://www.engineeringtoolbox.com/saturated-steam-properties-d_273.html
7. Enbridge Steam Saver Program. 2005.
8. Appendix B. Outside Air Temperature Bin Analysis table.
   https://focusonenergy.com/sites/default/files/TRM Fall 2015 _ 10-22-15.compressed2.pdf
   PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010.
   https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
   Since HOU is dependent on trap type, a weighted average HOU was calculated for this measure. Approximately 10% of traps are float-and-thermostatic type traps (Wisconsin TRM v1.0). These are under pressure whenever the boiler is operating, an estimated nine months or 6,570 hours per year. The remaining 90% of traps are thermostatic and are under pressure only when the building is in heating, approximately 5,392 hours per year according to the Outside Air Temperature Bin Analysis table in Appendix B. These values produce a weighted average of 5,510 hours per year.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry; system pressure < 50 psig
02	01/2015	Initial TRM entry; system pressure > 50 psig
03	07/2016	Corrected algorithm for subsonic flow (when $P2 \geq 0.58 * P1$) and adjusted derating factor to match savings calculations to billing analysis results
04	05/2018	Adjusted derating factor to 5.9%
05	12/2020	Updated cost

Chiller Plant Setpoint Adjustment

	Measure Details
Measure Master ID	EBTU Chiller Plant: Chilled Water Setpoint Adjustment, 3659 Condenser Water Setpoint Adjustment, 3660
Workpaper ID	W0066
Measure Unit	Per ton
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$108.00[2]

Measure Description

The intent of this measure is to capture savings associated with adjusting the chilled water setpoint to a higher temperature that is determined to still meet the building cooling load requirement. This involves re-programming the chiller plant controls to optimize chilled water setpoint temperatures for the building based on usage. This measure includes condenser water temperature setpoint adjustments as well.

This measure is not applicable to DX cooling systems. This measure is not applicable to buildings that already use a chilled water reset control strategy or that normally change their chilled water setpoint temperature on a regular basis for control.

The measure can be applied only once per building during the EUL. This measure is meant to be a part of the Express Building Tune-Up Program to help optimize building HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

Description of Baseline Condition

The baseline measure is a chiller plant with an opportunity for energy savings from adjusting either the chilled and/or condenser water supply setpoint temperature values of a chiller system up or down a few degrees, respectively. The existing chiller cannot already use a chiller control that varies the chiller and condenser temperatures on a regular basis.

Description of Efficient Condition

This efficient measure is a chiller plant that has undergone a setpoint increase in the chilled water and/or a setpoint decrease in the condenser water loop supply temperatures. The HVAC professional implementing these changes must also verify that any change in setpoint temperature values must still be determined to adequately meet building cooling loads to avoid undoing the setpoint changes later.

Annual Energy-Savings Algorithm

Savings are determined by summing the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours found in the EBTU workbook.[3,4]

$$kWh_{SAVED} = kWh_{BASE} - kWh_{PROPOSED}$$

$$kWh_{BASE} = \Sigma\ [(\Delta T_{EXISTING\ CHILLED\ H2O} * 500 * \text{Chiller GPM} * \text{bin hrs} * \text{Chiller\_Eff} * \text{Area Load} / 12{,}000) - (\Delta T_{BASELINE\ LMTD} * 500 * \text{Condenser GPM} * \text{bin hrs} * \text{Chiller\_Eff} * \text{Area Load} / 12{,}000)]$$

$$kWh_{PROPOSED} = \Sigma\ [(\Delta T_{PROPOSED\ CHILLED\ H2O} * 500 * \text{Chiller GPM} * \text{bin hrs} * \text{Chiller\_Eff} * \text{Area Load} / 12{,}000) - (\Delta T_{PROPOSED\ LMTD} * 500 * \text{Condenser GPM} * \text{bin hrs} * \text{Chiller\_Eff} * \text{Area Load} / 12{,}000)]$$

Where:

$\Delta T_{EXISTING\ CHILLED\ H2O}$ = Estimated chilled water return temperature - existing chilled water supply temperature

$\Delta T_{PROPOSED\ CHILLED\ H2O}$ = Estimated chilled water return temperature - proposed chilled water supply temperature

500 = Water sensible heat equation constant

Chiller GPM = (= 2 GPM/ton)[5]

bin hours = Bin hours used in workbook for each respective city[4]

Chiller_Eff = kW/ton partial load rating (= based on chiller type; see table below)

Area Load = Percentage based on linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2.5% dry bulb design summer/winter conditions for different Wisconsin cities[6] (see Assumptions for more explanation of 2.5% dry bulb design conditions)

12,000 = Btu to ton conversion factor

$\Delta T_{BASLINE\ LMTD}$ = Logarithmic mean (see equation below)

LMTD = $(\Delta T_A - \Delta T_B) / [\ln(\Delta T_A / \Delta T_B)] = (\Delta T_A - \Delta T_B) / [\ln \Delta T_A - \ln \Delta T_B)]$

Where:

ΔT_A = Existing condenser water supply temperature (= 95°F)[7]

ΔT_B = Existing chilled water return temperature – existing chilled water supply temperature

Condenser GPM = (= 3 GPM/ton for electric chillers)[5]

$\Delta T_{PROPOSED\ LMTD}$ = Logarithmic mean (see equation below)

LMTD = $(\Delta T_A - \Delta T_B) / [\ln(\Delta T_A / \Delta T_B)] = (\Delta T_A - \Delta T_B) / [\ln \Delta T_A - \ln \Delta T_B)]$

Where:

ΔT_A = Proposed condenser water supply temperature (=95°F)[7]

ΔT_B = Proposed chilled water return temperature – proposed chilled water supply temperature

Cooling Efficiency Factor by System Type[8]

Cooling System Type	Cooling System Efficiency Factor at Partial Load (kW/ton)
Air-Cooled Chiller	0.95
Water-Cooled Chiller	0.64

The workbook calculator requires the following measure-specific inputs to be provided from the trained professional performing the tune-up/optimization measure:

- Chiller capacity (tons) = AHRI rated capacity (if possible), otherwise = general rated capacity
- Existing and proposed chilled water setpoints
- Existing and proposed condenser water setpoints
- Cooling system type (air-cooled chiller or water-cooled chiller)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / Hours_{COOL} * CF$

Where:

$Hours_{COOL}$ = Annual cooling hours of operation (= varies by city; see table below)

Annual Cooling Hours by City

City	BIN Annual Cooling Hours (Outside Air Temperature > 60°F)[9]
Green Bay	2,748
La Crosse	2,971
Madison	2,876
Milwaukee	2,830

CF = Coincidence factor (= 1)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Assumptions

- Chilled and condenser water flow rates are assumed to be 2 GPM and 3 GPM per ton, respectively, of cooling system refrigeration capacity.[5]
- 2.5% dry bulb design conditions mean that for cooling/heating seasons, the HVAC system is designed to adequately handle the cooling/heating of a given building for all outdoor air temperatures that do not exceed the hottest/coldest 2.5% of hours in the respective season. Explained another way, this is the point where the cooling/heating system can adequately handle the cooling/heating load of a given building for 97.5% of the total anticipated peak cooling/heating hours for the year.

Sources

1. Cadmus. EUL Response Memo. April 26, 2013. (Used Retrocommissioning Program EUL standard and direction from CB&I to keep 5 year EUL standard).
2. RSMeans. Facilities Construction Cost Data. 29th Edition. 2013. Assumed $54.00 per hour labor rate and estimated two hours for completion.
3. Wisconsin Focus on Energy. EBTU Measures Workbook Calculator.

4. National Renewable Energy Laboratory. Bin temperature data from respective Wisconsin city TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
5. Edison Electric Institute. Technical Information Handbook. p. 23. 2000.
6. ASHRAE Handbook, Fundamentals Volume for Wisconsin Cities. 1985. http://publicecodes.cyberregs.com/icod/ipc/2012/icod_ipc_2012_appd.htm
7. Edison Electric Institute. Technical Information Handbook. p. 12. 2000.
8. ASHRAE 90.1-2007. Table 6.8.1C. Simple average of minimum efficiency for chillers with capacity between 0 tons and 300 tons.

Revision History

Version Number	Date	Description of Change
01	09/2013	Initial TRM entry

Cooling System Tune-Up

	Measure Details
Measure Master ID	Chiller System Tune Up: Air Cooled, ≤ 500 Tons, 2666 Air Cooled, > 500 Tons, 2667 Water Cooled, ≤ 500 Tons, 2668 Water Cooled, > 500 Tons, 2669
Workpaper ID	W0067
Measure Unit	Per ton
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by cooling mechanism
Peak Demand Reduction (kW)	Varies by cooling mechanism
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by cooling mechanism
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$35.00[4]

Measure Description

This measure is a chiller system tune-up for air and water-cooled chillers completed in accordance with the chiller system tune-up checklist.

Tune-up requirements:

- Clean condenser coil/tubes
- Check cooling tower for scale or buildup
- Check contactors condition
- Check evaporator condition
- Check low-pressure controls
- Check high-pressure controls
- Check filter, replace as needed
- Check belt, replace as needed
- Check crankcase heater operation
- Check economizer operation

Measurement requirements:

- Record system pressure psig
- Record compressor amp draw
- Record liquid line temperature in °F
- Record subcooling and superheat temperatures in °F
- Record suction pressure psig and temperature in °F
- Record condenser fan amp draw
- Record supply motor amp draw

Description of Baseline Condition

The baseline is air-cooled and water-cooled chillers that operate at a diminished efficiency from design specifications.

Description of Efficient Condition

The efficient condition is a chiller system tune-up conducted to ensure that equipment is operating at its best and as preventative maintenance to extend the life of the equipment. Tune-ups improve the chiller’s efficiency and performance and are useful system checks, as regular maintenance keeps the equipment operating as specified.

Annual Energy-Savings Algorithm

Because the existing chiller efficiency cannot be determined without extensive testing, the ASHRAE 90.1-2007[3] minimum efficiency for chillers is used for the baseline efficiency.

Minimum Efficiencies from ASHRAE 90.1-2007

Equipment Type	Size Category	Minimum Efficiency
Air Cooled, with Condenser	All capacities	2.80 COP; 3.05 IPLV
Air Cooled, without Condenser	All capacities	3.10 COP; 3.45 IPLV
Water Cooled, Electrically Operated, Positive Displacement (Reciprocating)	All capacities	4.2 COP; 5.05 IPLV
Water Cooled, Electrically Operated, Positive Displacement (Rotary Screw and Scroll)	< 150 tons	4.45 COP; 5.20 IPLV
	≥ 150 tons and < 300 tons	4.90 COP; 5.60 IPLV
Water Cooled, Electrically Operated, Positive Displacement (Rotary Screw and Scroll)	≥ 300 tons	5.50 COP; 6.15 IPLV
Water Cooled, Electrically Operated, Centrifugal	< 150 tons	5.00 COP; 5.25 IPLV
	≥ 150 tons and < 300 tons	5.55 COP; 5.90 IPLV
	≥ 300 tons	6.10 COP; 6.40 IPLV

The annual energy savings and demand reduction are calculated by applying a percentage savings to the baseline consumption. Parametric runs were applied to estimate deemed savings for this measure.

Existing Equipment as a Baseline:

kWh_{SAVED} = ($IPLV_{BASLINE\ EXISTING}$) * ton * HOU * % savings

Where:

$IPLV_{BASLINE\ EXISTING}$ = Integrated part load value of baseline chiller (= 3.05 for air cooled; = 5.85 for water cooled)[3]

ton = Equipment size (= 50, 100, 150 for air cooled; = 100, 200, 300 for water cooled)

HOU = Determined from weather bin hours and building design cooling load (~ 1,440)

% savings = Percentage savings associated with a chiller tune-up (= 5%)[2]

Summer Coincident Peak Savings Algorithm

Existing Equipment as a Baseline:

kW_{SAVED} = (Full Load $kW/Ton_{BASELINE\ EXISTING}$ * % savings) * CF * Tons

Where:

Full Load $kW/ton_{BASELINE\ EXISTING}$ = Full load power draw of baseline chiller[3]

CF = Coincidence factor (= 0.80)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 5 years)[1]

Deemed Savings

Deemed Savings by Measure Type

	Air Cooled (MMID 2666 if ≤ 500 Tons; MMID 2667 if > 500 Tons)	Water Cooled (MMID 2668 if ≤ 500 Tons; MMID 2669 if > 500 Tons)
Average Annual Deemed Savings (kWh/year/ton)	83	44
Peak Demand Reduction (kW/ton)	0.0461	0.0242
Average Lifecycle Deemed Savings (kWh/year/ton)	415	218

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. United States Department of Energy. *Building Technologies Program: Hospitals Benefit by Improving Inefficient Chiller Systems.* White paper. August 2011. The paper found that coil cleaning, the primary savings associated with this cooling tune-up measure, reduces annual cooling energy consumption by 5% to 7%.
3. ASHRAE 90.1-2007 air cooled and water-cooled chiller efficiencies. Simple averages were taken from the following sizes (in tons): air cooled 50, 100, 150; water cooled 100, 200, 300. The respective IPLVs were applied: air cooled 3.05, 3.05, 3.05; water cooled 5.25, 5.9, 6.4.
4. Illinois Technical Reference Manual. p. 154. 2013. Incremental Cost source listed as: Act on Energy Commercial Technical Reference Manual No. 2010-4. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry

Guest Room Energy Management

	Measure Details
Measure Master ID	Guest Room Energy Management Controls: Electric Heat PTAC Systems, 2373 PTHP Systems, 4748 Not Otherwise Specified, 2374
Workpaper ID	W0068
Measure Unit	Per room
Measure Type	Prescriptive (MMIDs 2373 and 4748); Hybrid (MMID 2374)
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Agriculture, Commercial, Industrial, Schools & Government
Annual Energy Savings (kWh)	Varies by system type
Peak Demand Reduction (kW)	Varies by system type
Annual Therm Savings (Therms)	0 (MMIDs 2373 and 4748); Varies for MMID 2374
Lifecycle Energy Savings (kWh)	Varies by system type
Lifecycle Therm Savings (Therms)	0 (MMIDs 2373 and 4748); Varies for MMID 2374
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$260[2]

Measure Description

A guest room energy management system controls HVAC systems in hotel rooms by setting back thermostat setpoints when the room is unoccupied. Guest room energy management controls reduce the energy wasted by reducing over-heating and over-cooling unoccupied rooms. Lighting controls are not part of this measure.

Description of Baseline Condition

The baseline condition is standard thermostats with no automatic temperature setbacks controlling the HVAC systems serving hotel guest rooms or similar rooms. The HVAC equipment has code minimum heating and cooling efficiencies. The HVAC system for MMID 2373 is a packaged terminal air conditioner (PTAC) with electric resistance heat and code minimum cooling efficiencies shown in the table below.

Minimum Cooling Efficiency Requirements for Packaged Terminal Air Conditioners

New Construction or Retrofit	EER[3]
New Construction	$14.0 - (0.300 * Cap_{COOL} / 1,000)$
Retrofit	$10.9 - (0.213 * Cap_{COOL} / 1,000)$

The HVAC system for 4748 is a packaged terminal heat pump (PTHP) with supplemental electric resistance heat and code minimum efficiencies shown in the table below.

Minimum Cooling Efficiency Requirements for Packaged Terminal Heat Pumps

New Construction or Retrofit	EER[3]	COP[3]
New Construction	$14.0 - (0.300 * Cap_{COOL} / 1{,}000)$	$3.2 - (0.026 * Cap_{COOL} / 1{,}000)$
Retrofit	$10.8 - (0.213 * Cap_{COOL} / 1{,}000)$	$2.9 - (0.026 * Cap_{COOL} / 1{,}000)$

The HVAC system for 2374 matches the system for the project.

Description of Efficient Condition

The efficient condition is an occupancy-based guest room energy management system controlling the baseline HVAC system. Occupancy control may be key-activated or sensed due to motion or body heat. “Front Desk Only” controls do not qualify. When the room is occupied, the room temperature setpoint is controlled by the occupants. When the room is unoccupied, the guest room energy management system sets back the temperature setpoint to an unoccupied heating or cooling setpoint.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{SAVED,COOL} + kWh_{SAVED,HEAT}$

$kWh_{SAVED,COOL} = EFLH_{COOL} * Cap_{COOL} * \%\ Savings / (1{,}000 * EER)$

$kWh_{SAVED,HEAT} = \{[EFLH_{HEAT,EL} * (Cap_{HEAT,EL} + Cap_{BOILER,EL})] + [EFLH_{HEAT,HP} * Cap_{HEAT,HP} / (3{,}412 * COP)]\} * \%\ Savings$

Where:

$EFLH_{COOL}$ = Equivalent full-load hours during cooling mode (= 663 for hotel/motel)[4]

Cap_{COOL} = Nominal cooling capacity (= 9,000 Btu/h for MMIDs 2373 and 4748, = user input for MMID 2374; see Assumptions)

% Savings = Percentage of savings (= 18.4%)[5]

1,000 = Watts to kilowatt conversion factor

EER = Energy efficiency ratio in Btu/h per watt (= varies for MMIDs 2373 and 4748, = user input for MMID 2374; see Assumptions)

$EFLH_{HEAT,EL}$ = Equivalent full-load hours during heating mode (= 1,890 for MMIDs 2373 and 2374, = 729 for MMID 4748; see Assumptions)

$Cap_{HEAT,EL}$ = Heating capacity of electric heater (= 2.36 kW for MMIDs 2373 and 4748, = user input for MMID 2374; see Assumptions)

$Cap_{BOILER,EL}$ = Heating capacity of electric boiler (= 0 kW for MMIDs 2373 and 4748, = user input for MMID 2374; see Assumptions)

$EFLH_{HEAT,HP}$ = Equivalent full-load hours during heating mode of heat pump (= 0 for MMIDs 2373 and 2374, = 1,161 for 4748; see Assumptions)

$Cap_{HEAT,HP}$ = Nominal heating capacity of heat pump (= 0 Btu/h for MMIDs 2373 and 2374; = 0.893 * Cap_{COOL} for MMID 4748; see Assumptions)

3,412 = Btu/h to kilowatt conversion factor

COP = Coefficient of performance (= 1.0 for MMID 2373, = varies for MMID 4748, = user input for MMID 2374; see Assumptions)

$Therm_{SAVED} = EFLH_{HEAT} * Cap_{HEAT} * \% Savings / (100,000 * Eff)$

Where:

$EFLH_{HEAT}$ = Equivalent full-load hours during heating mode (= 1,890; see Assumptions)

Cap_{HEAT} = Heating capacity of natural gas equipment (= 0 Btu/h for MMIDs 2373 and 4748, = user input for MMID 2374)

% Savings = Percentage of savings (= 18.4%)[5]

100,000 = Btu to therms conversion factor

Eff = Thermal efficiency of the natural gas–fired equipment as a fraction (= 0 for MMIDs 2373 and 4748, = user input for MMID 2374)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Cap_{COOL} * \% Savings * CF / (1,000 * EER)$

Where:

CF = Coincidence factor (= 0.8)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

The energy savings are presented in the table below.

Annual and Lifecycle Savings by Measure

MMID	System	New Construction			Retrofit		
		kW	Annual kWh	Lifecycle kWh	kW	Annual kWh	Lifecycle kWh
2373	PTAC	0.1172	918	7,344	0.1475	943	7,544

4748	PTHP	0.1172	584	4,672	0.1491	629	5,032

Assumptions

For MMID 2373, the EER is based on a PTAC unit with 9,000 Btu/h capacity.

Cooling Efficiency of Packaged Terminal Air Conditioners

New Construction or Retrofit	EER
New Construction	11.30
Retrofit	8.98

For MMID 4748, the EER and COP are based on a PTHP with a 9,000 Btu/h cooling capacity. The weighted average capacity of PTHPs incented by Focus on Energy from January 1, 2016 through May 31, 2018 was 9,175 Btu/h.[7]

Efficiencies of Packaged Terminal Heat Pumps

New Construction or Retrofit	EER	COP
New Construction	11.30	3.0
Retrofit	8.88	2.7

For MMID 2374, the EER is the electrical efficiency of the overall system, which might include auxiliary equipment like cooling tower fans and pumps, if applicable.

The heating capacity of the heat pump as a percentage of cooling capacity is the average of data from the Air-Conditioning, Heating & Refrigeration Institute for listed PTHPs.[8] For a cooling capacity of 9,000 Btu/h, the heating capacity is 8,038 Btu/h (= 0.893 * 9,000 Btu/h). The equivalent electric heater capacity is 2.36 kW (= 8,038 Btu/h / 3,412 kW per Btu/h).

No savings are claimed for evaporator fans, condenser fans, cooling tower fans, or pumps. No water savings are claimed for any cooling towers on water source heat pump systems.

Cooling equivalent full-load hours are for hotel/motel and are not the average of multiple commercial building types.

Data for determining the heating equivalent full-load hours are presented in the table below.

Supporting Inputs for Equivalent Full-Load Heating Hours by City for Business[9]

Location	$EFLH_{HEAT}$	Weighting by Participant
Green Bay	1,852	22%
Lacrosse	1,966	3%
Madison	1,934	18%
Milwaukee	1,883	48%
Wisconsin Average	1,909	9%
Weighted Average	**1,890**	**100%**

$EFLH_{HEAT,HP}$ values were adjusted to account for electric resistance heat when the outside temperature is below 40°F. The controls are assumed to run only the electric heater when the outside temperature is below 25°F, run both the heat pump and electric heater between 25°F and 40°F, and run only the heat pump above 40°F.[10] No heating is assumed above 65°F, the common base for heating degree days. Using average bin weather data for 20 Wisconsin locations, the heat pump is expected to operate 61.41% of the hours when the temperature is below 65°F (= 4,245/6,914, but with unrounded values). The adjusted $EFLH_{HEAT}$ value is 1,890 hours * 61.41% = 1,161 hours for hotel/motel. The electric heater operates during the remaining heating hours (= 1,890 – 1,161 = 729 hours).

Supporting Calculation for Electric Heat Adjustment for Heat Pumps

Temperature Range	Hours in Temperature Range	Heat Control	Percentage of Heat Pump Hours	Total Heat Pump Hours
40°F to 65°F	3,274	Heat pump only	100%	3,274
25°F to 40°F	1,943	Heat pump + electric heater	50%	971
Less than 25°F	1,697	Electric heater only	0%	0
Total	**6,914**	**-**	**-**	**4,245**

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. *Illinois Statewide Technical Reference Manual for Energy Efficiency.* Version 6.0. p. 158. February 8, 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Version_6.0_dated_February_8_2017_Final_Volumes_1-4_Compiled.pdf
3. *2015 International Energy Conservation Code.* Table C403.2.3(3). 2015. Accessed October 2018. https://codes.iccsafe.org/public/document/IECC2015

4. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com
DEER model runs were weather normalized for Wisconsin statewide use by population density.
5. Pacific Northwest National Laboratory (Sullivan, G.P., and J. Blanchard). *Guest Room HVAC Occupancy-Based Control Technology Demonstration*. p. 1. September 2012. http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/creea_guest_room_occupancy-based_controls_report.pdf
6. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Section 4.5.7 Rooftop A/C. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. Historical Focus on Energy project data, MMIDs 2699 to 2702 for January 2016 to May 2018, which shows 1,717 PTHPs installed and an average of 9,175 Btu capacity.
8. Air-Conditioning, Heating & Refrigeration Institute. Accessed May 2018. www.ahridirectory.org
9. Several Cadmus metering studies reveal that the ENERGY STAR EFLHs calculators are overestimated by 25%. The $EFLH_{HEAT}$ was adjusted by population-weighted heating degree days and TMY3 values.
10. *ENERGY STAR Multifamily High Rise Program Simulation Guidelines*. Version 1.0, Revision 03. Section 3.8.2.2, p. 19. January 2015. https://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/mfhr/ENERGY%20STAR%20MFHR%20Simulation%20Guidelines_Version_1%200_Rev03.pdf?5c90-3dd6

Revision History

Version Number	Date	Description of Change
01	10/10/2018	Initial TRM entry

Economizer Optimization

	Measure Details
Measure Master ID	Economizer, RTU Optimization, 3066 Economizer Repair / Upgrade, Building Tune-up, 5290
Workpaper ID	W0069
Measure Unit	MMID 3066: Per rooftop unit MMID 5290: Per rooftop unit (see Assumptions)
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	MMID 3066: Economizer MMID 5290: Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	RTU Optimization = 10 (MMID 3066),[1] Economizer Optimization = 4 (MMID 5290)[2]
Incremental Cost ($/unit)	RTU Optimization = $1,301.58 (MMID 3066),[3] Economizer Optimization = $250.00 per roof-top unit (MMID 5290)[4]

Measure Description

A majority of commercial spaces are heated and cooled by packaged roof-top units or packaged air handling units. MMID 3066 is installing an air-side economizer on cooling equipment that does not already have one, which will offset or reduce the need for mechanical cooling.

The intent of MMID 5290 is to ensure proper economizer functionality and capture savings associated with correcting improper operation or damage of outside air economizer units. Additionally, this measure allows an existing dry-bulb economizer to be upgraded to an enthalpy economizer. This measure can be applied only once per building address during the EUL lifecycle. It is meant to be a part of the Whole Building Tune-up offering to help optimize building HVAC systems to operate more efficiently.

Neither measure applies to newly constructed facilities.

Description of Baseline Condition

For MMID 3066, the baseline is a packaged roof-top unit or air handler with a fixed ventilation rate (fixed damper; no economizer). For MMID 5290, the baseline is a roof-top unit or air handling unit with an economizer that is either not in operation at all or a dry-bulb economizer that is in operation but has a limited outdoor air temperature range of operation and has the potential to expand. Additionally, fixed dry-bulb changeover economizers (enable economizer at fixed outside air temperature) may be upgraded to enthalpy changeover economizers (enable economizer at fixed outside air enthalpy).

Description of Efficient Condition

For MMID 3066, the efficient equipment is a packaged roof-top unit or air handler that includes an economizer controller, actuator, and sensor that provide air-side economizing. For MMID 5290, the efficient condition is a functioning dry-bulb economizer (if not previously functional), increasing the economizer outside air temperature operating range above baseline range, or upgrading a dry-bulb changeover economizer (enable economizer at a fixed outside air temperature) to an enthalpy changeover economizer (enable at fixed outside air enthalpy). The efficient condition OAT economizer range should not exceed 55°F to 75°F.

Annual Energy-Savings Algorithm

The following algorithms calculate the hourly cooling load using TMY3 hourly weather data[5] and customer reported existing and efficient economizer operating parameters. MMID 3066 uses a baseline of no economizer and an efficient condition of a dry-bulb changeover economizer, and limits weather data to April 1 to October 31. MMID 5290 uses full year weather data and has multiple possibilities for baseline and efficient conditions.

$kWh_{SAVED} = kWh/year_{BASELINE} – kWh/year_{PROPOSED}$

$kWh/year_{BASELINE} = \Sigma_{8760} (kW_{HOUR\text{-}INTERVAL\text{-}BASELINE} * 1 \text{ hour})$

$kW_{HOUR\text{-}INTERVAL\text{-}BASELINE} = (CAP_{COOL} * R_{CAP} – CAP_{ECON}) * (12 / EER) * Econ_{BASE}$

$kWh/year_{PROPOSED} = \Sigma_{8760} (kW_{HOUR\text{-}INTERVAL\text{-}PROPOSED} * 1 \text{ hour})$

$kW_{HOUR\text{-}INTERVAL\text{-}PROPOSED} = (CAP_{COOL} * R_{CAP} – CAP_{ECON}) * (12 / EER) * Econ_{PROP}$

$CAP_{ECON} = 4.5 * CFM * (h_{RA} – h_{OA}) / 12{,}000$ for enthalpy economizers

$CAP_{ECON} = 1.08 * CFM * (T_{RA} – T_{OA}) / 12{,}000$ for dry-bulb economizers

Where:

CAP_{COOL} = Cooling capacity of equipment in tons (= varies by equipment, actual equipment values should be used)

R_{CAP} = Cooling load at which the air conditioning compressor is operating as a percentage of the full load cooling capacity, interpolated for every hourly temperature value between (55°F, 0%) and (95°F, 90%)

12 = Conversion factor from EER to kilowatts per ton

EER = Energy efficiency ratio of the roof-top unit or air handling unit, in Btu/(W*hr) (= user input; if not known see table below)

Energy Efficiency Ratio by System Type

Cooling System Type	Cooling System Efficiency (EER)[6, 7]
Rooftop Unit ≥ 5.42 and < 11.25 tons	11.00
Rooftop Unit ≥ 11.25 and < 20.00 tons	10.80
Rooftop Unit ≥ 20.00 and < 63.33 tons	9.80
Rooftop Unit ≥ 63.33 tons	9.50
Air Cooled Chiller < 150 tons	9.88
Air Cooled Chiller ≥ 150 tons	9.88
Water Cooled Positive Displacement Chiller < 75 tons	15.69
Water Cooled Positive Disp Chiller ≥ 75 tons and < 150 tons	16.33
Water Cooled Positive Disp Chiller ≥ 150 tons and < 300 tons	17.91
Water Cooled Positive Disp Chiller ≥ 300 tons and < 600 tons	19.43
Water Cooled Positive Displacement Chiller ≥ 600 tons	20.96
Water Cooled Centrifugal Chiller < 150 tons	18.39
Water Cooled Centrifugal Chiller ≥ 150 tons and < 300 tons	19.28
Water Cooled Centrifugal Chiller ≥ 300 tons and < 400 tons	20.78
Water Cooled Centrifugal Chiller ≥ 400 tons and < 600 tons	20.96
Water Cooled Centrifugal Chiller ≥ 600 tons	20.96

$Econ_{BASE}$ = Binary variable (0 = off or 1 = on) that indicates whether the baseline economizer is in operation. For MMID 3066, $ECON_{BASE}$ = 0 for all hours since measure assumes no economizer. For MMID 5290, $ECON_{BASE}$ varies depending on existing economizer setup (none, dry-bulb with too low of changeover temperature, or enthalpy with too low of changeover enthalpy setting).

$Econ_{PROP}$ = Binary variable (0 = off or 1 = on) that indicates whether the efficient economizer is in operation. For MMID 3066, $ECON_{PROP}$ = 1 when outside air temperature is less than user reported changeover temperature (minimum of 60°F). For MMID 5290, $ECON_{PROP}$ varies depending on the improvement made to the economizer setup (add dry-bulb, add enthalpy, improve dry-bulb changeover temperature, or improve enthalpy changeover setting).

4.5 = Total heat constant, lb_{AIR}/CFM-hr

1.08 = Sensible heat constant, Btu/hr-CFM-°F

CFM = Total supply airflow through rooftop unit, CFM (= user input if known, otherwise see Assumptions)

h_{RA} = Enthalpy of return air, Btu/lb (= calculated using Psych[8] Excel plug-in based on user input return air temperature and relative humidity)

h_{OA} = Enthalpy of outside air, Btu/lb (= calculated using Psych[8] Excel plug-in based on temperature and relative humidity from TMY3 weather data for the hour)

T_{RA} = Temperature of return air, °F (= user input)

T_{OA} = Temperature of outside air, °F (= from TMY3 weather data for the hour)

The customer or trade ally applying for this measure must supply certain information:

- Cooling type (DX or chiller) and capacity (tons)
- Cooling efficiency (EER) when known, otherwise a default value based on cooling system type will be used
- Supply airflow of the rooftop unit or air handler if known (CFM) i.e., the total outside airflow possible when economizer is operating at 100% outside air.
- Existing economizer OAT enable temperature (°F); 'none' is also a possibility
- Type of proposed economizer (dry-bulb or enthalpy)
    - If dry-bulb, proposed economizer OAT enable temperature (°F)
    - If enthalpy, proposed economizer enthalpy enable setting (Btu/lb)

Summer Coincident Peak Savings Algorithm

There is no peak demand reduction from economizers because they are not expected to operate during peak demand hours based on typical economizer temperature ranges.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years for MMID 3066[1], = 4 years for MMID 5290[2])

Assumptions

Measure unit is listed as 'Per Rooftop Unit' to reflect the savings calculated using the algorithms, however, this measure is part of the Whole Building Tune-Up Offering where a flat incentive is paid per building, no matter how many rooftop unit economizers are repaired.

The fraction of full capacity of direct expansion air conditioning equipment is assumed to be a linear function of outside air dry-bulb temperature (0% at 55°F and 90% at 95°F). For chillers, it is also assumed to be linear but from 34% at 53°F to 85% at 95°F, which matches the assumptions in workpaper W0059 for efficient chillers. This assumes some minor oversizing of the cooling equipment, allowing some extra capacity for cooling beyond 95°F.

In the event the CFM of the existing air handling unit or rooftop unit is not known, it can be estimated using 400 CFM per ton of cooling[9].

Sources

1. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." Updated 2014 EUL Table, EUL_ID = HVAC-addEcono and HVAC-RepEcono. 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
2. Navigant. "Effective Useful Life for Retro-commissioning and Behavior Programs" memo. September 17, 2019. https://ilsag.s3.amazonaws.com/ComEd-EUL-Comm-RCx-and-Behavior-Memo-2019-09-17.pdf. Four years is the EUL for the Operational Efficiency Offering.
3. Northeast Energy Efficiency Partnerships. *Incremental Cost Study Phase Two Final Report: A Report on 12 Energy Efficiency Measure Incremental Costs in Six Northeast and Mid-Atlantic Markets*. Table 13. Cost for 15 ton capacity single enthalpy economizer, p. 31. January 2013. www.neep.org/incremental-cost-study-phase-2
   Historical project data obtained from SPECTRUM found that seven units over four projects from January 2019 to September 2020 had an average size of 15.7 tons. Interpolating this with the NEEP reference table produces $1,301.58 per ton.
4. Focus on Energy. Engineering Judgement. While RSMeans 2016 shows $59.00 per hour under *23 09 33.10 – Electronic Control System for HVAC*, engineer stakeholders for Focus on Energy believe that $140 per hour is a more realistic rate. This measure has three possible outcomes: repair broken economizer (bad actuator, damper linkage adjustment, etc.), expand temperature range of operation (programing change), or upgrade to an enthalpy economizer (humidity sensor likely needed). An incremental cost of $250 per rooftop unit was assumed as the average cost for these possible outcomes.
5. Natural Renewable Energy Laboratory. Bin temperature data from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
6. International Code Council. *2015 International Energy Conservation Code.*. Table C403.2.3(1). 2015. https://codes.iccsafe.org/public/document/IECC2015/chapter-4-ce-commercial-energy-efficiency
   Direct expansion cooling efficiency values determined from minimum efficiencies for system capacities of ≥ 5.5 tons with "All Other" for heating section type.
7. International Code Council. *2015 International Energy Conservation Code*. Table C403.2.3(7). 2015. https://codes.iccsafe.org/public/document/IECC2015/chapter-4-ce-commercial-energy-efficiency

Chiller efficiency values determined from simple average of Path A and Path B minimum efficiencies and then converted from kW/ton to EER .

8. "Psych" Excel Plug-in from Western Cooling Efficiency Center at UC Davis, accessed August 2021. https://wcec.ucdavis.edu/resources/software-resource-applications
   Enthalpy for a given dry bulb temperature and relative humidity was converted assuming 14.7 PSI atmospheric pressure.
9. “Rule of Thumb Calculations (400 cfm/ton)”, Trane, published 6/24/21. https://tranecds.custhelp.com/app/answers/detail/a_id/918/~/rule-of-thumb-calculations-%28400-cfm%2Fton%29

Revision History

Version Number	Date	Description of Change
01	01/2016	Initial TRM entry
02	10/2020	Added MMID 3066
03	1/2022	Update MMID 3661 for requirements of new Whole Building Tune-up offer, update cost and EUL

Data Center Airside Economizer

	Measure Details
Measure Master ID	Air-Side Economizer, Data Center/Telecom, 4776
Workpaper ID	W0070
Measure Unit	Per ton
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Economizer
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by location
Peak Demand Reduction (kW)	Varies by location
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by location
Lifecycle Therm Savings (Therms)	Varies by location
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$108.00[2]

Measure Description

This measure is installing an air-side economizer that offsets or reduces the need for mechanical cooling in data centers or similar computer facilities that operate continuously. When the outside air is below the economizer high limit temperature, the air conditioning compressors can be turned off or run for fewer hours. For water-cooled systems, there are also savings associated with turning off cooling tower pumps and fans.

Description of Baseline Condition

The baseline condition is an air handler with a fixed ventilation rate (fixed damper, no air- or water-side economizer), where the minimum ventilation rate for data centers is typically zero. The cooling system operates continuously the entire year to meet the continuous data center cooling load.

Description of Efficient Condition

The efficient condition is an air handler that includes an air-side economizer controller, actuator, and sensor, controlled by either the dry bulb temperature or enthalpy.

Annual Energy-Savings Algorithm

The electrical energy saved is equal to the energy used by the cooling system in the baseline during hours that the economizer system provides full or partial cooling. Greater detail of savings algorithm inputs can be found in the workbook associated with this workpaper.

$kWh_{SAVED} = \Sigma\ [(LF * CAP * Eff_{COOL} + 0.746 * HP_{CT\_FAN} * ML_{CT\_FAN} / Eff_{CT\_FAN} + 0.746 * HP_{CT\_PUMP} * ML_{CT\_PUMP} / Eff_{CT\_PUMP}) * Econ_{OPERATING}]$ for each hour

Where:

LF = Average load factor on cooling system (= 0.65)[3]

CAP = Installed (non-backup/redundant) cooling capacity in tons (= user input)

Eff_{COOL} = Cooling system efficiency in kilowatts per ton (= user input)

0.746 = Conversion from horsepower to kilowatts

HP_{CT_FAN} = Horsepower of cooling tower fan motor, if any (= 0 if no cooling tower, = user input otherwise)

ML_{CT_FAN} = Motor loading of cooling tower fan motor, if any (= 0 if no cooling tower, = user input otherwise; if not known assume 0.8)

Eff_{CT_FAN} = Motor efficiency of cooling tower fan motor, if any (= 0 if no cooling tower, = user input otherwise; if not known assume code minimum based on horsepower)

HP_{CT_PUMP} = Horsepower of cooling tower water pump motor, if any (= 0 if no cooling tower, = user input otherwise)

ML_{CT_PUMP} = Motor loading of cooling tower water pump motor, if any (= 0 if no cooling tower, = user input otherwise; if not known assume 0.8)

Eff_{CT_PUMP} = Motor efficiency of cooling tower water pump motor, if any (= 0 if no cooling tower, = user input otherwise; if not known assume code minimum based on horsepower)

$Econ_{OPERATING}$ = Fraction that indicates the degree of economizer operation (= 1 when the outside air (dry bulb) temperature is below the design mixed air temperature, = 0 when the outside air temperature is above the economizer high limit temperature setpoint, = linear interpolation in between these values)

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = average of $[(LF * CAP * Eff_{COOL} + 0.746 * HP_{CT\_FAN} * ML_{CT\_FAN} / Eff_{CT\_FAN} + 0.746 * HP_{CT\_PUMP} * ML_{CT\_PUMP} / Eff_{CT\_PUMP}) * Econ_{OPERATING}]$ across all hours during the peak period of 1 p.m. to 4 p.m. weekdays in June, July, and August.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Assumptions

Savings calculations are based on several assumptions:

- The cooling load is constant throughout the year
- The cooling system efficiency is constant at all outside temperatures
- The minimum ventilation airflow during non-economizer hours is 0 CFM

The hourly interval weather data were obtained from TMY3 data.[4]

Motor efficiencies, if not available, are assumed to be the code minimum for a totally enclosed fan cooled at 1,800 rpm.

The following table shows the default motor efficiencies based on horsepower.

Default Motor Efficiency

hp	Efficiency[5]
1	82.5%
1.5	84.0%
2	84.0%
3	87.5%
5	87.5%
7.5	89.5%
10	89.5%
15	91.0%
20	91.0%
25	92.4%
30	92.4%
40	93.0%
50	93.0%
60	93.6%
75	94.1%
100	94.5%
125	94.5%
150	95.0%
200	95.0%

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” EUL Table. 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
2. RSMeans. Facilities Construction Cost Data. 29th Edition. 2013. Assumed $54.00 per hour labor rate and estimated two hours for completion.

3. Technical Support Document to Final Rule: Standards, Federal Register, 77 FR 28928:28994-5. Section V. Methodology and Discussion of Comments for Computer Room Air Conditioners, Subsection D., Energy Use Characterization. May 16, 2012. http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0029-0038
4. National Renewable Energy Laboratory. "TMY3 Weather Data: National Solar Radiation Data Base." http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html.
5. ASHRAE 90.1-2013. Table 10.8-2. Accessed December 2018. https://ashrae.iwrapper.com/ViewOnline/Standard_90.1-2013_I-P

Revision History

Version Number	Date	Description of Change
01	10/04/2018	Initial TRM entry

Hot Water Supply Reset

	Measure Details
Measure Master ID	Hot Water Supply Reset, Building Tune-up, 5291 Unoccupied Mode Hot Water Supply Reset, Building Tune-up, 5266
Workpaper ID	W0071
Measure Unit	Per # of HW reset controls implemented (see Assumptions)
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$140.00[2]

Measure Description

These measures are part of the Whole Building Tune-up set of control system repairs and improvements for existing buildings. Measure 5291 (formerly 3662) was originally developed for the Express Building Tune-up offer that ran through 2019.

The intent of these measures is to capture savings by lowering the boiler hot water supply setpoint temperature for the primary heating loop based on actual building load and/or outdoor air temperature. This measure is meant to help optimize HVAC systems to operate more efficiently at existing building load conditions.

Description of Baseline Condition

The baseline measure is an eligible building with a boiler hot water heating system that has working controls in place but does not use a hot water supply reset strategy.

Description of Efficient Condition

The efficient measure is a trained HVAC service professional adding a hot water supply reset strategy to the control system that will still safely meeting buildings heating load requirements. The reset temperatures should be appropriate for the efficiency level of the boiler, i.e., 80% boilers can use 180°F maximum supply temperatures if needed to meet peak heating loads but 90%+ condensing boilers should have a much lower maximum supply temperature that maintains the condensing ability of the boiler.

For standard hot water reset controls, the reset strategy should incorporate maximum and minimum water temperatures to correspond with the minimum and maximum outdoor air temperature range, respectively. Savings are calculated based on the particular existing and proposed reset strategy, accounting for boiler capacity.

For unoccupied mode hot water reset, the control strategy will reset the hot water supply temperature to a fixed lower value while the building is in unoccupied mode, and return to normal supply temperature for morning warm-up and occupied mode.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{Therm}_{\text{BASELINE}} - \text{Therm}_{\text{PROPOSED}}$

$\text{Therm}_{\text{BASELINE}} = \Sigma\ [500 * \text{GPM} * (\text{HWST}_{\text{BASE}} - \text{HWRT}) * \text{LF} / 100{,}000 / \text{Boiler Eff} * \text{Bin Hours} * \text{HRS}_{\text{ADJ}}]$

$\text{Therm}_{\text{PROPOSED}} = \Sigma\ [500 * \text{GPM} * (\text{HWST}_{\text{PROP}} - \text{HWRT}) * \text{LF} / 100{,}000 / \text{Boiler Eff} * \text{Bin Hours} * \text{HRS}_{\text{ADJ}}]$

$\text{GPM} = \text{BC} * \text{OF} * \text{Boiler Eff} / (500 * \Delta T_{\text{DESIGN}})$

Where:

500 = Water sensible heat formula constant, Btu/gpm-°F-hr

BC = Boiler rated input capacity (Btu per hour)

OF = Boiler oversizing factor (= 77%)[3]

ΔT_{DESIGN} = Design temperature difference for the hot water system (= 30°F, see assumptions)

$\text{HWST}_{\text{BASE}}$ = Existing hot water maximum supply temperature in °F (= user defined)

$\text{HWST}_{\text{PROP}}$ = Proposed hot water reset curve temperature in °F (= user defined)

HWRT = Hot water return temperature (= estimated based on OAT and hottest water supply temperature in the system; return temperature schedule is a constant between baseline and proposed used to model heat loss reduction

LF = Load fraction, percentage of design heating load based on linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and average of 99% ASHRAE heating design temperatures for 22 Wisconsin cities.[4]

100,000 = Conversion from Btu to therm

Boiler Eff = Efficiency of natural gas to heat conversion for heating purposes (= user defined, AFUE for < 300 MBh, Thermal Efficiency for ≥ 300 MBh)

Bin Hours = Dry-bulb temperature and time of day (also known as temperature bin data) (= based on statewide BIN weather data)[5]

HRS_{ADJ} = Adjustment for hours per week building is unoccupied for measure 5266 (= 1.0 for MMID 5291, = 1 – [unoccupied hours]/168 for occupied mode of MMID 5266, = [unoccupied hours]/168 for unoccupied mode of MMID 5266, where [unoccupied hours] = user input)

Summer Coincident Peak Savings Algorithm

There is no peak demand reduction for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 4 years)[1]

Assumptions

- Measure unit is listed as 'Per HW reset controls implemented' to reflect the savings calculated using the algorithms, however, this measure is part of the Whole Building Tune-Up Offering where a flat incentive is paid per building, no matter how many hot water systems receive these controls.
- Return water temperature schedule is assumed to be at ΔT=30°F for the coldest OAT (design heating load) and at ΔT=10°F for the warmest OAT compared to the existing hot water heating setpoint.[6]
- Assumed that the return water temperature schedule across the OAT range will stay the same between existing and hot water reset schedule to model the reduction of heat losses and subsequent energy savings.
- Assumed a constant GPM flow rate (should be based on the heating season average GPM if possible, or the rated boiler flow rate when boiler is at ΔT=20°F operation).
- Assumed that the hot water setpoint at minimum OAT range will be greater than or equal to the existing hot water setpoint constant.
- If hot water reset temperatures at higher OAT dip below the constant estimated for return water scheduled temperatures, then the hot water reset supply temperature will equal the calculated return temperature (since it effectively shuts off the boiler).
- Assumed that boiler operation occurs only during periods when OAT < 60°F.
- Assumed that the HVAC service professional making adjustment ensures that boiler return water will stay above the boiler minimum.

Sources

1. Navigant. "Effective Useful Life for Retro-commissioning and Behavior Programs" memo. September 17, 2019. https://ilsag.s3.amazonaws.com/ComEd-EUL-Comm-RCx-and-Behavior-Memo-2019-09-17.pdf. Four years is the EUL for the Operational Efficiency Offering.
2. Assumed $140.00 per hour labor rate for controls technician and estimated one hour for completion, assuming the digital control system is already in place.
3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Page 4-28. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. ASHRAE Handbook: Fundamentals. Chapter 14 – Climatic Design Information and CD ROM handbook supplement. 2017.
5. Natural Renewable Energy Laboratory. Bin temperature data comes from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
6. Edison Electric Institute. *Technical Information Handbook*. p. 24. 2000. This value converts the output to Btus (8.33 lb/gal * 60 min/hr * 1 Btu/°F-lb-hr = 500 Btu-min/gal-°F).

Revision History

Version Number	Date	Description of Change
01	08/10/2015	Initial TRM entry
02	1/7/2022	Edit for revised structure of whole building tune-up offer, updated cost and EUL

Natural Gas Furnace Tune-Up, Small Business

	Measure Details
Measure Master ID	Natural Gas Furnace Tune-Up, Small Business, 3916
Workpaper ID	W0072
Measure Unit	Per MBtu per hour of furnace capacity
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by furnace capacity
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by furnace capacity
Lifecycle Energy Savings (kWh)	Varies by furnace capacity
Lifecycle Therm Savings (Therms)	Varies by furnace capacity
Water Savings (gal/yr)	0
Effective Useful Life (years)	2[1]
Measure Incremental Cost ($/unit)	$1.53 per MBtu/hr[2]

Measure Description

This measure is for a natural gas furnace that provides space heating at a small business. Inspecting, cleaning, and adjusting the furnace will improve the performance for correct and efficient operation.

Description of Baseline Condition

The baseline condition is a natural gas furnace for a small business customer that has not had a tune-up in the previous two years.

Description of Efficient Condition

To qualify for a small business furnace tune-up, a trained HVAC technician must complete the following:

- Measure before and after combustion efficiency using an electronic flue natural gas analyzer
- Check and clean blower assembly and components per manufacturer’s recommendations
- Lubricate motor, where applicable, and inspect and replace fan belt, if required
- Inspect for natural gas leaks
- Clean burner per manufacturer’s recommendations and adjust as needed
- Check ignition system and safety systems and clean and adjust as needed
- Check and clean heat exchanger per manufacturer’s recommendations
- Inspect exhaust/flue for proper attachment and operation
- Inspect control box, wiring, and controls for proper connections and performance

- Check air filter and clean or replace as needed
- Inspect duct work connected to furnace for leaks or blockages
- Measure temperature rise and adjust flow as needed
- Check for correct line and load volts/amps
- Perform carbon monoxide test and adjust heating system until results are within acceptable limits

Annual Energy-Savings Algorithm

Natural Gas Savings

$\text{Therm}_{\text{SAVED}} = \text{CAP} * \text{EFLH}_{\text{HEAT}} * [1/\text{Eff}_{\text{BASE}} – 1/(\text{Eff}_{\text{BASE}} + \text{Eff}_{\text{INCREASE}})] / 100$

Electric Savings

$\text{kWh}_{\text{SAVED}} = \text{Therm}_{\text{SAVED}} * \text{FanEnergy\%} * 29.31$

Where:

CAP = Furnace capacity (input), MBtu/hr

$\text{EFLH}_{\text{HEAT}}$ = Equivalent full-load hours of heating (= 1,890)[3]

Eff_{BASE} = Furnace efficiency before the tune-up (= user-defined input)

$\text{Eff}_{\text{INCREASE}}$ = Furnace efficiency improvement due to tune-up (= user-defined input)

100 = Conversion factor from MBtu/hr to therms

FanEnergy%= Furnace fan energy use as a percentage of annual fuel consumption (= 3.14%)[1]

29.31 = Conversion factor from therms to kWh

Summer Coincident Peak Savings Algorithm

There are no summer peak coincident savigns for this measure since electric use only occurs during the heating season.

Lifecycle Energy-Savings Algorithm

$\text{Therms}_{\text{LIFECYCLE}} = \text{Therms}_{\text{SAVED}} * \text{EUL}$

$\text{kWh}_{\text{LIFECYCLE}} = \text{kWh}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 2 years)[1]

Assumptions

The Illinois TRM entry for small business furnace tune-ups[1] assumes a tune-up efficiency improvement of approximately 2%. Based on engineering judgment, average furnace efficiency may be approximately 80%. Using those assumed inputs, the reference savings for this measure are shown in the following table.

Savings per MBh of Furnace Capcity

Peak Demand Reduction (kW)	Annual Savings		Lifecycle Savings	
	Electric (kWh per MBtu/hr)	Natural Gas (therms per MBtu/hr)	Electric (kWh per MBtu/hr)	Natural Gas (therms per MBtu/hr)
0.0	0.530	0.576	1.061	1.152

Assumptions

The average of the furnace tune-up costs[2] identified online were averaged, resulting in $127.50 per furnace tune up. Using average furnace size for MMID 3491 and 3492 found an average size of 83.3 MBh for 188 measures from January 1, 2016 to October 31, 2017, which results in a cost of $1.53/MBh.

Sources

1. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0, Volume 2*. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Almost_Final_PDF/IL_TRM_Effective_060116_Version_5.0_Vol_2_C_and_I_012216_Clean.pdf
2. Capital Heating & Cooling. Website. Accessed November 2017. https://www.capitalhvac.com/TipsArticles/furnace-tune-up-cost

   Cost Helper. Website. Accessed November 2017. http://home.costhelper.com/furnace-tune-up.html

   Home Improvement Educator. Website. Accessed November 2017. http://www.homeimprovementeducator.com/seasonal/fall-furnace-tuneups.html

   Engineering judgement based on local pricing and typical furnace size.
3. Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLHs are overestimated by 25%. The $EFLH_{HEAT}$ was adjusted by population-weighted HDD and TMY3 values.

Revision History

Version Number	Date	Description of Change
01	09/2016	Initial TRM entry
02	01/2019	Removed MMID 4098

Gas Furnaces, Business

	Measure Details
Measure Master ID	Furnace with ECM, ≥95%+ AFUE, NG, 3491 Furnace with ECM, ≥90%+ AFUE, NG, 3492 Furnace with ECM, ≥95%+ AFUE, Propane, 4869 Furnace with ECM, ≥90%+ AFUE, Propane, 4870
Workpaper ID	W0073
Measure Unit	Per MBh input capacity (for savings) Per furnace (for incentive and incremental cost)
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Furnace
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Annual Propane Savings (Gallons)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	Varies by measure
Annual Propane Savings (Gallons)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	21[1]
Incremental Cost ($/unit)	≥95%+ AFUE = $664.85 (MMID 3491);[2,11] ≥90%+ AFUE = $232.31 (MMID 3492)[2,12]

Measure Description

Residential-style natural gas and propane furnaces are available with higher thermal efficiencies than the baseline code-minimum efficiency, which saves energy by consuming less natural gas. These measures are specific to business and common area multifamily applications.

In addition to natural gas savings, furnaces can save electricity through more efficient blower motors. These are commonly ECMs and can generally be constant-torque or constant airflow (true variable speed). Additional electric savings can be achieved by employing these motor types with a burner staging strategy that allows for the furnace blower to run at a lower speed when the full heating capacity of the furnace is required. While the blower may run longer on these furnaces, the reduced electrical use at these lower speeds creates significant savings.

Description of Baseline Condition

The current federal standard for residential-sized furnaces is an 80%[3] AFUE single-stage furnace with a blower motor that meets a fan energy rating (FER) performance requirement,[4,5] generally necessitating an ECM.

Description of Efficient Condition

The efficient condition is a multi-stage furnace with a minimum AFUE of 95% for MMID 3491 or 90% for MMID 3492 as listed by the Air-Conditioning, Heating and Refrigeration Institute. These efficient furnaces also generally have more efficient ECMs than baseline furnaces.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{Cap} * (\text{AFUE}_{\text{EE}} / \text{AFUE}_{\text{BASE}} - 1) * \text{EFLH}_{\text{HEAT}} / \text{ConvF}$

$\text{kWh}_{\text{SAVED}} = \text{kWh}_{\text{MOTOR}} / \text{AvgSize}$

Where:

Cap = Input capacity of the efficient furnace in MBh (= user input)

AFUE_{EE} = Thermal efficiency of efficient equipment (= 0.95 for MMID 3491; = 0.90 for MMID 3492)

$\text{AFUE}_{\text{BASE}}$ = Thermal efficiency of baseline equipment (= 0.80)[3]

$\text{EFLH}_{\text{HEAT}}$ = Equivalent full load heating hours (=1,890; see Assumptions)[6]

ConvF = Fuel conversion factor (= 100 MBtu per therm, = 91.3 MBtu per gallon propane)[13]

$\text{kWh}_{\text{MOTOR}}$ = Electric energy saved as a result of furnace motor upgrade (= 70 kWh; see Assumptions)

AvgSize = Average furnace size in MBh to convert ECM per furnace savings to per MBh savings (= 58 MBh for multifamily,[7] = 84.3 MBh for business[8])

Summer Coincident Peak Savings Algorithm

No demand savings are claimed for this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

$\text{kWh}_{\text{LIFECYCLE}} = \text{kWh}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 21 years)[1]

Deemed Savings

Savings are presented in the table below.

Therm and Electric Savings by Measure, per MBh Input

MMID	Sector	Eff$_{EE}$	kW	Annual		Lifecycle	
				kWh	Therms	kWh	Therms
3491	Residential- multifamily	95%	0	1.21	3.54	25.4	73.5
	Commercial, Industrial, Agriculture, Schools & Government		0	0.83	3.54	17.4	73.5
3492	Residential- multifamily	90%	0	1.21	2.36	25.4	50.4
	Commercial, Industrial, Agriculture, Schools & Government		0	0.83	2.36	17.4	50.4

Propane and Electric Savings by Measure, per MBh Input

MMID	Sector	Eff$_{EE}$	kW	Annual		Lifecycle	
				kWh	Gallons Propane	kWh	Gallons Propane
4869	Residential- multifamily	95%	0	1.21	3.88	25.4	81.9
	Commercial, Industrial, Agriculture, Schools & Government		0	0.83	3.89	17.4	81.9
4870	Residential- multifamily	90%	0	1.21	2.59	25.4	54.6
	Commercial, Industrial, Agriculture, Schools & Government		0	0.83	2.59	17.4	54.6

Assumptions

Previously, multifamily applications for these measures reflected a mix of in-unit and common area furnaces, and the residential EFLH$_{HEAT}$ value of 1,158 was used.[6] Now, however, multifamily applications for these measures are for common areas only, and the commercial value for EFLH$_{HEAT}$ is used. Data for determining the equivalent full-load heating hours for business are presented in the table below.

Supporting Inputs for Equivalent Full-Load Heating Hours by City for Business[7]

Location	EFLH$_{HEAT}$	Weighting by Participant
Green Bay	1,852	22%
Lacrosse	1,966	3%
Madison	1,934	18%
Milwaukee	1,883	48%
Wisconsin Average	1,909	9%
Weighted Average	**1,890**	**100%**

Previously, savings from furnace ECM upgrades (416 kWh) were derived from a 2014 Cadmus study that calculated savings over an assumed PSC motor baseline. However as of July 3, 2019, the U.S. Department of Energy required residential-sized furnace blower motors to meet a fan energy ratio performance standard[4,5] that can generally only be met by ECMs, rendering the 2014 study obsolete. However, there are multiple efficiency levels of ECM blower motors,[9] and a majority of Focus on Energy furnaces perform at the higher end. Because fan energy ratio values are not published, average annual auxiliary electrical energy consumption (E_{AE})[10] is used to estimate the potential savings from staging during heating and from more efficient motors.

More details on this are outlined in the residential furnaces workpaper (workpaper ID W0207).

The efficient E_{AE} is estimated to be the average from the AHRI database for Focus on Energy–qualified (AFUE ≥95%) multi-stage burner models. The average E_{AE} for 981 such models is 398.8 kWh.

The baseline E_{AE} value is estimated to be the average for noncondensing furnace models that do not otherwise meet Focus on Energy requirements. The average E_{AE} for 1,961 such models is 468.5 kWh.

Therefore, the deemed electric savings for furnaces are 468.5 – 398.8 = 70 kWh.

Incremental Costs

A 2015 U.S Department of Energy Technical Support Document[2] estimates the average cost for 80 MBh, 80% AFUE furnaces to be $2,410. Adjusting this up 12% for inflation to 2020 dollars produces $2,699.20. Data from the Focus on Energy database SPECTRUM shows the average furnace size for MMID 3491 to be 71 MBh, and the average size for MMID 3492 to be 101 MBh. SPECTRUM data also shows average costs per furnace of $3,229.09 for 3491[11] and $3,201.43 for 3492.[12] For MMID 3491, adjusting the baseline cost down 5% to approximately account for the 80 MBh vs. 71 MBh sizes produces a $3,229.09 - $2,699.20 * 0.95 = $664.85 incremental cost. For MMID 3492, adjusting the baseline cost up 10% to approximately account for the 80 MBh vs. 101 MBh sizes produces $3,201.43 - $2,699.20 * 1.1 = $232.31.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. U.S. Department of Energy. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces*. Table 8.5.1. February 10, 2015. https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0027 Used the difference between the north region's 80% and 95% furnaces (for MMID 3491) and between 80% and 90% furnaces (for MMID 3492).

3. Electronic Code of Federal Regulations. https://www.ecfr.gov/cgi-bin/text-idx?SID=a9921a66f2b4f66a32ec851916b7b9d9&mc=true&node=se10.3.430_132&rgn=div8
4. Electronic Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430, Subpart C, §430.32. Table 1—Energy Conservation Standards for Covered Residential Furnace Fans. https://www.ecfr.gov/cgi-bin/text-idx?SID=0423028877ce42bb0c3e0e2529ac80ba&mc=true&node=se10.3.430_132&rgn=div8
5. Regulations.gov. *2014-07-03 Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnace Fans; Final Rule*. Table I.1. https://www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0117
6. U.S. Environmental Protection Agency and U.S. Department of Energy. "Life Cycle Cost Estimate for ENERGY STAR Qualified Air Source Heat Pump(s)." April 2009. https://www.energystar.gov/sites/default/files/asset/document/ASHP_Sav_Calc.xls
   Several Cadmus metering studies have revealed that the ENERGY STAR EFLH calculator is overestimated by 25%. $EFLH_{HEAT}$ for this workpaper was adjusted by population-weighted heating degree days and TMY3 values.
7. Wisconsin Focus on Energy. Historical project data.
   Average size of 58 multifamily applications of MMID 3491 paid in 2019. These applications likely reflect in-unit furnaces. This value should be altered to reflect common area furnaces in the future.
8. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. September 2014 through November 2018.
   Average furnace size of 719 furnaces in 517 business projects for MMID 3491.
9. U.S. Department of Energy. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnace Fans*. June 2014. https://www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0111
10. Electronic Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430 Subpart B, Appendix N. https://www.govinfo.gov/app/details/CFR-2013-title10-vol3/CFR-2013-title10-vol3-part430-subpartB-appN
11. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. For MMID 3491, average cost of 654 projects, 1,277 furnaces, and 186,584 MBh from January 2018 to July 2020 is $22.15 per MBh and $3,229.09 per furnace.
12. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. For MMID 3491, average cost of 3 projects, 7 furnaces, and 706 MBh from January 2018 to April 2020 is $41.41 per MBh and $3,201.43 per furnace.
13. U.S. Energy Information Administration. "Energy Units and Calculators Explained." https://www.eia.gov/energyexplained/?page=about_energy_units

Revision History

Version Number	Date	Description of Change
01	10/11/2018	Initial release
02	3/3/2020	Updated electric savings per new motor efficiency requirements
03	2/2021	Updated incremental cost, added propane measure
04	1/2022	Updated EUL

Outside Air Intake Control Optimization

	Measure Details
Measure Master ID	Outside Air Intake Control Optimization, Building Tune-up, 5292
Workpaper ID	W0074
Measure Unit	Per CFM reduced
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Schools & Government
Annual Energy Savings (kWh)	Varies by baseline and proposed energy consumption
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by baseline and proposed energy consumption
Lifecycle Energy Savings (kWh)	Varies by baseline and proposed energy consumption
Lifecycle Therm Savings (Therms)	Varies by baseline and proposed energy consumption
Water Savings (gal/year)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$200.00[2]

Measure Description

The intent of this measure is to capture savings associated with reducing outside air (OA) supply cubic feet per minute (CFM) on an air handling unit to a minimum or, in the case of broken or out of adjustment OA-dampers, repairing the dampers back to original condition. The outside air intake levels should always conform to local codes and ASHRAE 62.1 standards. Measure can be applied only once per building during the EUL. This measure is meant to be a part of the Whole Building Optimization program to help optimize building HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

Description of Baseline Condition

The baseline measure is an eligible building that a qualified HVAC control professional has verified can save energy by reducing the outside air intake CFM compared to existing levels or repairing broken dampers. The building must currently exceed the minimum outside air intake levels for standard occupancy as defined by local or state requirements.

Description of Efficient Condition

The efficient measure is having a trained HVAC professional determine an appropriate adjustment/repair to the outside air intake levels that conforms to all applicable building codes but is reduced and will still meet the buildings requirements for proper ventilation. Measure rebates do not apply if the outside air CFM needs to increase.

Annual Energy-Savings Algorithm

Savings are determined by summing the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours found in the Outside Air Intake Control Optimization workbook.[3,4] Savings assume a single fixed outside air CFM across all outdoor air temperatures. The user inputs the initial value as the baseline, and the final value as the efficient case.

$kWh_{SAVED} = (Btu_{BASELINE} - Btu_{PROPOSED}) / 12{,}000 * Chiller\_Eff$

$Therm_{SAVED} = (Btu_{BASELINE} - Btu_{PROPOSED}) / 100{,}000 / Gas\ Eff$

$Btu_{BASELINE} = \Sigma\ (1.08 * \text{OA existing supply CFM} * |SAT - OAT| * \text{Bin Hours})$

$Btu_{PROPOSED} = \Sigma\ (1.08 * \text{OA proposed supply CFM} * |SAT - OAT| * \text{Bin Hours})$

Where:

1.08 = Constant for air sensible heat equation[5]

OA existing supply CFM = Actual outside air supply airflow (= based on user input)

SAT = Supply AIr temperature (= 60°F for SAT_C, OAT > 60°F = 75°F for SAT_H, OAT < 60°F)

OAT = Outside air temperature (= determined by Wisconsin BIN data in EBTU workbook)[4]

Bin Hours = Dry-bulb temperature and time of day (also known as temperature bin data)

OA proposed supply CFM = Proposed air supply airflow (= based on user input) (= based on user input)

12,000 = Conversion factor from Btu to tons

Chiller_Eff = Kilowatts per ton (= varies by chiller type based on 80% of full load rating, see table below)

Cooling Efficiency by System Type

Cooling System Type	Cooling System Efficiency Factor at Partial Load (kW/ton)
Direct Expansion	1.15[6]
Air-Cooled Chiller	0.95[7]
Water-Cooled Chiller	0.64[7]

Annual hours of fan operation = Hours in use (= based on user input)

100,000 = Conversion from Btu to therm

Gas Eff = Efficiency of gas unit (variable input from customer)

The workbook calculator requires the following measure-specific inputs to be provided from the trained professional performing the repair/optimization measure:

- Existing outside air intake volume in CFM
- Modified outside air intake volume in CFM (must still meet code minimum for carbon dioxide level control)
- Number of hours outside air supply fan runs annually
- Type of cooling system (DX, air cooled, water cooled)
- Efficiency of gas fired heating system

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / Hours_{COOL} * CF$

Where:

$Hours_{COOL}$ = Annual cooling hours of operation (= varies by city; see table below)

Annual Cooling Hours by City[8]

City	BIN Annual Cooling Hours (OAT > 60°F)
Green Bay	2,748
La Crosse	2,971
Madison	2,876
Milwaukee	2,830

CF = Coincidence factor (= 1 assuming that the reduction of outside air intake CFM will be constant over entire summer peak period)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 4 years)[1]

Assumptions

- Measure unit is listed as ‘Per CFM Reduced’ to reflect the savings calculated using the algorithms, however, this measure is part of the Whole Building Tune-Up Offering where a flat incentive is paid per building, no matter how much CFM is reduced.

- Partial load kW/ton rating for DX, air cooled, and water-cooled chillers is the average of the IEER and IPLV minimum efficiency values.[6,7]
- Assumed use of 1 CFM of total supply air per square foot of conditioned building space.
- Assumed heating and cooling balance temperature of 60°F

Sources

1. Navigant. "Effective Useful Life for Retro-commissioning and Behavior Programs" memo. September 17, 2019. https://ilsag.s3.amazonaws.com/ComEd-EUL-Comm-RCx-and-Behavior-Memo-2019-09-17.pdf. Four years is the EUL for the Operational Efficiency Offering.
2. Focus on Energy. Engineering Judgement. While RSMeans 2016 shows $59 per hour under *23 09 33.10 – Electronic Control System for HVAC*, engineer stakeholders for Focus on Energy believe that $140 per hour is a more realistic rate. This measure will either involve adjusting linkages or re-calibrating damper signals, which would be approximately 1 hour of labor, or repairing/replacing broken or damaged dampers, which would be considerably more expensive. An average cost of $200 is deemed.
3. Wisconsin Focus on Energy. EBTU Measures Workbook Calculator.
4. Natural Renewable Energy Laboratory. Bin temperature data comes from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
5. Edison Electric Institute. Technical Information Handbook. p. 24. 2000.
6. International Energy Conservation Code. Table 503.2.3(1). 2009. DX cooling efficiency values determined from simple average of minimum efficiencies for systems with ≥ 5.5-ton capacity.
7. ASHRAE 90.1-2007, Table 6.8.1C. Chiller unit part load efficiency values determined from simple average of minimum efficiencies for chillers with capacity 0 tons to 300 tons.
8. Appendix B: Common Variables, 'Outside Air Temperature Bin Analysis.'

Revision History

Version Number	Date	Description of Change
01	11/2014	Initial TRM entry
02	12/2021	Removed fan savings, added OA damper repair scenario to description, updated cost and EUL.

Schedule Optimization

	Measure Details
Measure Master ID	Schedule Optimization, Building Tune-up, 5295
Workpaper ID	W0075
Measure Unit	Per rooftop unit
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Schools & Government
Annual Energy Savings (kWh)	Varies by type of schedule optimization
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by type of schedule optimization
Lifecycle Energy Savings (kWh)	Varies by type of schedule optimization
Lifecycle Therm Savings (Therms)	Varies by type of schedule optimization
Water Savings (gal/year)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$420.00[2]

Measure Description

This measure captures savings associated with resetting the scheduled weekly building nighttime (or unoccupied) supply air setpoint temperatures via programmable thermostats or direct digital control (DDC) systems. This is a simple temperature setback measure and not a temperature reset control strategy.

For this measures' savings to apply, the heating supply fuel must be natural gas, and cooling must be supplied by an electrically powered system. The measure can be applied only once per building during the EUL. This measurewas originally part of the Express Building Tune-Up offer that ran through 2019, but has been adapted for the Whole Building Tune-up offering.

Description of Baseline Condition

The baseline measure is a building that already has an HVAC system not using its hourly setback scheduling or a building that can increase its scheduled setback hours. An eligible building must have a consistent weekly operation schedule throughout the year. The average setback hours will be used when schedules vary day-to-day during the week or over the weekend. A building's standard heating and cooling schedule are both eligible for adjustment.

Description of Efficient Condition

This efficient measure is an increased number of average scheduled setback hours controlled through a building programmable HVAC system. A building's standard daily scheduled setback time must be increased by at least one hour during the weekdays or weekends to be eligible for an incentive.

Annual Energy-Savings Algorithm

Savings are the difference between the sums of the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours.[3,4]

Energy savings are summed over every hour of the year, effectively assuming that the same hour of the day (e.g., 1:00 a.m. to 2:00 a.m.) for each day in a given month will yield the same Btu/hour of energy use.

$kWh_{SAVED} = kWh_{BASE} - kWh_{PROPOSED}$

$Therm_{SAVED} = Therm_{BASE} - Therm_{PROPOSED}$

$kWh_{BASE} = \Sigma_{EXISTING} (1.08 * \text{Hourly CFM} * |SAT - MAT| * \text{\# of days per month} / 12{,}000 * chiller\_eff)$

$Therm_{BASE} = \Sigma_{EXISTING} (1.08 * \text{Hourly CFM} * |SAT - MAT| * \text{\# of days per month} / 100{,}000 / boiler\_eff)$

Baseline data is based on the user-defined existing building schedule.

$kWh_{PROPOSED} = \Sigma_{PROPOSED} (1.08 * \text{Hourly CFM} * |SAT - MAT| * \text{\# of days per month} / 12{,}000 * chiller\_eff)$

$Therm_{PROPOSED} = \Sigma_{PROPOSED} (1.08 * \text{Hourly CFM} * |SAT - MAT| * \text{\# of days per month} / 100{,}000 / boiler\_eff)$

$MAT = (RAT * CFM_{RA} + OAT_{AVE} * CFM_{OA}) / CFM_{TOT}$

Proposed data is based on the user-defined proposed building schedule, and should reflect a reduction of HVAC running during occupied hours compared to the baseline.

Where:

1.08 = Constant for air sensible heat equation, Btu/CFM-hr[5]

Hourly CFM = Total building airflow in CFM multiplied by hourly area load (where the area load is a percentage value based on a linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2% dry bulb design summer (see Assumptions), 99% dry bulb design winter conditions for different Wisconsin cities)[6]

SAT = Supply air temperature for occupied hours (= 60°F for OAT > 60°F; = 75°F for OAT ≤ 60°F); for scheduled unoccupied temperature setback hours, SAT is the standard occupied hour temperature setting, plus or minus the user-defined setback temperature for cooling and heating periods, respectively

MAT = Mixed air temperature

RAT = Return air temperature (= 75°F for OAT > 60°F; 68°F for OAT ≤ 60°F)

CFM_{RET} = Return air CFM, = Total Airflow CFM - Outside Air CFM

OAT_{AVE} = Weighted Average Hourly Temperature (Calculated based on the maximum and minimum temperatures over every given hour of the day and number of occurrences per month based on bin data[3])

CFM_{OA} = Outside Air CFM, amount of outside air expected based on facility type and square footage as determined through CBECS statistical data inserted in the EBTU workbook[7,3]

CFM_{TOT} = Total Airflow CFM (1 CFM per square foot of facility space)

# of days per month = Varies by month (= 31 in January; = 28 in February; etc.)

12,000 = Btu to ton conversion factor

chiller_eff = Cooling efficiency of chiller (= User input, if unknown use table below)

Cooling Efficiency by System Type

Cooling System Type	Cooling System Efficiency Factor at Partial Load Rating (kW/ton)
Direct Expansion[8]	1.15
Air-Cooled Chiller[9]	0.95
Water-Cooled Chiller[9]	0.60

100,000 = Btu to therm conversion factor

boiler_eff = Efficiency of natural gas to heat conversion for heating purposes (= User input, if unknown use 80%)

The workbook calculator requires the following inputs to be provided from the trained professional performing the tune-up/optimization measure:

- Majority facility space type (e.g., offices, classroom, lobby, health club)
- Square footage of facility's conditioned space affected by schedule change
- Baseline (pre) and efficient (post) heating and cooling schedule hours, indicating when the system turns on and off during a typical weekday and weekend in 24-hour time format
- Amount of planned temperature setback degrees during scheduled unoccupied times
- Type of facility cooling system (direct expansion, air cooled, or water cooled)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure, as the temperature setback scheduling is not expected to occur during Wisconsin Focus on Energy peak demand hours of 1:00 p.m. to 4:00 p.m. from June through August.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (=4 years)[1]

Assumptions

- Measure unit is listed as 'Per Rooftop Unit' to reflect the savings calculated using the algorithms, however, this measure is part of the Whole Building Tune-Up Offering where a flat incentive is paid per building, no matter how many rooftop units have their scheduling adjusted.
- RAT fixed values (75°F for OAT > 60°F and 68°F for OAT < 60°F) are for calculation purposes
- SAT setpoints are increased or decreased by 5°F during weekly scheduled unoccupied hours during cooling and heating periods, respectively
- Heating and cooling balance temperature of 60°F
- Therm savings are calculated when daily weighted hourly temperatures are less than 60°F
- kWh savings are calculated when daily weighted hourly temperatures are greater than 60°F
- Same average weekly hours schedule is repeated throughout the year
- Total supply is 1 CFM per building square foot
- 2% and 1% dry bulb design conditions for cooling/heating seasons means that the HVAC system is designed to adequately handle the cooling/heating of a given building for all outdoor air temperatures that do not exceed the hottest/coldest 2% and 1% of hours of the respective season. Explained another way, it means the cooling/heating system can adequately handle the cooling/heating load of a given building for 98% and 99% of the total anticipated peak cooling/heating hours for the year.

Sources

1. Navigant. "Effective Useful Life for Retro-commissioning and Behavior Programs" memo. September 17, 2019. https://ilsag.s3.amazonaws.com/ComEd-EUL-Comm-RCx-and-Behavior-Memo-2019-09-17.pdf. Four years is the EUL for the Operational Efficiency Offering.
2. Focus on Energy. Engineering Judgement. While RSMeans 2016 shows $59 per hour under *23 09 33.10 – Electronic Control System for HVAC*, engineer stakeholders for Focus on Energy believe that $140 per hour is a more realistic rate, and that three hours is a realistic average time to complete, assuming three rooftop units at one hour each per building.
3. Wisconsin Focus on Energy. EBTU Measures Workbook Calculator.
4. National Renewable Energy Laboratory. Bin temperature data comes from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W

5. Edison Electric Institute. Technical Information Handbook. Pg. 24. 2000. This value reflects 60 min/hr * 0.24 Btu/lb_{air} * 0.075 lb_{air}/ft^3 = 1.08 Btu/CFM-hr
6. American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. ASHRAE Handbook: Fundamentals. Chapter 14 – Climatic Design Information. “Appendix: Design Conditions for Selected Locations.” 2021.
7. U.S. Energy Information Administration. “2003 CBECS Survey Data.” http://www.eia.gov/consumption/commercial/data/2003/
8. International Energy Conservation Code. Table 403.2.3(1). 2012. CHAPTER 4 [CE] COMMERCIAL ENERGY EFFICIENCY | 2012 International Energy Conservation Code | ICC publicACCESS
Direct expansion cooling efficiency values (air conditioners, air cooled) determined as simple averages of minimum efficiencies for system capacities of ≥ 5.5 tons.
9. ASHRAE 90.1-2010, Table 6.8.1-3.
Chiller unit part-load efficiency values were determined as simple averages of minimum efficiencies for air cooled chillers with capacity of < 150 tons and ≥ 150 tons, and for water cooled chillers <150 tons and between 150 and 300 tons, Path A.

Revision History

Version Number	Date	Description of Change
01	11/2014	Initial TRM entry
02	12/2017	Renamed measures to remove square footage bins and change measure unit to average setback hour
03	1/7/2022	Revisions to convert from old EBTU offer to new whole building tune-up offering, updated cost and EUL

Supply Air Temperature Reset

	Measure Details
Measure Master ID	Supply Air Temperature Reset, Heating, 3672 Supply Air Temperature Reset, Cooling, 3673
Workpaper ID	W0076
Measure Unit	Per degree Fahrenheit
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Schools & Government
Annual Energy Savings (kWh)	Varies by type of reset
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by type of reset
Lifecycle Energy Savings (kWh)	Varies by type of reset
Lifecycle Therm Savings (Therms)	Varies by type of reset
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$96.00[2]

Measure Description

This measure captures savings associated with implementing a new supply air temperature (SAT), cooling or heating, reset strategy or optimizing a programmed SAT reset strategy based on OAT ranges. To claim the measure savings, the heating must be supplied by a natural gas boiler, and the cooling system must be electrically powered. The savings apply specifically to constant air volume (CAV) systems.

This measure is meant to be a part of the Express Building Tune-Up Program to help optimize building HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

Description of Baseline Condition

This baseline measure is an HVAC system with preset SAT setpoints that are not based on OAT.

Description of Efficient Condition

This efficient measure is implementing or optimizing an SAT reset strategy based on OAT. The reset strategy should incorporate a maximum and minimum supply air temperature for both heating and cooling modes to correspond with a minimum and maximum outdoor air temperature range, respectively.

Annual Energy-Savings Algorithm

Savings are the sum of the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours.[3,4]

$\text{kWh}_{\text{SAVED}}$ = Σ (SAT Btu Baseline – SAT Btu Proposed) / 12,000 * chiller_eff * % building affected

$\text{Therm}_{\text{SAVED}}$ = Σ (SAT Btu Baseline – SAT Btu Proposed) / 100,000 / boiler_eff * % building affected

SAT Btu Baseline = [(1.08 * Area_Load * $|\text{SAT}_{\text{BASE}}$ - OAT$|$ * Outside Air CFM + 1.08 * Area_Load * $|\text{SAT}_{\text{BASE}}$ - RAT$|$ * Return Air CFM] * bin hours

SAT Btu Proposed = [(1.08 * Area_Load * $|\text{SAT}_{\text{RESET}}$ - OAT$|$ * Outside Air CFM + 1.08 * Area_Load * $|\text{SAT}_{\text{RESET}}$ - RAT$|$ * Return Air CFM] * bin hours

Where:

1.08 = Constant for air sensible heat equation[5]

Area Load = Percentage value based on linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2.5% dry bulb design summer/winter conditions for different Wisconsin cities[6] (see Assumptions for more explanation about the 2.5% dry bulb design conditions)

SAT_{BASE} = Supply air temperature baseline (= user defined input; constant)

OAT = Outside Air Temperature (= determined from workbook bin data)

Outside Air CFM = Amount of outside air expected based on facility type and square footage as determined through CBECS statistical data inserted in the EBTU workbook[7,3]

RAT = Return air temperature (= 75°F for OAT > 60°F; = 68°F for OAT < 60°F)

Return Air CFM = Total building airflow – Outside Air CFM

bin hours = Heating and cooling hours for each city based on OAT[4]

$\text{SAT}_{\text{RESET}}$ = OAT reset range (= user input)

12,000 = Btu to ton conversion factor

chiller_eff = Cooling efficiency of chiller (= varies by chiller type; see table below)

Cooling Efficiency by System Type

Cooling System Type	Cooling System Efficiency Factor at Partial Load (kW/ton)
Direct Expansion	1.15[8]
Air-Cooled Chiller	0.95[9]
Water-Cooled Chiller	0.64[9]

% building affected = Amount of total building conditioned square footage affected by implementing the SAT reset control (= user defined input)

100,000 = Btu to therm conversion factor

boiler_eff = Efficiency of natural gas to heat conversion for heating purposes (= 80%)

The workbook calculator requires the following measure-specific inputs to be provided from the trained professional performing the tune-up/optimization measure:

- OAT Reset Range – Heating and Cooling (°F)
- Existing Facility Supply Air Heating and Cooling Temperature Setpoints (°F)
- SA Reset Temperature Range – Heating and Cooling (°F)
- Facility Type (e.g., office, library, retail)
- Useable Facility Square Footage
- Percentage of Total Facility Area Cooled
- Percentage of Total Facility Area Heated
- Number of Building Zones Affected
- Type of Chiller System
- Percentage of Building Square Footage Affected

Summer Coincident Peak Savings Algorithm

There is no peak demand reduction associated with this measure because during peak demand times, the cooling system will be operating above the bounds of the SAT reset curve.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Assumptions

- Partial load kW/ton rating for air-cooled and water-cooled chillers is average IPLV minimum efficiency value found in Focus on Energy HVAC catalog[9]
- Total supply of 1 CFM per building conditioned square foot
- Heating and cooling balance temperature = 60°F
- 2.5% dry bulb design conditions means that for cooling/heating seasons, the HVAC system is designed to adequately handle the cooling/heating of a given building for all outdoor air temperatures that do not exceed the hottest/coldest 2.5% of hours of the respective season. Explained another way, this means the cooling/heating system can adequately handle the

cooling/heating load of a given building for 97.5% of the total anticipated peak cooling/heating hours for the year.

Sources

1. Cadmus. EUL Response Memo. April 26, 2013.
   Used Retrocommissioning Program EUL standard and direction from CB&I to keep five year EUL standard.
2. RSMeans 2013 Facilities Construction Cost Data, 29th Edition
3. Wisconsin Focus on Energy. EBTU Measures Workbook Calculator.
4. Natural Renewable Energy Laboratory. Bin temperature data comes from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
5. Edison Electric Institute. Technical Information Handbook. p. 24. 2000.
6. ASHRAE. Handbook, Fundamentals Volume for Wisconsin Cities. 1985. http://publicecodes.cyberregs.com/icod/ipc/2012/icod_ipc_2012_appd.htm
7. U.S. Energy Information Administration. National CBECS Statistical Data. 2003. http://www.eia.gov/consumption/commercial/data/2003/
8. International Energy Conservation Code. Table 503.2.3(1). 2009. DX cooling efficiency values determined as simple average minimum efficiencies for systems with capacity ≥ 5.5 tons.
9. ASHRAE 90.1-2007. Table 6.8.1C. Chiller unit part load efficiency values are simple average minimum efficiencies for chillers with capacity of 0 tons to 300 tons.

Revision History

Version Number	Date	Description of Change
01	11/2014	Initial TRM entry

Temperature Sensor Calibration

	Measure Details
Measure Master ID	Temperature Sensor Calibration, 3674
Workpaper ID	W0077
Measure Unit	Per degree of calibration
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Schools & Government
Annual Energy Savings (kWh)	Varies by temperature ranges and hours
Peak Demand Reduction (kW)	Varies by temperature ranges and hours
Annual Therm Savings (Therms)	Varies by temperature ranges and hours
Lifecycle Energy Savings (kWh)	Varies by temperature ranges and hours
Lifecycle Therm Savings (Therms)	Varies by temperature ranges and hours
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$108.00[2]

Measure Description

This measure captures savings by calibrating temperature sensors in an air handling unit feeding a particular building zone. The measure savings are specific to air distribution systems, but are otherwise flexible. This measure does not include the cost to replace sensors that have completely failed.

To apply measure savings, the heating supply must be produced by a natural gas boiler, while the cooling system must be electrically powered. The measure can be applied only once per building during the EUL. This measure is meant to be a part of the Express Building Tune-Up Program to help optimize building HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

This measure is applicable for supply air temperature (SAT) and indoor air room temperature (IAT) sensors that are measuring and providing control feedback to the building HVAC systems.

Description of Baseline Condition

The baseline measure is a facility’s SAT and IAT sensors not having been calibrated and no Wisconsin Focus on Energy rebate applied for at least five years.

Description of Efficient Condition

The efficient measure is to re-calibrate SAT and IAT sensors by averaging three separate temperature readings with a secondary calibrated temperature device within close proximity of the sensor to be calibrated. This will determine the amount the facility temperature sensors are off from actual in order to make the necessary calibrations. The recalibrated sensors will help ensure that excess energy is not being wasted to heat or cool a space. Broken sensors that need total replacement are not eligible. Calibrated sensors should be adjusted to within two decimal places.

Annual Energy-Savings Algorithm

Savings are the sum of the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours found in the EBTU workbook.[3,4]

kWh_{SAVED} = Σ (Temp Sensor cooling Btu Baseline – Temp Sensor cooling Btu Proposed) / 12,000 * chiller_eff * % building affected * bin hours

$Therm_{SAVED}$ = Σ (Temp Sensor heating Btu Baseline – Temp Sensor heating Btu Proposed) / 80% / 100,000 * % building affected * bin hours

Temp Sensor cooling/heating Btu Baseline = 1.08 * $Area\_Load_{BASE}$ * |SAT - OAT| * Outside Air CFM + 1.08 * $Area\_Load_{BASE}$ * Δ (SAT - RAT) * Return Air CFM

Temp Sensor cooling/heating Btu Proposed = 1.08 * $Area\_Load_{PROP}$ * |SAT - OAT| * Outside Air CFM + 1.08 * $Area\_Load_{PROP}$ * Δ (SAT - RAT) * Return Air CFM

Where:

1.08 = Constant for air sensible heat equation[5]

$Area\_Load_{BASE}$ = Percentage value based on linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2.5% dry bulb design summer/winter conditions for different Wisconsin cities[6] (see Assumptions for more explanation about the 2.5% dry bulb design conditions)

SAT = Supply air temperature (= 60°F for OAT > 60°F; = 75°F for OAT < 60°F)

OAT = Outside air temperature

Outside Air CFM = Amount of outside air expected based on facility type and square footage as determined through CBECS statistical data inserted in the EBTU workbook[7,3]

RAT = Return air temperature (= 75°F for OAT > 60°F; = 68°F for OAT < 60°F)

Return Air CFM = Total building airflow – Outside Air CFM (per zone)

$Area\_Load_{PROP}$ = Percentage value based on linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT ± calibrated values, and 2.5% dry bulb design maximum/minimum temperatures for different Wisconsin cities[6]

12,000 = Btu to ton conversion factor

chiller_eff = kW/ton based on 80% of full load rating of chiller units (= based on type of chiller; see table below)

Cooling Efficiency by System Type

Cooling System Type	Cooling System Efficiency Factor at Partial Load (kW/ton)
Direct Expansion	1.15[8]
Air-Cooled Chiller	0.95[9]
Water-Cooled Chiller	0.64[9]

% building affected = Amount of total building square footage affected by sensor calibration (= user defined)

bin hours = Heating and cooling hours for each city based on OAT[4]

80% = Efficiency of natural gas to heat conversion for heating purposes

100,000 = Btu to therm conversion factor

The workbook calculator requires the following measure-specific inputs to be provided from the trained professional performing the tune-up/optimization measure:

- An average of three separate measurement reading of the un-calibrated air handling unit temperature sensor to determine the current baseline reading (measurements should be out two decimal places)
- An average of three separate temperature readings of the calibrated air flowing near the un-calibrated temperature sensor, used to read and calibrate the un-calibrated sensor (measurements should be out two decimal places)
- Majority facility space type (e.g., offices, classroom, lobby, health club)
- Percentage of facility being heated
- Percentage of facility being cooled
- Square footage of usable facility space
- Chiller system type (direct expansion, air cooled, or water cooled)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / Hours_{COOL} * CF$

Where:

$Hours_{COOL}$ = Annual cooling hours of operation (= based on city; see table below)

Annual Cooling Hours by City

City	BIN Annual Cooling Hours (OAT > 60°F)[10]
Green Bay	2,745
La Crosse	2,971
Madison	2,874
Milwaukee	2,830

CF = Coincidence factor (= 1)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (=5 years)[1]

Assumptions

- Therm savings are calculated only when the calibrated reading is greater than the original sensors reading
- kWh savings are calculated only when the calibrated reading is less than the original sensor reading
- Heating and cooling balance temperature = 60°F
- Total supply of 1 CFM per building square foot
- 2.5% dry bulb design conditions means that for cooling/heating seasons, the HVAC system is designed to adequately handle the cooling/heating of a given building for all outdoor air temperatures that do not exceed the hottest/coldest 2.5% of hours of the respective season. Explained another way, this means the cooling/heating system can adequately handle the cooling/heating load of a given building for 97.5% of the total anticipated peak cooling/heating hours for the year.

Sources

1. Cadmus. EUL Response Memo. April 26, 2013.
   Used Retrocommissioning Program EUL standard and direction from CB&I to keep 5 year EUL standard)
2. RSMeans. Facilities Construction Cost Data. 29th Edition. 2013. Assumed $54.00 per hour labor rate and estimated two hours for completion.
3. Wisconsin Focus on Energy. EBTU Measures Workbook Calculator.

4. Natural Renewable Energy Laboratory. Bin temperature data comes from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
5. Edison Electric Institute. Technical Information Handbook. p. 24. 2000.
6. ASHRAE. Handbook, Fundamentals Volume for Wisconsin Cities. 1985. http://publicecodes.cyberregs.com/icod/ipc/2012/icod_ipc_2012_appd.htm
7. U.S. Energy Information Administration. National CBECS Statistical Data. 2003. http://www.eia.gov/consumption/commercial/data/2003/
8. International Energy Conservation Code. Table 503.2.3(1). 2009. DX cooling efficiency values determined as simple average minimum efficiencies for systems with capacity ≥ 5.5 tons.
9. ASHRAE 90.1-2007. Table 6.8.1C. Chiller unit part load efficiency values are simple average minimum efficiencies for chillers with capacity of 0 tons to 300 tons.
10. Appendix B: Common Variables, ‘Outside Air Temperature Bin Analysis.’

Revision History

Version Number	Date	Description of Change
01	11/2014	Initial TRM entry

Valve Repair

	Measure Details
Measure Master ID	Valve Repair, Chilled Water, Building Tune-up, 5293 Valve Repair, Hot Water, Building Tune-up, 5294
Workpaper ID	W0078
Measure Unit	Per valve (see Assumptions)
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by type of repair
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by type of repair
Lifecycle Energy Savings (kWh)	Varies by type of repair
Lifecycle Therm Savings (Therms)	Varies by type of repair
Water Savings (gal/year)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$140.00[2]

Measure Description

This measure captures savings associated with repairing a chilled or hot water valve serving a cooling/heating coil in a central air handling unit. This measure is for addressing a valve that has failed at least 70% open .

The incremental cost does not account for the potential replacement of unrepairable/broken valves. The heating supply must be produced by a natural gas boiler, and the cooling system must be electrically powered. The measure can be applied only once per building during the EUL. This measure is meant to be a part of the Whole Building Tune-Up Offering to help optimize building HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

Description of Baseline Condition

The baseline measure is a chilled or hot water valve in need of repair due to being stuck open at 70% or greater. If the valve is stuck at some point less than 70% open, this measure does not apply.

Description of Efficient Condition

The efficient measure is replacing or repairing a failed valve back to its optimal working state.

Annual Energy-Savings Algorithm

Savings are the sum of the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours found in the WBTU-Valve Repair workbook.[3,4]

$$kWh_{SAVED} = \Sigma_{TEMP} [BTU_{COOL,BASE} - BTU_{COOL,EE}] * IPLV / 12{,}000$$

$$Therm_{SAVED} = \Sigma_{TEMP} [BTU_{HEAT,BASE} - BTU_{HEAT,EE}] / (80\% * 100{,}000)$$

$$BTU_{COOL,BASE} = Tons * 12{,}000 * \%V_{STUCK} * HOU_{ADJ} * Area\ Load$$

$$BTU_{COOL,EE} = Tons * 12{,}000 * \%V_{WORK} * HOU_{ADJ} * Area\ Load$$

$$BTU_{HEAT,BASE} = MBh * 1{,}000 * \%V_{STUCK} * HOU_{ADJ} * Area\ Load$$

$$BTU_{HEAT,EE} = MBh * 1{,}000 * \%V_{WORK} * HOU_{ADJ} * Area\ Load$$

$$HOU_{ADJ} = HOU_{BIN} * EFLH / 8{,}760$$

$$\%V_{WORK} = (1 - 25\%) * (OAT - T_{DES,HEAT}) / (T_{DES,HEAT} - T_{BAL}) \text{ for heating}$$

$$(1 - 25\%) * (OAT - T_{HIGH}) / (T_{HIGH} - T_{BAL}) \text{ for cooling}$$

Where:

Σ_{TEMP} = Summary of consumption across outdoor air temperature bins

$BTU_{COOL,BASE}$ = Baseline BTU cooling consumption in a given OAT temperature bin

$BTU_{COOL,EE}$ = Efficient BTU cooling consumption in a given OAT temperature bin

$BTU_{HEAT,BASE}$ = Baseline BTU heating consumption in a given OAT temperature bin

$BTU_{HEAT,EE}$ = Efficient BTU heating consumption in a given OAT temperature bin

IPLV = Efficiency of cooling system in kilowatts per ton (= based on user defined type of chiller; see table below)

Cooling Efficiency (IPLV) by System Type

Chiller Type	Cooling System Efficiency Factor at Part Load (kW/ton)
Air-Cooled	0.95[6]
Water-Cooled	0.64[6]

12,000 = Btu to ton conversion factor

80% = Efficiency of natural gas to heat conversion for heating purposes

100,000 = Btu to therm conversion factor

Tons = Capacity of cooling coil being served (= user defined)

$\%V_{STUCK}$ = Percentage valve is stuck open in baseline condition (= user defined)

HOU_{BIN} = The number of average hours of occurrence during a month or year of a particular range of weather condition[4]

EFLH = Equivalent Full Load Hours (see table below)

Equivalent Full-Load Heating and Cooling Hours by City

City	$EFLH_{COOL}$[7]	$EFLH_{HEAT}$[7]
Green Bay	344	1,852
La Crosse	323	1,966
Madison	395	1,934
Milwaukee	457	1,883

8,760 = Total hours in a year

Area Load = Percentage value based on linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2.5% dry bulb design summer/winter conditions for different Wisconsin cities[5] (see Assumptions for more explanation about the balance point temperature and the 2.5% dry bulb design conditions)

MBh = Capacity of heat coil being served (= user defined)

1,000 = Kilowatt conversion factor

$\%V_{WORK}$ = Percent valve is open at a given outdoor temperature bin (see Assumptions)

OAT = Outdoor air temperature for a given outdoor temperature bin

$T_{DES,HEAT}$ = 99% design temperature for heating (= -2.8°F for Green Bay, = -4.2°F for La Crosse, = -1.2°F for Madison, = 3.6°F for Milwaukee)

T_{BAL} = Balance point temperature (= 60°F, assumed)

T_{HIGH} = Temperature for highest temperature bin (= 94°F, assumed)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 4 years)[1]

Assumptions

- Measure unit is listed as 'Per Valve' to reflect the savings calculated using the algorithms, however, this measure is part of the Whole Building Tune-Up Offering where a flat incentive is paid per building, no matter how many valves are repaired.
- 2.5% dry bulb design conditions means that for cooling/heating seasons, the HVAC system is designed to adequately handle the cooling/heating of a given building for all outdoor air temperatures that do not exceed the hottest/coldest 2.5% of hours of the respective season. Explained another way, this means the cooling/heating system can adequately handle the cooling/heating load of a given building for 97.5% of the total anticipated peak cooling/heating hours for the year.
- For the percent working valve position calculation, a (1 - 0.25) component is used to make a conservative adjustment, assuming the valve is still 25% open at the balancing point.

Sources

1. Navigant. "Effective Useful Life for Retro-commissioning and Behavior Programs" memo. September 17, 2019. https://ilsag.s3.amazonaws.com/ComEd-EUL-Comm-RCx-and-Behavior-Memo-2019-09-17.pdf. Four years is the EUL for the Operational Efficiency Offering.
2. Focus on Energy. Engineering Judgement. While RSMeans 2016 shows $59 per hour under *23 09 33.10 – Electronic Control System for HVAC*, engineer stakeholders for Focus on Energy believe that $140 per hour is a more realistic rate, and that one hour is a realistic average time to complete. This includes verifying valve status and re-connecting if disconnected, or changing programming parameters. This also assumes the valve actuator or valve body has not failed, in which case the cost would be much higher.
3. Wisconsin Focus on Energy. WBTU-Valve Repair Workbook Calculator.
4. Natural Renewable Energy Laboratory. Bin temperature data comes from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
5. ASHRAE. Handbook, Fundamentals Volume for Wisconsin Cities. 1985. http://publicecodes.cyberregs.com/icod/ipc/2012/icod_ipc_2012_appd.htm
6. ASHRAE 90.1-2007. Table 6.8.1C. Chiller unit part load efficiency values are simple average minimum efficiencies for chillers with capacity of 0 tons to 300 tons.
7. Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLH are over-estimated by 25%. The EFLHHEAT were adjusted by population-weighted HDD and TMY-3 values.

Revision History

Version Number	Date	Description of Change
01	11/2014	Initial TRM entry
02	12/2021	Added WBTU measure, updated cost and EUL

VFD Fan Motor Control Restoration

	Measure Details
Measure Master ID	VFD Fan Motor Control Restoration, 3677
Workpaper ID	W0079
Measure Unit	Per horsepower
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by temperature ranges and hours
Peak Demand Reduction (kW)	Varies by temperature ranges and hours
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by temperature ranges and hours
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$56.00[2]

Measure Description

This measure captures savings associated with correcting the operating setting on a variable frequency drive (VFD) controlling an HVAC system-related fan motor that is stuck in ‘hand’ mode or is in bypass mode. Measure rebate does not apply if the original VFD was incented by Wisconsin Focus on Energy. Measure rebate applies to all other VFDs only once per building during the EUL. This measure is meant to be a part of the Express Building Tune-Up Program to help optimize building HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

Description of Baseline Condition

The baseline measure is a fan motor in a facility using a VFD for motor control, but not using the ‘automatic’ VFD control features.

Description of Efficient Condition

The efficient measure is restoring the automatic control features of a VFD controlling a fan motor load. The VFD should not be manually altered in its control operation after being set to automatic mode.

Annual Energy-Savings Algorithm

Savings are the sum of the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours found in the EBTU workbook.[3,4]

kWh_{SAVED} = VFD Motor Baseline - VFD Motor Proposed

VFD Motor Baseline = Σ [Motor hp * 0.7465 / Motor eff * (Motor loading $\%_{BASE}$)^2.5 * Adjusted Run Hours]

VFD Motor Proposed = Σ [Motor hp * 0.7465 / Motor eff * (Motor loading $\%_{PROP}$)^2.5 * Adjusted Run Hours]

Where:

Motor hp = VFD controlled motor nameplate horsepower rating

0.7465 = Horsepower to kW conversion factor

Motor eff = Specific VFD controlled motor nameplate efficiency; otherwise use default of 90%

Motor Loading $\%_{BASE}$ = Percent capacity (Load Factor) of motor at baseline (= user defined)

Adjusted Run Hours = Bin hours * (annual VFD operational hours / 8,760 annual hours)

Motor Loading $\%_{PROP}$ = Percent capacity (Load Factor) of motor proposed; assumes the VFD is set back to 'automatic' control based on user-defined loading minimum and maximum percentages and on area load (area load is a percentage based on a linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2.5% dry bulb design summer/winter conditions for different Wisconsin cities;[5] see Assumptions for more explanation about the 2.5% dry bulb design conditions)

The workbook calculator requires the following measure-specific inputs to be provided from the trained professional performing the tune-up/optimization measure:

- Annual hours of VFD/fan operation
- Fan VFD application (cooling tower fan, chiller system fan, boiler/heating fan)
- Existing VFD control state (auto, manual, bypassed/off)
- Fan motor nameplate capacity controlled by VFD (horsepower)
- Fan motor nameplate efficiency percentage
- Measured speed at setpoint if VFD is stuck in 'hand' mode (Hz)
- VFD fan control loading minimum and maximum percentages

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / Hours_{FAN} * CF$

Where:

$Hours_{FAN}$ = Annual hours of operation for the fan controlled by the VFD

CF = Coincidence factor (= based on VFD fan use; see table below)

Coincidence Factor by VFD Fan Use[6]

VFD Use	CF	Details
Cooling Tower Fan	0.9	DEER model runs were weather-normalized for statewide use by population density
Boiler Draft/Heating Fan	0.0	Assumed that heating fan not operating at peak summer period

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=5 years)[1]

Assumptions

- Assumes 100% load factor for all motors running in a VFD bypassed state.
- 2.5% dry bulb design conditions means that for cooling/heating seasons, the HVAC system is designed to adequately handle the cooling/heating of a given building for all outdoor air temperatures that do not exceed the hottest/coldest 2.5% of hours of the respective season. Explained another way, this means the cooling/heating system can adequately handle the cooling/heating load of a given building for 97.5% of the total anticipated peak cooling/heating hours for the year.

Sources

1. Cadmus. EUL Response Memo. April 26, 2013. Used the Retrocommissioning Program EUL standard and direction from CB&I to keep 5 year EUL standard.
2. RSMeans 2013 Facilities Construction Cost Data, 29th Edition
3. Wisconsin Focus on Energy. EBTU Measures Workbook Calculator.
4. Natural Renewable Energy Laboratory. Bin temperature data comes from respective Wisconsin cities TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
5. ASHRAE. Handbook, Fundamentals Volume for Wisconsin Cities. 1985. http://publicecodes.cyberregs.com/icod/ipc/2012/icod_ipc_2012_appd.htm
6. Wisconsin Focus on Energy Technical Reference Manual. p. 225, Variable Frequency Drive, summer coincident peak savings algorithm VFD coincidence factor chart. 2015.

Revision History

Version Number	Date	Description of Change
01	10/2014	Initial TRM entry

VFD Pump Control Restoration

	Measure Details
Measure Master ID	VFD Pump Control Restoration, 3678
Workpaper ID	W0080
Measure Unit	Per horsepower
Measure Type	Hybrid
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by temperature ranges and hours
Peak Demand Reduction (kW)	Varies by temperature ranges and hours
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by temperature ranges and hours
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$56.00[2]

Measure Description

This measure captures savings associated with correcting the operating setting on a variable frequency drive (VFD) controlling an HVAC system-related pump motor that is stuck in ‘hand’ mode or is in bypass mode. Measure rebate does not apply if the original VFD was incented by Wisconsin Focus on Energy. Measure rebate applies to all other VFDs only once per building during the EUL. This measure is meant to be a part of the Express Building Tune-Up Program to help optimize building HVAC systems to operate more efficiently at existing building load conditions. It does not apply to newly constructed facilities that have not been commissioned.

Description of Baseline Condition

The baseline measure is a pump motor in a facility using a VFD for pump control, but not using the ‘automatic’ VFD control features.

Description of Efficient Condition

The efficient measure is restoring the automatic control features of a VFD controlling a pump load. The VFD should not be manually altered in its control operation after being set to automatic mode.

Annual Energy-Savings Algorithm

Savings are the sum of the baseline and proposed energy consumption formulas below across the bin data temperature ranges and corresponding bin temperature hours found in the EBTU workbook.[3,4]

kWh_{SAVED} = VFD Pump Baseline - VFD Pump Proposed

VFD Pump Baseline = Σ [Motor hp * 0.7465 / Motor eff * (Motor loading $\%_{BASE}$)^2.5 * Adjusted Run Hours]

VFD Pump Proposed = Σ [Motor hp * 0.7465 / Motor eff * (Motor loading $\%_{PROP}$)^2.5 * Adjusted Run Hours]

Where:

Motor hp = VFD controlled motor nameplate horsepower rating

0.7465 = Horsepower to kW conversion factor

Motor eff = Specific VFD controlled pump motor nameplate efficiency; otherwise use default of 90%

Motor Loading $\%_{BASE}$ = Percent capacity (Load Factor) of motor at baseline (= user defined)

Adjusted Run Hours = Bin hours * (annual VFD operational hours / 8,760 annual hours)

Motor Loading $\%_{PROP}$ = Percent capacity (Load Factor) of motor proposed; assumes the VFD is set back to 'automatic' control based on user-defined loading minimum and maximum percentages and on area load (area load is a percentage based on a linear interpolation of a 60°F dry bulb OAT balance point, bin data dry bulb OAT, and 2.5% dry bulb design summer/winter conditions for different Wisconsin cities;[5] see Assumptions for more explanation about the 2.5% dry bulb design conditions)

The workbook calculator requires the following measure-specific inputs to be provided from the trained professional performing the tune-up/optimization measure:

- Annual hours of VFD/fan operation
- Fan VFD application (cooling tower fan, chiller system fan, boiler/heating fan)
- Existing VFD control state (auto, manual, bypassed/off)
- Fan motor nameplate capacity controlled by VFD (horsepower)
- Fan motor nameplate efficiency percentage
- Measured speed at setpoint if VFD is stuck in 'hand' mode (Hz)
- VFD fan control loading minimum and maximum percentages

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / Hours_{PUMP} * CF$

Where:

$Hours_{PUMP}$ = Annual hours of operation for the pump controlled by the VFD

CF = Coincidence factor (= based on VFD pump use; see table below)

Coincidence Factor by VFD Pump Use[6]

VFD Use	CF	Source
Chilled Water Pump	0.9	DEER model runs were weather-normalized for statewide use by population density
Hot Water Pump	0.0	Assumed that heating/hot water pump not operating at peak times

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=5 years)[1]

Assumptions

- Assumes 100% load factor for all motors running in a VFD bypassed state.
- 2.5% dry bulb design conditions means that for cooling/heating seasons, the HVAC system is designed to adequately handle the cooling/heating of a given building for all outdoor air temperatures that do not exceed the hottest/coldest 2.5% of hours of the respective season. Explained another way, this means the cooling/heating system can adequately handle the cooling/heating load of a given building for 97.5% of the total anticipated peak cooling/heating hours for the year.

Sources

1. Cadmus. EUL Response Memo. April 26, 2013. Used the Retrocommissioning Program EUL standard and direction from CB&I to keep 5 year EUL standard.
2. RSMeans 2013 Facilities Construction Cost Data, 29th Edition
3. Wisconsin Focus on Energy. *EBTU Measures Workbook Calculator.* January 2015.
4. Natural Renewable Energy Laboratory. Bin temperature data from respective Wisconsin City TMY3 weather data. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html#W
5. ASHRAE. *Handbook, Fundamentals Volume for Wisconsin Cities*. 1985. http://publicecodes.cyberregs.com/icod/ipc/2012/icod_ipc_2012_appd.htm
6. *Wisconsin Focus on Energy Technical Reference Manual.* p. 225, Variable Frequency Drive, summer coincident peak savings algorithm VFD coincidence factor chart. 2015.

Revision History

Version Number	Date	Description of Change
01	10/2014	Initial TRM entry

Variable Speed ECM Pump, Domestic Hot Water Recirculation, Heating Water Circulation, and Cooling Water Circulation

	Measure Details
Measure Master ID	Variable Speed ECM Pump: Domestic Hot Water Recirculation, < 100 Watts Max Input, 3494 Domestic Hot Water Recirculation, < 100 Watts Max Input, 3494 Domestic Hot Water Recirculation, 100-500 Watts Max Input, 3495 Domestic Hot Water Recirculation, 500-1,000 Watts Max Input, 5011 Domestic Hot Water Recirculation, 1,000-1,500 Watts Max Input, 5012 Domestic Hot Water Recirculation, >1,500 Watts Max Input, 5010 Heating Water Circulation, < 100 Watts Max Input, 3497 Heating Water Circulation, 100-500 Watts Max Input, 3498 Heating Water Circulation, 500-1,000 Watts Max Input, 5013 Heating Water Circulation, 1,000-1,500 Watts Max Input, 5014 Heating Water Circulation, >1,500 Watts Max Input, 5015 Cooling Water Circulation, < 100 Watts Max Input, 3500 Cooling Water Circulation, 100-500 Watts Max Input, 3501 Cooling Water Circulation, 500-1,000 Watts Max Input, 5016 Cooling Water Circulation, 1,000-1,500 Watts Max Input, 5017 Cooling Water Circulation, >1,500 Watts Max Input, 5018 Water Loop Heat Pump Circulation, < 100 Watts Max Input, 3503 Water Loop Heat Pump Circulation, 100-500 Watts Max Input, 3504 Water Loop Heat Pump Circulation, 500-1,000 Watts Max Input, 5019 Water Loop Heat Pump Circulation, 1,000-1,500 Watts Max Input, 5020 Water Loop Heat Pump Circulation, >1,500 Watts Max Input, 5021 Wholesale, < 100 Watts Max Input: 5166
Workpaper ID	W0081
Measure Unit	Per pump
Measure Type	Prescriptive
Measure Group	Domestic Hot Water Recirculation – Domestic Hot Water Heating Water Circulation – HVAC Cooling Water Circulation – HVAC Water Loop Heat Pump Circulation – HVAC
Measure Category	Variable Speed Drive
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily, Residential- single family
Annual Electricity Savings (kWh)	Varies by wattage
Peak Demand Reduction (kW)	Varies by wattage
Annual Natural Gas Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by wattage
Lifecycle Natural Gas Savings (Therms)	0

	Measure Details
Annual Water Savings (gallons)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure and wattage, see Incremental Costs table

Measure Description

ECMs are high-efficiency brushless DC motors. These typically fractional horsepower motors have several benefits over the more common permanent split capacitor (PSC) fractional horsepower motor, including higher overall efficiency: PSC motors are generally 20% to 60% efficient, depending on their loading, while ECM motor efficiencies range from 70% to 80%. Other advantages include a reduction in the pump motor size, the variable speed capability of the pump, the ability to provide constant flow with varying pressures, a wider range of rpm, and the ability to be controlled by direct digital controls.

Domestic hot water (DHW) recirculating pumps are commonly used in multifamily and commercial buildings to shorten the amount of time it would otherwise take for hot water to reach the occupants on upper floors who have long piping runs. These recirculation pumps can be operated continuously or be controlled by a timer or an aquastat. An aquastat turns the pump on only when the temperature of the return line falls below a certain setpoint. Many of the ECM recirculating pumps currently on the market have integrated aquastat controls and the ability to be controlled and monitored wirelessly.

Heating and cooling water circulation pumps are commonly used in baseboard and radiant floor heating systems, as well as in coils of forced air systems in multifamily and commercial buildings. Single family residential homes also use heating and cooling water circulation pumps in hydronic heating systems. Cooling loops are often part of heat pump circulation systems. Often the primary and secondary loops run constantly throughout the heating or cooling season. ECM circulator pumps can modulate their own pump speed to match the load.

Description of Baseline Condition

The baseline condition is a standard efficiency, constant volume PSC pump for domestic heating or cooling circulation without variable speed capabilities.

Description of Efficient Condition

The efficient condition is a properly sized high-efficiency ECM pump for domestic heating or cooling circulation with variable speed capabilities to match demand.

Savings for this measure are from the reduction in pump motor size, the variable speed capability of the pump, and the increased efficiency of the ECMs versus the fraction horsepower from PSC motors.

Annual Energy-Savings Algorithm

Heating and Cooling Circulation Pumps

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU$

Water Loop Heat Pump Circulation Pumps

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * (HOU_{HEATING} + HOU_{COOLING})$

$HOU_{HEATING} = HDD * 24 / \Delta T_{HEAT}$

$HOU_{COOLING} = CDD * 24 / \Delta T_{COOL}$

DHW Recirculation Pumps

$kWh_{SAVED} = (Watts_{BASE} / 1{,}000 * HOU_{DHW-BASE}) – (Watts_{EE} / 1{,}000 * HOU_{DHW-EE})$

$HOU_{DHW-BASE} = HOU_{UNCONTROLLED} * 44.5\% + HOU_{CONTROLLED} * 55.5\%$

$HOU_{DHW-EE} = HOU_{CONTROLLED}$

Where:

$Watts_{BASE}$ = Power consumption of constant speed PSC pump (= $Watts_{EE}$ / R)

$Watts_{EE}$ = Power consumption of variable speed ECM pump (= see table below)

Assumed Powers for Ranges of ECM Pumps

Size Range, Watts	Assumed Power, Watts
<100	50
>100, ≤500	250
>500, ≤1,000	700
>1,000, ≤1,500	1,200
>1,500	1,800

1,000 = Kilowatt conversion factor

HOU = Average annual pump run hours

R = Ratio of ECM watts to baseline watts (40%; see Assumptions)[2]

HDD = Heating degree days (= 7,616; see Heating and Cooling Degree Days by Location table)[5]

24 = Conversion factor, hours per day

ΔT_{HEAT} = Design temperature difference for heating (= 80°F, using -15°F outdoor and 65°F indoor)

CDD = Cooling degree days (= 565; see table below)[5]

Heading and Cooling Degree Days by Location

Location	HDD[5]	CDD[5]
Milwaukee	7,276	548
Green Bay	7,725	516
Wausau	7,805	654
Madison	7,599	630
La Crosse	7,397	729
Minocqua	8,616	423
Rice Lake	8,552	438
Statewide Weighted	**7,616**	**565**

ΔT_{COOL} = Design temperature difference for cooling (= 20°F, using 95°F outdoor and 75°F indoor)

$HOU_{DHW\text{-}BASE}$ = Average annual baseline DHW recirculating pump run hours (= 5,114)[3]

$HOU_{DHW\text{-}EE}$ = Average annual efficient DHW recirculating pump run hours (= 2,190)[3]

$HOU_{UNCONTROLLED}$ = Average annual pump run hours for DHW recirculating continuously running (= 8,760)

44.5% = Fraction of baseline systems with no controls[4]

$HOU_{CONTROLLED}$ = Average annual pump run hours for DHW recirculating controlled by a timer or aquastat (= 2,190)[3]

55.5% = Fraction of baseline systems with timer or aquastat controls[4]

Summer Coincident Peak Savings Algorithm

The summer coincident peak savings algorithm only applies to cooling circulation pumps and DHW recirculation pumps.

$kW_{SAVED} = (Watts_{BASE}\text{-} - Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= 0.299 for chilled water pumps,[5] = 1.0 for DHW pumps)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Energy Savings for VSD ECM Pumps

Wattage	MMID	Energy Savings (kWh)	Lifecycle Savings (kWh)	Demand Reduction (kW)
DHW Recirculation Pumps				
<100	3494	530	7,946	0.0750
>100, ≤500	3495	2,649	39,731	0.3750
>500, ≤1,000	5011	7,417	111,248	1.0500
>1,000, ≤1,500	5012	12,714	190,710	1.8000
>1,500	5010	19,071	286,065	2.7000
Heating Water Circulation Pumps				
<100	3497	171	2,571	0.0000
>100, ≤500	3498	857	12,853	0.0000
>500, ≤1,000	5013	2,399	35,989	0.0000
>1,000, ≤1,500	5014	4,113	61,695	0.0000
>1,500	5015	6,170	92,543	0.0000
Cooling Water Circulation Pumps				
<100	3500	51	763	0.0224
>100, ≤500	3501	254	3,814	0.1121
>500, ≤1,000	5016	712	10,679	0.3140
>1,000, ≤1,500	5017	1,220	18,306	0.5382
>1,500	5018	1,831	27,459	0.8073
Water Loop HP Circulation Pumps				
<100	3503	222	3,333	0.0224
>100, ≤500	3504	1,111	16,667	0.1121
>500, ≤1,000	5019	3,111	46,667	0.3140
>1,000, ≤1,500	5020	5,333	80,001	0.5382
>1,500	5021	8,000	120,002	0.8073
Wholesale Circulation Pumps				
< 100 (80/20 split of MMIDs 3497 and 3494)	5166	243	3,645	0.0150

Assumptions

The Cadmus 2012 *ECM Circulator Pump* study[2] examined 18 ECM pump installations for boiler heating circulation applications. It found base pump sizes ranging from 83 watts to 774 watts and ECM pump sizes ranging from 14 watts to 88 watts, with size ratios ranging from 4% to 60% and an average ratio of 18%. This study is not viewed as statistically significant or representative of all measures in this workpaper, which can have other applications and be much larger.

Another study conducted for the U.S. DOE[6] mentioned that ECM circulator pumps can generally save 50% or more. A third study[7] showed savings ranging from 26% to 60%.

From all this information, a power ratio of 40% was chosen for these measures.

Variable Speed ECM Pump, <100 Watts Max Input

- Wattage inputs for qualifying pumps under 100 watts range from 3 watts to 93 watts. 50 watts was used as a conservative midpoint.

Variable Speed ECM Pump, 100 to 500 Watts Max Input

- Wattage inputs for qualifying pumps between 100 watts and 500 watts range from 130 watts to 500 watts. 250 watts was used as a conservative midpoint.

Variable Speed ECM Pump, 500 to 1,000 Watts Max Input

- Wattage inputs for qualifying pumps between 500 watts and 1,000 watts. 700 watts was used as a conservative midpoint.

Variable Speed ECM Pump, 1,000 to 1,500 Watts Max Input

- Wattage inputs for qualifying pumps between 1,000 watts and 1,500 watts. 1,200 watts was used as a conservative midpoint.

Variable Speed ECM Pump, >1,500 Watts Max Input

- Wattage inputs for qualifying pumps greater than 1,500 watts range from 1,501 watts to 2,500 watts. 1,800 watts was used as a conservative midpoint.

In order to provide wholesale incentives to contractors for the purchase of qualifying variable speed ECM pumps with less than 100 watts of maximum input, a blended distribution of existing measures was assumed. Estimates from participating midstream distributors indicate that 75% of pumps that receive wholesale incentives will be installed for heating water circulation and 25% will be installed for DHW recirculation. This estimate will be updated following a future survey of contractors. Recent Focus on Energy program data covering 71 units shows an 86%/14% split. An 80%/20% split is used for this workpaper.

Costs were derived by producing linear fits of cost versus wattage for 24 PSC and 23 ECM pumps, based on 2014 research.[8] Cost fits of PSC Cost = Wattage * 1.829 + 434.57 and ECM Cost = Wattage * 2.365 + 1,470.89 were derived. These fits were used with the assumed bin wattages above to produce the incremental costs in the table below.

Incremental Costs

Wattage Range	Assumed Wattage	PSC Cost	ECM Cost	Incremental Cost
<100	50	$526.02	$1,589.14	$1,063.11
>100, ≤500	250	$891.83	$2,062.15	$1,170.32
>500, ≤1,000	700	$1,714.90	$3,126.43	$1,411.53
>1,000, ≤1,500	1,200	$2,629.42	$4,308.97	$1,679.54
>1,500	1,800	$3,726.85	$5,728.01	$2,001.16

Sources

1. U.S. Department of Energy. *Pump Life Cycle Costs: A Guide to LCC Analysis for Pumping Systems*. p. 4. January 2001. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/pumplcc_1001.pdf
2. Cadmus. *Impact Evaluation of the 2011–2012 ECM Circulator Pump Pilot Program.* Table 2: Pump Spot Measurements. October 18, 2012.
3. DHW Recirculation System Control Strategies. Final Report 99-1. p. 3-30. January 1999. Hours of use for pumps with an aquastat control in multifamily applications.
4. Lawrence Berkeley National Laboratory. *Water Heaters and Hot Water Distribution Systems.* Prepared for California Energy Commission Public Interest Energy Research Program. p. 16, Figure 10: Control Types Installed or Maintained by Contractors. May 2008.
5. ASHRAE Estimation of Degree-Days: Fundamentals, Chapter 14. Calculated from TMY3 weather files of the seven Wisconsin locations using statewide weighted values calculated from 2010 U.S. Census data for Wisconsin.
6. National Renewable Energy Laboratory. *High-Performance Circulator Pump Demonstration*. September 2018. https://www.nrel.gov/docs/fy18osti/71705.pdf
7. General Services Administration. *Small Circulator Pumps with Automated Control*. September 2018. https://www.gsa.gov/cdnstatic/GPG_Findings-035-Small_Circulator_Pumps_with_Automated_Control.pdf
8. Pricing research, November 2014. PSC and ECM pump motors from Viridian, Stratos, Star, Top, and other brands were examined across https://www.tacocomfort.com/, https://wilo.com/us/en_us/, and https://www.grundfos.com/nz.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	01/2019	Removed MMIDs 3496, 3500, 3501, and 3503
03	02/2020	Improved algorithm, split larger motors into multiple bins, re-added previously removed MMIDs 3496, 3500, 3501, and 3503
04	01/2021	Added wholesale MMID

Industrial Ovens and Furnaces

Radiant Tube Inserts

	Measure Details
Measure Master ID	Radiant Tube Inserts, 2507
Workpaper ID	W0016
Measure Unit	Per insert
Measure Type	Hybrid
Measure Category	Boilers & Burner
Measure Group	Industrial Ovens and Furnaces
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies
Lifecycle Electricity Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Measure Incremental Cost ($/unit)	$368.64[2]

Measure Description

Radiant tube heaters are typically used in metal heat-treating furnaces. The heaters are long tubes, often in a U-shape, and have natural gas–fired burners at one end of the burner leg to produce a flame and heated gas that flows through the tube to produce heat for conditioning metals. Ceramic inserts with a twisted shape are available for the inside of the tubes that enhance the radiant heat transfer from the exhaust gases in the burner to the heat-treating furnace. This reduces heat exhaust and the natural gas usage of the heat treat system.

Description of Baseline Condition

The baseline condition is a traditional radiant tube with no heat transfer assisting devices in the exhaust leg of the radiant tube.

Description of Efficient Condition

The efficient condition is a radiant tube with new radiant inserts applied to a natural gas furnace used for heat treating.

Annual Energy-Savings Algorithm

$Therms_{SAVED} = Capacity_{FURNACE} * Hours * SF / 100,000$

Where:

$Capacity_{FURNACE}$ = Input capacity of heat treat furnace in Btu/hr (= actual)

Hours = Annual operating hours (= actual)

SF = Savings fraction for radiant tube inserts (= 15%)[3,4]

100,000 = Btu to therms conversion factor

Summer Coincident Peak Savings Algorithm

There are no peak demand savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therms_{LIFECYCLE} = Therms_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Assumptions

Savings calculations are extremely difficult to provide due to the complexity of heat transfer. Therefore, case studies are cited for savings estimates. One paper reports that the savings from several case studies have varied between 5% and 25%,[3] depending upon the existing furnace: if the furnace is relatively new and equipped with a recuperator, savings may be 5%, but if installed in an older furnace, savings can be up to 25%. The DOE EERE Advanced Manufacturing Office indicates a savings range of 15% to 20%.[4] A 2007 Focus on Energy report[5] indicates savings of 15% and 11% for two separate units under controlled test conditions. Another 2007 report[6] indicates savings of 18% and 29% for two separate units under controlled test conditions. Based on this information, a 15% savings fraction was deemed, which is the mid to low end of these ranges.

The savings calculated is for the retrofit of one complete furnace, while the incentive is paid based on number of individual radiant tube inserts.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report." Appendix B. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 330 units over six projects from 2012 to 2015.

3. Goetzler, William, Craig McDonald, and Ganesh Venkat. "Energy Efficiency Portfolio of the Future." ACEEE Summer Study on Energy Efficiency in Buildings, 2008. http://aceee.org/files/proceedings/2008/data/papers/7_212.pdf
4. U.S. Department of Energy. Advanced Manufacturing Office website. https://energy.gov/eere/amo/spyrocor-radiant-tube-heater-inserts
5. McLeer, Jim, and J. Murray. *Measurement & Verification – Final Report.* February 2007. Report on radiant tube inserts installed at Treat All Metals, Milwaukee, Wisconsin. Inspection dates of December 19, 2005, April 13, 2006, and February 7, 2007.
6. McLeer, Jim, and J. Murray. *Measurement & Verification – Final Report*. February 2007. Report on radiant tube inserts installed at Charter Steel, Saukville, Wisconsin. Inspection dates from October 19, 2005 through April 13, 2006.

Revision History

Version Number	Date	Description of Change
01	09/08/2017	Initial TRM workpaper
02	12/2018	Updated incremental cost

Information Technology

Efficient UPS and Efficient Rectifier

	Measure Details
Measure Master ID	Efficient UPS, 4777 Efficient Rectifier, 4778
Workpaper ID	W0082
Measure Unit	Per kilowatt of IT load
Measure Type	Hybrid
Measure Group	Information Technology
Measure Category	Other
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$59.00[1]

Measure Description

This measure is replacing an inefficient uninterruptable power supply (UPS) or rectifier with an efficient UPS or rectifier in a data center, telecom, or similar facility that operates 24 hours per day, seven days per week. UPS units provide backup power in data centers and draw power constantly to keep their batteries charged. A federal standard specifying minimum efficiencies goes into effect in 2019, so this measure is not applicable to new construction. A rectifier converts alternating current (AC) to direct current (DC).

Description of Baseline Condition

The baseline condition is an existing UPS or rectifier whose efficiency in normal mode (not in energy saver mode) is less than 90%.

Description of Efficient Condition

The efficient condition is a new UPS or rectifier whose efficiency in normal mode (not in energy saver mode) is at least 94%.

Annual Energy-Savings Algorithm

$KWh_{SAVED} = kWh_{BASE} - kWh_{EE}$

$kWh_{BASE} = Load * HOU_{EQUIP} / Eff_{BASE} + Load * (1 – Eff_{BASE}) * HOU_{COOL} * kW/ton_{COOL} * 3.413 / 12$

$kWh_{EE} = Load * HOU_{EQUIP} / Eff_{EE} + Load * (1 – Eff_{EE}) * HOU_{COOL} * kW/ton_{COOL} * 3.413 / 12$

Where:

Load = Average IT load in kilowatts (= user input; see Assumptions)
HOU_{EQUIP} = Hours of operation per year for UPS or rectifier (= 8,760)
Eff_{BASE} = Efficiency of existing UPS, fraction (= user input)
HOU_{COOL} = Hours of operation per year for the cooling system (= varies; see Assumptions)
kW/ton_{COOL} = Efficiency of cooling system in kilowatts per ton (= user input; see Assumptions)
3.413 / 12 = Factor to convert kilowatts of heat to tons of cooling
Eff_{EE} = Efficiency of new UPS or rectifier, fraction (= user input)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kW_{BASE} - kW_{EE}$

$kW_{BASE} = Load * CF_{EQ} / Eff_{BASE} + Load * CF_{COOL} * (1 – Eff_{BASE}) * kW/ton_{COOL} * 3{,}413 / 12{,}000$

$kW_{EE} = Load * CF_{EQ} / Eff_{EE} + Load * CF_{COOL} * (1 – Eff_{EE}) * kW/ton_{COOL} * 3{,}413 / 12{,}000$

Where:

CF_{EQ} = Coincidence factor for UPS or rectifier (= 1.0)
CF_{COOL} = Coincidence factor for cooling system (= 0.82)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Assumptions

Small IT systems (those smaller than or equal to 50 kW) are assumed to have no air-side economizer and to operate continuously throughout the year, so HOU_{COOL} = 8,760 hours. Larger systems are assumed to have an air-side economizer that allows the cooling system to be turned off for half the year, so

HOU_{COOL} = 4,380 hours. This corresponds to approximately a 45°F changeover temperature, which is a conservative assumption.

Normal mode efficiencies are to be used, rather than eco mode efficiencies, which can be disabled; using the value for normal mode is more conservative. The efficiency of the new UPS or rectifier comes from the manufacturer's published data. The efficiency of the existing UPS or rectifier can come from the manufacturer's data, by directly measuring input and output power, or from a display on the UPS.

Cooling system efficiency accounts for the power for any auxiliary equipment such as pumps and cooling towers. For an air-cooled chiller, $kW/ton_{COOL} = kW/ton_{CHILLER} + (kW_{CHILLED\_WATER\_PUMP}) / tons$. For a water-cooled chiller, $kW/ton_{COOL} = kW/ton_{COMPRESSOR} + (kW_{CHILLED\_WATER\_PUMP} + kW_{CONDENSER\_WATER\_PUMP} + kW_{COOLING\_TOWER\_FANS}) / tons$. For a direct expansion system, which has no auxiliary equipment, $kW/ton_{COOL} = 12 / EER$. The pump and fan power for any water-side economizers are neglected.

A more efficient UPS or rectifier gives off less waste heat than a less efficient UPS or rectifier, so in addition to lower cooling energy, heating energy may increase. However, due to the heat generation by equipment in typical data centers, any heaters seldom run, if at all. Any increase in heating energy is assumed to be negligible.

The coincidence factor for the UPS or rectifier is assumed to be 1.0 because the equipment operates all hours of the peak period.

Sources

1. California Municipal Utilities Association. *Savings Estimation Technical Reference Manual 2017, Third Edition.* Section 8.12, p. 8–15. https://www.cmua.org/files/CMUA-POU-TRM_2017_FINAL_12-5-2017%20-%20Copy.pdf
2. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Revision History

Version Number	Date	Description of Change
01	12/31/2018	Initial TRM entry

Laundry

Modulating Commercial Dryer Controls

	Measure Details
Measure Master ID	Modulating Commercial Dryer Controls: Small Capacity Low Use, 4902 Small Capacity High Use, 4903 Large Capacity Low Use, 4904 Large Capacity High Use, 4905
Workpaper ID	W0251
Measure Unit	Per dryer
Measure Type	Hybrid
Measure Group	Laundry
Measure Category	Dryer
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	10;[1] see Assumptions
Incremental Cost ($/unit)	$900.00[2]

Measure Description

This measure is a retrofit electronic control unit that adds intelligence to non-modulating commercial natural gas clothes dryers to improve their energy efficiency. It employs a regulated natural gas stepping technology based on sensor readings and a proprietary algorithm to reduce natural gas consumption through several processes:

- Replaces standard natural gas valves with a two-stage valve, allowing the natural gas to be modulated
- When the dryer turns on, modulates the natural gas between high (100%) and low (50%) based on dryer exhaust temperatures
- Once the sensor detects the optimal flue gas temperature, the natural gas valve locks into low or savings mode
- If the sensor detects a sudden decrease of flue temperature, it automatically re-engages high fire

Installing the technology is straightforward and does not make modifications to the dryer workings other than the natural gas supply. The Focus on Energy Emerging Technology program evaluated this technology in 2014.

Description of Baseline Condition

The baseline condition is an existing natural gas commercial clothes dryer without a modulating natural gas valve. The dryer must be rated between a 30 pound to 250 pound capacity with a minimum of 500 drying cycles per year.

Description of Efficient Condition

The efficient condition is an existing natural gas commercial clothes dryer with a retrofit kit to provide a modulating natural gas valve with at least two firing rates.

Annual Energy-Savings Algorithm

Gas_{SAVED} = CAP * BurnerOn% * (DryingTime / 60 * LoadsPerDay * DaysPerYear) * SF / 100,000

Where:

CAP = Burner capacity in Btu/hr (= user input)

BurnerOn% = Percentage of drying cycle when burner is on (= 70.6%; see Assumptions)[3]

DryingTime = Drying time per load in minutes (= user input; if unknown, use 30 minutes)

60 = Conversion factor from minutes to hours

LoadsPerDay = Average loads per day of clothes dried (= user input; if unknown, see Assumptions)

DaysPerYear = Days per year the dryer is used (= user input; assume 365 if not specified)

SF = Savings fraction (= 10%)[2]

100,000 = Conversion factor from Btu to therms

There are no electrical savings for this measure.

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Gas_{LIFECYCLE} = Gas_{SAVED}$ * EUL

Where:

EUL = Effective useful life (= 10 years)[1]

Assumptions

The incremental cost for this measure is listed as $800.00 to $1,000.00[2] (for material and installation), so the midpoint of this range was used ($900.00).

The expected useful life for the natural gas valve retrofit kit is assumed to reflect the remaining useful life of a commercial natural gas dryer, which is 14 years. The remaining useful life at time of install of a modulating dryer control is assumed to be 10 years.

The Emerging Technologies transition report[2] lists 10.3% savings for a specific project evaluated and recommended using 10% savings going forward. The more conservative 10% savings value was used.

The Emerging Technologies M&V report[3] indicates in the "Energy Savings and Economics" section that the tested dryer has a burner capacity of 395 MBh, typically runs for 40 minutes, and has a baseline energy use of 1.86 therms per load. Therefore, the BurnerOn% value was calculated as follows:

BurnerOn% = 1.86 therms / [(395 MBh / 100 MBtu per therm) * (40 min / 60 min per hour)] = 70.6%

The calculation process is the same for all four measures. The separate measures were established so a separate incentive could be set for each measure and maintain a more uniform incentive per lifecycle MMBtu across the range of dryer sizes and loads of clothes dried per year. From the dryer capacity versus burner size research,[4] typical dryer capacities are 30, 35, 50, 75, 120, 170, and 200 pounds. A 250 pound dryer (maximum size allowed under the offer) was also included. A capacity of 100 pounds was used to divide small and large capacity, putting four typical sizes in each category.

The Emerging Technologies M&V report[3] listed the usage of the studied hotel laundry at around 9,500 loads per year (and noted this was higher than typical usage), so the incentive per MMBtu was tested for a range of 500 to 10,000 loads per year. A dividing line of 2,500 loads per year or less was set as low usage, with high usage being set as more than 2,500 loads per yearyear.

In the event that a customer is not able to supply dryer cycles per year data, the values from the Illinois TRM[5] will be used, as shown in the following table.

Dryer Cycles Per Year Based on Facility Type

Facility Type	Cycles per Year	Cycles per Day
Coin-Operated Laundromats	1,483	4.063
Multifamily Dryers	1,074	2.942
On-Premise Laundromats	3,607	9.882

Cycles per day assume 365 days per year of operation.

In the event that only the pound capacity of the dryer or only the burner Btu per hour is available, the other value will be determined by using 2,340 Btu per pound capacity, which was calculated as a weighted average of specifications from three commercial dryer manufacturers, excluding the highest and lowest Btu per hour from each manufacturer (shown in the following table).

Typical Dryer Performance Data[5]

Manufacturer	Pound Capacity	Burner Btu/hr	Burner Btu/Lb Capacity	Exclude?
UniMac	25	64,000	2,560	No
	30	73,000	2,433	No
	35	90,000	2,571	No
	50	130,000	2,600	No
	55	112,000	2,036	Yes
	75	165,000	2,200	No
	75	225,000	3,000	Yes
	120	270,000	2,250	No
	170	395,000	2,324	No
	200	425,000	2,125	No
Maytag	35	64,000	1,829	No
	50	110,000	2,200	No
	75	130,000	1,733	Yes
	50	150,000	3,000	No
	75	175,000	2,333	No
	75	175,000	2,333	No
	120	375,000	3,125	No
	170	550,000	3,235	Yes
Speed Queen	25	64,000	2,560	No
	30	73,000	2,433	No
	35	90,000	2,571	No
	50	130,000	2,600	Yes
	55	112,000	2,036	Yes
	75	165,000	2,200	No
	120	270,000	2,250	No
	170	395,000	2,324	No
	200	425,000	2,125	No
	30	73,000	2,433	No
	45	95,000	2,111	No
Weighted Average (with exclusions)			**2,340**	**--**

Sources

1. Zhang, Yanda, and Julianna Wei. *Commercial Clothes Dryers, Codes and Standards Enhancement (CASE) Initiative for PY13: Title 20 Standards Development.* California Public Utilities Commission. July 2013. https://efiling.energy.ca.gov/GetDocument.aspx?tn=71757 https://efiling.energy.ca.gov/GetDocument.aspx?tn=74287&DocumentContentId=8161
2. Clean Tech Partners on behalf of Focus on Energy. *Emerging Technologies Program, Transition of Emerging Technology to Best Practice – Commercial Dryer Modulation Retrofit*. June 2019.
3. Clean Tech Partners on behalf of Focus on Energy. *Emerging Technologies Program, BiO-Therm Measurement and Verification Study.* 2014.
4. Typical dryer performance data compiled from manufacturer websites accessed on July 1 and July 2, 2019:
http://unimac.com/Products/heavy-duty-tumble-dryers
https://www.maytagcommerciallaundry.com/mclstorefront/Dryers/Multi-Load-Dryers/c/DryersMulti-LoadDryers
https://speedqueencommercial.com/en-us/products/single-pocket-tumble-dryers
5. Illinois Stakeholder Advisory Group. 2019 *Illinois Statewide Technical Reference Manual for Energy Efficiency Version 7.0*. Volume 2: Commercial and Industrial Measures. Page 566. https://s3.amazonaws.com/ilsag/IL-TRM_Effective_010119_v7.0_Vol_2_C_and_I_092818_Final.pdf

Revision History

Version Number	Date	Description of Change
01	8/2019	Initial TRM entry

Lighting

Daylighting Control

	Measure Details
Measure Master ID	Daylighting Control, 3406
Workpaper ID	W0084
Measure Unit	Per watt controlled
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$0.73[2]

Measure Description

Daylighting controls save energy by reducing the total wattage input of the connected lighting load by matching the light output of the connected electric lighting system to the amount of natural light supplied by the sun that enters the space being lit. This is accomplished using dimming light sources or a system that steps the light of the connected fixtures based on controlling the lamps inside each connected fixture to produce different levels of illumination. This measure will provide reinforcement that integrating daylighting controls is an effective method to further reduce energy consumption.

Description of Baseline Condition

The baseline condition is any lighting equipment that is not connected to a daylighting controls system.

Description of Efficient Condition

The efficient condition is any lighting equipment that is connected to a daylighting controls system.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Watts / 1,000 * HOU * SF$

Where:

Watts = Controlled lighting wattage (= user input)

SF = Savings factor for daylighting controls (= 28%)[6]

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= varies by sector; see table below)

Average Annual Run Hours by Sector

Sector	HOU[3,4]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239
Multifamily	5,950

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = Watts / 1,000 * CF * SF

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[3,5]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64
Multifamily	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (8 years)[1]

Deemed Savings

Savings

Sector	Annual kWh	kW	Lifecycle kWh
Commercial	1.04	0.0002	8.32
Industrial	1.33	0.0002	10.64
Agriculture	1.32	0.0002	10.56
Schools & Government	0.91	0.0002	7.28
Multifamily	1.67	0.0002	13.36

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/
2. Actual cost from 2015-16 program data for MMID 3406, 21 applications
3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3-2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
5. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.
6. Lawrence Berkeley National Laboratory. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. September 2011. https://eta.lbl.gov/sites/default/files/publications/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf

Revision History

Version Number	Date	Description of Change
01	04/2014	Initial TRM entry
02	12/2020	Updated savings factor

Bi-Level Controls, High Bay Fixtures

	Measure Details
Measure Master ID	Bi-Level Controls, High Bay Fixtures, General, 5062
Workpaper ID	W0085
Measure Unit	Per watt controlled
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector; see Deemed Savings tables
Peak Demand Reduction (kW)	Varies by sector; see Deemed Savings tables
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector; see Deemed Savings tables
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$0.43[2]

Measure Description

This measure is bi-level controls for high bay fixtures. Numerous new and existing installations use LED, linear fluorescent, ceramic metal halide, and pulse start metal halide fixtures to light their high bay interiors, commonly in full light output 24 hours a day. Bi-level controls and replacement products use ultrasonic and passive infrared sensors to adjust the light output to a safe but energy conserving low level when these spaces become unoccupied. These products save energy by more efficiently lighting the spaces based on occupancy.

Description of Baseline Condition

The baseline condition is LED, fluorescent, ceramic metal halide, or pulse start metal halide fixture input wattages with no lighting controls at building interior.

Description of Efficient Condition

The efficient condition is individually controlled light fixtures that may include dimming, stepped dimming, and high-low ballast controls. The control must include a passive infrared and/or ultrasonic occupancy sensor with a feature to stay “on” in case of failure. Fixtures must operate in a low standby light level during vacancy and switch to full light output upon occupancy. A conservative estimate of 50% of full wattage during unoccupied periods is assumed.

Annual Energy Savings Algorithm

The energy savings shown below were initially determined for each space type and sector. Using several years of historical data,[5] the weighted average, based on program implementation across space and sector types, was used to calculate a single savings value for each sector.

kWh_{SAVED} = Watts * HOU / 1,000 * SF_{OCC} * SF_{DIM}

Where:

Watts = Lighting wattage controlled, deemed (= user input)

HOU = Baseline hours per year (= varies by sector; see table below)

1,000 = Kilowatt conversion factor

SF_{OCC} = Occupancy savings factor, percentage of hours in unoccupied mode (= varies by building type; see Assumptions)

SF_{DIM} = Dimming savings factor, percentage of hours dimmed in unoccupied mode (= 50%, see Assumptions)

Hours of Use by Sector

Sector	HOU[3]
Commercial	3,730
Schools & Government	3,239
Industrial	4,745
Agriculture	4,698
Multifamily	5,950

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = Watts / 1,000 * CF

Where:

CF = Coincidence factor (= varies by space type; see table below)

Coincidence Factors by Space Type

Space Type	CF[3]
Gymnasiums	15%
Industrial	18%
Retail	6%
Warehouses	18%
Public Assembly	12%
Other	14%

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

The two tables below show deemed savings by sector.

Deemed Savings for Agriculture, Commercial, and Industrial Sectors

Space Type	kW	Agriculture		Commercial		Industrial	
		Weight[5]	Ann kWh	Weight[5]	Ann kWh	Weight[5]	Ann kWh
Gymnasium	0.0002	0.167	0.92	0.155	0.73	0.000	0.93
Industrial	0.0002	0.167	1.06	0.062	0.84	0.551	1.07
Retail	0.0001	0.167	0.23	0.541	0.19	0.000	0.24
Warehouse	0.0002	0.167	0.73	0.046	0.58	0.449	0.74
Public Assembly	0.0001	0.167	0.97	0.000	0.77	0.000	0.98
Other	0.0001	0.167	0.94	0.196	0.75	0.000	0.95
Annual Savings (kWh)		**0.81**		**0.44**		**0.92**	
Annual Savings (kW)		**0.0001**		**0.0001**		**0.0002**	
Lifecycle Savings (kWh)		**6.48**		**3.52**		**7.36**	

Deemed Savings for Schools & Government and Multifamily Sectors

Space Type	kW	Schools & Government		Multifamily	
		Weight[5]	Ann kWh	Weight[5]	Ann kWh
Gymnasium	0.0002	0.839	0.63	0.333	1.16
Industrial	0.0002	0.020	0.73	0.000	1.34
Retail	0.0001	0.000	0.16	0.000	0.30
Warehouse	0.0002	0.000	0.50	0.000	0.92
Public Assembly	0.0001	0.000	0.70	0.333	1.29
Other	0.0001	0.141	0.65	0.333	1.19
Annual Savings (kWh)		**0.64**		**1.21**	
Annual Savings (kW)		**0.0001**		**0.0001**	
Lifecycle Savings (kWh)		**5.12**		**9.68**	

Assumptions

Two references show the occupancy savings factor by space type,[3, 4] shown in the table below.

Occupancy Savings Factor by Space Type

Space Type	SF_{OCC}	Occupancy Savings Factor Source and Note
Gymnasiums	39%	Source 3
Industrial	45%	Source 3
Retail	10%	Average of source 3 (15%) and Table 3 in source 4 (5%)
Warehouses	31%	Table 4 in source 4 (source 3 not used because one if its three sources for warehouses is already in source 4 and the other two were not available for review)
Public Assembly	42%	Average of source 3 (47%) and Table 7 in source 4 (36%)
Other	40%	Source 3

These values were combined with usage of historical measures associated with these space types to produce savings for each sector. This data is from 28 projects from May 2014 through October 2016.[5] The weighting values are provided in the Deemed Savings tables above.

Bi-level controls are able to and must achieve at least a 50% reduction in power requirements. This value was used for the dimming savings factor.

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Data for MMID 3979, the previous per-fixture version of this measure. From January to November 2020 there were 18 applicatons and 22 measures, with an average watts controlled per fixture of 135.9 and cost per fixture of $57.90, for an average of $0.43 per watt controlled.
3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. Table 4-205 for occupancy savings factor nd Table 4-206 for coincidence factor. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Lawrence Berkeley National Laboratory. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. September 2011. https://eta.lbl.gov/sites/default/files/publications/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf
5. "Bi Level Controls for High Bay Supplemental Data."
   Adjustment Calcs Tab showing historical data from 28 projects from May 2014 through October 2016 used to weight savings for the sensor measures.

Revision History

Version Number	Date	Description of Change

01	12/2012	Initial TRM entry
02	10/2013	Changed entry from hybrid to prescriptive (MMID 3115)
03	11/2016	Used historical data to simplify deemed savings into one measure and updated EUL
04	12/2018	Updated incremental cost
05	10/2020	Change from per fixture to per watt controlled, updated savings fractions

Occupancy Sensors for High Bay Fixtures

	Measure Details
Measure Master ID	Occupancy Sensor, On/Off, High Bay, General, 5061
Workpaper ID	W0086
Measure Unit	Per watt controlled
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential - Multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$0.36[2]

Measure Description

This measure is occupancy sensors for high bay fixtures. Numerous new and existing installations use LED, fluorescent, ceramic metal halide, and pulse start metal halide fixtures to light their high bay interiors, commonly in full light output for 24 hours a day. Occupancy controls and replacement products use ultrasonic and passive infrared sensors to turn the fixture off when these spaces become unoccupied. These products save energy by more efficiently lighting the spaces based on occupancy.

Description of Baseline Condition

The baseline condition is LED, fluorescent, ceramic metal halide, and/or pulse start metal halide fixture input wattages with no lighting controls at the building interior.

Description of Efficient Condition

The efficient condition is an indoor wall, ceiling, or fixture mounted occupancy sensor being used to control a high bay fixture. The control must include a passive infrared and/or ultrasonic occupancy sensor with a feature stay “on” in case of failure.

Annual Energy-Savings Algorithm

The kWh savings shown below were initially determined for each space type and sector. Using several years of historical data,[5] the weighted average, based on the frequency of program implementation across space and sector types, was used to calculate a single kWh savings value for each sector.

kWh_{SAVED} = Watts * HOU / 1,000 * SF_{OCC}

Where:

Watts = Lighting wattage controlled, deemed (= user input)

HOU = Baseline hours per year (= varies by sector; see table below)

1,000 = Kilowatt conversion factor

SF_{OCC} = Occupancy savings factor, percentage of hours in unoccupied mode (= varies by bulding type; see Assumptions)

Hours of Use by Sector

Sector	HOU[3]
Commercial	3,730
Schools & Government	3,239
Industrial	4,745
Agriculture	4,698
Multifamily	5,950

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = Watts / 1,000 * CF

Where:

CF = Coincidence factor (=varies by space type; see table below)

Coincidence Factors by Space Type

Space Type	CF[3]
Gymnasiums	15%
Industrial	18%
Retail	6%
Warehouses	18%
Public Assembly	12%
Other	14%

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

Deemed Savings for Agriculture, Commercial, and Industrial Sectors

Space Type	kW	Agriculture		Commercial		Industrial	
		Weight[5]	Ann kWh	Weight[5]	Ann kWh	Weight[5]	Ann kWh
Gymnasium	0.0002	0.000	1.83	0.006	1.45	0.000	1.85
Industrial	0.0002	0.438	2.11	0.191	1.68	0.780	2.14
Retail	0.0001	0.000	0.47	0.064	0.37	0.000	0.47
Warehouse	0.0002	0.076	1.46	0.589	1.16	0.209	1.47
Public Assembly	0.0001	0.000	1.95	0.000	1.55	0.000	1.97
Other	0.0001	0.486	1.88	0.150	1.49	0.011	1.90
Annual Savings (kWh)		**1.95**		**1.26**		**1.99**	
Annual Savings (kW)		**0.0002**		**0.0002**		**0.0002**	
Lifecycle Savings (kWh)		**15.60**		**10.08**		**15.92**	

Deemed Savings for Schools & Government and Multifamily Sectors

Space Type	kW	Schools & Government		Multifamily	
		Weight[5]	Ann kWh	Weight[5]	Ann kWh
Gymnasium	0.0002	0.420	1.26	0.333	2.32
Industrial	0.0002	0.036	1.46	0.000	2.68
Retail	0.0001	0.000	0.32	0.000	0.60
Warehouse	0.0002	0.163	1.00	0.000	1.84
Public Assembly	0.0001	0.031	1.34	0.333	2.47
Other	0.0001	0.351	1.30	0.333	2.38
Annual Savings (kWh)		**1.24**		**2.39**	
Annual Savings (kW)		**0.0002**		**0.0001**	
Lifecycle Savings (kWh)		**9.92**		**19.12**	

Assumptions

Two references show SF_{OCC} by space type, as seen in the table below.

SF_{OCC} Values by Space Type

Space Type	SF_{OCC}	SF_{OCC} Source and Note
Gymnasiums	39%	Source 3
Industrial	45%	Source 3
Retail	10%	Average of source 3 (15%) and Table 3 in source 4 (5%)
Warehouses	31%	Table 4 in source 4. Source 3 not used because one if its three sources for warehouses is already in source 4, and the other two were not available for review
Public Assembly	42%	Average of source 3 (47%) and Table 7 in source 4 (36%)
Other	40%	Source 3

These values are combined with usage of historical measures associated with these space types to produce savings for each sector. This data is from 28 projects from May 2014 through October 2016[5]. The weighted values are provided in the tables above.

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf For lighting measure, add occupancy sensors or multi-level switching to a retrofit project where high bay fluorescent replaces HID.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Data for MMID 3978, the previous per-fixture version of this measure. From January to November 2020 there were 72 applications and 5,895 units, with an average watts controlled per fixture of 143.7 and cost per fixure of $51.98, for an average of $0.36 per watt controlled.
3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Section 4.9.17, p. 4-234. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Lawrence Berkeley National Laboratory. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. September 2011. https://eta.lbl.gov/sites/default/files/publications/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf
5. “Occupancy Sensors for High Bay Supplemental Data.”
   Adjustment Calcs Tab showing historical data from 431 projects from January 2014 – October 2016 used to weight savings for the sensor measures.

Revision History

Version Number	Date	Description of Change
01	10/07/2013	Updated deemed savings and all fixture options and wattages
02	11/01/2016	Used historical data to simplify deemed savings into one measure and updated EUL
03	10/12/2020	Change from per fixture to per watt controlled and update savings fractions

Non-High Bay Occupancy/Vacancy Sensor

	Measure Details
Measure Master ID	Non-High Bay Occupancy/Vacancy Sensor, 4812
Workpaper ID	W0087
Measure Unit	Per watt controlled
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gallons)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$0.55[2]

Measure Description

Non-high bay occupancy/vacancy sensors reduce energy consumption by reducing the operating hours for lighting equipment in low occupancy areas, such as hallways, storage rooms, and restrooms. Occupancy sensors automatically turn lights off a preset time after people leave a space and turn lights on automatically when movement is detected. Occupancy sensors feature a delay adjustment that determines the time that lights are on after no occupancy is detected, as well as a sensitivity adjustment that determines the magnitude of the signal required to trigger the occupied status.

The two primary technologies used for occupancy sensors are passive infrared (PIR) and ultrasonic. PIR sensors determine occupancy by detecting the difference in heat between a body and the background. Ultrasonic sensors detect people using volumetric detectors and broadcast sounds above the range of human hearing, then measure the time it takes the waves to return. Other sensing technologies, like microwaves or tools that incorporate dual methodologies, are also eligible.

Description of Baseline Condition

The baseline condition is no occupancy sensor, with lighting fixtures controlled by manual wall switches.

Description of Efficient Condition

The efficient condition is a hard-wired, fixture-, wall-, or ceiling-mounted occupancy sensor, where lighting fixtures are controlled by the sensors based on detected occupancy.

Annual Energy-Savings Algorithm

kWh_{SAVED} = Watts / 1,000 * SF * HOU

Where:

Watts = Controlled lighting wattage

1,000 = Kilowatt conversion factor

SF = Savings factor, deemed (= 24%)[3]

HOU = Average annual run hours (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

There are no deemed summer peak savings for these measures. Although occupancy sensors may reduce load during the peak period, most savings occur during non-peak hours.

kW_{SAVED} = Watts * CF / 1,000

Where:

CF = Coincidence factor (= 0)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

Savings

Sector	Annual kWh	Lifecycle kWh
Commercial	0.90	7.20
Industrial	1.14	9.12
Agriculture	1.13	9.04
Schools & Government	0.78	6.24
Multifamily	1.43	11.44

Assumptions

The deemed summer peak savings is set to zero. Although occupancy sensors may reduce load during the peak period, no savings are assumed because the measure uses are widely variable and most savings will occur during non-peak hours.

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. Appendix B. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 223 projects and 2,139 units from February 2019 to July 2020 is $0.55.
3. Lawrence Berkeley National Laboratory. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. September 2011. https://eta.lbl.gov/sites/default/files/publications/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluation323report.pdf
5. Tetra Tech. *ACES Deemed Savings Desk Review*. Table 1. November 3, 2010. https://focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf 16.3 hours per day for multifamily housing.

Revision History

Version Number	Date	Description of Change
01	01/01/2019	Initial TRM entry
02	12/2020	Updated savings factor

Occupancy Sensor, LED Refrigerated Case Lights

	Measure Details
Measure Master ID	Occupancy Sensor, LED Refrigerated Case Lights, 2482
Workpaper ID	W0088
Measure Unit	Per fixture controlled
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	65
Peak Demand Reduction (kW)	0.0075
Annual Therm Savings (Therms)	0
Life-cycle Energy Savings (kWh)	520
Life-cycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$37.92[2]

Measure Description

Controls for LED case lights effectively save energy by turning off lights when unnecessary. These motion controls may involve one sensor that controls a bank of cases, or one sensor per door. The sensors reduce the runtime of the case lighting, effectively reducing the lighting energy usage, and they also produce less waste heat in the cases, which decreases the cooling load on the refrigeration system and energy needed by the refrigeration compressors.

Description of Baseline Condition

The baseline condition is DLC-qualified vertical LED lighting in refrigerated display cases.

Description of Efficient Condition

The efficient condition is DLC-qualified vertical LED lighting in refrigerated display cases with case light occupancy sensors.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = [(Watts_{BASE}) + (Watts_{BASE}) / COP] * SF / 1,000 * HOU$

Where:

$Watts_{BASE}$ = Wattage of the LED case lighting (= 17.73)[3]

COP = Coefficient of performance (=2.3 for non-self-contained coolers,[4] 1.4 for non-self-contained freezers,[4] 0.5 for self-contained coolers,[5] 0.6 for self-contained freezers; weighted average savings applied, see Assumptions)[5]

SF = Savings factor (= 24%)[5]

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 8,760)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = [(Watts_{BASE}) + (Watts_{BASE}) / COP] * SF / 1{,}000$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=8 years)[1]

Assumptions

It is assumed that the fixtures are upgraded to LEDs in self-contained cases 10% of the time and in non-self-contained cases 90% of the time, based on historical Wisconsin program installations. It is also assumed that the fixtures are upgraded to LEDs in coolers 25% of the time and in freezers 75% of the time, as the majority of cases with doors are for freezer applications; however, more and more customers are beginning to install cases with doors for cooler applications. Therefore the weights are 22.5% non self-contained coolers, 67.5% non self-contained freezers, 2.5% self-contained coolers, and 7.5% self-contained freezers.

Because no studies of refrigeration occupancy sensors could be found, a savings value of 24% for occupancy sensors in general is used.

Self-contained coefficient of performance was converted from the kW per horsepower of each size tier in tables 4-71 and 4-72 of the Business Programs: Deemed Savings Manual V1.0[5] to kW per ton, where 1 ton of refrigeration is equal to 4.7143 hp, then is converted to COP, where COP is equal to 12 kW per ton divided by 3.412. The average COP for self-contained coolers and freezers was calculated based on the weighting from these same tables.

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf. Value for general occupancy sensors used.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 3,450 units over 22 projects from 2015 to 2018.
3. Design Lights Consortium. *Product List.* Vertical Refrigerated Case Luminaires primary use category. Accessed March 30, 2016. https://www.designlights.org/
4. United States Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office. "Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration." DOE Publication ID 6180. Table 3-7. September 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
   The capacity and power values were calculated to yield the EER, then converted to COP based on COP being equal to EER divided by 3.412.
5. Lawrence Berkeley National Laboratory. *A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings*. September 2011. https://eta.lbl.gov/sites/default/files/publications/a_meta-analysis_of_energy_savings_from_lighting_controls_in_commercial_buildings_lbnl-5095e.pdf

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Updated based on Focus on Energy Deemed Savings Manual
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost
04	12/2020	Updated savings factor

Networked Lighting Controls for New Construction

	Measure Details
Measure Master ID	Networked Lighting Controls, better than code, new construction, 5233
Workpaper ID	W0288
Measure Unit	Per project (see Assumptions)
Measure Type	Hybrid
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	17[1]
Incremental Cost ($/unit)	$0.57 per square foot[2]

Measure Description

The Design Lights Consortium defines NLC systems as the combination of sensors, network interfaces, and controllers that affect lighting changes in luminaires, retrofit kits, or lamps.[3] These NLCs save energy by more efficiently controlling the spaces through simplified commissioning, potential real-time usage information and analytics for end users, interoperability with other building systems, and flexible reconfiguration for when space or task uses change.

This measure is the installation of networked lighting controls in the interior of a newly-constructed building.

Description of Baseline Condition

The baseline condition is a lighting system with controls designed to meet ASHRAE 90.1-2013 new construction code minimums. Due to the various space types and complexity of code requirements for different spaces, the baseline is generalized for the savings calculations. Since daylighting and high bay occupancy sensors are commonly required in the Industrial and Schools & Government sectors, and the savings factor for those control strategies exceeds the NLC savings factor, non-high bay occupancy sensors are used as the baseline and spaces with daylighting and high bay occupancy sensors will be ineligible for incentives. The Commercial sector uses on/off high bay occupancy sensors as the baseline control strategy because it has the most conservative savings factor of all the baseline control strategy options.

Description of Efficient Condition

The efficient condition is a properly designed lighting system that includes the integration of a DLC NLC QPL listed (NLC4 or higher) controls system that includes operational occupancy sensing, zoning, and individual addressability strategies for individual fixtures controlled by a central bridge or gateway.[3]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Watts * HOU * (SF_{EFF} - SF_{BASE}) / 1{,}000$

Where:

Watts = Lighting wattage controlled (= user input; see Assumptions)

HOU = Hours of use (= customer input if known, otherwise varies by sector; see Hours of Use and Savings Factors by Sector table below)

SF_{EFF} = Networked lighting controls savings factor (= varies by sector, see Hours of Use and Savings Factors by Sector table below)

SF_{BASE} = Baseline controls savings factor (= varies by sector, see Hours of Use and Savings Factors by Sector table below)

1,000 = Kilowatt conversion factor

Hours of Use and Savings Factors by Sector

Sector	HOU[4]	SF_{EE}	SF_{EE} Note	SF_{BASE}*
Commercial	3,730	51%	Arithmetic average of retail (44%), restaurant (47%), and office (63%) building types from DLC study[5]	34%
Industrial	4,745	43%	Weighted average[6] of sectors from DLC study[5] (see Assumptions)	24%
Schools & Government	3,239	28%	Value for school building type from DLC study[5]	24%

* See Assumptions

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Watts * CF / 1{,}000$

Where:

CF = Coincidence factor (= varies by sector for retrofit kit only and connected controls interior; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Schools & Government[4]	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 17 years)[1]

Assumptions

Savings for this measure are calculated at a project level using the methodology above, though incentive rates are based on kilowatt-hour savings calculated by comparing baseline strategy (code) to a NLC system.

New buildings will have some level of lighting controls as a code requirement for most, if not all, of the spaces. This measure is intended to capture the additional savings for installing NLC which is considered above and beyond the code requirements per ASHRAE 90.1-2013. There are a few instances where the savings are low enough that an incentive is not justified, therefore Industrial and Schools & Government customers installing NLC in high bay spaces and or spaces requiring daylighting controls are not eligible for NLC. NLC installed in other spaces are still eligible.

The user will complete the Lighting Power Density (LPD) Workbook and the total controlled lighting wattage will be calculated as part of the LPD measure requirements (W0093).

The Commercial sector SF_{BASE} is from workpaper W0086. The Industrial and Schools & Government sectors SF_{BASE} are from workpaper W0087.

The Industrial sector SF_{EFF} comes from the DLC study and Focus on Energy historical data, weighted as shown in the following table.

Assumptions for Industrial Savings Factor

Building Type	Observed Savings Factor in DLC Study[5]	Fraction of MMIDs 3965 and 3966 Focus on Energy Savings for Industrial Sector Usage[6]	Weighted Average
Manufacturing	30%	36%	43%
Office	63%	11%	
Other	47% (overall average used)	53%	

Sources

1. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Data for MMID 5031 (Comprehensive Lighting Solutions or W0255) from January 2020 to November 2021 shows 24 projects and 8,186 fixtures, with annual kWh savings distributed 85% to high bay and low bay fixtures (similar to W0115, EUL = 20), 9.2% to 2x4 troffers (similar to W0133 and W0134, EUL = 14 years), and various other lighting types. Applying a weighted average of similar workpaper EULs yields an EUL of 18.9 years, but since this approach is approximate this is rounded down to 17 years.
2. Northwest Energy Efficiency Alliance. *2020 Luminaire Level Lighting Controls Incremental Cost Study*. January 7, 2021. https://neea.org/img/documents/2020-LLLC-Incremental-Cost-Study.pdf
Table 4 shows the 40,000 sq ft office building has 471 fixtures. Table 6 shows $48 incremental cost per fixture. A per square foot incremental cost is calculated to be 471 * $48 / 40,000 = $0.57 per sq ft.
3. DesignLights Consortium. "Networked Lighting Control System Technical Requirements V4.0, SSL QPL and NLC QPL." June 4, 2020. https://www.designlights.org
4. PA Consulting Group Inc. *State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0*. Table 3-2 Lighting Hours of Use in Commercial Applications. March 22, 2010. focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. DesignLights Consortium. *Report: Energy Savings from Networked Lighting Control (NLC) Systems*. September 21, 2017. Table 1. designlights.org/lighting-controls/reports-tools-resources/nlc-energy-savings-report/
The multifamily controls savings factor was derived by using the "Overall" building type value.
6. Wisconsin Focus on Energy. Historical project data for MMIDs 3965 and 3966, obtained from SPECTRUM. January 2017 through December 2019.
A weighted average of manufacturing, office, and overall/other building types (36%, 11%, and 53%, respectively) was used to determine the controls savings factor for the industrial sector.

Revision History

Version Number	Date	Description of Change
01	12/2021	Initial release

Comprehensive Lighting Solutions

	Measure Details
Measure Master ID	CLS – Fixture or Retrofit Kit Only, 5029 CLS – Fixture or Retrofit Kit/Lamp with Connected Controls, Interior, 5031 CLS – Fixture or Retrofit Kit/Lamp with Connected Controls, Exterior, 5030
Workpaper ID	W0255
Measure Unit	Per watt reduced
Measure Type	Hybrid
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Schools & Government, Residential- Multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Actual cost in current year

Measure Description

Comprehensive lighting solutions consist of two types of measures. First, a fixture or retrofit kit only is for lighting upgrades where fixture layouts have been redesigned, typically not one-for-one, and is installed when current conditions no longer meet the facility needs, resulting in reduced foot-candles and reduced energy usage. Second, a fixture or retrofit kit with connected controls is for lighting upgrades where either interior or exterior fixtures are upgraded in conjunction with DLC-listed advanced/networked lighting control (NLC) systems. The DLC defines NLC systems as the combination of sensors, network interfaces, and controllers that affect lighting changes in luminaires, retrofit kits, or lamps.[2] These NLCs save energy by more efficiently controlling the spaces through simplified commissioning, potential real-time usage information and analytics for end users, interoperability with other building systems, and flexible reconfiguration for when space or task uses change.

Description of Baseline Condition

The baseline condition is either an overlit facility or an interior or exterior lighting system that does not include connected controls strategies.

Description of Efficient Condition

The efficient condition is a properly designed lighting layout that includes DLC Solid State Lighting *Qualified Product List* (QPL) listed (Technical Requirement Table v4.4 or higher) or ENERGY STAR®

certified fixtures or retrofit kits and provides adequate light levels for the facility needs. In instances where connected controls strategies were not incorporated previously, the efficient condition also includes the integration of a DLC NLC QPL listed (Technical Requirement Table v4.0 or higher) controls system, either interior or exterior.[2]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = [(Watts_{BASE} * HOU * (1 – SF_{BASE})) – (Watts_{EE} * HOU * (1 – SF_{EE}))] / 1{,}000$

Where:

$Watts_{BASE}$ = Power consumption of baseline measure (= customer input)

HOU = Hours of use (= customer input or varies by sector; see table below)

SF_{BASE} = Baseline controls savings factor (= 0% for retrofit kit only and connected controls exterior; = 10% for connected controls interior, see Assumptions)

$Watts_{EE}$ = Power consumption of proposed, DLC or ENERGY STAR listed lighting equipment (= customer input)

SF_{EE} = Connected controls savings factor (= 0% for retrofit kit only; = varies by sector for connected controls interior and exterior; see table below and Assumptions)

1,000 = Kilowatt conversion factor

Hours of Use and Savings Factors by Sector

Sector	HOU[3,4]	SF_{EE}	SF_{EE} Note
Commercial	3,730	51%	Arithmetic average of retail (44%), restaurant (47%), and office (63%) building types from DLC study[5]
Industrial	4,745	43%	Weighted average[6] of sectors from DLC study[5] (see Assumptions)
Schools & Government	3,239	28%	Value for school building type from DLC study[5]
Residential- multifamily	5,950	47%	Overall average from DLC study[5]
Exterior	4,380	50%	Inferred from a paper on external bi-level controls[7]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= 0% for connected controls exterior; = varies by sector for retrofit kit only and connected controls interior; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[3]	0.77
Industrial[3]	0.77
Schools & Government[3]	0.64
Residential- multifamily[9]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

Both the EUL and the controls savings factor for multifamily building types and exterior systems will be evaluated in the near future.

The full measure cost is used because of the hybrid nature of these measures: It is difficult to determine incremental costs for projects with such a variety of scopes.

The baseline controls savings factor accounts for buildings that previously had either occupancy sensors or daylighting controls. A recent study of lighting controls[8] shows the fractions of various building types that were found to have controls installed. In addition, buildings with existing controls are less likely to install connected controls and not all the spaces within the buildings included in the study had controls. Based on this information, it is assumed that buildings receiving connected controls have a baseline HOU that was already reduced by 10% on average from existing baseline controls.

The industrial sector savings factor comes from the DLC study and Focus on Energy historical data, weighted as shown in the following table.

Assumptions for Industrial Savings Factor

Building Type	Observed Savings Factor in DLC Study[5]	Fraction of MMIDs 3965 and 3966 Focus on Energy Savings for Industrial Sector Usage[6]	Weighted Average
Manufacturing	30%	36%	43%
Office	63%	11%	
Other	47% (overall average used)	53%	

For multifamily building types, only common spaces are eligible for the connected controls interior measure (in-unit spaces are not eligible).

No studies could be found that examine NLC or occupancy sensing savings for exterior fixtures. A 2013 paper[7] summarizes savings from over ten studies of exterior bi-level controls. Approximately four of these studies showed savings up to 70%, although that value for most includes savings from the LED upgrade as well. The paper's summaries generally indicate that 30% - 40% is a conservative guess for savings from external bi-level controls. Exterior on/off occupancy controls and NLC should save more than this. An estimate of SF = 50% is used for exterior NLC.

Sources

1. Efficiency Vermont. *Technical Reference User Manual*. Lighting Power Density Measure. p. 89. March 16, 2015.
2. DesignLights Consortium. "Networked Lighting Control System Technical Requirements V4.0, SSL QPL and NLC QPL." June 4, 2020. https://www.designlights.org
3. PA Consulting Group Inc. *State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0*. Table 3-2 Lighting Hours of Use in Commercial Applications. March 22, 2010. focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. "NOAA Solar Calculator." esrl.noaa.gov/gmd/grad/solcalc/
   This report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
5. DesignLights Consortium. *Report: Energy Savings from Networked Lighting Control (NLC) Systems*. September 21, 2017. Table 1. designlights.org/lighting-controls/reports-tools-resources/nlc-energy-savings-report/
   The multifamily controls savings factor was derived by using the "Overall" building type value.
6. Wisconsin Focus on Energy. Historical project data for MMIDs 3965 and 3966, obtained from SPECTRUM. January 2017 through December 2019.
   A weighted average of manufacturing, office, and overall/other building types (36%, 11%, and 53%, respectively) was used to determine the controls savings factor for the industrial sector.
7. U.S. Department of Energy. *Exterior Lighting Control Guidance.* August 2013. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/exterior-lighting-control-guidance.pdf
   Study summaries indicate that 30 - 40% is a conservative guess for external bi-level controls. 50% is used as an estimate for external NLC.
8. Seventhwave. *Light Level Analysis in Buildings: A Market Characterization Study*. October 31, 2018. Figure 10. focusonenergy.com/sites/default/files/2018-11/WI_Light_Level_Final_Report_0.pdf

9. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	05/2020	Initial release

LED Exterior Fixture with NLC, Lumen Based, New Construction Only

	Measure Details
Measure Master ID	LED, Exterior Fixture with Networked Lighting Controls, New Construction Only: Low Output w/ NLC, ≤4,999 lumens, 5065 Mid Output w/ NLC, 5,000–9,999 lumens, 5066 High Output w/ NLC, 10,000–29,999 lumens, 5067 Very High Output w/ NLC, ≥30,000 lumens, 5068
Workpaper ID	W0263
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	NC-Commercial, NC-Industrial, NC-Schools & Government, NC-Agriculture, NC-Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	N/A
Annual Therm Savings (Therms)	N/A
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	N/A
Water Savings (gal/yr)	N/A
Effective Useful Life (years)	18[1]
Measure Incremental Cost ($/unit)	Varies by measure, see Installed Measure Cost table

Measure Description

Exterior LED fixtures with networked lighting controls (NLC) are an energy-saving alternative to traditional standard wattage high intensity discharge (HID) light sources with no controls that can be used for the same applications. LED light sources can be applied in almost every common application type where HID light sources are currently used. These measures are for new construction applications only (as a compliment to the exterior CLS retrofit measure MMID 5030). This paper is similar to W0113, for LED exterior lumen-based fixtures, with an additional savings factor for controls.

Description of Baseline Condition

The baseline condition is an exterior-mounted HID area luminaire, excluding stairwell and passageway luminaires, up to 1,000 watts. The baseline luminaire operates 4,380 hours per year with dusk to dawn/photocell controls. Per IECC-2015 C405.2.5 code, controls must automatically turn off the lighting as a function of available daylight.

Description of Efficient Condition

The efficient condition is DLC-listed LED luminaire in the “Outdoor” General Application category, excluding stairwell and passageway luminaires, with a DLC-listed NLC system capturing additional control savings.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} * HOU – Watts_{EE} * HOU * SF) / 1,000$

Where:

$Watts_{BASE}$ = Average power consumption of baseline measure (= 1,079 watts, 546 watts, 227 watts, and 116 watts)[2]

HOU = Average annual run hours of baseline measure (= 4,380)[3]

$Watts_{EE}$ = Average power consumption of efficient LED upgrade (= 315 watts, 134 watts, 63 watts, and 31 watts)[4]

SF = Savings factor for exterior NLC (= 50%, see Assumptions)[5]

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for these measures.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 18 years for measures with NLC)[1]

Annual and Lifecycle Energy Savings

Measure Description	MMID	Annual kWh Savings	Lifecycle kWh Savings
Low Output w/ NLC, ≤4,999 lumens	5065	440	7,920
Mid Output w/ NLC, 5,000–9,999 lumens	5066	861	15,498
High Output w/ NLC, 10,000–29,999 lumens	5067	2,098	37,764
Very High Output w/ NLC, ≥30,000 lumens	5068	4,036	72,648

Assumptions

No studies could be found that examine NLC or occupancy sensing savings for exterior fixtures. A 2013 paper[7] summarizes savings from over 10 studies of exterior bi-level controls. Approximately four of these studies showed savings up to 70%, although that value for most includes savings from the LED upgrade as well. The paper summary generally indicate that 30% to 40% is a conservative guess for savings from external bi-level controls. Exterior on/off occupancy controls and NLC should save more than the paper estimates, so this workpaper uses a 50% savings factor for exterior NLC.

Installed Measure Cost

Measure Description	MMID	Incremental Cost
Low Output w/ NLC, ≤4,999 lumens	5065	\$222.70[6]
Mid Output w/ NLC, 5,000–9,999 lumens	5066	\$306.81[7]
High Output w/ NLC, 10,000–29,999 lumens	5067	\$440.70[8]
Very High Output w/ NLC, ≥30,000 lumens	5068	\$989.83[9]

Sources

1. DesignLights Consortium. *Qualified Product List*. Accessed August 2017. https://www.designlights.org/search
   Average rated life of models participating in linear LED measures is 54,123 hours. With an HOU of 4,380 for standard fixtures, the EUL is 12 years. With an HOU of 2,190 for fixtures with NLC, the calculated lifetime is 24 years. Lighting EULs are capped at 20 years, and this is applied to savings from the wattage upgrade. The lifetime for the controls upgrade is 8 years. Dividing total lifetime savings by total annual savings yields a mean EUL of 18 years.
2. *Focus on Energy Default Wattage Guide*. Version 1.0. 2013.
3. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. *NOAA Solar Calculator.* http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This also includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
4. Wisconsin Focus on Energy. Historical project data for measures MMID 4280, 4281, 4282, and 4283, obtained from SPECTRUM. January 1, 2019 to June 30, 2020. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. Data cross-referenced with DLC QPL to determine weighted average wattage.
5. U.S. Department of Energy. *Exterior Lighting Control Guidance.* August 2013. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/exterior-lighting-control-guidance.pdf
   Study summaries indicate that 30% to 40% is a conservative guess for external bi-level controls. 50% is used as an estimate for external NLC.
6. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 2,633 projects and 18,865 units from February 2018 to July 2020 is \$187.73. Base cost of \$16.42 from October 2019 online lookups of base models, 50 watt to 150 watt metal halide bulbs. \$187.73 - \$16.42 = \$171.31. To account for controls cost, add 33% to the incremental fixture cost. \$171.31 * 1.3 = \$222.70.

7. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 2,742 projects and 24,905 units from February 2018 to July 2020 is $252.37. Base cost of $16.36 from October 2019 online lookups of base models, 150 watt to 250 watt metal halide bulbs. $252.37 - $16.36 = $236.01. To account for controls cost, add 33% to the incremental fixture cost. $236.01 * 1.3 = $306.81.
8. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 3,888 projects and 37,504 units from February 2018 to July 2020 is $361.65. Base cost of $22.65 from October 2019 online lookups of base models, 250 watt to 1,000 watt metal halide bulbs. $361.65 - $22.65 = $339.00. To account for controls cost, add 33% to the incremental fixture cost. $339.00 * 1.3 = $440.70.
9. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 602 projects and 8,372 units from March 2018 to July 2020 is $786.56. Base cost of $25.14 from October 2019 online lookups of base models, 1,000 watt metal halide bulbs. $786.56 - $25.14 = $761.41. To account for controls cost, add 33% to the incremental fixture cost. $761.41 * 1.3 = $989.83.

Revision History

Version Number	Date	Description of Change
01	10/2020	Initial TRM entry

8-Foot Linear Fluorescent T8 Replacement System

	Measure Details
Measure Master ID	T8, 2-Lamp, 4-Foot, HPT8 or RWT8: Replacing T12, 1-Lamp, 8-Foot, 0.78 < BF < 1.00, 3122 Replacing T12, 1-Lamp, 8-Foot, BF ≤ 0.78, 3123 Replacing T12HO, 1-Lamp, 8-Foot, 0.78 < BF < 1.00, 3124, 3801 Replacing T12HO, 1-Lamp, 8-Foot, BF ≤ 0.78, 3125 Replacing T12HO, 1-Lamp, 8-Foot, BF > 1.00, 3126, 3802 T8, 4-Lamp, 4-Foot, HPT8 or RWT8: Replacing T12, 2-Lamp, 8-Foot, 0.78 < BF < 1.00, 3127, 3803 Replacing T12, 2-Lamp, 8-Foot, BF ≤ 0.78, 3128 Replacing T12HO, 2-Lamp, 8-Foot, 0.78 < BF < 1.00, 3129, 3804 Replacing T12HO, 2-Lamp, 8-Foot, BF ≤ 0.78, 3130 Replacing T12HO, 2-Lamp, 8-Foot, BF > 1.00, 3131, 3805 Replacing T12VHO, 2-Lamp, 8-Foot, 0.78 < BF < 1.00, 3132 Replacing T12VHO, 2-Lamp, 8-Foot, BF ≤ 0.78, 3133 Replacing T12VHO, 2-Lamp, 8-Foot, BF > 1.00, 3134
Workpaper ID	W0092
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Fluorescent, Linear
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D[2]

Measure Description

This measure is high performance and reduced wattage 4-foot linear fluorescent lighting fixtures that use low ballast factors, high wattage lamps, or reduced wattage lamps are an energy-efficient alternative to 8-foot, standard wattage T12, T12HO, and T12VHO linear fluorescent fixtures. These products can be installed on a two-to-one basis to replace 1-lamp or 2-lamp T12 luminaires without sacrificing lighting quality.

Description of Baseline Condition

For existing buildings, the baseline measure is 8-foot, 1-lamp or 2-lamp standard T12, T12HO, and T12VHO linear fluorescent fixtures. High output (HO) 8-foot T12 baseline lamps range from 95 watts to 110 watts, while for very high output (VHO) lamps the range is 185 watts to 215 watts.

Description of Efficient Condition

The efficient measure is 2-lamp or 4-lamp, 4-foot, high performance T8 fixtures with normal and low ballast factor, and reduced wattage, 25-watt and 28-watt T8s with high, normal, and low ballast factors.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{8' T12} - kWh_{HP/RW}$

Where:

$kWh_{8' T12}$ = Annual electricity consumption of an 8-foot T12, T12HO, or T12VHO linear fluorescent lamp fixture

$kWh_{HP/RW}$ = Annual electricity consumption of a 4-foot, linear fluorescent, high performance or reduced wattage fixture

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Wattage/1{,}000 * CF$

Where:

Wattage = Wattage of installed fixture

1,000 = Kilowatt conversion factor

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[5]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Annual Deemed Savings for 8-FootLinear Fluorescent T8 Replacement System

Measure	MMID	Commercial 3,730 (0.77)		Schools & Gov 3,239 (0.64)		Industrial 4,745 (0.77)		Agriculture 4,698 (0.67)	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 1-Lamp, 8-Foot, 0.78 < BF < 1.00	3122	112	0.0231	97	0.0192	142	0.0231	141	0.0201
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 1-Lamp, 8-Foot, BF ≤ 0.78	3123	137	0.0283	119	0.0235	174	0.0283	173	0.0246
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 2-Lamp, 8-Foot, 0.78 < BF < 1.00	3127, 3803	129	0.0266	112	0.0221	164	0.0266	162	0.0231
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 2-Lamp, 8-Foot, BF ≤ 0.78	3128	175	0.0362	152	0.0301	223	0.0362	220	0.0315
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, BF > 1.00	3126, 3802	202	0.0416	175	0.0346	257	0.0416	254	0.0362
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, 0.78 < BF < 1.00	3124, 3801	269	0.0555	234	0.0461	342	0.0555	339	0.0483
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, BF ≤ 0.78	3125	294	0.0606	255	0.0504	374	0.0606	370	0.0527
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 2-Lamp, 8-Foot, BF > 1.00	3131, 3805	322	0.0665	280	0.0553	410	0.0665	406	0.0579
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 2-Lamp, 8-Foot, BF ≤ 0.78	3130	507	0.1047	440	0.0870	645	0.1047	639	0.0911
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, BF > 1.00	3134	967	0.1997	840	0.1660	1,230	0.1997	1,218	0.1738
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, 0.78 < BF < 1.00	3132	1,106	0.2284	960	0.1898	1,407	0.2284	1,393	0.1987
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, BF ≤ 0.78	3133	1,153	0.2379	1,001	0.1977	1,467	0.2379	1,452	0.2070

Lifecycle Deemed Savings for 8-Foot Linear Fluorescent T8 Replacement System

Measure	MMID	Commercial 3,730 (0.77)	Schools & Gov 3,239 (0.64)	Industrial 4,745 (0.77)	Agriculture 4,698 (0.67)
		kWh	kWh	kWh	kWh
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 1-Lamp, 8-Foot, 0.78 < BF < 1.00	3122	1,680	1,455	2,130	2,115
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 1-Lamp, 8-Foot, BF ≤ 0.78	3123	2,055	1,785	2,610	2,595
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 2-Lamp, 8-Foot, 0.78 < BF < 1.00	3127, 3803	1,935	1,680	2,460	2,430
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 2-Lamp, 8-Foot, BF ≤ 0.78	3128	2,625	2,280	3,345	3,300
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, BF > 1.00	3126, 3802	3,030	2,625	3,855	3,810
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, 0.78 < BF < 1.00	3124, 3801	4,035	3,510	5,130	5,085
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, BF ≤ 0.78	3125	4,410	3,825	5,610	5,550
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 2-Lamp, 8-Foot, BF > 1.00	3131, 3805	4,830	4,200	6,150	6,090
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 2-Lamp, 8-Foot, BF ≤ 0.78	3130	7,605	6,600	9,675	9,585
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, BF > 1.00	3134	14,505	12,600	18,450	18,270
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, 0.78 < BF < 1.00	3132	16,590	14,400	21,105	20,895
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, BF ≤ 0.78	3133	17,295	15,015	22,005	21,780

Measure Costs for 8-Foot Linear Fluorescent T8 Replacement System[2]

Measure	MMID	Cost ($)
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 1-Lamp, 8-Foot, 0.78 < BF < 1.00	3122	$41.00
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 1-Lamp, 8-Foot, BF ≤ 0.78	3123	$41.00
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 2-Lamp, 8-Foot, 0.78 < BF < 1.00	3127, 3803	$66.00
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12, 2-Lamp, 8-Foot, BF ≤ 0.78	3128	$66.00
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, BF > 1.00	3126, 3802	$41.00
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, 0.78 < BF < 1.00	3124, 3801	$41.00
T8, 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 1-Lamp, 8-Foot, BF ≤ 0.78	3125	$41.00
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 2-Lamp, 8-Foot, BF > 1.00	3131	$66.00
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO, 2-Lamp, 8-Foot, BF ≤ 0.78	3130	$66.00
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, BF > 1.00	3134	$66.00
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, 0.78 < BF < 1.00	3132	$66.00
T8, 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12VHO, 2-Lamp, 8-Foot, BF ≤ 0.78	3133	$66.00

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
   California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” EUL Table. 2014. http://www.deeresources.com/
   Rated ballast life of 70,000 hours, not rated on bulb life. As such the value is capped at 15 years.
2. 2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.
3. Michigan Master Measure Database. 2011 baselines. Updated May 26, 2011.
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. PA Consulting Group. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs Deemed Savings Manual V1.0.” Table 3.2 Coincidence

Factor for Lighting in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	12/2012	Initial TRM entry
02	10/2016	Removed MMID 3314
03	01/2019	Removed MMIDs 3307, 3309, and 3312

Interior New Construction Lighting, Lighting Power Density (LPD)

	Measure Details
Measure Master ID	Interior New Construction Lighting, Lighting Power Density, Interior, 4948
Workpaper ID	W0093
Measure Unit	Per project (see Assumptions)
Measure Type	Hybrid
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agricultural, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	N/A
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	N/A
Water Savings (gal/yr)	N/A
Effective Useful Life (years)	15[1]
Measure Incremental Cost ($/unit)	$0.90[2] per square foot

Measure Description

Newly constructed or repurposed buildings must follow lighting power density (LPD) limits defined by IECC 2015[3] with Wisconsin Amendments found in SPS Chapter 363. This measure is intended to encourage building owners and lighting designers to exceed code minimums in an easy-to-use format, taking advantage of code definitions.

Although multifamily buildings are not required to follow IECC 2015 LPD limits like other Wisconsin commercial buildings, common areas are eligible for this measure as an alternative to the Energy Design Assistance or Energy Design Review offerings. Multifamily In Unit areas are not eligible.

Description of Baseline Condition

The baseline condition is any newly constructed or repurposed multifamily building or a building subject to IECC 2015 with Wisconsin Amendments for the watts-per-square-foot building type definitions.

Description of Efficient Condition

The efficient condition is a lighting fixture design that is lower than code-defined LPD values without controls.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (LPD_{CODE} - LPD_{DESIGN}) * sq\ ft * HOU / 1,000$

Where:

LPD_{CODE} = Code-allowed watts per square foot (= defined by building type; see the Code Lighting Power Density by Building Type table)[3]

LPD_{DESIGN} = Proposed watts per square foot in lighting design

sq ft = Building square footage (= defined by user)

HOU = Average annual run hours (= defined by user or program-defined based on sector; see the Hours of Use by Sector table)[4,5]

1,000 = Kilowatt conversion factor

Code Lighting Power Density by Building Type

Building Area Type	LPD (watts/sq ft)[3]
Automotive Facility	0.80
Convention Center	1.01
Courthouse	1.01
Dining: Bar Lounge/Leisure	1.01
Dining: Cafeteria/Fast Food	0.90
Dining: Family	0.95
Dormitory	0.57
Exercise Center	0.84
Fire Station	0.67
Gymnasium	0.94
Health Care Clinic	0.90
Hospital	1.05
Hotel/Motel	0.87
Library	1.19
Manufacturing Facility	1.17
Motion Picture Theater	0.76
Multifamily – Common Area	0.51
Museum	1.02
Office	0.82
Parking Garage	0.21
Penitentiary	0.81
Performing Arts Theater	1.39
Police Station	0.87
Post Office	0.87
Religious Building	1.00
Retail	1.26

Building Area Type	LPD (watts/sq ft)[3]
School/University	0.87
Sports Arena	0.91
Town Hall	0.89
Transportation	0.70
Warehouse	0.66
Workshop	1.19

Hours ofUse by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily - Common Area[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (LPD_{CODE} – LPD_{DESIGN}) * \text{sq ft} / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)[4,6]

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily - Common Area[6]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

Savings for this measure are calculated at a project level using the methodology above, though incentive rates are based on kilowatt-hour savings below code.

This measure is a consolidation of MMIDs 4336, 4337, and 4338. Their historical project costs were used to produce the cost for this measure. Details can be seen in the Incremental Costs table.

Incremental Costs

MMID	Measure Name	Projects	Square Feet	Average Cost
4336	Interior New Construction Lighting LPD ≥20% below code	10	253,508	$1.31
4337	Interior New Construction Lighting LPD ≥30% below code	24	927,990	$1.42
4338	Interior New Construction Lighting LPD ≥40% below code	153	6,256,881	$1.28
Average / Total (used for MMID 4948)		**187**	**7,438,379**	**$1.30**

Sources

1. Efficiency Vermont. *Technical Reference User Manual*. Lighting Power Density Measure. p. 89. March 16, 2015.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM, for MMID 4948. Average cost of 10 projects and 159,321 square feet from March 2020 to May 2021 is $0.90 per square foot. This sample does not include the 3 projects with 115,796 square feet that used the previous default of $1.30 per square foot.
3. International Energy Conservation Code. Table C405.4.2(1). https://codes.iccsafe.org/content/IECC2015/chapter-4-ce-commercial-energy-efficiency
4. PA Consulting Group Inc. *State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0*. Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	11/01/2017	Initial TRM entry
02	12/2019	Added new MMID based on kilowatt-hours below code instead of percentage below code, updated baseline to 2015 IECC, and updated incremental cost
03	07/2020	Added multifamily common area sector

4-Foot Linear LED, Replacing 8-Foot T12 or T8, 1 or 2 Lamp

	Measure Details
Measure Master ID	4FT Linear LED 2L: Replacing 8FT 1L T8 or T12, 4314 Replacing 8FT 1L T8 or T12, Exterior, 4315 Replacing 8FT 1L T8 or T12, Exterior 24/7, 4316 Replacing 8FT 1L T8HO or T12HO, 4317 Replacing 8FT 1L T8HO or T12HO, Exterior, 4318 Replacing 8FT 1L T8HO or T12HO, Exterior 24/7, 4319 4FT Linear LED 4L: Replacing 8FT 2L T8 or T12, 4320 Replacing 8FT 2L T8 or T12, Exterior, 4321 Replacing 8FT 2L T8 or T12, Exterior 24/7, 4322 Replacing 8FT 2L T8HO or T12HO, 4323 Replacing 8FT 2L T8HO or T12HO, Exterior, 4324 Replacing 8FT 2L T8HO or T12HO, Exterior 24/7, 4325 4FT Linear LED 2L: Replacing 8FT 2L T8 or T12, 4326 Replacing 8FT 2L T8 or T12, Exterior, 4327 Replacing 8FT 2L T8 or T12, Exterior 24/7, 4328 Replacing 8FT 2L T8HO or T12HO, 4329 Replacing 8FT 2L T8HO or T12HO, Exterior, 4330 Replacing 8FT 2L T8HO or T12HO, Exterior 24/7, 4331
Workpaper ID	W0094
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Non-exterior and exterior 12-hour = 12 (MMIDs 4314, 4315, 4317, 4318, 4320, 4321, 4323, 4324, 4326, 4327, 4329, and 4330) Exterior 24-hour = 6 (MMIDs 4316, 4319, 4321, 4325, 4328, and 4331)[1]
Incremental Cost	1-lamp upgrades = \$58.65 (MMIDs 4314–4319);[2]

	Measure Details
	2-lamp upgrades = \$103.00 (MMIDs 4320–4325);[8] 2-lamp 8-foot to 2-lamp 4-foot standard upgrades = \$47.13 (MMIDs 4326 – 4328, 4457 – 4459)[9] 2-lamp 8-foot to 2-lamp 4-foot HO upgrades = \$44.32 (MMIDs 4329 – 4331, 4460 – 4462)[10]

Measure Description

Four-foot T8 LEDs are an energy-efficient alternative to standard 8-foot T8 or T12 fluorescent lamps commonly found throughout commercial, industrial, agriculture, school, government, and multifamily spaces. These products can replace 8-foot T8 or T12 lamps two-for-one, in tandem, and this measure incorporates several common retrofit scenarios.

Description of Baseline Condition

The baseline condition is 1- and 2-lamp standard output and high output 8-foot T8 or T12 fluorescent lamps.

Description of Efficient Condition

The efficient condition equipment must be DesignLights Consortium-listed in the T8 Four-Foot Linear Replacement Lamps General Application, and have a tested or reported wattage of 24 or less. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Average wattage of T8 and T12 systems (1 lamp = 65 watts, 2 lamp = 108 watts, 1 lamp HO = 103.5 watts, 2 lamp HO = 184 watts)

$Watts_{EE}$ = Average wattage consumption of DLC-listed 4-foot linear LED < 24 watts (= 16.5 watts)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector, see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950
Exterior[6]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) /1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector, see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[7]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years for non-exterior and exterior 12-hour; = 6 years for exterior 24-hour)[1]

Deemed Savings

Annual Energy Savings (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
4FT Linear LED 2L						
Replacing 8FT 1L T8 or T12	4314	119	152	150	104	190

Measure	MMID	Com-mercial	Indus-trial	Agri-culture	Schools & Gov	Multi-family
Replacing 8FT 1L T8 or T12, Exterior	4315	140	140	140	140	140
Replacing 8FT 1L T8 or T12, Exterior 24/7	4316	280	280	280	280	280
Replacing 8FT 1L T8HO or T12HO	4317	263	335	331	228	419
Replacing 8FT 1L T8HO or T12HO	4318	309	309	309	309	309
Replacing 8FT 1L T8HO or T12HO	4319	618	618	618	618	618
4FT Linear LED 4L						
Replacing 8FT 2L T8 or T12	4320	157	199	197	136	250
Replacing 8FT 2L T8 or T12, Exterior	4321	184	184	184	184	184
Replacing 8FT 2L T8 or T12, Exterior 24/7	4322	368	368	368	368	368
Replacing 8FT 2L T8HO or T12HO	4323	440	560	554	382	702
Replacing 8FT 2L T8HO or T12HO, Exterior	4324	517	517	517	517	517
Replacing 8FT 2L T8HO or T12HO, Exterior 24/7	4325	1,034	1,034	1,034	1,034	1,034
4FT Linear LED 2L						
Replacing 8FT 2L T8 or T12	4326	280	356	352	243	446
Replacing 8FT 2L T8 or T12, Exterior	4327	329	329	329	329	329
Replacing 8FT 2L T8 or T12, Exterior 24/7	4328	657	657	657	657	657
Replacing 8FT 2L T8HO or T12HO	4329	563	716	709	489	898
Replacing 8FT 2L T8HO or T12HO, Exterior	4330	661	661	661	661	661
Replacing 8FT 2L T8HO or T12HO, Exterior 24/7	4331	1,323	1,323	1,323	1,323	1,323

Demand Reduction (kW)

Measure	MMID	Com-mercial	Indus-trial	Agri-culture	Schools & Gov	Multi-family
4FT Linear LED 2L						
Replacing 8FT 1L T8 or T12	4314	0.0246	0.0246	0.0214	0.0205	0.0246
Replacing 8FT 1L T8 or T12, Exterior	4315	N/A	N/A	N/A	N/A	N/A
Replacing 8FT 1L T8 or T12, Exterior 24/7	4316	0.032	0.032	0.032	0.032	0.032
Replacing 8FT 1L T8HO or T12HO	4317	0.0543	0.0543	0.0472	0.0451	0.0543
Replacing 8FT 1L T8HO or T12HO	4318	N/A	N/A	N/A	N/A	N/A
Replacing 8FT 1L T8HO or T12HO	4319	0.0705	0.0705	0.0705	0.0705	0.0705
4FT Linear LED 4L						
Replacing 8FT 2L T8 or T12	4320	0.0323	0.0323	0.0281	0.0269	0.0323
Replacing 8FT 2L T8 or T12, Exterior	4321	N/A	N/A	N/A	N/A	N/A
Replacing 8FT 2L T8 or T12, Exterior 24/7	4322	0.042	0.042	0.042	0.042	0.042
Replacing 8FT 2L T8HO or T12HO	4323	0.0909	0.0909	0.0791	0.0755	0.0909
Replacing 8FT 2L T8HO or T12HO, Exterior	4324	N/A	N/A	N/A	N/A	N/A
Replacing 8FT 2L T8HO or T12HO, Exterior 24/7	4325	0.118	0.118	0.118	0.118	0.118

Measure	MMID	Com-mercial	Indus-trial	Agri-culture	Schools & Gov	Multi-family
4FT Linear LED 2L						
Replacing 8FT 2L T8 or T12	4326	0.0578	0.0578	0.0503	0.048	0.0578
Replacing 8FT 2L T8 or T12, Exterior	4327	N/A	N/A	N/A	N/A	N/A
Replacing 8FT 2L T8 or T12, Exterior 24/7	4328	0.075	0.075	0.075	0.075	0.075
Replacing 8FT 2L T8HO or T12HO	4329	0.1163	0.1163	0.1012	0.0966	0.1163
Replacing 8FT 2L T8HO or T12HO, Exterior	4330	N/A	N/A	N/A	N/A	N/A
Replacing 8FT 2L T8HO or T12HO, Exterior 24/7	4331	0.151	0.151	0.151	0.151	0.151

Lifecycle Savings (kWh)

Measure	MMID	Com-mercial	Indus-trial	Agri-culture	Schools & Gov	Multi-family
4FT Linear LED 2L						
Replacing 8FT 1L T8 or T12	4314	1,428	1,824	1,800	1,248	2,280
Replacing 8FT 1L T8 or T12, Exterior	4315	1,680	1,680	1,680	1,680	1,680
Replacing 8FT 1L T8 or T12, Exterior 24/7	4316	1,680	1,680	1,680	1,680	1,680
Replacing 8FT 1L T8HO or T12HO	4317	3,156	4,020	3,972	2,736	5,028
Replacing 8FT 1L T8HO or T12HO	4318	3,708	3,708	3,708	3,708	3,708
Replacing 8FT 1L T8HO or T12HO	4319	3,708	3,708	3,708	3,708	3,708
4FT Linear LED 4L						
Replacing 8FT 2L T8 or T12	4320	1,884	2,388	2,364	1,632	3,000
Replacing 8FT 2L T8 or T12, Exterior	4321	2,208	2,208	2,208	2,208	2,208
Replacing 8FT 2L T8 or T12, Exterior 24/7	4322	2,208	2,208	2,208	2,208	2,208
Replacing 8FT 2L T8HO or T12HO	4323	5,280	6,720	6,648	4,584	8,424
Replacing 8FT 2L T8HO or T12HO, Exterior	4324	6,204	6,204	6,204	6,204	6,204
Replacing 8FT 2L T8HO or T12HO, Exterior 24/7	4325	6,204	6,204	6,204	6,204	6,204
4FT Linear LED 2L						
Replacing 8FT 2L T8 or T12	4326	3,360	4,272	4,224	2,916	5,352
Replacing 8FT 2L T8 or T12, Exterior	4327	3,948	3,948	3,948	3,948	3,948
Replacing 8FT 2L T8 or T12, Exterior 24/7	4328	3,942	3,942	3,942	3,942	3,942
Replacing 8FT 2L T8HO or T12HO	4329	6,756	8,592	8,508	5,868	10,776
Replacing 8FT 2L T8HO or T12HO, Exterior	4330	7,932	7,932	7,932	7,932	7,932
Replacing 8FT 2L T8HO or T12HO, Exterior 24/7	4331	7,938	7,938	7,938	7,938	7,938

Sources

1. DesignLights Consortium. *Qualified Product List.* Accessed August 2017.
   https://www.designlights.org/lighting-controls/download-the-qpl/
   The average rated life of models participating in linear LED measures is 51,160 hours. Non-exterior measures (with a sector-average HOU of 4,103) and 12-hour measures (with an HOU of

4,380) have an EUL of 12 years. Exterior 24/7 measures (with an HOU of 8,760) have an EUL of 6 years.

2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 467 projects and 1,277 units from February 2018 to July 2020 is \$68.08. Base cost of \$9.43 from November 2020 lookups of T8 and T8HO models on www.1000bulbs.com, www.homedepot.com, www.bulbs.com, and www.lightbulbs.com. \$68.08 - \$9.43 = \$58.65.
3. DesignLights Consortium. *Product List.* Accessed October 13, 2017. https://www.designlights.org/search/
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

5. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. Common Area Lighting section, p. 9–11. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
7. Summit Blue Consulting. Con Edison Callable Load Study. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.
8. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 148 projects and 2,059 units from February 2018 to July 2020 is $85.55. Base cost of $9.43 from November 2020 lookups of T8 and T8HO models on www.1000bulbs.com, www.homedepot.com, www.bulbs.com, and www.lightbulbs.com. $85.5.5 - $9.43 * 2 = $66.69.
9. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 74 projects and 8,625 units from February 2018 to July 2020 is $56.95. Base cost of $9.43 from November 2020 lookups of T8 and T8HO models on www.1000bulbs.com, www.homedepot.com, www.bulbs.com, and www.lightbulbs.com. $56.95 - $9.43 * 2= $38.09.
10. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 10 projects and 418 units from February 2018 to July 2020 is $50.83. Base cost of $12.49 from November 2020 lookups of T8 and T8HO models on www.1000bulbs.com, www.homedepot.com, www.bulbs.com, and www.lightbulbs.com. $50.83 - $12.49 = $38.34.

Revision History

Version Number	Date	Description of Change
01	10/13/2017	Initial TRM entry
02	2/19/2020	Updated cost for MMIDs 4326 –4328, 4457 – 4459, 4329 – 4331, and 4460 – 4462
03	2/2020	Updated costs

LED Fixtures, High-Bay Linear Fluorescent to LED

	Measure Details
Measure Master ID	LED Fixture, High Bay, DLC Listed: ≤ 180 Watts, Replacing 4 Lamp T5HO or 6 Lamp T8, 3393 ≤ 180 Watts, Replacing 4 Lamp T5HO or 6 Lamp T8, Agriculture, 4701 ≤ 250 Watts, Replacing 6 Lamp T5HO or 8 Lamp T8, 4347 ≤ 250 Watts, Replacing 6 Lamp T5HO or 8 Lamp T8, Agriculture, 4702 ≤ 300 Watts, Replacing 8 Lamp T5HO or 10 Lamp T8, 4795 ≤ 350 Watts, Replacing 10 Lamp T5HO or 12 Lamp T8, 4796
Workpaper ID	W0259
Measure Unit	Per luminaire
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	≤ 180 Watts = $191.41 (MMIDs 3393 & 4701)[2] ≤ 250 Watts, ≤ 300 Watts, and ≤ 350 Watts = $271.65 (MMIDs 4347, 4702, 4795, and 4796)[3]

Measure Description

LED high-bay fixtures save energy when replacing fluorescent lamp high-bay products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace fluorescent lamp high-bay luminaires.

Description of Baseline Condition

The baseline condition is a combination of similar lumen output 4-foot fluorescent T5HO and T8 lamp high/low bay fixtures for existing buildings and new construction buildings. An average of 4-foot T5HO lamp and T8 lamp high/low bay luminaires was used to generate the baseline wattage. See the Assumptions section for a breakdown.

Description of Efficient Condition

The efficient condition is a DesignLights Consortium™ (DLC)-listed fixture listed in the High-Bay General Application, consuming less than or equal to the wattage respective to its measure name.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Average power consumption of respective T5HO lamp or T8 lamp configuration, high/low bay luminaires (see Baseline and Efficient Lamp Consumption table below)

$Watts_{EE}$ = Efficient consumption of LED fixture (see Baseline and Efficient Lamp Consumption table below)

HOU = Hours of use (= varies by sector; see Hours of Use by Sector table below)

1,000 = Kilowatt conversion factor

Baseline and Efficient Lamp Consumption

Measure	$Watts_{BASE}$	$Watts_{EE}$[4]
LED Fixture, ≤ 180 Watts, Replacing 4 Lamp T5HO or 6 Lamp T8, High Bay, DLC Listed, 3393, 4701	227	124
LED Fixture, ≤ 250 Watts, Replacing 6 Lamp T5HO or 8 Lamp T8, High Bay, DLC Listed, 4347, 4702	323	170
LED Fixture, ≤ 300 Watts, Replacing 8 Lamp T5HO or 10 Lamp T8, High Bay, DLC Listed, 4795	418	234
LED Fixture, ≤ 350 Watts, Replacing 10 Lamp T5HO or 12 Lamp T8, High Bay, DLC Listed, 4796	514	277

Hours of Use by Sector

Sector	HOU
Commercial[5]	3,730
Industrial[5]	4,745
Agriculture[5]	4,698
Schools & Government[5]	3,239
Multifamily[6]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= varies by sector, see Coincidence Factor by Sector table below)

Coincidence Factor by Sector

Sector	HOU
Commercial[5]	0.77
Industrial[5]	0.77
Agriculture[5]	0.67
Schools & Government[5]	0.64
Multifamily[7]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Deemed Savings

Annual and Lifecycle Savings by Measure

Measure	MMID	Sector	Annual kWh	Annual kW	Lifecycle kWh
LED Fixture, ≤ 180 Watts, Replacing 4 Lamp T5HO or 6 Lamp T8, High Bay, DLC Listed	3393	Commercial	384	0.0793	7,680
		Industrial	489	0.0793	9,780
		Schools & Gov	334	0.0659	6,680
		Multifamily	613	0.0793	12,260
	4701	Agriculture	484	0.0690	9,680
LED Fixture, ≤ 250 Watts, Replacing 6 Lamp T5HO or 8 Lamp T8, High Bay, DLC Listed	4347	Commercial	571	0.1178	11,420
		Industrial	726	0.1178	14,520
		Schools & Gov	496	0.0979	9,920
		Multifamily	910	0.1178	18,200
	4702	Agriculture	719	0.1025	14,380
LED Fixture, ≤ 300 Watts, Replacing 8 Lamp T5HO or 10 Lamp T8, High Bay, DLC Listed	4795	Commercial	686	0.1417	13,720
		Industrial	873	0.1417	17,460
		Agriculture	864	0.1233	17,280
		Schools & Gov	596	0.1178	11,920
		Multifamily	N/A	N/A	N/A
LED Fixture, ≤ 350 Watts, Replacing 10 Lamp T5HO or 12 Lamp T8, High Bay, DLC Listed	4796	Commercial	884	0.1825	17,680
		Industrial	1,125	0.1825	22,500
		Agriculture	1,113	0.1588	22,260
		Schools & Gov	768	0.1517	15,360
		Multifamily	N/A	N/A	N/A

Assumptions

Fixture weightings are based on a combination of feedback from energy audit experience, Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions, and individuals with lighting sales experience. Each fixture wattage is sourced from the Focus on Energy Default Wattage Guide (see Baseline Fixture Wattage table below).

Baseline Fixture Wattage

MMID	4-Foot Fixture Description	Fixture Wattage	Percentage Weighted	Baseline Wattage
3393, 4701	4 Lamp T5HO	234	25%	227
	6 Lamp T8	224	75%	
4347, 4702	6 Lamp T5HO	355	50%	323
	8 Lamp T8	291	50%	
4795	8 Lamp T5HO	468	50%	418
	10 Lamp T8	368	50%	
4796	10 Lamp T5HO	585	50%	514
	12 Lamp T8	442	50%	

In discussions with the DLC, it was determined that the rated lifetime hours reported in the DLC *Qualified Product List*[8] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer specification sheets often do list actual L70 test data, so these data were used to obtain a weighted average rated lifetime for participating models.[1]

Sources

1. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. January 1, 2019 to June 30, 2020. Programs included LEU, BIP, MF, S&G, SBP, B&I, and Midstream.
   The 39 participating models comprising 28,467 units and over 50% of total measure participation have a weighted average specification sheet rated life of 110,771 hours. With an average HOU of 4,472, the EUL is 25 years. Lighting EULs are capped at 20 years.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM.
   Average unit cost of 1,307 projects and 73,102 units from February 2018 to July 2020 is $208.75. Base cost of $17.34 from August 2018 lookups of eight T8 and T5 models. $208.75 - $17.34 = $191.41.
3. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM.
   Average unit cost of 172 projects and 14,236 units from April 2018 to September 2019 is $289.62. Base cost of $17.97 from August 2018 lookups of four T8 and T5 models. $289.62 - $17.97 = $271.65. Note that the costs for MMIDs 4795 and 4796 are likely higher than those for MMID 4347/4702, but their usage is 20 times less, so the same cost is applied.
4. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. January 1, 2019 to June 30, 2020. Programs included LEU, BIP, MF, S&G, SBP, B&I, and Midstream.
   Data was cross-referenced with DLC QPL to determine weighted average wattage.
5. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0.* Table 3-2 Lighting Hours of Use and Coincidence Factors by Sector. March 22, 2010.

https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

6. Tetra Tech. ACES Deemed Savings Desk Review. Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
7. Summit Blue Consulting. *Con Edison Callable Load Study.* May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows a multifamily housing (in unit) coincidence factor of 65% to 89%.
8. DesignLights Consortium. *Product List*. Accessed August 2020. https://www.designlights.org/search/

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	03/2017	Removed from TRM
03	09/2017	Reactivated measure from 2016 program offerings with updated wattages, deemed savings, and EUL
04	02/2020	Updated cost
05	09/2020	Combined MMIDs 3393, 4347, 4795, and 4796 (W0095, W0096, W0098, and W0099) into single workpaper and updated efficient consumption wattage of LED fixtures; added MMIDs 4701 & 4702 (Ag counterpart measures created to offer varying incentive amounts)

DLC Listed 2x2 LED Fixtures

	Measure Details
Measure Master ID	LED Fixture, 2x2, DLC Listed: Low Output, 3400 High Output, 3401
Workpaper ID	W0097
Measure Unit	Per luminaire
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agricultural, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	$93.15 for MMID 3400[2] $190.48 for MMID 3401[3]

Measure Description

LED 2x2 troffers save energy when replacing two- to four-lamp T8 products and two- to four-lamp 2G11 base lamps by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace 2x2 two- to four-lamp T8, T12, or 2G11 lamp base luminaires.

Description of Baseline Condition

The baseline condition is two-foot, two-, three-, and 4-lamp T8 or 2G11 lamp base troffers for existing buildings and new construction buildings.

Description of Efficient Condition

For low output 2x2 measures, the efficient condition is DesignLights Consortium™ (DLC)-listed in the "2x2 Luminaires for Ambient Lighting of Interior Commercial Spaces" and "Integrated Retrofit Kits for 2x2 Luminaires" primary use categories, which consume less than or equal to 36 watts.

For high output 2x2 measures, the efficient condition is DesignLights Consortium™ (DLC)-listed in the "2x2 Luminaires for Ambient Lighting of Interior Commercial Spaces" and "Integrated Retrofit Kits for 2x2 Luminaires" primary use categories, which consume less than or equal to 85 watts.

Annual Energy-Savings Algorithm

Low Output 2x2

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Baseline wattage, the average power consumption of 2-, 3-, or 4-lamp 17-watt T8 or 2-lamp T8 U-bend fixtures, weighted at 2%/38%/20%/40% (= 56 watts, see Assumptions section)

$Watts_{EE}$ = Energy efficient wattage, the average power consumption of DLC-listed LED fixtures less than or equal to 36 watts (= 28.58 watts)[4]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU[5,6]
Commercial[5]	3,730
Industrial[5]	4,745
Agriculture[5]	4,698
Schools & Government[5]	3,239
Multifamily[6]	5,950

High Output 2x2

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Baseline wattage, the average power consumption of 2-, 3-, or 4-lamp 2G11 base fixtures, weighted between 40-watt, 50-watt, and 55-watt lamps (= 146 watts, see Assumptions section)

$Watts_{EE}$ = Energy efficient wattage, the average power consumption of DLC-listed LED fixtures less than or equal to 85 watts (= 33.90 watts)[4]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table above)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor for wattage reduction (= varies by sector; see table below)

Coincidence Factor

Sector	CF
Commercial[5]	0.77
Industrial[5]	0.77
Agriculture[5]	0.67
Schools & Government[5]	0.64
Multifamily[7]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years)[1]

Deemed Savings

Annual Savings for DLC-Listed 2X2 LEDs

Measure	MMID	Savings	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Low Output	3400	kWh	102	130	129	89	163
		kW	0.0211	0.0211	0.0184	0.0175	0.0211
High Output	3401	kWh	418	532	527	363	667
		kW	0.0863	0.0863	0.0751	0.0717	0.0863

Lifecycle Savings for DLC-Listed 2X2 LEDs (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Low Output	3400	1,326	1,690	1,677	1,157	2,119
High Output	3401	5,434	6,916	6,851	4,719	8,671

Assumptions

Fixture lamp weightings used in baseline calculation are listed in the table below. The assumptions are based on a combination of feedback from energy audit experience, Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions, and individuals with lighting sales experience.

Fixture Lamp Weightings Used in Baseline Calculation

2 Lamp T8 Wattage	2 Lamp T8 U Bend Wattage	3 Lamp T8 Wattage	4 Lamp T8 Wattage
36	55	52	66
2%	40%	38%	20%

2-Lamp 40W 2G11 2x2	3-Lamp 40W 2G11 2x2	4-Lamp 40W 2G11 2x2
5%	25%	5%
2-Lamp 50W 2G11 2x2	**3-Lamp 50W 2G11 2x2**	**4-Lamp 50W 2G11 2x2**
5%	25%	5%
2-Lamp 55W 2G11 2x2	**3-Lamp 55W 2G11 2x2**	**4-Lamp 55W 2G11 2x2**
5%	20%	5%

In discussions with the DesignLights Consortium™, it has been determined that the rated lifetime hours reported in the DLC *Qualified Product List*[8] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC-certified. However, in these cases, manufacturer spec sheets often do list actual L70 test data. Therefore, these data were used to obtain a weighted average rated lifetime for participating models.[1]

Sources

1. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. 24 participating models comprising 6,050 units and >50% of total measure participation, have a weighted average spec sheet rated life of 59,974 hours. With an average HOU of 4,472, the EUL is 13 years.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 1,030 projects and 31,968 units from April 2018 to September 2019 is $106.37. Base cost of $13.22 from October 2019 online lookups. $106.37 - $13.22 = $93.15.
3. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 208 projects and 8,194 units from April 2018 to September 2019 is $214.35. Base cost of $23.88 from October 2019 online lookups. $214.35 - $23.88 = $190.48.
4. SPECTRUM. "Focus historical data." 1/1/19 to 6/30/20 application date ranges for LEU, BIP, MF, S&G, SBP, B&I, and Midstream. Data cross-referenced with DLC QPL determining weighted average wattage.
5. PA Consulting Group. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0. March 22, 2010. Table 3.2 for nonresidential HOU and CF. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Tetra Tech. ACES Deemed Savings Desk Review. November 3, 2010. Table 1. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

7. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.
8. DesignLights Consortium™. *Product List.* Accessed August 2020. https://www.designlights.org/search/

Revision History

Version Number	Date	Description of Change
01	04/01/2014	Initial TRM entry
02	10/07/2015	Updated savings and definitions
03	10/09/2017	Included 2x2 measures with LLLC
04	12/2018	Updated incremental cost
05	2/2020	Updated incremental cost
06	9/2020	Removed MMIDs 4332, 4463, 4333, 4464. Updated Watts_{EE} and EUL.

Four Pin-Base LED Lamp

	Measure Details
Measure Master ID	DLC Listed, Four Pin-Base Lamp Replacing CFL, Interior, 4779 DLC Listed, Four Pin-Base Lamp Replacing CFL, Exterior, 4780
Workpaper ID	W0100
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11 (see Assumptions)[1]
Incremental Cost ($/unit)	$0.84[2]

Measure Description

This measure is replacing four pin-base CFL lamps, interior or exterior, with four pin-base LED lamps.

Description of Baseline Condition

The baseline equipment is interior or exterior four pin-base CFL lighting.

Description of Efficient Condition

The efficient condition is an interior or exterior DLC-listed (Technical Requirements v4.4 minimum) four pin-base LED lamp, in the Four Pin-Base Replacement Lamps for CFLs category in one of the following primary use categories:

- Vertically / Horizontally-Mounted Lamps
    - Replacement Lamps (“Plug and Play”) (UL Type A)
- 2G11 Base Replacement Lamps
    - Internal Driver / Line Voltage Lamp-Style Retrofit Kits (UL Type B)
    - 2-Lamp External Drive Lamp-Style Retrofit Kits (UL Type C)
    - 3-Lamp External Drive Lamp-Style Retrofit Kits (UL Type C)
    - Dual Mode Internal Drive (UL Type A or B)

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) * HOU / 1{,}000 = Watts_{REDUCED} * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Power consumption of baseline lamp

$Watts_{EE}$ = Power consumption of DLC-listed LED product

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

$Watts_{REDUCED}$ = Watt reduction

Hours of Use by Sector

Sector	HOU
Commercial[3]	3,730
Industrial[3]	4,745
Agriculture[3]	4,698
Schools & Government[3]	3,239
Multifamily[4]	5,950
Exterior[5]	4,380
Average (non-exterior)	**4,472**

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[3]	0.77
Industrial[3]	0.77
Agriculture[3]	0.67
Schools & Government[3]	0.64
Multifamily[6]	0.77
Exterior	0

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years; see Assumptions)

Deemed Savings

Here, deemed savings are calculated on a per–watt reduction basis. The values in the table indicate the savings from defining $Watts_{REDUCED}$ as 1.0 in the algorithm above for each sector.

Annual Savings (per watt reduced)

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Interior	4779	3.73	0.0008	4.75	0.0008	4.7	0.0007	3.24	0.0006	5.95	0.0008
Exterior	4780	4.38	N/A	4.38	N/A	4.38	N/A	4.38	N/A	4.38	N/A

Lifecycle Savings (kWh per watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Interior	4779	41.03	51.70	52.25	35.64	65.45
Exterior	4780	48.18	48.18	48.18	48.18	48.18

Assumptions

Effective useful life was determined by dividing minimum rated life of DLC-listed products in the Four Pin-Base Replacement Lamps for CFLs category (50,000 hours)[1] by the average sector HOU of 4,472 hours.

The incremental cost per watt is the average of the differences between CFL lamps (13 watt, 26 watt, 32 watt, and 42 watt) and equivalent LED lamps (6 watt, 12 watt, 16 watt, and 22 watt, respectively). Prices were obtained from supplier websites.[2]

Sources

1. DesignLights Consortium. Website. Accessed October 2018. https://www.designlights.org/solid-state-lighting/testing-reporting-requirements/four-pin-base-replacement-lamps-for-cfls/
2. 1000 Bulbs. Accessed October 2018. www.1000bulbs.com
   Amazon. Accessed October 2018. www.amazon.com
   Bulbs. Accessed October 2018. www.bulbs.com
   Home Depot. Accessed October 2018. www.homedepot.com
   Grainger. Accessed October 2018. www.grainger.com
3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Tetra Tech. *ACES Deemed Savings Desk Review*. Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
5. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
6. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	10/19/2018	Initial TRM entry

ENERGY STAR LED Replacing Exterior Directional CFL

	Measure Details
Measure Master ID	LED, ENERGY STAR, Replacing Exterior Directional CFL: ≥ 23 Watt CFL, 3929 14–22 Watt CFL, 3930 ≤ 13 Watt CFL, 3931
Workpaper ID	W0103
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	≥ 23 watt CFL = $23.06 (MMID 3929); 14–22 watt CFL = $3.26 (MMID 3930); ≤ 13 watt CFL = $1.60 (MMID 3931)[2]

Measure Description

ENERGY STAR-listed LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with compact fluorescent lamps (CFLs). This measure will provide an energy-efficient alternative to using CFLs in several applications.

Description of Baseline Condition

The baseline condition is ENERGY STAR-listed CFLs and their incandescent equivalencies based on certified products dated September 19, 2016.

Description of Efficient Condition

The efficient condition is an ENERGY STAR-listed LED lamp in the Directional lamp category, with incandescent and CFL equivalency determined by ENERGY STAR’s product specification for lamps v2.0.[3]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Power consumption of CFL lamps (= varies by wattage equivalence; see table below)

Power Consumption of CFL Directional by Wattage Equivalence

Wattage Equivalence	Average Power Consumption of CFL Directional[4]
≥ 23 Watt CFL	23 Watts
14 Watt – 22 Watt CFL	15.6 Watts
≤ 13 Watt CFL	11 Watts

$Watts_{EE}$ = Power consumption of efficient LED lamp (= varies by wattage equivalence; see table below and Assumptions)

Power Consumption of LED Lamp by Wattage Equivalence

Wattage Equivalence	Average Power Consumption of LED Lamp[4]
≥ 23 Watt CFL	13.8 Watts
14 Watt – 22 Watt CFL	10.1 Watts
≤ 13 Watt CFL	6.9 Watts

HOU = Average annual run hours (= 4,380)[5]

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= 0)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 4 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing CFL

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
		kWh	kWh	kWh	kWh	kWh
≥ 23 Watt CFL	3929	40	40	40	40	40
14 Watt – 22 Watt CFL	3930	24	24	24	24	24
≤ 13 Watt CFL	3931	18	18	18	18	18

Average Lifecycle Deemed Savings for LED Lamp Replacing CFL

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
		kWh	kWh	kWh	kWh	kWh
≥ 23 Watt CFL	3929	160	160	160	160	160
14 Watt – 22 Watt CFL	3930	96	96	96	96	96
≤ 13 Watt CFL	3931	72	72	72	72	72

Assumptions

LED equivalent wattages are an average of ENERGY STAR-listed products. ENERGY STAR provides equivalent wattages for LEDs and CFLs based on incandescent lamps. For these calculations, ENERGY STAR-listed CFLs in the directional lamp category were accessed by their reported incandescent equivalents, then those incandescent equivalents were converted to reported LED equivalents and averaged within each specified CFL range.

Sources

1. Apex Analytics and Cadmus. Analysis of combining data from the Consortium for Retail Energy Efficiency Data with LED market projections to produce effective program lifetimes of screw-base LED bulbs. See workpapers W0228 and W0229. The market data and projections used to derive screw-in lighting EULs do not discriminate between commercial and residential sales, and therefore are applied here as well.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit costs of 17 projects and 296 units from February 2018 to December 2018 across Ag, AgSG, LEU, BIP, MF, S&G, SBP, and B&I programs show efficient costs of $28.84 for MMID 3929, $8.14 for MMID 3930, and $6.54 for MMID 3931. Baseline costs obtained from January 2021 online lookups across www.ilighting.com, www.lightingsupply.com, www.1000bulbs.com, and www.topbulb.com showing average baseline CFL costs of $5.78 for MMID 3929, $4.89 for MMID 3930, and $4.95 for MMID 3931.

3. ENERGY STAR. "ENERGY STAR Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria Version 2.0." https://www.energystar.gov/sites/default/files/Lamps%20Version%202.0%20Updated%20Spec.pdf
4. "ENERGY STAR Light Bulbs Certified Product List." Accessed September 19, 2016. https://www.energystar.gov/productfinder/product/certified-light-bulbs/results
5. U.S. Department of Commerce National Oceanic and Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/

Revision History

Version Number	Date	Description of Change
01	11/10/2016	Initial TRM entry
02	10/2017	Updated EUL Source
03	1/2021	Updated incremental cost

ENERGY STAR LED Replacing Exterior Directional Incandescent

	Measure Details
Measure Master ID	LED Lamp, ENERGY STAR, Replacing Exterior Directional Incandescent: 120W – 250W Incandescent, 3935 100W – 119W Incandescent, 3936 75W – 99W Incandescent, 3937 55W – 74W Incandescent, 3938 36W – 54W Incandescent, 3939 ≤ 35W Incandescent, 3940
Workpaper ID	W0104
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$35.33 (MMID 3935); $23.03 (MMID 3936); $19.30 (MMID 3937); $11.67 (MMID 3938); $4.02 (MMID 3939); $6.55 (MMID 3940)[2]

Measure Description

ENERGY STAR-listed LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent lamps. This measure will provide an energy-efficient alternative to using incandescent lamps in several applications.

Description of Baseline Condition

The baseline condition is ENERGY STAR-listed incandescent equivalencies based on certified LED products dated September 19, 2016. Weighted averages were taken based on the number of equivalent products certified in each wattage bin to reflect the range of products available in the market. Full incandescent wattages are used based on reflector/directional lamps being exempt from EISA legislation.[3]

Description of Efficient Condition

The efficient condition is an ENERGY STAR-listed LED lamp in Directional lamp category, with incandescent equivalency determined by ENERGY STAR's product specification for lamps v2.0.[4] Weighted averages were taken based on the number of LED products certified in each wattage bin to reflect the range of products available in the market.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Power consumption of incandescent lamps (= varies by wattage equivalence; see table below)

Baseline Wattage by Wattage Equivalence

Wattage Equivalence	Weighted Average Power Consumption of Incandescent Directional[1]
120 Watts – 250 Watts	132.2 Watts
100 Watts – 119 Watts	100.2 Watts
75 Watts – 99 Watts	78.6 Watts
55 Watts – 74 Watts	63.9 Watts
36 Watts – 54 Watts	49.2 Watts
≤ 35 Watts	32.5 Watts

$Watts_{EE}$ = Power consumption of efficient LED lamp (= varies by wattage equivalence; see table below)

Efficient Wattage by Wattage Equivalence

Wattage Equivalence	Weighted Average Power Consumption of LED Lamp[1]
120 Watts – 250 Watts	18.3 Watts
100 Watts – 119 Watts	17.1 Watts
75 Watts – 99 Watts	13.8 Watts
55 Watts – 74 Watts	9.7 Watts
36 Watts – 54 Watts	7.6 Watts
≤ 35 Watts	6.5 Watts

HOU = Average annual run hours (= 4,380)[5]

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= 0)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 4 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing Incandescent

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
		kWh	kWh	kWh	kWh	kWh
120 Watts – 250 Watts	3935	499	499	499	499	499
100 Watts – 119 Watts	3936	364	364	364	364	364
75 Watts – 99 Watts	3937	284	284	284	284	284
55 Watts – 74 Watts	3938	237	237	237	237	237
36 Watts – 54 Watts	3939	182	182	182	182	182
≤ 35 Watts	3940	114	114	114	114	114

Average Lifecycle Deemed Savings for LED Lamp Replacing Incandescent

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
		kWh	kWh	kWh	kWh	kWh
120 Watts – 250 Watts	3935	1,996	1,996	1,996	1,996	1,996
100 Watts – 119 Watts	3936	1,456	1,456	1,456	1,456	1,456
75 Watts – 99 Watts	3937	1,136	1,136	1,136	1,136	1,136
55 Watts – 74 Watts	3938	948	948	948	948	948
36 Watts – 54 Watts	3939	728	728	728	728	728
≤ 35 Watts	3940	456	456	456	456	456

Assumptions

Calculations are based on exterior lighting that operates 4,380 hours annually, 12 hours per day (dusk to dawn).

Sources

1. Apex Analytics and Cadmus. Analysis of combining data from the Consortium for Retail Energy Efficiency Data with LED market projections to produce effective program lifetimes of screw-base LED bulbs. See workpapers W0228 and W0229. The market data and projections used to derive screw-in lighting EULs do not discriminate between commercial and residential sales, and therefore are applied here as well.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 108 projets and 1,041 units from January 2018 to June 2020 across Ag, AgSG, LEU, BIP, MF, S&G, SBP, and B&I programs show efficient costs of $44.16 for MMID 3935, $32.79 for MMID 3936, $25.01 for MMID 3937, $20.33 for MMID 3938, $6.92 for MMID 3939, and $11.80 for MMID 3940. Baseline costs obtained from January 2021 online lookups across www.ilighting.com, www.lightingsupply.com, www.1000bulbs.com, www.homedepot.com, and www.mscdirect.com showing average baseline incandescent cost as $8.83 for MMID 3935, $9.76 for MMID 3936, and $5.71 for MMID 3937. Wisconsin incandescent cost data from Consortium of Retail Energy Efficiency Data (CREED) 2019 showed an average cost of $8.66 for MMID 3938, $2.90 for MMID 3939, and $5.25 for MMID 3940.
3. Lighting Facts. "The Energy Independence and Security Act (EISA) of 2007." http://www.lightingfacts.com/Library/Content/EISA
4. ENERGY STAR. "ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria Version 2.0." https://www.energystar.gov/sites/default/files/Lamps%20Version%202.0%20Updated%20Spec.pdf
5. U.S. Department of Commerce National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/

Revision History

Version Number	Date	Description of Change
01	11/08/2017	Initial TRM Entry
02	10/2017	Updated EUL Source
03	1/2021	Update incremental cost

ENERGY STAR LED Replacing Exterior Omnidirectional and Decorative Incandescent or CFL

	Measure Details
Measure Master ID	Omnidirectional LED Lamp, ENERGY STAR, Exterior: 1,600 – 1,999 Lumens, 5221 1,100 – 1,599 Lumens, 5222 800 – 1,099 Lumens, 5223 450 – 799 Lumens, 5224 250 – 449 Lumens, 5225 Decorative LED Lamp, ENERGY STAR, Exterior: 1,600 – 1,999 Lumens, 5226 1,100 – 1,599 Lumens, 5227 800 – 1,099 Lumens, 5228 450 – 799 Lumens, 5229 250 – 449 Lumens, 5230
Workpaper ID	W0105
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Omnidirectional = 5[1]; Decorative = 4[8]
Incremental Cost ($/unit)	Varies by measure,[2] see Exterior LED Lamp Incremental Cost table

Measure Description

ENERGY STAR-listed LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent and CFLs. This measure provides an energy-efficient alternative to using incandescents and CFLs in several applications.

Description of Baseline Condition

The baseline condition is a weighted average by number of incandescent lamps and CFLs installed in 2016.[3,4] EISA compliant 72-watt, 53-watt, 43-watt, 29-watt, and 25-watt incandescent lamps and 23.6-watt, 19-watt, 13.4-watt, 9.7-watt, and 7-watt CFLs were used in this calculation with respect to lumens.

Baseline Lamp Type and Sector SplitLumens	Perentage of Incandescent Lamps vs. CFLs[3,4]			
	Business Incand.	Business CFL	Residential Incand.	Residential CFL
All Categories	90.8%	9.2%	89.3%	10.7%

Description of Efficient Condition

The efficient condition is an ENERGY STAR-listed LED lamp in either the Omnidirectional or Decorative lamp category, with incandescent and CFL equivalency determined by the ENERGY STAR product specification for lamps v2.0.[5]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Average power consumption of incandescent lamps and CFLs (= varies by lumens and sector; see table below)

Power Consumption of Incandescent Lamps and CFLs (Watts)

Lumens	Business[6]	Residential[6]
1,600 – 1,999	67.5	66.8
1,100 – 1,599	49.9	49.4
800 – 1,099	40.3	39.8
450 – 799	27.2	26.9
250 – 449	23.3	23.1

$Watts_{EE}$ = Average power consumption of efficient LED lamp (= varies by lumens; see table below)

Power Consumption of Efficient LED Lamp (Watts)

Lumens	Omnidirectional Watts[6]	Decorative Watts[6]
1,600 – 1,999	15.41	15.41
1,100 – 1,599	11.61	14.00
800 – 1,099	9.06	8.11
450 – 799	5.53	5.57
250 – 449	3.75	4.09

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 4,380)[7]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= 0)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years for omnidirectional, = 4 years for decorative)[1]

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing Incandescent or CFL

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov.	Multifamily
		kWh	kWh	kWh	kWh	kWh
Omnidirectional						
1,600 – 1,999 Lumens	5221	228	228	228	228	225
1,100 – 1,599 Lumens	5222	168	168	168	168	165
800 – 1,099 Lumens	5223	137	137	137	137	135
450 – 799 Lumens	5224	95	95	95	95	94
250 – 449 Lumens	5225	86	86	86	86	85
Decorative						
1,600 – 1,999 Lumens	5226	228	228	228	228	225
1,100 – 1,599 Lumens	5227	157	157	157	157	155
800 – 1,099 Lumens	5228	141	141	141	141	139
450 – 799 Lumens	5229	95	95	95	95	94
250 – 449 Lumens	5230	84	84	84	84	83

Average Lifecycle Deemed Savings for LED Lamp Replacing Incandescent or CFL

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov.	Multifamily
		kWh	kWh	kWh	kWh	kWh
Omnidirectional						
1,600 – 1,999 Lumens	5221	1,140	1,140	1,140	1,140	1,125
1,100 – 1,599 Lumens	5222	840	840	840	840	825
800 – 1,099 Lumens	5223	685	685	685	685	675
450 – 799 Lumens	5224	475	475	475	475	470
250 – 449 Lumens	5225	430	430	430	430	425
Decorative						
1,600 – 1,999 Lumens	5226	912	912	912	912	900
1,100 – 1,599 Lumens	5227	628	628	628	628	620
800 – 1,099 Lumens	5228	564	564	564	564	556
450 – 799 Lumens	5229	380	380	380	380	376
250 – 449 Lumens	5230	336	336	336	336	332

Assumptions

Currently don't have historical project cost data broken out by omnidirectional vs decorative. Therefore will use same incremental cost for both, then will revisit in 2022 when have separate historical cost data.

Exterior LED Lamp Incremental Costs

Measure	Omnidirectional MMID	Decorative MMID	Incremental Cost
1,600 – 1,999 Lumens	5221	5226	$36.48
1,100 – 1,599 Lumens	5222	5227	$26.05
800 – 1,099 Lumens	5223	5228	$11.43
450 – 799 Lumens	5224	5229	$19.70
250 – 449 Lumens	5225	5230	$6.72

Sources

1. Apex Analytics and Cadmus. Analysis of combining data from the Consortium for Retail Energy Efficiency Data with LED market projections to produce effective program lifetimes of screw-base LED bulbs. See workpapers W0228 and W0229. The market data and projections used to derive screw-in lighting EULs do not discriminate between commercial and residential sales, and therefore are applied here as well.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 328 projects and 7,276 units from January 2018 to July 2020 across Ag, AgSG, LEU, BIP, MF, S&G, SBP, and B&I programs shows average efficient costs of $38.41 for MMID 3947, $27.43 for MMID 3948, $12.97 for MMID 3949, $21.02 for MMID 3950, and $8.31 for MMID 3951. Baseline costs obtained from weighted average of Wisconsin halogen (97.5%) and CFL (2.5%) cost data from Consortium of Retail Energy Efficiency Data (CREED) 2019, which showed an average cost of $1.93 for MMID 3947, $1.38 for MMID 3948, $1.54 for MMID 3949, $1.32 for MMID 3950, and $1.59 for MMID 3951.
3. Historical Focus on Energy project data for Business Incentive and Chain Stores and Franchise programs. January 1, 2016 through October 24, 2016.
   Analyzed actual units installed for 2,294 projects, consisting of MMIDs 3112, 3113, 3742, and 3745. Determined percentage of lighting technology by total units installed as 2.5% CFL and 97.5% incandescent.
4. Historical Focus on Energy project data for Multifamily Energy Savings Program. January 1, 2016 through November 3, 2016.
   225 projects, consisting of MMIDs 3160, 3162, 3743, and 3746. Analyzed actual units installed and determined percentage of lighting technology by total units installed as 4.24% CFL and 95.76% incandescent.
5. ENERGY STAR. “ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria Version 2.0.” https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Lamps%20V2%20Revised%20Spec.pdf

6. ENERGY STAR Qualified Product List. Accessed October 29 2021. https://www.energystar.gov/productfinder/ No ENERGY STAR qualified lamps in the 1,600-1,999 lumen decorative category, so used 15.41 watts from 1,600-1,999 lumen omnidirectional category.
7. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. “NOAA Solar Calculator.” http://www.esrl.noaa.gov/gmd/grad/solcalc/
8. ENERGY STAR Qualified Product List. Accessed October 2021. https://www.energystar.gov/productfinder. Average rated life of 2,010 decorative bulbs, excluding CFLs and in the Focus lumen range, is 16,486 hours. With an HOU of 4,380, the EUL is 4 years.

Revision History

Version Number	Date	Description of Change
01	11/15/2016	Initial TRM entry
02	10/2017	Updated EUL
03	2/2020	Updated incremental costs
04	1/2021	Update incremental cost
05	10/2021	Split omnidirectional and decorative into separate measures, update EULs, update Watts_{EE}.

ENERGY STAR LED Replacing Interior Directional CFL

	Measure Details
Measure Master ID	LED Lamp, ENERGY STAR, Replacing Interior Directional CFL: ≥ 23 Watt CFL, 3932 14–22 Watt CFL, 3933 ≤ 13 Watt CFL, 3934
Workpaper ID	W0106
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	business sectors and multifamily common areas = 4 (MMIDs 3932, 3933, and 3934)[1]
Incremental Cost ($/unit)	≥ 23 watt CFL = $10.14 (MMID 3932) 14–22 watt CFL = $5.93 (MMID 3933) ≤ 13 watt CFL = $1.93 (MMID 3934)[2]

Measure Description

ENERGY STAR-listed LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with compact fluorescent lamps (CFLs). This measure will provide an energy-efficient alternative to using CFL lamps in several applications.

Description of Baseline Condition

The baseline condition is ENERGY STAR-listed directional CFLs and their incandescent equivalencies based on certified products dated September 19, 2016.

Description of Efficient Condition

The efficient condition is an ENERGY STAR-listed LED lamp in the Directional lamp category, with incandescent and CFL equivalency determined by ENERGY STAR's product specification for lamps v2.0.[3]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Power consumption of CFLs (= varies by wattage equivalence; see table below)

Power Consumption of CFL Directional by Wattage Equivalence

Wattage Equivalence	Average Power Consumption of CFL Directional[1]
≥ 23 Watt CFL	23 Watts
14 Watt – 22 Watt CFL	15.6 Watts
≤ 13 Watt CFL	11 Watts

$Watts_{EE}$ = Power consumption of efficient LED lamp (= varies by wattage equivalence; see table below)

Power Consumption of LED Directional by Wattage Equivalence

Wattage Equivalence	Average Power Consumption of LED Directional Lamp[1]
≥ 23 Watt CFL	13.8 Watts
14 Watt – 22 Watt CFL	10.1 Watts
≤ 13 Watt CFL	6.9 Watts

HOU = Average annual hours of use (= varies by sector; see table below)

Annual Hours of Use by Sector

Sector	HOU
Commercial[5]	3,730
Industrial[5]	4,745
Agriculture[5]	4,698
Schools & Government[5]	3,239
Multifamily – Common Area[6]	5,950

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[5]	0.77
Industrial[5]	0.77
Agriculture[5]	0.67
Schools & Government[5]	0.64
Multifamily[7]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 4 years for business sectors and multifamily common area[1])

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing CFL

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
≥ 23 Watt CFL	3932	34	0.0071	44	0.0071	43	0.0062	30	0.0059
14 Watt – 22 Watt CFL	3933	21	0.0042	26	0.0042	26	0.0037	18	0.0035
≤ 13 Watt CFL	3934	15	0.0032	19	0.0032	19	0.0027	13	0.0026

Average Annual Deemed Savings for LED Lamp Replacing CFL - Multifamily

Measure	MMID	Multifamily – Common Area	
		kWh	kW
≥ 23 Watt CFL	3932	55	0.0071
14 Watt – 22 Watt CFL	3933	33	0.0042
≤ 13 Watt CFL	3934	24	0.0032

Average Lifecycle Deemed Savings for LED Lamp Replacing CFL

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily – Common Area
		kWh	kWh	kWh	kWh	kWh
≥ 23 Watt CFL	3932	204	264	258	180	330
14 Watt – 22 Watt CFL	3933	126	156	156	108	198
≤ 13 Watt CFL	3934	90	114	114	78	144

Assumptions

LED equivalent wattages are an average of ENERGY STAR-listed products. ENERGY STAR provides equivalent wattages for LEDs and CFLs based on incandescent lamps. For these calculations, ENERGY STAR-listed CFLs in the directional lamp category were accessed by their reported incandescent equivalents, then those incandescent equivalents were converted to reported LED equivalents, averaging within each specified CFL range.

Sources

1. Apex Analytics and Cadmus. Analysis of combining data from the Consortium for Retail Energy Efficiency Data with LED market projections to produce effective program lifetimes of screw-base LED bulbs. See workpapers W0228 and W0229. The market data and projections used to derive screw-in lighting EULs do not discriminate between commercial and residential sales, and therefore are applied here as well.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 87 projects and 3,160 units from February 2018 to July 2020 across Ag, AgSG, LEU, BIP, MF, S&G, SBP, and B&I programs showed efficient costs of $15.92 for MMID 3932, $10.82 for MMID 3933, and $6.88 for MMID 3934. Baseline costs obtained from January 2021 online lookups performed across www.ilighting.com, www.lightingsupply.com, www.topbulb.com, and www.1000bulbs.com showed an average baseline CFL cost of $5.78 for MMID 3932, $4.89 for MMID 3933, and $4.95 for MMID 3934.
3. ENERGY STAR. "ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria Version 2.0." https://www.energystar.gov/sites/default/files/Lamps%20Version%202.0%20Updated%20Spec.pdf
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. Table 3.2 Lighting Hours of Use in Commercial Applications. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. ACES Deemed Savings Desk Review. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluation

report.pdf
Table 1 lists 16.3 hours per day for multifamily common areas.

6. Cadmus. "Focus on Energy Evaluated Deemed Savings Changes." November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
2.01 hours per day for multifamily housing.
Coincidence factor of 5.5% found for multifamily housing.
7. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	11/10/2016	Initial TRM entry
02	04/2017	Added MMIDs 4078, 4079, and 4080
03	10/2017	Updated EUL Source
04	01/2019	Removed MMIDs 4078, 4079, and 4080
05	1/2021	Update incremental cost, remove multifamily in-unit measures

ENERGY STAR LED Replacing Interior Directional Incandescent

	Measure Details
Measure Master ID	LED Lamp, ENERGY STAR, Replacing Interior Directional Incandescent: 120W – 250W Incandescent, 3941 100W – 119W Incandescent, 3942 75W – 99W Incandescent, 3943 55W – 74W Incandescent, 3944 36W – 54W Incandescent, 3945 ≤ 35W Incandescent, 3946 BR30, Pack-Based, 4685
Workpaper ID	W0107
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Business sectors and multifamily common area = 6 (MMIDs 3941, 3942, 3943, 3944, 3945, and 3946)[1]
Incremental Cost ($/unit)	120W – 250W = $23.91 (MMID 3941); 100W – 119W = $7.52 (MMID 3942); 75W – 99W = $6.02 (MMID 3493); 55W – 74W = $3.01 (MMID 3944); 36W – 54W = $9.58 (MMID 3945); ≤ 35W = $6.19 (MMID 3496);[2] Pack-based = $4.15 (MMID 4685)[8]

Measure Description

ENERGY STAR-listed LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent lamps. This measure will provide an energy-efficient alternative to using incandescent lamps in several applications.

Description of Baseline Condition

The baseline condition is ENERGY STAR-listed incandescent equivalencies based on certified LED products dated September 19, 2016. Weighted averages were taken based on the number of equivalent products certified in each wattage bin to reflect the range of products available in the market. Full incandescent wattages are used based on reflector/directional lamps being exempt from EISA legislation.[3]

Description of Efficient Condition

The efficient condition is an ENERGY STAR-listed LED lamp in the Directional lamp category, with incandescent equivalency determined by ENERGY STAR's product specification for lamps v2.0.[4] Weighted averages were taken based on the number of LED products certified in each wattage bin to reflect the range of products available in the market.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU * ISR / 1,000$

Where:

$Watts_{BASE}$ = Power consumption of incandescent lamps (= varies for prescriptive measures, see table below; = 49.2 watts for MMID 4685)

Baseline Wattage by Wattage Equivalence

Wattage Equivalence	Weighted Average Power Consumption of Incandescent Directional[1]
120 Watts – 250 Watts	132.2 Watts
100 Watts – 119 Watts	100.2 Watts
75 Watts – 99 Watts	78.6 Watts
55 Watts – 74 Watts	63.9 Watts
36 Watts – 54 Watts	49.2 Watts
≤ 35 Watts	32.5 Watts

$Watts_{EE}$ = Power consumption of efficient LED lamp (= varies for prescriptive measures, see table below; = 8 watts for MMID 4685[9])

Efficient Wattage by Wattage Equivalence

Wattage Equivalence	Weighted Average Power Consumption of LED Lamp[1]
120 Watts – 250 Watts	18.3 Watts
100 Watts – 119 Watts	17.1 Watts
75 Watts – 99 Watts	13.8 Watts
55 Watts – 74 Watts	9.7 Watts
36 Watts – 54 Watts	7.6 Watts
≤ 35 Watts	6.5 Watts

HOU = Average annual hours of use (= varies by sector, see table below)

Hours of Use by Sector

Sector	HOU
Commercial[6]	3,730
Industrial[6]	4,745
Agriculture[6]	4,698
Schools & Government[6]	3,239
Multifamily[7]	5,950

ISR = In-service rate (= 1 for non-pack-based measures, = 0.83 for MMID 4685[10])

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1,000 * ISR$

Where:

CF = Coincidence factor (= varies by sector, see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[6]	0.77
Industrial[6]	0.77
Agriculture[6]	0.67
Schools & Government[6]	0.64
Multifamily[7]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 4 years for business sectors and multifamily common area[1])

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing Incandescent, Non-Res

Measure	MMIDs	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
120 – 250 Watts	3941	425	0.0877	540	0.0877	535	0.0763	369	0.0729
100 – 119 Watts	3942	310	0.0640	394	0.0640	390	0.0557	269	0.0532
75 – 99 Watts	3943	242	0.0499	308	0.0499	305	0.0434	210	0.0415
55 – 74 Watts	3944	202	0.0417	257	0.0417	254	0.0363	175	0.0347
36– 54 Watts	3945	155	0.0320	197	0.0320	195	0.0279	135	0.0266
≤ 35 Watts	3946	97	0.0201	124	0.0201	122	0.0174	84	0.0167
BR30, Pack-Based	4685	128	0.0263	162	0.0263	--	--	--	--

Average Annual Deemed Savings for LED Lamp Replacing Incandescent, Multifamily

Measure	MMID	Multifamily – Common Area	
		kWh	kW
120 Watts – 250 Watts	3941	677	0.0877
100 Watts – 119 Watts	3942	494	0.0640
75 Watts – 99 Watts	3943	386	0.0499
55 Watts – 74 Watts	3944	322	0.0417
36 Watts – 54 Watts	3945	247	0.0320
≤ 35 Watts	3946	155	0.0201
BR30, Pack-Based	4685	--	--

Average Lifecycle Deemed Savings for LED Lamp Replacing Incandescent (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily – Common Area
120 – 250 Watts	3941	1,700	2,160	2,140	1,476	2,708
100 – 119 Watts	3942	1,240	1,576	1,560	1,076	1,976
75 – 99 Watts	3943	968	1,232	1,220	840	1,544
55 – 74 Watts	3944	808	1,028	1,016	700	1,288
36 – 54 Watts	3945	620	788	780	540	988
≤ 35 Watts	3946	388	496	488	336	620
BR30, Pack-Based	4685	512	648	--	--	--

Sources

1. Apex Analytics and Cadmus. Analysis of combining data from the Consortium for Retail Energy Efficiency Data with LED market projections to produce effective program lifetimes of screw-

base LED bulbs. See workpapers W0228 and W0229. The market data and projections used to derive screw-in lighting EULs do not discriminate between commercial and residential sales, and therefore are applied here as well.

2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 766 projects and 27,125 units from January 2018 to July 2020 across Ag, AgSG, LEU, BIP, MF, S&G, SBP, and B&I programs shows average efficient costs of $32.74 for MMID 3941, $17.28 for MMID 3942, $11.73 for MMID 3943, $11.67 for MMID 3944, $12.48 for MMID 3945, and $11.48 for MMID 3946. Baseline cost obtained from January 2021 online lookups across www.1000bulbs.com, www.zoro.com, www.lightbulbandballastsupply.com, www.lightbulbs.com, www.bulbamerica.com, www.amazon.com, and www.homedepot.com showed average baseline incandescent costs of $8.83 for MMID 3941, $9.76 for MMID 3942, and $5.71 for MMID 3943. Wisconsin incandescent cost data from Consortium of Retail Energy Efficiency Data (CREED) 2019 showed an average cost of $8.66 for MMID 3944, $2.90 for MMID 3945, and $5.25 for MMID 3946.
3. Lighting Facts. "The Energy Independence and Security Act (EISA) of 2007." http://www.lightingfacts.com/Library/Content/EISA
4. ENERGY STAR. "ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria Version 2.0." Last modified February 2016. https://www.energystar.gov/sites/default/files/Lamps%20Version%202.0%20Updated%20Spec.pdf
5. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. Table 3.2 Lighting Hours of Use in Commercial Applications. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Tetra Tech. ACES Deemed Savings Desk Review. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Table 1 lists 16.3 hours per day for multifamily common areas.
7. Cadmus. "Focus on Energy Evaluated Deemed Savings Changes." November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
   2.01 hours per day for multifamily housing.
   Coincidence factor of 5.5% found for multifamily housing.
8. AM Conservation Group. Price quote for Focus on Energy program. March 2018.
9. AM Conservation. Website. Accessed March 19, 2018. http://www.amconservationgroup.com/products/energy-efficient-lighting/led-br30d-lamp/?variation_id=10231

Lamp to be used is same model, but 4,000 K color temperature instead of 2,700 K as shown on specification sheet.

10. Navigant. *ComEd Rural Small Business Energy Efficiency Kits IPA Program Impact Evaluation Report*. August 1, 2018. Table 7-1. http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_PY9_Rural_SB_EE_Kits_IPA_Program_Impact_Evaluation_Report_2018-08-01.pdf Average of ISR values for office (0.75), restaurant (0.86), and retail (0.87) sites used.

Revision History

Version Number	Date	Description of Change
01	11/08/2016	Initial TRM entry
02	04/2017	Added MMIDs 4082–4086
03	10/2017	Updated EUL
04	3/19/2018	Added MMID 4685
05	12/2018	Updated costs, removed MMIDs 4081 – 4086, added MMID 4685
06	2/2020	Updated cost for MMIDs 3944 and 4030
07	1/2021	Update incremental cost, remove multifamily in-unit measures

ENERGY STAR LED Replacing Omnidirectional and Decorative Incandescent or CFL

	Measure Details
Measure Master ID	Omnidirectional LED Lamp, ENERGY STAR, Interior: 1,600 – 1,999 Lumens, 5211 1,100 – 1,599 Lumens, 5212 800 – 1,099 Lumens, 5213 450 – 799 Lumens, 5214 250 – 449 Lumens, 5215 Decorative LED Lamp, ENERGY STAR, Interior: 1,600 – 1,999 Lumens, 5216 1,100 – 1,599 Lumens, 5217 800 – 1,099 Lumens, 5218 450 – 799 Lumens, 5219 250 – 449 Lumens, 5220
Workpaper ID	W0108
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Omnidirectional = 5[1]; Decorative = 4[9]
Measure Incremental Cost ($/unit)	Varies by measure,[2] see Interior LED Lamp Incremental Cost table

Measure Description

ENERGY STAR-listed LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescents and CFLs. This measure provides an energy-efficient alternative to using incandescents and CFLs in several applications.

Description of Baseline Condition

The baseline condition is a weighted average by number of incandescent lamps and CFLs installed for 2016 and 2017.[3] EISA-compliant 72-watt, 53-watt, 43-watt, 29-watt, and 25-watt incandescent lamps and 23.6-watt, 19-watt, 13.4-watt, 9.7-watt, and 7-watt CFLs were used in calculation with respect to lumens.

Baseline Lamp Type and Sector Split

Lumens	Perentage of Incandescent Lamps vs. CFLs[3]			
	Business Incand.	Business CFL	Residential Incand.	Residential CFL
All Categories	90.8%	9.2%	89.3%	10.7%

Description of Efficient Condition

The efficient condition is an ENERGY STAR-listed LED lamp in either the Omnidirectional or Decorative lamp category, with incandescent and CFL equivalency determined by ENERGY STAR's product specification for lamps v2.0.[4]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Power consumption of incandescent lamps and CFLs (= varies by number of lumens; see table below)

Baseline Wattage by Lumens

Lumens	Power Consumption of Incandescent Lamps and CFLs (watts)[5]	
	Business	Residential
1,600 – 1,999	67.5	66.8
1,100 – 1,599	49.9	49.4
800 – 1,099	40.3	39.8
450 – 799	27.2	26.9
250 – 449	23.3	23.1

$Watts_{EE}$ = Power consumption of efficient LED lamp (= varies by number of lumens; see table below)

Efficient Wattage by Lumens

Lumens	Omnidirectional		Decorative	
	MMID	Power Consumption of Efficient LED Lamp	MMID	Power Consumption of Efficient LED Lamp

1,600 – 1,999[5]	5211	15.41 watts	5216	15.41
1,100 – 1,599[5]	5212	11.61 watts	5217	14.00
800 – 1,099[5]	5213	9.06 watts	5218	8.11
450 – 799[5]	5214	5.53 watts	5219	5.57
250 – 449[5]	5215	3.75 watts	5220	4.09

HOU = Average annual hours of use (= varies by sector; see table below)

Hour of Use by Sector

Sector	HOU
Commercial[6]	3,730
Industrial[6]	4,745
Agriculture[6]	4,698
Schools & Government[6]	3,239
Multifamily[7]	5,950

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[6]	0.77
Industrial[6]	0.77
Agriculture[6]	0.67
Schools & Government[6]	0.64
Multifamily[8]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years for omnidirectional[1], = 4 years for decorative[1])

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing Incandescent or CFL, Non-Res

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
Omnidirectional									
1,600 – 1,999 Lumens	5211	194	0.040	247	0.040	245	0.035	169	0.033
1,100 – 1,599 Lumens	5212	143	0.030	182	0.030	180	0.026	124	0.025
800 – 1,099 Lumens	5213	116	0.024	148	0.024	147	0.021	101	0.020
450 – 799 Lumens	5214	81	0.017	103	0.017	102	0.015	70	0.014
250 – 449 Lumens	5215	73	0.015	93	0.015	92	0.013	63	0.013
Decorative									
1,600 – 1,999 Lumens	5216	194	0.040	247	0.040	245	0.035	169	0.033
1,100 – 1,599 Lumens	5217	134	0.028	170	0.028	169	0.024	116	0.023
800 – 1,099 Lumens	5218	120	0.025	153	0.025	151	0.022	104	0.021
450 – 799 Lumens	5219	81	0.017	103	0.017	102	0.015	70	0.014
250 – 449 Lumens	5220	72	0.015	91	0.015	90	0.013	62	0.012

Average Annual Deemed Savings for LED Lamp Replacing Incandescent or CFL, Multifamily

Measure	MMID	Multifamily Common Area	
		kWh	kW
Omnidirectional			
1,600 – 1,999 Lumens	5211	306	0.040
1,100 – 1,599 Lumens	5212	225	0.029
800 – 1,099 Lumens	5213	183	0.024
450 – 799 Lumens	5214	127	0.017
250 – 449 Lumens	5215	115	0.015
Decorative			
1,600 – 1,999 Lumens	5216	306	0.040
1,100 – 1,599 Lumens	5217	210	0.027
800 – 1,099 Lumens	5218	189	0.024
450 – 799 Lumens	5219	127	0.017
250 – 449 Lumens	5220	113	0.015

Average Lifecycle Deemed Savings for LED Lamp Replacing Incandescent or CFL (kWh)

Measure	MMID	Comm.	Indust.	Agricul.	Schools & Gov	Multifamily Common Area
Omnidirectional						
1,600 – 1,999 Lumens	5211	970	1,235	1,225	845	1,530
1,100 – 1,599 Lumens	5212	715	910	900	620	1,125
800 – 1,099 Lumens	5213	580	740	735	505	915
450 – 799 Lumens	5214	405	515	510	350	635
250 – 449 Lumens	5215	365	465	460	315	575
Decorative						
1,600 – 1,999 Lumens	5216	776	988	980	676	1,224

1,100 – 1,599 Lumens	5217	536	680	676	464	840
800 – 1,099 Lumens	5218	480	612	604	416	756
450 – 799 Lumens	5219	324	412	408	280	508
250 – 449 Lumens	5220	288	364	360	248	452

Assumptions

Currently don't have historical project cost data broken out by omnidirectional vs decorative. Therefore will use same incremental cost for both, then will revisit in 2022 when have separate historical cost data available.

Interior LED Lamp Incremental Costs

Measure	Omnidirectional MMID	Decorative MMID	Incremental Cost	
1,600 – 1,999 Lumens	5211	5216	$16.91	
1,100 – 1,599 Lumens	5212	5217	$8.66	
800 – 1,099 Lumens	5213	5218	$4.84	
450 – 799 Lumens	5214	5219	$3.73	
250 – 449 Lumens	5215	5220	$5.87	

Sources

1. Apex Analytics and Cadmus. Analysis of combining data from the Consortium for Retail Energy Efficiency Data with LED market projections to produce effective program lifetimes of screw-base LED bulbs. See workpapers W0228 and W0229. The market data and projections used to derive screw-in lighting EULs do not discriminate between commercial and residential sales, and therefore are applied here as well.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 1,734 projects and 75,624 units from January 2018 to July 2020 across Ag, AgSG, LEU, BIP, MF, S&G, SBP, and B&I programs shows average efficient costs of $13.21 for MMID 3952, $9.10 for MMID 3953, $7.16 for MMID 3954, $7.21 for MMID 3955, and $8.57 for MMID 3956. Baseline cost obtained from weighted average of Wisconsin halogen (97.5%) and CFL (2.5%) cost data from Consortium of Retail Energy Efficiency Data (CREED) 2019, which showed an average cost of $1.93 for MMID 3952, $1.38 for MMID 3953, $1.54 for MMID 3954, $1.32 for MMID 3955, and $1.59 for MMID 3956.

3. Wisconsin Focus on Energy. Historical Focus on Energy project data. SPECTRUM. January 1, 2016 to December 31, 2017.
   Business Incentive, Chain Stores and Franchise, Ag School and Government, and Large Energy User programs had 1,234 projects, consisting of MMIDs 3112, 3113, 3742, and 3745. Data analysis of actual units installed revealed percentage of lighting technology by total units installed of 9.2% for CFLs and 90.8% for incandescents.
   Multifamily Energy Savings Program had 279 projects, consisting of MMIDs 3160, 3162, 3743, and 3746. Data analysis of actual units installed revealed percentage of lighting technology by total units installed of 10.7% for CFLs and 89.3% for incandescents.
4. ENERGY STAR. “ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) Eligibility Criteria Version 2.0.” Last modified February 2016. https://www.energystar.gov/sites/default/files/Lamps%20Version%202.0%20Updated%20Spec.pdf
5. ENERGY STAR Qualified Product List. Accessed October 29 2021.
   https://www.energystar.gov/productfinder/
   No ENERGY STAR qualified lamps in the 1,600-1,999 lumen decorative category, so used 15.41 watts from 1,600-1,999 lumen omnidirectional category.
6. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. Table 3-2 Lighting Hours of Use in Commercial Applications.
   https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010.
   https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Table 1 lists 16.3 hours per day for multifamily common areas.
8. PA Consulting Group. *Focus on Energy Evaluation, ACES: Default Deemed Savings Review Final Report*. June 24, 2008. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf
   Coincidence factor is within range of similar programs; see Table 4-1 showing multifamily housing CF of 65% to 83%.
9. ENERGY STAR Qualified Product List. Accessed October 2021.
   https://www.energystar.gov/productfinder. Average rated life of 2,010 decorative bulbs, excluding CFLs and in the Focus lumen range, is 16,486 hours. With an average HOU of 3,849, the EUL is 4 years.

Revision History

Version Number	Date	Description of Change
01	03/2017	Initial TRM entry
02	04/2017	Added MMIDs 4087–4091
03	10/2017	Updated EUL
04	03/2018	Added MMID 4686
05	02/2020	Updated costs
06	1/2021	Update incremental cost, remove multifamily in-unit measures
07	10/2021	Split omnidirectional and decorative into separate measures, update EULs, update Watts$_{EE}$, remove pack measure.

LED Downlights Replacing CFL Downlight

	Measure Details
Measure Master ID	LED Fixture, Downlights: ≤ 18 Watts, Replacing 1-Lamp Pin-Based CFL Downlight, 3394
Workpaper ID	W0110
Measure Unit	Per luminaire
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	≤ 18 watts = $4.880 (MMID 3394)[2]

Measure Description

LED downlights can be used to replace existing 1- and 2-lamp pin-based CFL downlights used for the same application without sacrificing performance. LED downlights save energy because they consume less wattage than the 1- and 2-lamp pin-based CFL downlights products they replace.

Description of Baseline Condition

Low Wattage Downlights

The baseline condition is pin-based CFL downlights containing 1-lamp of 26 watts, 32 watts, or 42 watts in existing buildings and new construction or any 1-lamp pin-based CFL downlight between 26 watts and 45 watts. An average of 33.3% each for 1-lamp 26-watt pin-based CFL downlights, 1-lamp 32-watt pin-based CFL downlights, and 1-lamp 42-watt pin-based CFL downlights was used to generate the baseline usage (see Assumptions).

High Wattage Downlights

The baseline condition is pin-based CFL downlights containing 2-lamps of 26 watts, 32 watts, or 42 watts each in existing buildings and new construction or any 2-lamp pin-based CFL downlight with 26 watts to 45 watts. An average of 33.3% each for 2-lamp 26-watt pin-based CFL downlights, 2-lamp 32-watt pin-based CFL downlights, and 2-lamp 42-watt pin-based CFL downlights was used to generate the baseline usage (see Assumptions).

Description of Efficient Condition

Low Wattage Downlights

The efficient condition is low-wattage downlights that are ENERGY STAR-rated and/or Wisconsin Focus on Energy QPL-listed LED downlights that consume ≤ 18 watts.

High Wattage Downlights

The efficient condition is high-wattage downlights that are ENERGY STAR-rated and/or Wisconsin Focus on Energy QPL-listed LED downlights that consume > 18 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{CFL} – Watts_{LEDEE}) / 1{,}000 * HOU$

Where:

$Watts_{CFL}$ = Wattage of 1-lamp or 2-lamp pin-based CFL downlights with 26-watt, 32-watt, or 42-watt lamps (= 37 as average for low wattage system; = 75 as average for high wattage systems)

$Watts_{LEDEE}$ = Average power consumption of ENERGY STAR-rated and/or Wisconsin Focus on Energy QPL-listed LED fixture (= 13 for systems ≤ 18 watts; = 32 for systems > 18 watts)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{CFL} - Watts_{LEDEE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor

Sector	CF
Commercial[6]	0.77
Industrial[6]	0.77
Agriculture[6]	0.67
Schools & Government[6]	0.64
Multifamily[7]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Downlights Replacing 1 Lamp or 2 Lamp Pin-Based CFL

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED downlights > 18 watts	3395	160	0.0330	203	0.0330	201	0.0287	139	0.0274	255	0.0330

Average Lifecycle Deemed Savings for LED Downlights Replacing 1 Lamp or 2 Lamp Pin-Based CFL (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED downlights > 18 watts	3395	1,760	2,233	2,211	1,529	2,805

Assumptions

Fixture lamp weightings are based on a combination of energy audit experience and feedback from Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions and individuals with lighting sales experience.

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 8,139 LED downlight fixtures is 46,550 hours. With a sector-averaged HOU of 4,472, the EUL is 10 years

2. August 2018 online lookups of 4 base and efficient models show an average efficient lamp price of $9.28 and base lamp price of $4.40, for an incremental cost of $4.88.
3. ENERGY STAR product list. August 28, 2015. (Average measured wattage taken from listed products in the Downlight Recessed, Downlight Solid State Retrofit, and Downlight Surface Mount fixture types, filtered by wattage limits).
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Multifamily Applications for Common Areas (5,949.5 annual operating hours based on 16.3 hours/day * 365 days/year).
6. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Coincidence Factor for Lighting in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	04/01/2014	Initial TRM entry
02	08/28/2015	Updated savings information
03	10/2017	Updated EUL
04	12/2018	Updated incremental cost, removed MMID 3394

LED Downlight Fixtures > 18 Watts

	Measure Details
Measure Master ID	LED Fixture, Downlight, > 18 Watts, 3749, 3820
Workpaper ID	W0112
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost	$16.76[2]

Measure Description

LED downlight fixtures can replace existing incandescent fixtures without sacrificing performance, and save energy because they consume less wattage than the incandescent products they replace.

Description of Baseline Condition

Several wattage baselines are averaged together to produce a single baseline. An incandescent baseline of 72 watts is used due to EISA legislation stating that 72 is the maximum replacement wattage for a 100-watt general service incandescent lamp.[7] Systems with 50 watts to 100 watt HID lamps are also used.

Description of Efficient Condition

The efficient equipment is an ENERGY STAR-rated downlight fixture that consumes > 18 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Wattage of baseline incandescent fixtures; a weighted average of 25% 72-watt incandescent and 50-watt, 70-watt, and 100-watt HIDs was used to generate the baseline wattage; see Assumptions (= 88.8 watts)[8]

$Watts_{EE}$ = Wattage of efficient LED products (= 32 watts)[3]

HOU = Hours of use (= varies by sector; see table below)

1,000 = Kilowatt conversion factor

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[6]	0.77
Industrial[6]	0.77
Agriculture[6]	0.67
Schools & Government[6]	0.64
Multifamily[9]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Downlights > 18 Watts

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Downlights > 18 Watts Replacing 100 Watt Incandescent or 50 Watt o 100 Watt HID	3749, 3820	212	0.0438	270	0.0438	267	0.0381	184	0.0364	338	0.0438

Average Lifecycle Deemed Savings for LED Downlights > 18 Watts

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Downlights > 18 Watts Replacing 100 Watt Incandescent or 50 Watt o 100 Watt HID	3749, 3820	2,120	2,700	2,670	1,840	3,380

Assumptions

Fixture lamp weightings are based on a combination of energy audit experience and feedback from Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions and individuals with lighting sales experience. Incandescent and HID baselines are used because audit and market experience reveals that customers are likely to replace failed equipment with the same technology, as replacements are still available on the market with no changes to fixture performance.

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017.
   https://www.energystar.gov/productfinder/
   Average rated life of 8,139 LED downlight fixtures is 46,550 hours. With a sector-averaged HOU of 4,472, the EUL is 10 years.
2. August 2018 online lookups of four base and efficient models on www.1000bulbs.com, www.bulbs.com, and www.topbulb.com show an average efficient lamp price of $19.90 and base lamp price of $3.14, for an incremental cost of $16.76.
3. ENERGY STAR product list from October 13, 2015. Average measured wattage of Downlight Recessed, Downlight Solid State Retrofit and Downlight Surface Mount fixture types, filtered by wattage limits.

4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/ sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Multifamily Applications for Common Areas (5,949.5 annual operating hours based on 16.3 hours/day * 365 days/year).
6. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Coincidence Factor for Lighting in Commercial Applications. March 22, 2010. https:// focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. The Energy Independence and Securities Act (EISA) of 2007 Lighting Facts Summary: http://www.lightingfacts.com/Library/Content/EISA
8. *Focus on Energy Default Wattage Guide.* HID wattages based on metal halide technologies.
9. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	10/13/2015	Initial TRM entry
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost

LED Exterior Fixture, Lumen Based

	Measure Details
Measure Master ID	LED, Exterior Fixture: Low Output, ≤4,999 lumens, 4280 Mid Output, 5,000–9,999 lumens, 4281 High Output, 10,000–29,999 lumens, 4282 Very High Output, ≥30,000 lumens, 4283
Workpaper ID	W0113
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	Low Output, ≤4,999 lumens = $171.31 (MMID 4280)[2] Mid Output, 5,000–9,999 lumens = $236.01 (MMID 4281)[3] High Output, 10,000–29,999 lumens = $339.00 (MMID 4282)[4] Very High Output, ≥30,000 lumens = $761.41 (MMID 4283)[5]

Measure Description

Exterior LED fixtures are an energy-saving alternative to traditional standard wattage high intensity discharge (HID) light sources that have been used for the same applications. LED light sources can be applied in almost every common application type where HID light sources are currently used. These measures are for replacing existing HID fixtures and new construction applications.

Description of Baseline Condition

The baseline condition is any existing, exterior-mounted HID area luminaire, excluding stairwell passageway luminaires, up to 1,000 watts.

Description of Efficient Condition

The efficient condition is a complete DesignLights Consortium™ (DLC)-listed LED luminaire in the “Outdoor” General Application category, excluding stairwell and passageway luminaires.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Power consumption of baseline measure (= varies by lumen output, see table below and Assumptions)

$Watts_{EE}$ = Power consumption of efficient LED luminaire (= varies by lumen output, see table below)

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 4,380)[6]

Wattages Used for Deemed Savings Calculations

Measure	MMID	$Watts_{BASE}$	$Watts_{EE}$[7]
Low Output ≤4,999 lumens	4280	116	31
Mid Output 5,000–9,999 lumens	4281	227	63
High Output 10,000–29,999 lumens	4282	546	134
Very High Output ≥30,000 lumens	4283	1,079	315

Annual Deemed Savings

Measure	MMID	Commercial, Industrial, Agriculture, Schools & Gov, Multifamily	
		kWh	kW
Low Output ≤4,999 lumens	4280	372	N/A
Mid Output 5,000–9,999 lumens	4281	718	N/A
High Output 10,000–29,999 lumens	4282	1,805	N/A
Very High Output ≥30,000 lumens	4283	3,346	N/A

Summer Coincident Peak Savings Algorithm

There are no peak savings for these measures.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years)[1]

Deemed Lifecycle Savings

Measure	MMID	Commercial, Industrial, Agriculture, Schools & Gov, Multifamily (kWh)
Low Output ≤4,999 lumens	4280	4,836
Mid Output 5,000–9,999 lumens	4281	9,334
High Output 10,000–29,999 lumens	4282	23,465
Very High Output ≥30,000 lumens	4283	43,498

Assumptions

Incremental costs are the average costs through internet research of typical baseline HID equipment inside lumen bins. Baseline equipment was then compared against average costs of DLC participating equipment through prescriptive program product code tracking in those respective lumen bins.

Baseline system wattages were averaged by common metal halide lamps in respective lumen bin categories taken from the Focus on Energy *Default Wattage Guide*.[8] Low output included 50 watt, 70 watt, 100 watt, and 150 watt; mid output included 150 watt,175 watt, and 250 watt; high output included 250 watt, 320 watt (pulse start metal halide),400 watt, and 1,000 watt; and high output was 1,000 watts.

Sources

1. DesignLights Consortium. *Qualified Product List*. Accessed August 2020. https://www.designlights.org/search
   Average rated life of models in the DLC "Outdoor" category is 57,756 hours. With an average HOU of 4,472, the EUL is 13 years.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 2,633 projects and 18,865 units from February 2018 to July 2020 is $187.73. Base cost of $16.42 from October 2019 online lookups of base models, 50 - 150 watt metal halide bulbs. $187.73 - $16.42 = $171.31.

3. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 2,742 projects and 24,905 units from February 2018 to July 2020 is $252.37. Base cost of $16.36 from October 2019 online lookups of base models, 150 - 250 watt metal halide bulbs. $252.37 - $16.36 = $236.01.
4. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 3,888 projects and 37,504 units from February 2018 to July 2020 is $361.65. Base cost of $22.65 from October 2019 online lookups of base models, 250 - 1000 watt metal halide bulbs. $361.65 - $22.65 = $339.00.
5. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 602 projects and 8,372 units from March 2018 to July 2020 is $786.56. Base cost of $25.14 from October 2019 online lookups of base models, 1000 watt metal halide bulbs. $786.56 - $25.14 = $761.41.
6. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
7. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. Data cross-referenced with DLC QPL determining weighted average wattage.
8. Wisconsin Focus on Energy. Default Wattage Guide. Version 1.0. 2013.

Revision History

Version No.	Date	Description of Change
01	09/20/2017	Initial TRM entry s
02	2/2020	Updated incremental costs
03	9/2020	Removed MMIDs 4441, 4442, 4443, and 4444. Updated Watts$_{EE}$. Reorganized sources.

LED Fixture Downlights

	Measure Details
Measure Master ID	LED Fixture, Downlights, Interior, 4354 LED Fixture, Downlights, In Unit, 4355 LED Fixture, Downlights, Exterior, 4356
Workpaper ID	W0114
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$1.55 per watt reduced for MMID 4354[2] $1.29 per watt reduced for MMID 4356;[9] $0.85 per watt reduced for MMID 4475;[10] $0.88 per watt reduced for MMID 4476[11] $1.10 per watt reduced for MMID 4355[12]

Measure Description

These LED upgrade measures are the replacement of incumbent light sources used in downlights with energy-efficient LED luminaires or retrofit kits, in both new construction and retrofit scenarios.

Description of Baseline Condition

The baseline equipment is any downlight with an incumbent lighting technology source. For new construction applications, the baseline wattage will be determined by multiplying the proposed LED wattage by 2.5 (see the Assumptions section).[3]

Description of Efficient Condition

The efficient condition is any complete LED luminaire or retrofit kit used to upgrade existing equipment on a one-for-one basis. LED products must be on the ENERGY STAR qualified product list to be eligible.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

$= Watts_{REDUCED} * HOU / 1,000$

Where:

$Watts_{BASE}$ = Power consumption (per fixture) of current installed lighting equipment

$Watts_{EE}$ = Power consumption (per fixture) of efficient LED equipment

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

$Watts_{REDUCED}$ = Watt reduction

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily – Common Area[5]	5,950
Multifamily – In Unit[6]	734
Exterior[7]	4,380

Summer Coincident Peak Savings Algorithm

$kW_{SAVED}= (Watts_{BASE} - Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily – Common Area[8]	0.77
Multifamily – In Unit[6]	0.055
Exterior	0.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Annual Energy Savings (kWh per watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Downlights Interior	4354	3.73	4.75	4.7	3.24	5.95
LED Downlights, In Unit	4355	N/A	N/A	N/A	N/A	0.73
LED Downlights Exterior	4356	4.38	4.38	4.38	4.38	4.38

Annual Demand Reduction (kW per watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Downlights Interior	4354	0.0008	0.0008	0.0007	0.0006	0.0008
LED Downlights, In Unit	4355	N/A	N/A	N/A	N/A	0.0001
LED Downlights Exterior	4356	0.0000	0.0000	0.0000	0.0000	0.0000

Lifecycle Savings (kWh per watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Downlights Interior	4354	37.3	47.5	47.0	32.4	59.5
LED Downlights, In Unit	4355	N/A	N/A	N/A	N/A	7
LED Downlights Exterior	4356	43.8	43.8	43.8	43.8	43.8

Assumptions

The incremental cost on a per-watt basis was calculated using the following:

Cost in \$/W = [Actual Measure Cost Sum] / [First Year kWh Savings
* 1,000 / Average Sector Hours (4,472)]

For new construction scenarios, a photometric and input wattage analysis was performed comparing CFL upgrade options under MMIDs 3394 and 3395 ranging from one-lamp, 26-watt CFLs to two-lamp, 42 watt CFLs. Lumen outputs and input wattages were pulled from IES files and compared against ENERGY STAR-listed downlights. The average CFL to LED wattage ratio was 2.5, as shown in the table below.

LED Versus CFL Wattages

CFL Model	Rated Lamp Lumens	CFL Wattage	IES File Lumen Output	Selected Lumen Range	Average ENERGY STAR LED Wattage in Lumen Range	CFL vs LED Wattage Ratio
Lithonia						
6VF 1/26TRT 6O9AZ	1,800	29	953	≤ 955	10.9	2.66
6VF 1/32TRT 6O9AZ	2,400	36	1,285	956–1,290	15.1	2.38
6VF 1/42TRT 6O9AZ	3,200	48	1,601	1,291–1,605	20.8	2.31
6HF 2/26DTT F6O2AZ	1,800	62	1,753	1,606–1,755	23	2.7
Gotham						
AF 2/32TRT 10AR	2,400	69	2,975	1,756–2,980	31.5	2.19
AF 2/42TRT 8AR	3,200	93	4,010	2,981–4,015	44.5	2.09
Average						**2.5**

Sources

1. ENERGY STAR. *Qualified Product List*. Accessed November 2017. https://www.energystar.gov/productfinder/
   Average rated life of 8,402 LED downlight fixtures is 46,324 hours. With a sector-averaged HOU of 4,472, the EUL is 10 years.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 861 projects and 1,343,026 units from January 2020 to July 2021 is $1.60. Base cost of $0.05 from August 2018 online lookups of base models. $1.60 - $0.05 = $1.55.
3. ENERGY STAR. *Qualified Product List*. Accessed November 2017. https://www.energystar.gov/productfinder/
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use and Coincidence Factors by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

   Multifamily Applications for Common Areas (5,949.5 annual operating hours based on 16.3 hours/day * 365 days/year).
6. Cadmus. “Focus on Energy Evaluated Deemed Savings Changes.” November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
   Report lists 2.01 hours per day for multifamily housing.
   Report lists coincidence factor of 5.5% for multifamily housing.
7. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. *NOAA Solar Calculator*. http://www.esrl.noaa.gov/gmd/grad/solcalc/

This also includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.

8. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.
9. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 11,460 watts reduced over 12 projects from 2016 to 2018 is $1.34. August 2018 online lookups of 12 baseline lamps on www.1000bulbs.com, www.topbulb.com, www.lowes.com, and www.homedepot.com show a baseline cost of $0.05 per watt for a halogen replacement bulb. The incremental cost is therefore $1.29.
10. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 2,701 watts reduced over two projects from 2016 to 2018 is $0.90. August 2018 online lookups of 12 baseline lamps on www.1000bulbs.com, www.topbulb.com, www.lowes.com, and www.homedepot.com show a baseline cost of $0.05 per watt for a halogen replacement bulb. The incremental cost is therefore $0.85.
11. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 390 watts reduced over one project from 2016 to 2018 is $0.93. August 2018 online lookups of 12 baseline lamps on www.1000bulbs.com, www.topbulb.com, www.lowes.com, and www.homedepot.com show a baseline cost of $0.05 per watt for a halogen replacement bulb. The incremental cost is therefore $0.88.
12. Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 30,140 watts reduced over 17 projects from 2016 to 2018 is $1.15. August 2018 online lookups of 12 baseline lamps on www.1000bulbs.com, www.topbulb.com, www.lowes.com, and www.homedepot.com show a baseline cost of $0.05 per watt for a halogen replacement bulb. The incremental cost is therefore $1.10.

Revision History

Version Number	Date	Description of Change
01	11/08/2017	Initial TRM entry
02	12/2018	Updated incremental cost
03	2/2020	Updated incremental cost
04	1/2022	Updated incremental cost

LED Fixtures, High Bay

	Measure Details
Measure Master ID	LED Fixture, High Bay: < 155 Watts, Replacing 250 Watt HID, 3091, 4695 < 250 Watts, Replacing 320–400 Watt HID, 3092, 4696 < 250 Watts, Replacing 400 Watt HID, 3093, 4697 < 365 Watts, Replacing 400 Watt HID, 3094, 4698 < 500 Watts, Replacing 1,000 Watt HID, 3095, 4699 < 800 Watts, Replacing 1,000 Watt HID, 3096, 4700
Workpaper ID	W0115
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by wattage and sector
Peak Demand Reduction (kW)	Varies by wattage and sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure and sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	< 155 Watts = $214.89 (MMIDs 3091, 4695)[2] < 250 Watts and < 365 Watts = $254.08 (MMIDs 3092, 3093, 3094, 4696, 4697, 4698)[3] < 500 Watts and < 800 Watts = 522.59 (MMIDs 3095 3096, 4699, 4700)[10]

Measure Description

High-bay LED fixtures are an energy-saving alternative to traditional standard wattage HID light sources used for the same applications. LED light sources can be used in almost every common type of application where HID light sources are currently found.

LED options have become popular for dairy facilities' upgrades to long daylighting (LDL), a process used to help increase cows' milk production by simulating longer days and therefore increasing the animal food intake and milk production. LDL requires a minimum of 15 foot-candles of photopic light being present at cow eye level for 16 to 18 hours each day.[4] Agriculture measures under MMIDs 4695, 4696, and 4698 assume LDL operations for a percentage of the applications[5], while other measures assume the general hours of use for the agriculture sector.

Description of Baseline Condition

The baseline is standard HID lamps that range from 250 watts to 1,000 watts.

Description of Efficient Condition

To meet program requirements, the LED replacements must be complete fixtures that are DesignLights Consortium™ listed. Lamp-only replacements are not eligible for incentive.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Baseline consumption of standard HID fixture (= varies by sector; see table below)

$Watts_{EE}$ = Efficient consumption of LED fixture (= varies by sector; see table below)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Baseline and Efficient Lamp Consumption

Measure	$Watts_{BASE}$[6]	$Watts_{EE}$[7]
LED Fixture, High Bay, < 155 Watts Replacing 250-Watt HID	293	122
LED Fixture, High Bay, < 250 Watts Replacing 400-Watt HID	356	166
LED Fixture, High Bay, < 250 Watts Replacing 320-Watt to 400-Watt HID	455	155
LED Fixture, High Bay, < 365 Watts Replacing 400-Watt HID	455	268
LED Fixture, High Bay, < 800 Watts Replacing 1,000-Watt HID	1,079	304
LED Fixture, High Bay, < 500 Watts Replacing 1,000-Watt HID	1,079	263

Hours of Use by Sector

Sector	HOU
Commercial[8]	3,730
Industrial[8]	4,745
Agriculture[5]	5,698 (MMID 4695) 6,093 (MMID 4696) 4,698 (MMIDs 4697, 4699, and 4700) 6,182 (MMID 4698) (see Assumptions)
Schools & Government[8]	3,239

Summary Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[8]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Deemed Savings

Average Deemed Savings for High Bay LED Fixtures

Measure	Sectors	MMID	Annual kWh	kW	Lifecycle kWh
LED Fixture, High Bay:					
< 155 Watts, Replacing 250 Watt HID	Commercial	3091	638	0.1317	12,760
	Industrial		811	0.1317	16,220
	Schools & Government		554	0.1094	11,080
	Agriculture	4695	974	0.1146	19,480
< 250 Watts, Replacing 320–400 Watt HID	Commercial	3092	709	0.1463	14,180
	Industrial		902	0.1463	18,040
	Schools & Government		615	0.1216	12,300
	Agriculture	4696	1,158	0.1273	23,160
< 250 Watts, Replacing 400 Watt HID	Commercial	3093	1,119	0.2310	22,380
	Industrial		1,424	0.2310	28,480
	Schools & Government		972	0.1920	19,440
	Agriculture	4697	1,409	0.2010	28,180
< 365 Watts, Replacing 400 Watt HID	Commercial	3094	698	0.1440	13,960
	Industrial		887	0.1440	17,740
	Schools & Government		606	0.1197	12,120
	Agriculture	4698	1,156	0.1253	23,120
	Commercial	3095	2,891	0.5968	57,820

Measure	Sectors	MMID	Annual kWh	kW	Lifecycle kWh
LED Fixture, High Bay:					
< 500 Watts, Replacing 1,000 Watt HID	Industrial		3,677	0.5968	73,540
	Schools & Government		2,510	0.4960	50,200
	Agriculture	4699	3,641	0.5193	72,820
< 800 Watts, Replacing 1,000 Watt HID	Commercial	3096	3,044	0.6283	60,880
	Industrial		3,872	0.6283	77,440
	Schools & Government		2,643	0.5222	52,860
	Agriculture	4700	3,834	0.5467	76,680

Deemed Savings

Historical data for agriculture measures was examined to produce fractions of standard and long daylighting applications. Agricultural HOU is a weighted average from this analysis, per the Agriculture HOU Table.

Agriculture HOU

New MMID	Standard			Long Daylighting			New HOU
	Old MMIDs	Old % of Units	Old HOU	Old MMIDs	Old % of Units	Old HOU	
4695	3806, 3091	34%	4,698	3019	66%	6,205	5,688
4696	3810, 3092	7%		3020	93%		6,093
4698	3808, 3094	2%		3021	98%		6,182

Assumptions

In discussions with the DesignLights Consortium™, it was determined that the rated lifetime hours reported in the DLC *Qualified Product List*[9] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer spec sheets often do list actual L70 test data, so these data were used to obtain a weighted average rated lifetime for participating models.[1]

Sources

1. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. 21 participating models comprising 7,477 units and >50% of total measure participation, have a weighted average spec sheet rated life of 94,359 hours. With an average HOU of 4,265, the EUL is 22 years. Lighting EULs are capped at 20 years.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 672 projects and 18,470 units from January 2018 to July 2020 is $232.87. Base cost of

$17.98 from October 2019 online lookups of base models, 250 watt metal halide bulbs. $232.87 - $17.98 = $214.89.

3. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 2,315 projects and 56,873 units from January 2018 to July 2020 is $278.42. Base cost of $24.34 from November 2020 lookups of 320 - 400 watt metal halide bulbs. $278.42 - $24.34 = $254.08.
4. University of Wisconsin Madison, Healthy Farmers, Healthy Profits Project. "Work Efficiency Tip Sheet: Long-Day Lighting in Dairy Barns." Second Edition. August 2000. https://fyi.uwex.edu/energy/files/2016/05/lighting4web.pdf
5. Wisconsin Focus on Energy. "LED Fixtures High Bay Agriculture LDL Supplemental Data." Excel workbook.
   Adjustment calculation tab shows historical data from 259 projects from July 2013 to September 2016, which were used to weight savings for Agricultural LDL and non-LDL high-bay applications.
6. Wisconsin Focus on Energy. *Focus on Energy Default Wattage Guide 2013*. Version 1.0.
   All values are based on metal halide fixtures, except as otherwise noted.
7. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 2017 through December 2017.
   Participation data for MMIDs 3091 through 3096 and online lookups performed in February 2018 show that the average wattages of participating products are 106 watts (3091), 164 watts (3092), 154 watts (3093), 254 watts (3094), 268 watts (3095), and 264 watts (3096).
8. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. Table 3.2 for nonresidential HOU and CF. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
9. DesignLights Consortium™. *Product List.* Accessed August 2020. https://www.designlights.org/search/
10. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 143 projects and 5,407 units from January 2018 to July 2020 is $547.73. Base cost of $25.14 from November 2020 lookups of 1000 watt metal halide bulbs. $547.73 - $25.14 = $522.59.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	11/2016	Incorporated LDL savings for agriculture sector
03	10/2017	Updated EUL
04	05/2018	Updated savings and EUL
05	02/2020	Updated Incremental Cost and Sources, clarified Agriculture MMIDs
06	09/2020	Updated Watts$_{EE}$ and EUL.

LED Fixture, Quantity Modification

	Measure Details
Measure Master ID	LED Fixture, Quantity Modification, Interior, 4357 LED Fixture, Quantity Modification, Exterior, 4358
Workpaper ID	W0116
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$1.41 per watt reduced, interior; $1.36 per watt reduced, exterior[2]

Measure Description

These LED upgrade measures are the replacement of incumbent light sources with energy-efficient LEDs on a non-one-for-one replacement fixture basis (for example, there may be one LED fixture replacing two non-LED fixtures).

Description of Baseline Condition

The baseline equipment is any incumbent lighting technology source within complete luminaires.

Description of Efficient Condition

The efficient condition is any complete LED luminaire or retrofit kit that is upgrading existing equipment on a non-one-for-one basis. Replacement lamp products are not eligible for these measures. LED products must be on a qualified product list when applicable.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Watts_{REDUCED} * HOU / 1{,}000$

$Watts_{REDUCED} = Qty_{BASE} * Watts_{BASE} – Qty_{EE} * Watts_{EE}$

Where:

Qty_{BASE} = Quantity of currently installed fixtures

$Watts_{BASE}$ = Per-fixture power consumption of current installed lighting equipment

Qty_{EE} = Quantity of efficient LED fixtures

$Watts_{EE}$ = Per-fixture power consumption of efficient LED equipment

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

$Watts_{REDUCED}$ = Watt reduction

Hours of Use by Sector

Sector	HOU
Commercial[3]	3,730
Industrial[3]	4,745
Agriculture[3]	4,698
Schools & Government[3]	3,239
Multifamily[4]	5,950
Exterior[5]	4,380

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[3]	0.77
Industrial[3]	0.77
Agriculture[3]	0.67
Schools & Government[3]	0.64
Multifamily[6]	0.77
Exterior	0.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Annual Energy Savings (kWh per watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Downlights Interior	4357	3.73	4.75	4.7	3.24	5.95
LED Downlights, Exterior	4358	4.38	4.38	4.38	4.38	4.38

Annual Demand Reduction (kW per watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Downlights Interior	4357	0.0008	0.0008	0.0007	0.0006	0.0008
LED Downlights, Exterior	4358	0.0000	0.0000	0.0000	0.0000	0.0000

Lifecycle Savings (per kWh reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Non-1-for-1 Interior	4357	56	71	71	49	89
LED Non-1-for-1 Exterior	4358	66	66	66	66	66

Assumptions

The incremental cost on a per-watt basis was calculated using the following:

Interior = (Actual Interior LED Fixture Measure Cost Sum) / (First Year kWh Savings / Average Sector Hours (4,472)) / 1,000

Exterior = (Actual Exterior LED Fixture Measure Cost Sum) / (First Year kWh Savings / Exterior Hours (4,380)) / 1,000

Sources

1. Engineering judgement. The model mix for this measure is not yet known. In future program years, this will be adjusted based on known product mix and their rated lifetimes.
2. SPECTRUM. Average cost of 12,093 interior fixture units and 4,692 exterior fixture units in Small Business Program. January 2017–December 2017 application date ranges.
3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use and Coincidence Factors by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Multifamily Applications for Common Areas (5,949.5 annual operating hours based on 16.3 hours/day * 365 days/year).
5. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. *NOAA Solar Calculator*. http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This also includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
6. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	11/07/2017	Initial TRM entry

LED Linear Ambient Fixture, Replacing T5 Lamp(s) in Cross Section

	Measure Details
Measure Master ID	LED Fixture, Linear Ambient, Replacing: 1 or 2 T5 Lamp(s) in Cross Section, 3738 3 or 4 T5 Lamps in Cross Section, 3739 1 or 2 T5 Lamp(s) in Cross Section, Exterior, 24 hour, 4785 1 or 2 T5 Lamp(s) in Cross Section, Exterior, 12 hour, 4786 3 or 4 T5 Lamps in Cross Section, Exterior, 24 hour, 4787 3 or 4 T5 Lamps in Cross Section, Exterior, 12 hour, 4788
Workpaper ID	W0117
Measure Unit	Per linear foot of fixture(s)
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agricultural, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure and sector
Peak Demand Reduction (kW)	Varies by measure and sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure and sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/day)	0
Effective Useful Life (years)	Interior = 13 (MMIDs 3738, 3739), Exterior 24 hour = 6 (MMIDs 4785, 4787), Exterior 12 hour = 13 (MMIDs 4786, 4788)[1]
Incremental Cost ($/unit)	1 or 2 T5 Lamp(s) = $12.59 (MMIDs 3738, 4785, 4786), 3 or 4 T5 Lamps = $29.38 (MMIDs 3739, 4787, 4788)[2]

Measure Description

LED linear ambient luminaires save energy when replacing T5 products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace T5 luminaires.

LED linear ambient luminaires are typically a surface mount or pendant type fixture for office, retail, school, etc. applications. Because these fixtures come in many lengths and may be bolted together, the measure unit is per linear foot and measure types are based on how many lamps wide the baseline luminaire is composed of—the cross section.Description of Baseline Condition

The baseline condition is one, two, three, or four interior or exterior lamp(s) in cross section T5 surface-mount or suspended fixtures in existing and new construction buildings.

Description of Efficient Condition

The efficient condition is LED products that are DesignLights Consortium™ (DLC)-listed in the interior or exterior Linear Ambient General Application category.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * HOU$

Where:

$Watts_{BASE}$ = Average per-foot power consumption of baseline fixture (=8.60 watts for 1- and 2-lamp T5 products, weighted 93.57% and 6.43%, respectively; = 23.90 watts for 3- and 4-lamp T5 products, weighted 100% and 0%, respectively)[3,4]

$Watts_{EE}$ = Efficient per-foot power consumption of DLC-listed LED fixture (= 7.06 watts for 1- and 2-lamp T5 products; =8.14 watts for 3- and 4-lamp T5 products)[5]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use for Interior Fixtures

Sector	HOU
Commercial[6]	3,730
Industrial[6]	4,745
Agriculture[6]	4,698
Schools & Government[6]	3,239
Multifamily[7]	5,950

Hours of Use for Exterior Fixtures

MMID	HOU
4785, 4787	8,760
4786, 4788	4,380

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor

Sector	CF
Commercial[6]	0.77
Industrial[6]	0.77
Agriculture[6]	0.67
Schools & Government[6]	0.64
Multifamily[8]	0.77
Exterior - 24 hour	1.0
Exterior - 12 hour	0

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years for MMIDs 3738, 3739, 4786, 4788; = 6 years for MMIDs 4785 and 4787)[1]

Deemed Savings

Annual Savings

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
1 or 2 T5 Lamps	3738	6	0.0012	7	0.0012	7	0.0010	5	0.0010	9	0.0012
	4785	13	0.0015	13	0.0015	13	0.0015	13	0.0015	13	0.0015
	4786	7	n/a	7	n/a	7	n/a	7	n/a	7	n/a
3 or 4 T5 Lamps	3739	59	0.0121	75	0.0121	74	0.0106	51	0.0101	94	0.0121
	4787	138	0.0158	138	0.0158	138	0.0158	138	0.0158	138	0.0158
	4788	69	n/a	69	n/a	69	n/a	69	n/a	69	n/a

Lifecycle Savings (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
1 or 2 T5 Lamps	3738	78	91	91	65	117
	4785	78	78	78	78	78
	4786	91	91	91	91	91
3 or 4 T5 Lamps	3739	767	975	962	663	1,222
	4787	828	828	828	828	828
	4788	897	897	897	897	897

Assumptions

Baseline wattages were obtained from the 2013 Focus on Energy *Default Wattage Guide,*[3] with input wattages based on 4-foot, 28-watt T5 reference lamps with a normal ballast factor. The average per-foot power consumptions are 8.1 watts for 1-lamp, 15.8 watts for 2-lamp, 23.9 watts for 3-lamp, and 31.5 watts for 4-lamp fixtures. Baseline wattage was then weighted by participation model's equivalent lumen output.[4]

Sources

1. DesignLights Consortium™. *Qualified Product List.* Accessed August 2020. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in linear LED measures is 56,232 hours. For interior measures with an average HOU of 4,472, the EUL is 13 years. For exterior 24-hour measures, the EUL 6 years. For exterior 12-hour measures, the EUL 13 years
2. 1000 Bulbs. Website. Accessed July 2018. www.1000bulbs.com
   Top Bulb. Website. Accessed July 2018. www.topbulb.com
   Average efficient cost of $16.35 and base cost of $3.76 for MMIDs 3738, 4618, 4791, 4785, and 4786. Average efficient cost of $38.15 and base cost of $8.77 for MMIDs 3739, 4619, 4792, 4787, and 4788.
3. Focus on Energy. *Default Wattage Guide*. 2013.
4. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. For 1- and 2-lamp products, it was found that 93.57% of products have less than 1350 lumens/foot output. For 3- and 4-lamp products, it was found that 100% of products have less than 2362.5 lumens/foot output.
5. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. For 1- and 2-lamp products, participating models installed were 6.86W/ft and 9.9W/ft, respectively. For 3- and 4-lamp products, participating models installed were 8.14W/ft and 15.16W/ft, respectively. Values were then weighted by measure participation.
6. PA Consulting Group. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0. Table 3-2 Lighting Hours of Use and Coincidence Factors by Sector. March 22, 2010.
   https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Table 1 lists 16.3 hours per day for multifamily common areas.

8. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	10/16/2015	Initial TRM entry
02	10/10/18	Added exterior and in-unit measures, updated cost
03	09/2020	Removed MMIDs 4618, 4619, 4791, & 4792. Updated $\text{Watts}_{\text{BASE}}$, Watts_{EE}, and EUL.

LED Linear Ambient Fixture, Replacing T8/T12 Lamps in Cross Section

	Measure Details
Measure Master ID	LED Fixture, Linear Ambient, Replacing: 1 or 2 T8/T12 Lamp(s) in Cross Section, 3740 3 or 4 T8/T12 Lamps in Cross Section, 3741 1 or 2 T8/T12 Lamp(s) in Cross Section, Exterior, 24 hour, 4781 1 or 2 T8/T12 Lamp(s) in Cross Section, Exterior, 12 hour, 4782 3 or 4 T8/T12 Lamps in Cross Section, Exterior, 24 hour, 4783 3 or 4 T8/T12 Lamps in Cross Section, Exterior, 12 hour, 4784
Workpaper ID	W0118
Measure Unit	Per linear feet of fixture(s)
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agricultural, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure and sector
Peak Demand Reduction (kW)	Varies by measure and sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure and sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Interior = 13 (MMIDs 3740, 3741), Exterior 24 hour = 6 (MMIDs 4781, 4783), Exterior 12 hour = 13 (MMIDs 4782, 4784)[1]
Incremental Cost ($/unit)	1 or 2 T8/12 Lamp(s) = $15.98 (MMIDs 3740, 4781, 4782)[2] 3 or 4 T8/12 Lamps = $19.27 (MMIDs 3741, 4783, 4784)[3]

Measure Description

LED linear ambient fixtures save energy when replacing one to four T8/T12 lamps in cross section by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace one- to four-lamp T8/T12 luminaires.

LED linear ambient luminaires are typically a surface mount or pendant type fixture for office, retail, school, etc. applications. Because these fixtures come in many lengths and may be bolted together, the measure unit is per linear foot and measure types are based on how many lamps wide the baseline luminaire is composed of—the cross section.

Description of Baseline Condition

The baseline condition is one to four lamp(s) in cross section T8/T12 surface-mount or suspended fixtures in existing and new construction buildings.

Description of Efficient Condition

The efficient condition is LED products that are DesignLights Consortium™ (DLC)-listed in the Linear Ambient General Application category.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Average per-foot power consumption of baseline fixture (= 8.60 watts for 1- and 2-lamp T8 products, weighted 32.27% and 67.73%, respectively; = 23.90 watts for 3- and 4-lamp T8 products, weighted 51.02% and 48.98%, respectively)[4,5]

$Watts_{EE}$ = Baseline per foot power consumption of DLC-listed LED fixture (= 8.16 watts for 1- and 2-lamp T8 products; = 12.00 watts for 3- and 4-lamp T8 products)[6]

1,000 = Kilowatt conversion factor

HOU = Hours-of-use (= varies by sector; see tables below for interior and exterior fixtures)

Hours of Use for Interior Fixtures

Sector	HOU
Commercial[7]	3,730
Industrial[7]	4,745
Agriculture[7]	4,698
Schools & Government[7]	3,239
Multifamily[8]	5,950

Hours of Use for Exterior Fixtures

MMID	HOU
4781, 4783	8,760
4782, 4784	4,380

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[7]	0.77
Industrial[7]	0.77
Agriculture[7]	0.67
Schools & Government[7]	0.64
Multifamily[9]	0.77
Exterior - 24 hour	1.0
Exterior - 12 hour	0

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years for interior MMIDs 3740 and 3741; = 6 years for 24-hour exterior MMIDs 4781 and 4783; = 13 years for exterior 12-hour MMIDs 4782 and 4784)[1]

Deemed Savings

Annual Savings

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
1 or 2 T8/T12 Lamps	3740	15	0.0030	19	0.0030	19	0.0026	13	0.0025	24	0.0030
	4781	35	0.0040	35	0.0040	35	0.0040	35	0.0040	35	0.0040
	4782	17	n/a	17	n/a	17	n/a	17	n/a	17	n/a
3 or 4 T8/T12 Lamps	3741	46	0.0094	58	0.0094	58	0.0082	40	0.0078	73	0.0094
	4783	107	0.0122	107	0.0122	107	0.0122	107	0.0122	107	0.0122
	4784	54	n/a	54	n/a	54	n/a	54	n/a	54	n/a

Lifecycle Savings (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
1 or 2 T8/T12 Lamps	3740	195	247	247	169	312
	4781	210	210	210	210	210
	4782	221	221	221	221	221
3 or 4 T8/T12 Lamps	3741	598	754	754	520	949
	4783	642	642	642	642	642
	4784	702	702	702	702	702

Assumptions

Baseline wattages were obtained from the 2015 CEE Legacy Ballast list using the normal ballast factor only.[4] CEE's input wattages are based on a 4-foot, 32-watt T8 reference lamp. The average per-foot power consumptions are 7.5 watts for 1-lamp, 14.3 watts for 2-lamp, 21.4 watts for 3-lamp, and 27.2 watts for 4-lamp. Baseline wattage was then weighted by participation model's equivalent lumen output.[4]

Sources

1. DesignLights Consortium™. *Qualified Product List*. Accessed August 2020. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in linear LED measures is 56,232 hours. For interior measures with an average HOU of 4,472, the EUL is 13 years. For exterior 24-hour measures, the EUL 6 years. For exterior 12-hour measures, the EUL 13 years
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 2,083 projects and 547,083 units from April 2018 to September 2019 is $18.92. Base cost of $2.94 from July 2018 online lookups of base models. $18.92 - $2.94 = $15.98.
3. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 695 projects and 142617.8 units from April 2018 to September 2019 is $26.12. Base cost of $6.85 from July 2018 online lookups of base models. $26.12 - $6.85 = $19.27.
4. Consortium for Energy Efficiency. *Legacy Ballast List*. Normal ballast factor. 2015. http://library.cee1.org/content/commercial-lighting-qualifying-products-lists
5. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. For 1- and 2-lamp products, it was found that 32.27% of products have less than 1050 lumens/foot output. For 3- and 4-lamp products, it was found that 51.02% of products have less than 2450 lumens/foot output.
6. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. For 1- and 2-lamp products, participating models installed were 5.69W/ft and 9.34W/ft, respectively. For 3- and 4-lamp products, participating models installed were 7.16W/ft and 17.04W/ft, respectively. Values were then weighted by measure participation.
7. PA Consulting Group. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0. Table 3-2 Lighting Hours of Use and Coincidence Factors by Sector. March 22, 2010.
   https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
8. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010.
   https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
   Table 1 lists 16.3 hours per day for multifamily common areas.

9. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	10/16/2015	Initial TRM entry
02	10/10/2018	Added exterior and in-unit measures, updated cost
03	2/2020	Updated incremental costs
04	09/2020	Removed MMIDs 4620, 4621, 4789, and 4790. Updated Watts$_{BASE}$, Watts$_{EE}$, and EUL.

LED Replacement of 4-Foot T8 Lamps, Direct Wire

	Measure Details
Measure Master ID	LED Replacement of 4-Foot T8 Lamps, Direct Wire, 3759 LED Replacement of 4-Foot T8 Lamps, Direct Wire, Exterior, 4350 LED Replacement of 4-Foot T8 Lamps, Direct Wire, Exterior, 24/7, 4351
Workpaper ID	W0119
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	Interior = 12 (MMIDs 3759, 3839), Exterior 12-hour = 12 (MMID 4350), Exterior 24-hour = 6 (MMID 4351)[1]
Incremental Cost	$9.96[2]

Measure Description

Four-foot T8 LEDs are an energy-efficient alternative to standard 4-foot 32-watt, 28-watt, and 25-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, schools and government, and multifamily sectors. These products can replace 32-watt, 28-watt, and 25-watt T8 lamps one for one, and this measure incorporates those that replace the existing fluorescent lamp(s) and remove the ballast(s).

Description of Baseline Condition

The baseline condition is 4-foot standard 32-watt, 28-watt, and 25-watt T8 lamps on low (0.78), normal (0.88), and high (1.15) ballast factor ballasts. Lamps are weighted 60%, 30%, and 10%, respectively, in the savings calculations. Also, 32-watt lamp ballast factors are weighted 10%, 70%, and 20% with respect to low, normal, and high ballast factors; and 28-watt and 25-watt lamp ballast factors are weighted 5%, 90%, and 5% in the savings calculations (see the Assumptions section).

Description of Efficient Condition

The efficient condition is DesignLights Consortium™ (DLC)-listed equipment with a measured wattage less than 24 and direct wires to line voltage, not operating off the existing fluorescent ballast(s) or external driver. This measure is not intended to be used in refrigerated case lighting applications.

Products must carry a safety certification from a NRTL, such as UL or ETL, and use non-shunted sockets for products that are single-end feed and sockets that are twist-lock and warrantied for line voltage, and be installed by a licensed electrician and have a re-lamp label applied to modified fixture.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Weighted electricity consumption of standard 4-foot 32-watt, 28-watt, and 25-watt T8 fluorescent lamp operating on low, normal, and high ballast factor ballasts (= 27.43 watts)

$Watts_{EE}$ = Energy efficient wattage, UL Type B (= 16.00 watts)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950
Exterior[6]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[7]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years for MMIDs 3759, 3839, 4350; = 6 years for MMID 4351)[1]

Deemed Savings

Annual Savings for LED Replacement of 4-Foot T8 Lamps

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Direct Wire	3759, 3839	43	0.0088	54	0.0088	54	0.0077	37	0.0073	68	0.0088
Direct Wire, Exterior	4350	50	N/A	50	N/A	50	N/A	50	N/A	50	N/A
Direct Wire, Exterior 24/7	4351	100	0.0114	100	0.0114	100	0.0114	100	0.0114	100	0.0114

Lifecycle Savings (kWh) for LED Replacement of 4-Foot T8 Lamps

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Direct Wire	3759, 3839	516	648	648	444	816
Direct Wire, Exterior	4350	600	600	600	600	600
Direct Wire, Exterior 24/7	4351	600	600	600	600	600

Assumptions

Lamp weightings are based on a combination of energy audit experience, feedback from Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions, and from individuals with lighting sales experience.

It is assumed that an exterior lamp is on for a nighttime average of 4,380 hours, while 8,760 hours are assumed for 24/7 parking garage.

In discussions with the DesignLights Consortium™, it was determined that the Rated Lifetime hours reported in the DLC Qualified Product List[8] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer spec sheets often do list actual L70 test data, so these data were used to obtain a weighted average rated lifetime for participating models.[1]

Sources

1. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. 35 participating models comprise >50% of total measure participation have a weighted average spec sheet rated life of 52,498 hours. With an average HOU of 4,472 for interior measures, the EUL is 12 years. With an HOU of 4380 for exterior 12-hour measure, the EUL is 12 years. With an HOU of 8760 for exterior 24-hour measure, the EUL is 6 years.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 5,607 projects and 1,295,390 units from January 2018 to July 2020 is $11.88. Base cost of $1.92 from August 2018 online lookups of base models. $11.88 - $1.92 = $9.96.
3. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. Data cross-referenced with DLC QPL determining weighted average wattage.
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

5. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. Common Area Lighting Section, p. 9–11. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   Report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
7. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.
8. DesignLights Consortium™. *Product List.* Accessed August 2020. https://www.designlights.org/search/

Revision History

Version Number	Date	Description of Change
01	03/24/2015	Initial TRM entry
02	10/12/2017	Added 12-hour and 24-hour measures
03	12/2018	Updated incremental cost, removed MMID 4094
04	02/2020	Updated incremental cost
05	09/2020	Removed MMID 4471 and 4472. Updated Watts_{EE} and EUL.

LED Replacement of 4-Foot T8 Lamps Using Existing Ballast

	Measure Details
Measure Master ID	LED Replacement of 4-Foot T8 Lamps: Using Existing Ballast, 3512 Using Existing Ballast, Exterior, 4348 Using Existing Ballast, Exterior 24/7, 4349
Workpaper ID	W0120
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	Interior = 12 (MMIDs 3512, 3823), Exterior 12-hour = 12 (MMID 4348), Exterior 24-hour = 6 (MMID 4349)[1]
Incremental Cost	$5.43[2]

Measure Description

Four-foot T8 LEDs are an energy-efficient alternative to standard 4-foot 32-watt, 28-watt, and 25-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 32-watt, 28-watt, and 25-watt T8 lamps one-for-one operating off the existing fluorescent ballast.

Description of Baseline Condition

The baseline condition is 4-foot standard 32-watt, 28-watt, and 25-watt T8 lamps on low (0.78), normal (0.88), and high (1.15) ballast factor ballasts (weighted 60%, 30%, and 10%, respectively, in the savings calculations). The 32-watt lamps are weighted 10%, 70%, and 20% with respect to low, normal, and high ballast factors, while 28-watt and 25-watt lamps are weighted 5%, 90%, and 5% for the same ballast factors in the savings calculations (see the Assumptions section).

Description of Efficient Condition

The efficient condition is DesignLights Consortium™ (DLC)-listed equipment in the Linear Replacement Lamps category, with a UL Type A primary use category, and a tested or reported wattage of 24 or less. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Weighted electricity consumption of standard 4-foot 32-watt, 28-watt, and 25-watt T8 fluorescent lamp operating on low, normal, or high ballast factor ballasts (= 27.4 watts)

$Watts_{EE}$ = Energy efficient wattage, UL Type A (= 16.71 watts)[3]

HOU = Hours of use (= varies by sector; see table below)

1,000 = Kilowatt conversion factor

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950
Exterior[6]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[7]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years for MMIDs 3512, 3823, 4348; = 6 years for MMID 4349)[1]

Deemed Savings

Annual Savings for LED Replacement of 4-Foot T8

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Using Existing Ballast	3512, 3823	40	0.0083	51	0.0083	50	0.0072	35	0.0069	64	0.0083
Using Existing Ballast, Exterior	4348	47	N/A	47	N/A	47	N/A	47	N/A	47	N/A
Using Existing Ballast, Exterior 24/7	4349	94	0.0107	94	0.0107	94	0.0107	94	0.0107	94	0.0107

Lifecycle Savings for LED Replacement of 4-Foot (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Using Existing Ballast	3512, 3823	480	612	600	420	768
Using Existing Ballast, Exterior	4348	564	564	564	564	564
Using Existing Ballast, Exterior 24/7	4349	564	564	564	564	564

Assumptions

Lamp weightings are based on a combination of energy audit experience, feedback from Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions, and from individuals with lighting sales experience.

It is assumed that an exterior lamp is on for a nighttime average of 4,380 hours; 8,760 hours are assumed for 24/7 parking garage.

In discussions with the DesignLights Consortium™, it was determined that the rated lifetime hours reported in the DLC Qualified Product List[8] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer spec sheets often do list actual L70 test data, so these data were used to obtain a weighted average rated lifetime for participating models.[1]

Sources

1. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. 13 participating models comprise >50% of total measure participation have a weighted average spec sheet rated life of 54,582 hours. With an average HOU of 4,472 for interior measures, the EUL is 12 years. With an HOU of 4380 for exterior 12-hour measure, the EUL is 12 years. With an HOU of 8760 for exterior 24-hour measure, the EUL is 6 years.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 621 projects and 271,510 units from January 2020 to July 2021 is $7.35. Base cost of $1.92 from August 2018 online lookups of base models. $7.35 - $1.92 = $5.43.
3. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. Data cross-referenced with DLC QPL determining weighted average wattage.
4. PA Consulting Group. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0. Table 3-2 Lighting Hours of Use and Coincidence Factors by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. Table 1. www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. “NOAA Solar Calculator.” http://www.esrl.noaa.gov/gmd/grad/solcalc/
   Report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
7. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.
8. DesignLights Consortium™. *Product List.* Accessed August 2020. https://www.designlights.org/search/

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	11/11/2016	Updated savings
03	10/12/2017	Added 12-hour and 24-hour measures
04	12/2018	Updated incremental cost
05	2/2020	Updated incremental cost
06	9/2020	Removed MMID 4469 and 4470. Updated Watts_{EE} and EUL.

LED Replacement of 4-Foot T8 Lamps w/ External Driver

	Measure Details
Measure Master ID	LED Replacement of 4-Foot T8 Lamps: w/ External Driver, 3511 w/ External Driver, Exterior, 4352 w/ External Driver, Exterior 24/7, 4353
Workpaper ID	W0121
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	Interior = 13 (MMIDs 3511, 3822), Exterior 12-hour = 13 (MMID 4352), Exterior 24-hour = 6 (MMID 4353)[1]
Incremental Cost	$6.56[2]

Measure Description

Four-foot T8 LEDs are an energy-efficient alternative to standard 4-foot 32-watt, 28-watt, and 25-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school, government, and multifamily spaces. These products can replace 32-watt, 28-watt, and 25-watt T8 lamps one-for-one, and this measure incorporates those that replace the existing fluorescent lamp(s), remove the ballast(s), and use an external driver.

Description of Baseline Condition

The baseline condition is 4-foot standard 32-watt, 28-watt, and 25-watt T8 lamps on low (0.78), normal (0.88), and high (1.15) ballast factor ballasts. Lamps are weighted 60%, 30%, and 10%, respectively, in the savings calculations. The 32-watt lamp ballast factors are weighted 10%, 70%, and 20% with respect to low, normal, and high. The 28-watt and 25-watt lamp ballast factors are weighted 5%, 90%, and 5% in the savings calculations (see Assumptions section).

Description of Efficient Condition

Efficient equipment must be DesignLights Consortium™ (DLC)-listed in the Linear Replacement Lamps category, with a UL Type C primary use category and a tested or reported wattage of 24 or less. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) /1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Weighted electricity consumption of standard 4-foot 32-watt, 28-watt, or 25-watt T8 fluorescent lamp operating on low/normal/high ballast factor ballasts (= 27.43 watts)

$Watts_{EE}$ = Energy efficient wattage, UL Type C (= 17.65 watts)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950
Exterior[6]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) /1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[7]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years for MMIDs 3511, 3822, 4352; = 6 years for MMID 4353)[1]

Deemed Savings

Annual Savings for LED Replacement of 4-Foot T8

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
w/ External Driver	3511, 3822	36	0.0075	46	0.0075	46	0.0066	32	0.0063	58	0.0075
w/ External Driver, Exterior	4352	43	N/A	43	N/A	43	N/A	43	N/A	43	N/A
w/ External Driver, Exterior 24/7	4353	86	0.0098	86	0.0098	86	0.0098	86	0.0098	86	0.0098

Lifecycle Savings for LED Replacement of 4-Foot T8 (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
w/ External Driver	3511, 3822	468	598	598	416	754
w/ External Driver, Exterior	4352	559	559	559	559	559
w/ External Driver, Exterior 24/7	4353	516	516	516	516	516

Assumptions

Lamp weightings are based on a combination of energy audit experience, feedback from Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions, and from individuals with lighting sales experience.

It is assumed that an exterior lamp is on for a nighttime average of 4,380 hours, and 8,760 hours are assumed for a 24/7 parking garage.

In discussions with the DesignLights Consortium™, it has been determined that the rated lifetime hours reported in the DLC *Qualified Product List*[8] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC-certified. However, in these cases, manufacturer spec sheets often do list actual L70 test data. Therefore, these data were used to obtain a weighted average rated lifetime for participating models.[1]

Sources

1. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. 5 participating models comprise >50% of total measure participation have a weighted average spec sheet rated life of 56,675 hours. With an average HOU of 4,472 for interior measures, the EUL is 13 years. With an HOU of 4380 for exterior 12-hour measure, the EUL is 13 years. With an HOU of 8760 for exterior 24-hour measure, the EUL is 6 years.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 84 projects and 114,001 units from January 2020 to July 2021 is $8.48. Base cost of $1.92 from August 2018 online lookups of base models. $8.48 - $1.92 = $6.56.
3. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. Data cross-referenced with DLC QPL determining weighted average wattage.
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use and Coincidence Factors by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. Common Area Lighting Section, pages 9-11. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
This report includes times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.

7. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.
8. DesignLights Consortium™. *Product List.* Accessed August 2020. https://www.designlights.org/search/

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	04/2017	Added MMID 4093
03	10/12/2017	Added 12-hour and 24-hour measures
04	01/2019	Removed MMID 4093
05	2/2020	Updated incremental cost
06	9/2020	Removed MMID 4473 and 4474. Updated Watts_{EE} and EUL.

LED Replacement of 4-Foot T5 or T5HO Lamps, Direct Wire

	Measure Details
Measure Master ID	LED Replacement of 4-Foot T5 Lamps, Direct Wire, 4805 LED Replacement of 4-Foot T5HO Lamps, Direct Wire, 4806
Workpaper ID	W0122
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost	$10.49[2]

Measure Description

Four-foot T5 or T5HO LEDs are an energy-efficient alternative to standard 4-foot 28-watt T5 or 54-watt T5HO fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 28-watt T5 or 54-watt T5HO lamps one for one, and this measure incorporates those that replace the existing fluorescent lamp(s) and remove the ballast(s).

Description of Baseline Condition

The baseline condition is 4-foot standard 28-watt T5 or 54-watt T5HO lamps.

Description of Efficient Condition

The efficient condition is DLC-listed equipment that is direct wired to line voltage, not operating off the existing fluorescent ballast(s) or external driver. This measure is not intended for use in refrigerated case lighting applications. Products must carry a safety certification from a NRTL (such as UL or ETL), must use non-shunted sockets for products that are single-end feed as well as sockets that are twist-lock and warrantied for line voltage, must be installed by a licensed electrician, and must have a re-lamp label applied to modified fixture.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 4-foot, 28-watt T5 or 54-watt T5HO lamps (= 33 watts for T5, = 62 watts for T5HO; see Assumptions)

$Watts_{EE}$ = Average annual electricity consumption of DLC-listed 4-foot linear LED, UL Type B (= 17.1 watts for T5, = 24.8 watts for T5HO)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[6]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Annual Savings for LED Replacement of 4-Foot T5 or T5HO Lamps

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
4-Foot T5 Lamps, Direct Wire	4805	59	0.0122	75	0.0122	75	0.0106	51	0.0102	94	0.0122
4-Foot T5HO Lamps, Direct Wire	4806	139	0.0286	176	0.0286	175	0.0249	120	0.0238	221	0.0286

Lifecycle Savings (kWh) for LED Replacement of 4-Foot T5 or T5HO Lamps

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
4-Foot T5 Lamps, Direct Wire	4805	885	1,125	1,125	765	1,410
4-Foot T5HO Lamps, Direct Wire	4806	2,085	2,640	2,625	1,800	3,315

Assumptions

In discussions with the DLC, it was determined that the rated lifetime hours reported in the DLC Qualified Product List[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC-certified. However, in these cases, manufacturer specification sheets often list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where a 4-foot, 28-watt T5 equals 33 watts and a 4-foot T5HO lamp equals 62 watts.

Sources

1. EUL based on LED 4-foot T8 lamps, Direct Wire SPECTRUM data.
   Online lookups from MMID 3759 participation data and January through December 2017 show that 20 participating models, comprising 140,570 units and 50% of total measure participation, have an average specification sheet rated life of 69,000 hours. With an average HOU of 4,472, the EUL is 15 years.
2. 1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
   Payless-4-lighting. Website. Accessed September 2018. payless-4-lighting.com
   Ledt8bulbs. Website. Accessed September 2018. ledt8bulb.com
   Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
   Bulbs. Website. Accessed September 2018. bulbs.com
   Average cost from retail sources. Baseline lamps cost $3.26. Based on 151 projects with 34,686 lamps from January 2020 through July 2021, efficient lamps cost $13.75. Therefore, the incremental cost is $13.75 - $3.26 = $10.49.
3. DesignLights Consortium. *Product List.* Accessed September 18, 2018. https://www.designlights.org/search/
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. *ACES Deemed Savings Desk Review*. Common Area Lighting Section, p. 9–11. November 3, 2010. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of 4-Foot T5 or T5HO Lamps Using Existing Ballast

	Measure Details
Measure Master ID	LED Replacement of 4-Foot T5 Lamps Using Existing Ballast, 4807 LED Replacement of 4-Foot T5HO Lamps Using Existing Ballast, 4808
Workpaper ID	W0123
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$10.12[2]

Measure Description

Four-foot T5 or T5HO LEDs are an energy-efficient alternative to standard 4-foot 28-watt T5 or 54-watt T5HO fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 28-watt T5 or 54-watt T5HO lamps one-for-one operating off the existing fluorescent ballast.

Description of Baseline Condition

The baseline condition is 4-foot standard 28-watt T5 or 54-watt T5HO lamps.

Description of Efficient Condition

The efficient condition is DLC-listed equipment in the Linear Replacement Lamps category, with a UL Type A primary use category. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 4-foot 28-watt T5 or 54-watt T5HO lamps (= 33 watts for T5, = 62 watts for T5HO; see Assumptions)

$Watts_{EE}$ = Average annual electricity consumption of DLC-listed 4-foot linear LED, UL Type A (= 19.5 watts for T5, = 28.5 watts for T5HO)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[6]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[6]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED T5 or T5HO Lamp

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Replacement of 4-Foot T5 Lamps Using Existing Ballast	4807	50	0.0104	64	0.0104	64	0.0091	44	0.0087	80	0.0104
LED Replacement of 4-Foot T5HO Lamps Using Existing Ballast	4808	125	0.0258	159	0.0258	157	0.0224	108	0.0214	199	0.0258

Average Lifecycle Deemed Savings for LED T5 or T5HO Lamp

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Replacement of 4-Foot T5 Lamps Using Existing Ballast	4807	550	704	704	484	880
LED Replacement of 4-Foot T5HO Lamps Using Existing Ballast	4808	1,375	1,749	1,727	1,188	2,189

Assumptions

In discussions with the DLC, it was determined that the rated lifetime hours reported in the DLC Qualified Product List[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer specification sheets often list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where a 4-foot 28-watt T5 equals 33 watts and a 4-foot T5HO lamp equals 62 watts.

Sources

1. EUL based on LED 4-Foot T8 Lamps Using Existing Ballast SPECTRUM data. Online lookups from January 2018 and MMID 3512 participation data from January through December 2017 show that 13 participating models, comprising 162,906 units and 51% of total measure participation, all have a specification sheet rated life of 50,000 hours. With an average HOU of 4,472, the EUL is 11 years.
2. 1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
   Payless-4-lighting. Website. Accessed September 2018. payless-4-lighting.com
   1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Bulbs. Website. Accessed September 2018. bulbs.com
   LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Average cost from retail sources. Baseline lamps cost $3.26. Efficient lamps cost $13.38. Therefore, the incremental cost is $10.12.
3. DesignLights Consortium. *Product List.* Accessed September 18, 2018. https://www.designlights.org/search/
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. *ACES Deemed Savings Desk Review*. Table 1. November 3, 2010. www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of 4-Foot T5 or T5HO Lamps w/ External Driver

	Measure Details
Measure Master ID	LED Replacement of 4-Foot T5 Lamps w/ External Driver, 4803 LED Replacement of 4-Foot T5HO Lamps w/ External Driver, 4804
Workpaper ID	W0124
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$49.32[2]

Measure Description

Four-foot T5 or T5HO LEDs are an energy-efficient alternative to standard 4-foot 28-watt T5 or 54-watt T5HO fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 28-watt T5 or 54-watt T5HO lamps one-for-one, and this measure incorporates those that replace the existing fluorescent lamp(s), remove the ballast(s), and use an external driver.

Description of Baseline Condition

The baseline condition is 4-foot standard 28-watt T5 or 54-watt T5HO lamps.

Description of Efficient Condition

Efficient equipment must be DLC-listed in the Linear Replacement Lamps category, with a UL Type C primary use category. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) /1,000 * HOU$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 4-foot 28-watt T5 or 54-watt T5HO lamps (= 33 watts for T5, = 62 watts for T5HO; see Assumptions)

$Watts_{EE}$ = Average annual electricity consumption of DLC-listed 4-foot linear LED, UL Type C (= 21.7 watts for T5, = 26.7 watts for T5HO)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) /1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[6]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Annual Savings for LED Replacement of 4-Foot T5 or T5HO

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
4-Foot T5 Lamps w/ External Driver	4803	42	0.0087	54	0.0087	53	0.0076	37	0.0072	67	0.0087
4-Foot T5HO Lamps w/ External Driver	4804	132	0.0272	168	0.0272	166	0.0237	114	0.0226	210	0.0272

Lifecycle Savings for LED Replacement of 4-Foot T5 or T5HO (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
4-Foot T5 Lamps w/ External Driver	4803	462	594	583	407	737
4-Foot T5HO Lamps w/ External Driver	4804	1,452	1,848	1,826	1,254	2,310

Assumptions

In discussions with the DLC, it has been determined that the rated lifetime hours reported in the DLC *Qualified Product List*[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC-certified. However, in these cases, manufacturer specification sheets often list actual L70 test data. Therefore, these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where a 4-foot, 28-watt T5 equals 33 watts and a 4-foot T5HO lamp equals 62 watts.

Sources

1. EUL based on LED 4-Foot T8 Lamps w/ External Driver SPECTRUM data. Online lookups from January 2018 and MMID 3511 participation data from January through December 2017 show that two participating models, comprising 3,950 units and 51% of total measure participation, have a specification sheet rated life of 50,000 hours. With an average HOU of 4,472, the EUL is 11 years.
2. 1000Bulbs. Website. Accessed September 2018. 1000bulbs.com
   Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
   Payless-4-lighting. Website. Accessed September 2018. payless-4-lighting.com
   Ledt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Bulbsdepot. Website. Accessed September 2018. bulbsdepot.com
   Ledt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Average cost from retail sources. Baseline lamps cost $3.26. Efficient lamps cost $20.63. Efficient lamp driver cost $31.95. Therefore, the incremental cost is $49.32.
3. DesignLights Consortium. *Product List.* Accessed September 18, 2016. https://www.designlights.org/search/
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. *ACES Deemed Savings Desk Review*. Common Area Lighting section, pp. 9–11. November 3, 2010. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of 8-Foot T8 Lamps, Direct Wire

	Measure Details
Measure Master ID	LED Replacement of 8’ T8 or T12 Lamps, Direct Wire (UL Type B), 4810 LED Replacement of 8’ T8 or T12 Lamps, Direct Wire (UL Type B), Exterior, 4832 LED Replacement of 8-Foot T8 Lamps, Direct Wire (UL Type B), Exterior 24/7, 4835
Workpaper ID	W0125
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$23.29[2]

Measure Description

Eight-foot T8 LEDs are an energy-efficient alternative to standard eight-foot 59-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 59-watt T8 lamps one-for-one, and this measure incorporates those that replace the existing fluorescent lamp(s) and remove the ballast(s).

Description of Baseline Condition

The baseline condition is 8-foot standard 59-watt T8 lamp.

Description of Efficient Condition

The efficient condition is DLC-listed equipment direct wired to line voltage, not operating off the existing fluorescent ballast(s) or external driver. This measure is not intended to be used in refrigerated case lighting applications. Products must carry a safety certification from a NRTL, such as UL or ETL, and use non-shunted sockets for products that are single-end feed and sockets that are twist-lock and warrantied for line voltage, and must be installed by a licensed electrician and have a re-lamp label applied to modified fixture.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * HOU$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 8-foot 59-watt T8 fluorescent lamp (= 61 watts; see Assumptions)

$Watts_{EE}$ = Average annual electricity consumption of DLC-listed 8-foot linear LED, UL Type B (= 39.0 watts)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950
Exterior[6]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[7]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Annual Savings for LED Replacement of 8-Foot T8 Lamps

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Direct Wire	4810	82	0.0169	104	0.0169	103	0.0147	71	0.0141	131	0.0169
Direct Wire, Exterior	4832	96	0	96	0	96	0	96	0	96	0
Direct Wire, Exterior 24/7	4835	192	0.022	192	0.022	192	0.022	192	0.022	192	0.022

Lifecycle Savings (kWh) for LED Replacement of 8-Foot T8 Lamps

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Direct Wire	4810	1,230	1,560	1,545	1,065	1,965
Direct Wire, Exterior	4832	1,440	1,440	1,440	1,440	1,440
Direct Wire, Exterior 24/7	4835	2,880	2,880	2,880	2,880	2,880

Assumptions

In discussions with the DLC, it was determined that the Rated Lifetime hours reported in the DLC Qualified Product List[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer specification sheets often list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where an 8-foot, 59-watt T8 lamp equals 61 watts.

It is assumed that an exterior lamp is on for a nighttime average of 4,380 hours per year; 8,760 hours are assumed for 24/7 lighting use.

Sources

1. EUL based on LED 4-Foot T8 Lamps, Direct Wire SPECTRUM data. Online lookups from January 2018 and MMID 3759 participation data from January through December 2017 show that 20 models, comprising 140,570 units and 50% of total measure participation, have an average specification sheet rated life of 69,000 hours. With an average HOU of 4,472, the EUL is 15 years.
2. 1000Bulbs. Website. Accessed September 2018. 1000bulbs.com
   Bulbs. Website. Accessed September 2018. bulbs.com
   Ledt8bulb. Website. Accessed September 2018. ledt8bulb.com
   1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
   LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Average cost from retail sources. Baseline lamps cost $10.37. Efficient lamps cost $33.66. Therefore, the incremental cost is $23.29.
3. DesignLights Consortium. *Product List.* Accessed September 18, 2018. https://www.designlights.org/search/
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. Common Area Lighting Section, p. 9–11. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   Report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting, as well as time clock scheduled lighting.
7. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of 8-Foot T8 Lamps Using Existing Ballast

	Measure Details
Measure Master ID	LED Replacement of 8' T8 or T12 Lamp: Utilizing Existing Ballast (UL Type A), 4811 Utilizing Existing Ballast (UL Type A), Exterior, 4830 Utilizing Existing Ballast (UL Type A), Exterior 24/7, 4833
Workpaper ID	W0126
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$16.69[2]

Measure Description

Eight-foot T8 LEDs are an energy-efficient alternative to standard eight-foot 59-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 59-watt T8 lamps one-for-one operating off the existing fluorescent ballast.

Description of Baseline Condition

The baseline condition is an 8-foot standard 59-watt T8 lamp.

Description of Efficient Condition

The efficient condition is 8-foot LED DLC-listed equipment in the Linear Replacement Lamps category, with a UL Type A primary use category. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 8-foot 59-watt T8 fluorescent lamp (= 61 watts; see Assumptions)

$Watts_{EE}$ = Average annual electricity consumption of DLC-listed 8-foot linear LED, UL Type A (= 34.5 watts)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950
Exterior[6]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[7]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED T8 Lamp

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Replacement of 8-Foot T8 Lamps											
Using Existing Ballast	4811	99	0.0204	126	0.0204	124	0.0178	86	0.017	158	0.0204
w/External Driver, Exterior	4830	116	0	116	0	116	0	116	0	116	0
w/External Driver, Exterior 24/7	4833	232	0.0265	232	0.0265	232	0.0265	232	0.0265	232	0.0265

Average Lifecycle Deemed Savings for LED T8 Lamp

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Replacement of 8-Foot T8 Lamps						
Using Existing Ballast	4811	1,089	1,386	1,364	946	1,738
w/External Driver, Exterior	4830	1,276	1,276	1,276	1,276	1,276
w/External Driver, Exterior 24/7	4833	2,552	2,552	2,552	2,552	2,552

Assumptions

In discussions with the DLC, it was determined that the rated lifetime hours reported in the DLC Qualified Product List[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer specification sheets often list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where an 8-foot, 59-watt T8 lamp equals 61 watts.

Sources

1. EUL based on LED 4-Foot T8 Lamps Using Existing Ballast SPECTRUM data. Online lookups from January 2018 and MMID 3512 participation data from January through December 2017 show that 13 models, comprising 162,906 units and 51% of total measure participation, all have a specification sheet rated life of 50,000 hours. With an average HOU of 4,472, the EUL is 11 years.
2. 1000Bulbs. Website. Accessed September 2018. 1000bulbs.com
   Bulbs. Website. Accessed September 2018. bulbs.com
   Ledt8bulb. Website. Accessed September 2018. ledt8bulb.com
   1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Greenelectricalsupply. Website. Accessed September 2018. greenelectricalsupply.com
   Lighting-spot. Website. Accessed September 2018. lighting-spot.com
   Average cost from retail sources. Baseline lamps cost $10.37. Efficient lamps cost $27.06. Therefore, the incremental cost is $16.69.
3. DesignLights Consortium. *Product List.* Accessed September 18, 2016. https://www.designlights.org/search/
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. *ACES Deemed Savings Desk Review*. Common Area Lighting section, p. 9–11. November 3, 2010. www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   Report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting, as well as time clock scheduled lighting.
7. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of 8-Foot T8 Lamps w/ External Driver

	Measure Details
Measure Master ID	LED Replacement of 8' T8 or T12 Lamp: w/ External Driver (UL Type C), 4809 w/ External Driver (UL Type C), Exterior, 4831 w/ External Driver, (UL Type C) Exterior 24/7, 4834
Workpaper ID	W0127
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$57.68[2]

Measure Description

Eight-foot T8 LEDs are an energy-efficient alternative to standard eight-foot 59-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 59-watt T8 lamps one-for-one, and this measure incorporates those that replace the existing fluorescent lamp(s), remove the ballast(s), and use an external driver.

Description of Baseline Condition

The baseline condition is 8-foot standard 59-watt T8 lamp.

Description of Efficient Condition

Efficient equipment must be DLC-listed in the Linear Replacement Lamps category, with a UL Type C primary use category. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) /1,000 * HOU$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 8-foot, 59-watt T8 fluorescent lamp (= 61 watts; see Assumptions)

$Watts_{EE}$ = Average annual electricity consumption of DLC-listed 8-foot linear LED, UL Type C (= 32.7 watts)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950
Exterior[6]	4,380
Exterior 24/7	8,760

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) /1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[7]	0.77
Exterior	0.00
Exterior 24/7	1.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Annual Savings for LED Replacement of 8-Foot T8

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
w/ External Driver	4809	106	0.0218	134	0.0218	133	0.019	92	0.0181	168	0.0218
w/ External Driver, Exterior	4831	124	0	124	0	124	0	124	0	124	0
w/ External Driver, Exterior 24/7	4834	248	0.0283	248	0.0283	248	0.0283	248	0.0283	248	0.0283

Lifecycle Savings for LED Replacement of 8-Foot T8 (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
w/ External Driver	4809	1,166	1,474	1,463	1,012	1,848
w/ External Driver, Exterior	4831	1,364	1,364	1,364	1,364	1,364
w/ External Driver, Exterior 24/7	4834	2,728	2,728	2,728	2,728	2,728

Assumptions

In discussions with the DLC, it has been determined that the rated lifetime hours reported in the DLC *Qualified Product List*[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer specification sheets often list actual L70 test data. Therefore, these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where an 8-foot, 59-watt T8 lamp equals 61 watts.

Sources

1. EUL based on LED 4-Foot T8 Lamps w/ External Driver SPECTRUM data. Online lookups from January 2018 and MMID 3511 participation data from January through December 2017 show that two models, comprising 3,950 units and 51% of total measure participation, have a specification sheet rated life of 50,000 hours. With an average HOU of 4,472, the EUL is 11 years.
2. 1000Bulbs. Website. Accessed September 2018. 1000bulbs.com
   Bulbs. Website. Accessed September 2018. bulbs.com
   Ledt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Itsthyme. Website. Accessed September 2018. itsthyme.com
   Ledt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Ledt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Average cost from retail sources. Baseline lamps cost $10.37. Efficient lamps cost $36.10. Efficient lamp driver cost $31.95. Therefore, the incremental cost is $57.68.
3. DesignLights Consortium. *Product List.* Accessed September 18, 2016. https://www.designlights.org/search/
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Tetra Tech. *ACES Deemed Savings Desk Review*. Common Area Lighting section, pp. 9–11. November 3, 2010. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
6. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This report includes times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting, as well as time clock scheduled lighting.
7. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of U-Bend or 2-Foot T8 Lamps, Direct Wire

	Measure Details
Measure Master ID	LED Replacement of U-Bend T8 Lamps, Direct Wire, 4801 LED Replacement of 2-Foot T8 Lamps, Direct Wire, 4798
Workpaper ID	W0128
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	U-Bend T8 Lamps = $12.39 (4801),[2] 2-Foot T8 Lamps = $7.41 (4798)[3]

Measure Description

U-bend or 2-foot LEDs are an energy-efficient alternative to standard 32-watt U-bend T8 or 17-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 32-watt U-bend T8 or 17-watt T8 lamps one-for-one, and this measure incorporates those that replace the existing fluorescent lamp(s) and remove the ballast(s).

Description of Baseline Condition

The baseline condition is 32-watt U-bend T8 or 2-foot 17-watt T8 lamps.

Description of Efficient Condition

The efficient condition is DLC-listed equipment direct wired to line voltage, not operating off the existing fluorescent ballast(s) or external driver. This measure is not intended to be used in refrigerated case lighting applications. Products must carry a safety certification from a NRTL, such as UL or ETL, and use non-shunted sockets for products that are single-end feed and sockets that are twist-lock and warrantied for line voltage, and must be installed by a licensed electrician and have a re-lamp label applied to the modified fixture.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 32-watt U-bend T8 or 17-watt T8 lamps (= 29 watts for U-bend T8, = 20 watts for 2-foot T8; see Assumptions)

$Watts_{EE}$ = Annual electricity consumption of DLC-listed U-bend LED or 2-foot T8, UL Type B (= 16.1 watts for U-bend T8, = 9.6 watts for 2-foot T8)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[6]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Annual Savings for LED Replacement of LED U-Bend or 2-Foot Lamps

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
U-Bend T8 Lamps, Direct Wire	4801	48	0.01	61	0.01	61	0.0087	42	0.0083	77	0.01
2-Foot T8 Lamps, Direct Wire	4798	39	0.008	49	0.008	49	0.007	34	0.0067	62	0.008

Lifecycle Savings for LED Replacement of LED U-Bend or 2-Foot Lamps (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
U-Bend T8 Lamps, Direct Wire	4801	720	915	915	630	1,155
2-Foot T8 Lamps, Direct Wire	4798	585	735	735	510	930

Assumptions

In discussions with the DLC, it was determined that the Rated Lifetime hours reported in the DLC *Qualified Product List*[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer specification sheets often list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where a 32-watt T8 U-bend lamp is 29 watts and a 2-foot, 17-watt T8 lamp is 20 watts.

Sources

1. EUL based on LED 4-Foot T8 Lamps, Direct Wire SPECTRUM data. Online lookups from January 2018 and MMID 3759 participation data from January through December 2017 show that 20 participating models, comprising 140,570 units and 50% of total measure participation, have an average specification sheet rated life of 69,000 hours. With an average HOU of 4,472, the EUL is 15 years.
2. 1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com

Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
1000bulbs. Website. Accessed September 2018. 1000bulbs.com
Topbulb. Website. Accessed September 2018. topbulb.com
LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com
Average U-bend LED cost from retail sources. Baseline lamps cost $7.31. Efficient lamps cost $19.69. Therefore, the incremental cost is $12.39.

3. 1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
   Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
   1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
   LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Average 2-Foot LED cost from retail sources. Baseline lamps cost $2.71. Efficient lamps cost $10.11. Therefore, the incremental cost is $7.41.
4. DesignLights Consortium. *Product List.* Accessed September 18, 2018. https://www.designlights.org/search/
5. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Tetra Tech. *ACES Deemed Savings Desk Review*. Common Area Lighting Section, p. 9–11. November 3, 2010. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
7. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of U-Bend or 2-Foot T8 Lamps Using Existing Ballast

	Measure Details
Measure Master ID	LED Replacement of U-Bend T8 Lamps Using Existing Ballast, 4802 LED Replacement of 2-Foot Lamps Using Existing Ballast, 4799
Workpaper ID	W0129
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	U-Bend Lamps = $13.49 (4802),[2] 2-Foot Lamps = $9.66 (4799)[3]

Measure Description

U-bend or 2-foot LEDs are an energy-efficient alternative to standard 32-watt U-bend T8 or 17-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 32-watt U-bend T8 or 17-watt T8 lamps one-for-one operating off the existing fluorescent ballast.

Description of Baseline Condition

The baseline condition is standard 32-watt U-bend T8 or 2-foot 17-watt T8 lamps.

Description of Efficient Condition

The efficient condition is DLC-listed equipment in the Linear Replacement Lamps category, with a UL Type A primary use category. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Annual electricity consumption of standard 32-watt U-bend T8 or 17-watt T8 lamps (= 29 watts for U-bend T8, = 20 watts for 2-foot T8; see Assumptions)

$Watts_{EE}$ = Average annual electricity consumption of DLC-listed U-bend LED or 2-foot T8, UL Type A (= 16.4 watts for U-bend T8, = 10.3 watts for 2-foot T8)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[6]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED U-Bend or 2-Foot Lamp

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Replacement of U-Bend T8 Lamps Using Existing Ballast	4802	47	0.0097	60	0.0097	59	0.0084	41	0.0081	75	0.0097
LED Replacement of 2-Foot T8 Lamps Using Existing Ballast	4799	38	0.0079	49	0.0079	48	0.0069	33	0.0066	61	0.0079

Average Lifecycle Deemed Savings for LED U-Bend or 2-Foot Lamp (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Replacement of U-Bend T8 Lamps Using Existing Ballast	4802	517	660	649	451	825
LED Replacement of 2-Foot T8 Lamps Using Existing Ballast	4799	418	539	528	363	671

Assumptions

In discussions with the DLC, it was determined that the rated lifetime hours reported in the DLC Qualified Product List[3] often do not reflect actual L70 test data. Despite DLC’s requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer specification sheets often list actual L70 test data, so these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where a 32-watt T8 U-bend lamp is 29 watts and a 2-foot, 17-watt T8 lamp is 20 watts.

Sources

1. EUL based on LED 4-Foot T8 Lamps Using Existing Ballast SPECTRUM data. Online lookups from January 2018 and MMID 3512 participation data from January through December 2017 show that 13 models, comprising 162,906 units and 51% of total measure participation, all have a specification sheet rated life of 50,000 hours. With an average HOU of 4,472, the EUL is 11 years.
2. 1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
   Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
   1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
   LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com

Average U-bend LED cost from retail sources. Baseline lamps cost $7.31. Efficient lamps cost $20.79. Therefore, the incremental cost is $13.49.

3. 1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
   Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
   1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
   LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Average 2-foot LED cost from retail sources. Baseline lamps cost $2.71. Efficient lamps cost $12.36. Therefore, the incremental cost is $9.66.
4. DesignLights Consortium. *Product List.* Accessed September 18, 2018. https://www.designlights.org/search/
5. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Tetra Tech. *ACES Deemed Savings Desk Review*. Table 1. November 3, 2010. www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
7. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Replacement of U-Bend or 2-Foot T8 Lamps w/ External Driver

	Measure Details
Measure Master ID	LED Replacement of U-Bend T8 Lamps w/ External Driver, 4800 LED Replacement of 2-Foot T8 Lamps w/ External Driver, 4797
Workpaper ID	W0130
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	11[1]
Incremental Cost	U-Bend T8 Lamps = $39.53 (4800),[2] 2-Foot T8 Lamps = $31.39 (4797)[3]

Measure Description

U-bend and 2-foot LEDs are an energy-efficient alternative to standard 32-watt U-bend T8 or 17-watt T8 fluorescent lamps found commonly throughout commercial, industrial, agriculture, school and government, and multifamily sectors. These products can replace 32-watt U-bend T8 or 17-watt T8 lamps one-for-one, and this measure incorporates those that replace the existing fluorescent lamp(s), remove the ballast(s), and use an external driver.

Description of Baseline Condition

The baseline condition is standard 32-watt, U-bend T8 or 2-foot, 17-watt T8 lamps.

Description of Efficient Condition

Efficient equipment must be DLC-listed in the Linear Replacement Lamps category, with a UL Type C primary use category. This measure is not intended to be used in refrigerated case lighting applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU$

Where:

$\text{Watts}_{\text{BASE}}$ = Annual electricity consumption of standard 32-watt U-bend T8 or 17-watt T8 lamps (= 29 watts for U-bend T8, = 20 watts for 2-foot T8; see Assumptions)

Watts_{EE} = Average annual electricity consumption of DLC-listed U-bend LED or 2-foot T8, UL Type C (= 15.2 watts for U-bend T8, = 11.1 watts for 2-foot T8)[3]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[4]	3,730
Industrial[4]	4,745
Agriculture[4]	4,698
Schools & Government[4]	3,239
Multifamily[5]	5,950

Summer Coincident Peak Savings Algorithm

$\text{kW}_{\text{SAVED}} = (\text{Watts}_{\text{BASE}} - \text{Watts}_{\text{EE}}) / 1{,}000 * \text{CF}$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[4]	0.77
Industrial[4]	0.77
Agriculture[4]	0.67
Schools & Government[4]	0.64
Multifamily[6]	0.77

Lifecycle Energy-Savings Algorithm

$\text{kWh}_{\text{LIFECYCLE}} = \text{kWh}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Annual Savings for LED Replacement of LED U-Bend or 2-Foot Lamp

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
U-Bend T8 Lamps w/ External Driver	4800	52	0.0106	66	0.0106	65	0.0093	45	0.0088	82	0.0106
2-Foot T8 Lamps w/ External Driver	4797	33	0.0069	42	0.0069	42	0.006	29	0.0057	53	0.0069

Lifecycle Savings for LED Replacement of LED U-Bend or 2-Foot Lamp (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
U-Bend T8 Lamps w/ External Driver	4800	572	726	715	495	902
2-Foot T8 Lamps w/ External Driver	4797	363	462	462	319	583

Assumptions

In discussions with the DLC, it has been determined that the rated lifetime hours reported in the DLC *Qualified Product List*[3] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC-certified. However, in these cases, manufacturer specification sheets often list actual L70 test data. Therefore, these data were used to obtain an average rated lifetime for participating models.[1]

Each baseline lamp wattage is sourced from the Focus on Energy Default Wattage Guide, where a 32-watt, T8 U-bend lamp is 29 watts and a 2-foot, 17-watt T8 lamp is 20 watts.

Sources

1. EUL based on LED 4-Foot T8 Lamps w/ External Driver SPECTRUM data. Online lookups from January 2018 and MMID 3511 participation data from January through December 2017 show that two participating models, comprising 3,950 units and 51% of total measure participation, have a specification sheet rated life of 50,000 hours. With an average HOU of 4,472, the EUL is 11 years.
2. 1000Bulbs. Website. Accessed September 2018. 1000bulbs.com
   Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
   Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com

Prolighting. Website. Accessed September 2018. prolighting.com
Bulbsdepot. Website. Accessed September 2018. bulbsdepot.com
LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com
Average U-bend LED cost from retail sources. Baseline lamps cost $7.31. Efficient lamps cost $17.88. Efficient lamp driver cost $28.95. Therefore, the incremental cost is $39.53.

3. 1000bulbs. Website. Accessed September 2018. 1000bulbs.com
   Warehouse-lighting. Website. Accessed September 2018. warehouse-lighting.com
   Atlantalightbulbs. Website. Accessed September 2018. atlantalightbulbs.com
   Prolighting. Website. Accessed September 2018. prolighting.com
   Bulbsdepot. Website. Accessed September 2018. bulbsdepot.com
   LEDt8bulb. Website. Accessed September 2018. ledt8bulb.com
   Average 2-foot LED cost from retail sources. Baseline lamps cost $2.71. Efficient lamps cost $10.60. Efficient lamp driver cost $23.50. Therefore, the incremental cost is $31.39.
4. DesignLights Consortium. *Product List.* Accessed September 18, 2016. https://www.designlights.org/search/
5. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use and Coincidence Factor by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Tetra Tech. *ACES Deemed Savings Desk Review*. Common Area Lighting Section, pp. 9–11. November 3, 2010. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
7. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	09/2018	Initial TRM entry

LED Track/Mono/Accent Fixtures

	Measure Details
Measure Master ID	LED Fixture, Track/Mono/Accent, 4813 LED Fixture, Track/Mono/Accent, In-Unit, 4814
Workpaper ID	W0131
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$2.29[2]

Measure Description

LED track, mono-point, and accent fixtures can replace existing non-solid-state fixtures without sacrificing performance, and these fixtures save energy because they consume less wattage than non-solid-state lighting products.

Description of Baseline Condition

The baseline is the power consumption of the existing lighting equipment.

Description of Efficient Condition

The efficient equipment is an ENERGY STAR or DLC rated fixture

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{LEDEE}) * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Per-fixture power consumption of current installed lighting equipment (= actual; provided by the Trade Ally for each project)

$Watts_{LEDEE}$ = Power consumption of qualified LED fixture (= actual; provided by the Trade Ally for each project)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[3]	3,730
Industrial[3]	4,745
Agriculture[3]	4,698
Schools & Government[3]	3,239
Multifamily – Common Area[4]	5,950
Multifamily – In Unit[5]	734

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LEDEE}) / 1,000 * CF$

Where:

CF = Coincidence factor (+ varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[3]	0.77
Industrial[3]	0.77
Agriculture[3]	0.67
Schools & Government[3]	0.64
Multifamily – Common Area[6]	0.77
Multifamily – In Unit[5]	0.055

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Average Annual Deemed Savings per Watt Reduced, Non-Res

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Track/Mono/Accent	4813	3.73	0.0008	4.75	0.0008	4.70	0.0007	3.24	0.0006

Average Annual Deemed Savings per Watt Reduced, Multifamily

Measure	MMIDs	Multifamily – Common Area		Multifamily – In Unit	
		kWh	kW	kWh	kW
LED Track/Mono/Accent	4813, 4814	5.95	0.0008	0.734	0.0006

Average Lifecycle Deemed Savings Per Watt Reduced, Non-Res

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov
LED Track/Mono/Accent	4813	41.03	52.25	51.70	35.64

Average Lifecycle Deemed Savings Per Watt Reduced, Multifamily

Measure	MMIDs	Multifamily – Common Area	Multifamily – In Unit
LED Track/Mono/Accent	4813, 4814	65.45	8.07

Assumptions

Incremental cost was calculated on a per-watt basis from the Focus on Energy historical program data from January 2015 to October 2018 for MMIDs 3736 and 3737. The average of the sector hours is from the Hours of Use by Sector table above, excluding the in-unit sector since the historical program data does not exist.

$$\text{Cost in \$/W} = [\text{Actual Measure Cost Sum}] / [\text{First Year kWh Savings} * 1{,}000 / \text{Average Sector Hours } (4{,}472)]$$

For multifamily new construction projects, a 2.0 factor of the proposed LED wattage was assumed to obtain the baseline wattage. This was based on ENERGY STAR qualified products' average source efficacy (83 LPW) for fixtures that fall under the measure scope (Accent Light Line-Voltage, Chandelier, Close to Ceiling Mount, Decorative Pendant, LED Surface Mount Wall Sconce Retrofit, Other, Pendant, and Wall Sconces) from October 2018, divided by the EISA 2020 45 lumen/watt screw-in source standard. The ratio of 1.84 was rounded to 2.0 to be conservative, and in recognition that Wisconsin residential code only requires 50% of installed lamps to be high efficiency. January through September 2018 multifamily program data indicates that there was no participation from any DLC products, hence an ENERGY STAR exclusive product list was used.

Sources

1. Average rated life of ENERGY STAR and DLC listed products divided by average nonresidential sector hours (47,051 / 4,472 = 10.52 years, rounded to 11 years). Qualifying equipment are complete luminaires and not replacement lamps.
2. SPECTRUM. Historical program data for MMIDs 3736 and 3737 based on 9,720 units from January 2015 to October 2018 applications.
3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3-2. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Tetra Tech. *ACES Deemed Savings Desk Review*. Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
5. Cadmus. "Focus on Energy Evaluated Deemed Savings Changes." November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
   2.01 hours per day and 5.5% coincidence factor for multifamily housing.
6. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	10/10/2018	Initial TRM entry, replacing MMIDs 3736 and 3737

LED Troffer, 1x4, Replacing 4’ 1- and 2-Lamp T8 Troffer

	Measure Details
Measure Master ID	LED Troffer, 1x4, Replacing 4-Foot 1- or 2-Lamp T8 Troffer, 3760
Workpaper ID	W0132
Measure Unit	Per luminaire or retrofit kit
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Schools & Government, Agricultural, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	13[1]
Measure Incremental Cost ($/unit)	$63.89[2]

Measure Description

LED 1x4 troffers save energy when replacing 1- or 2-lamp T8 products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace 1- or 2-lamp T8 luminaires.

Description of Baseline Condition

The baseline condition is 4-foot 1- and 2-lamp T8 troffers in existing buildings and new construction.

Description of Efficient Condition

The efficient condition is LED products that are DesignLights Consortium™ (DLC)-listed in the “1x4 Luminaires for Ambient Lighting of Interior Commercial Spaces,” “Integrated Retrofit Kits for 1x4 Luminaires,” or “Linear Retrofit Kits for 1x4 Luminaires” primary use categories, which consume ≤ 43 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Baseline wattage, or the average power consumption of a 1-lamp 32-watt T8 and a 2-lamp 32-watt T8, weighted 50%/50% (= 43.56 watts)[3]

$Watts_{EE}$ = Energy efficient wattage (= 27.3 watts)[4]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[5]	3,730
Industrial[5]	4,745
Agriculture[5]	4,698
Schools & Government[5]	3,239
Multifamily[6]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[5]	0.77
Industrial[5]	0.77
Agriculture[5]	0.67
Schools & Government[5]	0.64
Multifamily[7]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years)[1]

Deemed Savings

Annual Savings

Measure	MMID	Savings	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Troffer, 1x4, Replacing 4’ 1- and 2-Lamp T8 Troffer	3760	kWh	61	77	76	53	97
		kW	0.0125	0.0125	0.0109	0.0104	0.0125

Lifecycle Savings (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Troffer, 1x4, Replacing 4’ 1- and 2-Lamp T8 Troffer	3760	793	1,001	988	689	1,261

Assumptions

In discussions with the DesignLights Consortium™, it was determined that the rated lifetime hours reported in the DLC *Qualified Product List*[8] often do not reflect actual L70 test data. Despite DLC’s requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer spec sheets often do list actual L70 test data, so these data were used to obtain a weighted average rated lifetime for participating models.[1]

Sources

1. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. 4 participating models comprise >50% of total measure participation have a weighted average spec sheet rated life of 59,041 hours. With an average HOU of 4,472, the EUL is 13 years.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 571 projects and 18,558 units from January 2018 to July 2020 is $120.92. Base cost of $57.03 from online lookups of base models on or before December 2017. $120.92 - $57.03 = $63.89.
3. Consortium for Energy Efficiency. “Legacy Ballast List.” 2015.
4. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. Data cross-referenced with DLC QPL determining weighted average wattage.
5. PA Consulting Group. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0. Table 3-2 Lighting Hours of Use and Coincidence Factors by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

6. Tetra Tech. *ACES Deemed Savings Desk Review*. Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
7. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.
8. DesignLights Consortium™. *Product List.* Accessed August 2020. https://www.designlights.org/search/

Revision History

Version Number	Date	Description of Change
01	01/01/2013	Initial TRM entry
02	08/14/2015	Updated savings information
03	09/29/2017	Updated to include 1x4 LED troffer without controls (MMID 3760) and with controls (MMID 4334)
04	09/2020	Removed MMID 4334 and 4465. Updated Watts_{EE} and EUL.

LED Troffer, 2x4, Replacing 4-Foot, 3-4 Lamp T8 Troffer

	Measure Details
Measure Master ID	LED Troffer, 2x4, Replacing 4-Foot, 3-4 Lamp T8 Troffer, 3111
Workpaper ID	W0133
Measure Unit	Per luminaire or retrofit kit
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	N/A
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	N/A
Water Savings (gal/yr)	N/A
Effective Useful Life (years)	14[1]
Incremental Cost	$106.02[2]

Measure Description

LED 2x4 troffers save energy when replacing three-lamp or four-lamp T8 products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace three-lamp or four-lamp T8 luminaires.

Description of Baseline Condition

The baseline measure is 4-foot, three-lamp and four-lamp T8 troffers for existing buildings and new construction buildings.

Description of Efficient Condition

The efficient measures are LED products that are DesignLights Consortium™ (DLC)-listed in the “2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces,” “Integrated Retrofit Kits for 2x4 Luminaires,” or “Linear Retrofit Kits for 2x4 Luminaires” primary use categories, which consume 55 watts or less.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Average power consumption of three-lamp, 32-watt T8 and 4-lamp, 32-watt T8, weighted 50% each (= 97.3 watts)[3]

$Watts_{EE}$ = Energy efficient wattage (= 39.2 watts)[4]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[5]	3,730
Industrial[5]	4,745
Agriculture[5]	4,698
Schools & Government[5]	3,239
Multifamily[6]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[5]	0.77
Industrial[5]	0.77
Agriculture[5]	0.67
Schools & Government[5]	0.64
Multifamily[7]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 14 years)[1]

Deemed Savings

Annual Savings for LED Replacement of 4-Foot T8

Measure	MMID	Savings	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Troffer, 2x4, Replacing 4-Foot 3-4 Lamp T8 Troffer	3111	kWh	217	276	273	188	346
		kW	0.0447	0.0447	0.0389	0.0372	0.0447

Lifecycle Savings for LED Replacement of 4-Foot T8 (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Troffer, 2x4, Replacing 4-Foot 3-4 Lamp T8 Troffer	3111	3,038	3,864	3,822	2,632	4,844

Assumptions

In discussions with the DesignLights Consortium™, it was determined that the rated lifetime hours reported in the DLC *Qualified Product List*[8] often do not reflect actual L70 test data. Despite DLC's requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer spec sheets often do list actual L70 test.

Sources

1. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. 37 participating models comprise >50% of total measure participation have a weighted average spec sheet rated life of 62,168 hours. With an average HOU of 4,472, the EUL is 14 years.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 3,413 projects and 247,509 units from January 2018 to July 2020 is $114.00. Base cost of $7.98 from October 2019 online lookups of 32 watt T8 lamps, average of 3x and 4x. $114.00 - $7.98 = $106.02.
3. Consortium for Energy Efficiency. *Legacy Ballast List*. 2015.
4. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. Data cross-referenced with DLC QPL determining weighted average wattage.
5. PA Consulting Group. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0. Table 3-2 Lighting Hours of Use and Coincidence Factors by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

6. Tetra Tech. *ACES Deemed Savings Desk Review*. Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluation report.pdf
7. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.
8. DesignLights Consortium™. *Product List.* Accessed August 2020. https://www.designlights.org/search/

Revision History

Version Number	Date	Description of Change
01	01/01/2013	Initial TRM measure
02	08/14/2015	Updated savings information
03	11/11/2016	Updated savings information and definitions
04	10/2017	Updated EUL
05	11/2017	Added 2x4 measure with LLLC
06	2/2020	Updated incremental cost
07	09/2020	Removed MMID 4335 and 4466. Updated Watts_{EE} and EUL.

LED Troffer, 2x4, Replacing 4' 1- or 2-Lamp T8 Troffer

	Measure Details
Measure Master ID	LED Troffer, 2x4, Replacing 4-Foot 1- or 2-Lamp T8 Troffer, 4793
Workpaper ID	W0134
Measure Unit	Per luminaire or retrofit kit
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Schools & Government, Agricultural, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	14[1]
Measure Incremental Cost ($/unit)	$106.02[2]

Measure Description

LED 2x4 troffers save energy when replacing 1- or 2-lamp T8 products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace 1- or 2-lamp T8 luminaires.

Description of Baseline Condition

The baseline condition is 4-foot 1- and 2-lamp T8 troffers in existing buildings and new construction.

Description of Efficient Condition

The efficient condition is LED products that are DesignLights Consortium™ (DLC)-listed in the "2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces," "Integrated Retrofit Kits for 2x4 Luminaires," or "Linear Retrofit Kits for 2x4 Luminaires" primary use categories, which consume less than 44 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Baseline wattage, or the average power consumption of a 1-lamp 32-watt T8 and a 2-lamp 32-watt T8, weighted 50% each (= 43.56 watts)[3]

$Watts_{EE}$ = Energy-efficient wattage (= 31.5 watts)[4]

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU
Commercial[5]	3,730
Industrial[5]	4,745
Agriculture[5]	4,698
Schools & Government[5]	3,239
Multifamily[6]	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[5]	0.77
Industrial[5]	0.77
Agriculture[5]	0.67
Schools & Government[5]	0.64
Multifamily[7]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 14 years)[1]

Deemed Savings

Annual Savings

Measure	MMID	Savings	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Troffer, 2x4, Replacing 4’ 1- and 2-Lamp T8 Troffer	4793	kWh	45	57	57	39	72
		kW	0.0093	0.0093	0.0081	0.0077	0.0093

Lifecycle Savings (kWh)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Troffer, 2x4, Replacing 4’ 1- and 2-Lamp T8 Troffer	4793	630	798	798	546	1,008

Assumptions

In discussions with the DesignLights Consortium™, it was determined that the rated lifetime hours reported in the DLC *Qualified Product List*[8] often do not reflect actual L70 test data. Despite DLC’s requirement to provide lumen maintenance test data, manufacturers often simply report the minimum 50,000-hour threshold required to be DLC certified. However, in these cases, manufacturer spec sheets often do list actual L70 test

Sources

1. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. 5 participating models comprise >50% of total measure participation have a weighted average spec sheet rated life of 63,788 hours. With an average HOU of 4,472, the EUL is 14 years.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 3,413 projects and 247,509 units from January 2018 to July 2020 is $114.00. Base cost of $7.98 from October 2019 online lookups of 32 watt T8 lamps, average of 3x and 4x. $114.00 - $7.98 = $106.02.
3. Consortium for Energy Efficiency. “Legacy Ballast List.” 2015.
4. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. 1/1/19 to 6/30/20. Programs: LEU, BIP, MF, S&G, SBP, B&I, and Midstream. Data cross-referenced with DLC QPL determining weighted average wattage.
5. PA Consulting Group. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0. Table 3-2 Lighting Hours of Use and Coincidence Factors by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

6. Tetra Tech. *ACES Deemed Savings Desk Review*. Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
7. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.
8. DesignLights Consortium™. *Product List.* Accessed August 2020. https://www.designlights.org/search/

Revision History

Version Number	Date	Description of Change
01	01/01/2019	Initial TRM entry
02	2/2020	Updated incremental cost
03	09/2020	Removed MMID 4794. Updated Watts$_{EE}$ and EUL. Added Multifamily to tables.

Mogul Screw-Base (E39) Light Emitting Diode Lamp

	Measure Details
Measure Master ID	LED Lamp, DLC: High/Low-Bay Mogul Screw-Base (E39), 3962 High/Low-Bay Mogul Screw-Base (E39), Agriculture, 4703 Mogul Screw-Base (E39), Exterior, 3963
Workpaper ID	W0135
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	$143.44 for interior (MMIDS 3962 and 4703), $142.52 for exterior (MMID 3963)[2]

Measure Description

This measure is replacing interior or exterior HID, compact fluorescent or incandenscent lighting with modul screw bases (E39).

Description of Baseline Condition

The baseline equipment is interior or exterior HID, compact fluorescent or incandenscent lighting with modul screw bases (E39).

Description of Efficient Condition

The efficient condition is a Design Lights Consortium-listed mogul screw-base (E39) LED lamp, in the Mogul Screw-Base (E39) Replacements for HID Lamps category.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) * HOU / 1{,}000$

$= Watts_{REDUCED} * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Power consumption of baseline lamp

$Watts_{EE}$ = Power consumption of DLC-listed LED product

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see Hours of Use table below)

$Watts_{REDUCED}$ = Watt reduction

Hours of Use by Sector

Sector	HOU
Commercial[3]	3,730
Industrial[3]	4,745
Agriculture[3]	4,698
Schools & Government[3]	3,239
Multifamily[4]	5,950
Exterior[5]	4,380

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= varies by sector; see Concidence Factor table below)

Coincidence Factor by Sector

Sector	CF
Commercial[3]	0.77
Industrial[3]	0.77
Agriculture[3]	0.67
Schools & Government[3]	0.64
Multifamily[6]	0.77
Exterior	0.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years)[1]

Deemed Savings

Here, deemed savings are calculated on a per-watts reduced basis. The values in the Average Savings and Lifecycle Savings tables below indicate the savings from defining $\text{Watts}_{\text{REDUCED}}$ = 1 in the algorithm above for each sector.

Annual Savings (per Watt reduced)

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Interior	3962, 4703	3.73	0.0008	4.75	0.0008	4.7	0.0007	3.24	0.0006	5.95	0.0008
Exterior	3963	4.38	N/A	4.38	N/A	4.38	N/A	4.38	N/A	4.38	N/A

Lifecycle Savings (kilowatt-hours per Watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
Interior	3962, 4703	48.49	61.75	61.1	42.12	77.35
Exterior	3963	56.94	56.94	56.94	56.94	56.94

Sources

1. DesignLights Consortium. *Qualified Product List.* Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in high-bay HID to LED measures is 57,667 hours. With an HOU of 4,457 or 4,380, the EUL is 13 years.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM.
   Average cost of new mogul base LED lamps from October 2017 to September 2019 is $156.50. Base cost is $13.06 for interior and $13.98 for exterior per January 2020 online lookups at 1000bulbs.com, lightingsupply.com, amazon.com, and bulbs.com. For interior, lighting is assumed to be 80% HID, 10% CFL, and 10% incandescent. For exterior, lighting is assumed to be 90% HID, 5% CFL, and 5% incandescent. The incremental cost is therefore $143.44 for interior and $142.52 for exterior.
3. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0.” Updated March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

4. Tetra Tech. "ACES Deemed Savings Desk Review." Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
5. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This report includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
6. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	11/03/2016	Initial release
02	10/2017	Updated EUL
03	02/2020	Updated measure description and baseline condition text and baseline technology incremental cost
04	12/2020	Added Ag sector MMID

Bi-Level Controls for Interior and Parking Garages

	Measure Details
Measure Master ID	LED Fixture, Bi-Level: Stairwell and Passageway, 3097 Lighting Controls, Bi-Level: Parking Garage Fixtures, Dusk to Dawn, 5063 Parking Garage Fixtures, 24 Hour, 5064
Workpaper ID	W0136
Measure Unit	MMID 3097: Per fixture MMIDs 5063 and 5064: Per watt controlled
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	MMID 3097 = Light Emitting Diode (LED) MMIDs 5063 and 5064 = Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	LED Fixture = 15 (MMID 3097);[1, 2] Lighting Controls = 8 (MMIDs 5063 and 5064)[2]
Incremental Cost ($/unit)	See Incremental Cost By Measure table

Measure Description

Numerous existing installations use LED, fluorescent, ceramic metal halide, and pulse-start metal halide fixtures to light their interior stairwells and passageways as well as parking garages. These fixtures commonly operate in full light output 24 hours a day. Bi-level controls and replacement products use ultrasonic and passive infrared sensors to adjust the light output to a safe but energy-conserving low light level when these spaces become unoccupied. These products save energy by more efficiently lighting spaces based on occupancy.

Description of Baseline Condition

The baseline condition is LED, fluorescent, ceramic metal halide, and pulse-start metal halide fixture input wattages with no lighting controls at building interiors and parking garages.

Description of Efficient Condition

The efficient condition is individually controlled light fixtures that may include dimming, stepped dimming, high-low ballast controls, or a combination. Control must include a passive infrared or ultrasonic occupancy sensor (or both) with a fail-safe feature (where it fails in "on" position in case of sensor failure). Fixtures must operate in low-standby light level during vacancy and switch to full light output upon occupancy. The fixture cannot exceed 50% of full wattage during unoccupied periods.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{BASE} - kWh_{EE}$

$kWh_{BASE} = Watts_{BASE} * HOU / 1{,}000$

$kWh_{EE} = Watts_{EE} * HOU / 1{,}000 * [(1 - SF_{OCC}) + SF_{OCC} * (1 - SF_{DIM})]$

Where:

kWh_{BASE} = Energy consumption of baseline equipment (standard non-controlled fixture)

kWh_{EE} = Energy consumption of efficient equipment (bi-level controlled fixture)

$Watts_{BASE}$ = Input wattage of the baseline fixture (= 57.4 watts for MMID 3097,[3] = user input for MMIDs 5063 and 5064)

HOU = Hours of use (= 8,760 for parking garages, = 4,380 for dusk to dawn use, = varies by sector for interior; see table below)

Interior Hours of Use by Sector

Sector	Hours of Use
Commercial[9]	3,730
Industrial[9]	4,745
Agriculture[9]	4,698
Schools & Government[9]	3,239
Multifamily[10]	5,950

1,000 = Kilowatt conversion factor

$Watts_{EE}$ = Input wattage of efficient fixture on full power (= 36.8 watts for MMID 3097,[4] = $Watts_{BASELINE}$ for MMIDs 5063 and 5064)

SF_{OCC} = Occupancy savings factor, percentage of hours in unoccupied mode (= 73% for MMID 3097,[7] = 56.3% for MMIDs 5063 and 5064[8])

SF_{DIM} = Dimming savings factor, percentage dimmed in unoccupied mode (= 50% for MMID 3097,[5] = 60% for MMIDs 5063 and 5064[6])

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / HOU * CF$

Where:

CF = Coincidence factor (= 1 for 24/7 parking; = 0 for dusk to dawn parking; = varies by sector for interior; see table below)

Interior Coincidence Factor by Sector

Sector	CF
Commercial[9]	0.77
Industrial[9]	0.77
Agriculture[9]	0.67
Schools & Government[9]	0.64
Multifamily[11]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years for MMID 3097,[1,2] = 8 years for MMIDs 5063 and 5064[2])

Deemed Savings

Annual and lifecycle savings are shown in the following table.

Annual and Lifecycle Savings

Measure	MMID	Unit	Sector	Annual Savings (kWh)	Annual Savings (kW)	Lifecycle Savings (kWh)
LED Fixture, Bi-Level, Stairwell and Passageway	3097	Per fixture	Commercial	127	0.0262	1,905
			Industrial	161	0.0262	2,415
			Agriculture	160	0.0228	2,400
			Schools & Gov	110	0.0218	1,650
			Multifamily	202	0.0262	3,045
Lighting Controls, Bi-Level, Parking Garage Fixtures, Dusk to Dawn	5063	Per watt reduced	All	1.48	0.0000	11.8
Lighting Controls, Bi-Level, Parking Garage Fixtures	5064		All	2.96	0.0003	23.7

Assumptions

It was assumed that an exterior lamp for dusk to dawn use is "on" for an average of 4,380 hours (or 8,760 hours for 24/7 parking garages). Savings for interior are based on the sector hours.

General bi-level controls are able to and must achieve at least a 50% reduction in power requirements. This value is used for the dimming savings factor for stairwell and passageway measures.

For parking garage measures, the California Energy Commission indicates high and low wattages as shown in the table below. From this data, 60% was used as conservative value for the dimming savings factor.

High and Low Wattages for Dimming Savings Factor[6]

Site	High Wattage	Low Wattage	SF_{DIM}
Site 1	165	77	53.3%
Site 2	47	16	66.0%
Site 3	70	7	90.0%
Average	**282**	**100**	**64.5%**

Incremental Costs

Incremental costs are shown in the following table.

Incremental Cost by Measure

Measure	MMID	Unit	Incremental Cost	Source
LED Fixture, Bi-Level, Stairwell and Passageway	3097	Per fixture	$215.15	12
Lighting Controls, Bi-Level, Parking Garage Fixtures, Dusk to Dawn	5063	Per watt controlled	$0.78	13
Lighting Controls, Bi-Level, Parking Garage Fixtures	5064		$0.78	13

Sources

1. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 2019 through September 2020. Participation data and online lookups performed in October 2020 show that nine models, comprising 223 units and 78% of total measure participation, have an average specification sheet rated life of 91,300 hours for MMID 3097. With an average HOU of 4,472, their EUL is 20.4 years. Lighting EULs are capped at 20 years, which was applied to savings from the wattage upgrade. The lifetime for the controls upgrade is 8 years. Dividing total lifetime savings by total annual savings yields a mean EUL of 15 years.

2. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
3. Consortium for Energy Efficiency. *Legacy Ballast List*. Normal ballast factor and two-lamp, 32-watt T8 lamps. 2015. http://library.cee1.org/content/commercial-lighting-qualifying-products-lists
   Average input watts for 2-lamp, 32 watts per lamp, normal ballast factor (155 models).
4. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 2019 through September 2020. Participation data for MMID 3097 and online lookups performed in October 2020 show that the average of participating products is 36.8 watts.
5. The incentive catalog requirement for this measure is that when in unoccupied mode it cannot exceed 50% of full wattage, making the dimming savings factor = 100% - 50% = 50%.
6. California Energy Commission. Public Interest Energy Research Program. *Case Study: Bi-Level LED Parking Garage Luminaires*. https://cltc.ucdavis.edu/sites/default/files/files/publication/case-study-bi-level-led-garage-luminaires.pdf
   Average dimmed across the three test sites is 64.5%, conservatively rounded to 60%.
7. California Energy Commission. Public Interest Energy Research Program. *Project 5.1 Bi-Level Stairwell Fixture Performance Final Report.* October 2005. ww2.energy.ca.gov/publications/displayOneReport_cms.php?pubNum=CEC-500-2005-141-A16
   Average of "Time Dimmed(%)" across the four test sites during weekday operation (Table 2, pg. 22). Also cited by the New York TRM Version 7.0.
8. California Energy Commission. Public Interest Energy Research Program. *Case Study: Bi-Level LED Parking Garage Luminaires.* https://cltc.ucdavis.edu/sites/default/files/files/publication/case-study-bi-level-led-garage-luminaires.pdf
   Average occupied across the three test sites is 43.7%, therefore the occupancy savings factor is 56.3%. Also cited by the New York TRM Version 7.0.
9. PA Consulting Group. State of Wisconsin Public Service Commission of Wisconsin. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
10. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. Common Area Lighting Section. p. 9–11. http://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
11. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
    Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) coincidence factor of 65% to 89%.

12. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. 2016 to 2018. Average cost of 1,939 units over 101 projects.
13. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM for MMIDs 3251 and 3252. January 2019 to March 2020.
    Average cost of 1,158 fixures controlled over 29 projects is $0.78 per watt controlled, with an average of 81 watts controlled per fixture.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/2017	Updated EUL
03	01/2019	Removed MMIDs 3117, 3596, and 3597
04	10/2020	Updated savings algorithm, removed MMID 3343, replaced MMIDs 3251 and 3252 with new MMIDs that are per watt controlled

Delamping, T12 to T8, T8 to T8

	Measure Details
Measure Master ID	Delamping: T12 to T8, 4-Foot, 2276 T8 to T8, 2277 T12 to T8, 8-Foot, 3320
Workpaper ID	W0137
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	MMIDs 2276 and 2277 = Delamping MMID 3320 = Fluorescent, Linear
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

This measure is the permanent removal of standard T12 and T8 lamps from two, three, and four lamp 4-foot and 8-foot fixtures. Although the savings are not accounted for here, the measure requires:

- Delamped fixtures must also include upgrading the remaining lamps to HPT8 or RWT8 lamps.
- If a qualifying combination of lamps and ballast are installed, delamped fixtures can also qualify for incentives for HPT8 or RWT8 systems based on the number of lamps in the delamped fixture.

If the existing fixture contains standard T8 ballasts, the ballast is not required to be replaced. Only the lamps must be upgraded. In this case, the project would only qualify for a reduced watt lamp incentive if reduced watt lamps are used. The project would not qualify for a system upgrade incentive.

Description of Baseline Condition

The baseline condition is a weighted average of two, three, and four lamp T12 and T8 fixtures (see Assumptions for weighting metrics).

Description of Efficient Condition

The efficient condition is a weighted average of one, two, and three lamp low, normal, and high ballast factor T8 fixtures with 32-watt lamps (see Assumptions for weighting metrics).

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Watts of baseline equipment (existing standard T12 and T8 fixture(s))

$Watts_{EE}$ = Power consumption of efficient measure (delamped T8 fixture(s))

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU[2]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239
Multifamily	5,950

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[2]	0.77
Industrial[2]	0.77
Agriculture[2]	0.67
Schools & Government[2]	0.64
Multifamily[4]	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Average Annual Deemed Savings for Linear Fluorescent Delamping

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Delamping T12 to T8 (4-Foot)	2276	192	0.040	244	0.040	242	0.035	167	0.033	306	0.040
Delamping T8 to T8 (4-Foot)	2277	96	0.020	122	0.020	121	0.017	83	0.017	153	0.020
Delamping T12 to T8 (8-Foot)	3320	357	0.074	454	0.074	450	0.064	310	0.061	N/A	N/A

Average Lifecycle Deemed Savings for Linear Fluorescent Delamping

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
		kWh	kWh	kWh	kWh	kWh
Delamping T12 to T8 (4-Foot)	2276	1,920	2,440	2,420	1,670	3,060
Delamping T8 to T8 (4-Foot)	2277	960	1,220	1,210	830	1,530
Delamping T12 to T8 (8-Foot)	3320	3,570	4,540	4,500	3,100	N/A

Assumptions

Weighting of delamping quantities is based on historical program data.

The baseline condition is a weighted average of two, three, and four lamp T12 and T8 fixtures:

- Delamping T12 to T8 (4-Foot)
    - 2 Lamp (10%)
    - 3 Lamp (30%)
    - T12 - 4 Lamp (60%)
- Delamping T8 to T8
    - 2 Lamp (10%)
    - 3 Lamp (30%)
    - T8 - 4 Lamp (60%)
- Delamping T12 to T8 (8-Foot)
    - T12 - 2 Lamp (80%)
    - HOT12 - 2 Lamp (20%)

Efficient Condition:

- Delamping T12 to T8 (4-Foot)

  - 2 to 1 Lamp (10%)
  - 3 to 1 Lamp (5%)
  - 3 to 2 Lamp (25%)
  - 4 to 2 Lamp (50%)
  - T8 - 4 to 3 Lamp (10%)
- Delamping T8 to T8
  - 2 to 1 Lamp (10%)
  - 3 to 1 Lamp (5%)
  - 3 to 2 Lamp (25%)
  - 4 to 2 Lamp (50%)
  - T8 - 4 to 3 Lamp (10%)
- Delamping T12 to T8 (8-Foot)
  - T8 – 2 Lamp (8-Foot) to 2 Lamp (4-Foot) (100%)

Sources

1. Vermont Energy Investment Corporation. *State of Ohio Energy Efficiency Technical Reference Manual*. p. 169. August 6, 2010. http://s3.amazonaws.com/zanran_storage/amppartners.org/ContentPages/2464316647.pdf.
2. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
3. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
4. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2019	Removed MMID 3184

LED Signage Retrofit

	Measure Details
Measure Master ID	LED, Signage Retrofit, Interior, 3903 LED, Signage Retrofit, Exterior, 3904
Workpaper ID	W0138
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	Interior = $3.55[2] (MMID 3903) Exterior = $2.35[7] (MMID 3904)

Measure Description

This interior or exterior LED signage measure is intended for the replacement of incumbent signage light sources with an energy-efficient LED. Using LED technology saves energy over standard products by providing a similar lumen output at a lower input wattage.

Description of Baseline Condition

Baseline equipment is intended to be any incandescent, HID, fluorescent, or neon-lighted interior or exterior commercial signage. Replacement lamp products that intend to use existing sockets or lamp holders for electrical connection are not eligible.

Description of Efficient Condition

The efficient condition is LED products intended for use in sign lighting. Applications include, but are not limited to, channel lettering, backlit displays, and menu boards. A minimum 30% wattage reduction is required in order to be eligible. A qualified product list is not applicable at this time.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000 = Watts_{REDUCED} * HOU / 1,000$

Where:

$Watts_{BASE}$ = Power consumption of baseline installed signage system
$Watts_{EE}$ = Power consumption of LED signage product
1,000 = Kilowatt conversion factor
HOU = Hours of use (= varies by sector; see table below)

$Watts_{REDUCED}$ = Watt reduction

Hours of Use by Sector

Sector	HOU
Commercial[3]	3,730
Industrial[3]	4,745
Agriculture[3]	4,698
Schools & Government[3]	3,239
Multifamily[4]	5,950
Exterior[5]	4,380

Summer Coincident Peak Savings Algorithm

Exterior applications have no summer coincident peak savings.

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1,000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF
Commercial[3]	0.77
Industrial[3]	0.77
Agriculture[3]	0.67
Schools & Government[3]	0.64
Multifamily[6]	0.77
Exterior	0.00

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Annual Savings (per watt reduced)

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Signage Retrofit, Interior	3903	3.73	0.0008	4.75	0.0008	4.7	0.0007	3.24	0.0006	5.95	0.0008
LED Signage Retrofit, Exterior	3904	4.38	0.0000	4.38	0.0000	4.38	0.0000	4.38	0.0000	4.38	0.0000

Lifecycle kWh Savings (per watt reduced)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
LED Signage Retrofit, Interior	3903	41	52	51	36	65
LED Signage Retrofit, Exterior	3904	48	48	48	48	48

Assumptions

Reference workpapers[1,2] give incremental costs and savings on a per foot basis. The following formula was used to convert to a per-watt reduced cost metric, then averaged between sources:

$(kWh_{SAVED} / \text{Incremental Cost per foot}) / HOU * 1{,}000$

Sources

1. DesignLights Consortium. Qualified Product List. Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in LED signage measures is 50000 hours. With an HOU of 4,472, the EUL is 11 years.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 12 projects and 2,759 units from March 2018 to November 2019 is $3.65 per watt reduced. Base cost of $0.10 per watt reduced estimated from Decembver 2020 online lookups of T8 and metal halide lamps.

3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Tetra Tech. *ACES Deemed Savings Desk Review*. Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
5. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. "NOAA Solar Calculator." http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This also includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
6. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.
7. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 328 projects and 251,914 units from January 2018 to July 2020 is $2.45 per watt reduced. Base cost of $0.10 per watt reduced estimated from December 2020 online lookups of T8 and metal halide lamps.

Revision History

Version Number	Date	Description of Change
01	06/15/2016	Initial TRM entry
02	10/2017	Updated EUL
03	12/2020	Updated cost

LED Fixture, Downlights, ≤ 18 Watts, Replacing Incandescent Downlight, Exterior

	Measure Details
Measure Master ID	LED Fixture, Downlights, ≤ 18 Watts, Replacing Incandescent Downlight, Exterior, 3405
Workpaper ID	W0139
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	193
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	1,932
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$2.18[3]

Measure Description

LED downlight luminaires can replace existing incandescent luminaires without sacrificing performance; they save energy because they consume less wattage than the incandescent luminaries they replace. There is no demand reduction since this measure is used during evening and night lighting hours.

Description of Baseline Condition

The baseline measure is 50-watt to 72-watt incandescent luminaires.

Description of Efficient Condition

The efficient measure is ENERGY STAR-rated LED downlights that consume ≤ 18 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{INC} - Watts_{LED}) / 1{,}000 * HOU * Con_{FACT}$

Where:

$Watts_{INC}$ = Wattage of standard incandescent fixture (= 62)

$Watts_{LED}$ = Wattage of LED product (= 13)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= 4,380)

Con_{FACT} = Control factor (= 0.90)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (11 years)[1]

Assumptions

A weighted average of 16.66% each for 50-watt, 53-watt, 60-watt, 65-watt, 70-watt, and 72-watt incandescent luminaires was used to generate the baseline wattage. 4,380 hours run time of fixtures based on an annual average of 12 hours per day from NOAA data.[2] This also includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting. Applying a controls factor allows for a more conservative estimate of savings. Based on project experience, less than 10% of the exterior fixtures on the market have additional controls that may operate at conditions other than dusk to dawn.

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 8,139 LED downlight fixtures is 46,550 hours. With an HOU of 4,380, the EUL is 11 years.
2. U.S. Department of Commerce National Oceanic & Atmospheric Administration. “NOAA Solar Calculator.” http://www.esrl.noaa.gov/gmd/grad/solcalc/
3. August 2018 online lookups of four base and efficient models show an average efficient lamp price of $3.97 and base lamp price of $1.79, for an incremental cost of $2.18.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost

Exterior LED Downlights Luminaires > 18 Watts

	Measure Details
Measure Master ID	Exterior LED Downlights Luminaires > 18 Watts, 3404
Workpaper ID	W0140
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	226.3
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	2,263
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$20.03[3]

Measure Description

LED downlight luminaires can replace existing incandescent luminaires used for the same application without sacrificing performance. LED downlights save energy because they consume less wattage than the incandescent luminaries they replace.

Description of Baseline Condition

The baseline condition is 80-watt halogen and 50-watt to 100-watt HID luminaires.

Description of Efficient Condition

The efficient condition is ENERGY STAR-rated LED downlights that consume less than 18 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{INC} - kWh_{LED}$

$kWh_{INC} = Wattage_{INC} / 1{,}000 * HOU * CF$

$kWh_{LED} = Wattage_{LED} / 1{,}000 * HOU * CF$

Where:

kWh_{INC} = Annual electricity consumption of standard wattage incandescent fixtures

kWh_{LED} = Annual electricity consumption of LED products

Wattage = Instantaneous electric consumption of lamp or fixture

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 4,380)[3]

CF = Controls factor that accounts for the small percentage of systems in the market with additional controls (= 0.9)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Downlights > 18 Watts

Measure	Exterior 4380 (0.00)	
	Savings (kWh)	Savings (kW)
LED Downlights > 18 watts	226.3	0.0

Average Lifecycle Deemed Savings for LED Downlights > 18 Watts

Measure	Exterior 4380 (0.00)
	Savings (kWh)
LED Downlights > 18 watts	2,489

Assumptions

A weighted average of 25% each for 80-watt halogen, 50-watt HID, 70-watt HID, and 100-watt HID luminaires was used to generate the baseline wattage.
The 4,380 HOU was based on an annual average of 12 hours per day from NOAA data.[2] This includes when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.

Applying a controls factor allows for a more conservative savings estimate. Based on project experience, less than 10% of the exterior fixtures on the market have additional controls that may operate at conditions other than dusk to dawn.

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 8,139 LED downlight fixtures is 46,550 hours. With an HOU of 4,380, the EUL is 11 years.
2. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. NOAA Solar Calculator. http://www.esrl.noaa.gov/gmd/grad/solcalc/
3. August 2018 online lookups of four base and efficient models show an average efficient lamp price of $29.32 and base lamp price of $9.29, for an incremental cost of $20.03.

Revision History

Version Number	Date	Description of Change
01	04/2014	Initial TRM entry
02	10/2017	Updated EUL source
03	12/2018	Updated incremental cost

Exterior LED Fixtures Replacement

	Measure Details
Measure Master ID	LED Fixture, Exterior: Replacing 150–175 Watt HID, 3099, 3824 Replacing 250 Watt HID, 3102, 3825 Replacing 320–400 Watt HID, 3826 Replacing 400 Watt HID, 3107, 3827 Replacing 70–100 Watt HID, 3108, 3828
Workpaper ID	W0141
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by wattage
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by wattage
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

Exterior LED fixtures are an energy-saving alternative to traditional standard wattage HID light sources that have been used for the same applications. LED light sources can be applied in almost every common application type where HID light sources are currently found. This measure is only for replacing existing HID fixtures.

Description of Baseline Condition

The baseline condition is existing HID lamps between 70 watts and 400 watts.[2]

Description of Efficient Condition

The efficient condition is LED fixtures that meet program requirements. Replacements must be complete fixtures or a retrofit of interior components with a total power reduction of 40% or more. Lamp-only replacements are not eligible for an incentive. LEDs must be on the qualifying DLC list.[3]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) /1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Wattage of standard HID fixture (= varies by measure; see table below)

$Watts_{EE}$ = Wattage of LED fixture (= varies by measure; see table below)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= 4,380)

Wattages Used for Deemed Savings Calculations[4]

Measure	MMID	$Watts_{BASE}$	$Watts_{EE}$
Exterior LED replacing 70-watt to 100-watt HID Average	3108, 3828	111.5	31
Exterior LED replacing 150-watt to 175-watt HID Average	3099, 3824	194.5	59
Exterior LED replacing 250-watt HID Average	3102, 3825	299.0	94
Exterior LED replacing 400-watt HID	3107, 3827	463.0	178

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years)[1]

Deemed Savings

Average Annual Deemed Savings for Exterior LED Fixtures

Measure	MMID	kWh	kW
Exterior LED replacing 70-watt to 100-watt HID Average	3108, 3828	353	0
Exterior LED replacing 150-watt to 175-watt HID Average	3099, 3824	593	0
Exterior LED replacing 250-watt HID Average	3102, 3825	898	0
Exterior LED replacing 400-watt HID	3826, 3107, 3827, 3290	1,248	0

Average Lifecycle Deemed Savings for Exterior LED Fixtures

Measure	MMID	kWh
Exterior LED replacing 70-watt to 100-watt HID Average	3108, 3828	4,589
Exterior LED replacing 150-watt to 175-watt HID Average	3099, 3824	7,709
Exterior LED replacing 250-watt HID Average	3102, 3825	11,674
Exterior LED replacing 400-watt HID	3826, 3107, 3827, 3290	16,224

Assumptions

Calculations are based on exterior lighting that operates 4,380 hours annually, 12 hours per day (dusk to dawn).

LED lamps can achieve a 40% reduction in power requirements.

Sources

1. DesignLights Consortium. *Qualified Product List.* Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in exterior HID to LED measures is 57,025 hours. With an HOU of 4,380, the EUL is 13 years.
2. Online research.
3. Design Lights Consortium. *Qualified Products List*.
4. Wisconsin Focus on Energy. *Default Wattage Guide*. Version 1.0. 2013.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/2017	Updated EUL
03	05/2018	Corrected savings values per 2017 deemed savings
04	01/2019	Removed MMIDs 3289, 3301, 3105, 3106, 3303, and 3304
05	2/2020	Updated incremental costs in Appendix D

LED, Horizontal Case Lighting

	Measure Details
Measure Master ID	LED, Horizontal Case Lighting, 3114
Workpaper ID	W0143
Measure Unit	Linear foot of lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	134
Peak Demand Reduction (kW)	0.015
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	938
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	7[1]
Incremental Cost ($/unit)	$27.17[2]

Measure Description

Light emitting diode (LED) fixtures use less electricity than fluorescent fixtures to produce an equivalent amount of light, and they produce less heat, reducing the amount of cooling load on the refrigeration system and the energy needed to the refrigeration compressor. Additionally, LEDs offer a more even light distribution on the refrigerated product, better showcasing it and making it appear to “pop” in the case.

Description of Baseline Condition

The baseline condition is horizontal F58 T8 linear fluorescent lamp with normal ballast factor electronic ballast in refrigerated display cases.

Description of Efficient Condition

The efficient condition is DLC-qualified horizontal LED lighting in refrigerated display cases.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = ((Watts_{BASE} – Watts_{EE}) + (Watts_{BASE} – Watts_{EE}) / COP) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Wattage of the linear fluorescent case lighting (= 15 watts for 4 feet of 60-watt fixtures)[3]

$Watts_{EE}$ = Wattage of the LED case lighting (= 4.419 watts)[4]

COP = Coefficient of performance (= 2.225 weighted average, = 2.3 for non-self-contained coolers, = 1.4 for non-self-contained freezers)[5]

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 8,760)[6]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = ((Watts_{BASE} – Watts_{EE}) + (Watts_{BASE} – Watts_{EE}) / COP) / 1{,}000$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=7 years)[1]

Assumptions

The majority of open multideck-style cases in the market are cooler cases; however, there are also open multideck-style cases for freezer applications present in Wisconsin, although very rare to find in stores. In order to accurately portray the market, a weighted average of 95% cooler cases and 5% freezer cases, based on historical site audits and discussions with grocery owner and store managers in Wisconsin since 2008.

The low temperature and medium temperature system coefficient of performances are derived from the information on Table 3-7 of the U.S. DOE Publication ID 6180. The capacity and power values were calculated to yield the EER, then converted to coefficient of performance (based on COP = EER / 3.412).

Sources

1. DesignLights Consortium. Qualified Product List. Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in LED refrigeration lighting measures is 63,940 hours. With an HOU of 8,760, the EUL is 7 years.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 141 projects and 32,626 units from April 2018 to September 2019 is $27.90. Base cost of $0.73 per foot. $27.90 - $0.73 = $27.17.
3. Philips Advance. “2016-2017 Atlas Full Line Guide to LED Drivers, LED Modules, Ballasts and Lighting Controls.” p. 3-68. March2016. http://images.philips.com/is/content/PhilipsConsumer/PDFDownloads/United%20States/ODLI20160307_001_UPD_en_US_PAd-1522BR_Atlas2016.pdf
   F58T8 Refrigeration Lamps using ICN-2S54-N ballast.

4. DesignLights Consortium. Product List. March 30, 2016. https://www.designlights.org/QPL Average measured wattage taken from listed products in the Horizontal Refrigerated Case Luminaires primary use category.
5. U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office. “Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration.” DOE Publication ID 6180. Table 3-7. September 2009. https://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
6. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	03/2017	Removed MMID 3335, modified savings
03	10/2017	Updated EUL
04	12/2018	Updated incremental cost
05	2/2020	Updated incremental cost

LED, Vertical Case Lighting, Replacing Linear Fluorescent

	Measure Details
Measure Master ID	LED, Reach-In Refrigerated Case, Replacing T12 or T8, 2456
Workpaper ID	W0144
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	650
Peak Demand Reduction (kW)	0.074
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	4,550
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	7[1]
Incremental Cost ($/unit)	$60.40[6]

Measure Description

LED fixtures use less electricity than fluorescent fixtures to produce an equivalent amount of light, and they produce less heat, reducing the amount of cooling load on the refrigeration system and the energy needed to the refrigeration compressor. Additionally, LEDs offer a more even light distribution on the refrigerated product, showcasing it better and making it appear to “pop” in the case.

Description of Baseline Condition

The baseline condition is vertical F58 T8 linear fluorescent lamp with normal ballast factor electronic ballast in refrigerated display cases.

Description of Efficient Condition

The efficient condition is DLC-qualified vertical LED lighting in refrigerated display cases.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = ((Watts_{BASE} – Watts_{EE}) + (Watts_{BASE} – Watts_{EE}) / COP) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Wattage of the linear fluorescent case lighting (= 60)[2]

$Watts_{EE}$ = Wattage of the LED case lighting (= 17.73)[3]

COP = Coefficient of performance (= 1.52 weighted average: 2.3 for non-self-contained coolers,[4] 1.4 for non-self-contained freezers,[4] 0.5 for self-contained coolers,[5] and 0.6 for self-contained freezers)[5]

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 8,760)[5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * (1 + 1 / COP) / 1,000$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 7 years)[1]

Assumptions

Based on historical Wisconsin program installations, it is assumed that the fixtures are upgraded to LEDs in self-contained cases 10% of the time and in non-self-contained cases 90% of the time. It is also assumed that the fixtures are upgraded to LEDs in coolers 25% of the time and freezers 75% of the time as the majority of cases with doors are still freezer cases; however, more and more customers are beginning to install cases with doors for cooler applications.

The self-contained coefficient of performance is converted from the kW per horsepower of each size tier in Tables 4-71 and 4-72 of the Business Programs: Deemed Savings Manual V1.0. The kW per horsepower is converted to kW per ton, where 1 ton of refrigeration = 4.7143 hp, then is converted to COP, where COP = 12 / kW per ton / 3.412. The average COP for self-contained coolers and freezers is calculated based on the weighting from Tables 4-71 and 4-72.

Sources

1. DesignLights Consortium. Qualified Product List. Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in LED refrigeration lighting measures is 63,940 hours. With an HOU of 8,760, the EUL is 7 years.
2. Philips Advance. "Lighting Electronics Atlas 2016-2017." F58T8 Refrigeration Lamps using ICN-2S54-N ballast, p. 3-68. http://images.philips.com/is/content/PhilipsConsumer/PDFDownloads/United%20States/ODLI20160307_001_UPD_en_US_PAd-1522BR_Atlas2016.pdf
3. DesignLights Consortium. *Qualified Product List for Vertical Refrigerated Case Luminaires.* Average of rated wattages. March 30, 2016.

4. U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office. "Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration." DOE Publication ID 6180. Table 3-7. September 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
The capacity and power values were calculated to yield the EER, then converted to COP based on COP = EER / 3.412.
5. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 758 projects and 20,599 units from April 2018 to September 2019 is $67.29. October 2019 online lookups of 3 models show average base cost of $6.89. $67.29 - $6.89 = $60.40.

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Update from Focus on Energy Deemed Savings Manual
02	04/2017	Added MMID 4095
03	10/2017	Updated EUL
04	12/2018	Updated incremental cost, removed MMID 4095
05	2/2020	Updated incremental cost

LED Lamp Replacing Incandescent Lamp ≤ 40 Watts

	Measure Details
Measure Master ID	LED, ≤ 40 Watt, ENERGY STAR, Replacing Incandescent, 3112
Workpaper ID	W0145
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$2.12[4]

Measure Description

ENERGY STAR-rated LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent lamps. This measure will provide an energy-efficient alternative to using incandescent lamps in several applications.

Description of Baseline Condition

The baseline condition is standard 25-watt and 40-watt incandescent lamps.

Description of Efficient Condition

Efficient equipment must be an ENERGY STAR-rated LED lamp.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * HOU$

Where:

$Watts_{BASE}$ = Average consumption of standard 25-watt or 40-watt incandescent lamp (= 32.5 watts)

$Watts_{EE}$ = Consumption of reduced ENERGY STAR-rated lamp of equivalent lumen output to ≤ 40-watt incandescent (= 6 watts)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU[2]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[3]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing Incandescent Lamp ≤ 40 Watts

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Lamps ENERGY STAR ≤ 40 Watts	3112	100	0.0204	127	0.0204	126	0.0178	87	0.0169

Average Lifecycle Deemed Savings for LED Lamp Replacing Incandescent Lamp ≤ 40 Watts

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov
		kWh	kWh	kWh	kWh
LED Lamps ENERGY STAR ≤ 40 Watts	3112	500	635	630	435

Assumptions

Assumes an average of 25-watt and 40-watt incandescent lamps in calculation of baseline usage.

Assumes that average ENERGY STAR-rated LED of 5.64 watts for ≤ 40-watt replacement products.

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/ Average rated life of 3,453 omnidirectional and decorative LEDs is 21787 hours. With a sector-averaged HOU of 4,103, the EUL is 5 years.
2. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use and Coincidence Factors by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use and Coincidence Factors by Sector. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. August 2018 online lookups of four base and efficient models on www.1000bulbs.com and www.bulbs.com show an average efficient lamp price of $2.88 and base lamp price of $0.76, for an incremental cost of $2.12.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost

LED Lamp Replacing Incandescent Lamp > 40 Watts

	Measure Details
Measure Master ID	LED, > 40 Watt, ENERGY STAR, Replacing Incandescent, 3113, 3821
Workpaper ID	W0146
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$1.64[4]

Measure Description

ENERGY STAR-rated LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent lamps. This measure will provide an energy-efficient alternative to using incandescent lamps in several applications.

Description of Baseline Condition

The baseline condition is standard 53-watt, 60-watt, 65-watt, 70-watt, 72-watt, and 80-watt incandescent lamps.

Description of Efficient Condition

Efficient equipment must be an ENERGY STAR-rated LED lamp.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Average power consumption of standard incandescent lamps (= 66.7 watts)

$Watts_{EE}$ = Power consumption of ENERGY STAR-rated LED lamp with a lumen output rating equivalent to a > 40-watt incandescent (= 14.2 watts)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU[2]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[3]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing Incandescent Lamp > 40 Watts

Measure	MMID	Commercial		Industrial		Agriculture		Schools & Gov	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
LED Lamps ENERGY STAR > 40 Watts	3113, 3821	196	0.0404	249	0.0404	247	0.0352	170	0.0336

Average Lifecycle Deemed Savings for LED Lamp Replacing Incandescent Lamp > 40 Watts

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Gov
		kWh	kWh	kWh	kWh
LED Lamps ENERGY STAR > 40 Watts	3113, 3821	980	1,245	1,235	850

Assumptions

An average of 16.67% each of 53-watt incandescent, 60-watt incandescent and halogens, 65-watt incandescent, 70-watt halogens, 80-watt halogens, and 100-watt halogen lamps was used to generate the baseline wattage.[3]

An average of 20% each of 9-watt, 11-watt, 13-watt, 18-watt, and 20-watt ENERGY STAR-rated LED lamps was used to generate the new wattage.[3]

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21,787 hours. With a sector-averaged HOU of 4,103, the EUL is 5 years.
2. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
3. Based on market knowledge.
4. August 2018 online lookups of four base and efficient models on www.1000bulbs.com and www.bulbs.com show an average efficient lamp price of $2.88 and base lamp price of $1.24, for an incremental cost of $1.64.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost

LED Exit Signs

	Measure Details
Measure Master ID	LED Exit Sign, Retrofit, 2768 LED Exit Sign, Retrofit, Pack-Based, 4687
Workpaper ID	W0148
Measure Unit	Per sign
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[5]
Incremental Cost ($/unit)	Prescriptive = $16.24 (MMID 2768)[6] Pack-Based = $10.49 (MMID 4687)[7]

Measure Description

Exit signs that have earned the ENERGY STAR label use 5 watts or less, compared to standard signs that use up to 40 watts.[1] Savings result from replacing incandescent or fluorescent exit signs with LED exit signs, which use significantly less electricity. The savings estimate assumes that both incandescent and fluorescent exit signs undergo early replacement rather than replacement at failure.

Description of Baseline Condition

The baseline condition is an incandescent (40 watt) or CFL (16 watt) exit sign with one or two bulbs.

Description of Efficient Condition

The efficient condition is an LED exit sign where the fixture meets ENERGY STAR v2.0 specifications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * HOU * ISR$

Where:

$Watts_{BASE}$ = Wattage of baseline measure (= 11 for CFL exit sign; = 35 for incandescent exit sign)[3]

$Watts_{EE}$ = Wattage of LED exit sign (= 1.67 for MMID 2768;[9] = 4.0 for MMID 4687[2])

1,000 = Kilowatt conversion factor

HOU = Hours of use (= 8,760)[4]

ISR = In-service rate (= 1 for prescriptive measures, = 0.66 for pack-based measures)[8]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * CF * ISR$

Where:

CF = Coincidence factor (= 1.0)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[5]

Deemed Savings

Annual and Lifecycle Savings for LED Exit Signs

Type of Savings	MMID	Baseline Measure Type		
		CFL	Incandescent	Default
Annual Energy Savings (kWh)	2768	82	292	187
	4687, Pack Based	--	--	110
Peak Demand Reduction (kW)	2768	0.0093	0.0333	0.02115
	4687, Pack Based	--	--	0.0125
Lifecycle Energy Savings (kWh)	2768	820	2,920	1,870
	4687, Pack Based	--	--	1,100

Assumptions

The default assumption is generated using 50% CFL replacements and 50% incandescent replacements. For comparison, the Illinois TRM[10] assumes a 70% incandescent versus 30% CFL split, so using a 50/50 split is more conservative (lower savings).

Sources

1. ENERGY STAR. “ENERGY STAR Savings Calculator.” http://www.energystar.gov/index.cfm?c=exit_signs.pr_exit_signs
2. AM Conservation. “LED Screw-In Exit Sign Retrofit Kit.” Website. Accessed March 2018. http://www.amconservationgroup.com/products/energy-efficient-lighting/led-screw-in-exit-

sign-retrofit-kit/?variation_id=2195
Pack-based measures are 4.0 watts.

3. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency*. Version 6.0, Volume 2. February 8, 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_2_C_and_I_020817_Final.pdf
4. Shelter Analytics and Northeast Energy Efficiency Partnership. *Mid-Atlantic Technical Reference Manual*. Version 7.0. May 2017. http://www.neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V7_FINAL.pdf
5. Lithonia. Website. Accessed March 2018. http://www.lithonia.com/commercial/lqm.html#.WXzqHVGQyM8

   Cooper Industries. Website. Accessed March 2018. http://www.cooperindustries.com/content/dam/public/lighting/products/documents/sure_lites/spec_sheets/sure-lites-apxel-adx121365-sss.pdf
   Grainger Exit Signs. Website. Accessed March 2018. https://www.grainger.com/ec/pdf/COMPASS-CCE-Exit-Series-Spec-Sheet.pdf
   Lifetime of 10 years is cited for above products.
6. October 2018 online lookups of 6 base and efficient models show an average efficient fixture price of $18.31 and base bulb price of $2.07, for an incremental cost of $16.24.
7. Quote from Resource Action Programs. March 2018.
8. Navigant. *ComEd Rural Small Business Energy Efficiency Kits IPA Program Impact Evaluation Report*. Table 7.1, p. 10. August 1, 2018. http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_PY9_Rural_SB_EE_Kits_IPA_Program_Impact_Evaluation_Report_2018-08-01.pdf
   In-service rate for MR-16 lamp used as subsititute for LED exit sign retrofit to represent a more difficult installation process than a typical A-lamp LED.
9. Historical Focus on Energy project data. SPECTRUM. January 1, 2017 to June 29, 2018. Multifamily Energy Savings Program MMID 2768 had 57 projects with 755 exit signs (note that three projects with 45 exit signs were excluded due to not being able to determine wattage from specification sheet provided for the project). Weighted average of the installed exit signs was 1.67 watts.
10. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0, Volume 2: Commercial and Industrial*. February 8, 2017. p. 377. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_2_C_and_I_020817_Final.pdf

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	03/2018	Added pack-based measure

DLC High Bay < 18,500 Lumens Replacing or Instead of 6L T8 or 4L T5HO

	Measure Details
Measure Master ID	DLC HB <18,500 Lumens, Replacing or Instead of 6L T8 or 4L T5HO, 3809
Workpaper ID	W0149
Measure Unit	Per luminaire
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Lighting Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$224.14[2]

Measure Description

LED high bay fixtures save energy when replacing 4-lamp T5HO or 6-lamp T8 high bay products by providing a similar lumen output with lower input wattage. These products can be installed on a one-for-one basis to replace 4-lamp T5HO or 6-lamp T8 high bay luminaires.

Description of Baseline Condition

The baseline condition is a combination of 4-foot 4-lamp T5HO and 6-lamp T8 high/low bay fixtures for existing buildings and new construction buildings. An average of 25% 4-foot 4-lamp T5HO and 75% 6-lamp T8 high/low bay luminaires was used to generate the baseline wattage (see Assumptions).

Description of Efficient Condition

The efficient condition is a DesignLights Consortium-listed LED fixture in the High-Bay General Application, outputting less than 18,500 lumens.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1{,}000$

Where:

$Watts_{BASE}$ = Average power consumption of current 4-lamp T5HO and 6-lamp T8 high/low bay luminaires (= 226.5 watts; see Assumptions)

$Watts_{EE}$ = Average power consumption of DLC-listed LED high/low bay luminaire (= 118 watts)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU[3,4]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239
Multifamily	5,950

Summer Coincident Peak Savings Algorithm

Exterior applications have no summer coincident peak savings.

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) * CF / 1{,}000$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[3,5]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64
Multifamily	0.77

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Annual Savings for DLC HB < 18,500 Lumens Replacing or Instead of 6L T8 or 4L T5HO

Commercial		Industrial		Agriculture		Schools & Gov		Multifamily	
kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
405	0.0837	516	0.0837	511	0.0728	352	0.0696	647	0.0837

Lifecycle Savings for DLC HB < 18,500 Lumens Replacing or Instead of 6L T8 or 4L T5HO

Commercial	Industrial	Agriculture	Schools & Gov	Multifamily
4,455	5,676	5,621	3,872	7,117

Assumptions

Fixture weightings are based on a combination of feedback from energy audit experience, Lighting Certified individuals through the National Council on Qualifications for the Lighting Professions, and individuals with lighting sales experience. Each fixture wattage is sourced from the Focus on Energy Default Wattage Guide.

Sources

1. DesignLights Consortium. Qualified Product List. Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in linear LED measures is 51,160 hours. With an HOU of 4,472, the EUL is 11 years.
2. August 2018 online lookups of four base and efficient models on www.1000bulbs.com, www.bulbs.com, www.lightbulbsupply.com, www.topbulb.com, and www.warehouse-lighting.com show an average efficient fixture price of $236.90 and base bulb price of $12.76, for an incremental cost of $224.14.
3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/ sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

4. Tetra Tech. *ACES Deemed Savings Desk Review*. Table 1. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
5. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	07/29/2016	Replaces MMID 3393
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost, removed MMID 3901

High Bay Fluorescent Lighting

	Measure Details
Measure Master ID	High Bay Fluorescent Lighting: T8 4L Replacing 250-399 W HID, 3811 T8 6L Replacing 400-999 W HID, 3812 T5HO 4L Replacing 400-999 W HID, 3813 T5HO 6L Replacing 400-999 W HID, 3814
Workpaper ID	W0150
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Fluorescent, Linear
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Varies by measure
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

In high-bay lighting applications (ceiling heights generally over 15 feet), HID fixtures have typically been used due to their high lumen output. In recent years, however, improvements in fluorescent lamps and the emergence of new high-intensity fluorescent fixtures have made fluorescent lighting the most cost-effective choice for lighting high indoor spaces. These high-intensity fluorescent systems are more energy efficient than HID solutions and feature lower lumen depreciation rates, better dimming options, virtually instant start-up and re-strike, better color rendition, and reduced glare. Similar high-intensity fluorescent lighting fixtures are also available for low bay applications, generally with equipment available in the same product family as the manufacturers' high bay products.

Description of Baseline Condition

The baseline condition is HID fixtures and lamps.

Description of Efficient Condition

The efficient condition varies by the wattage of the baseline lamp (see table below).

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Wattage of a HID lamp (= varies by measure; see table below)

$Watts_{EE}$ = Wattage of HOT5 or HOT8 lamp (= varies by measure; see table below)

Wattages Used for Deemed Savings Calculations

Measure	$Watts_{BASE}$	$Watts_{EE}$
2L HOT5	293	117
3L HOT5	293	179
4L T8	293	151
4L HOT5	356	234
6L T8	356	224
4L HOT5	455	234
6L HOT5	455	355
6L T8	455	224
8L T8	455	291
6L HOT5	1,079	355
8L HOT5	1,079	585
(2) 4L HOT5	1,079	468
(2) 6L HOT5	1,079	709
8L T8	1,079	291
10L T8	1,079	366
(2) 6L T8	1,079	447

1,000 = Kilowatt conversion factor

HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU[2]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[2]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (3811, 3813, 3814 = 14 years[1] and 3812 = 15 years)[2]

Deemed Savings

Annual Electric Savings (kWh/year/lamp removed)

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Government
T8 4L Replacing 250-399 W HID	3811	532	676	669	462
T5HO 4L Replacing 400-999 W HID	3813	824	1,049	1,038	716
T5HO 6L Replacing 400-999 W HID	3814	375	477	472	326
T8 6L Replacing 400-999 W HID	3812	863	1,098	1,088	750

Summer Peak Savings

Measure	MMID	Commercial	Industrial	Agriculture	Schools & Government
T8 4L Replacing 250-399 W HID	3811	0.11	0.11	0.095	0.091
T5HO 4L Replacing 400-999 W HID	3813	0.17	0.17	0.148	0.141
T5HO 6L Replacing 400-999 W HID	3814	0.077	0.077	0.067	0.064
T8 6L Replacing 400-999 W HID	3812	0.178	0.178	0.155	0.148

Lifecycle Savings (kWh)

New Fixture Type	MMID	Commercial	Industrial	Agriculture	Schools & Government
T8 4L Replacing 250-399 W HID	3811	7,441	9,466	9,373	6,462

New Fixture Type	MMID	Commercial	Industrial	Agriculture	Schools & Government
T5HO 4L Replacing 400-999 W HID	3813	11,541	14,681	14,536	10,021
T5HO 6L Replacing 400-999 W HID	3814	5,248	6,676	6,610	4,557
T8 6L Replacing 400-999 W HID	3812	12,089	15,379	15,226	10,498

Sources

1. Average of: Cadmus 2013 database;
   2007 GDS residential measure life report: http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf;
   California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
   PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010.
   https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
2. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." EUL Table. 2014. http://www.deeresources.com/
   Rated ballast life of 70,000 hours. Not rated on bulb life as such capped at 15 years.
3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010.
   https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	10/2016	Removed MMID 2885
03	04/2017	Added MMID 2885
04	01/2019	Removed MMIDs 2884, 3329, 3331, 2886, 2887, 3333, 2888, 2889, 2885, 2890, 3330, 2891, 2892, 3332, 2893, 2894, 3334, 2895, 2896, and 2897

Exterior – Induction, PSMH, CMH, Linear Florescent Fixtures

	Measure Details
Measure Master ID	Induction, PSMH/CMF or Linear Fluorescent, Exterior: Replacing 150-175 Watt HID, 3829 Replacing 250 Watt HID, 3830 Replacing 320 -Watt HID, 3084 Replacing 400 Watt HID, 3832 Replacing 70-100 Watt HID, 3833
Workpaper ID	W0151
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Other
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by fixture
Peak Demand Reduction (kW)	Varies by fixture
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by fixture
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

Induction, PSMH, CMH, and linear fluorescent lighting fixtures save energy by reducing the light fixture wattage compared to standard metal halide fixtures, without sacrificing illumination quality and safety. These lighting technologies are appropriate for exterior applications.

Description of Baseline Condition

The baseline measure is standard HID lamps between 70 watts and 400 watts, located on exterior poles or high canopies.

Description of Efficient Condition

The efficient measure is induction, PSMH, CMH, and linear fluorescent fixtures between 35 watts and 250 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Wattage of baseline HID fixture
$Watts_{EE}$ = Wattage of efficient induction fixture, PSMH fixture, CMH fixture, or linear fluorescent fixture
1,000 = Kilowatt conversion factor
HOU = Hours of use (= 4,380)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Deemed Savings by Measure

Measure	MMID	Annual Savings (kWh)	Peak Demand Reduction (kW)	Lifecycle Savings (kWh)
Induction, PSMH/CMH, or Linear Fluorescent, Replacing 70-Watt to 100-Watt HID, Exterior	3833	247	0	3,712
Induction, PSMH/CMH, or Linear Fluorescent, Replacing 150-Watt to 175-Watt HID, Exterior	3829	329	0	4,938
Induction, PSMH, CMH, or Linear Fluorescent Replacing 250-Watt HID, Exterior	3830	605	0	9,076
Induction, PSMH, CMH, or Linear Fluorescent Replacing 320-Watt HID, Exterior	3084	556	0	8,344
Induction, PSMH, CMH, or Linear Fluorescent Replacing 400-Watt HID, Exterior	3832	972	0	14,585

Assumptions

The induction wattages shown below include the ballast wattage, which was calculated as 10% of the lamp wattage based on the manufacturer specifications. All exterior replacement calculations use 4,380 hours of annual operation, half the total hours in a year.

70-watt to 100-watt HID exterior replacements are weighted as follows:

- Baseline = 50% 70-watt HID and 50% 100-watt HID (= 111.5 watts)
- Eligible Replacements = 50% linear fluorescent ≤ 60 watts, 25% 35-watt induction, and 25% 55-watt induction (= 55 watts)

150-watt to 175-watt HID exterior replacements are weighted as follows:

- Baseline = 50% 150-watt HID and 50% 175-watt HID (= 194.5 watts)
- Eligible Replacements = 33.33% 100-watt induction, 33.33% 100-watt PSMH or CMH, and 33.33% ≤ 120-watt linear fluorescent (= 119 watts)

250-watt HID exterior replacements are weighted as follows:

- Baseline = 100% 250-watt HID (= 299 watts)
- Eligible Replacements = 14.3% 120-watt to 125-watt induction, 14.3% 150-watt induction, 14.3% 165-watt induction, 14.3% 125-watt PSMH or CMH, 14.3% 140-watt PSMH or CMH, 14.3% 150-watt PSMH or CMH, and 14.3% ≤ 155-watts linear fluorescent (= 161 watts)

320-watt HID exterior replacements are weighted as follows:

- Baseline = 100% 320-watt HID (= 368 watts)
- Eligible Replacements = 16.6% 200-watt induction, 16.6% 225-watt induction, 16.6% 250-watt induction, 16.6% 200-watt PSMH or CMH, 16.6% 210-watt PSMH or CMH, and 16.6% 220-watt PSMH or CMH (= 241 watts)

400-watt HID exterior replacements are weighted as follows:

- Baseline = 100% 400-watt HID (= 463 watts)
- Eligible Replacements = 16.6% 200-watt induction, 16.6% 225-watt induction, 16.6% 250-watt induction, 16.6% 200-watt PSMH or CMH, 16.6% 210-watt PSMH or CMH, and 16.6% 220-watt PSMH or CMH (= 241 watts)

Source

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” 2014. http://www.deeresources.com/
   Rated ballast life of 70,000 hours. Not rated on bulb life. Capped at 15 years.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2019	Removed MMIDs 3078, 3081, 3086, and 3087

High Bay – Induction, PSMH, CMH Fixtures

	Measure Details
Measure Master ID	High Bay – Induction, PSMH, CMH Fixtures: ≤ 250 Watt, Replacing 320-400 Watt HID, 3816 ≤ 250 Watt, Replacing 400 Watt HID, 3817 Replacing 250 Watt HID, 3815
Workpaper ID	W0152
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Other
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

Induction, pulse-start metal halide, and ceramic metal halide lighting fixtures save energy by reducing the light fixture wattage compared to standard metal halide fixtures, without sacrificing illumination quality and safety. These lighting technologies are appropriate for high bay applications.

Description of Baseline Condition

The baseline condition is standard HID lamps between 250 watts and 1,000 watts, located in a parking garage.

Description of Efficient Condition

The efficient condition is induction, pulse-start metal halide, and ceramic metal halide fixtures between 120 watts and 750 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED\ IND} = kWh_{HID} - kWh_{IND}$

$kWh_{SAVED\ PSMH} = kWh_{HID} - kWh_{PSMH}$

$kWh_{SAVED\ CMH} = kWh_{HID} – kWh_{CMH}$

Where:

kWh_{HID} = Annual electricity consumption of standard HID fixture
kWh_{IND} = Annual electricity consumption of induction lighting fixture
kWh_{PSMH} = Annual electricity consumption of pulse start metal halide fixture
kWh_{CMH} = Annual electricity consumption of ceramic metal halide fixture

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Wattage / 1,000 * CF$

$kW_{IND} = kW_{PEAK\ HID} – kW_{PEAK\ IND}$

$kW_{PSMH} = kW_{PEAK\ HID} – kW_{PEAK\ PSMH}$

$kW_{CMH} = kW_{PEAK\ HID} – kW_{PEAK\ CMH}$

Where:

$kW_{PEAK\ HID}$ = Peak demand of existing HID system
$kW_{PEAK\ IND}$ = Peak demand of new induction lighting system
$kW_{PEAK\ PSMH}$ = Peak demand of new pulse start metal halide lighting system
$kW_{PEAK\ CMH}$ = Peak demand of new ceramic metal halide lighting system
HOU = Hours of use (= varies by sector; see table below)

Hours of Use by Sector

Sector	HOU[2]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239

CF = Coincidence factor (= varies by sector; see table below)

Coincidence Factor by Sector

Sector	CF[3]
Commercial	0.77
Industrial	0.77
Agriculture	0.67
Schools & Government	0.64

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE\ IND} = (kWh_{HID} - kWh_{IND}) * EUL$

$kWh_{LIFECYCLE\ PSMH} = (kWh_{HID} - kWh_{PSMH}) * EUL$

$kWh_{LIFECYCLE\ CMH} = (kWh_{HID} – kWh_{CMH}) * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Average Annual Deemed Savings for High Bay Induction PSMH/CMH Fixtures

Measure	MMID	Commercial 3,730 (0.77)		Schools & Gov 3,239 (0.64)		Industrial 4,745 (0.77)		Agriculture 4,698 (0.67)	
		kWh	kW	kWh	kW	kWh	kW	kWh	kW
HB PSMH, CMH, IND Replacing 250 Watt HID	3815	510	0.1053	443	0.0875	649	0.1053	642	0.0916
HB PSMH, CMH, IND (250 Watt or Less) Replacing 400 Watt HID	3817	827	0.1706	718	0.1418	1,052	0.1706	1,042	0.1484
HB PSMH, CMH, IND (250 Watt or Less) Replacing 320-400 Watt HID NC (Based on 320 watt savings)	3816	499	0.1031	433	0.0857	635	0.1031	628	0.0897

Average Lifecycle Deemed Savings for High Bay Induction PSMH/CMH Fixtures

Measure	MMID	Commercial 3,730 (0.77)	Schools & Gov 3,239 (0.64)	Industrial 4,745 (0.77)	Agriculture 4,698 (0.67)
		kWh	kWh	kWh	kWh
HB PSMH, CMH, IND Replacing 250 Watt HID	3815	7,650	6,645	9,735	9,630
HB PSMH, CMH, IND (250 Watt or Less) Replacing 400 Watt HID	3817	12,405	10,770	15,780	15,630
HB PSMH, CMH, IND (250 Watt or Less) Replacing 320-400 Watt HID NC (Based on 320 watt savings)	3816	7,485	6,495	9,525	9,420

Measure Costs for High Bay Induction PSMH/CMH Fixtures

Measure	MMID	Cost ($)
HB PSMH, CMH, IND Replacing 250 Watt HID	3815	$100.00
HB PSMH, CMH, IND (250 Watt or Less) Replacing 400 Watt HID	3817	$240.00
HB PSMH, CMH, IND (250 Watt or Less) Replacing 320-400 Watt HID NC (Based on 320 watt savings)	3816	$290.00

Assumptions

Hours of operation and coincidence factor based on sector. Induction wattage shown includes ballast wattage, which was calculated as 10% of lamp wattage based on the manufacturer specifications. 250-watt HID high bay replacements of ≤ 155 watts weighted as follows:

- Baseline = 100% 250-watt HID
- Eligible Replacements = 16.6% 120-watt to 125-watt induction, 16.6% 150-watt induction, 16.6% 165-watt induction,16.6% 125-watt PSMH or CMH, 16.6% 140-watt PSMH or CMH, and 16.6% 150-watt PSMH or CMH

320-watt HID high bay replacements of ≤ 250 watts weighted as follows:

- Baseline = 100% 320-watt HID
- Eligible Replacements = 16.6% 200-watt induction, 16.6% 225-watt induction, 16.6% 165-watt induction, 16.6% 200-watt PSMH or CMH, 16.6% 210-watt PSMH or CMH, and 16.6% 220-watt PSMH or CMH

400-watt HID high bay replacements of ≤ 365 watts weighted as follows:

- Baseline = 100% 400-watt HID
- Eligible Replacements = 16.6% 250-watt induction, 16.6% 300-watt induction, 16.6% 250-watt PSMH or CMH, 16.6% 270-watt PSMH or CMH, 16.6% 315-watt PSMH or CMH, and 16.6% 320-watt PSMH

1,000-watt HID high bay replacements of ≤ 800 watts weighted as follows:

- Baseline = 100% 1,000-watt HID
- Eligible Replacements = 50% 750-watt induction, and 50% 575-watt PSMH or CMH

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use in Commercial Applications. March 22, 2010.

https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Coincidence Factor for Lighting in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	12/2012	Initial TRM entry
02	09/2015	Updates and revisions
03	01/2019	Removed MMIDs 3075,3076, 3077, 3818, 3090, and 3074

Motors and Drives

Variable Frequency Drive (Variable Torque and Constant Torque)

	Measure Details
Measure Master ID	VFD, Process Fan, 2647 VFD, Process Pump, 2648, 3835, 4414 VFD, Constant Torque, 3280, 3836, 4412 VFD, Boiler Draft Fan, 2640 VFD, Cooling Tower Fan, 2641 VFD, Chilled Water Distribution Pump, 2726 VFD, HVAC Fan, 2643 VFD, HVAC Heating Pump, 2644 VFD, Pool Pump Motor, 2646 VFD, Agriculture Primary Use Water System, 4043 VFD, Agriculture Secondary Use Water System, 2639 VFD, Agriculture Secondary Use Water System, Low HOU, 4411 VFD, Irrigation Well Pump, 4949 VFD, Ventilation/Circulation Fan, 3777 VFD, Ventilation/Circulation Fan, Low HOU, 4413 VFD, Domestic Water Pump, 4757 VSD Vacuum Pump, Variable Torque, 4361 VSD Vacuum Pump, Constant Torque, 4362
Workpaper ID	W0155
Measure Unit	Per horsepower
Measure Type	Hybrid
Measure Group	Agriculture: MMIDs 2639, 4949, 3777, 4043, 4411, 4413, and 4415 Boilers & Burners: MMIDs 2640 and 2644 Compressed Air, Vacuum Pumps: MMIDs 4361, 4362 HVAC: MMIDs 2641, 2643, and 2726 Domestic Hot Water: MMID 4757 Pools: MMID 2646 Process: MMIDs 2647, 2648, 3280, 3835, 3836, 4412, and 4414
Measure Category	Variable Speed Drive
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential-multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0

	Measure Details
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure

Measure Description

Fans, pumps, conveyors, and other motor-driven equipment require controls to vary their operation to produce the desired output (such as getting sufficient airflow to cool a building, obtaining hot water for heating, or moving product down a conveyor). Traditionally, flow rates have been reduced by increasing the head and riding the pump (or fan) curve back to a new flow rate (known as throttling control). Alternately, some systems have bypasses that divert a portion of the flow back to the pump or fan inlet to reduce system flow (bypass control). Other systems simply start and stop the motor to meet the given load (on/off control). An alternate way to provide control of motor systems is to use VFDs, which physically slow the motors driving pumps, fans, and other equipment to achieve reduced flow rates at considerable energy savings.

There are three categories of motor applications, but only two (variable torque and constant torque) have the potential for energy savings when adding VFDs:[4]

- ***Variable Torque Loads:*** This category consists of centrifugal pumps and fans, regenerative blowers, and a few types of vacuum pumps. For these applications, the motors follow the fan or affinity laws, resulting in the input power varying with the cube of the pump or fan rotational speed. This means that small reductions in flow (such as 20%) can produce large input power savings (50% in this example).
- ***Constant Torque Loads:*** This category consists of equipment where the torque requirement is independent of speed. Examples of constant torque applications include cranes, hoists, conveyors, extruders, mixers, positive displacement pumps, and most types of vacuum pumps. This means that the input power varies linearly with the rotational speed (where a 20% reduction in speed equals a 20% reduction in input power). Most vacuum pumps—including piston, diaphragm, rocking-piston, rotary-vane, and lobed-rotor types—are positive displacement pumps.
- ***Constant Horsepower Loads:*** This category consists of equipment where the torque varies inversely with the speed of the motor. Therefore, the power requirement does not vary, regardless of speed. Examples of constant horsepower loads include lathes, drilling, and milling equipment. This equipment category does not offer energy savings for installing VFDs[5] and is therefore ineligible for VFD incentives.

Description of Baseline Condition

The baseline condition is a motor for a variable torque or constant torque application operating at full speed and using throttling, bypass, or on/off control to handle variable outputs from the driven device (such as the pump or fan).

Description of Efficient Condition

The efficient condition is adding a VFD to the motor to vary the electric frequency (Hertz) going to the motor, which allows the speed of the motor to be varied. For variable torque (pump and fan) applications, the VFD must be automatically controlled by a variable input signal. Constant torque applications have the option to be manually controlled, as these are often used to vary the speed of equipment associated with production in a manufacturing environment.

Annual Energy-Savings Algorithm

Non-HVAC Fan Measures

Energy savings for non-HVAC fan measures are custom calculated using a spreadsheet tool,[6] which is based on an engineering bulletin[7] and savings calculators from two different VFD manufacturers.[8,9] Energy savings for the HVAC fan measure (MMID 2643) are described in the next section.

The spreadsheet tool uses power curves developed from data obtained by measuring the operating characteristics of various fans and pumps. The curves are representative of typical VFD operation.

The spreadsheet tool uses this equation:

$$\text{Power at Design GPM [CFM]} = \text{Controlled Horsepower} * \text{Conversion Constant [kW/hp]} * \text{Motor Load at Design GPM [CFM]} / \text{Nameplate Efficiency}$$

These two equations are used to determine energy usage for each capacity level:

$$\text{Percentage of Design Kilowatts} = A1 + (A2 * \text{Capacity}) + (A3 * (\text{Capacity})^2) + (A4 * (\text{Capacity})^3)$$

$$\text{Percentage of Design Kilowatts for VFD} = A1 + (A2 * \text{Capacity}) + (A3 * (\text{Capacity})^2) + (A4 * (\text{Capacity})^3)$$

In the equations above, the A1, A2, A3, and A4 variables are unique to each “before VFD” control type, which allows for a quadratic equation to represent the load profile. The Equation Variables: Before VFD table below shows values for A1, A2, A3, and A4.

Equation Variables: Before VFD

Control	A1	A2	A3	A4
Outlet Control Valve	55.21240	0.63700	-0.00190	0.00000
Eddy Current Clutch	16.39683	-0.05647	0.01237	-0.00003
Torque Converter	13.51137	0.34467	0.01269	-0.00007
Bypass Valve	102.00000	0.00000	0.00000	0.00000
VFD Pump	27.44751	-1.00853	0.01762	0.00000
On/Off	100.00000	0.00000	0.00000	0.00000
Inlet Guide Vane, Forward Curved Fans	20.00000	0.06808	-0.00128	0.00009
Inlet Guide Vanes	47.26190	0.67944	-0.01554	0.00014
Inlet Damper Box	50.25833	0.71648	-0.01452	0.00013
Outlet Damper, Forward Curved Fans	20.41905	0.10983	0.00745	0.00000
Discharge Damper	55.92857	-0.56905	0.02462	-0.00014
Eddy Current Drives	16.39683	-0.05647	0.01237	-0.00003
VFD Fan	5.90000	-0.19567	0.00766	0.00004
Constant Torque VFD	0.00000	1.00000	0.00000	0.00000

HVAC Fan Measure

Energy savings for HVAC fan measures are custom calculated using the same spreadsheet tool as for the other measures,[6] but with a different algorithm that relies on data collected by Cadmus from 2014 through 2016.[11]

Cadmus installed 56 meters on HVAC fan VFD motors in the fall of 2014 and removed them in the fall of 2015. These meters provided hourly average power consumption for these VFD motors for one year, and their hourly average consumption per motor horsepower is used as an efficient-case input. Cadmus also installed 66 meters on constant-speed HVAC fans in March 2015 and removed them in April 2016. These meters provided monthly average motor consumption per horsepower for these motors, serving as a baseline.

These two datasets were combined with user-imputed weekly motor run schedules and motor size to calculate baseline and efficient energy consumption, as well as energy savings. The savings were calculated for every hour of the year and summed to produce annual savings.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Expected useful life (= 15 years)[1]

Summer Coincident Peak Savings Algorithm

Non-HVAC Fan Measures

$kW_{SAVED} = kWh_{SAVED} / HOURS * CF$

Where:

HOURS = Annual hours of operation for system controlled by VFD (= customer input)

CF = Coincidence factor (= varies by VFD use; see Coincidence Factor by VFD Use table below)

Coincidence Factor by VFD Use

VFD Use	CF	Source
Hot Water Pump	0.0	Heating pumps operate in winter (off peak)
Chilled Water Pump	0.9	DEER model runs, weather normalized for statewide use by population density
Constant Volume Fan (on/off control)	0.9	
Air Foil/Inlet Guide Vanes	0.9	
Forward Curved Fan with Discharge Damper	0.9	
Forward Curved Inlet Guide Vanes	0.9	
Inlet Guide Vanes (fan type unknown)	0.9	
Cooling Tower Fan	0.9	
Process Pump, Agriculture Primary/Secondary Water Pumps	0.78	Per Michigan Energy Measures Database[10]
Process Fan	0.78	Assume same CF as for other process equipment
Constant Torque (process applications)	0.78	Assume same CF as for other process equipment
Pool Pump	0.78	Assume same CF as for other process equipment
Boiler Draft Fan (HVAC)	0.0	Does not run in summer
Boiler Draft Fan (process)	0.78	Assume same CF as for other process equipment
Agriculture Field Irrigation Pump	Hybrid	Based on customer feedback on supplemental data sheet. Irrigation happening during peak time: 0-10%=0.00 10-50%=0.33 50-90%=0.66 90-100%=1.00
Agriculture Ventilation/Circulation Fans	1.0	Assumes the temperature is above 50°F and fans are running during the majority of peak hours
Vacuum Pump	0.95	VSD air compressor CF used as an approximation of VSD vacuum pump CF, per Illinois and Minnesota TRMs[12,13]
Domestic Water Pump	0.50	Hawaii Technical Reference Manual, PY2016[14]

HVAC Fan Measure

Because the calculation for the HVAC fan measure requires estimates of hour-by-hour energy savings for the entire year, the coincident peak savings can be directly calculated, rather than being determined using a coincidence factor, according to the following formula:

$$kW_{SAVED} = (kWh_{BASE,PEAK} - kWh_{EFF,PEAK}) / 198$$

Where:

$kWh_{BASE,PEAK}$ = Total baseline energy consumption during peak hours

$kWh_{EFF,PEAK}$ = Total VFD energy consumption during peak hours

198 = Total peak period hours[11]

Assumptions

The following rules and requirements apply to the VFD application:

- Variable torque VFDs must be used in conjunction with a process or HVAC fan or pumping application.
- Redundant or back-up units do not qualify.
- Replacement of existing VFDs does not qualify.
- VFD speed (for variable torque applications) must be automatically controlled by differential pressure, flow, temperature, or another variable signal.
- VFD speed (for constant torque applications) may be either automatically or manually controlled.
- VFDs may not be beneficial in pump systems where static head makes up a large portion of the total system head. It is also important that the load on the system vary over time to take advantage of the savings a VFD can provide. These system aspects must be well-understood and discussed with the equipment vendor in advance of applying VFD technology.
- Incremental cost are assumed to equal the measure installed cost. HVAC and process systems either have equipment described under the Description of Baseline Condition section or have a VFD. Baseline condition equipment is required for operation, so VFD is a replacement technology, not an incremental improvement in efficiency (like for a chiller or boiler).
- The system using the VFD must operate a minimum of 2,000 hours for the commercial, industrial, schools and government, and residential multifamily sectors. A minimum of 1,000 hours is required for the agriculture sector, except for applications with low HOUs (MMIDs 4411–4414), where equipment operates between 500 and 1,000 hours annually. MMID 4949 must operate a minimum of 500 hours annually.
- VFDs used on variable torque vacuum pumps will be processed as “VFD Pump” and “Other Pump” for the load profiles used in the VFD calculation.
- Several HVAC-related VFD measures are not eligible for new construction applications because they are considered part of the baseline condition:[15] MMID 2641 (cooling tower fan), MMID 2643 (HVAC fan), MMID 2644 (heating pump), and MMID 2726 (chilled water distribution pump).

Incremental Costs

The full average cost per horsepower, based on historical Focus on Energy data, is used as the incremental cost. Costs and additional information can be seen in the Incremental Costs table.

Incremental Costs[2,3]

Measure Types	MMIDs	SPECTRUM Data January 2018 - July 2020			Incremental Cost
		Project	Units	Average HP	
VFD, Boiler Draft, HVAC, or Cooling Tower Fan	2640, 2643, 2641	804	1,588	14	$196.94
VFD, Non-Process Pump	4949, 2726, 2644	309	583	20	$171.04
VFD, High Speed Vent or Circ Fan	3777, 4413	110	1,527	3	$303.67
VFD, Ag Water System	2639, 4043, 4411	61	76	11	$317.03
VFD, Pool Pump Motor	2646	7	7	12	$659.59
VFD, Process Pumps	2648, 3835, 4414	373	760	55	$186.16
VFD, Process Fans	2647	216	1,468	13	$222.89
VFD, Constant Torque	3280, 3836, 4412	285	727	19	$193.69
VSD Vacuum Pump, 30 hp, Variable Torque	4361	2016 - 2017 data for 1,069 projects			$210.52
VSD Vacuum Pump, 30 hp, Constant Torque	4362	2016 - 2017 data for 111 projects			$122.48

Sources

1. California Public Utilities Commission. *2008 Database for Energy-Efficiency Resources.* Version 2008.2.05. "Effective/Remaining Useful Life Values." December 16, 2008. http://www.deeresources.com/
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 2,165 projects and 6,736 units from January 2018 to July 2020.
3. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. The vacuum pump VFD measures saw little use between 2018 and 2020, only 18 units total. Older data is used for costs for these measures. For variable torque vacuum pump VFDs, cost set at $210.52

per hp, based on 2016 - 2017 data of 1,069 projects. For constant torque vacuum pump VFDs, cost set at $122.48 per horsepower based on 2016 - 2017 data of 111 projects.

4. U.S. Department of Energy, Energy Efficiency and Renewable Energy Advanced Manufacturing Office. “Motor Systems Tip Sheet #11, Adjustable Speed Drive Part Load Efficiency.” https://energy.gov/sites/prod/files/2014/04/f15/motor_tip_sheet11.pdf
5. Smart Energy Design Assistance Center. “SEDAC Tech Note – Variable Frequency Drives.” November 2011. http://smartenergy-form.arch.illinois.edu/pdf/TechNote_VFD.pdf
6. Focus on Energy. “2020 VFD Calc-Business and Ag Measures.” VFD calculation spreadsheet.
7. Westinghouse. “Flow Control.” Bulletin B-851, F/86/Rev-CMS 8121.
8. ABB Pump Save (version 4.4). ABB energy saving spreadsheet tools. Previously available.
   http://www.abb.com/product/seitp322/5fcd62536739a42bc12574b70043c53a.aspx
   ABB Fan Save (version 4.4). Previously available.
   http://www.abb.com/product/seitp322/5b6810a0e20d157fc1256f2d00338395.aspx
   ABB has replaced both Fan Save and Pump Save with EnergySave Calculator
9. Toshiba Cost Savings Estimator. https://www.toshiba.com/tic/motors-drives/low-voltage-adjustable-speed-drives/hvac
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10. Michigan Public Service Commission. *Michigan Energy Measure Database*. 2020.
    https://www.michigan.gov/mpsc/0,9535,7-395-93309_94801_94808_94811---,00.html
    Refer to “VFD HP 1.5 Process Pumping” and “VFD for Process Fans” measures.
11. Cadmus. HVAC fan VFD metering study. July 2016.
    Monthly power consumption data for 56 HVAC fan VFD motors over one year and hourly power consumption data for 66 HVAC fan constant speed motors over one year.
12. Illinois Energy Efficiency Stakeholder Advisory Group. “Illinois Statewide Technical Reference Manual for Energy Efficiency.” Version 6.0. p. 464. February 8, 2017.

http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_2_C_and_I_020817_Final.pdf

13. Minnesota Department of Commerce Division of Energy Resources. "State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs." Version 2.1. http://mn.gov/commerce-stat/pdfs/mn-trm-v2.1.pdf
14. Hawaii Energy Efficiency Program. "Technical Reference Manual (TRM)." PY2016. https://hawaiienergy.com/files/about/information-and-reports/PY16_-_Hawaii_Energy_TRM.pdf
15. American Society of Heating, Refrigerating and Air Conditioning Engineers. *ASHRAE Standard 90.1-2013.* Sections 6.5.3.2, 6.5.4.2, 6.5.4.5.2, 6.5.5.2.1, 6.5.11.1.c, footnote d of Table 11.5.2-1. Appendix G, section G3.1.3.5, G3.1.3.10, G3.1.3.11, G3.1.3.15.

Revision History

Version Number	Date	Description of Change
01	11/21/2013	Added constant torque (conveyor, mixer, positive displacement pump) kilowatt and kilowatt-hour savings for select VFDs
02	10/2017	Added more measure types; added new low-HOU agriculture measures
03	12/2018	Added domestic water pump measure
04	12/2019	Added MMID 4949 for irrigation well pump—combining and replacing MMIDs 3776 and 4415 with 500 annual operating hours minimum requirement
05	10/2020	Added assumption regarding ineligible new construction applications, updated costs

Other

DEET Behavioral Savings

	Measure Details
Measure Master ID	DEET, Savings Period 1, 3652 DEET, Savings Period 2, 3653 DEET, Savings Period 3, 3654 DEET, Savings Period 4, 3655 DEET, Savings Period 5, 3656 DEET, Savings Period 6, 3657 DEET, Savings Persistence, 3658 DEET, V2.0, Year 1, 4262 DEET, V2.0, Year 2, 4263 DEET, V2.0, Year 3, 4264 DEET, V2.0, Year 4, 4265
Workpaper ID	W0156
Measure Unit	Per building
Measure Type	Hybrid
Measure Group	Other
Measure Category	Whole Building
Sector(s)	Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$12,000.00[2]

Measure Description

According to the U.S. Environmental Protection Agency, 30% of a district's total energy may be used inefficiently or unnecessarily.[3] Schools have a considerable opportunity to reduce energy consumption and district energy costs. Recommended behavior changes that will conserve energy include turning off unnecessary lights, shutting down computers, reducing phantom loads, and disseminating regular energy conservation reminders.

Delivery Energy Efficiency Together (DEET) was initially offered in July 2015 as a series of behavioral incentives based on savings measured directly from utility bills in K-12 schools every six months for three years (MMIDs 3652-3658). The amount of kW, kWh, and therm savings incentives is determined by comparing reporting period utility bills to an established baseline (12 months prior to starting the initiative). Program/sector kW, kWh, and therm savings are determined by comparing reporting period consumption to previous year consumption using utility bills.

In September 2017, a new DEET model was released (MMIDs 4262-4265) that only offers kWh and therm savings and incentives. As with the older model, this newer model determines savings by comparing current utility bills to the prior reporting period. However, unlike the older model that determines incentives by comparing current utility bills to a pre-measure baseline, this newer model determines incentives by comparing current utility bills to the prior year consumption (rolling baseline versus static baseline in the initial model). Schools have an option of renewing their enrollment on an annual basis up to three times for a total of four years.

School staff will participate in pre- and post-participation energy behavior surveys and energy awareness campaigns. Points are earned for reducing kWh and therm usage and are redeemed for energy-related prizes such as LED light bulbs and power strips. Periodic reports are provided to schools to illustrate the impact of their energy conservation efforts.

Both models are intended to capture all energy savings with the DEET measures; therefore, participating schools are not eligible for any other Focus on Energy measures while enrolled in DEET.

Description of Baseline Condition

For both models, the baseline condition is a school building that has not completed any measures incented by Focus on Energy within 12 months. In addition, participating buildings must not be planning for major renovations or energy upgrades within three years from the start of the initiative for the original model and within the next year for the new model.

Description of Efficient Condition

DEET participants will use less energy than their baseline by expanding management-driven savings to include occupant behavioral energy savings, sustaining energy reductions, increasing occupancy involvement in energy reduction initiatives, and increasing occupants’ realization of the financial and environmental impact of individual and group energy consumption.

Annual Energy-Savings Algorithm

For the original model, kWh and therm savings are calculated every six months for three years (for a total of six calculation/reporting periods). For the new model, savings are calculated three times each year (three calculation/reporting periods). For both models, measured savings will use the previous year consumption as a baseline.

$kWh_{SAVED} = kWh_{BP} – kWh_{RP}$

$Therm_{SAVED} = Therm_{BP} – Therm_{RP}$

$Therm_{BP} = (Therm_{BPACT}) * (HDD_{30YRAVG} / HDD_{BP})$

$Therm_{RP} = Therm_{NORM} = (Therm_{RPACT}) * (HDD_{30YRAVG} / HDD_{RP})$

Where:

kWh_{BP} = Electrical consumption during baseline period (= varies by building)

kWh_{RP} = Electrical consumption during reporting period (= varies by building)

$Therm_{BP}$ = Natural gas consumption during baseline period (= varies by building)

$Therm_{RP}$ = Natural gas consumption during reporting period (= varies by building)

$Therm_{BPACT}$ = Actual natural gas consumption during baseline period (= varies by building)

$HDD_{30YRAVG}$ = 30-year average heating degree days

HDD_{BP} = Heating degree days during baseline period (= varies by year)

$Therm_{NORM}$ = Natural gas consumption normalized for heating loads (= varies by building)

$Therm_{RPACT}$ = Actual natural gas consumption for reporting period (= directly from utility bill; varies by building)

HDD_{RP} = Heating degree days during reporting period (= varies by year)

Summer Coincident Peak Savings Algorithm

Kilowatt savings are only calculated for the original model. There are no kilowatt savings calculated for the new model due to high variability in use of school facilities over peak periods. For example, a building may host summer school one year and not the next year, resulting in a decrease in demand not related to DEET energy conservation efforts. Kilowatt savings under traditional facility-use conditions are typically insignificant.

There will be no peak savings for periods 1, 3, and 5. For periods 2, 4, and 6, the monthly kilowatts for June, July, and August of the reporting year is averaged and used as the kW_{RP}.

$kW_{SAVED} = kW_{BP} - kW_{RP}$

Where:

kW_{BP} = Average monthly kW usage for baseline year (= average of kW_{JUNE} + kW_{JULY} + kW_{AUG}; varies by building)

kW_{RP} = Average monthly kW usage for reporting year (= average of kW_{JUNE} + kW_{JULY} + kW_{AUG}; varies by building)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$$

Where:

EUL = Effective useful life (= 4 years)[1]

Assumptions

The 30-year average heating degree days per month by Wisconsin city[4] are provided in the table below.

30-Year Heating Degree Day Values Per Month by Wisconsin City

Month	Milwaukee	Green Bay	Wausau	Madison	La Crosse	Minocqua	Rice Lake
January	1,443	1,591	1,440	1,561	1,623	1,632	1,623
February	1,211	1,238	1,313	1,272	1,200	1,293	1,455
March	934	1,019	1,278	844	911	1,222	1,125
April	595	630	550	607	514	574	531
May	358	265	460	217	242	321	414
June	126	87	39	105	80	124	84
July	29	38	33	18	10	73	45
August	36	74	54	45	40	97	64
September	116	182	143	233	186	294	185
October	471	560	568	568	522	528	571
November	817	932	844	916	861	969	1,007
December	1,262	1,288	1,261	1,404	1,373	1,665	1,624
Total	**7,398**	**7,903**	**7,982**	**7,791**	**7,561**	**8,793**	**8,726**

The incremental cost of $12,000 per building was based on the following assumptions:

- According to project experience, we assumed that staff will spend approximately 45 minutes per month for DEET initiative activities such as reviewing DEET-related emails and reports, addressing energy topics in staff meetings, and discussing energy with students.
- We assumed an average staff wage of $30 per hour based on working 1,500 hours for the median teacher salary of $45,227 in La Crosse, Wisconsin.[5] (Note that administrators have a higher salary and support staff have a lower salary). The total, at $30 per hour multiplied by 0.75 hours per nine months a year, is $202.50 (rounded to $200).
- We assumed an average of 50 staff per building based on field experience ($200 multiplied by 50 staff/building = $10,000/building).
- Finally, based on rough estimates from general data available to the program, we assumed each building would spend an average of $2,000 in buildings and grounds discretionary funds on small energy projects (such as replacing incandescents and CFLs with LEDs, installing timers and power strips, and adding LED task lighting or vending misers). Since this is the first time an initiative like DEET has been proposed in Wisconsin, we concluded that an incremental cost of $10,000 for staff time and $2,000 for energy projects per building is reasonable and appropriate.

The EUL of four years was based on the following assumptions:

Program Effective Useful Life = Lifetime Savings / First Year Savings

$$\text{Lifetime Savings} = 1^{st}\text{ Yr Savings} + \sum_{t=2}^{\infty} 1^{st}\text{ Yr Savings} * (1-\delta)^{t-1} * (1-\alpha)^{t-1}$$

This formula assumes that savings decay indefinitely and at a constant annual rate of (1-δ) * (1-α), with δ being the rate of savings decrease and α being the rate of staff attrition. As this is an infinite series, it converges to a lifetime savings value of:

$$\frac{\text{First Year Savings}}{\delta + \alpha - \delta * \alpha}$$

Therefore, the EUL can be calculated as follows:

$$\text{EUL} = \frac{\text{Lifetime Savings}}{\text{1st Year Savings}} = \frac{\left(\frac{\text{1st Year Savings}}{\delta + \alpha - \delta * \alpha}\right)}{(\text{1st Year Savings})} = \frac{1}{\delta + \alpha - \delta * \alpha}$$

Assuming an annual savings decay rate of 20% and an annual participant attrition rate of 7%, the EUL is four years:

$$\text{EUL} = 1 / (0.20 + 0.07 - 0.20 * 0.07) \approx 4 \text{ Years}$$

Although the decay rate and attrition rate values are based on home energy report studies,[1] they are the best available information to apply to this program. School staff are similar to residential customers in that good energy-related habits will decrease over time at a similar decay rate and staff will move out of their buildings at a similar attrition rate as residential customers moving to new homes.

Sources

1. The Cadmus Group, Inc. (Khawaja, Sami M. and J. Stewart). *Long-Run Savings and Cost-Effectiveness of Home Energy Report Programs*. Winter 2014/2015. http://www.cadmusgroup.com/wp-content/uploads/2014/11/Cadmus_Home_Energy_Reports_Winter2014.pdf
2. Staff estimate. $2,000.00 for energy projects and $10,000.00 average staff time in average-sized building.
3. United States Environmental Protection Agency. *Schools: An Overview of Energy Use and Energy Efficiency Opportunities.* Brochure. 2006. http://www.energystar.gov/ia/partners/publications/pubdocs/Schools.pdf
4. National Renewable Resource Laboratory, Renewable Resource Data Center. "National Solar Radiation Database (Base of 65°F) Typical Meteorological Year 3." http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html

5. Salary.com. "Public School Teacher Salaries, La Crosse, WI." 2015. http://www1.salary.com/WI/La-Crosse/Public-School-Teacher-salary.html

Revision History

Version Number	Date	Description of Change
01	09/01/2015	Initial TRM entry
02	09/14/2017	Updated EUL and added new model measure

Process

Process Exhaust Filtration

	Measure Details
Measure Master ID	Process Exhaust Filtration, 3244
Workpaper ID	W0157
Measure Unit	Per CFM
Measure Type	Hybrid
Measure Group	Process
Measure Category	Filtration
Sector(s)	Commercial, Industrial
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by project
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by project
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1,2,3]
Incremental Cost ($/unit)	$2.98[6]

Measure Description

Process exhaust air filtration systems save energy by reducing the heat load on a make-up air system by recirculating filtered process air instead of bringing in colder outdoor make-up air during the heating season. Energy savings result from the reduced temperature difference through the heat exchanger of the supply air system. The temperature difference between the filtered indoor air and the indoor supply air temperature is much lower than the difference between outdoor air and indoor supply air temperature. This reduction in heat load results in natural gas savings.

Exhaust filtration systems typically use cartridge filters and are frequently found in welding fume exhaust and paint booth exhaust applications. This measure is incented per CFM of make-up air eliminated and savings will be realized in industrial and service facilities. Systems must run a minimum of 2,000 hours annually in order to be eligible.

Description of Baseline Condition

The baseline condition is 100% of process exhaust fumes being evacuated from the space associated with the industrial process, with ventilation provided by 100% outside air with heating provided by a natural gas fired make-up air unit.

Description of Efficient Condition

The efficient condition is a filtration system that reduces or eliminates the need to discharge 100% of process exhaust by filtering and recirculating the air and thereby reducing or eliminating make-up air demand and associated heating energy.

Annual Energy-Savings Algorithm

Btu/°F = CFM * Specific Heat

$\text{Btu}_{\text{SAVED}}$ = Btu/°F * ΔT * HOU

$\text{Therm}_{\text{SAVED}}$ = $\text{Btu}_{\text{SAVED}}$ / (System Efficiency * 100,000)

Note: Fan energy savings are neglected for this measure, as eliminating the makeup air fan is offset by the increased energy usage of the exhaust fan due to static pressure increases.

Where:

Btu/°F = Energy required to heat volume of make-up air for each additional degree Fahrenheit
CFM = Volumetric flow rate of eliminated make-up air unit (= actual)
Specific Heat = 1.08 Btu/hr/CFM-°F (dry air)
$\text{Btu}_{\text{SAVED}}$ = Total energy required to heat eliminated make-up air
ΔT = Difference between average indoor temperature and average outside winter temperature
HOU = Annual hours requiring exhaust (= actual)
$\text{Therm}_{\text{SAVED}}$ = Natural gas energy required to heat make-up air before eliminated
System Efficiency = Heating efficiency of make-up air system (= actual)
100,000 = Conversion from Btu to therm

Summer Coincident Peak Savings Algorithm

There are no peak savings associated with this measure.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}}$ = $\text{Therm}_{\text{SAVED}}$ * EUL

Where:

EUL = Effective useful life (15 years)[1,2,3]

Assumptions

The average inside temperature, 65°F, assumed to equal design temperature. Average outdoor winter temperature of 30.8°F.[5] (Therefore ΔT = 65°F – 30.8°F = 34.2°F).

Sources

1. Using current EULs, rooftop units are very similar to the industrial ventilation system but without a heating or cooling coil. Focus on Energy currently uses a 15 year EUL for rooftop units.
2. Chartered Institution of Building Services Engineers. "Probabilistic Estimation of Service Life." http://www.cibse.org/knowledge/cibse-technical-symposium-2011/probabilistic-estimation-of-service-life.

   The industrial ventilation system would consist of a fan and a set of filters; fan EUL is 15 to 20 years depending on type and filter EUL is 15 to 20 years depending on type.
3. Wisconsin DOA guideline document for lifecycle costing of state building projects. Page 36 lists 10 to 20 years for rooftop units and 15 to 30 years for fans depending on type.
4. SPECTRUM historical projects (custom projects that implemented comparable measures).
5. Focus on Energy Deemed Savings Manual.
6. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 236,800 CFM over 12 projects (average size 19,733 CFM) from January 2018 to July 2021.

Revision History

Version Number	Date	Description of Change
01	07/2015	Initial TRM entry
02	12/2018	Updated incremental cost
03	12/2021	Updated incremental cost

Pressure Screen Rotor

	Measure Details
Measure Name	Pressure Screen Rotor, 2496
Workpaper ID	W0158
Measure Unit	Per horsepower
Measure Type	Hybrid
Measure Group	Process
Measure Category	Specialty Pulp & Paper
Sector(s)	Industrial
Annual Energy Savings (kWh)	Varies by horsepower
Peak Demand Reduction (kW)	Varies by horsepower
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by horsepower
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[2]
Incremental Cost ($/unit)	$200.77[3]

Measure Description

Paper mills use pressure screens to separate contaminants from the pulp produced from recycled products. A motor is used to spin the rotor at a high velocity, forcing the pulp through narrow slots or apertures that are a barrier to debris, stickies, contaminates, and uncooked or undeveloped bundles of wood fibers (shives). This makes contaminate-free pulp available for further processing.

Pressure screen rotors are an energy-efficient method of removing large contaminants from pulp stock. The new dual element foil design more efficiently removes the contaminants while using less power.

Description of Baseline Condition

The baseline technology for removing contaminants is with a narrow slotted screen.

Description of Efficient Condition

The efficient condition is a pressure screen rotor design.

Annual Energy-Savings Algorithm

There are two methods for estimating savings. The first method relies on pre-retrofit and post-retrofit amp measurements from the participant application; the second method determines deemed savings using an energy savings factor of 30% based on Focus on Energy project history.

Method #1: Custom Approach (Amps Known)

$kWh_{SAVED} = (Amps_{PRE} - Amps_{POST}) * 1.73 * V * PF * Hrs/wk * Weeks$

Method #2: Deemed Approach (Amps Unknown)

$kWh_{SAVED} = hp * LF / Eff * 0.746 * S * Hrs/wk * Weeks$

Where:

$Amps_{PRE}$ = Pre-retrofit pulper amps (= actual; requested in program application or measured)

$Amps_{POST}$ = Post-retrofit pulper amps (= actual; requested in program application or measured)

1.73 = Constant to calculate kWh

V = Voltage of pulper (= actual; requested in program application or reported by customer)

PF = Power factor (= actual reported by customer or deemed 0.75)

Hrs/wk = Hours per week (= actual; requested in program application or reported by customer)

Weeks = Weeks of operation per year (= actual; requested in program application or reported by customer)

hp = Motor horsepower (= actual; reported by customer)

LF = Motor load factor (= actual reported by customer or deemed 65%)

Eff = Estimated motor efficiency (= actual reported by customer or deemed 92%)

0.746 = Conversion from horsepower to watts

S = Deemed savings factor (= 30%)[1]

Summer Coincident Peak Savings Algorithm

Method #1: Custom Approach (Amps Known)

$kW = (Amps_{PRE} - Amps_{POST}) * 1.73 * V * PF$

Method #2: Deemed Approach (Amps Unknown)

$kW = hp * LF / Eff * 0.746 * S$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[2]

Sources

1. Focus on Energy industrial sector project history. 2013.

2. Engineering judgement.
3. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 12 units from 2012 to 2014.

Revision History

Version Number	Date	Description of Change
01	05/2015	Initial TRM entry
02	12/2018	Updated incremental cost

Repulper Rotor

	Measure Details
Measure Name	Repulper Rotor Without Extraction Plate, 2538 Repulper Rotor With Extraction Plate, 5210
Workpaper ID	W0159
Measure Unit	Per horsepower
Measure Type	Hybrid
Measure Group	Process
Measure Category	Specialty Pulp & Paper
Sector(s)	Industrial
Annual Energy Savings (kWh)	Varies by amperage
Peak Demand Reduction (kW)	Varies by amperage
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by amperage
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$200.44 for no extraction plate (MMID 2538)[2] $245.01 for with extraction plate (MMID 5210)[3]

Measure Description

A repulper is a large tank with a mixer, or rotor, on the bottom. Pulping rotors are rebuilt or replaced periodically, providing facility managers with the opportunity to investigate new repulper rotors for their facility. Manufacturers of paper process equipment designed new energy-efficient repulper rotors to help offset rising energy costs, including energy-efficient repulper rotors (new energy efficient repulping blades) replacing conventional rotors (existing conventional repulping blades, baseline). Energy efficient rotors have a tall, swept-back blade design that provides effective turbulence of the fiber suspension product and maximizes rotor fiber contact while consuming less horsepower than conventional rotors.

Description of Baseline Equipment

The baseline technology is a conventional rotor.

Description of Efficient Equipment

The efficient condition is an efficient rotor.

Annual Energy-Saving Algorithm

There are two mefthods for estimating savings. The first method relies on pre-retrofit and post-retrofit current measurements as provided in the participant application or obtained; the second method uses deemed savings using an energy savings factor of 23%.[4,5]

Method #1: Custom Approach (Amps Known)

$kWh_{SAVED} = (Amps_{PRE} - Amps_{POST}) * 1.73 * V * PF * Bwk * t * Weeks$

Method #2: Deemed Approach (Amps Unknown)

$kWh_{SAVED} = hp * LF / Eff * 0.746 * Bwk * t * Weeks * SF$

Where:

$Amps_{PRE}$ = Pre-retrofit pulper amps (= actual; from program application or measured)
$Amps_{POST}$ = Post-retrofit pulper amps (= actual; from program application or measured)
1.73 = Constant to calculate kWh with three-phase power
V = Voltage of pulper (= actual; from program application or reported by customer)
PF = Power factor (= actual reported by customer or deemed 0.75)
Bwk = Batches per week (= actual; from program application or reported by customer)
t = Time per pulp batch in minutes (= actual; from program application or reported by customer)
Weeks = Weeks of pulping per year (= actual; from program application or reported by customer)
hp = Motor horsepower (= actual; reported by customer)
LF = Motor load factor (= actual reported by customer or deemed 65%)
Eff = Estimated motor efficiency (=actual reported by customer or deemed 92%)
0.746 = Conversion from horsepower to watts
SF = Savings factor (= deemed 23%)[4,5]

Summer Coincident Peak Savings Algorithm

Method #1: Custom Approach (Amps Known)

$kW = (Amps_{PRE} - Amps_{POST}) * 1.73 * V * PF$

Method #2: Deemed Approach (Amps Unknown)

$kW = hp * LF / Eff * 0.746 * SF$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15[1] years)

Sources

1. Engineering judgement.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of ten units from 2014 through October 2021 = $200.44/hp.
3. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of five units from 2014 to October 2021 = $44.57/hp, plus cost of repulper rotor from Reference 2 = $245.01.
4. Wisconsin Focus on Energy. "Voith High Efficiency HM Rotor Energy Data: A Repulper Rotor Design Case Study." 2005. http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/5580/ESL-IE-05-05-21.pdf?sequence=4&isAllowed=y
5. *Focus on Energy Business Programs - Industrial Sector*. December 16, 2005. Repulper rotor reduces energy costs by 23%.

Revision History

Version Number	Date	Description of Change
01	05/2015	Initial TRM entry
02	12/2018	Updated incremental cost
03	11/2021	Added repulper rotor with extraction plate measure and updated incremental costs

High Efficiency Side Entry Agitator

	Measure Details
Measure Master ID	High Efficiency Side Entry Agitator, 4763
Workpaper ID	W0160
Measure Unit	Per agitator motor horsepower
Measure Type	Hybrid
Measure Group	Process
Measure Category	Specialty Pulp and Paper
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by application
Peak Demand Reduction (kW)	Varies by application
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$225.29[2]

Measure Description

In the paper-making process, fiber, filler, and chemical additives are pulped with water (slurried) in a pulper. This slurry, referred to as stock, is pumped to holding tanks that feed process equipment, like refiners and cleaners, en route to the paper machine. These holding tanks must continually be agitated to keep the slurry from settling out. Often times, multiple slurries come together in a single tank and must be mixed into a homogenous slurry before being pumped to the next operation. Side entry agitators are commonly used in the paper industry in stock blending and mixing tanks. Most of them employ marine type impellers, which are essentially boat propellers with the pitch and diameter selected for the specific application.

High-efficiency units are purpose built, replacement impellers designed to replace the typical marine impellers. The pitch and angles on high-efficiency impeller fins allow for improved circulation at lower torque. Only the impeller blades and hub are replaced. The shaft, gearbox, and motor are typically reused.

Description of Baseline Condition

The baseline condition is a typical agitator that uses a marine type impeller, very similar to a boat propeller. This is typically the standard impeller that is installed with the side entry agitator.

Description of Efficient Condition

The efficient condition is an engineered impeller specifically built to replace the standard marine type impeller to reduce energy intensity. Impeller diameter and revolutions per minute are changed specific to the application and tank design.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = HP * 0.746 * LF * Op\ Hours * SF$

Where:

HP = Agitator horsepower (= actual)
0.746 = Conversion factor; 1 hp = 0.746 kW
LF = Load factor; percentage load on the agitator motor over operating hours (= actual)
Op Hours = Agitator operating hours (= actual)
SF = Savings factor (= 15%; see Assumptions)[3]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / Op\ Hours$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Savings vary by application. This is a hybrid measure that uses inputs from the application, which are then entered into the savings algorithm above to generate the kilowatt-hour savings.

Assumptions

The agitator horsepower, load factor, and operating hours are all provided by the end user on the application. These values are known or given. The savings factor is based on manufacturer data[3] and successful customer installation.[4] The manufacturer claims that the typical savings factor with this type of impeller upgrade is 20%; to be conservative with the savings estimate, the savings algorithm above uses 15%.

Sources

1. Engineering judgement. An effective useful life of 15 years is deemed based on consultation with pulp and paper subject matter experts. End of life can occur due to the impeller blades wearing or being damaged by the paper making process. Note that the blades can be changed out individually if needed to maintain the efficient design. Subject matter experts state that 15 to 20 years is a typical EUL.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. October 2016 through October 2018.
   Weighted average cost of three previous Process, Not Otherwise Specified projects involving this technology is $225.29/hp.
3. GL&V Pulp and Paper Group. “GL&V Agitator Impeller Energy Upgrade Presentation.” May 2018. Presentation claims that these impellers are 20% more efficient than typical marine propeller, and details eight motors that were replaced with smaller models after impeller installation.
4. Clean Tech Partners. Wisconsin Focus on Energy Emerging Technologies Program. *Transition of Emerging Technology to Best Practice High Efficiency Side Entry Agitator*. August 2, 2018.
   One customer showed energy savings of 22.2% with this upgrade.

Revision History

Version Number	Date	Description of Change
01	12/4/2018	Initial TRM entry

Spline Rotor Upgrade for Refiners

	Measure Details
Measure Master ID	Spline Rotor Upgrade for Refiners, 4764
Workpaper ID	W0161
Measure Unit	Per refiner horsepower
Measure Type	Hybrid
Measure Group	Process
Measure Category	Specialty Pulp and Paper
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by application
Peak Demand Reduction (kW)	Varies by application
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$127.59[2]

Measure Description

Stock is the fiber slurry sent to a paper machine to make paper. This fiber slurry is forced between the rotor and stator of a refiner, both of which are fitted with removable plates that have patterns of bars and gaps that act to cut or fibrillate the fiber between the bars. Typically, as the bars wear, the dynamics change and greater pressure is required to keep the gap between the rotor and stator the same size using more horsepower to get the same action. With a double disc refiner, the rotor is floating between two stationery plates.

A non-splined rotor operation relies on the linear movement of the entire rotor and shaft assembly to displace and self-center between the stator plates. Inevitably some differences exist on the rotor sides, causing under-refinement on one side of the rotor and over-refinement on the other. When the splined hub is installed, the stock coming from both sides of the rotor is more homogeneous and less energy is required since the refiner is no longer over-refining to achieve the same sheet properties. This problem becomes more pronounced with mechanical condition in the refiner; specifically, as the shaft packing sleeve and motor coupling wear they will become less likely to displace freely.

Description of Baseline Condition

The baseline condition is a typical disc refiner where the rotor and shaft are allowed to move linearly. Essentially, the rotor is connected to a floating shaft and allowed to move side to side between the stators during the refining process. Over time, this can cause uneven refining due to the shaft not floating as well as it should and not remaining properly centered.

Description of Efficient Condition

The efficient condition is upgrading the refiners with spline technology to allow the splined rotor to balance on a splined hub, which is mounted to a non-floating fixed shaft. This improves the rotor centering, which in turn increases the refiner efficiency and performance.[3]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = HP * 0.746 * LF * HOU * SF$

Where:

HP = Refiner horsepower (= actual)

0.746 = Conversion factor for 1 hp (= 0.746 kW)

LF = Load factor; the percentage load on the refiner over operating hours (= actual)

HOU = Refiner operating hours (= actual)

SF = Savings factor (= estimated as 10%; see Assumptions)[3,4,5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / HOU$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Savings vary by application. This hybrid measure uses inputs from the application that are then entered into the savings algorithm above to generate the kilowatt-hour savings.

Assumptions

The refiner horsepower, load factor, and operating hours are provided by the application end user. These values are known or given.

The savings factor is based on manufacturer data.[3,4,5] Customers typically save in the range of 10% to 15%, with 12% to 14% being more typical as more installations are occurring with this technology. To be conservative with the savings estimate, the savings algorithm above uses 10%.

Sources

1. Engineering judgement. An effective useful life of 15 years is deemed based on consultation with pulp and paper subject matter experts. Refiner life typically lasts longer than 15 years, but they generally require a rebuild in the 15 to 20 year timeframe.
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. December 2015 through July 2018.
   Weighted average cost of six previous process (not otherwise specified) projects involving this technology is $127.59/refiner hp.
3. GL&V Pulp and Paper Group. "Upgrading Your Refiner Will Result in Improved Refining and Power Savings." May 2010.
   Memo claims spline rotors are 10% to 25% more efficient. Two case studies reduce power consumption by 12.5% and 32%.
4. GL&V Pulp and Paper Group. *DD 4600/3600 OEM Upgrades General Equipment Descriptions*. p. 4. 2010.
   Claims estimated energy savings of 15% with this type of refiner.
5. GL&V Pulp and Paper Group. *Power Savings with DD 4600/4500 Upgrade at 90% Motor Load*. 2010.
   Data claiming power savings of 10% to 15% depending on refiner size.

Revision History

Version Number	Date	Description of Change
01	02/2019	Initial TRM entry

Radiant Heater Band for Plastics

	Measure Details
Measure Master ID	Plastics Equipment, Radiant Heater Band Retrofit, 2490
Workpaper ID	W0162
Measure Unit	Per installed kilowatt of existing heater bands
Measure Type	Hybrid
Measure Group	Process
Measure Category	Process Heat
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$267.99 per kilowatt of existing heater bands[2]

Measure Description

This measure is replacing conduction band heaters on plastic forming machine barrels with radiant barrel heaters. Plastic forming machines include injection molding equipment, profile and sheet extrusion equipment, and blow molding equipment. The energy savings comes from two main factors—insulation and heating more quickly.

Description of Baseline Condition

The baseline condition is conduction band heaters on plastic forming machine barrels. These band heaters conduct heat directly to the barrel surface and typically are not insulated.

Description of Efficient Condition

The efficient condition is insulated radiant heaters, installed with an air gap between the heater and the barrel. The insulation makes the immediate work environment more comfortable for the machine operators, and makes the conditions more safe by lowering exposed surface temperatures.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = LF * kW_{EXISTING} * HOU * \% \text{ Savings}$

Where:

LF = Load factor (= 0.5; see Assumptions)

$kW_{EXISTING}$ = Existing heater kilowatt usage (= user input)

HOU = Hours of use (= user input)

% Savings = Percentage savings (= 15%; see Assumptions)[3]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = LF * kW_{EXISTING} * \% \text{ Savings}$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

Savings for MMID 2490 (created in 2012) were previously based on the average kilowatt and kilowatt-hour savings per kilowatt of existing heater for 41 projects completed prior to 2012.[4] These were fixed savings per heater of 903 kWh and 0.120 kW. However, that source of data is no longer available.

Two Focus on Energy projects, which had measurement and verification reports completed in 2008, had savings as shown in the table below.

Kilowatt Reduction from Two Projects

Project	Old Heater	New Heater	Difference	% Savings
Project 1	5.672[2]	4.807[2]	0.865	15%
Project 2	37.86[3]	13.59[3]	24.27	64%

However, in Project 2, the barrel temperatures in four of the five zones were 20°F to 35°F lower than the existing condition with the original band heaters, which increased energy savings beyond switching the heater type alone. The values for Project 1 align with industry experience,[5] and these are used for the basis of the 15% savings.

A load factor is also applied to the heater power (kW) to account for cycling on and off—Project 1 had an average kilowatt of approximately 50% of its peak kilowatt value.

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of six units from 2013 to 2016.
3. Wisconsin Focus on Energy (Laube, Dean). *Measurement & Verification – Final Report*. Northern Engraving Corporation. p. 5 and 9. February 2008.

Used total kilowatt and kilowatt-hour in report divided by the existing heater kilowatt in the report.

4. Wisconsin Focus on Energy. Historical project data, Excel workbook “Radiant Heater Bands-Plasatics1.xlsx.” Data for 41 projects.
5. Cadmus (Korn, Dave, and Charles Bicknell). “Review of Work Paper ‘Plastics Equipment – Efficient Radiant Heater and Retrofit.’” Memo. May 29, 2012.

Revision History

Version Number	Date	Description of Change
01	10/09/2018	Initial TRM entry

Industrial High Frequency Battery Chargers

	Measure Details
Measure Master ID	Industrial High Frequency Battery Chargers, 4765
Workpaper ID	W0163
Measure Unit	Per kilwatt-hour of battery charger capacity
Measure Type	Hybrid
Measure Group	Process
Measure Category	Other
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$400[1]

Measure Description

Industrial high-frequency battery chargers are used for portable industrial equipment like forklifts, fork trucks, and airport transport equipment in factories, warehouses, and similar facilities. They convert standard AC power to DC power stored in batteries. System inefficiencies occur during charging, charge maintenance, and standby. There are several factors to consider:

- Power Conversion Efficiency – the ratio of energy out of charger to the energy into charger
- Charge Return Factor – the ratio of energy into battery to the energy out of battery
- Maintenance Mode Losses – the power used by charger when connected battery is fully charged
- No Battery Mode Losses – the power used by charger when no battery is connected

High-frequency battery chargers are more efficient than other types of chargers, including ferroresonant, silicon controlled rectifier (SCR), and hybrids of these two technologies. Compared to ferroresonant chargers, high-frequency chargers do not have transformer losses, have better power factor, and have better electrical controls. Compared to SCR chargers, high-frequency chargers have lower switching losses and better power factor.

High-frequency battery chargers have a rated input power of more than 2 kW[2] and may be single phase or three phase. This measure does not apply to vehicle chargers or smaller chargers like those used for golf carts.

Description of Baseline Condition

The baseline condition is a ferroresonant, SCR, or hybrid battery charger, where operating hours are at least 1,000 hours per year.

Description of Efficient Condition

The efficient condition is battery charger that meets the minimum requirements as documented in California's appliance standard for Large Battery Charger Systems (shown in the table below).[2]

Minimum Requirements for Qualifying Large Battery Chargers

Performance Parameter		Requirement
Charge Return Factor	80% Depth of Discharge	$\leq$1.10
	40% Depth of Discharge	$\leq$1.15
Power Conversion Efficiency		$\geq$89%
Power Factor		$\geq$0.9
Maintenance Power Mode (watts)		$\leq$10 + 0.0012 * (Battery watt-hours), in watts
No Battery Mode Power (watts)		$\leq$10 watts

A list of approved products is available online.[3] Operating hours must be at least 1,000 hours per year.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{BASELINE} - kWh_{EE}$

$kWh_{BASELINE} = ((CAP * DOD * CHG * CRF_{BASE} / PCE_{BASE}) + (P_{MM,BASE} * HOU_{MM}) + (P_{NBM,BASE} * HOU_{NBM})) / 1{,}000$

$kWh_{EE} = ((CAP * DOD * CHG * CRF_{EE} / PCE_{EE}) + (P_{MM,EE} * HOU_{MM,EE}) + (P_{NBM,EE} * HOU_{NBM,EE})) / 1{,}000$

Where:

CAP = Battery charger capacity in watt-hours (= user input)
DOD = Degree of discharge (= user input; if unknown use 80%)[2]
CHG = Number of charging cycles per year (= user input)
CRF_{BASE} = Baseline charge return factor at degree of discharge (= 1.16; see Assumptions)
PCE_{BASE} = Baseline power conversion efficiency (= 85.1%; see Assumptions)
$P_{MM,BASE}$ = Baseline power in maintenance mode (= 99.1 watts; see Assumptions)
HOU_{MM} = Baseline number of hours per year in maintenance mode (= user input)
$P_{NBM,BASE}$ = Baseline power in no battery mode (= 55.4 watts; see Assumptions)
HOU_{NBM} = Baseline number of hours per year in no battery mode (= user input)
1,000 = Watt to kilowatt conversion factor
CRF_{EE} = Efficient charge return factor at degree of discharge (= user input)

PCE_{EE} = Efficient power conversion efficiency (= user input)

$P_{MM,EE}$ = Efficient power in maintenance mode in watts (= user input)

$P_{NBM,EE}$ = Efficient power in no battery mode in watts (= user input)

Summer Coincident Peak Savings Algorithm

There are no peak demand savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

Savings related to better efficiency in maintenance mode and no battery mode are small relative to savings in charging mode and are neglected.

The baseline values for power conversion efficiency, charge return factor, power in maintenance mode, and power in no battery mode are averages for ferroresonant, SCR, and hybrid chargers. The population fraction of each was derived from Table 1 of a Minnesota study,[5] showing that the general population of industrial battery chargers is 50% ferroresonant, 30% SCR, 5% hybrid, and 10% high frequency. Therefore the baseline splits are assumed to be 50 / (50 + 30 + 5) = 59% for ferroresonant, and so on.

Average Baseline Values[4]

Charger Type	Population Fraction[5]	Power Conversion Efficiency	Charge Return Factor	Maintenance Power (watts)	No Battery Power (watts)
Ferroresonant	59%	85%	1.15	81.7	18.2
SCR	35%	85%	1.18	137.1	125.3
Hybrid	6%	86%	1.12	62.3	14.1
Average		**85.1%**	**1.16**	**99.9**	**55.4**

Sources

1. Pacific Gas & Electric. “Analysis of Standards Options for Battery Charger Systems.” EUL: p. 43. Incremental cost: p. 45. Baseline wattages: p. 17. 2010.
   This report is cited in 2019 *Illinois Statewide Technical Reference Manual for Energy Efficiency.* Version 7.0, p. 581. September 28, 2018.
   http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_7/Final_9-28-18/IL-TRM_Effective_010119_v7.0_Vol_1-4_Compiled_092818_Final.pdf
2. California Energy Commission. *2016 Appliance Efficiency Regulations*. January 2017. Definition on p. 89. Mininum requirements on p. 230, Table W-1.
   http://www.energy.ca.gov/2017publications/CEC-400-2017-002/CEC-400-2017-002.pdf
3. California Energy Commission.
   https://cacertappliances.energy.ca.gov/Pages/ApplianceSearch.aspx
4. Pacific Gas and Electric Company (Matley, Ryan). *Industrial Battery Charger Energy Savings Opportunities.* Emerging Technologies Program Application Assessment Report #0808, p. 8. May 29, 2009. https://www.etcc-ca.com/reports/forklift-battery-charger
5. Minnesota Department of Commerce, Division of Energy Resources, Conservation Applied Research and Development. *Field Study of Industrial High Frequency Battery Chargers*. September 8, 2017.
   https://www.cards.commerce.state.mn.us/CARDS/security/search.do?documentId=%7b7849AB55-DFC6-4F87-AC80-BD0356BB32D9%7d

Revision History

Version Number	Date	Description of Change
01	10/01/2018	Initial TRM entry

Steam Trap Repair, < 10 psig, Industrial Process Heating

	Measure Details
Measure Name	Steam Trap Repair, < 10 psig, Industrial, 3999
Workpaper ID	W0164
Measure Unit	Per steam trap
Measure Type	Prescriptive
Measure Group	Process
Measure Category	Steam Trap
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	776
Lifecycle Electricity Savings (kWh)	0
Lifecycle Therm Savings (Therms)	4,656
Water Savings (gal/year)	0
Effective Useful Life (years)	6[1]
Incremental Cost ($/unit)	$166.23[2]

Measure Description

Steam distribution systems contain steam traps, which are automatic valves that remove condensate, air, and other non-condensable gases, while preventing or minimizing steam loss. This measure is the repair of failed open and leaking steam traps on industrial process heating steam systems.

Steam traps that fail in the open position allow steam to escape into the condensate lines before the available heat energy can be used for space heating, wasting the energy used to make the steam. By replacing or repairing traps that have failed in the open position, the wasted heating energy can be conserved.

The measure specifications are as follows:

- Boiler must be used for industrial process heating, not space heating
- Repaired traps must be leaking steam, not failed in the closed position or plugged
- The incentive is available once per year per system
- Municipal steam systems do not qualify
- When mass replacing steam traps, 20% of traps replaced will qualify
- System pressure must be < 10 psig

A steam trap survey and repair log must be completed. The information required to calculate savings includes a trap identification tag number, location description, nominal steam pressure, trap type, trap condition (functioning, failed open, or failed closed), and trap orifice diameter. The savings are based on a typical orifice diameter for low-pressure systems of 1/4-inch, based on project experience.

Description of Baseline Condition

The measure baseline is a steam trap that has failed in the open position and is leaking steam into the condensate line in a steam system. The steam from the boiler must be used for process heating and not for space heating applications. It is important to note that the trap must be failed in the open position and not failed in the closed position or plugged.

Description of Efficient Condition

The efficient condition is replacing or repairing traps that have failed in the open position, providing the ability to use steam heat that was previously wasted.

Annual Energy-Savings Algorithm

$\text{Therm}_{SAVED} = 1.9 * K * 60 * (\pi * D^2/4) * \sqrt{([P_{ABS} – \{P_1 – P_2\}] * [P_1 – P_2])} * h_{FG} * HOU * DF / (100{,}000 * eff)$

Where:

1.9 = Constant based on units and fluid flow equation[3]
K = Discharge coefficient (= 0.55)[4]
60 = Conversion from minutes to hours
D = Steam trap orifice diameter (= 1/4-inch)
P_{ABS} = System absolute pressure in pounds per square inch (= 20.7 psia; steam gage pressure at trap inlet (6 psig) + atmospheric pressure at sea level in pounds per square inch (14.7 psi))[5]
P_1 = Steam pressure at trap inlet (= 6 psig)[5]
P_2 = Steam pressure at trap outlet, condensate tank pressure (= 0 psig)
h_{FG} = Latent heat of steam at P_{ABS} (= 959)[6]
HOU = Annual hours of operation the boiler is on and the system is at design pressure (= 7,000)[7]
DF = Derating factor to account for the average percentage of time a trap fails in the open position and actual versus theoretical energy loss (= 32%)[5]
100,000 = Conversion factor from Btu to therms
eff = Boiler efficiency (= 80%)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure, as it does not generate electric savings.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 6 years)[1]

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. SPECTRUM. Pressure-based extrapolation of costs (2013-2014) for MMIDs 2542, 2548, and 2546 (new MMIDs 4001, 4002, 4003).
3. Hornaday, William T. "Steam: Its Generation and Use." Equation 50. Merchant Books, 2007. July 13, 2016. http://www.gutenberg.org/files/22657/22657-h/chapters/flow.html#page_321
   The equation applies to subsonic flow, which occurs when steam flows through an orifice where $P_2 \geq 58\%$ of P_1.
4. Manczyk Energy Consulting. "Estimating the Cost of Steam Loss Through the Orifice of a Steam Trap." http://invenoinc.com/file/Estimating-the-Steam-Loss-through-a-Orifice-of-a-Steam-Trap.pdf
   The discharge coefficient was determined by converging flow rates with the Napier equation at $P_2 = 0.58 * P_1$. The Napier equation is used to determine flow rate through an orifice when $P_2 \leq 0.58 * P_1$. The Napier equation is in fact Equation 49 in source 3, with an added discharge coefficient of 0.6. Matching Equation 50 in source 3 to the Napier formula in the link above, at $P_2 = 0.58 * P_1$, produces this equality: $1.9 * (\pi/4 * D^2) * K * \sqrt{}([P_1 - 0.42 * P_1] * 0.42 * P_1) * 60 = 24.24 * P_1 * D^2$. Note that 60 is inserted to convert lb/min to lb/hr, and that P_1 and P_2 are treated as absolute pressures. Solving this produces K = 0.55.
5. Cadmus. "Focus on Energy Steam Trap Study." 2016.
   In the study, Cadmus determined realized savings from billing data for 35 sites that had applied for steam trap incentives during the 2012 to 2014 program years. This study revealed 6 psig as the weighted average pressure of < 10 psig steam traps surveyed.
   These sites had an overall realization rate of billing data results to calculated savings (using algorithms in this workpaper with site-specific values and the previous derating factor of 50%) of 64%, suggesting that a derating factor of 32% would be more appropriate. Note: the 50% derating factor came from: Enbridge Steam Saver Program. 2005.
6. The Engineering Toolbox. "Properties of Saturated Steam - Imperial Units." http://www.engineeringtoolbox.com/saturated-steam-properties-d_273.html
7. 7,000 hours is an educated guess value that corresponds to a process running 9.7 months of the year.

Revision History

Version Number	Date	Description of Change
01	01/2017	Initial TRM entry

Steam Trap Repair, ≥ 10 psig, Industrial Process Heating

	Measure Details
Measure Name and ID	Steam Trap Repair, Industrial, 10-49 psig, 4000 50-124 psig, 4001 125-225 psig, 4002 >225 psig, 4003
Workpaper ID	W0165
Measure Unit	Per system psi (absolute)
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Steam Trap
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure, see algorithm below
Life-cycle Electricity Savings (kWh)	0
Life-cycle Natural Gas Savings (therms)	Varies by measure, see algorithm below
Water Savings (gal/year)	0
Effective Useful Life (years)	6[1]
Incremental Cost ($/unit)	Varies by measure, see Incremental Cost table below

Measure Description

Steam distribution systems contain steam traps, which are automatic valves that remove condensate, air, and other non-condensable gases, while preventing or minimizing steam loss. This measure is the repair of failed open and leaking steam traps on industrial process heating steam systems.

Steam traps that fail in the open position allow steam to escape into the condensate lines before the available heat energy can be used for space heating, wasting the energy used to make the steam. By replacing or repairing traps that have failed in the open position, the wasted heating energy can be conserved.

The measure specifications are as follows:

- Boiler must be used for industrial process heating, not for space heating applications
- Repaired traps must be leaking steam, and not be failed in the closed position or plugged
- The incentive is available once per year per system
- Municipal steam systems do not qualify

- When mass replacing steam traps, 20% of traps replaced will qualify
- System pressure must be ≥ 10 psig

A steam trap survey and repair log must be completed. The information required to determine the amount of savings includes a trap identification tag number, location description, nominal steam pressure, trap type, trap condition (functioning, failed open, or failed closed), and trap orifice diameter. The absolute system steam pressure at trap inlet (psia = psig + 14.7) is to be recorded by the implementers and used as savings input.

Description of Baseline Condition

The measure baseline is a steam trap that has failed in the open position and is leaking steam into the condensate line in a high pressure (≥ 10 psig) process heating steam system. The steam from the boiler must be used for process heating and not space heating applications. The boiler is assumed to operate with 80% efficiency. It is important to note that the trap must be failed in the open position and not be failed in the closed position or plugged.

Description of Efficient Condition

The efficient condition is replacing or repairing traps that have failed in the open position, providing the ability to use steam heat that was previously wasted.

Annual Energy-Savings Algorithm

Steam leakage rate follows the Napier equation:[2]

$\text{Therm}_{\text{SAVED}} = 24.24 * P_{\text{ABS}} * D^2 * h_{\text{FG}} * \text{HOU} * \text{DF} / (100{,}000 * \text{eff})$

Where:

24.24 = Constant from Napier equation when units for absolute system pressure are in psia and units of the steam trap diameter are in inches

P_{ABS} = System absolute pressure in pounds per square inch (= steam gauge pressure at trap inlet (as measured by implementers) + atmospheric pressure at sea level in pounds per square inch of 14.7)

D = Steam trap orifice diameter in inches (= varies by measure, and assumed based on system pressure range; see table below)

h_{FG} = Latent heat of vaporization for water at P_{ABS} (= varies by measure; see table below)

DF = Derating factor to account for the average percentage open a trap fails and actual versus theoretical energy loss (= 32%)[3]

HOU = Annual hours of operation the boiler is on and the system is at design pressure (= 7,000)[4]

100,000 = Conversion factor from Btu to therms
eff = Boiler efficiency (= 80%)

The amount of therms saved varies based on the system pressure (the system absolute pressure at trap inlet is to be recorded by implementers).

Orifice diameters are assumed based on system pressure range.

The latent heat of vaporization values (h_{FG}) correspond to the assumed system absolute pressures (P_{ABS}) listed in the table below. Mid-range assumed pressures were used to determine the deemed latent heat of vaporization values for each measure's pressure range. The implementers are to input the absolute system pressure at trap inlet when calculating savings. A simplified algorithm for calculating annual savings uses annual savings multipliers and is as follows:

$Therm_{SAVED}$ = System Absolute Pressure * Annual Savings Multiplier

= [System Gauge Pressure + 14.7] * Annual Savings Multiplier

Diameters, Pressures, Latent Heats, and Savings Multipliers

Measure Name	MMID	Assumed Orifice Diameter[3]	Assumed P_{ABSs} for h_{FG}[3]	Deemed h_{FG} Latent Heat of Steam (Btu/lb)[5]	Annual Savings Multiplier (therms/psia)
Steam Trap Repair, 10-49 psig, Industrial	4000	3/16"	40	933.4	22.3
Steam Trap Repair, 50-124 psig, Industrial	4001	1/8"	102.2	887.5	9.4
Steam Trap Repair, 125-225 psig, Industrial	4002	1/8"	190	846.9	9.0
Steam Trap Repair, >225 psig, Industrial	4003	1/8"	240	827.9	8.8

For example, for MMID 4000 (Steam Trap Repair, 10-49 psig, Industrial), a steam trap repaired on a 25 psig system has an annual savings multiplier of 22.3 and would result in an annual savings of 885.3 therms.

$Therm_{SAVED} = 24.24 * (25 + 14.7) * 0.1875^2 * 933.4 * 7{,}000 * 32\% / (100{,}000 * 80\%)$

Or

$Therm_{SAVED} = (25 + 14.7) * 22.3 = 885.3$

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure, as it does not generate electric savings.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 6 years)[1]

Incremental Cost

Incremental Costs

Measure Name	MMID	Incremental Cost	Source
Steam Trap Repair, 10-49 psig, Industrial	4000	$276.78	Average of 3 projects for MMID 2542, 2013 – 2014
Steam Trap Repair, 50-124 psig, Industrial	4001	$194.61	Average of 13 projects for MMID 2548, 2013 - 2014. One project with outlier cost excluded.
Steam Trap Repair, 125-225 psig, Industrial	4002	$600.18	Average of 3 projects for MMID 2546, 2013 - 2014
Steam Trap Repair, >225 psig, Industrial	4003	$895.65	Pressure-based extrapolation of costs (2013-14) for MMIDs 2542, 2548, and 2546.

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. “Steam Pressure Reduction: Opportunities and Issues.” November 2005. https://energy.gov/eere/amo/downloads/steam-pressure-reduction-opportunities-and-issues
3. Cadmus. “Focus on Energy Steam Trap Study.” 2016.
   The derating factor was calculated using study results. The study revealed realized savings from billing data for four sites that had applied for steam trap incentives during the 2012 through 2014 program years. These sites had an overall realization rate of billing data results to calculated savings (using algorithms in this workpaper with site-specific values and the previous derating factor of 50%) of 64%, suggesting that a derating factor of 32% is more appropriate. Note that the 50% derating factor came from: Enbridge Steam Saver Program. 2005.
   The study revealed that a 1/4-inch diameter is typical for steam traps of < 15 psi, and 1/8-inch diameter is typical for steam traps larger than 15psi. The difference is split for the < 50 psi range (at 3/16-inch).
   The median value pressure at inlet is +14.7; this study revealed industrial system pressures across this range.
4. 7,000 hours is an educated guess value that corresponds to a process running 9.7 months of the year.

5. The Engineering Toolbox. "Properties of Saturated Steam – Imperial Units." http://www.engineeringtoolbox.com/saturated-steam-properties-d_273.html
Latent and total heat in evaporated water - steam - at different gauge pressures and boiling temperatures. User must take the 'Assumed Pabs for hfg' value from the table above and subtract 14.7 psi to correspond to the correct gauge pressure listed in this sources table when looking up corresponding hfg value.

Revision History

Version Number	Date	Description of Change
01	07/2016	Initial TRM entry
02	01/2017	Revised Assumptions and algorithm

Refrigeration

Anti-Sweat Heater Controls

	Measure Details
Measure Master ID	Anti-Sweat Heater Controls: Freezer Case, Low Heat Door, 2197 Freezer Case, No Heat Door, 2198 Freezer Case, Standard Door, 2199 Refrigerated Case, Low Heat or No Heat Door, 2200 Refrigerated Case, Standard Door, 2201
Workpaper ID	W0166
Measure Unit	Per door
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$68.78[2]

Measure Description

Anti-sweat heater controls sense the humidity outside of refrigeration units and turn off anti-sweat heaters during period of low humidity. Without controls, anti-sweat heaters run continuously whether they are necessary or not. Qualifying controls turn off all heaters, including mullion heaters on cases with no door glass or frame heaters. By controlling all heaters, savings are still possible with no-heat doors. The primary energy savings result from the reduction in electric energy when the heaters are off. Secondary savings result from the reduced cooling load on the refrigeration unit when the heaters are off.

Description of Baseline Condition

The baseline condition is a refrigerated display case with doors, not using anti-sweat heater controls.

Description of Efficient Condition

The efficient condition is a refrigerated display case using anti-sweat heater controls.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Watts_{BASE} * (1 + 1 / COP) / 1{,}000 * F_S * HOU$

$Watts_{BASE}$ = Wattage of door heaters (=132 for MMID 2197, = 54 for MMID 2198, = 191 watts for MMID 2199, = 60.25 for MMID 2200 (see Assumptions), = 109 for MMID 2201)[3]

COP = Coefficient of performance (= 1.4 for MMIDs 2197, 2198, and 2199; = 2.3 for MMIDs 2200 and 2201)[4]

1,000 = Kilowatt conversion factor

F_S = Savings factor (= 46.5% for MMIDs 2197, 2198, and 2199; = 74.2% for MMIDs 2200 and 2201)[5]

HOU = Average annual run hours (= 8,760)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Watts_{BASE} * (1 + 1 / COP) / 1{,}000 * F_P$

F_P = Coincidence factor (= 10%)[5]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

EUL = Effective useful life (=12 years)[1]

Savings

Deemed Savings for Anti-Sweat Heater Controls

Measure Name	MMID	$Watts_{BASE}$	F_P	F_S	COP	First Year kWh Savings	Summer Peak kW Savings	EUL	Lifecycle kWh Savings
Freezer Case, Low Heat Door	2197	132	10%	46.5%	1.4	922	0.023	12	11,064
Freezer Case, No Heat Door	2198	54	10%	46.5%	1.4	377	0.009	12	4,524
Freezer Case, Standard Door	2199	191	10%	46.5%	1.4	1,334	0.033	12	16,008
Refrigerated Case, Low Heat or No Heat Door	2200	60.25	10%	74.2%	2.3	562	0.009	12	6,744
Refrigerated Case, Standard Door	2201	109	10%	74.2%	2.3	1,017	0.016	12	12,204

Assumptions

Based on historical program data and discussions with customers, it is assumed that low-heat cooler doors ($\text{Watts}_{\text{BASE}}$ = 63[3]) make up 75% of the installations, and no-heat cooler doors ($\text{Watts}_{\text{BASE}}$ = 52[3]) make up 25% of the installations, for the combined measure for anti-sweat heater controls for low-heat and no-heat cooler doors.

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 1,048 projects and 17,986 doors for MMIDs 2197, 2198, 2199, 2200, 2201 from January 2018 to July 2020 is $68.78.
3. Zero Zone RVZC and RVCC and Hussmann RL and RM specification sheets for reach-in cooler and freezer cases with doors, specification sheets published 2006/2007.
4. U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office. "Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration." DOE Publication ID 6180. Table 3-7. September 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
5. Energize Connecticut. "Connecticut Program Savings Document." 8th Edition for 2013 Program Year. p. 90 and Appendix 1, p. 253. October 30, 2012. http://www.energizect.com/sites/default/files/2013%20PSD_ProgramSavingsDocumentation-Final110112.pdf
   Report shows 6,500 hours off for coolers, 4,070 hours off for freezers; when divided by 8,760, this produces 74.2% and 46.5%, respectively, with a coincidence factor of 10% for all refrigeration controls.

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Update from Focus on Energy Deemed Savings Manual

Demand Defrost Controls

	Measure Details
Measure Master ID	Demand Defrost Controls, 4758
Workpaper ID	W0167
Measure Unit	Per kilowatt of electric defrost controlled
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	176 (per kilowatt of electric defrost controlled)
Peak Demand Reduction (kW)	0.020 (per kilowatt of electric defrost controlled)
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	1,760 (per kilowatt of electric defrost controlled)
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$619.00 per controller[2]

Measure Description

Evaporator coils in walk-in freezer systems must be intermittently defrosted to prevent the buildup of ice on the coil, which will not allow for proper heat exchange. Coil defrosting is an energy inefficient but necessary process that should only occur when necessary. Defrosting requires an input of heat into a refrigerated space, which increases the energy demand on the system to maintain the desired low temperature, thus lowering the efficiency of the system. Walk-in freezer systems that do not use demand defrost controls engage the defrost process more often and, at times, when not needed.

Demand defrost controls are composed of an array of sensors within the walk-in unit—such as temperature, air pressure, and humidity sensors—along with software to statistically model the process requirements of the system and call for a defrost cycle to engage when needed. Energy is saved in two ways: (1) less energy is required due to fewer defrost cycles, and (2) there is less heat being introduced into the system, thereby decreasing the load required to cool the space after a defrost cycle.

Description of Baseline Condition

The baseline condition is a walk-in freezer system without electronic demand defrost controls to engage the defrost cycle via a timer, which is assumed to cycle on every four hours for 20 minutes per cycle.

Description of Efficient Condition

The efficient condition is a walk-in freezer system with electronic demand defrost controls that engage the defrost cycle only when its array of sensors and statistical modeling deem it necessary.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kW_{DEFROST} * HOU_{BASE} * F_s * [1 + 3.412 / (12 * COP)]$

Where:

$kW_{DEFROST}$ = Wattage of electric defrost (= 1 kW)

HOU_{BASE} = Hours of use for baseline equipment (= 487; see Assumptions)[5]

F_s = Savings factor (= 30%)[3]

3.412/12 = Kilowatt to ton conversion factor (3.412 kW/MBh; 12 MBh/ton)

COP = Coefficient of performance (= 1.4)[5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (kWh_{SAVED} / HOU)$

Where:

HOU = Hours of freezer use (= 8,760 hours per year)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Assumptions

The unit of measure is per 1 kW of electric defrost system that is to be controlled. This unit of measure was chosen over other units of measure to allow for various sized walk-in freezer systems. The electric defrost load is directly proportional to the size of the walk-in freezer; therefore, the size of the freezer system is accurately incorporated into the savings algorithm.

Baseline hours are assumed to reflect four defrost cycles per day, at 20 minutes per cycle. This is consistent with the typical strategy for preset time cycle control, outlined in a study.[4]

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Grainger, Inc. *Average Cost of Defrost Timer Controls (= $146; average of 23 relevant products).* Baseline cost. Accessed September 2018. https://www.grainger.com/category/defrost-timer-control/
3. Heatcraft Refrigeration Products, LLC. *Cost of Smart Defrost Controls (= $765).* Efficient cost. Accessed September 2018. *https://www.heatcraftrpd.com/PDF/Archived/SDK_CutSheetGen1* Incremental cost= $765-$146=$619.
4. National Renewable Energy Laboratory. *Advanced Energy Retrofit Guide—Grocery Stores.* Appendix F.2.9: Detailed Retrofit Measure Description. p. 168. June 2013. https://www.osti.gov/biblio/1045045
5. Fricke, Brian A., and Sharma, Vishal. Oak Ridge National Laboratory. “Demand Defrost Strategies in Supermarket Refrigeration Systems.” October 2011. https://info.ornl.gov/sites/publications/files/pub31296.pdf
6. Navigant Consulting, Inc. “Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration.” Table 3-7. U.S. DOE Publication ID 6180. September 2009. https://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf

Revision History

Version Number	Date	Description of Change
01	09/21/2018	Initial TRM entry

Evaporator Fan Control

	Measure Details
Measure Master ID	Cooler Evaporator Fan Control, 2269 Evaporator Fan Control for Reach-in Cooler/Freezer, 4759
Workpaper ID	W0168
Measure Unit	Per motor
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	16[1]
Incremental Cost ($/unit)	$155.00[3]

Measure Description

Walk-in cooler and freezer refrigeration systems typically operate 24 hours per day, 365 days per year. These systems must run when the compressor is running to provide cooling, and they must run when the compressor is not running to provide air circulation, thus preventing the coil from freezing. The only time these fans do not operate is during the defrost cycle.

Significant energy savings can be realized by installing a more efficient evaporator fan motor and control fan system, which regulates the speed of the evaporator fan motor to meet the need during each phase of the refrigeration cycle. These systems save energy in two ways: (1) the evaporator fans consume less energy, and (2) the system results in less heat being introduced to the refrigerated chamber from the evaporator fan motors, which decreases the overall box load, thereby reducing the compressor/condenser on-duty cycle.

Description of Baseline Condition

The baseline condition is a refrigeration system with a shaded pole (SP), permanent split capacitor (PSC), or electronically commutated (ECM) evaporator fan motor in walk-in or reach-in coolers and/or freezers without an evaporator fan controller.

Description of Efficient Condition

The efficient condition is a refrigeration system with a SP, PSC, or ECM evaporator fan motor in walk-in or reach-in coolers and/or freezers with an evaporator fan controller to switch the fan to lower speeds when the temperature of the unit of refrigerant is determined to need lower air movement.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \sum[Watts_{FULL} – (Watts_{FULL} * (1 – LS) + Watts_{LOW} * LS)] * (1 + 1 / COP) * HOU / 1{,}000$

Where:

$Watts_{FULL}$ = Wattage of the fan motor at normal speed of 1,550 RPM (= varies by motor type; see table below)

LS = Fraction of time fan motor is on low speed setting (= 37%, average of 32% for freezers and 42% for coolers)[3]

$Watts_{LOW}$ = Wattage of the fan motor at low speed of 550 RPM (= varies by motor type; see table below)

COP = Coefficient of performance (= 1.85, average of 1.4 for freezers and 2.3 for coolers)[2]

HOU = Average annual run hours (= 8,517, see Assumptions)[7]

1,000 = Kilowatt conversion factor

Energy Savings for MMID 2269

Motor Nameplate HP[4]	Input Wattage		COP[2]	LS[3]	Savings		Weighted Percentage
	At 1,550 RPM (normal speed)*	At 550 RPM (low speed)*			Annual (kWh)	Coincident Peak (kW)	
SP							
1/47	70.54	8.15	1.85	37%	38.4	0.0045	12.7%
1/25	132.62	15.32	1.85	37%	17.2	0.0020	3.0%
1/20	165.78	19.15	1.85	37%	74.5	0.0088	10.5%
1/15	221.04	25.54	1.85	37%	468.2	0.0550	49.3%
1/8	414.44	47.88	1.85	37%	21.0	0.0025	1.2%
1/3	1,105.19	127.69	1.85	37%	31.5	0.0037	0.7%
PSC							
1/47	26.45	3.06	1.85	37%	1.4	0.0002	1.3%
1/25	49.73	5.75	1.85	37%	0.6	0.0001	0.3%
1/20	62.17	7.18	1.85	37%	2.8	0.0003	1.0%
1/15	82.89	9.58	1.85	37%	17.4	0.0020	4.9%
1/8	155.42	17.96	1.85	37%	0.8	0.0001	0.1%
1/3	414.44	47.88	1.85	37%	1.2	0.0001	0.1%

Motor Nameplate HP[4]	Input Wattage		COP[2]	LS[3]	Savings		Weighted Percentage
	At 1,550 RPM (normal speed)*	At 550 RPM (low speed)*			Annual (kWh)	Coincident Peak (kW)	
ECM							
1/47	22.67	2.62	1.85	37%	2.4	0.0003	2.5%
1/25	42.63	4.93	1.85	37%	1.1	0.0001	0.6%
1/20	53.29	6.16	1.85	37%	4.6	0.0005	2.0%
1/15	71.05	8.21	1.85	37%	29.2	0.0034	9.6%
1/8	133.21	15.39	1.85	37%	1.3	0.0002	0.2%
1/3	355.24	41.04	1.85	37%	2.0	0.0002	0.1%
Total					**715.5**	**0.084**	**100%**

* Motor input wattages are based on the motor nameplate wattage and efficiencies listed in tables below.

Energy Savings for MMID 4759

Motor Nameplate HP[6]	Input Wattage		COP[2]	LS[3]	Savings		Weighted Percentage
	At 1,550 RPM (normal speed)*	At 550 RPM (low speed)*			Annual (kWh)	Coincident Peak (kW)	
SP							
1/83	39.13	4.52	1.85	37%	11.7	0.0014	6.96%
1/38	84.78	9.80	1.85	37%	138.0	0.0162	37.90%
1/20	162.17	18.74	1.85	37%	226.2	0.0266	32.49%
PSC							
1/83	15.00	1.73	1.85	37%	0.4	0.0001	0.69%
1/38	32.50	3.75	1.85	37%	5.2	0.0006	3.75%
1/20	62.17	7.18	1.85	37%	8.6	0.0010	3.21%
ECM							
1/83	12.86	1.49	1.85	37%	0.7	0.0001	1.35%
1/38	27.86	3.22	1.85	37%	8.8	0.0010	7.35%
1/20	53.29	6.16	1.85	37%	14.4	0.0017	6.30%
Total					**414.1**	**0.049**	**100%**

* Motor input wattages are based on the motor nameplate wattage and efficiencies listed in tables below.

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = \sum[Watts_{FULL} * (1 - LS) + Watts_{LOW} * (LS)] / 1{,}000 * (1 + 1 / COP)$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 16 years)[1]

Assumptions

Based on engineering judgement, 15% of motors are assumed to be ECMs, which are poor candidates for the addition of motor controls. The remaining 85% of motors are PSC and SP, and these are assumed to follow the population split seen in historical applications using the existing ECM retrofit measures. This split is 91% SP and 9% PSC. Applying this to the 85% assumed share for SP and PSC motors for this measure produces 77% SP motors and 8% PSC motors. The low speed, 550 RPM, is associated with a 10% load. Using the same methodology for the part load efficiencies with a VFD,[5] the motor efficiencies are 16% for SP, 43% for PSC, and 50% for ECMs.

The motor sizes and their associated weighting for evaporator fans were determined from a review of historical applications using the existing ECM retrofit measures. The historical applications were randomly selected by program to ensure a sampling and review of all motor options. In programs where there were multiple facility (or customer) types available, applications were selected to capture information from the various facility (or customer) types. The applications used to obtain the motor sizes and wattages all contained complete motor information (make and model) for the correct application measure. Multiple location applications were not used in the random selection to ensure that one facility (or customer) type was not favored over the others in the motor sizes and wattages. At least 10% of the total number of applications per program were surveyed, along with the total number of motors surveyed accounting for at least 10% of the motors in each measure category. The quantity and size of each motor, and type of motor replaced, was recorded and used to determine the baseline and proposed wattages, as well as the weighting of each motor size. The table below summarizes the historical application findings and values for efficiencies.

Efficiency Values for MMID 2269

Motor Type	Motor Nameplate HP	Motor Nameplate kW (Motor Nameplate HP * 0.746)	Motor Efficiency		Motor Size Weighting[4]	Motor Type Weighting	
			Full Speed[5]	Low Speed		Historical[4]	Measure
SP	1/47	0.0159	23%	16%	16%	91%	77%
	1/25	0.0298	23%	16%	4%	91%	77%
	1/20	0.0373	23%	16%	14%	91%	77%
	1/15	0.0497	23%	16%	64%	91%	77%
	1/8	0.0933	23%	16%	2%	91%	77%
	1/3	0.2487	23%	16%	1%	91%	77%
PSC	1/47	0.0159	60%	43%	16%	9%	8%
	1/25	0.0298	60%	43%	4%	9%	8%
	1/20	0.0373	60%	43%	14%	9%	8%
	1/15	0.0497	60%	43%	64%	9%	8%
	1/8	0.0933	60%	43%	2%	9%	8%
	1/3	0.2487	60%	43%	1%	9%	8%

Motor Type	Motor Nameplate HP	Motor Nameplate kW (Motor Nameplate HP * 0.746)	Motor Efficiency		Motor Size Weighting[4]	Motor Type Weighting	
			Full Speed[5]	Low Speed		Historical[4]	Measure
ECM	1/47	0.0159	70%	50%	16%	N/A	15%
	1/25	0.0298	70%	50%	4%	N/A	15%
	1/20	0.0373	70%	50%	14%	N/A	15%
	1/15	0.0497	70%	50%	64%	N/A	15%
	1/8	0.0933	70%	50%	2%	N/A	15%
	1/3	0.2487	70%	50%	1%	N/A	15%

Efficiency Values for MMID 4759

Motor Type	Motor Nameplate HP	Motor Nameplate kW (Motor Nameplate HP * 0.746)	Motor Efficiency		Motor Size Weighting[6]	Motor Type Weighting	
			Full Speed[5]	Low Speed		Historical[4]	Measure
SP	1/83	0.0090	23%	16%	9%	91%	77%
	1/38	0.0195	23%	16%	49%	91%	77%
	1/20	0.0373	23%	16%	42%	91%	77%
PSC	1/83	0.0090	60%	43%	9%	9%	8%
	1/38	0.0195	60%	43%	49%	9%	8%
	1/20	0.0373	60%	43%	42%	9%	8%
ECM	1/83	0.0090	70%	50%	9%	N/A	15%
	1/38	0.0195	70%	50%	49%	N/A	15%
	1/20	0.0373	70%	50%	42%	N/A	15%

Controls are assumed to be installed in equal proportions for freezers and coolers due to equal proportions of freezers and coolers with motors throughout refrigerated spaces in retail applications. Evaporator fan motors run constantly to ensure proper airflow and circulation throughout the walk-in to maintain even product temperatures and avoid hot spots in the space. However, during times of defrost, evaporator fans do not run, as heat is being introduced to the system to remove the ice and frost build-up on the evaporator coils. Freezer hours of operation assume four defrost cycles per day at 20 minutes per defrost, producing 8,273 hours. This is consistent with the typical strategy for preset time cycle control, outlined in an Oak Ridge National Laboratory study.[7] As cooler operating temperatures are above freezing, defrost cycles are not required. Overall hours of operation are the average of cooler and freezer case hours of operation: (8,273 + 8,760) / 2 = 8,517.

MMID 4759 motor wattages were categorized into three motor sizes: < 12 watts, 16–23 watts, and > 37 watts,[6] each with an averaged wattage based on the motor sizes of 9 watts, 19.5 watts, and 37 watts, respectively. They also had population splits of 9%, 49%, and 42%, respectively.[4] These output wattages were used to obtain the motor input wattages, based on motor efficiencies.[3] The input wattages were averaged, based on the motor size ratio, to obtain the overall motor input wattages for the savings algorithms.

The low temperature and medium temperature system COPs were derived from the information on Table 3-7 of the U.S. DOE Publication ID 6180.[2] The capacity and power values were calculated to yield the EER and then converted to COP, based on COP = EER / 3.412.

Sources

1. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficiency Resources." Evaporator Fan Controller for Walk-In Coolers. 2008. www.deeresources.com/files/deer0911planning/downloads/EUL_Summary_10-1-08.xls
2. Navigant Consulting, Inc. "Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration." U.S. Department of Energy Publication ID 6180. Table 3-7. 2009. https://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
3. Regional Technical Forum. "Evaporator Fan Controls and Evaporator Fan Uniform Energy Savings Measures Calculations." 2010. https://nwcouncil.app.box.com/s/pt7getqkjxzmlvm5f87wn3eydvidvjb5
   Cost adjusted from $141 in 2010 dollars to $155 in 2017 dollars based on http://www.usinflationcalculator.com/
4. Focus on Energy historical application data for MMIDs 2308–2311, June 2012 through July 2015.
5. Navigant Consulting Group, Inc. "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment." Prepared for U.S. Department of Energy, Building Technologies Office. 2013. https://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
   Motor efficiencies are: 23% (average of 15% to 30% for evaporator fans or compressors) for SP (page 6); 60% (average of 50% to 70%) for PSC (page 5); and 70% for fractional horsepower ECMs (page 16). Part load efficiencies are in Figure 2.6 (page 12).
6. Pacific Gas & Electric Company. "Display Case ECM Motor Retrofit." Workpaper PGE3PREF124. Table 10. 2014.
7. Fricke, Brian A., and Sharma, Vishal. Oak Ridge National Laboratory. "Demand Defrost Strategies in Supermarket Refrigeration Systems." October 2011. https://info.ornl.gov/sites/publications/files/pub31296.pdf

Revision History

Version Number	Date	Description of Change
01	03/2016	Initial TRM entry
02	09/2018	Added measure 4759

Refrigeration Controls, Floating Head Pressure

	Measure Details
Measure Master ID	Refrigeration Controls, Floating Head Pressure, 4360
Workpaper ID	W0169
Measure Unit	Per horsepower
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Controls
Sector(s)	Commercial, Industrial, Schools & Government, Agriculture
Annual Energy Savings (kWh)	639
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	6,390
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$272.25[2]

Measure Description

Reducing the compressor discharge pressure reduces the pressure ratio across the compressor and improves the operating efficiency. Many systems have controls that maintain a minimum condensing pressure to ensure proper operation of all components. By letting the condensing pressure drop down at lower ambient temperatures with head pressure controls, energy savings can be achieved. The typical design target for refrigeration systems for head pressure is the equivalent of approximately 95°F saturated condensing temperature.

Description of Baseline Condition

The baseline condition is a refrigerated system with a set condensing temperature/pressure that is typically around 95°F saturated condensing temperature and 82°F ambient temperature.

Description of Efficient Condition

The efficient condition is a refrigerated system with a condensing temperature allowed to float down at a minimum of 20°F with ambient temperature of at least 75°F.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \sum [(-0.00239 * DB_{AVE} + 0.1791) * Hours_{BIN\ TEMP}]$

Where:

-0.00239 = Interpolation constant, units of kW / (hp * °F)[3]

DB_{AVE} = Average bin dry bulb temperature in °F, from TRM Appendix B: Common Variables

0.1791 = Interpolation constant, units of kW / hp[3]

$Hours_{BIN\ TEMP}$= Annual hours of Wisconsin Outside Air Temperature, from TRM Appendix B: Common Variables

Summer Coincident Peak Savings Algorithm

No summer coincident peak savings occurs below 75°F, which is assumed to be during non–summer coincident peak hours.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=10 years)[1]

Assumptions

Savings were calculated by adapting savings values from the Vermont Technical Reference Manual[3] to Wisconsin weather. First, per the table below, a distribution of compressor types was assumed so that weighted-average savings for Vermont could be calculated. The various compressor types were assumed to occur at equal weightings (33% each) based on various refrigeration compressor product lines available on the market. It is assumed that these compressor systems will be used for freezers (very low and low temperature) 50% of the time, and for coolers (medium temperature) 50% of the time, due to equal proportions of freezer and cooler refrigerated spaces in retail applications.

The very low temperature (typical for ice cream freezer applications) is assumed to occur 25% of the time for freezer applications and the low temperature (typical for frozen food applications) is assumed to occur 75% of the time for freezer applications. This weighting is due to product storage and facility designs: there is significantly more storage and display area for frozen food than for just ice cream. These weightings combined produce the average savings value of 633 kWh/hp. This represents the average savings for floating head pressure controls in the state of Vermont, using the assumed compressor type population weightings.

Floating Head Savings Values in the State of Vermont, With Assumed Compressor Type Weightings

Compressor Type	kWh/hp Savings based on Evaporator Temperature Range[3]			Compressor Type Weighting	Weighted Average kWh/hp Savings
	Very Low (-35 to -5 SST*)	Low (0 to 30 SST*)	Medium (35 to 55 SST*)		
Standard Reciprocating	695	727	657	33%	633
Discus	607	598	694	33%	
Scroll	669	599	509	33%	
Evaporator Temperature Weighting	12.5%	37.5%	50%	---	

* Saturated suction temperature

This average savings value was adjusted for the state of Wisconsin by interpolating savings as a function of temperature, and applying this to Wisconsin temperature bins. The linear interpolation was based on two points, as shown in the table below.

Temperatures and Savings Used in Linear Interpolation

Temperature	kW/hp	Notes
75°F	0	Floating head pressure controls are assumed to provide no savings above 75°F
43.09°F	0.076257	From Vermont TMY3 temperature bins,[4] 43.09°F is the average temperature in Vermont below 75°F
		0.076257 = 633 / 8,296
		633 is the assumed average savings, in kWh/hp, for floating head pressure controls in Vermont
		From the Vermont TRM TMY3 temperature bins,[4] Vermont has 8,296 hours per year under 75°F

The linear fit produced by interpolating these two points has a slope of -0.00239 and an intercept of 0.1791. This interpolation was then used to determine the energy savings for each weather bin of Wisconsin weather data based on the Outside Air Temperature Bin Analysis located in Appendix B: Common Variables. These savings were summarized, producing savings for Wisconsin of 639 kWh/hp.

Sources

1. PA Consulting Group. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study. Final Report.” August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Regional Technical Forum. “Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems.” UES Measure Workbook 1.6. Floating Head Pressure Controls for Single Compressor Systems measures. December 5, 2016. https://rtf.nwcouncil.org/measure/floating-head-pressure-controls-single-compressor-systems
   Average of all operating temperature and refrigeration system design, assuming multiple compressor systems would have the same cost as single compressor systems ($272.25).
3. Efficiency Vermont. “Technical Reference User Manual (TRM): Measure Savings Algorithms and Cost Assumptions.” P. 214. February 19, 2010.
4. National Renewable Energy Laboratory. TMY3 weather data. Bin temperature data from Montpelier, Vermont. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Initial TRM entry
02	07/2017	Updated savings

ENERGY STAR Commercial Ice Machines

	Measure Details
Measure Master ID	ENERGY STAR Commercial Ice Machine: Ice Making Head, 3906 Remote Condensing Unit, 3907 Self-Contained Unit, 3908
Workpaper ID	W0170
Measure Unit	Per ice machine
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Ice Machine
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	Varies by measure
Effective Useful Life (years)	10[2]
Measure Incremental Cost ($/unit)	$222.00[3]

Measure Description

Commercial ice machines are used in restaurants, hospitals, hotels, schools, offices, and grocery stores. ENERGY STAR-certified Automatic Commercial Ice Makers create energy savings ranging from 8% to 20% depending on size and type.[1]

Description of Baseline Condition

The baseline condition is a commercial ice maker that meets the DOE amended energy conservation standards required as of January 28, 2018.[5]

Description of Efficient Condition

The efficient condition is a new unit that meets the ENERGY STAR V3.0 performance specification that takes effect January 28, 2018.[1] Eligible products must be a commercial ice maker that is air-cooled batch or continuous type, and of ice making head, remote condensing unit, or self-contained design. Water-cooled ice makers, ice and water dispensing systems, and air-cooled remote condensing units that are designed only for connection to remote rack compressors are not eligible for ENERGY STAR qualification.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{BASE} – kWh_{ENERGY\ STAR}$

Where:

kWh_{BASE} = Average annual energy consumption for specific equipment types using the DOE federal standards that took effect January 28, 2018

$kWh_{ENERGY\ STAR}$ = Average annual energy consumption for specific equipment types using the ENERGY STAR Version 3.0 Energy Consumption Rate algorithms with average ice harvest rates by qualifying product data set as of August 14, 2017 (= varies by equipment type; see table below)

The ENERGY STAR V3.0 Energy Consumption Rate is the total energy consumed, stated in kilowatt-hours per one-hundred pounds (kWh/100 lb) of ice, stated in multiples of 0.1. For remote condensing (but not remote compressor) automatic commercial ice makers and remote condensing and remote compressor automatic commercial ice makers, the total energy consumed shall include the energy use of the ice-making mechanism, the compressor, and the remote condenser or condensing unit. The harvest rate (H) is the amount of ice (at 32°F) in pounds produced per 24 hours.

ENERGY STAR Version 3.0 Requirements for Air-Cooled Ice Makers[1]

Equipment Type		Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	Avg Harvest Rate* (lbs/24 hours, H)	# of Models on ENERGY STAR List	ENERGY STAR Requirement Energy Consumption Rate (kWh/100 lbs ice)
Batch-Type	Ice Making Head	H < 300	243	17	≤ 9.20 - 0.01134 * H
		300 ≤ H < 800	460	73	≤ 6.49 - 0.0023 * H
		800 ≤ H < 1,500	1,081	14	≤ 5.11 - 0.00058 * H
		1,500 ≤ H ≤ 4,000	1,550	3	≤ 4.24
	Remote Condensing Unit	H < 988	758	42	≤ 7.17 - 0.00308 * H
		988 ≤ H ≤ 4,000	1,409	37	≤ 4.13
	Self-Contained Unit	H < 110	65	42	≤ 12.57 - 0.0399 * H
		110 ≤ H < 200	149	28	≤ 10.56 - 0.0215 * H
		200 ≤ H ≤ 4,000	250	18	≤ 6.25
Continuous-Type	Ice Making Head	H < 310	0	0	≤ 7.90 – 0.005409 * H
		310 ≤ H < 820	586	21	≤ 7.08 – 0.002752 * H
		820 ≤ H ≤ 4,000	1,077	14	≤ 4.82
	Remote Condensing Unit	H < 800	669	7	≤ 7.76 – 0.00464 * H
		800 ≤ H ≤ 4,000	1,295	28	≤ 4.05
	Self-Contained Unit	H < 200	92	8	≤ 12.37 – 0.0261 * H
		200 ≤ H < 700	300	15	≤ 8.24 – 0.005429 * H
		700 ≤ H ≤ 4,000	0	0	≤ 4.44

Maximum Consumption and On-Peak Demand Values for ENERGY STAR Version 3.0 Qualifying Ice Makers

Equipment Type	Maximum Annual Consumption (kWh)	On-Peak Demand (kW)
Ice Making Head	11,222.3925	1.2811
Remote Condensing Unit	17,222.2577	1.9660
Self-Contained Unit	4,050.2318	0.4624

DOE Federal Standards – Effective January 28, 2018 (Air-Cooled Models)[5]

Equipment Type		Applicable Ice Harvest Rate Range (lbs of ice/24 hrs)	Avg Harvest Rate, H (lbs/24 hrs)	# of Models on ENERGY STAR List	DOE Requirement Energy Consumption Rate (kWh/100 lbs ice)
Batch-Type	Ice Making Head	H < 300	243	17	≤ 10 - 0.01233 * H
		300 ≤ H < 800	460	73	≤ 7.05 - 0.0025 * H
		800 ≤ H < 1,500	1,081	14	≤ 5.55 - 0.00063 * H
		1,500 ≤ H ≤ 4,000	1,550	3	≤ 4.61
	Remote Condensing Unit (not remote comp)	H < 988	758	42	≤ 7.97 - 0.00342 * H
		988 ≤ H ≤ 4,000	1,409	37	≤ 4.59
	Remote Condensing Unit (remote comp)	H < 930	752	41	≤ 7.97 - 0.00342 * H
		930 ≤ H < 4,000	1,398	38	≤ 4.79
	Self-Contained Unit	H < 110	65	42	≤ 14.79 - 0.0469 * H
		110 ≤ H < 200	149	28	≤ 12.42 - 0.02533 * H
		200 ≤ H ≤ 4,000	250	18	≤ 7.35
Continuous-Type	Ice Making Head	H < 310	0	0	≤ 9.19 - 0.00629 * H
		310 ≤ H < 820	586	21	≤ 8.23 - 0.0032 * H
		820 ≤ H < 4,000	1,077	14	≤ 5.61
	Remote Condensing Unit (not remote comp)	H < 800	669	7	≤ 9.7 - 0.0058 * H
		800 ≤ H < 4,000	1,295	28	≤ 5.06
	Remote Condensing Unit (remote comp)	H < 800	669	7	≤ 9.9 - 0.0058 * H
		800 ≤ H < 4,000	1,295	28	≤ 5.26
	Self-Contained Unit	H < 200	92	8	≤ 14.22 - 0.03 * H
		200 ≤ H < 700	300	15	≤ 9.47 - 0.00624 * H
		700 ≤ H < 4,000	0	0	≤ 5.1

Maximum Consumption and On-Peak Demand Values for DOE Federal Minimum Standards Qualifying Ice Makers

Equipment Type	Maximum Annual Consumption (kWh)	On-Peak Demand (kW)
Ice Making Head	12,467.0957	1.4232
Remote Condensing Unit	20,187.9087	2.3046
Self-Contained Unit	4,730.6305	0.5400

Based on the harvest rate for various ENERGY STAR-qualifying models pulled from the Qualified Products List[1] on August 14, 2017, each qualifying ice machine must meet an energy use limit based on the kilowatt-hours per 100 lbs of ice. The savings are based on the annual energy savings (kWh) when calculating the minimum energy consumption rate for both the ENERGY STAR Version 3.0 specification[4] and the DOE federal minimum standards that went into effect January 28, 2018.

Since the equipment categories for ENERGY STAR and DOE equipment standards do not align perfectly, kWh_{BASE} is the average ice harvest rate from eligible ENERGY STAR-qualifying models, when applying the average rates to the DOE Requirement Energy Consumption Rate formulas within each equipment type (ice making head, remote condensing unit, self-contained unit). $KWh_{ENERGY\ STAR}$ is the average of outputs from the ENERGY STAR Requirement Energy Consumption rate formulas for both the Batch-Type and Continuous Type within each equipment type (ice making head, remote condensing unit, self-contained unit), weighted by the number of ENERGY STAR-certified models within each equipment type.

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (kWh_{BASE} – kWh_{ENERGY\ STAR}) / HOU$

Where:

HOU = Hours of use (=8,760 hours)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[2]

Deemed Savings

Annual and Lifecycle Deemed Savings

Equipment Type	MMID	kW	Annual (kWh)	Lifecycle (kWh)	Annual (Gallons)
Ice Making Head	3906	0.1421	1,245	12,450	4,693
Remote Condensing Unit	3907	0.3385	2,966	29,660	4,581
Self-Contained Unit	3908	0.0777	680	6,800	3,911

Assumptions

For remote condensing units, the ENERGY STAR Version 3.0 performance specification does not differentiate between the two compressor arrangements (with remote compressor/not remote) listed in the DOE federal standards. Therefore, the baseline energy consumption value for remote condensing units is a blended calculation of the harvest rates (and the prevalence of the harvest rates) from the ENERGY STAR data set that factored in both DOE requirements for units with remote compressors and units where the compressor was built into the condensing unit.

Annual water savings will also be affected by the DOE and ENERGY STAR regulations that took place January 28, 2018. Water savings were calculated using the same weighted average process that was used for determining savings (averaging batch and continuous machines together). The values used are taken directly from the ENERGY STAR Certified Commercial Kitchen Equipment Calculator. For batch-type machines, the following values are reported: 6,228 for ice making head, 6,611 for remote condensing unit, and 4,933 for self-contained unit. It is reported that ENERGY STAR-certified continuous-type machines do not save any water in comparison to a standard model.[3]

For incremental measure cost, the ENERGY STAR commercial kitchen savings calculator[3] lists an incremental cost of $0 for batch ice machines and $222 for continuous ice machines. The same weighted average process used for determining savings (averaging batch and continuous machines together) was used to determine the incremental cost for the three different measures.

Sources

1. ENERGY STAR. “Commercial Ice Makers.” Website. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers
2. Commercial Foodservice Equipment Lifecycle Cost Calculator - Ice Machine. https://fishnick.com/saveenergy/tools/calculators/icemachinecalc.php
3. ENERGY STAR. “Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.” Calculator. 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx

4. “ENERGY STAR Version 3.0 Requirements for Air-Cooled Ice Makers.” https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers/partners
5. Regulations.gov. “10 CFR Part 431, Docket Number EERE-2010-BT-STD-0037.” https://www.regulations.gov/document?D=EERE-2010-BT-STD-0037-0137

Revision History

Version Number	Date	Description of Change
01	08/05/2016	New measure replacing CEE Tier 2 Ice Machines, removed MMIDs 3414–3424
02	08/16/2017	Updated savings to reflect ENERGY STAR Version 3.0
03	12/2018	Updated incremental cost

ECM Compressor and Condenser/Condensing Unit Fan Motor

	Measure Details
Measure Master ID	ECM Compressor Fan Motor, 2306 ECM Condenser/Condensing Unit Fan Motor, 2307
Workpaper ID	W0171
Measure Unit	Per motor
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Motor
Sector(s)	Commercial, Industrial, Schools & Government, Agriculture
Annual Energy Savings (kWh)	519
Peak Demand Reduction (kW)	0.083
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	8,304
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	16[1]
Incremental Cost ($/unit)	$306.00[2]

Measure Description

Compressor, condenser, and condensing packaged unit fans run when refrigerant is being piped through the system to absorb heat from a space. The fans blow air across the compressor and condenser to cool the equipment and refrigerant. The long-time standard in refrigeration equipment is shaded pole (SP) fan motors, which are highly inefficient and generate excessive heat. Higher-efficiency electronically commutated motors (ECMs) use 75% less energy to run and generate less heat. ECMs or brushless AC fan motors are used in conjunction with air-cooled condensers and/or compressors.

Incentives are available for ECMs replacing SP motors or permanent split capacitor (PSC) motors on existing condenser/packaged condensing unit and compressor fans. This measure does not apply to evaporator fan motors.

Description of Baseline Condition

The baseline condition is a SP or PSC compressor or condenser unit fan motor.

Description of Efficient Condition

The efficient condition is an ECM replacing the SP or PSC motor on a compressor or condenser unit fan.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Input of SP or PSC motor (= 221.0 watts, weighted average; see table below)[3]

$Watts_{EE}$ = Input of ECM (= 137.7 watts, weighted average; see table below)[3]

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 6,220)[4]

Motor Input Wattages

	SP 1/20 HP (37.3)*	SP 1/15 HP (49.7)*	PSC 1/10 HP (74.6)*	PSC 1/6 HP (124.3)*	PSC 1/3 HP (248.7)*	Weighted Wattage
Baseline motor efficiency[3]	22.5%	22.5%	60%	60%	60%	N/A
Input wattage of base motor	**165.8**	**221.0**	**124.3**	**207.2**	**414.4**	**221.0**
Efficiency[3] of equivalent ECM	70%	70%	70%	70%	70%	N/A
Input wattage of equivalent ECM	**53.3**	**71.0**	**106.6**	**177.6**	**355.2**	**137.7**
Weighting by motor type	50%		50%			N/A
Weighting by motor type and size	25%	25%	16.67%	16.67%	16.67%	N/A

* The heading values in parentheses indicate the motor output wattages, which were determined by converting horsepower ratings to watts. Then, the input wattages of the motors was determined based on the efficiencies for fractional refrigeration application motors in the U.S. Department of Energy study.[3]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

EUL = Effective useful life (= 16 years)[1]

Assumptions

It is assumed that any motor greater than or equal to 1/10 horsepower is a PSC motor and any motor less than 1/10 horsepower is a SP motor based on available options for compressor head fan motors, condenser fan motors, and condensing unit fan motors from various refrigeration manufacturers. The occurrence of SP and PSC motors in compressors and condensers/condensing units is 50%/50%. There are two standard refrigeration motor horespowers less than 1/10 horsepower (1/20 and 1/15), so each size has a weighting factor of 25% (50% occurrence split between two motor sizes). There are three standard refrigeration motor horsepowers greater than or equal to 1/10 horsepower (1/10, 1/6, and 1/3), so each has a weighting of 16.67% (50% occurrence split between three motor sizes).

It is assumed that the replacements will occur in 50% freezer applications and 50% cooler applications due to equal proportions of freezer and cooler display cases and walk-ins throughout refrigerated spaces in retail applications. The compressors, condenser, and condensing units are integral components for refrigerated display cases and walk-ins to maintain proper temperatures, and these units will proportionally match the number of freezer and cooler display cases and walk-ins present in a customer's facility.

The annual hours are based on the compressor duty cycles needed to maintain refrigeration temperatures based on case and walk-in loads. Based on Wisconsin weather conditions, the duty cycle for coolers is 62% and the duty cycle is 80%.[4] These duty cycles for each temperature were then weighted based on the replacement assumption of 50%/50% for coolers and freezers, yielding an average duty cycle of 71% and an average annual run hours of 6,220.

Sources

1. Average of Cadmus database, DEER, 2009 Focus study, 2007 GDS study.
2. Regional Technical Forum. "Commercial: Grocery - Compressor Head Fan Motor Retrofit to ECM." UES Measure Workbook 2.2. June 29, 2016. Cost converted from 2008 dollars to 2017 dollars. https://rtf.nwcouncil.org/measure/compressor-head-fan-motor-retrofit-ecm and http://www.usinflationcalculator.com/
3. U.S. Department of Energy, Building Technologies Office. "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment." p. 5, 6, 16. 2013. https://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
   Motor efficiencies are: 22.5% (average of 15% to 30% for evaporator fans or compressors) for SP, 60% (average of 50% to 70%) for PSC, and 70% for fractional horsepower ECMs.
4. PA Consulting Group. "Focus on Energy Evaluation Business Programs: Deemed Savings Manual V 1.0." p. 4–91. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Initial TRM entry
02	12/2017	

ECM Evaporator Fan Motor, Walk-In Cooler/Freezer

	Measure Details
Measure Master ID	ECM Evaporator Fan Motor: Walk-In Cooler, < 1/20 hp, 2308 Walk-In Cooler, 1/20 – 1 hp, 2309 Walk-In Freezer, < 1/20 hp, 2310 Walk-In Freezer, 1/20 – 1 hp, 2311
Workpaper ID	W0172
Measure Unit	Per motor
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Motor
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure

Measure Description

The long-time standard in refrigeration equipment is shaded pole (SP) fan motors, which are highly inefficient and generate excessive heat. Higher-efficiency electronically commuted motors (ECMs) use 75% less energy to run and generate less heat. ECMs or brushless AC fan motors are used in conjunction with walk-in cooler and freezer evaporators.

Incentives are available for ECMs replacing SP motors or permanent split capacitor (PSC) motors on existing walk-in cooler and freezer evaporator fan motors. This measure does not apply to evaporator fan motors in refrigerated display cases.

Description of Baseline Condition

The baseline condition is a SP or PSC walk-in cooler or freezer evaporator fan motor.

Description of Efficient Condition

The efficient condition is an ECM replacing a SP motor or a PSC motor on a walk-in cooler or freezer evaporator.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * (1 + 1 / COP) * HOU$

Where:

$Watts_{BASE}$ = Wattage of the existing SP and PSC fan motor (= weighted average based on historical data, see Deemed Savings table below)[2]

$Watts_{EE}$ = Wattage of the ECM fan motor (= weighted average based on historical data, see Deemed Savings table below)[2]

1,000 = Kilowatt conversion factor

COP = Coefficient of performance (= 2.3 for MMID 2308 and 2309, = 1.4 for MMID 2310 and 2311)[3]

HOU = Average annual run hours (= 8,760 for MMID 2308 and 2309, = 8,273 for MMID 2310 and 2311; see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * (1 + 1 / COP)$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Deemed Savings for ECM Evaporator Fan Motors

Measure Name	MMID	$Watts_{BASE}$[2]	$Watts_{EE}$[2]	COP[3]	Summer Peak kW Savings	First Year kWh Savings	EUL[1]	Life-cycle kWh Savings
Walk-In Cooler, < 1/20 hp	2308	78.23	26.64	2.3	0.07	613	15	9,195
Walk-In Cooler, 1/20 - 1 hp	2309	208.5	71.04	2.3	0.20	1,752	15	26,280
Walk-In Freezer, < 1/20 hp	2310	89.38	30.44	1.4	0.10	827	15	12,405
Walk-In Freezer, 1/20 - 1 hp	2311	240.6	81.97	1.4	0.27	2,234	15	33,510

Assumptions

The wattages are based on a review of historical applications using the existing measures, randomly selected to ensure a sampling of all motor options. For programs with multiple facility (or customer) types available, applications were selected to capture information from the various facility (or customer) types. The applications used to obtain the weighted average motor sizes and wattages all contained complete motor information (make and model) for the correct application measure. Multiple location applications were not used in the random selection to ensure that one facility (or customer) type was not favored over the others in the motor sizes and wattages. At least 10% of the total number of applications per program were surveyed, along with the total number of motors surveyed accounting for at least 10% of the motors in each measure category. The quantity and size of each motor, along with the type of motor the ECM was replacing, was all recorded and used to determine the weighted baseline and proposed wattages. The table below summarizes the historical application findings and values for efficiencies. These values were used to calculate $Watts_{BASE}$ and $Watts_{EE}$.

Efficiency Values for ECM Evaporator Fan Motors

Measure Name	MMID	% of Motors Surveyed[2]	Weighted Output Horsepower[2]	SP Efficiency[5]	SP Weight[2]	PSC Efficiency[5]	PSC Weight[2]	ECM Efficiency[5]
Walk-In Cooler, < 1/20 hp	2308	16%	1/40	23%	91%	60%	9%	70%
Walk-In Cooler, 1/20 - 1 hp	2309	19%	1/15	23%	91%	60%	9%	70%
Walk-In Freezer, < 1/20 hp	2310	9%	1/35	23%	91%	60%	9%	70%
Walk-In Freezer, 1/20 - 1 hp	2311	16%	1/13	23%	91%	60%	9%	70%

Evaporator fan motors run constantly to ensure proper airflow and circulation throughout the refrigerated display case to maintain even product temperatures. However, during times of defrost, evaporator fans do not run, as heat is being introduced to the system to remove the ice and frost build-up on the evaporator coils. Freezer hours of operation assume four defrost cycles per day at 20 minutes per defrost. As cooler operating temperatures are above freezing, defrost cycles are not required.

The low temperature and medium temperature system COPs were derived from the information on Table 3-7 of the U.S. DOE Publication ID 6180.[3] The capacity and power values were calculated to yield the EER, then converted to COP, based on COP = EER/3.412.

Incremental Cost

Efficient costs are derived from historical project data and online lookups of shaded pole motors.

Incremental Costs

Measure Name	MMID	SPECTRUM Data			Base Cost	Incremental Cost
		Projects	Units	Average Unit Cost		
Walk-In Cooler, < 1/20 hp	2308	52	323	$162.85	$114.90	$47.95
Walk-In Cooler, 1/20 - 1 hp	2309	721	4,249	$198.50	$169.04	$29.46
Walk-In Freezer, < 1/20 hp	2310	12	40	$238.69	$136.33	$102.36
Walk-In Freezer, 1/20 - 1 hp	2311	205	669	$212.76	$175.46	$37.30

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” EUL Table. 2014. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit costs for 990 projects and 5,281 units from January 2018 to July 2020. Minus base costs for shaded pole motors derived from December 2020 online lookups, from www.grainger.com and www.regalbeloit.com.
3. U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office. “Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration.” DOE Publication ID 6180. Table 3-7. September 2009. https://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
4. Regional Technical Forum, UES Measures. “Commercial: Grocery - ECMs for Walk-ins.” Measure Workbook 2.2, June 29, 2016. $260.00 for all ECMs for Walk-ins measures. http://rtf.nwcouncil.org/measures/measure.asp?id=162
5. United States Department of Energy, Building Technologies Office. “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment.” p. 5, 6, and 16. 2013. https://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
Motor efficiencies are: 23% (average of 15%-30% for evaporator fans or compressors) for SP; 60% (average of 50% - 70%) for PSC; and 70% for fractional horsepower ECMs.

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Update from Focus on Energy Deemed Savings Manual
02	04/2017	Added MMIDs 4065, 4066, 4067, 4068
03	10/2017	Updated EUL
04	01/2019	Removed MMIDs 4065, 4066, 4067, and 4068
05	12/2020	Updated cost

ECM Motor, Cooler/Freezer Case

	Measure Details
Measure Master ID	ECM Motor, Cooler/Freezer Case, 2312
Workpaper ID	W0173
Measure Unit	Per motor
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Motor
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	992
Peak Demand Reduction (kW)	0.116
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	14,880
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$20.30[5]

Measure Description

The long-time standard in refrigeration equipment is shaded pole (SP) fan motors, which are highly inefficient and generate excessive heat. Higher-efficiency electronically commuted motors (ECMs) use 75% less energy to run and generate less heat. ECMs or brushless AC fan motors are used in conjunction with refrigerated display case evaporators.

Incentives are available for ECMs replacing SP motors on existing refrigerated display case evaporator fan motors. This measure does not apply to evaporator fan motors in walk-in coolers and freezers.

Description of Baseline Condition

The baseline condition is a SP refrigerated display case evaporator fan motor.

Description of Efficient Condition

The efficient condition is an ECM replacing a SP motor on a refrigerated display case evaporator.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * (1 + 1 / COP) * HOU$

Where:

$Watts_{BASE}$ = Wattage of the existing SP fan motor (= 112.6 weighted average)[2,3]

$Watts_{EE}$ = Wattage of the ECM fan motor (=37)[2,3]

1,000 = Kilowatt conversion factor

COP = Coefficient of performance (= 1.85, average of 1.4 for freezers and 2.3 for coolers)[4]

HOU = Average annual run hours (= 8,517, see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * (1 + 1 / COP)$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=15 years)[1]

Assumptions

Replacements are assumed to occur in equal proportions for freezers and coolers, based on program experience that equal proportions of freezer and cooler display cases and motors are present throughout refrigerated spaces in retail applications. Evaporator fan motors run constantly to ensure proper airflow and circulation throughout the refrigerated display case to maintain even product temperatures. However, during times of defrost, evaporator fans do not run, as heat is being introduced to the system to remove the ice and frost build-up on the evaporator coils. Freezer hours of operation assume four defrost cycles per day at 20 minutes per defrost. As cooler operating temperatures are above freezing, defrost cycles are not required. Overall hours of operation are the average of cooler and freezer case hours of operation: (8,273 + 8,760) / 2 = 8,517.

The case motor wattages were categorized into three motor sizes: < 12 watts, 16 - 23 watts, and 1/20 hp,[2] each with an averaged wattage based on the motor sizes: 9 watts, 19.5 watts, and 37 watts, respectively. They also had population splits of 9%, 49%, and 42%, respectively. These output wattages were used to obtain the motor input wattages, based on motor efficiencies.[3] The input wattages were averaged, based on the motor size ratio,[2] to obtain the overall baseline and efficient motor input wattages for the savings algorithms.

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” EUL Table. 2005, 2008- High Efficiency Evaporator Fan Motors measure. http://www.deeresources.com/
2. Pacific Gas & Electric Company. “Display Case ECM Motor Retrofit.” Workpaper PGE3PREF124. Table 10. 2014.
3. United States Department of Energy, Building Technologies Office. "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment." p. 6 and 16. 2013. https://energy.gov/sites/prod/files/2014/02/f8/

Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
Motor efficiencies are: 23% (average of 15% to 30% for evaporator fans for compressors) for SP and 70% for fractional horsepower ECMs.

4. U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office. “Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration.” DOE Publication ID 6180. Table 3-7. September 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
The capacity and power values were calculated to yield the EER, then converted to COP, based on COP = EER / 3.412.
5. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 199 projects and 3,894 units January 2018 to May 2020 is $110.06. Minus baseline cost of $89.76, derived from December 2020 online lookups of shaded pole motors: 8 models of 1/83 hp motors averaging $58.75 and weighted at 9%, 4 models of 1/47 hp motors averaging $66.50 and weighted at 49%, and 6 models of 1/20 hp motors averaging $123.55 and weighted at 42%.

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Update from Focus on Energy Deemed Savings Manual
02	04/2017	Added MMID 4069
03	10/2017	Updated EUL
04	12/2018	Updated incremental cost, removed MMID 4069
05	12/2020	Updated incremental cost

Permanent Magnet Synchronous AC Fan Motor - Cooler/Freezer Case

	Measure Details
Measure Master ID	Permanent Magnet Synchronous (PMS) Evaporator Fan Motor, Refrigerated Case, Replacement, 4284
Workpaper ID	W0174
Measure Unit	Per motor
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Motor
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	1,036
Peak Demand Reduction (kW)	0.122
Annual Therm Savings (Therms)	0
Life-cycle Energy Savings (kWh)	15,540
Life-cycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$92.40[5]

Measure Description

The long-time standard in refrigeration equipment is shaded pole (SP) fan motors, which are highly inefficient and generate excessive heat. Higher-efficiency permanent magnet synchronous (PMS) motors use at least 80% less energy to run and they generate less heat. These motors are used in conjunction with refrigerated display case evaporators.

Incentives are available for PMS motors replacing SP motors on existing refrigerated display case evaporator fan motors. This measure does not apply to evaporator fan motors in walk-in coolers and freezers.

Description of Baseline Condition

The baseline condition is a SP refrigerated display case evaporator fan motor.

Description of Efficient Condition

The efficient condition is a PMS motor/fan assembly replacing an SP motor/fan assembly on a refrigerated display case evaporator.

PMS AC motors directly use grid-supplied AC current without the need to rectify to DC. Synchronous motors are so named because the rotation of the motor’s shaft is synchronized with the frequency of the supplied current. Previously, synchronous motors had been prohibitively expensive for commercial refrigeration evaporator fan applications because of the high cost of the electronic control circuit that is required to bring the synchronous motor up to synchronous speed. The controller for a PMS motor is simpler and lower in cost than previous synchronous motor controllers or electronically commutated motor controllers, making the PMS motors a cost-effective alternative in the commercial refrigeration market. For this application, installation costs are similar to costs for installing electronically commutated motors.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * (1 + 1 / COP) * HOU$

Where:

$Watts_{BASE}$ = Wattage of the existing SP fan motor (= 112.630 watts as a weighted average of three motor size categories, see Assumptions)[2,3]

$Watts_{EE}$ = Wattage of the PMS fan motor (= 33.643 watts)[6,7]

1,000 = Kilowatt conversion factor

COP = Coefficient of performance (= 1.85 averaged, = 1.4 for freezers, and = 2.3 for coolers)[4]

HOU = Average annual run hours (= 8,517, see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * (1 + 1 / COP)$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=15 years)[1]

Assumptions

Replacements are assumed to occur in equal proportions for freezers and coolers, based on program experience that equal proportions of freezer and cooler display cases and motors are present throughout refrigerated spaces in retail applications. Evaporator fan motors run constantly to ensure proper air flow and circulation throughout the refrigerated display case to maintain even product temperatures. However, during times of defrost, evaporator fans do not run, as heat is being introduced to the system to remove the ice and frost build-up on the evaporator coils. Freezer hours of operation assume four defrost cycles per day at 20 minutes per defrost. As cooler operating temperatures are above freezing, defrost cycles are not required. The overall hours of operation are the average of cooler and freezer case hours of operation: (8,273 + 8,760) / 2 = 8,517.

Based on the Pacific Gas and Electric workpaper,[2] the case motor wattages were categorized into three motor sizes: < 12 watts, 16 to 23 watts, and 1/20 HP. Each of these categories had an averaged wattage based on the motor sizes of 9 watts, 19.5 watts, and 37 watts, respectively. They also had population splits of 9%, 49%, and 42%, respectively. These output wattages were used to obtain the motor input wattages, based on motor efficiencies in the Navigant motor study.[3] The input wattages were averaged, based on the motor size ratio study provided in the Pacific Gas and Electric workpaper, to obtain the overall baseline and efficient motor input wattages for the savings algorithms. Motor wattages for the efficient option were obtained from the Wisconsin Focus on Energy.[5]

The low temperature and medium temperature system COPs are derived from the information on Table 3-7 of the U.S. Department of Energy Publication ID 6180.[4] The capacity and power values were calculated to yield the EER then converted to COP, based on COP = EER / 3.412.

PMS motors are expected to have an EUL comparable to electronically commutated motors.

SP motor efficiency is assumed to be 23%. SP evaporator fan motors are small, typically 9 watts to 37 watts. Motors at the low end of this range are about 20% efficient.[6] SP efficiency generally increases with motor size, but is still generally less than 30% in the 37-watt range. Therefore a 23% efficiency is reasonable, and matches the average of a range presented in a U.S. Department of Energy paper.[3]

PMS motor efficiency average is assumed to be 77%.[5,6,7] QM Power's conference presentation noted 75%+ efficiency for 9-watt to 20-watt PMS motors and 78%+ efficiency for 38-watt to 75-watt PMS motors.[7] The Oak Ridge National Laboratory completed a laboratory measurement of 73% for a 12-watt Q Sync motor.[7] Through a direct contact and discussion with Mark Martinez, technical representative at QM Power, he provided a 80% efficiency number for a 45-watt Q Sync motor.[5] Since the market is a mix of smaller and larger motors, a 77% efficiency average is assumed.

Sources

1. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." EUL Table. High Efficiency Evaporator Fan Motors measure. 2005, 2008. http://www.deeresources.com/
2. Pacific Gas & Electric Company. "Display Case ECM Motor Retrofit." Table 10. Workpaper PGE3PREF124. 2014.
3. Navigant Consulting Group, Inc. "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment." December 2013. https://energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf
4. Navigant Consulting, Inc. "Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration." Table 3-7. 2009. U.S. DOE Publication ID 6180. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf

5. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 10 units over two projects in 2018.
6. Fricke, B. and B. Becker, Oak Ridge National Laboratory. "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits." ORNL/TM-2015/466. 2015. http://info.ornl.gov/sites/publications/files/Pub58600.pdf
7. QM Power. "Q-Sync™ high efficiency fan motors for refrigeration, HVAC and appliance applications." http://www.arpae-summit.com/paperclip/exhibitor_docs/14AE/QM_Power_192.pdf

Revision History

Version Number	Date	Description of Change
01	05/11/2017	Initial TRM entry
02	09/07/2017	Modified inputs from Business Incentive Program, Aptim, and Cadmus
03	12/2018	Updated incremental cost

Cooler Night Curtains, Open Coolers

	Measure Details
Measure Master ID	Cooler Night Curtains, Open Coolers, 2271
Workpaper ID	W0175
Measure Unit	Per linear foot
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Refrigerated Case Door
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	249
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	1,245
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	$44.14[2]

Measure Description

Night curtains are used on open refrigerated cases (open coolers) to reduce heat transfer between the air inside of the case and the air outside of the case. The technology adds a barrier over the open face of the multideck-style case for use during closed hours. When curtains are in use, the heat transfer by convection and radiation is reduced, thereby reducing the cooling load on the refrigeration system.

Description of Baseline Condition

The baseline condition is an open multideck-style refrigerated display case without night curtains.

Description of Efficient Condition

The efficient condition is a permanently installed woven aluminum or perforated plastic night curtain.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Load_{CASE} / (3.412 * COP) * SF * HOU / 1,000$

Where:

$Load_{CASE}$ = Average refrigeration load without curtains (= 1,733.625 Btuh per linear foot weighted average of 1,727.5 Btuh per linear foot for coolers[3] and 1,850 Btuh per linear foot for freezers)[4]

3.412 = Conversion from Btu/h to watts

COP = Coefficient of performance (= 2.255, weighted average of 1.4 for freezers and 2.3 for coolers)[3]

SF = Savings factor (= 12.6%)[5]

HOU = Hours of use (= 8,760)[5]

1,000 = Kilowatt conversion factor

Summer Coincident Peak Savings Algorithm

There are no peak savings associated with this technology since the night curtains are not used during the peak period. The curtains are used during closed hours.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Assumptions

The savings factor and hours of use values reflect e-mail communication with the authors of the Southern California Edison study.[5] The authors recommended a savings factor of 12.6% for this application, and stated that the study reflected savings over a 24-hour period—not only at night when the night covers were applied.

Night curtains are installed on open multideck-style cases; the majority of these cases in the market are cooler cases; however, they are manufactured and used for freezer applications as well. While there are open multideck-style cases for freezers in Wisconsin, they are very rare to find in stores. In order to accurately portray the market, a weighted average of 95% cooler cases and 5% freezer cases, based on historical site audits and discussions with grocery owner and store managers in Wisconsin since 2008.

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf 2
2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 2,570 units over 26 projects from 2016 to 2018.
3. Navigant Consulting, Inc. “Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration.” U.S. Department of Energy Publication ID 6180. Tables 3-7, 4-2, and 4-4. 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf&id=6180
   The low temperature and medium temperature system COPs are from Table 3-7. The capacity

and power values were calculated to yield the EER, then divided by 3.412 to convert to COP. The open multideck-style cooler case load is based on the case length in the Baseline Case Description and Thermal Load Breakdown total for Vertical Open Medium Temp cases on Tables 4-2 and 4-4 (20,730 Btuh thermal load for a 12-foot display case = 1,727.5 Btuh per foot).

4. Manufacturer's specification sheet for open multideck style freezer case. Hussmann Excel F6L. November 2010.
5. Southern California Edison. "Display Case Shield Reduces Supermarket Energy Use." https://www.econofrost.com/acrobat/SouthernCaliforniaEdison.pdf
6. Pennsylvania Public Utility Commission. *2021 Technical Reference Manual, Volume 3*. August 2019. Page 129. https://www.puc.pa.gov/filing-resources/issues-laws-regulations/act-129/technical-reference-manual/

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Updated based on Focus on Energy Deemed Savings Manual
02	12/2018	Updated incremental cost
03	01/2022	Updated HOU, baseline load calculation, and savings factor

Energy-Efficient Case Doors

	Measure Details
Measure Master ID	Case Door: Freezer, Low Heat, 2234 Freezer, No Heat, 2235 Cooler, No Heat, 2236
Workpaper ID	W0176
Measure Unit	Per door
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Refrigerated Case Doors
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Life-cycle Energy Savings (kWh)	Varies by measure
Life-cycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	Freezer, low heat = $548.67 (MMID 2234); Freezer, no heat = $121.00 (MMID 2235); Cooler, no heat = $208.83 (MMID 2236)[2]

Measure Description

Anti-sweat heaters minimize condensation or sweating on cooler and freezer doors. A standard cooler or freezer case door has three heaters to mitigate condensate build-up so that the product behind the glass can be seen immediately after closing the door. Using low-heat or no-heat doors can reduce the energy consumption of the case by using lower wattage heaters or a reduced number of total heaters per door. The savings results from reduced electric energy consumed by the heaters, and from the reduced cooling load on the refrigeration system.

Description of Baseline Condition

The baseline condition is a cooler or freezer display case with standard energy doors.

Description of Efficient Condition

The efficient condition is a cooler or freezer display case using low-heat or no-heat doors.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = [(Watts_{BASE} – Watts_{EE}) * (1 + 1 / COP)] / 1,000 * HOU$

$Watts_{BASE}$ = Wattage of standard door heaters (= 191 for MMIDs 2234 and 2235; = 63 for MMID 2236)[3]

$Watts_{EE}$ = Wattage of door heaters (= 132 for MMID 2234; = 54 for MMID 2235; = 52 for MMID 2236)[3]

COP = Coefficient of performance (= 1.4 for MMIDs 2234 and 2235; = 2.3 for MMID 2236)[4]

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= 8,760)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = [(Watts_{BASE} – Watts_{EE}) * (1 + 1 / COP)] / 1,000$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

EUL = Effective useful life (=11 years)[1]

Deemed Savings

Deemed Savings

Measure Name	MMID	$Watts_{BASE}$	$Watts_{EE}$	COP	First Year kWh Savings	Summer Peak kW Savings	EUL	Lifecycle kWh Savings
Case Door, Freezer, Low Heat	2234	191	132	1.4	886	0.10	11	9,746
Case Door, Freezer, No Heat	2235	191	54	1.4	2,057	0.23	11	22,627
Case Door, Cooler, No Heat	2236	63	52	2.3	138	0.016	11	1,518

Sources

1. Average of 2009 Focus Study.
   California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
   Cadmus database March 2013.
2. No heat freezer: Price sheets for Styleline Classic II Plus freezer, and Anthony ELM, ELM 2, and 401 freezers. September 2016. Low heat freezer: Price sheets for Styleline Classic II Plus and Hybridoor freezers, and Anthony 401, 101, and Infinity freezers. September 2016. No heat cooler: Price sheets for Styleline Classic II Plus cooler, and Anthony ELM, ELM 2, 101, 101 No Heat, 401, Infinity, Vista C, and Vista B coolers. September 2016.
3. Zero Zone RVZC and RVCC and Hussmann RL and RM specification sheets for reach-in cooler and freezer cases with doors, specification sheets published 2006/2007.
4. U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office. "Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration." DOE Publication ID 6180. Table 3-7. September 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf

Revision History

Version Number	Date	Description of Change
01	03/11/2016	Update based on Focus on Energy Deemed Savings Manual

Reach In Refrigerated Case w/ Doors Replacing Open Multi Deck Case

	Measure Details
Measure Master ID	Reach In Refrigerated Case w/ Doors Replacing Open Multi Deck Case, 2509
Workpaper ID	W0177
Measure Unit	Per linear foot
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Refrigerated Case Door
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	976
Peak Demand Reduction (kW)	0.179
Annual Therm Savings (Therms)	113
Lifecycle Energy Savings (kWh)	14,640
Lifecycle Therm Savings (Therms)	1,695
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[8]
Incremental Cost ($/unit)	$805.95[9]

Measure Description

This measure is replacing existing open multi-deck cases with equivalent storage (in cubic feet or linear feet) of reach-in cases with doors. The estimated measure savings are conservative because case replacements use equivalent linear feet, but reach-in cases are designed to hold more cubic feet of product per linear foot (side-to-side measure) than multi-deck cases.

Description of Baseline Condition

The baseline is a 95% to 5% mix of cooler to freezer open multi-deck style cases.

Description of Efficient Condition

The replacement cases must have doors, be tied into a central refrigeration system, and be purchased new. New case upgrades that simply enclose and/or add doors to an existing multi-deck do not qualify for this incentive. New cases must be DOE 2017 Energy Compliant.

Annual Energy-Savings Algorithm

$$\mathrm{kWh_{SAVED}} = \{(\mathrm{P_{CE}} - \mathrm{P_{LE}} - \mathrm{P_{ME}} - \mathrm{P_{CE}}\cdot\mathrm{F_{CR}}) - [\mathrm{P_{CP}}\cdot(1 - \mathrm{F_I}) - \mathrm{P_{LP}} - \mathrm{P_{MP}} - \mathrm{P_{CP}}\cdot\mathrm{F_{CR}}\cdot(1 - F_I)]\} \cdot \left[\frac{\mathrm{LF}\cdot\mathrm{HOU}}{3{,}412\cdot\mathrm{COP_{REFRIG}}} - \frac{24\cdot\mathrm{CDD}}{(\mathrm{T_S} - \mathrm{T_R})\cdot 3{,}412\cdot\mathrm{COP_{ROOFTOP}}}\right]$$

$$Therm_{SAVED} = \{(P_{CE} - P_{LE} - P_{ME} - P_{CE} \cdot F_{CR}) - [P_{CP} \cdot (1 - F_I) - P_{LP} - P_{MP} - P_{CP} \cdot F_{CR} \cdot (1 - F_I)]\} \cdot \left[\frac{24 \cdot HDD}{(T_S - T_R) \cdot eff \cdot 100{,}000}\right]$$

Where:

P_{CE} = Total load of multideck case (= 1,727.5 Btuh per linear foot for coolers;[1] = 1,850 Btuh per linear foot for freezers[2])

P_{LE} = Lighting load of existing case (= 6.7 Btuh per linear foot)[2]

P_{ME} = Motor load of existing case (= 7.3 Btuh per linear foot)[2]

F_{CR} = Amount of case load associated with conduction and radiation (= 13%)[5]

P_{CP} = Total load of new enclosed case (= 332 Btuh per linear foot for coolers; = 528 Btuh per linear foot for freezers)[3]

F_I = Amount of case load associated with infiltration reduction (= 68%)[4]

P_{LP} = Lighting load of new case (= 8.2 Btuh per linear foot)[3]

P_{MP} = Motor load of new case (= 2.7 Btuh per linear foot for coolers; = 3.5 Btuh per linear foot for freezers)[3]

LF = Case load factor, the compressor duty cycle needed to maintain case temperatures, deemed (= 62% for coolers; = 80% for freezers)[6]

3,412 = Conversion from kilowatt-hours to Btu

HOU = Average annual operating hours of the case measured in hours per year, deemed (= 8,760)[6]

COP_{REFRIG} = Coefficient of performance of refrigeration system: a measure of the refrigeration system efficiency equal to the ratio of net heat removal to total energy input, deemed (= 2.3 for coolers; = 1.4 for freezers)[1]

24 = Hours per day

CDD = Cooling degree days, the sum of the number of degrees the average daily temperature is greater than a base temperature for a given time period, deemed (= 535)[6]

T_S = Temperature of store, deemed (= 65°F)[6]

T_R = Temperature of refrigerated case that needs to be maintained (= 36.5°F for coolers; = -11°F for freezers)[7]

$COP_{ROOFTOP}$ = Coefficient of performance of rooftop system: a measure of the efficiency of the rooftop system equal to the ratio of net heat removal to total energy input (= 3.2)[7]

HDD = Heating degree days, the sum of the number of degrees the average daily temperature is less than a base temperature for a given time period, deemed (= 7,699)[6]

eff = Heating system efficiency, the average combustion efficiency of the boiler (= 78%)[7]

100,000 = Conversion factor from Btu to therm

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = \{(P_{CE} - P_{LE} - P_{ME} - P_{CE} \cdot F_{CR}) - [P_{CP} \cdot (1 - F_I) - P_{LP} - P_{MP} - P_{CP} \cdot F_{CR} \cdot (1 - F_I)]\} \cdot \left[\frac{1}{3{,}412 \cdot COP_{REFRIG}} - \frac{24 \cdot CDD}{(T_S - T_R) \cdot 3{,}412 \cdot COP_{ROOFTOP} \cdot HOU}\right] \cdot CF$$

Where:

CF = Coincidence factor (= 1)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[8]

Assumptions

Refrigerated case temperatures were calculated as the average of the most commonly used settings for cooler and freezer cases: 35°F to 38°F and -14°F to -8°F, respectively.[7]

The majority of open multi-deck style cases in the market are cooler cases; however, open multi-deck style cases are also manufactured and used for freezer applications in Wisconsin (but very rare to find in stores). In order to accurately portray the market, a weighted average of 95% cooler cases and 5% freezer cases is used, based on historical site audits and discussions with grocery owner and store managers in Wisconsin since 2008.

Refrigerated display cases operated 24 hours per day, 7 days per week and are never shut off, as they must maintain proper food product temperatures to avoid product shrink, spoilage, and health code violations. As these cases are constantly on and running, the coincidence factor is set to 1.0 because the case demand reduction will be coincident with the utility peak demand.

The low temperature and medium temperature system COP values are derived from the information on Table 3-7 of the US DOE Publication ID 6180.[1] The capacity and power values were calculated to yield the EER then converted to COP, based on COP = EER/3.412. The open multi-deck style cooler case load is based on the case length in the Baseline Case section, and the thermal load breakdown total for vertical open medium temperature cases on Tables 3-2 and 3-4 (20,730 Btuh thermal load for a 12-foor display case = 1,727.5 Btuh per foot).

The EUL is the DEER[8] value for the "Refrigerator Upgrades (Condenser, Head Pressure, Suction Pressure, Subcooling, Variable Speed Compressors)" measure, which offers the best match in DEER for upgrades to centralized (non self-contained) refrigerated cases. The "Commercial Reach-In Refrigerator / Freezer" measure in DEER, which appears to be similar to this measure, is actually for ENERGY STAR self-contained refrigerators and freezers. Selecting a 15-year EUL for this measure ensures the EUL for the complete case is at least as long as the EUL for the ECMs that go into the case.

Sources

1. Navigant Consulting, Inc. *Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration*. U.S. Department of Energy Publication ID 6180. Tables 3-2, 3-4 and 3-7. 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf&id=6180
2. Manufacturer's specification sheet for open multideck style freezer case. Hussmann Excel F6L. November 2010.
3. Manufacturer's specification sheet for enclosed reach-in cases. Zero Zone RVCC30 and RVZC30. 2012.
4. Faramarzi, R., B. Coburn, R. Sarhadian, and Rafik. *Performance and Energy Impact of Installing Glass Doors on an Open Vertical Deli/Dairy Display Case.* ASHRAE Transactions: Symposia. 2002.
5. Fricke, Brian, and B. Becker. *Comparison of Vertical Display Cases: Energy and Productivity Impacts of Glass Doors Versis Open Vertical Display Cases*. ASHRAE report RP-1402. 2009.
6. PA Consulting Group. "State of Wisconsin Public Service Commission of Wisconsin, *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*." March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
7. U.S. Department of Energy Building Technology Program. *Advanced Energy Retrofit Guide: Practical Ways to Improve Energy Performance, Grocery Stores.* National Renewable Energy Laboratory. June 2012. http://www.nrel.gov/docs/fy13osti/54243.pdf
8. California Energy Commission and California Public Utilities Commission. 2008 Database for Energy Efficient Resources (DEER) Version 2008.2.05. www.deeresources.com/files/deer0911planning/downloads/EUL_Summary_10-1-08.xls
9. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 12 projects and 761 units for MMID 2509 from January 2018 to May 2020 is $805.95.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	08/2017	Updated COP to remain consistent with other refrigeration workpapers
03	12/2020	Updated cost

Retrofit Open Multi-Deck Cases with Doors

	Measure Details
Measure Master ID	Retrofit Open Refrigerated Cases with Doors, 3409
Workpaper ID	W0178
Measure Unit	Per linear foot
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Refrigerated Case Door
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	711
Peak Demand Reduction (kW)	0.131
Annual Therm Savings (Therms)	82
Lifecycle Energy Savings (kWh)	10,665
Lifecycle Therm Savings (Therms)	1,230
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[7]
Incremental Cost ($/unit)	$313.29[8]

Measure Description

Existing open multi-deck style cases can be retrofitted with doors. The doors are designed to fit right onto the open multi-deck style cases with minimal case modification. The measure incentives are based on per-foot of case enclosed.

Description of Baseline Condition

The baseline is a 95% to 5% mix of cooler to freezer open multi-deck style cases.

Description of Efficient Condition

The efficient condition is installing doors on the cooler or freezer multi-deck style cases.

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = [P_C \cdot F_I \cdot (1 - F_{CR})] \cdot \left[\frac{LF \cdot HOU}{3{,}412 \cdot COP_{REFRIG}} - \frac{24 \cdot CDD}{(T_S - T_R) \cdot 3{,}412 \cdot COP_{ROOFTOP}}\right]$$

$$Therm_{SAVED} = [P_C \cdot F_I \cdot (1 - F_{CR})] \cdot \left[\frac{24 \cdot HDD}{(T_S - T_R) \cdot eff \cdot 100{,}000}\right]$$

Where:

P_C = Total case load, the average energy consumption of the refrigerated case (= 1,727.5 Btuh for coolers;[1] = 1,850 Btuh for freezers[2])

F_I = Amount of infiltration reduction, the fraction of the case energy associated with infiltration (= 68%)[3]

F_{CR} = Amount of case load energy associated with conduction and radiation (= 13%)[4]

LF = Case load factor, the compressor duty cycle needed to maintain case temperatures, deemed (= 62% for coolers; = 80% for freezers)[5]

HOU = Average annual operating hours of the cases, deemed (= 8,760)[5]

3,412 = Conversion factor from kilowatt to Btuh

COP_{REFRIG} = Coefficient of performance of refrigeration system, a measure of the refrigeration system efficiency equal to the ratio of net heat removal to the total energy input, deemed (= 2.3 for coolers; = 1.4 for freezers)[1]

24 = Hours per day

CDD = Cooling degree days, the sum of the number of degrees that the average daily temperature is greater than a base temperature for a given time period (the State of Wisconsin uses a base temperature of 65°F, which is a standard value used in the HVAC industry), deemed (= 535)[5]

T_S = Temperature of store, deemed (= 65°F)[5]

T_R = Temperature that the refrigerated case needs to be maintained (= 36.5°F for coolers; = -11°F for freezers)[6]

$COP_{ROOFTOP}$ = Coefficient of performance of rooftop system, a measure of the rooftop system efficiency equal to the ratio of net heat removal to total energy input (= 3.2)[6]

HDD = Heating degree days, the sum of the number of degrees that the average daily temperature is less than a base temperature for a given time period (the State of Wisconsin uses a base temperature of 65°F, which is a standard value used in the HVAC industry), deemed (= 7,699)[5]

eff = Heating system efficiency, the average combustion efficiency of the boiler (= 78%)[6]

100,000 = Conversion factor from Btu to therm

Summer Coincident Peak Savings Algorithm

$$kW_{SAVED} = [P_C \cdot F_I \cdot (1 - F_{CR})] \cdot \left[\frac{1}{3{,}412 \cdot COP_{REFRIG}} - \frac{24 \cdot CDD}{(T_S - T_R) \cdot 3{,}412 \cdot COP_{ROOFTOP}} \cdot \frac{1}{HOU}\right] \cdot CF$$

Where:

CF = Coincidence factor (= 1)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[7]

Assumptions

Refrigerated case temperatures were calculated as the average of the most commonly used settings for cooler and freezer cases: 35°F to 38°F and -14°F to -8°F, respectively.[6]

The majority of open multi-deck style cases in the market are cooler cases; however, open multi-deck style cases are manufactured and used for freezer applications as well. The open multi-deck style cases for freezer cases are present in Wisconsin; however, they are very rare to find in stores. To accurately portray the market, a weighted average of 95% cooler cases and 5% freezer cases was used, based on historical site audits and discussions with grocery owner and store managers in Wisconsin since 2008.

The low temperature and medium temperature system COP values derived from information on Table 3-7 of the U.S. DOE Publication ID 6180.[1] The capacity and power values were calculated to yield the EER then converted to COP, based on COP = EER/3.412. The open multi-deck style cooler case load is based on the case length in the Baseline Case Description and Thermal Load Breakdown total for Vertical Open Medium Temp cases on Tables 3-2 and 3-4 (20,730 Btuh thermal load for a 12-foor display case = 1,727.5 Btuh per foot).

The EUL is the DEER[7] value for the "Refrigerator Upgrades (Condenser, Head Pressure, Suction Pressure, Subcooling, Variable Speed Compressors)" measure, which offers the best match in DEER for upgrades to centralized (non-self-contained) refrigerated cases. The "Commercial Reach-In Refrigerator / Freezer" measure in DEER, which appears to be similar to this measure, is actually for ENERGY STAR self-contained refrigerators and freezers. Selecting a 15-year EUL for this measure ensures that the EUL for the complete case is at least as long as the EUL for the ECMs that go into the case.

Sources

1. Navigant Consulting, Inc. *Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration*. U.S. Department of Energy Publication ID 6180. Tables 3-2, 3-4, and 3-7. 2009. http://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf&id=6180.
2. Manufacturer's specification sheet for open multideck style freezer case. Hussmann Excel F6L. November 2010.
3. Faramarzi, R., B. Coburn, R. Sarhadian, and Rafik. *Performance and Energy Impact of Installing Glass Doors on an Open Vertical Deli/Dairy Display Case*. ASHRAE Transactions: Symposia. 2002.
4. Fricke, Brian, and B. Becker. *Comparison of Vertical Display Cases: Energy and Productivity Impacts of Glass Doors Versus Open Vertical Display Cases*. ASHRAE report RP-1402. 2009.
5. PA Consulting Group. "State of Wisconsin Public Service Commission of Wisconsin, *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*." March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
6. U.S. Department of Energy Building Technology Program. *Advanced Energy Retrofit Guide: Practical Ways to Improve Energy Performance, Grocery Stores.* National Renewable Energy Laboratory. June 2012. http://www.nrel.gov/docs/fy13osti/54243.pdf
7. California Energy Commission and California Public Utilities Commission. "2008 Database for Energy Efficient Resources (DEER)." Version 2008.2.05. www.deeresources.com/files/deer0911planning/downloads/EUL_Summary_10-1-08.xls
8. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 1,434 units over 26 projects from January 2018 to July 2021.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	08/2017	Updated COP to remain consistent with other refrigeration workpapers
03	12/2021	Updated incremental cost

Strip Curtains for Walk-In Freezers and Coolers

	Measure Details
Measure Master ID	Strip Curtains for Walk-In Freezers and Coolers, 3183
Workpaper ID	W0179
Measure Unit	Per linear foot
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Strip Curtain
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	315 per linear foot
Peak Demand Reduction (kW)	0.036 per linear foot
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	1,260 per linear foot
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$50.00[4]

Measure Description

Strip curtains reduce the refrigeration load associated with the infiltration of non-refrigerated air into the refrigerated spaces of walk-in coolers or freezers. The most likely areas of application are grocery stores, supermarkets, restaurants, and refrigerated warehouse.

Description of Baseline Condition

The baseline condition is a walk-in cooler or freezer that with no strip curtain or an old, ineffective strip curtain installed.

Description of Efficient Condition

The efficient condition is adding a strip curtain or replacing the ineffective strip curtain on a walk-in cooler or freezer. Strip curtains must be at least 0.06 inches thick. Low temperature strip curtains must be used for low temperature applications.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \Delta kWh/LF * LF$

Where:

LF = Linear feet of door width of installation

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = \Delta kW/LF * LF$

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 4 years)[1]

Deemed Savings

The annual deemed savings is calculated based on methods and deemed savings included in the 2013 Pennsylvania TRM.[2] For the Small Business Program, a single deemed measure is developed using the expected mix of program customers and situations.

In order to create the Small Business Program measure mix, the following assumptions based on facility type are assumed (see Assumptions).

- Facility Types
    - Supermarket = 10%
    - Convenience Store = 30%
    - Restaurant = 60%
- Cooler and Freezer Mix
    - Coolers = 75%
    - Freezers = 25%
- Facilities that have existing ineffective strip curtains
    - 25% (75% have no existing strip curtains)

Comparison of Pennsylvania TRM to Focus on Energy Values by Facility Type*

Facility Type	PA TRM 2013 (Source 1)			Focus on Energy		
	Pre-Existing Curtains	Energy Savings (per sq ft)**	Demand Reduction (per sq ft)***	Measure Mix	Weighted Energy Savings (per sq ft)	Weighted Demand Reduction (per sq ft)
Supermarket - Cooler	Yes	37	0.0042	1.88%	0.69	0.00008
	No	108	0.0123	5.63%	6.08	0.00069
	Unknown	108	0.0123	0.00%	0.00	0.00000
Supermarket - Freezer	Yes	119	0.0136	0.63%	0.74	0.00009
	No	349	0.0398	1.88%	6.54	0.00075
	Unknown	349	0.0398	0.00%	0.00	0.00000
Convenience Store - Cooler	Yes	5	0.0006	5.63%	0.28	0.00003
	No	20	0.0023	16.88%	3.38	0.00039
	Unknown	11	0.0013	0.00%	0.00	0.00000
	Yes	8	0.0009	1.88%	0.15	0.00002

Facility Type	PA TRM 2013 (Source 1)			Focus on Energy		
	Pre-Existing Curtains	Energy Savings (per sq ft)**	Demand Reduction (per sq ft)***	Measure Mix	Weighted Energy Savings (per sq ft)	Weighted Demand Reduction (per sq ft)
Convenience Store - Freezer	No	27	0.0031	5.63%	1.52	0.00017
	Unknown	17	0.002	0.00%	0.00	0.00000
Restaurant - Cooler	Yes	8	0.0009	11.25%	0.90	0.00010
	No	30	0.0034	33.75%	10.13	0.00115
	Unknown	18	0.002	0.00%	0.00	0.00000
Restaurant - Freezer	Yes	34	0.0039	3.75%	1.28	0.00015
	No	119	0.0136	11.25%	13.39	0.00153
	Unknown	81	0.0092	0.00%	0.00	0.00000
Refrigerated Warehouse	Yes	254	0.029	0.00%	0.00	0.00000
	No	729	0.0832	0.00%	0.00	0.00000
	Unknown	287	0.0327	0.00%	0.00	0.00000
Focus on Energy Small Business Program Savings Values (per sq ft)					**45.00**	**0.00514**

* Sum values may differ due to rounding.

** The 2013 Pennsylvania TRM uses the Tamm Equation to determine electricity savings: $kWh = 365 * t_{OPEN} * (\eta_{NEW} – \eta_{OLD}) * 20 * CD * A * \{[(T_i - T_r)/T_i] * g * H\}^{\wedge}0.5 * 60 * (\rho_i * h_i – \rho_r * h_r) / (3{,}413 * COP_{ADJ})$

*** $kW_{SAVED} = kWh_{SAVED} / 8{,}760$

The unit of measurement for strip curtains is per linear foot of doorway width. It is assumed that all walk-in unit doors are 7 feet tall. The table below shows the energy savings per square foot to linear foot comparison for determining deemed savings.

Conversion of Energy Savings

Savings Type	Savings (per sq ft)	Door Height (Ft)	Deemed Value per Linear Foot
Annual Electricity Savings (kWh/year)	45	7	315
Demand Reduction (kW)	0.0051	7	0.036
Annual Natural Gas Savings (therms/year)	0	7	0

Using the EUL, the table below shows updated savings values for strip curtains.

Deemed Annual Savings

Savings Type	Annual Savings	EUL	Lifecycle Savings
Annual Electricity Savings (kWh/year)	315	4	1,260
Annual Natural Gas Savings (therms/year)	0	4	0

Assumptions

The primary cause of air infiltration into walk-in coolers and freezers is the air density difference between two adjacent spaces of different temperatures. The total refrigeration load due to infiltration through the main door into the unit depends on the temperature differential between the refrigerated and non-refrigerated airs, the door area and height, and the duration and frequency of door openings.

The avoided infiltration depends on the barrier efficacy of the newly installed strip curtains, and on the efficacy of the supplanted infiltration barriers, if applicable. The calculation of the refrigeration load due to air infiltration and the energy required to meet that load is rather straightforward, but relies on critical assumptions regarding the aforementioned operating parameters. The calculation for this measure follows the Pennsylvania TRM[1] calculation for Measure 3.17: Strip Curtains for Walk-In Freezers and Coolers. The assumptions in that protocol are based on values that were determined by direct measurement and monitoring of over 100 walk-in units in the 2006-2008 evaluation for the California Public Utility Commission.

Within the TRM calculation, the kW demand reduction is simplistic, but should be noted as a major assumption. The below quote is from Page 259 of the 2013 Pennsylvania TRM;

> “The peak demand reduction is quantified by multiplying savings per square foot by area. The source algorithm is the annual energy savings divided by 8760. This assumption is based on general observation that refrigeration is constant for food storage, even outside of normal operating conditions. This is the most conservative approach in lieu of a more sophisticated model.
>
> $$\Delta kW_{PEAK} = \Delta kWh / 8760$$”

There is no code requiring strip curtains for remodeling walk-in coolers and freezers.

Assumptions for Facility Types and Technology

The assumed levels of facility types within the Small Business Program for Focus on Energy are based on the Program Implementer’s experience between July 2012 and April 2013 (Staples Energy). Although data was not collected on existing walk-in coolers and freezers from the existing customer list, that list was categorized to differentiate restaurants, convenience stores (including liquor stores and florists), and supermarkets (including meat markets and fish markets).

The table below details the number of customers the Program Implementer visited in each category and the estimated number that will have walk-in refrigeration. The customer size in the small business sector indicates the amount of facilities that have walk-in refrigeration, and does not represent the standard mix for the total marketplace.

Percentage of Walk-In Refrigerators by Facility Type

Facility Type	Customer Visits	Percentage with Walk-In Refrigeration	Number with Walk-In Refrigeration	Percentage of Total Facilities
Restaurant	424	33%	139.92	59%
Convenience Store	96	70%	67.2	28%
Supermarket	39	80%	31.2	13%
Total	**559**		**238.32**	**100%**

The calculation uses a slightly more conservative number by reducing the supermarket total to 10% and increasing the convenience store and restaurant totals slightly.

The assumptions for the refrigerator/freezer mix were roughly determined from the same list of customers, broken out by type of facility. The assumptions included determining the numbers of freezers present at the following restaurant types: fast food, Asian cuisine, and fry kitchens. The supermarket freezer components are meat markets, fish markets, and an estimated amount of rural groceries.

Percentage of Walk-In Freezers by Facility Type*

Facility Type	Customer Visits	Number with Walk-In Freezer	Percentage with Walk-In Freezer	Percentage of Total Facilities
Restaurant	424	123	30%	22%
Convenience Store	96	0	0%	0%
Supermarket	39	19	50%	3%
Total	**559**	**142**		**25%**

* Percentages are rounded up

Sources

1. GDS Associates, Inc. The Measure Life Report for Residential and Commercial/Industrial Lighting and HVAC Measures. June 2007.
2. *Pennsylvania Technical Reference Manual*. 2013. http://www.puc.state.pa.us/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx
3. Commercial Facilities Contract Group. *2006-2008 Direct Impact Evaluation.* http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf
4. WESCO Distribution Pricing ($45.00) + Labor ($5.00) = $50.00

Revision History

Version Number	Date	Description of Change
01	04/22/2013	Initial submittal
02	01/2019	Removed MMID 3284

Refrigeration Savings for Lighting Upgrades

	Measure Details
Measure Master ID	Refrigeration Savings for Lighting Upgrades in Cooler, 5236 Refrigeration Savings for Lighting Upgrades in Freezer, 5235
Workpaper ID	W0286
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	19[1]
Incremental Cost ($/unit)	$0 (see Assumptions)

Measure Description

Light emitting diode (LED) fixtures use less electricity than fluorescent or HID fixtures to produce an equivalent amount of light, and they produce less heat, reducing the amount of cooling load on the refrigeration system and the energy needed to the refrigeration compressor. This measure provides a prescriptive method to claim refrigeration savings only for LEDs replacing traditional lighting sources in refrigerated warehouses. These refrigeration savings are registered as measures separately from the lighting savings—they represent the additional savings coming only from the reduction in refrigeration load stemming from a refrigerated lighting upgrade. These measures will typically be paired with workpapers W0115 and W0117, though others are possible.

Description of Baseline Condition

The baseline condition is fluorescent or HID lighting fixtures.

Description of Efficient Condition

The efficient condition is ENERGY STAR or DLC-qualified LED lighting in a refrigerated warehouse. Walk-in coolers and freezers are not eligible. Cooler space is defined as having evaporator temperatures from 10 to 35°F. Freezer space is defined as having evaporator temperatures from -25 to -15°F.

Annual Energy-Savings Algorithm

kWh_{SAVED} = ($Watts_{BASE}$ - $Watts_{EE}$) * HOU / (COP * 1,000)

= $Watts_{REDUCED}$ * HOU / (COP * 1,000)

Where:

$Watts_{BASE}$ = Total system wattage of fluorescent or HID lighting.

$Watts_{EE}$ = Total system wattage of ENERGY STAR and/or DLC-listed LED product.

COP = Coefficient of performance (= 2.3 for coolers, = 1.4 for freezers)[2]

1,000 = Kilowatt conversion factor

HOU = Average annual run hours (= varies by sector; see table below)[2]

Hours of Use by Sector

Sector	HOU[3]
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = ($Watts_{BASE}$ - $Watts_{EE}$) / (COP * 1,000)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 19 years)[1]

Deemed Savings

Here, deemed savings are calculated on a per-watts reduced basis. The values in the Average Savings and Lifecycle Savings tables below indicate the savings from defining $Watts_{REDUCED}$ = 1 in the algorithm above for each sector.

Annual Energy Savings per Watt Reduced

Measure	MMID	Sector	Annual kWh	Lifecycle kWh	kW
Refrigeration Savings, Cooler	AAAA	Commercial	1.62	30.8	0.0004
		Industrial	2.06	39.1	0.0004
		Agriculture	2.04	38.8	0.0004
		Schools & Gov	1.41	26.8	0.0004
Refrigeration Savings, Freezer	BBBB	Commercial	2.66	50.5	0.0007
		Industrial	3.39	64.4	0.0007
		Agriculture	3.36	63.8	0.0007
		Schools & Gov	2.31	43.9	0.0007

Assumptions

No additional costs for claiming refrigeration savings only. Costs are associated with LED fixtures only.

The low temperature and medium temperature system coefficient of performances are derived from the information on Table 3-7 of the U.S. DOE Publication ID 6180. The capacity and power values were calculated to yield the EER, then converted to coefficient of performance (based on COP = EER / 3.412).

Sources

1. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Rated lifetime data for fixtures used in custom lighting projects (MMID 2455, LED Not Otherwise Specified) in refrigerated warehouses. 51 projects and 493 fixtures from January 2019 to November 2021. 91.4% high bay (W0115, EUL = 20) and 8.6% linear ambient fixture (W0117, EUL = 13) installations. Average EUL is 19 years.
2. U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Office. “Energy Savings Potential and Research & Development Opportunities for Commercial Refrigeration.” DOE Publication ID 6180. Table 3-7. September 2009. https://www1.eere.energy.gov/buildings/pdfs/commercial_refrigeration_equipment_research_opportunities.pdf
3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. Table 3.2 for nonresidential HOU. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	10/2021	Initial TRM entry

Renewable Energy

Ground Source Heat Pump, Natural Gas and Electric Backup

	Measure Details
Measure Master ID	Ground Source Heat Pump: Electric Back-Up, 2820 Natural Gas Back-Up, 2821
Workpaper ID	W0180
Measure Unit	Per heat pump
Measure Type	Prescriptive
Measure Group	Renewable Energy
Measure Category	Geothermal
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	3,476
Peak Demand Reduction (kW)	0.8277
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	52,140
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Based on actual program data in current year

Measure Description

This measure is installing residential-sized geothermal (ground-source) heat pump systems in non-residential applications. Geothermal heat pump systems use the earth as a source of heating and cooling through the installation of an exterior underground loop working in combination with an interior heat pump unit. The measure provides a centralized heating and cooling system similar to that of a standard air-source heat pump.

Description of Baseline Condition

The baseline condition is an air-source heat pump of 13 SEER and 7.7 HSPF.[4]

Description of Efficient Condition

The efficient condition is a ground-source heat pump of 3.5 COP and 15 EER with either a multi-compressor or a multi-stage compressor as well as an ECM air handler. Additionally, the procedures followed when installing the equipment must conform to the ACCA Standard 5 Quality Installation requirements.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (EFLH_{COOL} * Btu/h_{COOL} * (1 / SEER_{BASE} – 1 / (EER_{EE} * 1.02))) / 1,000 + (EFLH_{HEAT} * Btu/h_{HEAT} * (1 / HSPF_{BASE} – 1 / (COP_{EE} * 3.412))) / 1,000$

Where:

$EFLH_{COOL}$ = Full-load cooling hours (= 599)[5]

Btu/h_{COOL} = Cooling capacity of equipment (= 40,089 Btu/hour)[3]

$SEER_{BASE}$ = Seasonal energy efficiency ratio of baseline equipment (= 13)[4]

EER_{EE} = Energy efficiency ratio of efficient equipment (= 22.43 kBtu/kWh)[3]

1.02 = Factor to determine SEER based on its EER

1,000 = Kilowatt conversion factor

$EFLH_{HEAT}$ = Full-load heating hours (= 1,466)[6]

Btu/h_{HEAT} = Heating capacity of equipment (= 30,579 Btu/hour)[3]

$HSPF_{BASE}$ = Heating seasonal performance factor of baseline equipment (= 7.7 kBtu/kWh)[4]

COP_{EE} = Coefficient of performance of efficient equipment (= 4.18)[3]

3.412 = Conversion from watts to Btu

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Btu/h_{COOL} * (1 / EER_{BASE} – 1 / EER_{EE})) / 1,000 * CF$

Where:

EER_{BASE} = Energy efficiency ratio of baseline equipment (= 12.75)[4]

CF = Coincidence factor (= 0.61)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

This system life expectancy is generally constrained by the heat pump exchanger and compressor equipment. The actual ground loop installation often has a much longer life expectancy.

The runtime differs for nonresidential and residential applications due to internal heat gains, additional ventilation requirements for nonresidential buildings, times of occupancy, and occupancy numbers. Heating run-times from the 2013 Pennsylvania TRM Draft for Commercial HVAC were used and adjusted using EFLH from the U.S. DOE ENERGY STAR Air Source Heat Pump Calculator[5] to account for differences in weather conditions. This resulted in a 42% reduction in hours from ENERGY STAR, or 1,466 hours.

Equivalent Full-Load Heating Hours from Pennsylvania TRM and ENERGY STAR

City	PA TRM (hours)[4]	ENERGY STAR (hours)
Allentown	1,098	2,492
Erie	1,720	2,901
Harrisburg	1,406	2,371
Philadelphia	1,461	2,328
Pittsburgh	1,411	2,380
Scranton	1,501	2,532
Williamsport	1,483	2,502
Average	**1,440**	**2,501**

Equivalent Full-Load Heating Hours from Wisconsin TRM and ENERGY STAR

City	ENERGY STAR (hours)[8]	WI TRM (hours)
Green Bay	2,641	1,521
La Crosse	2,445	1,408
Madison	2,547	1,467
Milwaukee	2,548	1,467
Average	**2,545**	**1,466**

Equivalent Full-Load Heating and Cooling Hours for Average Commercial Building

Building Type	$EFLH_{HEAT}$[6]	$EFLH_{COOL}$[5]
Average Commercial	**1,466**	**599**

The installation of a ground-source heat pump is more likely to happen in the northern part of the state due to the lack of available natural gas. A lower coincidence factor than residential (0.68)[5] and nonresidential (0.80)[5] air conditioning is used to account for the reduced occurrence of operation.

Coincidence Factors by Sector

Sector	Air Conditioner	GSHP
Residential	0.68[5]	0.50[3]
Nonresidential	0.80[7]	0.61

Sources

1. GDS Associates, Inc. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. June 2007. https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf
2. Energy Center of Wisconsin. *Update of Geothermal Analysis.* p. 19–21. August 31, 2009.
3. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
   DEER model runs were weather normalized for statewide use by population density.
4. International Energy Conservation Code. Table 503.2.3(1). 2009.
5. See similar measures A/C Split System, ≤ 65 MBh: SEER 14, 2194; SEER 15, 2192; and SEER 16+, 2193.
6. *Pennsylvania Technical Reference Manual*. 2013. Draft for Commercial HVAC.
   Adjusted values using EFLH from the U.S. DOE ENERGY STAR Air Source Heat Pump Calculator to account for differences in weather conditions.

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	10/2017	Updated EUL
03	05/2018	Deemed savings update applied

Vending & Plug Loads

Engine Block Heater Timer

	Measure Details
Measure Master ID	Timer, Engine Block Heater, 2810
Workpaper ID	W0181
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Vending & Plug Loads
Measure Category	Controls
Sector(s)	Agriculture
Annual Energy Savings (kWh)	738
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	11,070
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$25.00[2]

Measure Description

Engine block heater timers save energy by reducing the time that engine block heaters operate. Typically, block heaters are plugged in throughout the night. Using timers allows the heater to come on at a preset time during the night, rather than being on throughout the night. Beginning in September 2015, this measure is primarily being used for a Future Farmers of America Fundraiser coordinated by the Agriculture, Schools, and Government Implementer.

Description of Baseline Condition

The baseline measure is an engine block heater in use without a timer.

Description of Efficient Condition

The efficient measure is an engine block heater in use with a timer preset to power the heater on for fewer hours each night.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (P * hours * days * UF)$

Where:

P = Average power consumption of engine block heater (= 1.3 kW)[3]

hours = Reduction in number of hours block heater is used per night (= 9)[3]

days = Number of operating days per year (= 65)[3]

UF = Usage factor (= 0.97)[3]

Summer Coincident Peak Savings Algorithm

There are no peak savings since engine block heaters are not in use during the peak period.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

Inputs for the savings calculation were derived from a survey of 2015 Focus on Energy participants. Between September and November 2015, 115 customers requested 238 timers. During April and May 2016, 109 customers were surveyed via mail (four responses), 61 customers were emailed (six responses), and 31 customers were surveyed via phone (17 responses) for a total of 27 responses. This is a 23% customer response rate representing 65 of the 238 of timers (27%).

The survey revealed an average engine block heater use of 12 hours pre-timer and three hours post-timer. The difference of nine hours is the reduction in hours the block heater is used per night.

The survey also revealed that five timers were given away as gifts, and were omitted from the ‘potential in use’ data set. Of the remaining 60 timers, two were reported as not in use, resulting in 58 and a usage factor of 0.97.

Sources

1. Gutierrez, Alfredo. *Circulating Block Heater*. Prepared for the California Technical Forum. http://static1.squarespace.com/static/53c96e16e4b003bdba4f4fee/t/556f7c9ee4b0b65c3515c80c/1433369758093/Circulating+Block+Heater+Presentation_ver+2.pdf
   California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/
2. Implementer research, 2013. Average online cost of Engine Block Heat Timer.
3. 2015 Survey Data (27 customers; 65 timers). See Assumptions.

Revision History

Version Number	Date	Description of Change
01	10/01/2015	Initial release
02	06/01/2016	Updated Assumptions values and source

Vending Machine and Beverage Cooler Controls

	Measure Details
Measure Master ID	Beverage Cooler Controls, 2202 Vending Machine Controls: Occupancy Based, Cold Beverage Machine, 2611 Occupancy Based, Snack Machine, 2612 Sales Based, Cold Beverage Machine, 2613
Workpaper ID	W0182
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Refrigeration: MMIDs 2202 Vending & Plug Loads: MMIDs 2611, 2612, 2313
Measure Category	Controls
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Measure Incremental Cost ($/unit)	Beverage cooler controls = $233.00 (MMID 2202)[1,2] Vending cold beverage machine = $258.00 (MMID 2611)[1,2] Vending snack machine = $224.00 (MMID 2612)[1,2] Vending cold beverage, sales based = $159.00 (MMID 2613)[2,3]

Measure Description

This measure is for the installation of controls to any of the following machines:

- Beverage Cooler: a self-contained, refrigerated cooler with glass front door(s) storing cold beverages in cans or bottles. Lights illuminate products inside plus any signs on the front.
- Beverage Vending Machine: a self-contained, refrigerated vending machine that dispenses cold beverages in cans or bottles. Lights illuminate signs on the front.
- Snack Vending Machine: a non-refrigerated vending machine that dispenses non-perishable food. Lights illuminate products inside plus any signs on the front.

The controls limit the operation of refrigeration systems and turn off lights during unoccupied hours, referred to as sleep mode. Units without controls have lighting and refrigeration operating 24/7, even if the space where the unit is located is not occupied 24/7. The controls periodically power up the unit at regular intervals to maintain product temperature and provide compressor protection. Adding controls can significantly reduce the energy consumption of refrigeration systems (if applicable) and lighting. For occupancy-based measures, units are put into sleep mode when a passive infrared occupancy sensor registers no occupancy for 15 minutes. For sales-based controls, a logic algorithm is used to turn off the compressor based on sales data, but leaves the display lighting and card reader on. ENERGY STAR–qualified cold beverage machines do not qualify for sales-based machines.

Description of Baseline Condition

The baseline condition is a beverage cooler, beverage vending machine, or snack vending machine that does not have controls, such that lights and refrigeration (if applicable) operate continuously 24/7.

Description of Efficient Condition

The efficient condition is a beverage cooler, beverage vending machine, or snack vending machine that has controls to turn off certain lights and limit refrigeration operation (if applicable) during unoccupied periods. The controls are assumed to be installed in locations where the system will be in sleep mode at least six hours per day.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{BASE} * SF$

Where:

kWh_{BASE} = Baseline annual consumption (= 1,546 kWh for beverage cooler; = 1,762 kWh for beverage vending machine; = 175 kWh for snack vending machine; see Assumptions)

SF = Savings factor (= 16.67% for non-sales-based machines; = 15% for sales-based machines; see Assumptions)

Summer Coincident Peak Savings Algorithm

There are no demand savings deemed for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years)[1]

Deemed Savings

The calculated savings for each unit type is presented in the table below.

Energy Savings Values

Measure Description	MMID	Annual kWh	Lifecycle kWh
Beverage Cooler Controls	2202	258	1,290
Vending Machine Controls, Occupancy Based, Cold Beverage Machine	2611	294	1,470
Vending Machine Controls, Occupancy Based, Snack Machine	2612	29	145
Vending Machine Controls, Sales Based, Cold Beverage Machine	2613	264	1,320

Assumptions

The baseline energy consumption values for beverage coolers and beverage vending machines are determined by a federal standard.[4] The formulas for the maximum allowed kilowatt-hours per day are presented in the table below.

Baseline Energy Consumption Formulas for Beverage Coolers and Beverage Vending Machines

Machine Type	Maximum Allowed Consumption per Day (kWh)
Beverage Cooler	0.055 * Volume + 2.56
Beverage Vending Machine	0.073 * Volume + 3.16

The Volume in the above formulas is the refrigerated volume of the unit as defined in the federal standard. Using average volumes from ENERGY STAR product data,[5] the maximum allowed consumption per day and per year are presented in the table below.

Baseline Energy Consumption Values for Beverage Coolers and Beverage Vending Machines

Machine Type	Average Volume (cubic feet)	Maximum Allowed Consumption (kWh)	
		Per Day	Per Year
Beverage Cooler	30.5	4.24	1,546
Beverage Vending Machine	22.8	4.83	1,762

The baseline energy consumption for snack vending machines is based on a 20-watt light.[1]

$$\begin{aligned} kWh_{BASE} &= 0.02 \text{ kW} * \text{Hours On per Year} \\ &= 0.02 \text{ kW} * 8{,}760 \text{ hours/year} \\ &= 175 \text{ kWh/year} \end{aligned}$$

The percentage savings is the percentage of each day the units will be in sleep mode: this workpaper assumes four hours per day.[1]

$$\begin{aligned} \%\text{ savings} &= 100 * 4 \text{ hours} / 24 \text{ hours/day} \\ &= 16.67\% \end{aligned}$$

However, for sales-based controls, the light stays on during the four hours that the refrigeration system is controlled, so the savings factor is decreased such that there are 29 kWh less annual savings (0.02 kW * 4 hours/day * 365 days/year = 29 kWh), for a savings factor of 15%.

The assumed material costs for each unit type is presented in the tables below.

Average Cost for Beverage Cooler Controllers[2]

Model Number	Material Cost
CM150	$169
CM151	$161
CM170	$169
CM171	$161
Average	**$165**

Average Cost for Beverage Vending Machine Controllers[2]

Model Number	Material Cost
VM150	$189
VM151	$181
VM160	$199
VM170	$189
VM171	$181
VM180	$199
VM181	$191
Average	**$190**

Average Cost for Snack Machine Controllers[2]

Model Number	Material Cost
SM150	$160
SM151	$152
SM170	$160
SM171	$152
Average	**$156**

The assumed installation costs for each unit type is presented in the table below. Labor costs are assumed to be one hour at $68 per hour.[1]

Costs for Materials and Installation

Measure Description	MMID	Materials	Labor[1]	Total
Beverage Cooler Controls	2202	$165	$68	$233
Vending Machine Controls				
Occupancy Based, Cold Beverage Machine	2611	$190	$68	$258
Occupancy Based, Snack Machine	2612	$156	$68	$224
Sales Based, Cold Beverage Machine	2613	$91[3]	$68	$159

Sources

1. Pacific Gas & Electric. “PGECOREF111 R5 Vending Machine Controller.” Workpaper. (Use Category: “Appliance or Plug Load”, PA: “PGE”, Other Fields: “Any”) Measure life: p. 4. Hours per day off: p. 6. Light wattage: p. 12. Labor cost: p. 16. November 10, 2015. http://deeresources.net/workpapers
2. Website for USA Tech, the manufacturer of CoolerMiser for beverage coolers, VendingMiser for beverage vending machines, and SnackMiser for snack vending machines. Accessed May 2018. https://store.usatech.com/collections/energymiser-products
3. VendingMiserStore.com. Model VM2iQ. Accessed May 2018. https://www.vendingmiserstore.com/product/energymiser-vending-miser-internal-unit-model-vm150?gclid=Cj0KCQjw5-TXBRCHARIsANLixNxtO00k8MlEY1DyQ-WPMOfbvTolGpURNlbleQJMRN4K4tQwNnI8YJIaAsATEALw_wcB
4. Federal regulation: Title 10, Chapter II, Subchapter D, Part 431, Subpart Q, Section 431.296. Accessed May 2018. https://www.ecfr.gov/cgi-bin/text-idx?SID=e039793352d10c6ab6a2f36d45f5960b&mc=true&node=se10.3.431_1296&rgn=div8
5. ENERGY STAR. “Vending Machines Qualifying Product List. Accessed May 2018. https://www.energystar.gov/productfinder/product/certified-vending-machines/results.

Revision History

Version Number	Date	Description of Change
01	05/31/2018	Initial TRM entry

7 Outlet Advanced Power Strip, Business, Pack Based

	Measure Details
Measure Master ID	7 Outlet Advanced Power Strip, Business, Pack Based, 4684
Workpaper ID	W0028
Measure Unit	Per power strip
Measure Type	Prescriptive
Measure Group	Vending & Plug Loads
Measure Category	Controls
Sector(s)	Commercial, Industrial
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$13.50[2]

Measure Description

Advanced power strips have multiple plugs and the ability to automatically disconnect specific connected loads depending on the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. Savings generally occur during off hours, when connected equipment would have previously continued to consume electricity while in standby mode or when off.

Description of Baseline Condition

The baseline condition is a standard power strip that does not control connected loads (only has a manual switch for control).

Description of Efficient Condition

The efficient condition is an advanced power strip that has a load-sensing master plug and at least two controlled plugs.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = [kW_{WkDay} * (Hours_{WkDay} – HOU_{WkDay}) + kW_{WkEnd} * (Hours_{WkEnd} – HOU_{WkEnd})] * Weeks * ISR$

Where:

kW_{WkDay} = Standby power consumption of connected electronic on weekday off-hours (= 0.0315 kW)[4]

$Hours_{WkDay}$ = Total hours during the work week, from Monday at 7:30 a.m. to Friday at 5:30 p.m. (= 106 hours)

HOU_{WkDay} = Number of hours the business is open during the work week (= varies by sector; see table below and Assumptions)

kW_{WkEnd} = Standby power consumption of connected electronics on weekend off-hours (= 0.00617 kW)[4]

$Hours_{WkEnd}$ = Total hours during the weekend, from Friday at 5:30 p.m. to Monday at 7:30 a.m. (= 62 hours)

HOU_{WkEnd} = Number of hours the business is open during the weekend (= varies by sector; see table below and Assumptions)

Hours of Use by Sector

Sector	Annual Lighting Hours[5]	Weekly Lighting Hours	HOU_{WkDay}	HOU_{WkEnd}
Commercial	3,730	71.54	60	11.54
Industrial	4,745	91.00	80	11.00

Weeks = Number of weeks per year (= 52.14)

ISR = In-service rate (= 0.77 for pack-based measures)[3]

Summer Coincident Peak Savings Algorithm

There are no summer coincident peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

Annual and Lifecycle Deemed Savings by Sector

Sector	kWh_{SAVED}	$kWh_{LIFECYCLE}$
Commercial	71	568
Industrial	46	368

Assumptions

The standby power consumption for the weekday and weekend were assumed to be 0.0315 kW and 0.00617 kW, respectively.[4]

The total open business hours were based off lighting hours of use for each sector.[5] Commercial sector weekday hours of operation were assumed to be 60, based on 12 hours per weekday. Industrial sector weekday hours of operation were assumed to be 80, based on 16 hours per weekday (two 8-hour shifts). The weekend hours were assumed to be the remaining hours needed to total the lighting annual hours of use by sector.

Sources

1. Southern California Edison. “Smart Power Strips.” Work Paper SCE13CS002. Rev 3. January 25, 2016. http://deeresources.net/workpapers
2. Quote from Resource Action Programs, January 16, 2018.
3. Navigant. *ComEd Rural Small Business Energy Efficiency Kits IPA Program Impact Evaluation Report*. August 1, 2018. Table 7-5. http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd_EPY9_Evaluation_Reports_Final/ComEd_PY9_Rural_SB_EE_Kits_IPA_Program_Impact_Evaluation_Report_2018-08-01.pdf
4. Illinois Statewide Technical Reference Manual for Energy Efficiency. Version 6.0. pp. 498–500. February 8, 2017. http://www.ilsag.info/il_trm_version_6.html
5. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. Table 3.2 Lighting Hours of Use in Commercial Applications. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	03/14/2018	Initial TRM entry

Residential Measures

Through the residential portfolio, Wisconsin Focus on Energy delivers information, incentives, and implementation support to help residential customers in single family homes of one unit and multifamily buildings of four or more units access energy-efficient technologies that help control their electricity and natural gas use. These efficient technologies include, but are not limited to, lighting, heating and cooling systems, home appliances, insulation and air sealing services, and residential renewable energy systems.

Boilers and Burners

Combination Boiler, Natural Gas, AFUE ≥ 0.95

	Measure Details
Measure Master ID	Boiler, 95%+ AFUE, With DHW, NG, 3559 Boiler, Tier 2, 95%+ AFUE, With DHW, NG, 3778 Boiler, 95%+ Efficient, With DHW, Multifamily, NG, 5234
Workpaper ID	W0183
Measure Unit	Per combination boiler for MMIDs 3559 and 3778 Per MBh for MMID 5234
Measure Type	Prescriptive for MMIDs 3559 and 3778) Hybrid for MMID 5234
Measure Group	Boilers & Burners
Measure Category	Boiler
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	26[1]
Incremental Cost ($/unit)	$2,803.00[2]

Measure Description

Space heating boilers are pressure vessels that transfer heat to water for use in space heating. Boilers either heat water using a heat exchanger that works like an instantaneous water heater or by adding/connecting a separate tank with an internal heat exchanger to the boiler. A combination boiler contains a separate heat exchanger that heats water for domestic hot water use.

Qualifying combination boilers must be used for both space conditioning (boiler) and hot water heating with one appliance and energy source. Only participants who have a natural gas account with a participating natural gas utility are eligible for this rebate.

Description of Baseline Condition

The baseline condition is a boiler with the federal minimum of 82% AFUE[5] and a residential, natural gas-fueled, 0.6 EF storage water heater.[5] While water heater baselines vary by type and size, 0.6 is used as a representation of average UEF for medium to high draw for a 50-gallon tank, as discussed in workpaper W0267. This UEF is used to set baseline recovery efficiency.

Description of Efficient Condition

The efficient condition is a combination boiler unit with boiler AFUE of 95% or greater. The combination boiler must have a sealed combustion unit and be capable of modulating the firing rate. Measures that do not qualify for this incentive include boilers with a storage tank and redundant or backup boilers.

Annual Energy-Savings Algorithm

$$\text{Therm}_{\text{SAVED}} = \text{Therm}_{\text{SAVED,BOILER}} + \text{Therm}_{\text{SAVED,WH}}$$

$$\text{Therm}_{\text{SAVED,BOILER}} = \text{BC} * \text{EFLH} * (\text{EFF}_{\text{EE}} / \text{EFF}_{\text{BASE}} - 1) / 100$$

$$\begin{aligned}\text{Therm}_{\text{SAVED,WH}} = {} & (\text{GPD} * \text{N}_{\text{UNITS}} * 365 * 8.33 * 1 * \Delta\text{T}_{\text{w}} / 100{,}000) * (1 / \text{RE}_{\text{BASE}} - 1 / \text{E}_{\text{C,EE}}) \\ & + (\text{UA}_{\text{BASE}} / \text{RE}_{\text{BASE}} - \text{UA}_{\text{EE}} / \text{E}_{\text{C,EE}}) * \Delta\text{T}_{\text{s}} * 8{,}760 / 100{,}000\end{aligned}$$

Where:

BC = Boiler capacity (= 110 MBtu/hour for non-Multifamily;[3] = user input for Multifamily)

EFLH = Equivalent full-load hours (= 1,158)[4]

EFF_{EE} = Efficient Condition (= 95% for non-Multifamily; = user input for Multifamily)

EFF_{BASE} = Baseline Condition (= 82% AFUE for boilers < 300 MBh and 82% TE for boilers ≥ 300 MBh)[5]

100 = Conversion from MBtu to therm

GPD = Gallons of hot water used per day (= 42.75 for non-Multifamily;[6,7] = 34.14 for Multifamily[6,8])

N_{UNITS} = Number of apartments or condos served by boiler system (= 1 for non-Multifamily; = user input for Multifamily)

365 = Days per year

8.33 = Density of water (lb/gal)

1 = Specific heat of water (Btu/lb °F)

$\Delta\text{T}_{\text{w}}$ = Average difference between cold water inlet temperature (52.3°F) and hot water delivery temperature (125°F) (= 72.7°F)[9]

100,000 = Conversion from Btu to therm

RE_{BASE} = Recovery efficiency of the baseline tank type water heater (= 76%)[10]

$\text{E}_{\text{C,EE}}$ = Combustion efficiency of combination boiler used to provide DHW (= 95% for non-Multifamily;[11] = user input for Multifamily)

UA_{BASE} = Overall heat loss coefficient of baseline tank-type water heater (= 14.0 Btu/hr-°F) [12]

UA_{EE} = Overall heat loss coefficient of combination boiler (= 0 Btu/hr-°F)

ΔT_S = Temperature difference between stored hot water (125°F) and ambient indoor temperature (65°F) (= 60°F)

8,760 = Hours per year

Summer Coincident Peak Savings Algorithm

There is no peak demand reduction for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 26 years)[1]

Deemed Savings

Prescriptive Savings for Non-Multifamily Combination Boiler

MMID	Annual Therms	Lifecycle Therms
3559, 3778	324	8,424

Assumptions

Because the efficiency of a residential water heater is measured in UEF, the true thermal efficiency and overall heat loss coefficient (UA_{BASE}) is not available. A TE of 76% and a UA_{BASE} of 14 is assumed.

The overall heat loss of the combination heater is assumed to be 0 Btu/hr-°F due to the minimal amount of domestic hot water stored within the unit. The average difference of 60°F assumes pipe and ambient air temperatures of 125°F and 65°F, respectively.

Gallons per day are calculated by fitting a polynomial equation to data from Table 3 of the Florida Solar Energy Center study.[6] An average value of 2.43 occupants per single family home and 1.93 per multifamily home was used for Wisconsin, based on U.S. Census data.[7] The fitted equation is GPD = -0.0089 * x2 + 16.277 * x + 3.25, where x is the average number of occupants per home.

Sources

1. United States Department of Energy. Technical Support Document: Energy Efficiency Standards for Consumer Products and Industrial Equipment: Residential Boilers. December 22, 2015.
2. Navigant Consulting. A Report on Costs in Six Northeast & Mid-Atlantic Markets. p. A-10. NEEP Regional Evaluation, Measurement & Verification Forum, 2011. Mid-sized (126 MBh) Residential Combination Heat/Hot Water Incremental Cost 95 CAE is $2,803.00.
3. Average input capacity of boilers under 300 MBh in the 2013 SPECTRUM Database.

4. Cadmus. Focus on Evaluated Energy Deemed Savings Changes. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf Residential boilers are assumed to have sizing practices similar to furnaces, and therefore have the same EFLH.
5. Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430, Subpart C, § 430.32. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32
6. Florida Solar Energy Center. Estimating Daily Domestic Hot-Water Use in North American Homes. June 30, 2015. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-464-15.pdf
7. U.S. Census Bureau. “Demographic Profile for Wisconsin.” May 12, 2011. https://www.census.gov/newsroom/releases/archives/2010_census/cb11-cn137.html
8. U.S. Energy Information Administration. Residential Energy Consumption Survey. 2009. https://www.eia.gov/consumption/residential/index.php
9. Public Service Commission of Wisconsin. Request for Proposals. Issued for Mass Markets Portfolio Residential Energy Efficiency Program Implementation. July 26, 2011.
10. Air-Conditioning, Heating, and Refrigeration Institute. https://www.ahridirectory.org/NewSearch?programId=24&searchTypeId=3. Average RE for 476 gas storage water heaters with UEF between 0.58 and 0.62.
11. ENERGY STAR. “ENERGY STAR Most Efficient 2015 — Boilers.” https://www.energystar.gov/index.cfm?c=most_efficient.me_boilers
12. United States Department of Energy. Technical Support Document: Energy Efficiency Standards for Consumer Products, Residential Water Heaters, Including Regulatory Impact Analysis. 2000.

Revision History

Version Number	Date	Description of Change
01	11/03/2014	Original
02	12/17/2014	Changed ΔT_S to match residential indirect, provided Assumptions for value used in calculation, and provided justification for UA_{EE} value
03	12/2018	Updated gallons per day calculation and EFLH values
04	10/2021	Included Residential- Multifamily MMID. Reorganized sources.

Residential Hot Water Boiler

	Measure Details
Measure Master ID	Hot Water Boiler, 95%+ AFUE, 1983 Hot Water Boiler, 95%+ AFUE, 3780 (Tier 2) Hot Water Boiler, 90% AFUE, 5263 Hot Water Boiler, 90% AFUE, Tier 2, 5264
Workpaper ID	W0184
Measure Unit	Per boiler
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Boiler
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Effective Useful Life (years)	26[1]
Incremental Cost ($/unit)	Varies by measure, see Assumptions[2]

Measure Description

Space heating boilers are pressure vessels that transfer heat to water for use primarily in space heating applications. Boilers either heat water using a heat exchanger that works like an instantaneous water heater, or by the addition of a separate tank with an internal heat exchanger that is connected to the boiler.

High-efficiency space heating boilers are applicable to any residential boiler used for space heating. They are not applicable to boilers used for process end uses, DHW, pools, or spas. The space heating boiler qualifications are listed in the table below.

Qualifications for Space Heating Boilers

Type	Input Rating	Required Efficiency
90% Efficient Boiler	≤ 300 MBh	AFUE ≥ 90%
95% Efficient Boiler	≤ 300 MBh	AFUE ≥ 95%

Description of Baseline Condition

The baseline equipment is a hot water boiler with 82% AFUE.[3]

Description of Efficient Condition

Energy-efficient space heating boilers often feature high-efficiency and/or low-NO_X burners, and typically have features such as forced air burners, relatively large heat exchange surfaces, and/or use heat recovery from stack gases.

Annual Energy-Savings Algorithm

$Therm_{SAVED} = CAP * EFLH * (EFF_{EE} / EFF_{BASELINE} - 1) / 100$

Where:

CAP= Boiler input capacity (= 117 MBtu/hour)[4]

EFLH = Equivalent full-load hours (= 1,158)[5]

$EFF_{BASELINE}$ = AFUE of baseline measure (= 82%)

EFF_{EE} = AFUE of efficient measure (= 95% or 90%)

100 = Conversion factor (100 MBtu per therm)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 26 years)[1]

Deemed Savings

Deemed Savings by Measure

Boiler Efficiency	Tier	MMID	Annual Therms	Lifecycle Therms	Incremental Cost
95% Boiler	Standard	1983	214	5,564	$1,854
	Tier 2	3780			
90% Boiler	Standard	5263	132	3,432	$1,400
	Tier 2	5264			

Sources

1. U.S. Department of Energy. *Technical Support Document: Energy Efficiency Program For Consumer Products and Commercial and Industrial Equipment: Residential Boilers.* December 22, 2015. Page 8F-10. https://www.regulations.gov/document/EERE-2012-BT-STD-0047-0070https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf

2. CLEAResult. Survey of trade allies. Summer 2021. $5,960.63 average cost for an 82% boiler and install, $7,815.00 cost for a 95% boiler and install. $7,815.00 - $5,960.63 = $1,854.38 cost for 95% boiler. Incremental cost for a 90% boiler estimated to be $1,400.
3. Energy Efficiency and Renewable Energy Office*. Annual Fuel Utilization Efficiency.* Section 10 CFR 430.23(n)(2). http://www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0102-0009.
4. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average input capacity of 1,012 boilers delivered between January 2020 and June 2021.
5. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes.* November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf Residential boilers are assumed to have sizing practices similar to furnaces, and therefore have the same EFLH.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2015	MMIDs 1982 and 1978 deactivated and removed
03	12/2018	Updated EFLH and savings algorithm
04	12/2021	Added 90% measure, updated CAP, EUL, and cost

Boiler Tune-Up, Single Family

	Measure Details
Measure Master ID	Boiler Tune-Up, Single Family, 4659
Workpaper ID	W0186
Measure Unit	Per tune-up
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	37
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	74
Water Savings (gal/yr)	0
Effective Useful Life (years)	2[1]
Incremental Cost ($/unit)	$150.00[2]

Measure Description

This measure is for a residential boiler that provides space heating. The boiler tune-up will improve efficiency by cleaning burners, the combustion chamber, and burner nozzles. The tune-up also includes adjusting airflow if needed and ensuring proper temperature rise, and may also include adjustments to the burner and natural gas inputs. The tune-up includes a check of venting, safety controls, and combustion air intake. Combustion efficiency is to be measured before and after the tune-up using an electronic flue gas analyzer.

Description of Baseline Condition

The baseline measure is an 82% AFUE boiler.

Description of Efficient Condition

The efficient condition is a boiler tuned up to nameplate efficiency by a technician. The maximum boiler size for measure eligibility is 300,000 Btu per hour. The incentive is available once in a 24-month period. The incentives are only available for space heating equipment.

Annual Energy-Savings Algorithm

$Therm_{SAVED} = BOF * CAP * SF * HDD * 24 / [(T_{INDOOR} – T_{OUTDOOR}) * AFUE_{PRE} * 100]$

Where:

BOF = Boiler oversize factor (= 77%, deemed)
CAP = Size of the boiler being tuned (= 108 MBh)[3]
SF = Savings factor (= 1.6%, deemed)[4]
HDD = Heating degree days (= 7,699)[4]
T_{INDOOR} = Indoor design temperature (= 65°F)[4]
$T_{OUTDOOR}$ = Outdoor design temperature (= -15°F)[4]
$AFUE_{PRE}$ = AFUE of boiler prior to tune-up (= 82%)[5]
100 = Conversion factor from MBh to therm

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 2 years)[1]

Sources

1. Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0*. Volume 3. p. 148. February 8, 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_3_Res_020817_Final.pdf
   Value for furnace tune-up used.
2. CLEAResult. Informal survey of four Wisconsin Trade Allies. December 2017.
3. Focus on Energy. *SPECTRUM Focus Prescriptive Database*.
   Program data collected from 2015 through 2017 shows that the average capacity of 110 delivered boilers is 108 MBh.
4. PA Consulting Group. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Program: Deemed Savings Manual V1.0." March 22, 2010. p. 4-11 (saving factor). https://focusonenergycom/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf.
5. PA Consulting Group. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation *ACES: Default Deemed Savings Review*." Final Report. June 24, 2008.

https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf

Energy Efficiency and Renewable Energy Office. "2008-07-28 Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnaces and Boilers; Final rule; technical amendment." Federal standard for residential boilers. Effective August 27, 2008. https://www.regulations.gov/document?D=EERE-2006-STD-0102-0009

Revision History

Version Number	Date	Description of Change
01	05/2018	Initial TRM entry

Building Shell

Air Sealing without Blower Door Test

	Measure Details
Measure Master ID	Air Sealing, Natural Gas Heat with Cooling, 4749 Air Sealing, Natural Gas Heat without Cooling, 4750 Air Sealing, Electric Heat with Cooling, 4751 Air Sealing, Electric Heat without Cooling, 4752
Workpaper ID	W0188
Measure Unit	Per conditioned square foot
Measure Type	Hybrid
Measure Group	Building Shell
Measure Category	Air Sealing
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$0.27[2]

Measure Description

Sealing air leaks in multifamily buildings reduces air infiltration by at least 10%. Sealing should be of the whole building, not just individual units, and should include caulking or spray foaming wall and roof penetrations, weatherstripping around doors and windows, and caulking other cracks as needed.

Description of Baseline Condition

The baseline condition is a multifamily building in its original condition.

Description of Efficient Condition

The efficient condition is a multifamily building with air leaks sealed sufficiently to reduce air infiltration by at least 10%.

Annual Energy-Savings Algorithm

Savings for air sealing are calculated when the corresponding systems are present. If not present, the respective savings values are considered zero. Savings are the sum of iterations over the full range of temperatures (-30°F to 100°F), for heating or cooling, broken into five-degree intervals. The total savings account for the distribution of the number of hours for each temperature interval.

$kWh_{SAVED} = kWh_{SAVED\_COOL} + kWh_{SAVED\_HEAT}$

$kWh_{SAVED\_COOL} = [60 * 0.075 * V * (H_{OUT} – H_{IN}) / (1{,}000 * EER)] * HOU_{COOL} * SF$

(This should be summed for each temperature bin above the outside temperature when the cooling system is "on.")

$kWh_{SAVED\_HEAT} = [1.08 * V * (T_{HEAT} – T_{OUT}) / (COP * 3{,}412)] * HOU_{HEAT} * SF$

(This should be summed for each temperature bin below the outside temperature when the heating system is "on." It equals zero if there is no electric heat.)

Where:

60 = Units conversion from minutes to hours

0.075 = Air density in lb/ft^3

V = Volume rate of infiltration air in CFM
= $ACH * A_{FLOOR} * HT_{CEILING} / 60$

Where:

ACH = Baseline air infiltration rate in air changes per hour (= 0.2 for buildings built in 2015 or later, = 1.0 during heating season for buildings built in 2014 or earlier, = 0.5 during cooling season for buildings built in 2014 or earlier; see Assumptions)[3]

A_{FLOOR} = Floor area of conditioned space in square feet (= user input)

$HT_{CEILING}$ = Average ceiling height in feet (= user input)

H_{OUT} = Enthalpy of outside air during the cooling season, in Btu/lb (= varies, from weather data)

H_{IN} = Enthalpy of inside air during the cooling season, in Btu/lb (= 28.3, see Assumptions)

1,000 = Conversion from Btu/h to MBh

EER = Efficiency of cooling equipment in Btu/watt (= user input)

HOU_{COOL} = Number of hours per year the outside temperature is above T_{COOL} + ΔT_{COOL} (= varies, from weather data)

Where:

T_{COOL} = Thermostat setpoint during cooling season (= 75°F, see Assumptions)

ΔT_{COOL} = Degrees above cooling thermostat setpoint (T_{COOL}) that cooling equipment is off (= 5°F, see Assumptions)

SF = Savings fraction (= 0.10, see Assumptions)

1.08 = Sensible heat constant in Btu/hr-CFM-°F

T_{HEAT} = Thermostat setpoint during heating season (= 65°F, see Assumptions)

T_{OUT} = Temperature of outside air during the heating season in °F (= from weather data)

COP = Coefficient of performance in watts of heat transferred per watt of electrical input (= 1.0 for electric resistance heat, = user input for heat pumps). If heat pump provides HSPF as efficiency, COP = HSPF / 3.412

3,412 = Conversion from Btu/h to kW

HOU_{HEAT} = Number of hours per year the outside temperature is below T_{HEAT} + ΔT_{HEAT} (= varies, from weather data)

Where:

ΔT_{HEAT} = Degrees below the heating thermostat setpoint (T_{HEAT}) that the heating equipment is off (= 10°F, see Assumptions)

$Therms_{SAVED} = [1.08 * V * (T_{HEAT} – T_{OUT}) / (Eff_{HEAT} * 100{,}000)] * HOU_{HEAT} * SF$

(This should be summed for each temperature below the outside temperature when the heating system is "on." It equals zero if there is no natural gas heat.)

Where:

Eff_{HEAT} = Thermal efficiency of heating equipment, fraction (= user input)

100,000 = Conversion from Btu to therms

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = CF * kWh_{SAVED\_COOL} / HOU_{COOL}$

Where:

CF = Coincidence factor (= 0.68)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

The indoor enthalpy during the cooling season is 28.3 Btu/lb, which corresponds to 75°F and 50% relative humidity.

Thermostat setpoints are assumed to be 75°F for cooling and 65°F for heating; these averages account for setbacks for nighttime and unoccupied periods. The cooling system is enabled when the outside temperature is at least 5°F warmer than the thermostat cooling setpoint of 75°F. The heating system is enabled when the outside temperature is 10°F cooler than than the thermostat heating setpoint of 65°F. Between the temperatures of 55°F (= 65°F - 10°F) and 80°F (= 75°F + 5°F), both the heating and cooling systems are off.

The enthalpy for each temperature bin shown in the table is identical to those for MMID 2314. Values are population weighted from TMY3 weather files.

Temperature Intervals and Corresponding Enthalpies

Temperature Range	Range Midpoint	Enthalpy (Btu/lb)[7]
95°F to 100°F	97.5°F	42.118
90°F to 95°F	92.5°F	40.566
85°F to 90°F	87.5°F	39.454
80°F to 85°F	82.5°F	35.131
75°F to 80°F	77.5°F	32.397
70°F to 75°F	72.5°F	30.686
65°F to 70°F	67.5°F	28.335
60°F to 65°F	62.5°F	25.217
55°F to 60°F	57.5°F	21.965
50°F to 55°F	52.5°F	19.174
45°F to 50°F	47.5°F	17.107
40°F to 45°F	42.5°F	15.063
35°F to 40°F	37.5°F	12.954
30°F to 35°F	32.5°F	10.992
25°F to 30°F	27.5°F	9.132
20°F to 25°F	22.5°F	7.610
15°F to 20°F	17.5°F	5.871
10°F to 15°F	12.5°F	4.039
5°F to 10°F	7.5°F	2.526
0°F to 5°F	2.5°F	1.301
-5°F to 0°F	-2.5°F	0.075
-10°F to -5°F	-7.5°F	-1.387
-15°F to -10°F	-12.5°F	-2.521
-20°F to -15°F	-17.5°F	-3.901
-25°F to -20°F	-22.5°F	-4.858
-30°F to -25°F	-27.5°F	-6.222

Temperature bin hours, population weighted for the state of Wisconsin, are listed in the table below.

Bin Hours[7]

Temperature Range	Green Bay	LaCrosse	Madison	Milwaukee	Average	Weighted Average
95°F to 100°F	0	7	0	5	3	**3**
90°F to 95°F	22	46	25	16	27	**21**
85°F to 90°F	62	121	86	59	82	**68**
80°F to 85°F	275	355	339	225	299	**267**
75°F to 80°F	398	445	486	400	432	**419**
70°F to 75°F	445	489	447	497	470	**474**
65°F to 70°F	675	762	723	692	713	**698**
60°F to 65°F	871	746	770	936	831	**877**
55°F to 60°F	647	583	605	545	595	**584**
50°F to 55°F	543	615	597	679	609	**626**
45°F to 50°F	404	444	491	471	453	**457**
40°F to 45°F	579	597	510	723	602	**638**
35°F to 40°F	777	826	905	883	848	**859**
30°F to 35°F	820	719	741	720	750	**748**
25°F to 30°F	507	425	396	423	438	**438**
20°F to 25°F	579	457	439	531	502	**520**
15°F to 20°F	443	319	353	390	376	**392**
10°F to 15°F	265	227	212	228	233	**234**
5°F to 10°F	178	208	164	125	169	**150**
0°F to 5°F	90	110	105	88	98	**93**
-5°F to 0°F	81	106	157	61	101	**88**
-10°F to -5°F	83	109	105	57	89	**76**
-15°F to -10°F	9	23	70	6	27	**21**
-20°F to -15°F	7	9	21	0	9	**6**
-25°F to -20°F	0	6	9	0	4	**2**
-30°F to -25°F	0	6	4	0	3	**1**

Four cities, shown in the table below, account for 91% of the population. The hours used for the remaining 9% of the population are the average of the four cities.

Population Weighting Percentages

Location	Weighting by Location
Green Bay	22%
Lacrosse	3%
Madison	18%
Milwaukee	48%
Average	**9%**

ACH Baseline and Reduction

Because of generally large site-to-site variation, calculating savings for air sealing measures normally requires performing a blower door test to measure the ACH value at 50 pascals of pressure difference. However, this is difficult to perform for multifamily sites—if performed on a single unit, the reading will reflect air leakage from adjacent units in addition to air leakage from the exterior. To perform on the entire building usually requires large and difficult coordination of residents.

This measure does not require a blower door test, instead employing prescriptive values for the baseline ACH and ACH reduction factor. These are conservative values selected based on several sources of data and subsequent reasoning. These data are presented in the table below.

Data for Baseline and Reduction in ACH

Data Source	Data Count	Baseline ACH		Average ACH Reduction %
		Summer	Winter	
2006 Lawrence Berkely National Laboratory study for the California Energy Commision[3]	24 units in four buildings	0.77	1.44	N/A
2014 and 2016 Focus on Energy data (SPECTRUM)	Seven buildings or units	0.56	1.00	55%
2008 Focus on Energy data (local)	344 units in 19 buildings	0.3		23%

In addition, the New York Technical Reference Manual[8] assumes (with no reference) baseline ACH values of 0.5 in summer and 1.0 in winter and an ACH reduction of 15%.

Based on these data and benchmarking, conservative values of an ACH of 1.0 in winter and 0.5 in summer and a reduction of 10% are assumed for older buildings. Actual ACH reduction is likely to vary greatly and the average value may be higher than this, but a deemed quantity for a highly variable value should be very conservative. In the future if enough blower door tests are performed for this measure, or if a billing analysis can be performed, these numbers will be revisited.

For new construction, defined as 2015 or later, the infiltration rate is determined by using the factor from ENERGY STAR[5] to convert from the infiltration rate at a pressure of 50 pascals (ACH50) to neutral pressure. For the zone where Wisconsin is located (Zone 2), this factor ranges from 11.7 for an exposed three-story building to 22.2 for a well-shielded one-story building. A moderate value of 15 is used. Dividing the code value of 3.0 ACH50[6] by 15 gives 0.2 ACH at neutral pressure.

Incremental Cost

Several sources were examined for the incremental cost.[2,9,10] The source chosen[2] was the most conservative (highest) and local to Wisconsin.

Sources

1. GDS Associates. *Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures*. 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
2. Energy House LLC. Personal communication with Doug McFee on April 10, 2019 suggests $0.27 per square foot.
3. Lawrence Berkely National Laboratory. Public Interest Energy Research Program. *Indoor-Outdoor Air Leakage of Apartments and Commercial Buildings.* Figure 10 (p. 31). December 2006. https://www.energy.ca.gov/2006publications/CEC-500-2006-111/CEC-500-2006-111.PDF
4. Cadmus. “Focus on Energy Evaluated Deemed Savings Changes.” November 14, 2014 https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
5. ENERGY STAR Home Sealing Specification. Table 4 (p. 5). October 16, 2001. (https://www.energystar.gov/ia/home_improvement/home_sealing/ES_HS_Spec_v1_0b.pdf)
6. International Code Council. 2015 International Energy Conservation Code. Section R402.4.1.2 https://codes.iccsafe.org/content/IECC2015/chapter-4-re-residential-energy-efficiency
7. National Solar Radiation Data Base, 1991- 2005 Update: Typical Meteorological Year 3. http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html
8. New York State Joint Utilities. *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs. Version 6*. p. 45 and 498. http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1100671bdd/$FILE/TRM%20Version%206%20-%20January%202019.pdf
9. Fixr. Home Air Sealing Cost. Accessed April 2019. https://www.fixr.com/costs/air-leaks-sealing. $350 - $600 for a 2,500 square foot home ($0.14 to $0.24 per square foot).
10. Steven Winter Associates. *Measure Guideline: Sealing Attics in Multifamily Buildings*. https://www.nrel.gov/docs/fy12osti/54720.pdf
$0.10 to $0.25 listed for air sealing and insulation.

Revision History

Version Number	Date	Description of Change
01	04/30/2019	Initial TRM entry

Attic Insulation, Multifamily

	Measure Details
Measure Master ID	Insulation, Attic: Natural Gas Heat with Cooling: Existing Insulation ≤ R-11, 3707 Existing Insulation R-12 to R-19, 3709 Existing Insulation R-20 to R-38, 5167 New Construction to R-49, 4824 Natural Gas Heat without Cooling: Existing Insulation R-12 to R-19, 3710 Existing Insulation ≤ R-11, 3708 Existing Insulation R-20 to R-38, 5168 New Construction to R-49, 4379 Electric Heat with Cooling: Existing Insulation ≤ R-11, 3711 Existing Insulation R-12 to R-19, 3713 Existing Insulation R-20 to R-38, 5169 New Construction to R-49, 4380 Electric Heat without Cooling: Existing Insulation ≤ R-11, 3712 Existing Insulation R-12 to R-19, 3714 Existing Insulation R-20 to R-38, 5170 New Construction to R-49, 4381
Workpaper ID	W0189
Measure Unit	Per square foot of roof (over conditioned space)
Measure Type	Prescriptive
Measure Group	Building Shell
Measure Category	Insulation
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/yr)	0
Effective Useful Life (years)	30[1]
Incremental Cost ($/unit)	Existing Insulation ≤ R-11 = $1.87 (MMIDs 3707, 3708, 3711, and 3712); Existing Insulation R-12 to R-19 = $1.62 (MMIDs 3709, 3710, 3713, and 3714);

	Existing Insulation R20 to R-38 = \$1.01 (MMIDs 5167, 5168, 5169, 5170) New Construction to R-49 = \$1.01 (MMIDs 4824, 4379, 4380, and 4381)[2]

Measure Description

This measure is installing additional attic insulation in an existing or new construction multifamily residence, assumed to be heated with either natural gas or electricity and may be electrically cooled.

For existing buildings, an additional requirement of this measure is that the existing space have less than or equal to R-11 insulation or R-12 to R-19 excluding assembly section, and be insulated to a minimum of R-38. This specific measure detail was determined through additional analysis and calculations in reference to the Illinois TRM attic insulation methodologies.[3] A framing factor was not included in the calculation, as attic insulation is typically deep enough to completely cover the framing, making the framing impacts negligible. Attics with an existing R-value greater than R-19 and attics with an efficient condition of significantly greater than R-38 will be treated as custom measures.

For retrofits or new construction, heating systems other than electric resistance or a natural gas furnace or boiler will be treated as custom measures.

Description of Baseline Condition

For existing buildings, there are two tiers of baseline condition for this measure incentive: Tier 1 is an attic insulated to R-11 or less and Tier 2 is an attic insulated to between R-12 and R-19.

For new construction, the baseline is an attic insulated to R-38.

Description of Efficient Condition

For existing buildings, the efficient condition is an attic insulated to R-38 or greater.

For new construction, the efficient condition is an attic insulated to R-49 to match ENERGY STAR residential insulation recommendations.[10]

Annual Energy-Savings Algorithm

The following equations are used when the corresponding systems are present. If not present, the respective savings values are considered zero.

$$Therms_{SAVED} = [(1 / R_{BASE} – 1 / R_{EE}) * HDD * 24 * Area] / (100{,}000 * AFUE)$$

$$kWh_{SAVED} = kWh_{SAVED\_HEAT} + kWh_{SAVED\_COOL}$$

$$kWh_{SAVED\_HEAT} = [(1 / R_{BASE} – 1 / R_{EE}) * HDD * 24 * Area] / (1{,}000 * HSPF)$$

$$kWh_{SAVED\_COOL} = [(1 / R_{BASE} – 1 / R_{EE}) * CDD * 24 * Area] / (1{,}000 * SEER)$$

Where:

R_{BASE} = Existing R-value of attic (= R-11, R-19, or R-38 for existing buildings, = R-38 for new construction)

R_{EE} = Proposed R-value of attic after retrofit (=R-49)[11]

HDD = Heating degree days (= 7,616; see table below)

24 = Hours per day

Area = Attic area to be insulated (in square feet)

100,000 = Conversion from Btu to therms

AFUE = Natural gas heating system efficiency (= 84%)[6]

1,000 = Kilowatt conversion factor

HSPF = Electric heating system efficiency (= 3.412 for electric resistance heat, the number of Btus in a watt-hour)

CDD = Cooling degree days (= 565; see table below)

SEER = Cooling system efficiency (= 13)[4,5]

Cooling and Heating Degree Days by City

Location	HDD[7]	CDD[7]
Milwaukee	7,276	548
Green Bay	7,725	516
Wausau	7,805	654
Madison	7,599	630
La Cross	7,397	729
Minocqua	8,616	423
Rice Lake	8,552	438
Statewide Weighted	**7,616**	**565**

Summer Coincident Peak Savings Algorithm[8]

$kW_{SAVED} = (kWh_{SAVED\_COOL} / EFLH_{COOL}) * CF$

Where:

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410)[9]

CF = Coincidence factor (= 0.68)[9]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therms_{LIFECYCLE} = Therms_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 30 years)[1]

Deemed Savings

Deemed Natural Gas and Electricity Savings per Square Foot of Attic Insulation

Measure	MMID	Annual kWh	Annual Therms	Peak kW	Lifecycle kWh	Lifecycle Therms
Natural Gas Heat with Cooling						
Existing Insulation ≤ R-11	3707	0.07	0.15	0.0001	2.21	4.6
Existing Insulation R-12 to R-19	3709	0.03	0.07	0.0001	1.01	2.1
Existing Insulation R-20 to R-38	5167	0.01	0.01	0.0000	0.18	0.4
New Construction to R-49	4824					
Natural Gas Heat without Cooling						
Existing Insulation ≤ R-11	3708	--	0.15	--	--	4.6
Existing Insulation R-12 to R-19	3710	--	0.07	--	--	2.1
Existing Insulation R-20 to R-38	5168	--	0.01	--	--	0.4
New Construction to R-49	4379					
Electric Heat with Cooling						
Existing Insulation ≤ R-11	3711	3.85	--	0.0001	115.5	--
Existing Insulation R-12 to R-19	3713	1.76	--	0.0001	52.8	--
Existing Insulation R-20 to R-38	5169	0.32	--	0.0000	9.7	--
New Construction to R-49	4380					
Electric Heat without Cooling						
Existing Insulation ≤ R-11	3712	3.78	--	--	113.3	--
Existing Insulation R-12 to R-19	3714	1.73	--	--	51.8	--
Existing Insulation R-20 to R-38	5170	0.32	--	--	9.5	--
New Construction to R-49	4381					

Assumptions

The summer coincident peak savings algorithm is derived from the Illinois TRM.[8]

The incremental costs for attic insulation are based on matching the measures listed above with the measures from DEER 2008, as shown in the following table. Costs from 2008 are increased 19% for inflation from 2008 to 2021.

Measure Details from Database for Energy Efficient Resources

Insulation Improvement	MMIDs	DEER 2008 Measure	Inflation-Adjusted DEER Cost ($/Sq Ft)		
			Material	Labor	Total
Retrofit R-11 to R-49 (R-38 improvement)	3707, 3708, 3711, 3712	Extrapolation of next two rows	$1.06	$0.81	$1.87
Retrofit R-19 to R-49 (R-30 improvement)	3709, 3710, 3713, 3714	Ceiling - Add R-30 batts	$0.89	$0.73	$1.62
Retrofit R-38 to R-49 (R-11 improvement)	4824, 4379, 4380, 4381	Ceiling - Add R-11 batts	$0.48	$0.54	$1.01
New Construction R-38 to R-49 (R-11 improvement)	5167, 5168, 5169, 5170				

Sources

1. Guidehouse. EMV Group A, Deliverable 16 EUL Research – Residential Insulation. June 29, 2021. https://pda.energydataweb.com/api/view/2518/CPUC%20Insulation%20EUL%20Draft%20Report%2006292021.pdf. Median insulation age value across all material types is 32 years. Focus lifetimes are capped at 30 years, pending further discussion.
2. California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." Revised Measure Cost Summary. June 2, 2008. Costs from 2008 are increased 19% for inflation from 2008 to 2021. http://www.deeresources.com/index.php/deer-versions/deer2008-for-09-11-planning-reporting
3. Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual*. Section 5.6.4 Wall and Ceiling/Attic Insulation. June 1, 2015. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf
4. Appliance Standards Awareness Project. "Central Air Conditioners and Heat Pumps." Accessed January 2018. http://www.appliance-standards.org/product/central-air-conditioners-and-heat-pumps
5. International Energy Conservation Code. Table 503.2.3(1). 2009.
6. Cadmus. *2016 Potential Study for Focus on Energy.*
   Data maintained by Cadmus and Wisconsin PSC. Residential site visits from the summer of 2016 revealed that the average AFUE of multifamily natural gas heat is 84%. Twenty-three sites had an average central natural gas heating AFUE of 83.6% while 15 sites had an in-unit natural gas heating AFUE of 85.6%, and sites had a 58.7%/41.3% split of central/in-unit heating.
7. ASHRAE Estimation of Degree-Days: Fundamentals, Chapter 14.
   Calculated from TMY3 weather files of the seven Wisconsin locations using statewide weighted values calculated from 2010 U.S. Census data for Wisconsin.

8. Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual.* Section 5.6.1 Air Sealing. June 1, 2015. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf
9. Cadmus. “Focus on Energy Evaluated Deemed Savings Changes.” November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
10. ENERGY STAR website. Accessed November 1, 2018. www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_insulation_table
11. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average installed insulation level for existing insulation measures is R-49. Based on 32 projects from June through November 2020.

Revision History

Version Number	Date	Description of Change
01	01/2016	Initial TRM entry
02	11/2017	Updated to add measures for new construction
03	11/2018	Changed new construction attic insulation from R-50 to R-49
04	01/2021	Updated efficient insulation level to R-49 for existing

Wall Insulation, Multifamily

	Measure Details
Measure Master ID	Insulation, Wall: NG Heat with Cooling, 3703 NG Heat without Cooling, 3704 Electric Heat with Cooling, 3705 Electric Heat without Cooling, 3706
Workpaper ID	W0190
Measure Unit	Per square foot of exterior wall
Measure Type	Prescriptive
Measure Group	Building Shell
Measure Category	Insulation
Sector(s)	Residential– multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/yr)	0
Effective Useful Life (years)	30[1]
Incremental Cost ($/year)	$1.86 for retrofit measures; $0.82 for new construction measures[2]

Measure Description

This measure is installing insulation to above-grade exterior walls in an existing or new construction multifamily residence. This measure includes any increase in R-value due to installed insulation, including but is not limited to fiberglass batts, spray foam, loose fill cellulose, metalized polymers, or other material that meets local and state building codes. Sill boxes are considered part of the exterior wall. A combination of insulation materials may be used, provided they meet the required efficient condition (for example, 2x4 construction will likely not meet R-20 with just cavity insulation and will likely require continuous insulation also).

Buildings with existing exterior wall insulation greater than R-5, exterior walls with an efficient condition of significantly greater than R-20, and application in buildings with heating systems other than electric resistance or a natural gas furnace or boiler will still be treated as custom.

For new construction projects, buildings with heating systems other than electric resistance or natural gas furnace or boiler will still be treated as custom.

Description of Baseline Condition

For existing buildings, the baseline condition is minimal wall insulation such that the existing R-value is at or less than R-5.

For new construction buildings, the baseline condition is R-20 wall insulation.

Description of Efficient Condition

For existing buildings, the efficient condition is exterior wall insulation that complies with International Energy Conservation Code 2009.[3] IECC 2009 lists R-21 exterior wall insulation for climate zone 7 (roughly the northern quarter of the state) and R-20 for climate zone 6 (remainder of the state). R-20 was selected to provide one common value statewide.

The use of R-13 cavity insulation plus R-5 insulated sheathing is considered equal to R-20 for climate zone 6 by IECC 2009. Since most of Wisconsin is in this climate zone, this is an acceptable alternative.

IECC 2009 provides an alternate compliance path which allows for a non-fenestration U-factor of 0.057 or less to be used instead of the R-20 or R-21 insulation to allow for alternative exterior wall construction types.[4] This is also an acceptable alternative.

For new construction buildings, the efficient condition is R-25 wall insulation.

Annual Energy-Savings Algorithm

$$\text{Therms}_{\text{SAVED}} = [(1 / R_{\text{BASE}} - 1 / R_{\text{EE}}) * \text{Area} * (1 - \text{FramingF})] * 24 * \text{HDD} / (100{,}000 * \text{AFUE})$$

$$\text{kWh}_{\text{SAVED}} = \text{kWh}_{\text{SAVED\_HEAT}} + \text{kWh}_{\text{SAVED\_COOL}}$$

$$\text{kWh}_{\text{SAVED\_HEAT}} = [(1 / R_{\text{BASE}} - 1 / R_{\text{EE}}) * \text{Area} * (1 - \text{FramingF})] * 24 * \text{HDD} / (1{,}000 * \text{HSPF})$$

$$\text{kWh}_{\text{SAVED\_COOL}} = [(1 / R_{\text{BASE}} - 1 / R_{\text{EE}}) * \text{Area} * (1 - \text{FramingF})] * 24 * \text{CDD} / (1{,}000 * \text{SEER})$$

Where:

R_{BASE} = Existing condition insulation R-value (= R-5 for existing buildings, = R-20 for new construction)

R_{EE} = Efficient condition insulation R-value (= R-20 for existing buildings, = R-25 for new construction)

Area = Wall area to be insulated in square feet

FramingF = Adjustment to account for area of framing (= 25%)[4]

HDD = Heating degree days (= 7,616; see table below)

AFUE = Natural gas heating system efficiency (= 84%)[5]

HSPF = Electric heating system efficiency (= 3.412 for electric resistance heat)

CDD = Cooling degree days (= 565; see table below)

SEER = Cooling system efficiency (= 13)[6,7]

Heating and Cooling Degree Days by Location

Location	HDD[8]	CDD[8]
Milwaukee	7,276	548
Green Bay	7,725	516
Wausau	7,805	654
Madison	7,599	630
La Cross	7,397	729
Minocqua	8,616	423
Rice Lake	8,552	438
Statewide Weighted	**7,616**	**565**

Summer Coincident Peak Savings Algorithm

The following algorithm is from Illinois TRM.[4]

$kW_{SAVED} = (kWh_{SAVED\_COOL} / EFLH_{COOL}) * CF$

Where:

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410)[9]

CF = Coincidence factor (= 0.68)[9]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therms_{LIFECYCLE} = Therms_{SAVED} * EUL$

Where:

EUL = Effective useful life (=25 years)[1]

Deemed Savings

Deemed Savings for Wall Insulation

Measure	MMID	Annual kWh	Annual Therms	Peak kW	Lifecycle kWh	Lifecycle Therms
Residential - Multifamily						
NG Heat with Cooling	3703	0.117	0.245	0.0002	3.52	7.34
NG Heat without Cooling	3704	-	0.245	-	-	7.34
Electric Heat with Cooling	3705	6.144	-	0.0002	184.32	-
Electric Heat without Cooling	3706	6.027	-	-	180.90	-
NC-Residential - Multifamily						
NG Heat with Cooling	3703	0.008	0.016	0.0000	0.23	0.49
NG Heat without Cooling	3704	-	0.016	-	-	0.49
Electric Heat with Cooling	3705	0.410	-	0.0000	12.29	-
Electric Heat without Cooling	3706	0.402	-	-	12.05	-

Assumptions

The incremental costs for wall insulation are based on matching the measures listed above with the measures from DEER 2008 shown in the following table.

Measure Values from Database for Energy Efficient Resources

	Insulation Improvement	DEER 2008 Measure	DEER Material Cost ($/Sq Ft)		
			Material	Labor	Total
Retrofit	Retrofit R-5 to R-20	Wall 2x6 R-19 Batts + R-5 Rigid	$0.92	$0.94	$1.86
New Construction	Increase R-20 to R-25	Wall 2x6 R-19 Batts + R-5 Rigid, less cost for Wall 2x6 R-19 Insulation-Batts (to obtain R-5 Rigid cost)	$0.41	$0.41	$0.82

Sources

1. Guidehouse. EMV Group A, Deliverable 16 EUL Research – Residential Insulation. June 29, 2021. https://pda.energydataweb.com/api/view/2518/CPUC%20Insulation%20EUL%20Draft%20Report%2006292021.pdf. Median insulation age value across all material types is 32 years. Focus lifetimes are capped at 30 years, pending further discussion.
2. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” Revised Measure Cost Summary. June 2, 2008. http://www.deeresources.com/index.php/deer-versions/deer2008-for-09-11-planning-reporting

3. *International Energy Conservation Code*. Chapter 4 – Residential Energy Efficiency, Tables 402.1.1 and 402.1.3. 2009.
4. Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual*. Section 5.6.4 Wall and Ceiling/Attic Insulation. Section 5.6.1 Air Sealing. June 1, 2015. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_4/2-13-15_Final/Updated/Illinois_Statewide_TRM_Effective_060115_Final_02-24-15_Clean.pdf
5. Cadmus. *2016 Potential Study for Focus on Energy.*
   Data maintained by Cadmus and Wisconsin PSC. Residential site visits from the summer of 2016 reveal that the average AFUE of multifamily natural gas heat is 84%. Twenty-three sites had an average central natural gas heating AFUE of 83.6% while 15 sites had an in-unit natural gas heating AFUE of 85.6%, and sites had a 58.7%/41.3% split of central/in-unit heating.
6. Appliance Standards Awareness Project. “Central Air Conditioners and Heat Pumps.” Accessed January 2018. http://www.appliance-standards.org/product/central-air-conditioners-and-heat-pumps
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8. *ASHRAE Estimation of Degree-Days: Fundamentals*. Chapter 14.
   Calculated from TMY3 weather files of the seven Wisconsin locations using statewide weighted values calculated from 2010 U.S. Census data for Wisconsin; 2010 US Census data for Wisconsin (statewide weighted values).
9. Cadmus. “Focus on Energy Evaluated Deemed Savings Changes.” November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Revision History

Version Number	Date	Description of Change
01	01/2016	Initial TRM entry
02	11/2017	Added measures for new construction

Whole Home Completion

	Measure Details
Measure Master ID	Project Completion, Electric Heat, 4883 Project Completion, Natural Gas Heat, 4884 Project Completion, Natural Gas Only, 4887 Project Completion, Tier 2, Electric Heat, 4885 Project Completion, Tier 2, Natural Gas Heat, 4886 Project Completion, Tier 2, Natural Gas Only, 4888
Workpaper ID	W0239
Measure Unit	Per residence
Measure Type	Prescriptive
Measure Group	Building Shell
Measure Category	Insulation
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	25[1,2] (see Assumptions)
Incremental Cost ($/unit)	Varies by measure,[3] see Annual Savings and Cost table below

Measure Description

This measure is insulation and air sealing work completed by a contractor in a home. Whole Home Completion covers work completed in several areas: attic, wall, foundation, and duct. Any combination of improvements may be completed. This measure covers all insulation and air sealing improvements completed as a single entity with combined savings:

- Blower door guided air sealing: pre and post blower door testing required
- Attic insulation: basic air sealing installed to *Materials and Installation* standards,[4] at least 600 square feet of attic area must be improved
- Foundation insulation: at least 50% of the sill or foundation wall area must be improved
- Wall insulation: basic air sealing installed to *Materials and Installation* standards,[4] at least 800 square feet of exterior wall must be improved, or at least 400 square feet of framed floor must be improved
- Duct sealing: not applicable to ductwork in a conditioned space (such as a basement or unvented crawlspace); all ductwork outside the conditioned space must be sealed and insulated

These measures have had *ex ante* savings calculated on a custom basis in previous program years using Snugg Pro modeling tools. A billing analysis approach was used in the PY 2020 evaluation to produce evaluated savings.[5,6] As part of this analysis, billing data from participant and nonparticipant sites was analyzed and incorporated into final results. Results are used here to produce prescriptive savings for each site instead of continuing to use modeling for individual projects.

Billing Analysis Participant Count

Measure Set	Participants	Nonparticipants (Control Group)
Tier 1 gas	1,295	138
Tier 1 electric	1,124	130
Tier 2 gas	168	47
Tier 2 electric	134	48

Description of Baseline Condition

The baseline condition is the air sealing and insulation levels of an existing home, with the following maximum existing conditions:

- Blower door guided air sealing: no air sealing work performed
- Attic insulation: no air sealing work performed, open cavity with an effective insulation of R-19 or less, closed cavity with no effective insulation
- Foundation insulation: no effective existing insulation
- Wall insulation: no air sealing work performed, wall cavity with no effective insulation, framed floor with an effective insulation of R-19 or less
- Duct sealing: unsealed or uninsulated duct in an unconditioned space

Description of Efficient Condition

The efficient condition is the air sealing and insulation levels of an existing home after work is completed by the contractor, with the following minimum conditions:

- Blower door guided air sealing: air sealing work performed
- Attic insulation: air sealing work performed, open cavity with insulation of R-38 or greater, closed cavity filled with insulation
- Foundation insulation: sill and/or wall insulation of R-5 or greater
- Wall insulation: air sealing work performed, closed cavity filled with insulation, framed floor cavity filled with insulation
- Duct sealing: ductwork sealed and insulated to R-8

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{BA}$

$Therm_{SAVED} = Therm_{BA}$

Where:

kWh_{BA} = Average kilowatt-hours saved per site, as determined by PY 2020 billing analysis data (= see Annual Savings and Cost table below, see Assumptions)

$Therm_{BA}$ = Average therms saved per site, as determined by PY 2020 billing analysis (= see Annual Savings and Cost table below, see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kW_{NET}$

Where:

kW_{NET} = Net kilowatts saved per site (= see Annual Savings and Cost table below, see Assumptions)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 25 years[1,2], see Assumptions)

Assumptions

EUL

An EUL of 30 is assumed for insulation savings[2] and an EUL of 15 is assumed for air sealing savings[1]. Approximately 58% of annual Whole Home savings come from insulation, and 42% from air sealing. This produces a weighted Whole Home measure EUL of 25 years.

Billing Analysis

The 2020 Focus on Energy Evaluation Report[5] and its appendices[6] present results for the PY 2020 billing analysis. This analysis represents an update of the one performed for the PY 2017 evaluation, which previously informed deemed TRM savings for these measures.

For gas savings, as seen in the report's Table 54 and Table 58, Tier 1 sites have 135 therm savings with ±9% precision at 90% confidence, and Tier 2 sites save 186 therms with ±22% precision at 90%

confidence. These values are specifically for sites with natural gas heat only, and therefore apply directly to therms savings for MMIDs 4884 and 4886.

For electric savings, as seen the report's Table 54 and Table 55, Tier 1 gas heat sites save 854 kWh with ±20% precision at 90% confidence, Tier 1 electric heat sites save 2,395 kWh with ±21% precision at 90% confidence, Tier 2 gas heat sites save 945 kWh with ±12% precision at 90% confidence.

As was the case for the 2017 billing analysis and the previous version of this workpaper, the precision for Tier 2 electric heat sites was too poor to use. In the previous version of this workpaper,[7] Tier 2 electric heat site savings was estimated as [Tier 2 all sites electric savings] * [Tier 1 gas heat site electric savings] / [Tier 1 all sites electric savings] to produce 749 kWh. For this current version of the workpaper, the Tier 2 electric heat site savings are estimated by multiplying the previous savings by the PY 2020 net to gross ratio (in this case essentially the realization rate) of 97%. This 97% value can be seen in Table 55 of the PY 2020 report.[5] Therefore PY 2021 Tier 2 electric heat sites savings are 2,880 * 97% = 2,793 kWh.

Demand reduction cannot be derived from billing analysis results. In the previous version of this workpaper, an initial demand reduction per unit was calculated by first dividing the total net demand reduction from 2017 (from Snugg pro modeling) by the total site count from 2017 (1,244 Tier 1 and 282 Tier 2 sites). Then the deemed net demand reduction was calculated by applying billing analysis derived kilowatt-hour net-to-gross ratios to the Snugg Pro calculated demand reduction. This approach is unaffected by whether a site has electric or natural gas heat, since it is assumed that no heating occurs during peak demand periods.

There is no updated set of Snugg Pro models with which to repeat this derivation. Therefore in this current version of the workpaper, the PY 2020 net to gross ratios (in this case essentially the realization rates) are multiplied by the previous demand savings. They are 0.3151 * 133% = 0.4191 kW for Tier 1 gas heat, 0.3151 * 97% = 0.3056 kW for Tier 1 electric heat, 0.3688 * 126% = 0.4647 kW for Tier 2 gas heat, and 0.3688 * 97% = 0.3577 for Tier 2 electric heat.

Deemed Savings

Project Completion Measure	MMID	kW[5,6]	Annual		Lifecycle	
			kWh[5,6]	Therms[5,6]	kWh	Therms
Project Completion, Electric Heat	4883	0.3056	2,395	0	59,875	0
Project Completion, Natural Gas Heat	4884	0.4191	854	135	21,350	3,375
Project Completion, Natural Gas Only	4887	0.0000	0	135	0	3,375
Project Completion, Tier 2, Electric Heat	4885	0.3577	2,793	0	69,825	0
Project Completion, Tier 2, Natural Gas Heat	4886	0.4647	945	186	23,625	4,650
Project Completion, Tier 2, Natural Gas Only	4888	0.0000	0	186	0	4,650

Costs

Measure	MMID	Cost	Note
Project Completion, Electric Heat	4883	$5,015.95	Average of 1,576 sites
Project Completion, Natural Gas Heat	4884		
Project Completion, Natural Gas Only	4887		
Project Completion, Tier 2, Electric Heat	4885	$5,688.17	Average of 229 sites
Project Completion, Tier 2, Natural Gas Heat	4886		
Project Completion, Tier 2, Natural Gas Only	4888		

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, Ventilation. June 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
   15-year value for air sealing is used.
2. Guidehouse. *EMV Group A, Deliverable 16 EUL Research – Residential Insulation*. June 29, 2021. https://pda.energydataweb.com/api/view/2518/CPUC%20Insulation%20EUL%20Draft%20Report%2006292021.pdf
   Page 29 shows median age of 32 years for household insulation. An EUL of 30 was used due to concern over extending EULs in Focus on Energy over 30 years.
3. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. January 2021 to November 2021. Average actual measure cost based on 1,805 projects.
4. Focus on Energy. *Material and Installation Standards.* September 2018. https://focusonenergy.com/sites/default/files/inline-files/0618-FOE-HP-1188339-M%26I%20Standards-Book-R2k_CLEAN.pdf
5. Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report, Volume II*. May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf
6. Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report, Volume III*. May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_III.pdf
7. Cadmus. *Wisconsin Focus on Energy 2020 Technical Reference Manual*. 2020. Page 1,028. https://www.focusonenergy.com/sites/default/files/Focus_on_Energy_2020_TRM.pdf

Revision History

Version Number	Date	Description of Change
01	01/01/2019	Initial TRM entry
02	12/2021	Updated with new billing analysis results, new EUL

DIY Building Shell Project Completion

	Measure Details
Measure Master ID	DIY Building Shell, Electric Heat, 5103 DIY Building Shell, Natural Gas Heat, 5104 DIY Building Shell, Natural Gas Heat, Non-Participating Electric Utility, 5105 Multifamily DIY Building Shell, Electric Heat, 5260 Multifamily DIY Building Shell, Natural Gas Heat, 5261 Multifamily DIY Building Shell, Natural Gas Heat, NPE Utility, 5262
Workpaper ID	W0256
Measure Unit	Per residence
Measure Type	Prescriptive
Measure Group	Other
Measure Category	Insulation
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	25[1,2]
Incremental Cost ($/unit)	Varies by measure[3]

Measure Description

This measure is very similar to the whole-home project completion measures (W0239), typically contractor installed, consisting of insulation and air sealing work completed by a homeowner after completing a do-it-yourself (DIY) weatherization training, and adjusted for homeowner installation. These measures consist largely of work completed primarily in the attic. Additional work can be done to the foundation, though attic insulation and air sealing are required.

Eligible weatherization measures:

- Air sealing and attic insulation (existing effective R-19 or less)
- Foundation insulation

This measure covers all insulation and air sealing improvements completed as a single entity with combined savings:

- Attic insulation: basic air sealing installed to *Material and Installation Standards*,[4] at least 600 square feet of attic area must be improved
- Sill box foundation insulation: at least 50% of the sill area must be improved

These measures must be installed according to the homeowner-adapted version of the program's *Material and Installation Standards* used in the contractor offering. Health and safety education is included in this training related to insulation and air sealing measures, combustion safety, and hazardous materials. Pre-existing conditions and the installation of measures must be verified by photographic or video records with program quality assurance staff. These records are submitted along with the incentive application.

Note that NPE (non-participating electric utility) is for sites that do not receive electric savings.

Description of Baseline Condition

The baseline condition is the air sealing and insulation levels of an existing home with the following maximum existing conditions:

- Attic insulation: no air sealing work performed, open cavity with an effective insulation of R-19 or less, closed cavity with no effective insulation
- Sill box foundation insulation: no effective existing insulation

Description of Efficient Condition

The efficient condition is the air sealing and insulation levels of an existing home after the homeowner completes a weatherization training class and installs materials according to industry guidelines. Work is completed by the homeowner with the following minimum conditions:

- Attic insulation: air sealing work performed, open cavity with insulation of R-38 or greater; closed cavity filled with insulation
- Sill box foundation insulation: sill insulation of R-5 or greater

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{BA,DIY} * F_{DIY}$

$Therm_{SAVED} = Therm_{BA,DIY} * F_{DIY}$

Where:

$kWh_{BA,DIY}$ = Average kilowatt-hours saved per site, as determined by analysis of 2020 billing analysis data (= see Annual Savings and Cost table below, see Assumptions)

F_{DIY} = Adjustment factor to account for expected quality of the work performed by a homeowner (= 75%)[5]

$Therm_{BA,DIY}$ = Average therms saved per site, as determined by analysis of 2020 billing analysis data (= see Annual Savings and Cost table below, see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kW$

Where:

kW_{NET} = Kilowatts saved per site (= see Annual Savings and Cost table below, see Assumptions)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therms_{LIFECYCLE} = Therms_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 25 years[1,2], see Assumptions)

Assumptions

EUL

An EUL of 30 is assumed for insulation savings[2] and an EUL of 15 is assumed for air sealing savings[1]. Approximately 58% of annual Whole Home savings come from insulation, and 42% from air sealing. This produces a weighted Whole Home measure EUL of 25 years.

Billing Analysis

These measures are derived in part from DIY offerings cited in the Vermont TRM,[5] which decrements savings for a DIY installation by 25% relative to a professional contractor installation.

The billing analysis results presented in the *Focus on Energy Calendar Year 2020 Evaluation Report*[6] reflect savings for the billing analysis sample. These sites all had professional installs of the full suite of whole-home measures, including attic insulation and sealing, sill box insulation, foundation insulation, wall insulation, and duct sealing.

However, the DIY whole-home measures only include attic insulation, attic sealing, and sill box insulation. Therefore, the 2020 data were re-analyzed to examine only sites that received these two measures—617 Tier 1 sites with natural gas heat, 22 Tier 1 sites with electric heat, and 58 Tier 2 sites with gas heat. The resulting kilowatt-hour savings were 3%% to 34% lower than those for the full suite of whole-home measures. Precision was poor in many cases, and assumptions were sometimes made to adjust results.

These results were then decremented by an additional 25% to account for DIY installation. They were also adjusted to reflect the fact that the DIY measures are not divided into Tier 1 and Tier 2 measures like the standard whole-home measures. In PY2020, 8.6% of sites with just attic insulation and air sealing were Tier 2 sites, and the results were weighted to reflect this difference.

To estimate demand reduction, the demand reduction for the current standard whole-home measures are altered. The current standard whole-home demand savings are 0.3056 for Tier 1 electric heat, 0.4191 for Tier 1 natural gas heat, 0.3577 for Tier 2 electric heat, and 0.4647 for Tier 2 natural gas heat. These were decreased by 38% to reflect the DIY measure mix, decreased by 25% to reflect DIY versus professional installation, and weighted to reflect 8.6% of sites being Tier 2.

Multifamily Adjustment

Whole Home DIY measures are also offered for multifamily sites. Savings for these sites follow those for single family sites, but are decremented a further 20% based on differences in delivered furnace sizes for single family and multifamily sectors.[7] Their costs are also decremented 20%.

Deemed Savings and Cost

Measure	MMID	Cost[3]	kW	Annual Savings		Lifecycle Savings	
				kWh	Therms	kWh	Therms
DIY Building Shell, Electric Heat	5103	$1,115.29	0.1684	1,200	0	30,000	0
DIY Building Shell, Natural Gas Heat	5104		0.2298	543	101	13,575	2,525
DIY Building Shell, Natural Gas Heat, NPE	5105		0.0000	0	101	0	2,525
Multifamily DIY Building Shell, Electric Heat	5260	$892.23	0.1347	960	0	24,000	0
Multifamily DIY Building Shell, NG Heat	5261		0.1838	434	81	10,860	2,020
Multifamily DIY Building Shell, NG Heat, NPE	5262		0.0000	0	81	0	2,020

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, Ventilation. June 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
A 20-year value for weatherization was used.
2. Guidehouse. *EMV Group A, Deliverable 16 EUL Research – Residential Insulation*. June 29, 2021. https://pda.energydataweb.com/api/view/2518/CPUC%20Insulation%20EUL%20Draft%20Report%2006292021.pdf
Page 29 shows median age of 32 years for household insulation. An EUL of 30 was used due to concern over extending EULs in Focus on Energy over 30 years.
3. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average cost of 40 projects from January 2021 to November 2021 is $1,115.29. Multifamily costs are assumed to be 80% of this, or $892.23.
4. Focus on Energy. *Material and Installation Standards.* September 2018. https://focusonenergy.com/sites/default/files/inline-files/0618-FOE-HP-1188339-M%26I%20Standards-Book-R2k_CLEAN.pdf

5. Efficiency Vermont. *Technical Reference Manual Measure Savings Algorithms and Cost Assumptions*. pp. 262–267. December 31, 2018. https://puc.vermont.gov/sites/psbnew/files/doc_library/Vermont%20TRM%20Savings%20Verification%202018%20Version_FINAL.pdf
6. Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report*. May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_III.pdf
7. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average delivered furnace size of 14,362 single family units in 2020 was 70.0 MBh, and for 264 multifamily units was 56.1 MBh. (70.0 - 56.1) / 70.0 = a 20% reduction. This ratio is assumed to apply to disparities in DIY Whole Home savings as well.

Revision History

Version Number	Date	Description of Change
01	01/2021	Initial TRM entry
02	12/2021	Update to reflect PY2020 billing analysis, multifamily measures

Domestic Hot Water

Kitchen/Bathroom Aerators and Showerheads (test)

	Measure Details
Measure Master ID	Faucet Aerator, Kitchen: 1.5 GPM, Online Store, 4910 1.5 GPM, Pop-Up Retail , 5311 1.5 GPM, Pack-based, 5312 Faucet Aerator, Bath: 1.0 GPM, Pack-based, 3863 1.0 GPM, Online Store, 4909 1.0 GPM, Online Store LTO, 5047 1.0 GPM, Pop-Up Retail , 5313 Showerhead: Upgraded, 1.5 GPM, Pack-based 4273 Handheld, 1.5 GPM, Pack-based 4274 Upgraded, 1.5 GPM, Online Store, 4911 Handheld, 1.5 GPM, Online Store, 5043 Upgraded, 1.5 GPM, Online Store LTO, 5048 Handheld, 1.5 GPM, Pop-Up Retail, 5314 Upgraded, 1.5 GPM, Pop-Up Retail, 5315
Workpaper ID	W0191
Measure Unit	Per aerator
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Aeration
Sector(s)	Residential- single family, Residential- multifamily, Upstream
Annual Energy Savings (kWh)	Varies by measure and sector
Peak Demand Reduction (kW)	Varies by measure and sector
Annual Therm Savings (Therms)	Varies by measure and sector
Lifecycle Electricity Savings (kWh)	Varies by measure and sector
Lifecycle Therm Savings (Therms)	Varies by measure and sector
Water Savings (gal/year)	Varies by measure and sector
Effective Useful Life (years)	10[1]
Measure Incremental Cost ($/unit)	Varies by measure[2]

Measure Description

This measure is installing low-flow kitchen or bathroom aerators or low-flow showerheads in existing buildings or new construction. Pack-based, upstream retail, and online store measures reduce both natural gas and electric consumption, based on building stock splits derived from the *2016 Focus on Energy Potential Study*.[7] All measures also reduce total water consumption.

Description of Baseline Condition

The baseline equipment is a kitchen or bathroom aerator at 2.2 GPM or a showerhead at 2.5 GPM.

Description of Efficient Condition

The efficient condition is a kitchen aerator at 1.5 GPM, a bathroom aerator at 1.0 GPM, or a showerhead at 1.5 GPM.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Gallons_{SAVED} * 8.33 * C * (T_{POINT\ OF\ USE} - T_{ENTERING}) / (EF_{ELECTRIC} * 3{,}412) * \%Elec$

$Therm_{SAVED} = Gallons_{SAVED} * 8.33 * C * (T_{POINT\ OF\ USE} - T_{ENTERING}) / (EF_{GAS} * 100{,}000) * \%Gas$

Aerators

$Gallon_{SAVED} = (GPM_{EXISTING} - GPM_{NEW}) * (PH / FH) * FLU * 365 * IR * DF$

Showerheads

$Gallon_{SAVED} = (GPM_{EXISTING} - GPM_{NEW}) * (PH * SPD / FH) * SLU * 365 * IR * DF$

Where:

$Gallons_{SAVED}$ = First-year water savings in gallons

8.33 = Density of water, lbs/gallon

C = Specific heat of water (= 1 Btu/lb °F)

$T_{POINT\ OF\ USE}$ = Temperature of water at point of use (= 93°F for kitchen aerators; = 86°F for bathroom aerators; = 101°F for showerheads)[5]

$T_{ENTERING}$ = Temperature of water entering water heater (= 52.3°F)[6]

$EF_{ELECTRIC}$ = Energy factor of electric water heater (= 94% for single family,[7] = 92% for multifamily,[7] see Assumptions)

3,412 = Conversion from Btu to kWh

%Elec = Fraction of sites with electric water heaters (= 20% for single family; = 14% for multifamily, see Assumptions)[7]

EF_{GAS} = Energy factor of natural gas water heater (= 61% for single family;[7] = 75% for multifamily,[7] see Assumptions)

%Gas = Fraction of sites with natural gas water heaters (= 73% for single family; = 86% for multifamily, see Assumptions)[7]

100,000 = Conversion from Btu to therm

$GPM_{EXISTING}$ = Baseline flow rate (= 2.2 GPM for kitchen and bathroom aerators; = 2.5 GPM for showerheads)[8]

GPM_{NEW} = Efficient flow rate (= 1.0 or 1.5 GPM for kitchen and bathroom aerators; = 1.5 GPM for showerheads)

PH = Persons per house (= 2.52 for single family homes, = 1.93 for multifamily units)[9]

FH = Fixtures per house (for single family homes = 1.0 for kitchen aerators, = 2.04 for bathroom aerators, and = 1.5 for showerheads; for multifamily units = 1.0 for kitchen aerators, = 1.43 for bathroom aerators, and = 1.0 for showerheads)[5]

FLU = Fixture length of use in minutes per person per day (= 4.5 for kitchen aerators; = 1.6 for bathroom aerators)[5]

365 = Conversion from days to years

IR = Installation rate (= see Installation Rates table)

Installation Rates

Measure Name	MMID	Sector	IR	Source
Faucet Aerator, Kitchen, 1.5 GPM, Online Store	4910	SF/MF	82%	10
Faucet Aerator, Kitchen, 1.5 GPM, Pop-Up Retail	5311	Pop-Up	42%	12
Faucet Aerator, Kitchen, 1.5 GPM, Pack-based	5312	SF/MF	55%	11
Faucet Aerator, Bath, 1.0 GPM, Pack-based	3863	SF/MF	55%	11
Faucet Aerator, Bath, 1.0 GPM, Online Store	4909	SF/MF	82%	10
Faucet Aerator, Bath, 1.0 GPM, Online Store LTO	5047	SF/MF	82%	10
Faucet Aerator, Bath, 1.0 GPM, Pop-Up Retail	5313	Pop-Up	40%	12
Showerhead, Upgraded, 1.5 GPM, Pack-based	4273	SF	72%	11
	4273	MF	66%	11
Showerhead, Handheld, 1.5 GPM, Pack-based	4274	SF	73%	11
	4274	MF	58%	11
Showerhead, Upgraded, 1.5 GPM, Online Store	4911	SF/MF	85%	10
Showerhead, Handheld, 1.5 GPM, Online Store	5043	SF/MF	85%	10
Showerhead, Upgraded, 1.5 GPM, Online Store LTO	5048	SF/MF	85%	10
Showerhead, Handheld, 1.5 GPM, Pop-Up Retail	5314	Pop-Up	55%	12
Showerhead, Upgraded, 1.5 GPM, Pop-Up Retail	5315	Pop-Up	55%	12

DF = Drain factor (= 0.75 for kitchen aerators, = 0.90 for bathroom aerators, = 1.0 for showerheads; see Assumptions)

SPD = Showers per person per day (= 0.6)[5]

SLU = Shower length of use (= 7.8 minutes per shower)[5]

Summer Coincident Peak Savings Algorithm

Aerators

$kW_{SAVED} = kWh_{SAVED} * CF / (PH * LU * 365 / 60 / FH)$

$CF = \%Peak_{AERATOR} * LU / 180$

Showerheads

$kW_{SAVED} = kWh_{SAVED} * CF / (PH * SPD * SLU * 365 / 60 / FH)$

$CF = \%Peak_{SHOWER} * SLU * SPD / 180$

Where:

kWh_{SAVED} = Calculated savings per faucet

CF = Coincidence factor (= 0.0033 for kitchen aerators, = 0.0012 for bathroom aerators, = 0.0023 for showerheads)

60 = Conversion from minutes to hours

$\%Peak_{AERATOR}$ = Amount of time faucet aerator is used during peak period (= 13%)[13]

180 = Number of minutes during peak period

$\%Peak_{SHOWER}$ = Amount of time shower is used during peak period (= 9%)[13]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings and Costs

Deemed Savings

Description	MMIDs	Sector	Water Savings	Annual		kW	Lifecycle	
				kWh	Therms		kWh	Therms
Kitchen Aerators, 1.5 GPM								
Online Store	4910	SF	1,782	38	7.23	0.0018	380	72.3
		MF	1,365	21	5.31	0.0013	210	53.1
Pop-Up Retail	5311	Pop-Up	898	19	3.63	0.0009	190	36.3
Pack-based	5312	SF	1,195	25	4.85	0.0012	250	48.5
		MF	915	14	3.56	0.0009	140	35.6
Bathroom Aerators, 1.0 GPM								
Pack-based	3863	SF	429	7.50	1.44	0.0007	75	14.4
		MF	468	5.86	1.51	0.0005	59	15.1
Online Store, Online Store LTO	4909, 5047	SF	639	11	2.15	0.0011	110	21.5
		MF	698	8.74	2.25	0.0008	87	22.5
Pop-Up Retail	5313	MF	314	5.37	1.05	0.0005	54	10.5
Showerheads, 1.5 GPM								
Upgraded, Pack-based	4273	SF	2,066	52	10	0.0026	523	100
		MF	2,176	39	10	0.0017	390	100
Handheld, Pack-based	4274	SF	2,095	53	10	0.0026	530	100
		MF	1,912	35	8.89	0.0015	350	88.9
Upgraded, Online Store Handheld, Online Store Upgraded, Online Store LTO	4911, 5043, 5048	SF	2,439	62	12	0.0030	620	120
		MF	2,802	51	13	0.0022	510	130
Handheld, Pop-Up Retail Upgraded, Pop-Up Retail	5314, 5315	Pop-Up	1,595	39	7.72	0.0018	390	77.2

Incremental Costs

Costs for Aerator and Showerhead Measures[2]

Description	MMIDs	Cost
Kitchen Aerators, 1.5 GPM		
Online Store	4910	$5.00
Retail	5311	$3.50
Pack-based	5312	$1.96
Bathroom Aerators, 1.0 GPM		
Pack-based	3863	$0.86
Online Store	4909	$1.25
Online Store LTO	5047	
Retail	5313	$1.25
Showerheads, 1.5 GPM		
Upgraded, Pack-based	4273	$5.91
Handheld, Pack-based	4274	$14.96
Upgraded, Online Store	4911	$7.00
Handheld, Online Store	5043	$19.00
Handheld, Pop-Up Retail	5314	$15.00
Upgraded, Online Store LTO	5048	$7.00
Upgraded, Pop-Up Retail	5315	$6.00

Assumptions

The peak percentage values of 9% and 13% for showerheads and aerators, respectively, were determined from Figure 2 of a study conducted by Aquacraft, Inc.[13] The peak values are from the 1 p.m. to 4 p.m. time period.

Two programs have independently applied drain factors. First, the Illinois TRM[3] uses values of 75% for kitchen usage and 90% for bathroom usage. These values were agreed to by the Illinois Technical Advisory Group, as no studies of drain factor are known. Second, the Ontario Energy Board[4] uses values of 50% for bathrooms and 70% for kitchens, citing a study from 2008. Because the citation used by the Ontario Energy Board to produce these numbers cannot be found, and because the Illinois TRM values are more recent and for a region that likely more closely reflects Wisconsin, the Illinois TRM values are used.

Energy Factors

Based on six units observed as part of the *2016 Potential Study,*[7] the average EF for single family electric water heaters is 94%. Based on 40 units observed from the same study, the average EF for single family natural gas water heaters is 61%.

Ninety-two multifamily sites were visited as part of the *2016 Potential Study.*[7] Of these, three sites with central electric DHW and recorded EF show an average EF of 91%, and 13 sites with in-unit DHW and recorded EF show an average EF of 93%. Overall, 70% of sites had central DHW, so the weighted average electric EF is 92%. Similarly, nine sites with central natural gas domestic hot water and recorded EF show an average EF of 82%. Two sites with in-unit natural gas DHW and recorded EF show an average EF of 59%. Therefore, the average natural gas EF is 75%.

Fuel Splits

All measures claim both natural gas and electric savings. For single family homes, these are weighted at 73% and 20%, respectively, based on water heater data from 104 sites audited as part of the *2016 Potential Study*[7] (7% of single family homes had propane water heaters).

Ninety-two multifamily sites were visited as part of the *2016 Potential Study*[7] and the water heater fuel type was recorded at many of these sites. Of these, 27 sites had known central water heater fuel types, with 15% being electric and 85% being natural gas. Twenty-three sites had known in-unit water heater fuel types, with 13% being electric and 87% being natural gas. Of the 92 sites visited, 70% had central water heaters and 30% had in-unit water heaters. Therefore, 86% of multifamily sites had natural gas hot water and 14% had electric hot water.

Pop-Up Retail Sector Split

For Pop-Up Retail measures, savings are weighted by approximate single family / multifamily participant counts, from 2020 program year Pop-Up Retail Survey results. Nine out of 120 respondents (7.5%) receiving an Energy and Water Savings Kit (containing showerheads, aerators, bulbs, pipe wrap, and a DHW turndown card) were multifamily participants. Nine out of 147 respondents receiving an LED Starter Kit, containing omnidirectional bulbs and a desk lamp, were multifamily participants. A rounded value of 7% is applied for these types of Pop-Up Retail measures, including TSVs.

Sources

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Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2015	Added measures/flow rates
03	11/2016	Added measures/flow rates
04	12/2017	Added measures/flow rates and updated per *Potential Study* results
05	04/2018	Added multifamily savings for pack-based measures
06	09/2018	Added drain factors, per 2018 Deemed Savings memo
07	01/2021	Added retail and online store measures
08	08/2021	Updated installation rates and costs, and added retail pop-up MMIDs

CADMUS

Showerhead Thermostatic Shut-off Valves

	Measure Details
Measure Master ID	Thermostatic Shut-Off Valve, Online Store, 5184 Thermostatic Shut-Off Valve, Pop-Up Retail, 5309 Thermostatic Shut-Off Valve with 1.5 GPM Showerhead, Online Store, 5186 Thermostatic Shut-Off Valve with 1.5 GPM Showerhead, Pop-Up Retail, 5310
Workpaper ID	W0268
Measure Unit	Per valve
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Aeration
Sector(s)	Residential- single family, Residential- multifamily, Residential- upstream
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	Varies by measure
Effective Useful Life (years)	10[1]
Measure Incremental Cost ($/unit)	Thermostatic Shut-Off Valve = $29.99 (MMIDs 5184 and 5309)[2] Thermostatic Shut-Off Valve with 1.5 GPM Showerhead = $39.99 (MMIDs 5186 and 5310)[2]

Measure Description

This measure is installing a temperature shut-off valve (TSV) to the existing showerhead or shower arm. The valve reduces the water flow to a trickle once the temperature reaches 95°F, prior to user entering the shower, thereby conserving water and saving energy required for water heating. The measure can also be installed in combination with a low-flow showerhead.

Description of Baseline Condition

The baseline condition is an existing showerhead without a TSV installed.

Description of Efficient Condition

The efficient condition is a temperature shut-off valve (TSV) on a residential showerhead or shower arm.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Gallons_{SAVED} * 8.33 * C * (T_{POINT\ OF\ USE} - T_{ENTERING}) / (EF_{ELECTRIC} * 3{,}412) * \%Elec$

$Therm_{SAVED} = Gallons_{SAVED} * 8.33 * C * (T_{POINT\ OF\ USE} - T_{ENTERING}) / (EF_{GAS} * 100{,}000) * \%Gas$

TSV alone

$$\text{Gallon}_{\text{SAVED}} = \text{GPM}_{\text{STOCK}} * (\text{PH} * \text{SPD} / \text{FH}) * \text{BW} * 365 * \text{IR}_{\text{TSV}}$$

TSV with low-flow showerhead

$$\text{Gallon}_{\text{SAVED}} = (\text{GPM}_{\text{BASE}} - \text{GPM}_{\text{NEW}}) * (\text{PH} * \text{SPD} / \text{FH}) * \text{SLU} * 365 * \text{IR}_{\text{SH}}$$
$$+ \text{GPM}_{\text{NEW}} * (\text{PH} * \text{SPD} / \text{FH}) * \text{BW} * 365 * \text{IR}_{\text{TSV}}$$

Where:

$\text{Gallons}_{\text{SAVED}}$ = First-year water savings in gallons

8.33 = Density of water, lbs/gallon

C = Specific heat of water (= 1 Btu/lb °F)

$\text{T}_{\text{POINT OF USE}}$ = Temperature of water at point of use (= 101°F for showerheads)[3]

$\text{T}_{\text{ENTERING}}$ = Temperature of water entering water heater (= 52.3°F)[4]

$\text{EF}_{\text{ELECTRIC}}$ = Energy factor of electric water heater (= 94% for single family,[5] = 92% for multifamily,[5] see Assumptions)

3,412 = Conversion from Btu to kWh

%Elec = Fraction of sites with electric water heaters (= 20% for single family; = 14% for multifamily, see Assumptions)[5]

EF_{GAS} = Energy factor of natural gas water heater (= 61% for single family;[5] = 75% for multifamily,[5] see Assumptions)

%Gas = Fraction of sites with natural gas water heaters (= 73% for single family; = 86% for multifamily, see Assumptions)[5]

100,000 = Conversion from Btu to therm

$\text{GPM}_{\text{STOCK}}$ = Flow rate of average showerhead installed (= 2.35 GPM)[6]

GPM_{BASE} = Baseline flow rate (= 2.5 GPM for showerheads)[7]

GPM_{NEW} = Efficient flow rate (= 1.5 GPM)

PH = Persons per house (= 2.52 for single family homes, = 1.93 for multifamily units)[8]

SPD = Showers per person per day (= 0.6)[3]

SLU = Shower length of use (= 7.8 minutes per shower)[3]

FH = Fixtures per house (= 1.5 for for single family homes, = 1.0 for multifamily units)[3]

BW = Behavioral waste time in minutes per shower (= 0.89)[9]

365 = Conversion from days to years

IR_{TSV} = Installation rate for thermostatic shut-off valves (= 0.85 for online store and 0.55 for retail pop-up)[11], see Assumptions)

IR_{SH} = Installation rate for showerheads (= 0.85 for online store and 0.55 for retail pop-up)[11]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} * CF / (PH * SPD * SLU * 365 / 60 / FH)$

$CF = \%Peak_{SHOWER} * SLU * SPD / 180$

Where:

kWh_{SAVED} = Calculated savings per faucet

CF = Coincidence factor (= 0.0023)

60 = Conversion from minutes to hours

180 = Number of minutes during peak period

$\%Peak_{SHOWER}$ = Amount of time shower is used during peak period (= 9%)[10]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Deemed Savings by Measure and Sector

Description	MMID	Sector	Water Savings (Gallons)	kW Saved	kWh Saved		Therms Saved	
					Annual	Lifecycle	Annual	Lifecycle
Thermostatic Shut-Off Valve								
Online Store	5184	SF	654	0.0008	17	170	3.18	31.8
		MF	751	0.0006	14	140	3.50	35.0
Retail Pop-Up	5309	Pop-Up	428	0.0005	11	110	2.07	20.7
Thermostatic Shut-Off Valve with 1.5 GPM Showerhead								
Online Store	5186	SF	2,857	0.0035	72	720	14	140
		MF	3,282	0.0025	59	590	15	150
Retail Pop-Up	5310	Pop-Up	1,868	0.0022	46	460	9.04	90.4

Assumptions

The installation rate for retail pop-up combination measure of showerhead and thermostatic shut-off valve together is based off of the 2020 retail participant survey results for the showerhead measure.

The peak percentage values of 9% and 13% for showerheads and aerators, respectively, were determined from Figure 2 of a study conducted by Aquacraft, Inc.[10] The peak values are from the 1 p.m. to 4 p.m. time period.

Energy Factors

Based on six units observed as part of the *2016 Potential Study,*[5] the average EF for single family electric water heaters is 94%. Based on 40 units observed from the same study, the average EF for single family natural gas water heaters is 61%.

Ninety-two multifamily sites were visited as part of the *2016 Potential Study.*[5] Of these, three sites with central electric DHW and recorded EF show an average EF of 91%, and 13 sites with in-unit DHW and recorded EF show an average EF of 93%. Overall, 70% of sites had central DHW, so the weighted average electric EF is 92%. Similarly, nine sites with central natural gas domestic hot water and recorded EF show an average EF of 82%. Two sites with in-unit natural gas DHW and recorded EF show an average EF of 59%. Therefore, the average natural gas EF is 75%.

Fuel Splits

Retail/Online measures claim both natural gas and electric savings. For single family homes, these are weighted at 73% and 20%, respectively, based on water heater data from 104 sites audited as part of the *2016 Potential Study*[4] (7% of single family homes had propane water heaters).

Ninety-two multifamily sites were visited as part of the *2016 Potential Study*[5] and the water heater fuel type was recorded at many of these sites. Of these, 27 sites had known central water heater fuel types, with 15% being electric and 85% being natural gas. Twenty-three sites had known in-unit water heater fuel types, with 13% being electric and 87% being natural gas. Of the 92 sites visited, 70% had central water heaters and 30% had in-unit water heaters. Therefore, 86% of multifamily sites had natural gas hot water and 14% had electric hot water.

Pop-Up Retail Sector Split

For Pop-Up Retail measures, savings are weighted by approximate single family / multifamily participant counts, from 2020 program year Pop-Up Retail Survey results. Nine out of 120 respondents (7.5%) receiving an Energy and Water Savings Kit (containing showerheads, aerators, bulbs, pipe wrap, and a DHW turndown card) were multifamily participants. Nine out of 147 respondents receiving an LED Starter Kit, containing omnidirectional bulbs and a desk lamp, were multifamily participants. A rounded value of 7% is applied for these types of Pop-Up Retail measures, including TSVs.

Sources

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Revision History

Version Number	Date	Description of Change
01	01/2021	Initial TRM entry
02	08/2021	Updated installation rates and added retail pop-up MMID placeholders

DHW Temperature Turndown, Pack-Based

	Measure Details
Measure Master ID	DHW Temperature Turn Down: Pack-based, Blended Natural Gas and Electric, 4271 Pop-Up Retail, 5308
Workpaper ID	W0192
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Controls
Sector(s)	Residential- single family, Residential- multifamily, Residential-upstream
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	Varies by sector
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	Varies by sector
Water Savings (gal/year)	Varies by sector
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	Pack-based = $0.95 (MMID 4271);[9] Pop-Up Retail = $3.00 (MMID 5308)[10]

Measure Description

This measures is one part of a homeowner kit—a card that measures the domestic hot water temperature, where the homeowner is responsible for turning the water heater temperature down to 120°F. The card comes included in packs containing other measures, through the Simple Energy Efficiency and Pop-Up Retail programs.

There are two main effects of hot water storage temperature on energy use. The primary effect is due to standby loss, which increases with hot water temperature. The secondary effect is that hotter stored water affects hot water end uses. This happens in two ways:

1. For batch appliances, such as most clothes washers, more energy is used for hot and warm wash cycles because a fixed number of gallons is drawn for each load. For mixed end uses (showers, sinks, and bathtubs), when the stored water is hotter, less of it is mixed with cold water to achieve the target use temperature. Since most hot water use is mixed temperature, a modest change in the hot water temperature (of 10°F to 20°F) has a relatively small impact on the energy required to heat the delivered hot water.
2. The reduction in standby loss also affects internal gains. For electric hot water, the reduction in internal gains from a temperature turn down results in a slightly smaller cooling load; assuming

that most water heaters in Wisconsin are in basements, and that basements have little or no direct air conditioning, this effect can be ignored. Heating effects are ignored for electric water heaters, assuming a predominance of natural gas heat; however, it should be accounted for at an appropriate efficiency in residences with a heat pump or electric resistance heat.

Description of Baseline Condition

The baseline condition is a residential hot water heater with a temperature setpoint of 125°F.

Description of Efficient Condition

The efficient condition is a residential water heater with a temperature setpoint of 120°F.

Annual Energy-Savings Algorithm

Electric Measures

$kWh_{SAVED} = [(HW_{BASE} + SB_{BASE}) - (HW_{EFF} + SB_{EFF})] * 365 * (1 / 3{,}412) * BR_{ELEC} * IR$

$$HW = \frac{GPD * C_P * (T_{WH}\text{-}T_{ENTERING})}{RE_{ELEC}} * \left[1 - \frac{UA_{ELEC} * (T_{WH}\text{-}T_{ROOM})}{Input_{ELEC}}\right]$$

$SB = UA_{ELEC} * 24 * (T_{WH} - T_{ROOM})$

$$UA_{ELEC} = \left(\frac{1}{EF_{ELEC}} - \frac{1}{RE_{ELEC}}\right) \Big/ \left[67.5 * \left(\frac{24}{Q_{OUT}} - \frac{1}{RE_{ELEC} * Input_{ELEC}}\right)\right]$$

Where:

HW_{BASE} = Baseline hot water energy use

SB_{BASE} = Baseline standby energy use

HW_{EFF} = Efficient hot water energy use

SB_{EFF} = Efficient standy energy use

365 = Number of days per year

3,412 = Conversion from Btu to kilowatt-hours

BR_{ELEC} = Electric blended rate (= 20%)[5]

IR = Installation rate (= 16% for single family and upstream, = 5% for multifamily; see Assumptions)[11]

GPD = Gallons of hot water use per day (= 32.8 for baseline measure, = 34.8 for efficient measure; see Assumptions)

C_P = Heat capacity of water (= 8.33 Btu/gallon/°F)

T_{WH} = Temperature in tank (= 125°F for baseline, = 120°F for efficient)

$T_{ENTERING}$ = Cold water mains temperature (= 52.3°F)[2]

RE_{ELEC} = Water heater recovery efficiency (= 0.98)[3]

UA_{ELEC} = Electric water heater equivalent heat loss factor (= 1.24 Btu/hr-°F)

T_{ROOM} = Ambient temperature surrounding tank (= 65°F; see Assumptions)

$Input_{ELEC}$ = Firing rate (= 15,354 Btu/hr; see Assumptions)[4]

24 = Number of hours per day

EF_{ELEC} = Energy factor (= 0.94)[5]

67.5 = Temperature difference during 24-hour test (see Assumptions)[4]

Q_{OUT} = Energy content of water drawn from water heater during 24-hour test (= 41,094 Btu/day; see Assumptions)[4]

Therm Measures

$Therm_{SAVED} = [(HW_{BASE} + SB_{BASE}) – (HW_{EFF} + SB_{EFF})] * 365 * (1 / 100{,}000) * BR_{GAS} * IR$

$HW = GPD * C_P * (T_{WH} – T_{ENTERING}) * 1 / RE_{GAS} * [1 – UA_{GAS} * (T_{WH} – T_{ROOM}/Input_{GAS})]$

$SB = UA_{GAS} * 24 * (T_{WH} – T_{ROOM})$

$$UA_{GAS} = \left(\frac{1}{EF_{GAS}} - \frac{1}{RE_{GAS}}\right) \bigg/ \left[67.5 * \left(\frac{24}{Q_{OUT}} - \frac{1}{RE_{GAS} * Input_{GAS}}\right)\right]$$

Where:

BR_{GAS} = Natural gas blended rate (= 73%)

RE_{GAS} = Water heater recovery efficiency (= 0.76)[3]

UA_{GAS} = Water heater equivalent heat loss factor (= 8.72 Btu/hr-°F)

$Input_{GAS}$ = Firing rate (= 38,000 Btu/hr; see Assumptions)[4]

EF_{GAS} = Energy factor (= 0.61)[5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (kWh_{SAVED} / 8{,}760) * CF$

Where:

8,760 = Number of hours in one year

CF = Coincidence factor (= 1)[12]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 4 years)[1]

Deemed Savings

Annual and Lifecycle Deemed Savings

Measure	MMID	Sector	Annual Savings		Demand Reduction (kW)	Lifecycle Savings	
			kWh	Therms		kWh	Therms
Pack Based	4271	Single family	1.51	0.62	0.0002	6.0	2.4
		Multifamily	0.47	0.19	0.0001	2.0	0.8
Retail Pop-Up	5308	Pop-Up	1.44	0.59	0.0002	5.72	2.3

Assumptions

Both the pack-based measure and pop-up retail event measure is applied to a mix of electric and natural gas water heaters. This mix was derived from the *2016 Potential Study for Focus on Energy* and is 73% natural gas, 20% electric, and 7% propane water heaters.[5]

Participant survey results[11] from the Focus on Energy 2020 Packs program evaluation revealed an installation rate of 16% for this measure. Of the 312 single family respondents, 151 (48%) said they had used the card to check their water temperature, and 49 (16%) said they had actually reduced their water temperature as a result of using the card.

These results are assumed to reflect the single family sector. Multifamily participants who receive turndown cards have sufficiently similar installation rates and so also use the 16% single family installation rate. However, potential study data indicates that only 30% of multifamily participants will have access to their water heater. Therefore, the multifamily installation rate is deemed to be 30% * 16% = 5%. This assumption may be revisited in future.

The gallons per day assumptions were as follows:

- Gallons per day were calculated by fitting a polynomial equation to data from Table 3 of the Florida Solar Energy Center study.[6] An average value of 2.43 occupants per home was used for Wisconsin, based on U.S. Census data.[7] The fitted equation is GPD = $-0.0089 * x^2 + 16.277 * x + 3.25$, where “x” is the average number of occupants per home. With x at 2.43, GPD is 42.8.
- Hot water use is broken into two components. Unmixed use, primarily for clothes washers and dishwashers, is direct draw from the water heater and does not vary with stored hot water temperature. Mixed use, for showers and sinks, is delivered to the fixture at 105°F, so the total draw from the water heater varies with stored water temperature. Table 3 from the Florida Solar Energy Center study[6] also displays washer use as a function of household size. A fitted

equation of GPD = 0.0071 * x^2 + 1.2729 * x + 3.42 produces an unmixed GPD of 6.6 gallons, and therefore a mixed GPD of 36.2 gallons.

- As the setpoint temperature goes down, the hot water consumption at the tank goes up. As the stored temperature is reduced, more hot and less cold must be mixed to reach the target of 105°F at the showerhead or sink. Therefore, the water heater draw is given as:
  - GPD_{BASE} = 6.6 + 36.2 * (105 - 52.3) / (125 - 52.3) = 32.8 GPD
  - GPD_{EFF} = 6.6 + 36.2 * (105 - 52.3) / (120 - 52.3) = 34.8 GPD

The home is assumed to be maintained at 65°F.

The derivation of heat loss factor (UA) comes from the U.S. Department of Energy test procedures for consumer and commercial water heaters.[8]

Some algorithm inputs were derived from the Home Energy Saver engineering documentation from the Lawrence Berkeley National Laboratory website:[4]

- $Input_{ELEC}$ is from the “User Inputs to the Water Heater Model” heading. This page shows that the rated input for electric water heaters is 4.5 kW, which is the equivalent of 15,354 Btu/hr. $Input_{GAS}$ is from the same page, which shows 38,000 Btu/hr.
- Q_{OUT} can be found under the “Standby Heat Loss Coefficient” heading, which shows that 41,094 Btu/day is drawn during the standard test.

Also under the “Standby Heat Loss Coefficient” heading, a temperature difference of 67.5°F is used. This reflects a test hot water temperature of 135°F and a room temperature of 67.5°F.

Pop-Up Retail Sector Split

For Pop-Up Retail measures, savings are weighted by approximate single family / multifamily participant counts, from 2020 program year Pop-Up Retail Survey results. Nine out of 120 respondents (7.5%) receiving an Energy and Water Savings Kit (containing showerheads, aerators, bulbs, pipe wrap, and a DHW turndown card) were multifamily participants. Nine out of 147 respondents receiving an LED Starter Kit, containing omnidirectional bulbs and a desk lamp, were multifamily participants. A rounded value of 7% is applied for these types of Pop-Up Retail measures, including DHWs.

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9. The pack-based domestic hot water turndown card is included in a free pack with other measures. The incremental cost is therefore the full bulk pricing cost of the card to Focus on Energy, or $0.95.
10. The Pop-Up Retail domestic hot water turndown card is included in a kit with other retail measures. The incremental cost is therefore the full bulk pricing cost of the card to Focus on Energy, or $3.00.
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Revision History

Version Number	Date	Description of Change
01	01/01/2012	Initial TRM entry
02	03/09/2013	Updated to new template and added lifecycle savings
03	04/22/2013	Revised and added comments
04	12/15/2013	Added multifamily sector and larger domestic hot water heater savings
05	10/16/2016	Removed MMIDs 2125 and 2131
06	03/19/2018	Added pack-based MMID
07	01/2021	Added pop-up retail MMID
08	08/2021	Updated installation rates and EUL, cost,

Pipe Insulation

	Measure Details
Measure Master ID	Insulation, DHW Pipe, Pack-based, 4272 Insulation, DHW Pipe, Pop-Up Retail, 5319
Workpaper ID	W0193
Measure Unit	Per kit
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Insulation
Sector(s)	Residential- multifamily, Residential- single family
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Electricity Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Pack-based = $3.67 (MMID 4272)[2] Pop-Up Retail = $6.00 (MMID 5319)[9]

Measure Description

Pipes are often uninsulated because the original insulation was damaged, the original insulation was removed (for example, as part of an asbestos abatement program) and never replaced, or the new pipe was installed but the insulation job was not completed. Insulating pipes reduces heat losses to unheated building areas and decreases problems with overheating in areas with uninsulated pipe.

This workpaper documents pipe insulation that is sent directly to customers via a Focus on Energy pack, in which customers install the pipe insulation on their own. While multifamily prescriptive insulation measures (MMIDs 3689–3692, 3699–3702, and 3755–3758) must be installed in unconditioned spaces, these pack-based measures may or may not be installed in conditioned spaces, such as when a water heater and its nearby piping are in a finished section of a home. In these cases, HVAC interactive factors must be considered.

The “Pack-based” measure comes in packs as part of the Simple Energy Efficiency Solution, and the “Pop-Up Retail” measure comes in packs as part of the Pop-Up Retail program.

Description of Baseline Condition

The baseline condition is piping for a space heating hot water system, steam loop system, or domestic hot water system with no insulation. Domestic hot water piping is assumed to be copper and space heating piping is assumed to be either copper or steel.

Description of Efficient Condition

Pack-based and upstream kits include a 15-foot long, 2-inch wide roll of R-2 foam insulation[3] for use with domestic hot water systems only. Each roll can insulate approximately nine linear feet of pipe. Pack-based insulation is delivered as part of a free pack. Upstream insulation is delivered as part of a discounted pack.

Annual Energy-Savings Algorithm

Electric Savings

$kWh_{SAVED} = (kWh_{UNCOND} * \%Uncond + kWh_{COND} * \%Cond) * ISR$

$kWh_{UNCOND} = Insul * Length * HOU / (EF_{ELEC} * 3{,}412) * f_{ELEC}$

$kWh_{COND} = kWh_{UNCOND} – kWh_{HEAT} + kWh_{COOL}$

Where:

kWh_{UNCOND} = Kilowatt-hours saved for insulation installed in unconditioned space, averaged across HVAC system splits (= 72.8 kWh for single family, = 52.1 kWh for multifamily; calculated values)

%Uncond = Fraction of insulation installed in unconditioned space (= 19% for single family,[4] = 0% for multifamily; see Assumptions)

kWh_{COND} = Kilowatt-hours saved for insulation installed in conditioned space, averaged across HVAC system splits (= 88.6 kWh for single family, = 21.3 kWh for multifamily; calculated values)

%Cond = Fraction of insulation installed in conditioned space (= 81% for single family, = 100% for multifamily; see Assumptions)[4]

ISR = Installation rate for insulation (= 35% for single family Pack-based, = 27% for multifamily Pack-based, = 25% for Pop-Up Retail)[5]

Insul = Hot water heat loss prevented by installing pipe insulation (= 14.81 Btuh/ft; see Assumptions)[6]

Length = Length of pipe covered by wrap (= 9 feet)

HOU = Hours of use (= 8,760)

EF_{ELEC} = Energy factor of electric water heater (= 94% for single family, = 92% for multifamily)[4]

3,412 = Conversion factor for kilowatt-hours per Btu

f_{ELEC} = Fraction of sites receiving insulation packs with electric hot water heating (= 20% for single family, = 14% for multifamily)[4]

kWh_{HEAT} = Heating kilowatt-hours reduced by pipe heat losses in conditioned space for an average pack (= 4.10 kWh for single family, = 35.96 kWh for multifamily; see Assumptions)

kWh_{COOL} = Cooling kilowatt-hours increased by pipe heat losses in conditioned space for an average pack (= 19.85 kWh for single family, = 5.21 kWh for multifamily; see Assumptions)

Natural Gas Savings

$Therms_{SAVED} = (Therms_{UNCOND} * \%Uncond + Therms_{COND} * \%Cond) * ISR$

$Therms_{UNCOND} = Insul * Length * HOU / (EF_{GAS} * 100{,}000) * f_{GAS}$

$Therms_{COND} = Therms_{UNCOND} – Therms_{HEAT}$

Where:

$Therms_{UNCOND}$ = Therms saved for insulation installed in unconditioned space, averaged across HVAC system splits (= 14.0 therms for single family, = 13.4 therms for multifamily; calculated values)

$Therms_{COND}$ = Therms saved for insulation installed in conditioned space, averaged across HVAC system splits (= 8.6 therms for single family, = 8.1 therms for multifamily; calculated values)

EF_{GAS} = Energy factor of natural gas water heater (= 61% for single family, = 75% for multifamily)[4]

100,000 = Conversion factor for Btu per therm

f_{GAS} = Fraction of sites receiving insulation packs with natural gas hot water heating (= 73% for single family, = 86% for multifamily)[4]

$Therms_{HEAT}$ = Heating therms reduced by pipe heat losses in conditioned space for an average pack (= 5.41 therms for single family, = 5.313 therms for multifamily; see Assumptions)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (kW_{UNCOND} * \%Uncond + kW_{COND} * \%Cond) * ISR$

$kW_{UNCOND} = kWh_{UNCOND} / 8{,}760$

$kW_{COND} = kW_{UNCOND} + kW_{COOL}$

$kW_{COOL} = kWh_{COOL} * CF / (8{,}760 * \%Cool)$

Where:

CF = Coincidence factor (= 100%)[7]

%Cool = Portion of constant pipe heat loss that goes to increasing cooling needed (= 27%; see Assumptions)

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therms_{SAVED} * EUL$

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Deemed Savings for Natural Gas and Electricity

Measure	MMID	Sector	kW	Annual		Lifecycle		Incremental Cost
				kWh	therms	kWh	therms	
Insulation, DHW Pipe, Pack-Based	4272	Single Family	0.0064	36	4.04	540	60.6	$2.43
		Multifamily	0.0026	6.94	2.63	104.1	39.5	$2.43
		Pop-Up	0.0044	24	2.86	369	42.9	$6.00

Assumptions

The heat loss per foot of pipe insulation installed was calculated using CheCalc[6] and the following assumptions:

- Pipe diameters of 0.5-inch and 0.75-inches were modeled, and the average results of the two were used
- Hot water temperature = 125°F
- Ambient temperature = 65°F
- Wind = 0

- Insulation is elastomeric
- Surface emissivity = 0.04 (aluminum, new, bright)
- Thickness = 0.125 inches

The resulting loss factor for bare pipe was 31.68 Btuh/ft, and the resulting loss factor for insulated pipe was 13.84 Btuh/ft, for a difference of 17.84 Btuh/ft.

Savings calculations assume that for insulation installed in an unconditioned space, the energy savings comes completely from the pipe losses and resultant extra consumption at the water heater. For insulation installed in a conditioned space, these energy savings are still in place, but heat loss in the winter produces decreased heating requirements (which reduces overall savings) and heat loss in the summer produces increased cooling requirements (which increases overall savings). Savings for installing in both unconditioned and conditioned spaces is calculated, and the final savings is a weighted average of these two.

For installations in a conditioned space, it is assumed that 49% of pipe heat losses go toward reducing heating requirements, and 27% go toward increasing cooling requirements.[8] Therefore, the total therms of heating reduced per pack installed in a conditioned space is Insul * Length * HOU * 49% / 100,000 = 5.721 therms, and the total therms of cooling increased per pack installed in a conditioned space is Insul * Length * HOU * 27% / 100,000 = 3.153 therms.

Single Family Assumptions

The 2016 Focus on Energy Potential Study[4] revealed that 19% of single family water heaters were installed in unconditioned spaces. It is assumed that 19% of delivered pipe insulation will also be installed in unconditioned spaces, and 81% will be installed in conditioned spaces.

The value for heating therms reduced (5.721) is combined with HVAC system population splits and efficiencies shown in the table below to produce single family kWh_{HEAT} and $Therms_{HEAT}$, which are the population-averaged reduced heating needs for a pack of insulation installed.

For example, the “Input Therms Reduced” for homes with a natural gas furnace is (5.721 / 91.4%), or 6.260 therms. This means that since the average home with a natural gas furnace is assumed to have a furnace that is 91.4% efficient and the heating requirements for the home are assumed to be reduced by 5.721 therms per year when insulation is installed in conditioned space, the therm consumption of the home is assumed to be reduced by 6.26 therms.

A similar calculation is conducted for homes with a boiler, producing a reduced therm consumption of 6.977 for those homes. These two values are combined with the HVAC system population fractions to produce the average input therms reduced for an installed pack, which is ($Therms_{HEAT}$ = 82% * 6.260 + 4% * 6.977), or 5.412 therms. Similar algorithms are also applied to produce the “Input kWh Reduced.”

Weighted Average Heating Input Reduced, Single Family

Primary Heating System	Population Fraction*	Average Efficiency	Average Efficiency Source	Input Therms Reduced**	Input kWh Reduced**
Natural gas furnace	82%	91.4%	Potential Study[4]	6.260	0.000
Propane furnace	7%	N/A	N/A	0.000	0.000
Wood stove	5%	N/A	N/A	0.000	0.000
Natural gas boiler	4%	82%	Federal standard	6.977	0.000
Electric baseboard	2%	3.412 HSPF	Conversion	0.000	167.680
Heat pump	1%	7.7 HSPF	Federal standard	0.000	74.300
Weighted Average Heating Input Reduced***				**5.412**	**4.100**

* This data comes from the 2016 Focus on Energy Potential Study.[4]

** These represent kWh_{HEAT} and $Therms_{HEAT}$ divided by the system efficiency.

*** This represents the sum of the population fraction and input heating reduced.

Similarly, the value for cooling therms increased is combined with HVAC system population splits and efficiencies shown in the table below to produce kWh_{COOL}. For instance, the assumed value for the "Input kWh Increased" for homes with a central air conditioner is (3.153 therms) * (100 Btu per them) / (12.1 Btu / kWh) = 26.05 kWh. A similar calculation is conducted for heat pumps, and their assumed values for the "Input kWh Increased" are combined with population splits to produce kWh_{COOL} = 75% * 26.05 + 1% * 30.091 = 19.85 kWh.

Note that it is assumed that room air conditioners are not installed in the same room as the pipe insulation, so heat losses through the piping do not contribute to increased cooling needs.

Weighted Average Cooling Input Increased, Single Family

Primary Cooling System	Population Fraction*	Average Efficiency	Average Efficiency Source	Input kWh Increased**
Central air conditioner	75%	12.1 SEER	Potential Study[4]	26.050
Room air conditioner	19%	10.2 SEER	Potential Study[4]	0.000
Heat pump	1%	8.4 SEER	Federal standard	30.091
Weighted Average Heating Input Reduced***				**19.850**

* This data comes from the 2016 Focus on Energy Potential Study.[4]

** This represent kWh_{HEAT} and $Therms_{HEAT}$ divided by the system efficiency.

*** This represents the sum of the population fraction and input heating reduced.

Multifamily Assumptions

Multifamily packs are delivered directly to residents, and not to building owners or managers. Therefore, savings are reliant on participants having access to the piping around their hot water heater. Potential study data indicates that 30% of multifamily water heaters are in-unit. It is deemed that half of these residents do not have access to the piping around their water heater. It is also assumed that 40% of these participants would install the insulation (similar to the single family ISR). Therefore, the multifamily installation rate is deemed to be 30% * 50% * 40% = 6%. It is assumed that 100% of this insulation is installed in conditioned space.

The value for heating therms reduced, combined with HVAC system population splits and efficiencies shown in the tables below, produces the multifamily kWh_{HEAT}, $Therms_{HEAT}$, and kWh_{COOL}, which are the population-averaged reduced heating needs and increased cooling needs for a pack of insulation installed. Note that the multifamily value for kWh_{HEAT} of 35.956 is significantly higher than the single family value; this is because of the higher population fraction for electric heat at multifamily sites.

Weighted Average Heating Input Reduced, Multifamily

Primary Heating System	Population Fraction*	Average Efficiency	Average Efficiency Source	Input Therms Reduced**	Input kWh Reduced**
Natural gas furnace	24%	84%	Potential Study[4]	6.811	0.000
Natural gas boiler	54%	84%	Federal standard	6.811	0.000
Electric baseboard	21%	3.412 HSPF	Conversion	0.000	167.680
Heat pump	1%	7.7 HSPF	Federal standard	0.000	74.300
Weighted Average Heating Input Reduced***				**5.313**	**35.956**

* This data comes from the 2016 Focus on Energy Potential Study.[4]

** These represent kWh_{HEAT} and $Therms_{HEAT}$ divided by the system efficiency.

*** This represents the sum of the population fraction and input heating reduced.

Weighted Average Cooling Input Increased, Multifamily

Primary Cooling System	Population Fraction*	Average Efficiency	Average Efficiency Source	Input kWh Increased**
Central air conditioner	75%	12.1 SEER	Potential Study[4]	26.050
Room air conditioner	19%	10.2 SEER	Potential Study[4]	0.000
Heat pump	1%	8.4 SEER	Federal standard	30.091
Weighted Average Heating Input Reduced***				**5.412**

* This data comes from the 2016 Focus on Energy Potential Study.[4]

** This represent kWh_{HEAT} and $Therms_{HEAT}$ divided by the system efficiency.

*** This represents the sum of the population fraction and input heating reduced.

Note that data for HVAC system splits and efficiencies was sometimes sparse for multifamily sites—the average natural gas and electric hot water efficiencies are based on data obtained from just 11 and 16 units. However, savings for multifamily packs is largely driven by the installation rate, followed by the electric and natural gas hot water fuel splits (based on a 50-site sample). Hot water and HVAC efficiencies play a relatively minor role in savings amount.

Pop-Up Retail Sector Split

For Pop-Up Retail measures, savings are weighted by approximate single family / multifamily participant counts, from 2020 program year Pop-Up Retail Survey results. Nine out of 120 respondents (7.5%) receiving an Energy and Water Savings Kit (containing showerheads, aerators, bulbs, pipe wrap, and a DHW turndown card) were multifamily participants. Nine out of 147 respondents receiving an LED Starter Kit, containing omnidirectional bulbs and a desk lamp, were multifamily participants. A rounded value of 7% is applied for these types of Pop-Up Retail measures.

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, Pipe Wrap. 2007. https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf
2. Pack-based pipe insulation is included in a free pack with other measures. The incremental cost is the full bulk pricing cost of the insulation to Focus on Energy, $3.67.
3. Grainger. “FROST KING Foam and Foil Pipe Insulation Wrap.” Accessed March 2018. https://www.grainger.com/product/FROST-KING-1-8-x-2-x-15-ft-Foam-and-Foil-48H494
4. Cadmus. *2016 Potential Study for Focus on Energy.* Data maintained by Cadmus and Wisconsin Public Service Commission.
   Data includes information 120 single family sites and 92 multifamily units.
5. *Cadmus. Focus on Energy Calendar Year 2020 Evaluation Report Volume II.* Table 13 and Table 20. *May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf*
6. CheCalc. “Insulation Heat Loss Calculation.” Accessed March 2018. https://checalc.com/calc/inshoriz.html
7. This measure assumes a flat loadshape since savings relate to reducing standby losses and as such the coincidence factor is 1.
8. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0. Volume 3: Residential Measures*. p. 168. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Effective_060116_v5.0_Vol_3_Res_021116_Final.pdf
   For the waste heat cooling savings factor, REM Rate determined the percentage of lighting savings that result in reduced cooling loads (27%) and increased heating loads (49%). Lighting is used as a proxy for hot water heating since load shapes suggest that their seasonal usage patterns are similar.
9. Pop-Up Retail pipe insulation is included in a kit with other Pop-Up Retail measures. The incremental cost is the full bulk pricing cost of the insulation to Focus on Energy, $6.00.

10. *Cadmus. Focus on Energy Calendar Year 2020 Evaluation Report Volume II. p. 14 and p. 22. May 21, 2021.* *https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf*

Revision History

Version Number	Date	Description of Change
01	08/2018	Initial TRM entry
02	08/2021	Updated installation rates and costs, changed to pop-up retail MMID

Pipe Insulation, Multifamily

	Measure Details
Measure Master ID	Insulation, Piping: Hot Water Space Heating: 0.5” and 0.75” Pipe, NG, 3685; Elec, 3689 1” and 1.25” Pipe, NG, 3686; Elec, 3690 1.5” and 2” Pipe, NG, 3687; Elec, 3691 3” and 4” Pipe, NG, 3688; Elec, 3692 Steam Space Heating: 0.5” and 0.75” Pipe, NG, 3751; Elec, 3755 1” and 1.25” Pipe, NG, 3752; Elec, 3756 1.5” and 2” Pipe, NG, 3753; Elec, 3757 3” and 4” Pipe, NG, 3754; Elec, 3758 Domestic Hot Water: 0.5” and 0.75” Pipe, NG, 3695; Elec, 3699 1” and 1.25” Pipe, NG, 3696; Elec, 3700 1.5” and 2” Pipe, NG, 3697; Elec, 3701 3” and 4” Pipe, NG, 3698; Elec, 3702
Workpaper ID	W0194
Measure Unit	Per linear foot of piping
Measure Type	Prescriptive
Measure Group	Boilers & Burners
Measure Category	Insulation
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/yr)	0
Effective Useful Life (years)	15[1]
Incremental Cost	Varies by measure[2]

Measure Description

Pipes are often uninsulated because the original insulation was damaged or removed, the original insulation was removed as part of an asbestos abatement program and never replaced, or the new pipe was installed but the insulation job was not completed. Insulating pipes reduces heat losses to unheated building areas and decreases problems with overheating in areas with uninsulated pipe. Piping is in an unconditioned space, likely a basement or mechanical room.

Description of Baseline Condition

The baseline condition is piping for a space heating hot water system, steam loop system, or domestic hot water system with no insulation. Domestic hot water piping is assumed to be copper, while space heating piping is assumed to be either copper or steel.

Description of Efficient Condition

The efficient condition is piping insulated with fiberglass insulation, K-value 0.27 Btu-in/hr-ft^2-°F, which is approximately R-5 for 1.5-inch thickness, R-3.5 for 1.0-inch thickness, and R-2 for 0.5-inch thickness. Foam insulation, K-value 0.30 Btu-in/hr-ft^2-°F, is also acceptable for domestic hot water systems. There are also specific requirements by system type:

- Hot water space heating systems must have 1.0-inch thick insulation for 3-inch and smaller pipe
- Hot water space heating systems must have 1.5-inch thick insulation for greater than 3-inch pipe
- Steam space heating systems must have 1.5-inch thick insulation
- Domestic hot water systems must have at least 0.5-inch thick insulation for less than 2-inch pipe
- Domestic hot water systems must have at least 1.0-inch thick insulation for 2-inch and larger pipe

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Insul_{SAVINGS} * Length * HOU / (TE * 3,412)$

$Therms_{SAVED} = Insul_{SAVINGS} * Length * HOU / (TE * 100,000)$

Where:

$Insul_{SAVINGS}$ = Energy savings through insulating nominal pipe sizes (see Insulation Savings Space Heating tables)

Length = Length of insulated pipe in feet (= 1 foot)

HOU = Annual hours of operation (= 4,000 for space heat; = 8,760 for domestic hot water; see Assumptions)

TE = Thermal efficiency (= 0.75 for natural gas; = 0.92 for electric)[3]

3,412 = Conversion from Btu to kilowatt-hours

100,000 = Conversion from Btu to therms

Insulation Savings Space Heating Hot Water Pipe[4]

Pipe Outside Diameter (in)	Insulation Thickness (in)	Copper Pipe	Steel Pipe	Heat Loss, Btu/hour-linear foot		
				Bare Pipe	Insulated Pipe	Insul$_{SAVINGS}$
0.5	1.0	50.0%	50.0%	60.36	11.94	48.42
0.75	1.0	50.0%	50.0%	73.18	14.37	58.81
1	1.0	50.0%	50.0%	89.13	14.92	74.21
1.25	1.0	50.0%	50.0%	109.65	19.21	90.44
1.5	1.0	50.0%	50.0%	123.85	19.44	104.41
2	1.0	50.0%	50.0%	151.60	22.73	128.87
3	1.0	50.0%	50.0%	216.55	30.94	185.61
4	1.5	50.0%	50.0%	273.70	28.03	245.67

Insulation Savings Space Heating Steam Pipe[4]

Pipe Outside Diameter (in)	Insulation Thickness (in)	Copper Pipe	Steel Pipe	Heat Loss, Btu/hour-linear foot		
				Bare Pipe	Insulated Pipe	Insul$_{SAVINGS}$
0.5	1.5	50.0%	50.0%	93.65	14.49	79.16
0.75	1.5	50.0%	50.0%	113.65	16.79	96.86
1	1.5	50.0%	50.0%	138.60	18.24	120.37
1.25	1.5	50.0%	50.0%	170.75	20.37	150.39
1.5	1.5	50.0%	50.0%	192.90	23.06	169.84
2	1.5	50.0%	50.0%	236.40	26.33	210.07
3	1.5	50.0%	50.0%	338.15	34.81	303.34
4	1.5	50.0%	50.0%	427.70	41.96	385.75

Insulation Savings Domestic Hot Water Pipe[4]

Pipe Outside Diameter (in)	0.5 Inch Insulation	1.0 Inch Insulation	Heat Loss, Btu/hour-linear foot		
			Bare Pipe	Insulated Pipe	Insul$_{SAVINGS}$
0.5	50.0%	50.0%	25.56	8.07	17.50
0.75	50.0%	50.0%	30.88	9.37	21.52
1	50.0%	50.0%	37.48	10.43	27.05
1.25	50.0%	50.0%	45.96	13.08	32.88
1.5	50.0%	50.0%	51.81	14.09	37.72
2	0.0%	100.0%	63.27	12.78	50.49
3	0.0%	100.0%	90.04	17.35	72.69
4	0.0%	100.0%	113.60	20.75	92.85

Summer Coincident Peak Savings Algorithm

To be consistent with single-family residential pipe insulation measures, domestic hot water piping insulation does not have demand savings. Heating hot water and steam piping are only in use during the winter and therefore also have no demand savings.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

$\text{kWh}_{\text{LIFECYCLE}} = \text{kWh}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

The following Deemed Savings tables list the natural gas and electricity deemed savings per linear foot of insulation for the direct install measures.

Deemed Savings, Natural Gas, Per Linear Foot

Measure	MMID	Measure Group	Annual kWh	Annual therms	Lifecycle kWh	Lifecycle therms	Incremental Cost
Hot Water Space Heat							
0.5” and 0.75” Pipe	3685	Space Heating	--	2.86	--	42.9	$9.40
1” and 1.25” Pipe	3686		--	4.39	--	65.9	$9.40
1.5” and 2” Pipe	3687		--	6.22	--	93.3	$9.40
3” and 4” Pipe	3688		--	11.50	--	172.5	$10.53
Steam Space Heat							
0.5” and 0.75” Pipe	3751	Space Heating	--	4.69	--	70.4	$11.65
1” and 1.25” Pipe	3752		--	7.22	--	108.3	$11.65
1.5” and 2” Pipe	3753		--	10.13	--	152.0	$11.65
3” and 4” Pipe	3754		--	18.38	--	275.6	$11.65
Domestic Hot Water							
0.5” and 0.75” Pipe	3695	Domestic Hot Water	--	2.28	--	34.2	$7.15
1” and 1.25” Pipe	3696		--	3.50	--	52.5	$7.15
1.5” and 2” Pipe	3697		--	5.15	--	77.3	$8.28
3” and 4” Pipe	3698		--	9.67	--	145.0	$9.40

Deemed Savings, Electricity, Per Linear Foot

Measure	MMID	Measure Group	Annual kWh	Annual therms	Lifecycle kWh	Lifecycle therms	Incremental Cost[2]
Hot Water Space Heat							
0.5” and 0.75” Pipe	3689	Space Heating	66.9	-	1,003	-	$9.40
1” and 1.25” Pipe	3690		102.7	-	1,540	-	$9.40
1.5” and 2” Pipe	3691		145.5	-	2,182	-	$9.40
3” and 4” Pipe	3692		268.9	-	4,034	-	$10.53
Steam Space Heat							
0.5” and 0.75” Pipe	3755	Space Heating	109.8	-	1,646	-	$11.65
1” and 1.25” Pipe	3756		168.8	-	2,533	-	$11.65
1.5” and 2” Pipe	3757		236.9	-	3,554	-	$11.65
3” and 4” Pipe	3758		429.7	-	6,446	-	$11.65
Domestic Hot Water							
0.5” and 0.75” Pipe	3699	Domestic Hot Water	53.3	-	799	-	$7.15
1” and 1.25” Pipe	3700		81.8	-	1,228	-	$7.15
1.5” and 2” Pipe	3701		120.5	-	1,807	-	$8.28
3” and 4” Pipe	3702		226.1	-	3,391	-	$9.40

Assumptions

For each pair of pipe diameters, the calculations are based on the average insulation savings.

The pipe insulation is being applied to multifamily central heating system supply and return pipes and multifamily domestic hot water piping.

- The heating season is November 1 to April 15, which is 166 days. The 166 days multiplied by 24 hours per day is 3,984 hours, which was rounded to 4,000 to be consistent with the business measure for steam pipe insulation (MMID 2430 in the October 2015 Wisconsin TRM).
- Space heating boiler supplies 180°F hot water, or 5-psi steam.
- Water heater supplies 125°F hot water (consistent with the hot water supply temperature for MMID 2760, domestic hot water plant replacement).
- Piping is in a basement or mechanical room that is unconditioned (assumption for MMID 2128, direct install domestic hot water piping insulation).
- Both copper and steel pipe are used for space heating, so space heating savings assume that 50% of pipe is copper and 50% is steel. All domestic hot water piping is assumed to be copper.

- For smaller pipe sizes that are only required to have 0.5-inch insulation, many installations may elect to use up to 1-inch insulation. Therefore, a 50/50 split of 0.5-inch and 1-inch insulation was assumed in the energy savings calculations.
- Incremental costs[2] are $7.15 per foot for 0.5-inch thick insulation, $9.40/ft for 1.0-inch thick insulation, and $11.65/ft for 1.5-inch thick insulation. When two different insulation thicknesses are used within a single measure (such as for MMIDs 3688, 3697, 3692, and 3701), the corresponding incremental costs are weighted 50/50 to determine the average.

Sources

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Revision History

Version Number	Date	Description of Change
01	01/2016	Initial TRM entry
02	09/2018	Updated efficiencies

Heat Pump Water Heater

	Measure Details
Measure Master ID	Heat Pump Water Heater: 2.0 UEF, 5008 2.6 UEF, 5009
Workpaper ID	W0200
Measure Unit	Per water heater
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Water Heater
Program(s)	Home Performance
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	2.0 UEF = 233 (MMID 5008); 2.6 UEF = 552 (MMID 5009)
Peak Demand Reduction (kW)	2.0 UEF = 0.0110 (MMID 5008); 2.6 UEF = 0.0262 (MMID 5009)
Annual Therm Savings (Therms)	37
Lifecycle Energy Savings (kWh)	2.0 UEF = 3,029 (MMID 5008); 2.6 UEF = 7,176 (MMID 5009)
Lifecycle Therm Savings (Therms)	481
Water Savings (gal/yr)	0
Effective Useful Life (years)	13[1]
Measure Incremental Cost ($/unit)	2.0 UEF = $1,030.00 (MMID 5008); 2.6 UEF = $1,199.00 (MMID 5009)[12]

Measure Description

This measure is the installation of a heat pump domestic hot water heater in place of a standard electric water heater in a residential home. The associated measure characteristics are presented based on the assumption of a natural gas–heated home with electric water heating.

Description of Baseline Condition

The baseline assumption is a UEF of 0.9207. The deemed measure algorithms and associated savings for the heat pump water heater were derived from the *Illinois Statewide Technical Reference Manual*, Section 5.4.3 Heat Pump Water Heaters[2] (except where noted).

Description of Efficient Condition

The efficient condition is a heat pump water heater that is ENERGY STAR certified.

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = \Delta kWh_{ELEC} * Frac_{ELEC} + \Delta kWh_{GAS} * Frac_{GAS} + \Delta kWh_{PROP} * Frac_{PROP}$$

$$Therms_{SAVED} = \Delta Therms_{ELEC} * Frac_{ELEC} + \Delta Therms_{GAS} * Frac_{GAS} + \Delta Therms_{PROP} * Frac_{PROP}$$

Where:

ΔkWh_{ELEC} = Electric savings from replacing electric water heater
$Frac_{ELEC}$ = Fraction of installations replacing electric water heaters (= 47%; see Assumptions)
ΔkWh_{GAS} = Electric savings from replacing natural gas water heater
$Frac_{GAS}$ = Fraction of installations replacing natural gas water heaters (= 46%; see Assumptions)
ΔkWh_{PROP} = Electric savings from replacing propane water heater
$Frac_{PROP}$ = Fraction of installations replacing propane water heaters (= 7%; see Assumptions)
$\Delta Therms_{ELEC}$= Natural gas savings from replacing electric water heater
$\Delta Therms_{GAS}$ = Natural gas savings from replacing natural gas water heater
$\Delta Therms_{PROP}$ = Natural gas savings from replacing propane water heater

Electric Water Heater Replacement

$$\Delta kWh_{ELEC} = \frac{GPD * 365 * 8.33 * \Delta T * C_P}{3{,}412} * \left(\frac{1}{UEF_{BASE,ELEC}} - \frac{1}{UEF_{EFF}}\right) + kWh_{COOL}$$

$$kWh_{COOL} = \frac{GPD * 365 * 8.33 * \Delta T * C_P}{3{,}412} * \frac{LF * 27\%}{COP_{COOL}} * LM * \%AC$$

$\Delta Therms_{ELEC} = \Delta Therms_{HEAT}$

$$\Delta Therms_{HEAT} = -\frac{GPD * 365 * 8.33 * \Delta T * C_P}{100{,}000} * \frac{LF * 49\%}{EFF_{HEAT}} * Frac_{NGHEAT}$$

Where:

GPD = Gallons per day (= 42.75, see Assumptions)[5,6]
365 = Number of days per year
8.33 = Specific weight of water (lb/gallon)
ΔT = Average difference between cold water inlet temperatures (52.3°F)[7] and hot water delivery temperature (125°F)[8] (= 72.7°F)
C_P = Specific heat of water (= 1.0 Btu/(lb * ◦F))
3,412 = Btu to kilowatt-hour conversion factor
$UEF_{BASE,ELEC}$ = Baseline uniform energy factor for electric water heater (= 0.926; see Assumptions)[3]
UEF_{EFF} = Efficient uniform energy factor (= 2.0 for MMID 5008, = 2.6 for MMID 5009)[4]

kWh_{COOL} = Cooling savings from conversion of heat in home to water heat that reflects a reduction in cooling load

LF = Location factor (= 0.81)[9]

27% = Reduction of waste heat resulting in cooling savings[2]

COP_{COOL} = Coefficient of performance of cooling system (= 3.52)[10]

LM = Latent multiplier (= 1.33)[11]

%AC = Percentage of homes with AC (= 92.5%)[10]

$\Delta Therms_{HEAT}$ = Heating savings from conversion of heat in home to water heat that reflects an increase in heating load

100,000 = Btu to therm conversion factor

49% = Reduction of waste heat resulting in heating increase[2]

EFF_{HEAT} = Efficiency of heating system (= 91.5%)[13]

$Frac_{NGHEAT}$ = Fraction of single family homes with natural gas heating (= 86%)[9]

Natural Gas Water Heater Replacement

$$\Delta kWh_{GAS} = \frac{GPD * 365 * 8.33 * \Delta T * C_P}{3{,}412} * \left(0 - \frac{1}{UEF_{EFF}}\right) + kWh_{COOL}$$

$$\Delta Therms_{GAS} = \frac{GPD * 365 * 8.33 * \Delta T * C_P}{100{,}000} * \left(\frac{1}{UEF_{BASE,GAS}} - 0\right) + \Delta Therms_{HEAT}$$

Where:

$UEF_{BASE,GAS}$ = Baseline uniform energy factor for natural gas water heater (= 0.603; see Assumptions)[3]

Propane Heater Replacement

$\Delta kWh_{PROP} = \Delta kWh_{GAS}$

$\Delta Therms_{PROP} = \Delta Therms_{HEAT}$

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED}$ / Hours * CF

Where:

Hours = Hours of use (= 2,533)[2]

CF = Coincidence factor (= 0.12)

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therms_{SAVED} * EUL$

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years)[1]

Assumptions

The incremental measure cost of the heat pump water heater equipment was determined to be \$1,030.00 for 2.0 UEF units and \$1,199.00 for ≥2.6 UEF units, based on the Illinois TRM.[2] This is relatively high since it is still considered to be an emerging technology, but given the appropriate market uptake and awareness is expected to decrease over time.

The baseline efficiency was derived from federal standard for electric storage water heaters[3] and generally follows the form UEF = 0.9307 – (0.0002 * V), where V is the tank size volume. Several sets of coefficients exist across water heater types, tank size ranges, and draw patterns, as shown in the Baseline UEF Values for Tank Sizes of ≥20 Gallons and ≤55 Gallons table below. Reviewing water heater models with tank size ≤55 gallons in the AHRI database[14] shows 12 low-use models, 435 medium-use models, and 583 high-use models. It also shows that a majority of units are between 40 and 50 gallons.

Therefore, for the baseline UEFs, values of 0.926 and 0.603 were chosen for natural gas and electric, respectively. These reflect averages of 40 gallon to 50 gallon, medium and high draw pattern values.

Baseline UEF Values for Tank Sizes of ≥20 Gallons and ≤55 Gallons

Fuel	Draw Pattern	UEF Formula	UEF Value for Tank Size Of (Gallons)…			
			30	40	50	55
Natural gas	Very Small	0.3456 – (0.0020 * V)	0.2856	0.2656	0.2456	0.2356
	Low	0.5982 – (0.0019 * V)	0.5412	0.5222	0.5032	0.4937
	Medium	0.6483 – (0.0017 * V)	0.5973	0.5803	0.5633	0.5548
	High	0.6920 – (0.0013 * V)	0.6530	0.6400	0.6270	0.6205
Electric	Very Small	0.8808 – (0.0008 * V)	0.8568	0.8488	0.8408	0.8368
	Low	0.9254 – (0.0003 * V)	0.9164	0.9134	0.9104	0.9089
	Medium	0.9307 – (0.0002 * V)	0.9247	0.9227	0.9207	0.9197
	High	0.9349 – (0.0001 * V)	0.9319	0.9309	0.9299	0.9294

Gallons per day were calculated by fitting a polynomial equation to data from Table 3 of the Florida Solar Energy Center study.[5] The fitted equation is $GPD = -0.0089 * x^2 + 16.277 * x + 3.25$, where x is the average number of occupants per home.

A heating system efficiency of 91.5% was assumed.[13]

For the 2020 program year, this measure uses a midstream delivery. The average splits of water heater fuel types being replaced by these heat pump water heaters is unknown. However, data from the 2017 *Focus on Energy Potential Study*[16] shows that the stock residential hot water fuel splits are 73% natural gas, 20% electric, and 7% propane. However, it is expected that these midstream heat pump water heaters will replace a higher fraction of electric water heaters, so the electric fraction was increased to 47% at the expense of the natural gas fraction, for overall fractions of 47% electric, 46% natural gas, and 7% propane. There is some chance that the propane fraction may actually be higher as well; these fractions will be investigated in future via installations, survey data, or both.

Sources

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2. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0.* Volume 3: Residential Measures. p. 168. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Effective_060116_v5.0_Vol_3_Res_021116_Final.pdf

   Waste heat cooling savings factor: REMRate determined a percentage of lighting savings (27%) that results in reduced cooling loads (lighting is used as a proxy for hot water heating since load shapes suggest that their seasonal usage patterns are similar).

   Waste heat heating increase factor: REMRate determined a percentage of lighting savings (49%) that results in increased heating loads (lighting is used as a proxy for hot water heating since load shapes suggest that their seasonal usage patterns are similar).

   Hours: Full load hours assumption is based on Efficiency Vermont analysis of Itron eShapes.
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Revision History

Version Number	Date	Description of Change
01	11/06/2012	Initial release
02	12/7/2016	Updated to new formatting
03	1/26/2017	Made edits to align with latest formatting, corrected some values and references
04	12/2019	Updated for midstream delivery, including propane baseline

Water Heater, Indirect

	Measure Details
Measure Master ID	Water Heater, Indirect, 90% to 94%, 5267, Water Heater, Indirect, 90% to 94%, Tier 2, 5268 Water Heater, Indirect, 1988 (95%+) Water Heater, Indirect, Tier 2, 3784 (95%+)
Workpaper ID	W0201
Measure Unit	Per water heater
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Water Heater
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$988.50[2]

Measure Description

Indirect water heaters are applicable to any indirectly fueled water heater, and must be paired with a high-efficiency boiler. In addition, qualifying indirect water heaters must be whole-house units or used for domestic water heating.

Unlike other water heaters, indirect water heaters use a boiler as the heat source. The water heater may also have a direct energy source for non-heating seasons when the boiler is shut off and thus not able to meet the water heating demands.[3]

Description of Baseline Condition

The base case is a residential, gas-fueled, storage water heater with an EF of 0.6.[4] While water heater baselines vary by type and size, 0.6 is used as a representation of average UEF for medium to high draw for a 50-gallon tank, as discussed in workpaper W0267. This UEF is used to set baseline recovery efficiency.

Description of Efficient Condition

Indirect water heaters must be connected to a boiler with an AFUE of 90% or greater.

Annual Energy-Savings Algorithm

$$\text{Therm}_{SAVED} = (\text{GPD} * 365 * 8.33 * 1 * \Delta T_{w} / 100{,}000) * (1 / \text{RE}_{BASE} - 1 / \text{E}_{C,EE})$$
$$+ (\text{UA}_{BASE} / \text{RE}_{BASE} - \text{UA}_{EE} / \text{E}_{C,EE}) * \Delta T_{s} * 8{,}760 / 100{,}000$$

Where:

GPD = Average daily hot water consumption (= 42.75 gallons per day, see Assumptions)[5,10]

365 = Days per year

8.33 = Density of water (lb/gallon)

1 = Specific heat of water (Btu/lb °F)

ΔT_{w} = Average difference between the cold water inlet temperatures (52.3°F) and the hot water delivery temperature (125°F) (= 72.7°F)[6]

100,000 = Conversion factor (Btu/therm)

RE_{BASE} = Recovery efficiency of the baseline tank type water heater (= 76%)[6]

$\text{E}_{C,EE}$ = Combustion efficiency of energy-efficient boiler used to heat indirect water heater (= 90% or 95%)[7]

UA_{BASE} = Overall heat loss coefficient of base tank type water heater (= 14.0 Btu/hr-°F)[8]

UA_{EE} = Overall heat loss coefficient of indirect water heater storage tank (= 6.1 Btu/hr-°F; see table below)[9]

Typical Values for UA_{EE}

Volume (gal)	H (bare tank) inches	Diameter (bare tank) inches	Insulation	UA (Btu/hr-°F)
40	44	17	1 in foam	4.1
			2 in foam	2.1
80	44	24	1 in foam	6.1
			2 in foam	3.1
120	65	24	1 in foam	8.4
			2 in foam	5.4

ΔT_{S} = Temperature difference between the stored hot water temperature (125°F) and the ambient indoor temperature (65°F) (= 60°F)

8,760 = Conversion factor (hours/year)

Summer Coincident Peak Savings Algorithm

Indirect water heaters consume no electrical energy; therefore, they have no impact on demand reduction.

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIFECYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (15 years)[1]

Deemed Savings

Deemed Savings by Measure

Measure	MMID	Annual Therms	Lifecycle Therms
Water Heater, Indirect, 90% to 94%	5267	81	1,215
Water Heater, Indirect, 90% to 94%, Tier 2	5268		
Water Heater, Indirect (95%+)	1988	88	1,320
Water Heater, Indirect, Tier 2, 3784 (95%+)	3784		

Assumptions

Because the efficiency of residential water heater is measured in UEF, the true UEF and UA_{BASE} is not available. A thermal efficiency of 76% and a UA_{BASE} of 14 is assumed. The average difference of 60°F assumes pipe and ambient air temperatures of 125°F and 65°F, respectively.

Gallons per day were calculated by fitting a polynomial equation to data from Table 3 of the Florida Solar Energy Center study.[5] An average value of 2.43 occupants per home was used for Wisconsin, based on US Census data.[10] The fitted equation is GPD = -0.0089 * x2 + 16.277 * x + 3.25, where x is the average number of occupants per home.

Sources

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Revision History

Version Number	Date	Description of Change
01	01/01/2012	Initial TRM entry
02	10/30/2014	Updated therms based on 72.7°F temperature
03	12/2018	Updated gallons per day calculation
04	12/2021	Added 90% AFUE measure.

Natural Gas Storage Water Heater, 0.64 UEF

	Measure Details
Measure Master ID	Water Heater, NG, UEF of 0.64 or Greater, 5265
Workpaper ID	W0301
Measure Unit	Per water heater
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Water Heater
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	9.84
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	128.0
Water Savings (gal/year)	0
Effective Useful Life (years)	13[1]
Incremental Cost ($/unit)	$400.00[2]

Measure Description

This measure is residential-sized, tank-type storage, domestic water heaters (small storage water heaters), defined as equipment with an input rating ≤ 75,000 Btuh and a storage volume from 20 to 55 gallons. There is a program incentive for participants who install a small storage water heater that has an efficiency rating ≥ 0.64 Uniform Energy Factor (UEF).

Description of Baseline Condition

The base case is a residential, natural gas–fueled storage water heater with a UEF of 0.60 (see Assumptions).[3]

Description of Efficient Condition

The efficient condition is a higher efficiency natural gas storage-type water heater with a UEF compliant with ENERGY STAR qualification criteria.

Annual Energy-Savings Algorithm

$$\text{Therm}_{\text{SAVED}} = [(\text{GPD} * 365 * 8.33 * C_{\text{P,WATER}} * \Delta T_{\text{W}}) / 100{,}000] * [(1 / \text{UEF}_{\text{BASE}}) - (1 / \text{UEF}_{\text{EE}})]$$

Where:

GPD = Average daily hot water consumption (= 42.8 gallons per day; see Assumptions)

365 = Days per year

8.33 = Density of water (pounds per gallon)

$C_{P,WATER}$ = Specific heat of water (= 1 Btu/lb °F)

ΔT_w = Average difference between the cold water inlet temperatures (52.3°F)[4] and the hot water delivery temperature (125°F) (= 72.7°F)[5]

100,000 = Conversion factor from Btu to therm

UEF_{BASE} = Energy factor of the baseline water heater (= 0.60)

UEF_{EE} = Energy factor of the efficient water heater (= 0.64)

Summer Coincident Peak Savings Algorithm

Natural gas–fired storage water heaters consume no electrical energy; therefore, they have no impact on demand reduction.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years)[1]

Assumptions

The federal standard baseline is calculated by taking an average of the UEF_{BASE} calculated using 40- and 50-gallon water heaters, for medium and high water draw patterns. This produces a baseline uniform energy factor of 0.60. See workpaper W0267 for more details. Gallons per day were calculated by fitting a polynomial equation to data from Table 3 of the Florida Solar Energy Center study.[6] An average value of 2.43 occupants per home was used for Wisconsin, based on US Census data.[7] The fitted equation is $GPD = -0.0089 * x^2 + 16.277 * x + 3.25$, where x is the average number of occupants per home.

Sources

1. PA Consulting Group Inc. "State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study." Final Report. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
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4. U.S. Department of Energy. "Domestic Hot Water Scheduler."
Average water main temperature of all locations measured in Wisconsin by scheduler, weighted by city populations.

5. Wisconsin State Legislature. Chapter 704. Landlord and Tenant. Section 704.06. https://docs.legis.wisconsin.gov/statutes/statutes/704/06
Water heater setpoints typically range between 120°F and 140°F because temperatures below 120°F are susceptible to Legionella bacteria and heaters set to temperatures above 140°F can quickly scald users. http://www.nrel.gov/docs/fy12osti/55074.pdf
6. Florida Solar Energy Center. *Estimating Daily Domestic Hot-Water Use in North American Homes*. June 30, 2015. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-464-15.pdf
7. United States Census Bureau. *2010 Demographic Profiles*. Accessed May 15, 2017.

Revision History

Version Number	Date	Description of Change
01	01/01/2012	Initial TRM entry
02	10/30/2014	Updated therm based off 72.7°F for the change in temperature
03	04/27/2017	Updated therms based on new federal baseline and other figures
04	12/2021	Restored measure, updated to UEF

Natural Gas Instant Water Heater

	Measure Details
Measure Master ID	5165
Workpaper ID	W0267
Measure Unit	Per water heater
Measure Type	Prescriptive
Measure Group	Domestic Hot Water
Measure Category	Water Heater
Sector(s)	Residential- single family; Residential- multifamily
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	49
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	637
Water Savings (gal/year)	0
Effective Useful Life (years)	13[1]
Measure Incremental Cost ($/unit)	$1,096.60[2]

Measure Description

This measure is for the replacement of failed or working domestic natural gas–fired storage water heaters in residential and multifamily buildings and for the installation of natural gas–fired instantaneous water heaters.

Description of Baseline Condition

The baseline condition is a natural gas–fueled, residential-duty commercial storage water heater with a 0.60 UEF. See the Assumptions for more details.

Description of Efficient Condition

The efficient condition is a natural gas–fueled, residential, natural gas–fired instantaneous water heater meeting ENERGY STAR criteria.

Annual Energy-Savings Algorithm

$Therm_{SAVED} = [(GPD * 365 * 8.33 * C_{P,WATER} * \Delta T_{W}) / 100{,}000] * [(1 / UEF_{BASE}) – (1 / UEF_{EE})]$

Where:

GPD = Average daily hot water consumption (= 42.75 gallons per day; see Assumptions)[3,4]

365 = Days per year

8.33 = Density of water (pounds per gallon)

$C_{P,WATER}$ = Specific heat of water (= 1 Btu/lb-°F)

ΔT_w = Difference between the average cold water inlet temperature and the hot water delivery temperature (= T_{OUT} - T_{IN})

T_{IN} = Average cold water inlet temperature (= 52.3°F)[5]

T_{OUT} = Hot water delivery temperature (= 125°F)[6]

100,000 = Conversion factor from Btu to therm

UEF_{BASE} = Energy factor of the baseline water heater based on tank size (= see Assumptions, Baseline Efficiency table)

UEF_{EE} = Energy factor of the efficient water heater (= 0.87)[7]

Summer Coincident Peak Savings Algorithm

Natural gas–fired instantaneous water heaters consume no electrical energy, aside from a combustion air fan; therefore, they have a negligible impact on demand reduction.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therms_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 13 years)[1]

Deemed Savings

Energy Savings for Instantaneous Natural Gas–Fired Water Heater

Measure	MMID	Baseline Rated Storage	Draw Pattern	Annual Therm	Lifecycle Therms
Instantaneous Natural Gas–Fired Water Heater	5165	<2 gallons and >50,000 Btu/h	Medium/High	49	637

Assumptions

The baseline is assumed to be a new, nautral gas–fired, residential storage water heater that meets or exceeds minimum federal efficiency standards.

Based on data of available products and as defined in the federal standard,[1] water heaters are assumed to have a medium or high draw pattern. Reviewing water heater models with a tank size ≤55 gallons in the AHRI database[9] shows 12 low-use models, 435 medium-use models, and 583 high-use models. It also shows the majority of units as between 40 gallons and 50 gallons.

The baseline efficiency was derived from federal standard for water heaters[1] and generally follows the form UEF = 0.6597 – (0.0009 * V), where V is the tank size volume. Several sets of coefficients exist across water heater types, tank size ranges, and draw patterns, as shown in the Baseline UEF Values table below. Therefore, for the baseline UEF, a value of 0.60—which is the average for medium and high draw for a 50 gallon tank—was chosen. This reflects an average of 40 gallons to 50 gallons, with medium- and high-draw pattern values.

Baseline UEF Values

Tank Size	Fuel	Draw Pattern	UEF Formula	UEF Value for Tank Size (Gallons)			
				30	40	50	55
≥20 gallons and ≤55 gallons	Natural gas	Very Small	0.3456 – (0.0020 * V)	0.2856	0.2656	0.2456	0.2356
		Low	0.5982 – (0.0019 * V)	0.5412	0.5222	0.5032	0.4937
		Medium	0.6483 – (0.0017 * V)	0.5973	0.5803	0.5633	0.5548
		High	0.6920 – (0.0013 * V)	0.6530	0.6400	0.6270	0.6205

Sources

1. United States Department of Energy. *2010 Residential Heating Products Final Rule Technical Support Document*. p. 20159. https://www.govinfo.gov/content/pkg/FR-2010-04-16/pdf/2010-7611.pdf
   This source is used to support the measure category in aggregate. For all water heaters, life expectancy will depend on local variables such as water chemistry and homeowner maintenance. Some categories, including condensing storage and tankless water heaters, do not yet have sufficient field data to support separate values. Preliminary data show that lifetimes may exceed 20 years, though this has yet to be sufficiently demonstrated.
2. U.S. Department of Energy. *2010 Residential Heating Products Final Rule Technical Support Document*. Tables 8.2.13-14, 8.2.16. http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf
3. Florida Solar Energy Center. *Estimating Daily Domestic Hot-Water Use in North American Homes.* June 30, 2015. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-PF-464-15.pdf
4. U.S. Census Bureau. “Demographic Profile for Wisconsin.” May 12, 2011. https://www.census.gov/newsroom/releases/archives/2010_census/cb11-cn137.html
5. U.S. Department of Energy. “Domestic Hot Water Scheduler.” Average water main temperature of all locations measured in Wisconsin by scheduler, weighted by city populations.
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   National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy12osti/55074.pdf
   Water heater setpoints typically range between 120°F and 140°F because temperatures below 120°F are susceptible to Legionella bacteria and heaters set to temperatures above 140°F can quickly scald users.

7. ENERGY STAR. “ENERGY STAR Product Specification for Residential Water Heaters.” Version 3.2. Effective April 16, 2015. https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements_1.pdf
8. Electronic Code of Federal Regulations. §430.32, Energy and Water Conservation Standards and their Compliance Dates. https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8
9. Air-Conditioning, Heating, & Refrigeration Institute. *AHRI Directory of Certified Product Performance*. Accessed December 2019. https://www.ahridirectory.org/Search/SearchHome

Revision History

Version Number	Date	Description of Change
01	12/2020	Initial TRM entry

HVAC

Room Air Conditioner, ENERGY STAR

	Measure Details
Measure Master ID	Room Air Conditioner, ENERGY STAR, 4035
Workpaper ID	W0202
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Air Conditioner
Sector(s)	Residential- upstream
Annual Energy Savings (kWh)	40
Peak Demand Reduction (kW)	0.0223
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	360
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	9[1]
Incremental Cost ($/unit)	$114.00[1]
Important Comments	Measure under Retail Product Platform (RPP) Pilot

Measure Description

A room air conditioner is a factory-encased air conditioner that is designed (1) as a unit for mounting in a window, through a wall, or as a console, and (2) for delivery without ducts of conditioned air to an enclosed space. This measure consists of ENERGY STAR-certified room air conditioner units that meet the ENERGY STAR Version 4.0 requirements.[2] ENERGY STAR-certified units are 15% more efficient than non-qualified models.

Description of Baseline Condition

The baseline condition is a non-ENERGY STAR-certified standard room air conditioner. The resulting energy usage is the (market-weighted) average energy consumption across product classes and the (simple) average energy consumption across operating hours associated with the Wisconsin cities of Green Bay, La Crosse, Madison, and Milwaukee.[4]

Description of Efficient Condition

The efficient condition is ENERGY STAR-certified room air conditioners that meet ENERGY STAR Version 4.0 requirements.[2] The resulting energy usage is the (market-weighted) average across product classes and the (simple) average across operating hours associated with the Wisconsin cities of Green Bay, La Crosse, Madison, and Milwaukee.[1]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = UEC_{BASE} - UEC_{EE}$

Where:

UEC_{BASE} = Annual unit energy consumption of baseline unit (= 442.11 kWh)[1,2]
UEC_{EE} = Annual unit energy consumption of measure unit (= 401.79 kWh)[1]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (kWh_{SAVED} / Hours) * CF$

Where:

Hours = Hours of operation per year (= 543)[3]
CF = Coincidence factor (= 0.3)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 9 years)[1]

Sources

1. ENERGY STAR. *Retail Products Platform: Product Analysis for Room Air Conditioners.* Effective May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U.
Lifetime based on Appliance Magazine - Market Research. “The U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture 2013.” December 2013.
Incremental costs are based on the Room Air Conditioner TSD Life-Cycle Cost and Payback Analysis "2011-04-18_TSD_Chapter_8_Life-Cycle_Cost_and_Payback_Period_Analyses.pdf". To calculate an average incremental cost, a weighted average was created based on the market share of each product subtype. http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0053
Baseline energy consumption is based on the federal standard for room air conditioners. Accessed November 21, 2016. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=52&action=viewlive
It is calculated by taking a market share weighted average of the unit energy consumption of all product subtypes listed in the ENERGY STAR specification. It is assumed that the room air conditioner is in operation for 543 hours per year, an average of the hours for the four Wisconsin cities listed in the Analysis workbook. This value was used to replace the national value of 750 hours per year used for the various types of AC in the workbook.
Efficient energy consumption is based on the ENERGY STAR Version 4.0 standard for Room Air Conditioners.[2] The efficient condition energy consumption is calculated by taking a market share

weighted average of the unit energy consumption of all product subtypes listed in the ENERGY STAR specification. It is assumed that the room air conditioner is in operation for 543 hours per year, an average of the hours for the four Wisconsin cities listed in the Analysis workbook. This value was used to replace the national value of 750 hours per year used for the various types of AC in the workbook.

2. ENERGY STAR. *Program Requirements for Room Air Conditioners – Eligibility Criteria.* Version 4.0. Accessed November 17, 2016. www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Room%20Air%20Conditioners%20Program%20Requirements.pdf
3. RLW Analytics. *Final Report Coincidence Factor Study Residential Room Air Conditioners.* June 23, 2008. http://www.puc.state.nh.us/electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/124_SPWG%20Room%20%20AC%20Evaluation%20FINALReport%20June%2023%20ver7.pdf

Revision History

Version Number	Date	Description of Change
01	06/24/2016	Initial TRM entry

Communicating Thermostats

	Measure Details
Measure Master ID	Communicating Thermostat, Existing Natural Gas Boiler, 4298 Communicating Thermostat, Existing Natural Gas Furnace, 4299 Communicating Thermostat, Existing Air-Source Heat Pump, 4300
Workpaper ID	W0203
Measure Unit	Per thermostat
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by existing heating system
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by existing heating system
Lifecycle Energy Savings (kWh)	Varies by existing heating system
Lifecycle Therm Savings (Therms)	Varies by existing heating system
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$137.06[2]

Measure Description

Standard programmable thermostats require customers to adjust temperature setpoints at different times of the day to allow for some energy savings during unoccupied periods. Communicating thermostats provide this base level of functionality and can be programmed remotely through Wi-Fi.

Description of Baseline Condition

The baseline condition is a manual or standard programmable thermostat installed in a home with an existing natural gas furnace, natural gas boiler, or air-source heat pump (ASHP).

Description of Efficient Condition

The efficient condition is a communicating thermostat installed in a home to replace the existing thermostat. To qualify as communicating, the thermostat must be Wi-Fi capable (with the Wi-Fi connection established by the customer), but not certified as an ENERGY STAR Connected Thermostat, and not included as a qualifying smart thermostat for the smart thermostat measure prior to 2018.

Annual Energy-Savings Algorithm

$$\text{Therm}_{\text{SAVED}} = (0.75 * \text{CONS}_{\text{THERM,BA}} + 0.25 * \text{CONS}_{\text{THERM,CALC}}) * \text{ESF}_{\text{THERM}} * \text{P}_{\text{MF,AREA}}$$

$$\text{CONS}_{\text{THERM,CALC}} = \text{HOURS}_{\text{HEATING}} * \text{CAP}_{\text{GAS}} / (\text{AFUE} * 100)$$

$kWh_{SAVED} = kWh_{SAVED\ COOLING} + kWh_{SAVED\ HEATING}$

$kWh_{SAVED\ COOLING} = (0.75 * CONS_{KWh,COOL,BA} * P_{MF,AC} + 0.25 * CONS_{KWh,COOL,CALC}) * ESF_{KWh,COOLING}$

$CONS_{KWh,COOL,CALC} = EFLH_{COOL} * CAP_{COOL} * AC\% / SEER$

$kWh_{SAVED\ HEATING} = (0.75 * CONS_{KWh,HEAT,BA} + 0.25 * CONS_{KWh,HEAT,CALC}) * ESF_{KWh,HEATING}$

$CONS_{KWh,HEAT,CALC} = EFLH_{HEAT,KWh} * CAP_{ASHP,HEAT} / (HSPF * 3.412)$

Where:

$CONS_{THERM,BA}$ = Annual therms consumed by smart thermostat participants before smart thermostat installation, as determined by Cadmus billing analysis (= 653 therms for furnace; = 1,050 therms for boiler; = 0 therms for ASHP)

$CONS_{THERM,CALC}$ = Annual therms consumed by communicating thermostat participants before communicating thermostat installation (= 896 therms for furnace; = 1,375 therms for boiler; = 0 therms for ASHP, see Assumptions)

ESF_{THERM} = Heating energy savings fraction for communicating thermostats (= 2.8% for furnace; = 3.0% for boiler; = 0% for ASHP)

$P_{MF,AREA}$ = Scale factor for multifamily home size (= 100.0% for single family; =52.9% for multifamily,[9] see Assumptions)

$HOURS_{HEATING}$ = Annual home heating hours (= 1,158 hours for furnace[3] or boiler;[4] = 0 hours for ASHP)

CAP_{GAS} = Natural gas heating system capacity (= 70.7 MBtu/hour for furnace;[9] = 110 MBtu/hour for boiler[6])

AFUE = AFUE of system (= 91.4% for furnace;[9] = 80% for boiler)

100 = Conversion from therms to MBtu

$CONS_{KWh,COOL,BA}$ = Annual cooling kilowatt-hours consumed by smart thermostat participants before smart thermostat installation, as determined by Cadmus billing analysis (= 1,584 kWh for furnace, boiler, and ASHP)

$P_{MF,AC}$ = Scale factor for multifamily homes with natural gas furnaces and central air conditioners (= 100.0% for single family and multifamily with boiler and ASHP; = 112.6% for multifamily with natural gas furnace,[9] see Assumptions)

$CONS_{KWh,COOL,CALC}$ = Annual cooling kilowatt-hours consumed by communicating thermostat participants before communicating thermostat installation (= 729 kWh for furnace and boiler; = 867 kWh for ASHP, see Assumptions)

$ESF_{KWh,COOLING}$ = Kilowatt-hour energy savings fraction for cooling for communicating thermostats (= 12.4%)

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410 for furnace, boilers, and ASHP)[3]

CAP_{COOL} = Cooling system capacity (= 25.6 MBtu/hour)[9]

AC% = Fraction of participants with an air conditioner (= 84% for furnace and boiler;[9] = 100% for ASHP)

SEER = Seasonal energy efficiency rating (= 12.1)[9]

$CONS_{KWh,HEAT,BA}$ = Annual heating kilowatt-hours consumed by smart thermostat participants before smart thermostat installation (= 808 kWh for furnace; = 0 kWh for boiler; = 962 kWh for ASHP, see Assumptions)

$CONS_{KWh,HEAT,CALC}$ = Annual heating kilowatt-hours consumed by communicating thermostat participants before communicating thermostat installation (= 0 kWh for furnace and boiler; = 2,902 kWh for ASHP, see Assumptions)

$ESF_{KWh,HEATING}$ = Kilowatt-hour energy savings fraction for heating for communicating thermostats (= 8.6% for furnace; = 0% for boiler; = 7.3% for ASHP)

$EFLH_{HEAT,KWh}$ = Equivalent full-load heating hours (= 1,890 for ASHP;[7] = 0 for furnace and boiler)

$CAP_{ASHP,HEAT}$ = ASHP heating capacity (= 37.2 MBtu/hour)

HSPF = Heating seasonal performance factor (= 7.1)

3.412 = Conversion from Btu to watts

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure. It is assumed that only a small minority of participants have regular behavioral patterns that would produce demand reduction. These patterns entail not being at home during the peak period and not already setting the temperature back during that time.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Annual and Lifecycle Savings by Communicating Thermostat Measure

Method of Home Heating	MMID	Sector	Peak kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms
Natural Gas Boiler	4298	SF	0	170	1,700	36	360
		MF	0	90	900	19	190
Natural Gas Furnace	4299	SF	0	223	2,230	20	200
		MF	0	128	1,280	11	110
Air-Source Heat Pump	4300	SF	0	280	2,800	0	0
		MF	0	148	1,480	0	0

Assumptions

Because manual and programmable thermostats often last for decades, measure cost and savings assume a technology-based upgrade as opposed to end-of-life replacement, so the baseline condition would have continued with existing equipment.

The GDS Associates document[1] cited for EUL is also used by the Illinois TRM for programmable thermostats.

For the 2016 Focus evaluation, Cadmus conducted a billing analysis to examine savings for participants who installed smart thermostats as part of MMIDs 3609, 3610, and 3611 (updated to MMIDs 4301, 4302, and 4303). The 2016 *Focus on Energy Evaluation Report*[9] discusses these findings, and results from that billing analysis are analyzed further in the updated workpaper for these MMIDs. This study did not examine communicating thermostats, but it did reveal that smart thermostat participants had lower pre-install heating consumption and higher pre-install cooling consumption than the TRM calculations had predicted. This indicates that the sample for the billing analysis—participants who installed smart thermostats—systematically differs from the Wisconsin general population. These differences may apply to participants who install communicating thermostats as well. Therefore, the pre-install consumption values are a weighted average, based 25% on the previous TRM calculations and assumptions and based 75% on the billing analysis results for consumption. For details on savings calculations for smart thermostats, refer to measures 3609, 3610, and 3611.

Values for energy savings factors for communicating thermostats were derived by extrapolating data from the Minnesota TRM.[8] This TRM finds a heating and cooling energy savings factor of 5.4% for communicating thermostats, and a heating and cooling energy savings factor of 8.9% for smart thermostats. Therefore, this TRM shows that energy savings factors for communicating thermostats are 60.7% of those for smart thermostats. That ratio was applied to the energy savings factors for communicating thermostats in this workpaper, using the energy savings factors for smart thermostats found from the 2016 Cadmus billing analysis. Details are shown in the table below.

Energy Savings Factors for Communicating Thermostats

Parameter	Thermostat Type	Furnace	Boiler	ASHP
ESF_{THERM}	Smart	4.6%	5.0%	N/A
	Communicating	2.8%	3.0%	N/A
$ESF_{KWh,COOL}$	Smart	20.5%	20.5%	20.5%
	Communicating	12.4%	12.4%	12.4%
$ESF_{KWh,HEAT}$	Smart	14.2%	N/A	12.0%
	Communicating	8.6%	N/A	7.3%

The capacity of residential heat pumps installed in Wisconsin is assumed to be 3.1 tons, based on an analysis of 75 ASHPs installed between 2013 and 2015 in Focus on Energy residential programs. At 12,000 Btu/hour/ton, the assumed average capacity is 37.2 MBtu/hour.

The default efficiency levels are based on existing heating and cooling equipment efficiencies of 80% AFUE boilers and HSPF 7.1 ASHPs. Current baselines for boilers and ASHPs assume 82% AFUE and HSPF 7.7, respectively, based on current installation standards in Wisconsin (and assuming that the average customer in Wisconsin is slightly below the baseline due to some homes still using older equipment). Updated values for average furnace capacity and AFUE, cooling capacity and SEER, and fraction of homes with a central air conditioner installed were updated based on data from the 2016 Focus on Energy potential study.[9]

Supporting inputs for cooling load hours (furnaces and ASHPs) in several Wisconsin cities are shown in the table below.

Supporting Inputs for Equivalent Full-Load Cooling Hours by City

Location	$EFLH_{COOL}$ (furnace, boiler, and ASHP)[3,7]	$EFLH_{HEAT}$ (ASHP)[7]	Weighting by Participant[3]
Green Bay	344	1,852	22%
Lacrosse	323	1,966	3%
Madison	395	1,934	18%
Milwaukee	457	1,883	48%
Wisconsin Average	380	1,909	9%
Weighted Average	**410**	**1,890**	**100%**

The billing analysis that serves as the basis for smart thermostat savings examined thermostats installed in single family residences. Multifamily residences are assumed to have the same energy savings fractions, but consumptions scale due to two factors:

- First, all multifamily heating and cooling consumptions scale based on residence size. Data from the Wisconsin Focus on Energy potential study[9] indicate that the average single family home has 1,652 sq ft of finished space, while the average multifamily unit has 874 sq ft of finished space.

Therefore, all consumption values for multifamily homes incorporate an area scaling factor of $P_{MF,AREA}$ equal to 874 divided by 1,652 (52.9%). This applies to factors derived from the billing analysis and from calculations.

- Second, billing analysis derived multifamily cooling consumption for natural gas furnace sites is also scaled. The average natural gas furnace cooling consumption observed in the billing analysis is directly dependent on the fraction of those homes that have central air conditioners. That fraction, while not specifically known for the billing analysis sample, may be different for multifamily sites receiving smart thermostats. The potential study[5] sample may be different from the billing analysis sample, but its data can be used here. The potential study data shows that 85.5% of multifamily sites with natural gas furnaces also have central air conditioners, and that this fraction for single family sites is 75.9%. Therefore, for multifamily sites with natural gas furnaces, there is an assumed cooling consumption scaling factor of $P_{MF,AC}$ equal to 85.5 divided by 75.9 (112.6%).

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, HVAC Controls. June 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
   Used programmable thermostat EUL as the closest proxy.
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 7 projects and 290 units from June 2019 to December 2019 is $176.17 for multifamily sector (no single family usage). Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.
3. Cadmus. *Focus on Evaluated Energy Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
4. Ibid. Residential boilers are assumed to have sizing practices similar to furnaces, and therefore have the same EFLH.
5. *SPECTRUM Focus Prescriptive Database*. 2013.
   Average input capacity of boilers under 300 MBtu/hour.
6. *Illinois Statewide Technical Reference Manual*.
   Calculated using an average from Illinois TRM, applied to Wisconsin cooling degree days.
7. Minnesota Department of Commerce, Division of Energy Resources. *State of Minnesota Technical Reference Manual for Energy Conservation Improvement Programs, Version 2.0*. April 2016. http://mn.gov/commerce-stat/pdfs/mn-trm-v2.0-041616.pdf
8. Cadmus. *Focus on Energy Calendar Year 2016 Evaluation Report, Volume II*. May 19, 2017. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202016%20Volume%20II%20-%20%28Low%20Res%29.pdf

9. Cadmus. 2016 Potential Study for Focus on Energy. Data maintained by Cadmus and Wisconsin PSC. Data includes information 103 single family sites and 92 multifamily units.

Revision History

Version Number	Date	Description of Change
01	06/2017	Initial TRM entry
02	12/2018	Updated incremental cost and boiler EFLH
03	12/2020	Updated cost

Smart Thermostat, Installed With Home Heating Measure

	Measure Details
Measure Master ID	Smart Thermostat, Installed with: 95% AFUE NG Furnace, 3612 96% AFUE NG Furnace, 4054 97% AFUE NG Furnace, 4055 98% AFUE NG Furnace, 4056 95% AFUE NG Boiler, 3613 90% AFUE NG Boiler, 5271 Furnace and A/C, 3614 Air Source Heat Pump, 3615
Workpaper ID	W0205
Measure Unit	Per Thermostat
Measure Type	Prescriptive
Measure Group	HVAC: MMIDs 3612, 4054, 4055, 4056, 3614, 3615 Boilers & Burners: MMID 3613
Measure Category	Controls
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	Varies by heating system installed
Peak Demand Reduction (kW)	Varies by heating system installed
Annual Therm Savings (Therms)	Varies by heating system installed
Life-cycle Energy Savings (kWh)	Varies by heating system installed
Life-cycle Therm Savings (Therms)	Varies by heating system installed
Water Savings (gal/yr)	0
Effective Useful Life (years)	9[1]
Measure Incremental Cost ($/unit)	$173.89[2]

Measure Description

Standard programmable thermostats require customers to adjust temperature setpoints at different times of the day, changing temperatures during unoccupied periods to allow for some energy savings. Communicating thermostats provide this base level of functionality but can be programmed remotely through Wi-Fi.

Smart thermostats provide enhanced functionality that can include:

- Easier use and programming, both on the thermostat and remotely via smartphone apps and web portals.
- Occupancy sensing that enables energy savings from automatic setbacks during unoccupied periods. Occupancy sensing may use sensors in the thermostat or capability to track the residents' location through a smartphone app.

- Learning capability or automatic schedule generation/modification. Such thermostats are capable of dynamically adjusting and/or constructing a program schedule based on actual occupancy patterns, eliminating the need for programming.
- Intelligent control of HVAC equipment, including minimizing the energy expended for recovery from setback, having intelligent control of two-stage HVAC sources, and minimizing the use of inefficient electric-resistance heat associated with most heat pumps.
- Use of outside temperature and other weather data to better ensure comfort and minimize energy use.
- Encourage use of more energy-efficient set temperatures (for example, an icon of a leaf appears when the set temperature is moved in the direction of less energy use).
- Algorithms that make frequent subtle temperature changes in order to save energy.

The savings calculations for these measures are based on the deemed savings values for the smart thermostat and communicating thermostat workpapers (MMIDs 4301 – 4303 and 4298 – 4300). Savings for those measures are based on a billing analysis that examined weather-normalized gas and electric consumption at sites, before and after receiving a smart thermostat. For the measures in this workpaper, the calculated savings for MMIDs 4301 – 4303 and 4298 – 4300 are modified based on the known efficiencies of the HVAC units that the thermostats are being installed with, which are different from the average efficiencies of sites from the billing analysis. The combined furnace and AC measure is also modified based on the assumed fraction of billing analysis sites with ACs.

Description of Baseline Condition

The baseline condition is a manual or programmable thermostat installed in a home with new, program qualified, natural gas furnace, natural gas boiler, furnace/AC combo, or air source heat pump.

See Assumptions section for detail on weighted average applied to savings to account for combination of manual and programmable thermostats that comprise the baseline population in Wisconsin.

Description of Efficient Condition

The efficient condition is a smart thermostat installed in a home to replace an existing manual or programmable thermostat. To qualify as smart, the thermostat must be certified as an ENERGY STAR Connected Thermostat, or otherwise meet the following criteria:

- Must be Wi-Fi capable
- Must be capable of internet connection
- Must feature occupancy sensing, via geolocation and/or motion sensing
- The above features must be built-in and not require add-on devices or services
- The application and connectivity service must be free after thermostat purchase
- Thermostat default behavior must be to set back temperature when house is unoccupied

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{CONS}_{\text{THERM}} (\text{AFUE}_{\text{BILL}} / \text{AFUE}_{\text{MEAS}}) * \text{ESF}_{\text{THERM}}$

Furnace and Boiler Measures

$\text{kWh}_{\text{SAVED}} = \text{CONS}_{\text{kWh,COOL}} * \text{ESF}_{\text{kWh,COOL}} + \text{CONS}_{\text{kWh,HEAT}} * \text{ESF}_{\text{kWh,HEAT}}$

Furnace + AC Measure

$\text{kWh}_{\text{SAVED}} = \text{CONS}_{\text{kWh,COOL}} / \text{AC\%}_{\text{BILL}} * (\text{SEER}_{\text{BILL}} / \text{SEER}_{\text{MEAS}}) * \text{ESF}_{\text{kWh,COOL}} + \text{CONS}_{\text{kWh,HEAT}} * \text{ESF}_{\text{kWh,HEAT}}$

Air Source Heat Pump Measure

$\text{kWh}_{\text{SAVED}} = \text{CONS}_{\text{kWh,COOL}} / \text{AC\%}_{\text{BILL}} * (\text{SEER}_{\text{BILL}} / \text{SEER}_{\text{MEAS}}) * \text{ESF}_{\text{kWh,COOL}} + \text{CONS}_{\text{kWh,HEAT}} * (\text{HSPF}_{\text{BILL}} / \text{HSPF}_{\text{MEAS}}) * \text{ESF}_{\text{kWh,HEAT}}$

Where:

$\text{CONS}_{\text{THERM}}$ = Annual therms consumed by smart thermostat billing analysis participants before smart thermostat installation (= 653 therms for furnace; = 1,050 therms for boiler; = 0 therms for ASHP)

$\text{AFUE}_{\text{BILL}}$ = Deemed average AFUE of billing analysis sample (= 92.8% for furnace measures; = 80% for boiler measures, see Assumptions)

$\text{AFUE}_{\text{MEAS}}$ = AFUE of installed furnace (see table below)

$\text{ESF}_{\text{THERM}}$ = Therm energy savings fraction (= 4.6% for furnace; = 5.0% for boiler; = 0% for ASHP)

$\text{CONS}_{\text{kWh,COOL}}$ = Annual cooling kilowatt-hours consumed by smart thermostat billing analysis participants before smart thermostat installation (= 1,584 kWh for furnace, boiler, and ASHP)

$\text{ESF}_{\text{kWh,COOL}}$ = Kilowatt-hour energy savings fraction for cooling (= 20.5% for furnace, boiler, and ASHP)

$\text{CONS}_{\text{kWh,HEAT}}$ = Annual heating kilowatt-hours consumed by smart thermostat billing analysis participants before smart thermostat installation (= 808 kWh for furnace; = 0 kWh for boiler; = 962 kWh for ASHP)

$\text{ESF}_{\text{kWh,HEAT}}$ = Kilowatt-hour energy savings fraction for heating (= 14.2% for furnace; = 0% for boiler; = 12% for ASHP)[3]

$\text{AC\%}_{\text{BILL}}$ = Deemed fraction of billing analysis sample with air conditioning (= 92.5%, see Assumptions)

$\text{SEER}_{\text{BILL}}$ = Deemed average SEER of billing analysis sample (= 13.9, see Assumptions)

$\text{SEER}_{\text{MEAS}}$ = SEER of installed air conditioner (= 16)

$HSPF_{BILL}$ = Deemed average HSPF of billing analysis sample (= 7.7, see Assumptions)

$HSPF_{MEAS}$ = HSPF of installed air source heat pump (= 8.4)

Deemed Installed Furnace AFUE Across Measures

Measure	MMID	Deemed Installed Furnace AFUE
Smart Thermostat, Installed with 95% AFUE NG Furnace	3612	95%
Smart Thermostat, Installed with 96% AFUE NG Furnace	4054	96%
Smart Thermostat, Installed with 97% AFUE NG Furnace	4055	97%
Smart Thermostat, Installed with 98% AFUE NG Furnace	4056	98%
Smart Thermostat, Installed with 95% AFUE NG Boiler	3613	95%
Smart Thermostat, Installed with 95% AFUE NG Boiler	5271	90%
Smart Thermostat, Installed with Furnace and A/C	3614	95%

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure. It is assumed that only a small minority of participants have regular behavioral patterns that would produce demand reduction. These patterns entail not being at home during the peak period and not already setting the temperature back during that time.

Life-cycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 9 years)[1]

Deemed Savings

Deemed Savings

Measure	MMID	Peak kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms
Smart Thermostat, Installed With:						
95% AFUE NG Furnace	3612	0	439	3,951	29	261
96% AFUE NG Furnace	4054	0	439	3,951	29	261
97% AFUE NG Furnace	4055	0	439	3,951	29	261
98% AFUE NG Furnace	4056	0	439	3,951	28	252
95% AFUE NG Boiler	3613	0	325	2,925	44	396
90% AFUE NG Boiler	5271	0	325	2,925	47	423
Furnace and A/C	3614	0	420	3,780	29	261
Air Source Heat Pump	3615	0	411	3,699	0	0

Assumptions

For more context on the background of the smart and communicating thermostats averaged in this workpaper, including savings formulas, assumptions, and citations, see the workpapers for measures 4301, 4302, and 4303 (smart) and for measures 4298, 4299, and 4300 (communicating).

It is assumed that furnace sites participating in the billing analysis had an average furnace $AFUE_{BILL}$ of 92.8%. This reflects the average market value AFUE, as calculated as part of the 2017 Standard Market Practice analysis in the 2017 Focus on Energy Evaluation Report.[3] This value was chosen over the stock value of 91.4%, recorded as part of the 2016 Focus on Energy Potential Study,[4] because it was assumed that smart thermostat participants generally have more efficient furnaces than the average WI site.

Pre-install consumption was scaled based on the difference between $AFUE_{BILL}$ and $AFUE_{MEAS}$—because the furnaces are more efficient, consumption without the thermostat would have been less than the pre-thermostat consumption recorded as part of the billing analysis.

A related normalization is performed regarding the fraction of billing analysis furnace sites with and without air conditioners. The average cooling kWh consumption of all such sites is 653 kWh. But the average consumption of those sites with an air conditioner is higher. For instance, if 80% of billing analysis furnace sites had air conditioners it could be assumed that the average site with an air conditioner consumed 653 / 80% = 816 kWh for its cooling needs, and this should be the pre-thermostat consumption for the furnace and AC combination measure.

This fraction likely lies between two known values. The first one is the 84.0% value recorded by the 2016 Focus on Energy Potential Study,[4] which reflects the average value for all WI single family sites. The second one is the 92.5% value that reflects the fraction of sites receiving a furnace-only measure that also have an air conditioner.[5] It is assumed that sites receiving a smart thermostat are more likely to have an air conditioner than general building stock, and that the fraction of billing analysis furnace sites with air conditioners is 92.5%. Therefore the pre-thermostat consumption for sites with a furnace and AC combo measure is 653 / 92.5% = 705.9 kWh.

It is also assumed that billing analysis furnace sites and sites installing a smart thermostat along with their furnace-only measure have the same air conditioner fraction.

The assumed SEER of sites from the billing analysis, $SEER_{BILL}$, is 13.9. Like $AFUE_{BILL}$, this reflects the 2017 Standard Market Practice analysis in the 2017 Focus on Energy Evaluation Report[3] and was chosen over the stock baseline of 12.1.[4]

Air source heat pump base HSPF is assumed to be 7.7, matching the value assumed by the air source heat pump measure (MMID 2992).

Sources

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2. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. July 2017 to December 2017. Average actual measure cost of smart thermostat measures incented by Focus on Energy is $213.00 (MMIDs 3609, 3610, and 3611). Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.
3. Cadmus. *Focus on Energy Calendar Year 2017 Evaluation Report*. Volume II. May 22, 2018. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202017%20Volume%20II%20FINAL.pdf
4. Cadmus. *2016 Potential Study for Focus on Energy.*
   Data maintained by Cadmus and Wisconsin PSC.
   Based on site visit data from 103 single family homes in Wisconsin.
5. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Revision History

Version Number	Date	Description of Change
01	9/2018	Initial TRM entry
02	1/2022	Added 90% boiler measure, updated EUL

Smart Thermostats, Contractor Install

	Measure Details
Measure Master ID	Smart Thermostat, Existing Natural Gas Boiler, Contractor Install, 5256 Smart Thermostat, Existing Natural Gas Furnace, Contractor Install, 5258 Smart Thermostat, Existing Air-Source Heat Pump, Contractor Install, 5254
Workpaper ID	W0297
Measure Unit	Per thermostat
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by existing heating system
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by existing heating system
Lifecycle Energy Savings (kWh)	Varies by existing heating system
Lifecycle Therm Savings (Therms)	Varies by existing heating system
Water Savings (gal/year)	0
Effective Useful Life (years)	9[1]
Incremental Cost ($/unit)	$207.67[2]

Measure Description

Standard programmable thermostats (PTs), when running a program, automatically change temperature setpoints according to a schedule. Typical 5/2 PT schedules include weekday setbacks during working hours as well as daily setbacks during sleep hours. When used, these setbacks result in more energy-efficient temperatures during unoccupied and overnight periods to enable energy savings. However, research has suggested that many PTs are kept in permanent-hold,[6] which effectively eliminates savings from automatic setbacks: "...90% of respondents reported that they rarely or never adjusted the thermostat to set a weekend or weekday program. Photographs of thermostats were collected in one online survey, which revealed that about 20% of the thermostats displayed the wrong time and that about 50% of the respondents set their programmable thermostats on 'long-term hold' (or its equivalent)."

Some consumers, however, may manually setback their manual or programmable thermostat to achieve savings even when kept in permanent hold.

Compared to PTs, smart thermostats provide enhanced functionality that can include:

- More simple use and programming, both on the thermostat and remotely via smartphone apps and web portals
- Occupancy sensing that enables energy savings from automatic setbacks during unoccupied periods (occupancy sensing may use sensors in the thermostat or capability to track the resident's location through a smartphone app)
- Learning capability or automatic schedule generation or modification (such thermostats are capable of dynamically adjusting or constructing a program schedule based on actual occupancy patterns, eliminating the need for programming)
- Intelligent control of HVAC equipment, including minimizing energy expended for recovery from setback, intelligent control of two-stage HVAC sources, and minimizing the use of inefficient electric-resistance heat (which is associated with most heat-pumps)
- Use of outside temperature and other weather data to better ensure comfort and minimize energy use
- Encourage the use of more energy-efficient set temperatures, such as a leaf icon that appears when the set temperature is moved in the direction of less energy use
- Algorithms that make frequent, subtle set temperature changes to save energy

Description of Baseline Condition

The baseline condition is a manual or standard programmable thermostat installed in a home with an existing natural gas furnace, natural gas boiler, or air-source heat pump (ASHP). Customer may purchase through any retailer and apply for the incentive online or purchase through the Focus on Energy Online Marketplace and receive the incentive instantly.

Description of Efficient Condition

The efficient condition is a smart thermostat installed in a home by a contractor to replace an existing manual or programmable thermostat. To qualify as smart, the thermostat must be certified as an ENERGY STAR Connected Thermostat,or meet the following requirements:

- Must be Wi-Fi capable
- Must be capable of internet connection
- Must feature occupancy sensing, via geolocation and/or motion sensing
- The above features must be built-in and not require add-on devices or services
- The application and connectivity service must be free after thermostat purchase
- Thermostat default behavior must be to set back temperature when house is unoccupied

.

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{CONS}_{\text{THERM}} * \text{ESF}_{\text{THERM}} * \text{P}_{\text{MF,AREA}}$

$\text{kWh}_{\text{SAVED}} = (\text{CONS}_{\text{kWh,COOL}} * \text{P}_{\text{MF,AC}} * \text{ESF}_{\text{kWh,COOL}} + \text{CONS}_{\text{kWh,HEAT}} * \text{ESF}_{\text{kWh,HEAT}}) * \text{P}_{\text{MF,AREA}}$

Where:

$\text{CONS}_{\text{THERM}}$ = Annual therms consumed by smart thermostat participants before smart thermostat installation (= 653 therms for furnace; = 1,050 therms for boiler; = 0 therms for ASHP)

$\text{ESF}_{\text{THERM}}$ = Therm energy savings fraction (= 4.6% for furnace; = 5.0% for boiler; = 0% for ASHP)

$\text{P}_{\text{MF,AREA}}$ = Scale factor for multifamily home size (= 100.0% for single family; =52.9% for multifamily, see the Assumptions section)[7]

$\text{CONS}_{\text{kWh,COOL}}$ = Annual cooling kilowatt-hours consumed by smart thermostat participants before smart thermostat installation (= 1,584 kWh for furnace, boiler, and ASHP)

$\text{P}_{\text{MF,AC}}$ = Scale factor for multifamily homes with natural gas furnaces and central air conditioners (= 100.0% for single family and multifamily with boiler and ASHP; = 112.6% for multifamily with natural gas furnace, see the Assumptions section)[7]

$\text{ESF}_{\text{kWh,COOL}}$ = Kilowatt-hour energy savings fraction for cooling (= 20.5% for furnace, boiler, and ASHP)

$\text{CONS}_{\text{kWh,HEAT}}$ = Annual heating kilowatt-hours consumed by smart thermostat participants before smart thermostat installation (= 808 kWh for furnace; = 0 kWh for boiler; = 962 kWh for ASHP)

$\text{ESF}_{\text{kWh,HEAT}}$ = Kilowatt-hour energy savings fraction for heating (= 14.2% for furnace; = 0% for boiler; = 12% for ASHP)[3]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure. It is assumed that only a small minority of participants have regular behavioral patterns that would produce demand reduction, such as not being at home during the peak period and not already setting the temperature back during that time.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 9 years)[1]

Deemed Savings

Annual and Lifecycle Savings by Measure

Measure	MMID	Sector	Peak kW	Annual kWh	Lifecycle kWh	Annual therms	Lifecycle therms
Smart Thermostat, Existing Natural Gas Boiler, Contractor Install	5256	SF	0	325	2,925	53	477
		MF	0	172	1,548	28	252
Smart Thermostat, Existing Natural Gas Furnace, Contractor Install	5258	SF	0	439	3,951	30	270
		MF	0	254	2,286	16	144
Smart Thermostat, Existing Air Source Heat Pump, Contractor Install	5254	SF	0	440	3,960	-	-
		MF	0	233	2,097	-	-

Assumptions

For the CY2016 Focus evaluation, Cadmus conducted a billing analysis to examine savings for participants who installed smart thermostats as part of MMIDs 3609, 3610, and 3611 (former versions of measures 4301, 4302, 4303). There were 2,427 natural gas customers and 2,110 electric customers for this analysis. Following a Princeton Scorekeeping Method (PRISM) modeling approach, the analysis filtered weather-sensitive electric and natural gas consumption from total electric and natural gas usage, and determined smart thermostat savings as a percentage of this consumption.

The 2016 Focus on Energy Evaluation Report[4] discusses these findings, but does not break them into components for heating and cooling, or for furnace, boiler, and ASHP smart thermostat measures: that analysis is discussed below.

Therm Savings

Of the 2,427 natural gas customers, 2,329 had a natural gas furnace. Based on the billing data for these participants, their baseline natural gas consumption averages 653 therms, and the savings fraction from installing a smart thermostat for these participants is 4.6% (30 therms).

There were 93 participants with a natural gas boiler. Their average baseline natural gas consumption is 1,050 therms, and the savings fraction for these participants is 5.0%. The relative precision for all these values is ≤ 9%.

Electric Savings

Furnaces

Of the 2,110 electric customers, 2,089 had a natural gas furnace installed. Many of these homes also had an air conditioner installed: the sample represents an average split of homes with and without air conditioning where smart thermostats were installed.

The average baseline electric consumption for participant houses with a natural gas furnace is 2,392 kWh. This consisted of 1,584 kWh in the cooling season and 808 kWh in the heating season. Heating season consumption may be from furnace motors and participant homes with electric space heating.

The analysis revealed savings factors of 20.5% for cooling season consumption and 14.2% for heating season consumption, with an overall electric savings factor of 18.4%. Relative precision values for heating and cooling consumption and cooling savings are ±8%, and relative precision for heating savings is ±24%.

Boilers

Electric data for boilers is limited, since the billing analysis only examined electric data for three homes. While the results are imprecise due to the small sample (at ±55% to ±75% precision), cooling consumption and savings were observed for these homes, which indicates many had air conditioner installed and controlled by their thermostat. Therefore, the cooling consumption and savings for participants with natural gasfurnace is applied to the smart thermostat with boiler measure.

Air-Source Heat Pumps

The billing analysis examined data for 18 homes with an ASHP. Cooling consumption and savings values for these homes were generally imprecise, with precision around ±35%. Therefore, the cooling consumption and savings values for furnaces was used, knowing that these values generally reflect homes with an air conditioner.

Previously, the ASHP heating consumption value was 2,902 kWh, based on the heat pump providing all heat during winter. However, the billing analysis revealed an ASHP heating consumption of value of 962 kWh. This value is also imprecise, at ±60%, but still indicates that ASHPs are not generally providing all a participant’s home winter heating needs. Therefore, the value of 962 kWh is used for baseline ASHP heating consumption. The ASHP heating savings value is extremely imprecise, so a value of 12% is obtained and used from a different study.[3]

All the above values were for the average participant in each of the three measures, and represent an average split of system AFUE and SEER values, houses with and without air conditioning, space heating, manual and programmable thermostats, and other variables.

Scaling for Multifamily

The billing analysis that serves as the basis for this study examined thermostats installed in single family residences. Multifamily residences are assumed to have the same energy savings fractions, but consumptions scale due to two factors.

First, all multifamily heating and cooling consumptions scale based on residence size. Data from the Wisconsin Focus on Energy Potential Study[7] indicate that the average single family home has 1,652 sq ft of finished space, while the average multifamily unit has 874 sq ft of finished space. Therefore, all consumption values for multifamily homes incorporate an area scaling factor of $P_{MF,AREA}$ equal to 874 divided by 1,652 (52.9%).

Second, multifamily cooling consumption for natural gas furnace sites is also scaled. The average natural gas furnace cooling consumption observed in the billing analysis is directly dependent on the fraction of those homes that have central air conditioners. That fraction, while not specifically known for the billing analysis sample, may be different for multifamily sites receiving smart thermostats. The Potential Study sample may be different from the billing analysis sample, but its data can be used here. The Potential Study data shows that 85.5% of multifamily sites with natural gas furnaces also have central air conditioners, and that this fraction for single family sites is 75.9%. Therefore for multifamily sites with natural gas furnaces, there is an assumed cooling consumption scaling factor of $P_{MF,AC}$ equal to 85.5 divided by 75.9 (112.6%).

Sources

1. Cadmus. *EUL Analysis of Residential Smart Communicating Thermostat—Vendor A and B*. February 1, 2019. https://www.caetrm.com/media/reference-documents/SWHC039-01_A8_-_EUL_Analysis.pdf
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 39,243 projects and 39,984 units from January 2018 to July 2020 is $246.78 (MMIDs 3612 - 3615, 4054 - 4056, and 4301 - 4303 in single family sectors). Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.
3. Apex Analytics. *Nest Thermostat Heat Pump Control Pilot Evaluation*. Prepared for Energy Trust of Oregon. October 10, 2014. https://nest.com/downloads/press/documents/energy-trust-of-oregon-pilot-evaluation-whitepaper.pdf
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5. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 5.0. Volume 3: Residential Measures*. February 11, 2016. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Final/IL-TRM_Effective_060116_v5.0_Vol_3_Res_021116_Final.pdf

6. Meier, Alan, C. Aragon, T Peffer, D. Perry, and M. Pritoni. *Usability of Residential Thermostats: Preliminary Investigations*. October 2011. http://www.sciencedirect.com/science/article/pii/S0360132311000874
7. Cadmus. *2016 Potential Study for Focus on Energy*. Data maintained by Cadmus and Wisconsin PSC. Data includes information 103 single family sites and 92 multifamily units.

Revision History

Version Number	Date	Description of Change
01	03/2015	Initial TRM entry
02	06/2017	Updated based on Cadmus billing analysis
03	11/2017	Updated to include multifamily savings
04	12/2018	Updated incremental cost
05	08/2020	Updated incremental cost
06	12/2021	Updated EUL, changed MMIDs and measure names to clarify that these are now for contractor install only

Smart Thermostat, Retail Purchase

	Measure Details
Measure Master ID	Smart Thermostat, Existing Natural Gas Boiler, Retail Purchase, 5257 Smart Thermostat, Existing Natural Gas Furnace, Retail Purchase, 5259 Smart Thermostat, Existing Air-Source Heat Pump, Retail Purchase, 5255
Workpaper ID	W0298
Measure Unit	Per thermostat
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
4Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/yr)	0
Effective Useful Life (years)	9[1]
Incremental Cost ($/unit)	$207.67[2]

Measure Description

Standard programmable thermostats require customers to adjust temperature setpoints at different times of the day, manually changing temperatures during unoccupied periods to allow for some energy savings.

Smart thermostats provide enhanced functionality that can include several features:

- Easier use and programming, both on the thermostat and remotely via smartphone apps and web portals.
- Occupancy sensing that enables energy savings from automatic setbacks during unoccupied periods. Occupancy sensing may use sensors in the thermostat or capability to track the resident’s location through a smartphone app.
- Learning capability or automatic schedule generation and modification. Such thermostats are capable of dynamically adjusting and/or constructing a program schedule based on actual occupancy patterns, eliminating the need for programming.
- Intelligent control of HVAC equipment, including minimizing the energy expended for recovery from setback, having intelligent control of two-stage HVAC sources, and minimizing the use of inefficient electric-resistance heat associated with most heat pumps.

- Use of outside temperature and other weather data to better ensure comfort and minimize energy use.
- Encourage use of more energy-efficient set temperatures (for example, an icon of a leaf appears when the set temperature is moved in the direction of less energy use).
- Algorithms that make frequent, subtle temperature changes in order to save energy.

The savings calculations for these measures are based on the deemed savings values for the contractor install smart thermostat workpaper (W0297, MMIDs 4301–4303), which contains a thorough explanation of billing analysis results.

Description of Baseline Condition

The baseline condition is a manual or standard programmable thermostat installed in a home with an existing natural gas furnace, natural gas boiler, air-source heat pump (ASHP), or other HVAC system. While the measure names reflect the three systems analyzed in the PY 2016 Smart Thermostat Pilot billing analysis, the estimated savings for each have been updated to reflect actual HVAC system mix for each.

Description of Efficient Condition

The efficient condition is a smart thermostat, purchased through the online store, installed in a home to replace the existing thermostat.

To qualify as *smart*, the thermostat must be certified as an ENERGY STAR Connected Thermostat or Meet the following requirements:

- Must be Wi-Fi capable
- Must be capable of internet connection
- Must feature occupancy sensing, via geolocation and/or motion sensing
- The above features must be built-in and not require add-on devices or services
- The application and connectivity service must be free after thermostat purchase
- Thermostat default behavior must be to set back temperature when house is unoccupied

Annual Energy-Savings Algorithm

$Therm_{SAVED} = \Sigma_{HVAC\text{-}SYS} (Fraction_{HVAC\text{-}SYS} * Therms_{HVAC\text{-}SYS}) * P_{MF,AREA}$

$kWh_{SAVED} = \Sigma_{HVAC\text{-}SYS} (Fraction_{HVAC\text{-}SYS} * kWh_{HVAC\text{-}SYS}) * P_{MF,AREA} * P_{MF,AC}$

Where:

$\Sigma_{HVAC\text{-}SYS}$ = Summary (sum product) across HVAC system types in the Survey Respondents by HVAC System Type and Estimated Savings for Various Surveyed HVAC Systems tables below

$Fraction_{HVAC\text{-}SYS}$ = Fraction of surveyed sites with a particular HVAC system type (see Survey Respondents by HVAC System Type table below)

$Therms_{HVAC\text{-}SYS}$ = Estimated therm savings for the HVAC system type (see Estimated Savings for Various Surveyed HVAC Systems table below)

$P_{MF,AREA}$ = Scale factor for multifamily home size (= 100.0% for single family; = 52.9% for multifamily, see Assumptions)[3]

$kWh_{HVAC\text{-}SYS}$ = Estimated kWh savings for the HVAC system type (see Estimated Savings for Various Surveyed HVAC Systems table below)

$P_{MF,AC}$ = Scale factor for multifamily homes with natural gas furnaces and central air conditioners (= 100.0% for single family and multifamily with boiler and ASHP; = 109.6% for multifamily with natural gas furnace, see Assumptions)[3]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure. It is assumed that only a small minority of participants have regular behavioral patterns that would produce demand reduction. These patterns entail not being at home during the peak period and not already setting the temperature back during that time.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 9 years)[1]

Deemed Savings

Deemed Savings for Self-Installed Thermostats

Measure	MMID	Sector	Peak kW	Annual kWh	Annual Therms	Lifecycle kWh	Lifecycle Therms
Existing Natural Gas Boiler, Retail Purchase	5257	Single family	0	86	53	774	477
		Multifamily	0	45	28	405	252
Existing Natural Gas Furnace, Retail Purchase	5259	Single family	0	457	28	4,113	252
		Multifamily	0	265	15	2,385	135
Existing Air Source Heat Pump, Retail Purchase	5255	Single family	0	909	10	8,181	90
		Multifamily	0	481	5.29	4,329	47.6

Assumptions

For the CY2016 Focus evaluation, Cadmus conducted a billing analysis to examine savings for participants who installed smart thermostats as part of MMIDs 3609, 3610, and 3611 (former versions of measures 4301, 4302, 4303). These participants had one of three HVAC systems in place: a gas boiler, a gas furnace, or an air-source heat pump. Details are are discussed in detail in the workpaper for contractor-installed thermostats, W0297. The final annual savings by HVAC system can be seen in the Savings by System from CY2016 Billing Analysis table below.

Savings by System from CY2016 Billing Analysis

HVAC System	Savings kWh_{COOL}	Savings kWh_{HEAT}	Savings Therms	Billing Analysis Savings Note
Natural gas furnace	324.7	114.7	30	Some sites had AC and others did not; savings reflect overall sample.
Natural gas boiler	324.7	0.0	53	Poor precision for kWh, assumed same kWh_{COOL} as furnace and kWh_{HEAT} = 0.
Air source heat pump	324.7	115.4	0	Poor precision for savings. Assumed same kWh_{COOL} as furnace. Used billing analysis baseline consumption but applied 12% savings fraction from other work.

The previous thermostat MMIDs (4301, 4302, 4303) have been used for user-installed thermsotats for some time. Subsequent survey efforts have shown that they are often installed with HVAC systems that do not line up with those in the measure names, and on which the original savings are based. These systems include alternate heating systems such as propane furnaces and pellet stoves, and may or may not include central air conditioning (CAC). These survey results by system can be seen for each MMID in the Survey Respondents by HVAC System Type table below.

Survey Respondents by HVAC System Type

HVAC System	MMID 4301, Boiler		MMID 4302, Furnace		MMID 4303, ASHP	
	Count	%	Count	%	Count	%
NG furnace	0	0.0%	21	18.3%	1	33.3%
NG furnace + CAC	0	0.0%	80	69.6%	0	0.0%
Propane furnace	0	0.0%	2	1.7%	0	0.0%
Propane furnace + CAC	0	0.0%	0	0.0%	0	0.0%
Oil furnace	0	0.0%	0	0.0%	0	0.0%
Oil furnace + CAC	0	0.0%	0	0.0%	0	0.0%
Elec furnace	0	0.0%	3	2.6%	0	0.0%
Elec furnace + CAC	0	0.0%	1	0.9%	2	66.7%
NG boiler	4	80.0%	2	1.7%	0	0.0%
NG boiler + CAC	1	20.0%	1	0.9%	0	0.0%
Elec boiler + CAC	0	0.0%	0	0.0%	0	0.0%
Propane boiler + ASHP	0	0.0%	0	0.0%	0	0.0%
ASHP	0	0.0%	3	2.6%	0	0.0%
GSHP / geothermal	0	0.0%	0	0.0%	0	0.0%
Wood Pellets + CAC	0	0.0%	2	1.7%	0	0.0%
NG furnace	0	0.0%	21	18.3%	1	33.3%
Total	**5**		**115**		**3**	

For each of these HVAC system types, savings were estimated based on the original savings for the measures, and making rough rudimentary assumptions. Those savings and assumptions are presented in the Estimated Savings for Various Surveyed HVAC Systems table below. Note that it is assumed that 75.9% of the original furnace site population from the CY2016 billing analysis had air conditioners. This is the fraction of single family sites with gas furnaces that also had air conditioning observed in the 2016 Focus on Energy Potential Study.

Estimated Savings for Various Surveyed HVAC Systems

HVAC System	Estimated Savings		Savings Note
	kWh	Therms	
NG furnace	114.7	30	Like savings from MMID 4301, but assume heating kWh (furnace motor) only
NG furnace + CAC	542.6	30	Like savings from MMID 4301, but cooling kWh is increased assuming original savings reflect that 75.9% of sites had CAC
Propane furnace	114.7	0	Assume same kWh as gas furnace
Propane furnace + CAC	542.6	0	Assume same kWh as gas furnace + CAC
Oil furnace	114.7	0	Assume same kWh as gas furnace
Oil furnace + CAC	542.6	0	Assume same kWh as gas furnace + CAC
Elec furnace	879.0	0	Convert NG furnace therms to kWh
Elec furnace + CAC	1,306.8	0	Same, and add cooling kWh as for gas furnace
NG boiler	0.0	53	Same as MMID 4301
NG boiler + CAC	427.8	53	Add cooling savings from MMID 4301, increased assuming original savings reflect that 75.9% of sites had CAC
Elec boiler + CAC	1,552.9	0	Convert therms to kWh
Propane boiler + ASHP	382.4	0	Assume ASHP for cooling, count half of ASHP heating
ASHP	440.0	0	Same as MMID 4303
GSHP / geothermal	440.0	0	Assume same as ASHP
Wood Pellets + CAC	427.8	0	Assume cooling savings from MMID 4301, increased assuming original savings reflect that 75.9% of sites had CAC

Because users must select one of the three original HVAC systems when obtaining a rebated user-installed thermostat, those system names are preserved in the measure names. The savings for each reflects a weighted average of the survey responses for actual HVAC system types (the Survey Respondents by HVAC System Type table) and the rough estimated savings for each HVAC system type (the Estimated Savings for Various Surveyed HVAC Systems table). Those results can be seen in the Deemed Savings for Self-Installed Thermostats table above.

It is assumed that self-installed smart thermostats will have an installation rate matching that of the 2016 smart thermostat pilot.

Scaling for Multifamily

The billing analysis that serves as the basis for this study examined thermostats installed in single family residences. Multifamily residences are assumed to have the same energy savings fractions, but savings scale due to two factors.

First, all multifamily heating and cooling consumptions scale based on residence size. Data from the Wisconsin Focus on Energy Potential Study[3] indicate that the average single family home has 1,652 sq ft of finished space, while the average multifamily unit has 874 sq ft of finished space. Therefore, all consumption values for multifamily homes incorporate an area scaling factor of $P_{MF,AREA}$ equal to 874 divided by 1,652 (52.9%).

Second, multifamily cooling consumption for natural gas furnace sites is also scaled. The average natural gas furnace cooling consumption observed in the billing analysis is directly dependent on the fraction of those homes that have central air conditioners. That fraction, while not specifically known for the billing analysis sample, may be different for multifamily sites receiving smart thermostats. The Potential Study sample may be different from the billing analysis sample, but its data can be used here. The Potential Study data shows that 85.5% of multifamily sites with natural gas furnaces also have central air conditioners, and that this fraction for single family sites is 75.9%. Multifamily savings in W0297 are 193 kWh from cooling, 61 kWh from heating, a ratio of 193 / (193 + 61) = 75.98% from cooling. Therefore for multifamily sites with natural gas furnaces, there is an assumed cooling consumption scaling factor of $P_{MF,AC}$ equal to (1 - 75.98%) + (75.98% * 112.6%) = 109.6%.

Sources

1. Cadmus. *EUL Analysis of Residential Smart Communicating Thermostat—Vendor A and B*. February 1, 2019. https://www.caetrm.com/media/reference-documents/SWHC039-01_A8_-_EUL_Analysis.pdf
2. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 39,243 projects and 39,984 units from January 2018 to July 2020 is $246.78 (MMIDs 3612 - 3615, 4054 - 4056, and 4301 - 4303 in single family sectors). Minus the cost of a manual thermostat, which is $39.11 based on online lookups from July 2018.
3. Cadmus. 2016 Potential Study for Focus on Energy. Data maintained by Cadmus and Wisconsin PSC. Data includes information 103 single family sites and 92 multifamily units.

Revision History

Version Number	Date	Description of Change
01	12/2021	Initial TRM entry

Smart Thermostat, Electric Baseboard

	Measure Details
Measure Master ID	Smart Thermostat, Line Voltage, Electric Baseboard, 5050
Workpaper ID	W0258
Measure Unit	Per home
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Controls
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/yr)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$139.00 per thermostat[2]

Measure Description

Thermostats for typical central HVAC systems get power and send signals via low voltage wires running to the furnace, boiler, air conditioner, or heat pump control panel. However, the controls for baseboard electric heaters are installed as part of the full-voltage circuit powering the heater, typically 120 volt or 240 volt. Therefore, this equipment is often referred to as line voltage thermostats. These are often manual thermostats, although programmable varieties have been widely available for some time.

Recently, line voltage smart thermostats have become available that offer several features similar to standard smart thermostats:

- More simple use and programming
- Occupancy sensing (via sensors on the thermostat or location tracking via smartphone app)
- Learning capability, automatic schedule generation or modification, or both
- Encourages the use of more energy-efficient set temperatures

Description of Baseline Condition

The baseline condition is a manual or standard programmable thermostat installed in a home with baseboard electric heat.

Description of Efficient Condition

The efficient condition is a smart thermostat installed in a home to replace the existing thermostat. To qualify as smart, the thermostat must have occupancy sensing capability, learning capability, automatic schedule generation, or a combination of those funtions.

Baseboard smart thermostats are required to be installed on each baseboard heater in the home and the home is required to be heated by only baseboard heat.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = CONS_{kWh,HEAT} * ESF_{kWh,HEAT}$

Where:

$CONS_{kWh,HEAT}$ = Estimated average annual heating kilowatt-hours consumed by homes with baseboard electric heat (= 8,280 kWh for single family, = 3,750 kWh for multifamily; see Assumptions)[3]

$ESF_{kWh,HEAT}$ = Kilowatt-hour energy savings fraction for heating (= 5%; see Assumptions)

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 10 years)[1]

Deemed Savings

Annual and Lifecycle Savings

Sector	Peak Savings (kW)	Annual Savings (kWh)	Lifecycle Savings (kWh)
Single family	0	414	4,140
Multifamily	0	188	1,880

Assumptions

Very few studies have been conducted to examine smart thermostat performance with electric heat (heat pump, baseboard, or resistance heat with forced air); these and other studies examining natural gas savings are presented in the Known Smart Thermostat Billing Analysis Studies table below. Note that this table only shows studies with a baseline that is a mix of manual and programmable thermostats, and only known natural gas studies only in the Upper Midwest. Findings from these studies were used to deem a savings fraction of 5% for baseboard heater smart thermostats.

Known Smart Thermostat Billing Analysis Studies
(Upper Midwest Heating and U.S. Electric Heating)

State	Source	Equipment	Participant Count	Findings
FL	4	Mixed heat pumps and resistance	30	9.6% of heating load
OR	5	Heat pumps	176	4% of whole home load, 12% of HVAC load
OR	6	Heat pumps	113 treatment 211 control	4.7% of whole home load, 12% of heating load
MI	7	Natural gas heating	6,479	28 therms savings
WI	8	Natural gas heating	2,427	4.8% of heating load
IL	9	Natural gas heating	2,118 treatment 2,058 control	6.7% of heating load
IL	10	Natural gas heating	76	3% of heating load

To estimate base consumption for homes with baseboard heat, data from the 2015 Residential Energy Consumption Survey[3] was used. Four filters were applied and a weighted average was obtained:

- Census division = 3 (IN, IL, MI, OH, WI)
- Type of housing = single family detached, single family attached, or multifamily apartment in a building with more than five units
- Equipment type = built-in electric units installed in walls, ceilings, basements, or floors
- Heating fuel = electricity

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures*. Table 1, HVAC Controls. 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
   Used programmable thermostat effective useful life as the closest proxy.
2. Retail cost of Mysa baseboard heater thermostat, as of August 2020.
3. U.S. Energy Information Administration. 2015 Residential Energy Consumption Survey Data. https://www.eia.gov/consumption/residential/data/2015/
4. D. Parker, K. Sutherland, and D. Chaser (Florida Solar Energy Center). ACEEE Evaluation of the Space Heating and Cooling Energy Savings of Smart Thermostats in a Hot-Humid Climate Using Long-Term Data. 2016. https://www.aceee.org/files/proceedings/2016/data/papers/8_163.pdf
5. P. Kelvsen, and R. Weber (Bonneville Power Administration). *A Look Inside the Eye on the Wall: Sub-Metering Data Analysis and Savings Assessment of the Nest Learning Thermostat*. https://www.aceee.org/files/proceedings/2016/data/papers/1_351.pdf

6. Apex Analytics LLC. *Energy Trust of Oregon Nest Thermostat Heat Pump Control Pilot Evaluation*. October 10, 2014. https://storage.googleapis.com/nest-public-downloads/press/documents/energy-trust-of-oregon-pilot-evaluation-whitepaper.pdf
7. Navigant. *Michigan Tier 3 Thermostat Calibraton Study*. May 15, 2018. https://www.michigan.gov/documents/mpsc/Tier_3_Tstat_Calibration_Study_EWR_Presentation_623038_7.pdf
8. Cadmus. Focus on Energy PY2016 smart thermostat billing analysis results. See TRM workpaper W0204 for more detail.
9. Navigant. *Residential Smart Thermostats. Impact Analysis – Gas Preliminary Findings*. December 16, 2015. https://s3.amazonaws.com/ilsag/Smart_Tstat_Preliminary_Gas_Impact_Findings_2015-12-08_to_IL_SAG.pdf
10. Gas Technology Institute. *Emerging Technology Program, 1022: Home Energy Management System Utilizing a Smart Thermostat*. Executive Summary. May 4, 2015. https://www.nicorgasrebates.com/-/media/Files/NGR/PDFs/ETP/1022_Smart_Thermostat-HEMS_FINAL_APPROVED_Public_Project_Report_to_Nicor_Gas_05-04-2015.pdf

Revision History

Version Number	Date	Description of Change
01	08/2020	Initial TRM entry

Gas Furnaces

	Measure Details
Measure Master ID	NG Furnace, Multi-Stage+, 95% AFUE, 4962 NG Furnace, Multi-Stage+, 96% AFUE, 4963 NG Furnace, Multi-Stage+, 97% AFUE, 4964 NG Furnace, Multi-Stage+, 98%+ AFUE, 4965 NG Furnace, Multi-Stage+, Tier 2, 95% AFUE, 4966 NG Furnace, Multi-Stage+, Tier 2, 96% AFUE, 4967 NG Furnace, Multi-Stage+, Tier 2, 97% AFUE, 4968 NG Furnace, Multi-Stage+, Tier 2, 98%+ AFUE, 4969 NG Furnace, Single-Stage, 95% AFUE, 4970 NG Furnace, Single-Stage, 96% AFUE, 4971 NG Furnace, Single-Stage, Tier 2, 95% AFUE, 4972 NG Furnace, Single-Stage, Tier 2, 96% AFUE, 4973 MF NG Furnace, Multi-Stage+, 95% AFUE, 4950 MF NG Furnace, Multi-Stage+, 96% AFUE, 4951 MF NG Furnace, Multi-Stage+, 97% AFUE, 4952 MF NG Furnace, Multi-Stage+, 98%+ AFUE, 4953 MF NG Furnace, Multi-Stage+, Tier 2, 95% AFUE, 4954 MF NG Furnace, Multi-Stage+, Tier 2, 96% AFUE, 4955 MF NG Furnace, Multi-Stage+, Tier 2, 97% AFUE, 4956 MF NG Furnace, Multi-Stage+, Tier 2, 98%+ AFUE, 4957 MF NG Furnace, Single-Stage, 95% AFUE, 4958 MF NG Furnace, Single-Stage, 96% AFUE, 4959 MF NG Furnace, Single-Stage, Tier 2, 95% AFUE, 4960 MF NG Furnace, Single-Stage, Tier 2, 96% AFUE, 4961
Workpaper ID	W0207
Measure Unit	Per furnace
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Furnace
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by heating stage, tier, and sector
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	Varies by AFUE, tier, and sector
Lifecycle Energy Savings (kWh)	Varies by rated input heating capacity and AFUE
Lifecycle Therm Savings (Therms)	Varies by AFUE, tier, and sector
Water Savings (gal/year)	0
Effective Useful Life (years)	21[1]

	Measure Details
Incremental Cost ($/unit)	Varies by measure, see Deemed Savings and Costs table below

Measure Description

Conventional natural gas furnaces produce by-products, such as water vapor and carbon dioxide, that are usually vented out through a chimney along with a considerable amount of heat. This occurs not only when the furnace is in use, but also when it is turned off. Newer designs increase energy efficiency by reducing the amount of heat that escapes and by extracting heat from the flue gas before it is vented. These furnaces use much less natural gas than conventional furnaces.

In addition to natural gas savings, furnaces can save electricity through more efficient blower motors. These are commonly ECMs and can generally be constant-torque or constant airflow (true variable speed). Additional electric savings can be achieved by employing these motor types with a burner staging strategy that allows for the furnace blower to run at lower speed when the full heating capacity of the furnace is required. While the blower may run for longer on these furnaces, the reduced electrical use at these lower speeds creates significant savings.

Multifamily measures are for in-unit furnaces, as opposed to MMIDs 3491 and 3492, which are considered common area furnaces.

Description of Baseline Condition

The current federal furnace standard is an 80% AFUE single-stage furnace with a blower motor that meets a fan energy rating (FER) performance requirement.[6,7] However, data on furnace sales in Wisconsin indicate a higher AFUE market baseline for natural gas furnaces. Non-income eligible measures (Tier 1) use a 92.8% AFUE furnace as the baseline, based on sales and audit data indicating that this was the average AFUE of units sold in Wisconsin in 2015.[2] Income eligible measures (Tier 2) maintain an 80% AFUE baseline, the lowest AFUE for which sales were present in the sales data, due to income restraints for participating consumers. Multifamily measures are assumed to have a baseline AFUE of 86.7%, which is an average of the PY2020 single family market AFUE of 93.34%[3] and the low-income AFUE value of 80%. This presumes that multifamily baselines are a mix of low-income and whole-market values.

Description of Efficient Condition

The efficient furnace condition varies by measure-specific requirements; the measure master name largely explains the efficient condition for each measure. For all measures, the efficient condition pertains to a furnace installed in either a single family or a multifamily residential application.

Annual Energy-Savings Algorithm

$Therm_{SAVED} = CAP * hours_{HEATING} * (AFUE_{EE} / AFUE_{BASE} – 1) / 100$

$kWh_{SAVED} = kWh_{BASE} - kWh_{EE}$

Where:

CAP = Rated input heating capacity (= varies by measure, see Deemed Inputs table below, see Assumptions)[3]

$hours_{HEATING}$ = Hours of heating operation (= 1,158 hours)[4]

$AFUE_{EE}$ = Efficient AFUE (= varies by measure, see Deemed Inputs table below)

$AFUE_{BASE}$ = Baseline AFUE (= 86.7% for multifamily; = 80.0% for Tier 2; = 92.8% for single family Tier 1, see Assumptions)

kWh_{BASE} = Electric energy consumed for the baseline motor (= 482.8 kWh for Tier 1 multi-stage; = 468.5 kWh for Tier 2 multi-stage, see Assumptions)

kWh_{EFF} = Electric energy consumed for the efficient furnace motor upgrade (= 0 varies by measure, see Deemed Inputs table below, see Assumptions)

Deemed Inputs[3]

Measure	MMID	CAP	$AFUE_{BASE}$	$AFUE_{EFF}$	EAE_{BASE}	EAE_{EFF}
NG Furnace, Multi-stage+, 95% AFUE	4962	62.3	95.0	92.8	317.4	482.8
NG Furnace, Multi-stage+, 96% AFUE	4963	70.0	96.1	92.8	353.9	482.8
NG Furnace, Multi-stage+, 97% AFUE	4964	76.5	97.2	92.8	359.1	482.8
NG Furnace, Multi-stage+, 98%+ AFUE	4965	75.1	98.2	92.8	317.6	482.8
NG Furnace, Multi-stage+, Tier 2, 95% AFUE	4966	65.6	95.0	80.0	325.8	468.5
NG Furnace, Multi-stage+, Tier 2, 96% AFUE	4967	64.5	96.1	80.0	331.1	468.5
NG Furnace, Multi-stage+, Tier 2, 97% AFUE	4968	69.1	97.1	80.0	303.1	468.5
NG Furnace, Multi-stage+, Tier 2, 98%+ AFUE	4969	63.3	98.0	80.0	285.6	468.5
NG Furnace, Single-stage, 95% AFUE	4970	62.9	95.0	92.8	0	0
NG Furnace, Single-stage, 96% AFUE	4971	64.5	96.2	92.8	0	0
NG Furnace, Single-stage, Tier 2, 95% AFUE	4972	61.2	95.0	80.0	0	0
NG Furnace, Single-stage, Tier 2, 96% AFUE	4973	61.8	96.1	80.0	0	0
MF NG Furnace, Multi-stage+, 95% AFUE	4950	63.0	95.0	86.7	372.5	482.8
MF NG Furnace, Multi-stage+, 96% AFUE	4951	55.6	96.1	86.7	289.0	482.8
MF NG Furnace, Multi-stage+, 97% AFUE	4952	63.0	97.3	86.7	274.1	482.8
MF NG Furnace, Multi-stage+, 98%+ AFUE	4953	66.0	98.1	86.7	295.0	482.8
MF NG Furnace, Multi-stage+, Tier 2, 95% AFUE	4954	60.0	95.0	80.0	321.0	468.5
MF NG Furnace, Multi-stage+, Tier 2, 96% AFUE	4955	50.8	96.1	80.0	269.0	468.5

Measure	MMID	CAP	$AFUE_{BASE}$	$AFUE_{EFF}$	EAE_{BASE}	EAE_{EFF}
MF NG Furnace, Multi-stage+, Tier 2, 97% AFUE	4956	60.0	97.4	80.0	213.0	468.5
MF NG Furnace, Multi-stage+, Tier 2, 98% AFUE	4957	51.4	98.0	80.0	267.7	468.5
MF NG Furnace, Single-stage, 95% AFUE	4958	57.5	95.0	86.7	0	0
MF NG Furnace, Single-stage, 96% AFUE	4959	55.3	96.3	86.7	0	0
MF NG Furnace, Single-stage, Tier 2, 95% AFUE	4960	42.0	95.0	80.0	0	0
MF NG Furnace, Single-stage, Tier 2, 96% AFUE	4961	44.0	96.5	80.0	0	0

Summer Coincident Peak Savings Algorithm

No demand savings are claimed for this measure.

Lifecycle Energy-Savings Algorithm

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=21years)[1]

Assumptions

Previously, savings from ECM furnace motor upgrades were derived from a 2014 Cadmus study. As reviewed in the 2014 Deemed Savings memo,[4] this study metered the furnace motors of 67 Focus on Energy participants who had received furnaces with ECMs. There was no federal standard for furnace blower motors at that time, and savings were estimated over a PSC motor, deemed to be a reasonable baseline. This study showed an average of 1,158 hours of heating with an average savings of 0.116 kW in that mode, over an assumed PSC motor baseline—therefore 1,158 * 0.116 kW = 134.3 kWh of heating mode savings. The study also showed an average of 1,020 hours in circulation mode with an average 0.207 kW savings in that mode, for 211.1 kWh of savings in circulation mode. Assuming a SEER upgrade from 12 to 13 as a result of the ECM produces cooling savings of 70.7 kWh. Therefore, the total rounded savings for a PSC to ECM upgrade were 134.3 + 211.1 + 70.7 = 416 kWh.

As of July 3, 2019, the U.S. Department of Energy required residential furnace blower motors to meet a fan energy rating (FER) performance standard that can generally only be met by ECMs, rendering the 2014 study's savings historical. However, as discussed in the Measure Description section and elaborated in the Final Rule Technical Support Document (FRTSD) for furnace fans,[8] there are multiple efficiency levels of ECMs—constant torque, constant torque with a multi-stage furnace burner, constant airflow, and constant airflow with a multi-stage furnace burner. A majority of Focus on Energy furnaces are constant airflow, and therefore offer some electrical savings over a code baseline furnace blower motor.

However, FER information for furnace models have only recently been found to be publicly available, which makes it difficult to determine savings. In addition, FER may not reflect actual energy usage and savings in Wisconsin, due to a few possible issues. First, different assumed versus actual heating, cooling, and circulation mode hours. Additionally, the performance of constant torque blower motors may have improved over the assumptions made in the FRTSD,[8] since the final required FER levels align with its assumptions for constant torque motors with multi-stage burners, but many furnace models with constant torque motors and single stage burners are being manufactured today. These issues may be supported by the fact that results from the 2014 Cadmus study do not align with assumed consumption values in the FRTSD.

As an alternative to FER, the average annual auxiliary electrical energy consumption (E_{AE}) is used to estimate the potential savings from staging during heating and from more efficient motors. E_{AE} is the electrical consumption for the furnace for all heating-related consumption and any standby use[9] and is available for most furnace models in the AHRI database.[10] E_{AE} does not include electrical use in cooling or circulation mode. There may be some additional savings for qualified furnaces in these modes, but without better reporting of FER, or a study, no electrical savings is assumed for cooling or continuous modes. Electrical savings are only deemed for multi-stage furnaces because the bulk of these savings come from operating the furnace fan in the low-fire heating stage. Because furnace capacity (MBh), blower capacity (CFM), and motor type and staging are significant factors in furnace electrical energy consumption, savings should be re-evaluated when there is more data on E_{AE} values for delivered Focus on Energy furnaces.

The efficient E_{AE} for each measure is deemed to be the average value delivered in the PY2020 evaluation year. These values can be seen in the Deemed Inputs table above.

The Tier 1 baseline E_{AE} value is estimated as the average for furnace models that are not Focus on Energy–qualified and have an AFUE in the range of the Tier 1 market baseline of 92.8%. This includes 92% to 94% AFUE single- or multi-stage and 95%+ AFUE single-stage. The average E_{AE} from the AHRI database for 1,010 such models is 482.8 kWh. The Tier 2 baseline E_{AE} value is estimated to be the average for noncondensing furnace models that do not otherwise meet Focus on Energy requirements. The average E_{AE} for 1,961 such models is 468.5 kWh.

Incremental costs come from a 2020 dealer and distributor survey effort.[5]

Deemed Savings

Deemed Savings and Costs by Measure

Measure	MMID	kW	Annual		Lifecycle		Incremental Cost[5]
			kWh	Therms	kWh	therms	
NG Furnace, Multi-stage+, 95% AFUE	4962	0	165	17	3,465	357	$1,407.50
NG Furnace, Multi-stage+, 96% AFUE	4963	0	129	29	2,709	609	$541.31
NG Furnace, Multi-stage+, 97% AFUE	4964	0	124	42	2,604	882	$1,207.92
NG Furnace, Multi-stage+, 98%+ AFUE	4965	0	165	51	3,465	1,071	$2,308.33
NG Furnace, Multi-stage+, Tier 2, 95% AFUE	4966	0	143	142	3003	2,982	$2,311.57
NG Furnace, Multi-stage+, Tier 2, 96% AFUE	4967	0	137	150	2,877	3,150	$1,445.38
NG Furnace, Multi-stage+, Tier 2, 97% AFUE	4968	0	165	171	3,465	3,591	$2,111.98
NG Furnace, Multi-stage+, Tier 2, 98%+ AFUE	4969	0	183	165	3,843	3,465	$3,212.40
NG Furnace, Single-stage, 95% AFUE	4970	0	0	17	0	357	$0.00
NG Furnace, Single-stage, 96% AFUE	4971	0	0	27	0	567	$48.06
NG Furnace, Single-stage, Tier 2, 95% AFUE	4972	0	0	133	0	2,793	$542.68
NG Furnace, Single-stage, Tier 2, 96% AFUE	4973	0	0	144	0	3,024	$952.12
MF NG Furnace, Multi-stage+, 95% AFUE	4950	0	110	70	2,310	1,470	$2,296.76
MF NG Furnace, Multi-stage+, 96% AFUE	4951	0	194	70	4,074	1,470	$1,430.57
MF NG Furnace, Multi-stage+, 97% AFUE	4952	0	209	89	4,389	1,869	$2,097.18
MF NG Furnace, Multi-stage+, 98%+ AFUE	4953	0	188	100	3,948	2,100	$3,197.59
MF NG Furnace, Multi-stage+, Tier 2, 95% AFUE	4954	0	148	130	3,108	2,730	$2,553.57
MF NG Furnace, Multi-stage+, Tier 2, 96% AFUE	4955	0	200	118	4,200	2,478	$1,687.38
MF NG Furnace, Multi-stage+, Tier 2, 97% AFUE	4956	0	256	151	5,376	3,171	$2,353.98
MF NG Furnace, Multi-stage+, Tier 2, 98% AFUE	4957	0	201	134	4,221	2,814	$3,454.40
MF NG Furnace, Single-stage, 95% AFUE	4958	0	0	64	0	1,344	$708.57
MF NG Furnace, Single-stage, 96% AFUE	4959	0	0	71	0	1,491	$937.32
MF NG Furnace, Single-stage, Tier 2, 95% AFUE	4960	0	0	91	0	1,911	$784.68
MF NG Furnace, Single-stage, Tier 2, 96% AFUE	4961	0	0	105	0	2,205	$1,194.12

* Note that multifamily Tier 1 and multifamily Tier 2 measures have the same savings—they are currently counted separately because of different incentive rates.

Sources

1. U.S. Department of Energy. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnaces*. August 30, 2016. https://downloads.regulations.gov/EERE-2014-BT-STD-0031-0217/attachment_1.pdf 21.5 years listed, a conservative value of 21 years is used.
2. Cadmus. *Focus on Energy Calendar Year 2015 Evaluation Report.* May 20, 2016. Table J-4. https://www.focusonenergy.com/sites/default/files/Evaluation%20Report%20-%202015%20Appendices%20%28High%20Resolution%29.pdf
3. Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report, Volume II Program Evaluations*. May 21, 2021. https://focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf
4. Focus on Energy. *Deemed Savings Report.* October 27, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
5. CLEAResult. Survey of trade allies. Summer 2020.
6. Electronic Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430, Subpart C, §430.32. Table 1—Energy Conservation Standards for Covered Residential Furnace Fans. https://www.ecfr.gov/cgi-bin/text-idx?SID=0423028877ce42bb0c3e0e2529ac80ba&mc=true&node=se10.3.430_132&rgn=div8
7. Regulations.gov. *2014-07-03 Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnace Fans; Final Rule*. Table I.1. https://www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0117
8. U.S Department of Energy. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Furnace Fans*. June 2014. https://www.regulations.gov/document?D=EERE-2010-BT-STD-0011-0111
9. Electronic Code of Federal Regulations. Title 10, Chapter II, Subchapter D, Part 430 Subpart B, Appendix N. https://www.govinfo.gov/app/details/CFR-2013-title10-vol3/CFR-2013-title10-vol3-part430-subpartB-appN
10. Air-Conditioning, Heating, and Refrigeration Institute. "Directory of Certified Product Performance." www.ahridirectory.org

Revision History

Version Number	Date	Description of Change
01	03/05/2012	Initial release
02	11/05/2012	Updated memo
03	02/20/2013	Reviewed and updated for new formatting
04	08/15/2014	Updated to new format, changed from 2014 Baseline Study and ECM Study
05	09/29/2014	Revised to reflect final results from the 2014 ECM study
06	10/29/2014	Revised to reflect additions from 2014 Cadmus ECM study and Deemed Savings report
07	04/28/2016	Added 96%, 97%, 98% AFUE measures
08	04/24/2017	Fixed discrepancies in kilowatts, LC kilowatt-hours, and EUL
09	10/2017	Updated EUL
10	12/2018	Updated savings algorithm
11	5/2019	Updated costs for Tier 1 measures
12	1/2020	Reconfigured to reflect new measure mix, added in-unit multifamily measures, and updated furnace fan savings. Deleted details of MMIDs 3679, 3781, 3783, 1981, 3782, 3868, 3870, 3440, and 3871.
13	12/2021	Updated with actual CAP, $AFUE_{EE}$, EAE_{EE}, updated costs and EUL

Single Package Vertical HVAC Unit

	Measure Details
Measure Master ID	Single Package Vertical HVAC Unit: ≥ 90%+ Thermal Efficiency, Natural Gas, 3694 ≥ 90%+ Thermal Efficiency, ≥ 10.0 EER Cooling, Natural Gas, 3693
Workpaper ID	W0209
Measure Unit	Per furnace
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Furnace
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	Varies by measure
Water Savings (gal/year)	0
Effective Useful Life (years)	23[1]
Incremental Cost ($/unit)	$550.00[2]

Measure Description

Conventional natural gas furnaces produce by-products, such as water vapor and carbon dioxide, which are usually vented out through a chimney along with a considerable amount of heat. This occurs not only when the furnace is in use, but also when it is turned off. Newer designs increase energy efficiency by reducing the amount of heat that escapes and by extracting heat from the flue gas before it is vented. These furnaces use much less energy than conventional furnaces.

Description of Baseline Condition

The current federal furnace standard is 78% AFUE without an ECM. Single package vertical units rated by AHRI generally have a thermal efficiency rating of 80% or 82%.[3] Roughly equal quantities of 80% and 82% units are available,[3] so a baseline of 81% thermal efficiency is used. A review of specification sheets for the 80% to 82% efficient models indicated they are only available with standard permanent split capacitor motor (PSC). Per ASHRAE Standard 90.1-2007, the minimum cooling efficiency for new single package vertical units is 9.0 EER.[5]

Description of Efficient Condition

The efficient condition is a single package vertical furnace with a thermal efficiency of 90% or higher and a multi-speed ECM motor installed in a multifamily building and used for space heating only.

Additional savings for qualified cooling efficiency requires a single package vertical unit with an EER of 10.0 or higher.

Annual Energy-Savings Algorithm

$Therm_{SAVED} = CAP * Hours_{HEATING} * (\eta_{EE} / \eta_{BASE} - 1) * (1/100)$

$kWh_{SAVED} = kWh_{SAVED\ HEATING} + kWh_{SAVED\ CIRC} + kWh_{SAVED\ COOLING}$

$kWh_{SAVED\ HEATING}$ (applies to all systems as ECM savings from heating season) = $Hours_{HEATING} * \Delta kW_{HEAT}$

$kWh_{SAVED\ CIRC}$ (applies to all systems as ECM savings from cooling season, since AHRI data indicates that all listed natural gas single package vertical units have cooling) = $Hours_{CIRC} * \Delta kW_{CIRC}$

$kWh_{SAVED\ COOLING}$ (applies if the system meets the requirement for high-efficiency cooling) = $Tons * EFLH_{COOL} * Cooling_{QUALIFIES} * 12\ kBtu/ton * (1/EER_{BASE} – 1/EER_{ECM})$

Where:

CAP = Rated input heating capacity (= 40.4 MBtu/hr)[3]

$Hours_{HEATING}$ = Heating hours (= 1,158)[4]

η_{BASE} = Baseline efficiency (= 81% thermal efficiency)[3]

η_{EE} = Energy efficient unit efficiency (= 90% thermal efficiency)[3]

100 = Conversion factor from therm to MBtu

ΔkW_{HEAT} = Heating demand (=0.116 kW)[4]

$Hours_{CIRC}$ = Annual hours on circulate setting (= 1,020)[4]

ΔkW_{CIRC} = Demand on circulate setting (= 0.207 kW)[4]

Tons = Cooling capacity (= 1.548 tons)[3]

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410)[4]

$Cooling_{QUALIFIES}$ = Binary variable indicating whether the efficient unit meets the minimum qualifying EER of 10.0 (1 = yes; 0 = no)

12 kBtu/ton = Conversion factor from EER to kW/ton

EER_{BASE} = Energy efficiency rating of efficient unit (= 9.0)[5]

EER_{ECM} = Energy efficiency rating of efficient unit (= 10.7)[3]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED\ COOLING} = Tons * 12\ kBtu/ton * (1/EER_{BASE} – 1/EER_{ECM}) * CF$

Where:

CF = Coincidence factor (= 68%)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (=23 years)[1]

Deemed Savings

Deemed Savings for Single Package Vertical HVAC Units

	≥ 90%+ Thermal Efficiency, Natural Gas, 3694	≥ 90%+ Thermal Efficiency, ≥ 10.0 EER Cooling, Natural Gas, 3693
Annual Energy Savings (kWh)	345	480
Peak Demand Reduction (kW)	0	0.223
Annual Therm Savings (Therms)	52	52
Lifecycle Energy Savings (kWh)	7,946	11,038
Lifecycle Therm Savings (Therms)	1,196	1,196

Sources

1. Energy Center of Wisconsin. Energy Efficiency and Customer-Sited Renewable Energy: Achievable Potential in Wisconsin 2006-2015, Volume II. Technical Appendix. p. 192. November 2005. https://seventhwave.org/publications/energy-efficiency-and-customer-sited-renewable-energy-achievable-potential-wisconsin
2. MESP program manager discussion with vendor of single package vertical units early 2015. Vendor noted an incremental cost of $500.00 to $600.00 to upgrade from an 80% to 90% efficient unit. Used $550.00 as the midpoint of this range.
3. Air Conditioning, Heating, and Refrigeration Institute. “Single Package Vertical Systems – AC” category under Commercial, filtered to thermal efficiency > 0 (eliminate cooling only and electric heat models). Accessed September 8, 2015. https://www.ahridirectory.org/ahridirectory/pages/home.aspx
4. Cadmus. “Focus on Energy Evaluated Deemed Savings Changes.” November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
5. ASHRAE Standard 90.1-2007, Table 6.8.1D for SPVAC (single package vertical air conditioning).

Revision History

Version Number	Date	Description of Change
01	10/08/2015	Initial entry
02	01/11/2016	Revised per Cadmus comments
03	01/21/2016	Revised per PSC comments
04	12/2018	Updated savings algorithm

Ductless Mini-Split Heat Pump

	Measure Details
Measure Master ID	Ductless Mini-Split: Replacing Electric Resistance and CAC, 3874 Replacing Electric Resistance and CAC, Tier 2, 3891 Replacing Electric Resistance and Room AC, 3875 Replacing Electric Resistance and Room AC, Tier 2, 3892 Replacing Electric Furnace and CAC, 3876 Replacing Electric Furnace and CAC, Tier 2, 3893 Replacing Electric Resistance and No AC, 3877 Replacing Electric Resistance and No AC, Tier 2, 3894 Replacing Gas Furnace and CAC, 5022 Replacing Gas Boiler and CAC, 5023
Workpaper ID	W0210
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Other
Sector(s)	Residential- single family, Residential- multifamily, Commercial
Annual Energy Savings (kWh)	Varies by baseline measure
Peak Demand Reduction (kW)	Varies by baseline measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by baseline measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	18[1]
Incremental Cost	$2,889.00[2]

Measure Description

This measure is a residential-sized variable speed mini-split and multi-split heat pump system (MSHPs) with an output capacity equal to or less than 65,000 Btu per hour.[3] This workpaper documents the energy savings for MSHPs with energy efficiency performance of 18 SEER and 9.0 HSPF or greater that has inverter technology.

Description of Baseline Condition

Qualifying baseline scenarios involve electric heat (baseboard, furnace), electric cooling (central AC, room AC), and natural gas heat (furnace or boiler). The new MSHP system could be installed as the primary heating or cooling system for a home or as a secondary heating or cooling system for a single room.

Description of Efficient Condition

The efficient condition is a MSHP with an efficiency of at least 18 SEER and 9.0 HSPF or greater.

The savings calculation is dependent on the baseline heating fuel type and whether an incentive for the installation has been provided by both a natural gas and electric utility, just an electric utility, or just a natural gas utility.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{HEAT} + kWh_{COOL}$

$kWh_{HEAT} = CAP_{HEAT} * HOU_{HEAT\text{-}EE} * (Elec_{BASE} * DLF_{BASE} / HSPF_{BASE} – 1 / HSPF_{EE}) / 1{,}000$

$kWh_{COOL} = CAP_{COOL} * HOU_{COOL\text{-}EE} * (AC_{BASE} * DLF_{BASE} / SEER_{BASE} – 1 / SEER_{EE}) / 1{,}000$

$Therms_{SAVED} = Gas_{BASE} * CAP_{EE} * HOU_{HEAT\text{-}EE} * DLF_{BASE} / (AFUE_{BASE} * 100{,}000)$

Where:

CAP_{HEAT} = Heating capacity of efficient equipment (= 19,110 Btu/hour)[4]

$HOU_{HEAT\text{-}EE}$ = Hours of use for efficient equipment heating (= 1,940)[5]

$Elec_{BASE}$ = Factor indicating whether the baseline case was electric heat (= 0 if baseline natural gas heat, = 1 if baseline electric heat)

DLF_{BASE} = Duct leakage factor of baseline equipment that accounts for the percentage of energy lost to duct leakage and conduction for ducted systems (= see table below)[3]

Duct Leakage Factor of Baseline Equipment

Existing HVAC Type	DLF
Central AC	1.15
Electric or natural gas furnace	1.15
Natural gas boiler	1.00
Electric resistance (baseboard, space heaters)	1.00
Room AC	1.00

$HSPF_{BASE}$ = Baseline heating seasonal performance factor (= 3.412 for electric baseboard, = 3.242 for electric furnace)[3]

$HSPF_{EE}$ = Efficient measure heating seasonal performance factor (= 10.6)[4]

1,000 = Kilowatt conversion factor

CAP_{COOL} = Cooling capacity of efficient equipment (= 21,193 Btu/hour; see Assumptions)[4]

$HOU_{COOL\text{-}EE}$ = Hours of use for efficient equipment cooling (= 369; see Assumptions)[6]

AC_{BASE} = Factor indicating whether baseline case had AC (= 0 if no baseline AC, = 1 if baseline AC)

$SEER_{BASE}$ = Baseline seasonal energy efficiency ratio (= 13.0 for central AC, = 11.3 for room AC)[3]

$SEER_{EE}$ = Efficient measure seasonal energy efficiency ratio (= 20.2)[4]

Gas_{BASE} = Factor indicating whether baseline case had natural gas heat (= 0 if electric resistance or heat pump baseline, = 1 if natural gas heat baseline)

$AFUE_{BASE}$ = Natural gas heating baseline AFUE (= 91.4% if furnace, = 80% if boiler)[7]

100,000 = Conversion factor from Btu to therms

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = CAP_{EE} * (AC_{BASE} * DLF_{BASE} / EER_{BASE} – 1 / EER_{EE}) / 1{,}000 * CF$

Where:

EER_{BASE} = Energy efficiency ratio of baseline unit (= 9.8 for room AC, = 11.0 for central AC)[3]

EER_{EE} = Energy efficiency ratio of efficient unit (= 12.4)[4]

CF = Coincidence factor (= 0.68)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 18 years)[1]

Deemed Savings

Annual and Lifecycle Savings for Ductless Mini-Split Heat Pumps

Base Heating	Base Cooling	Tier	MMID	Annual		kW	Lifecycle	
				kWh	Therms		kWh	Therms
Electric baseboard	Central AC	1	3874	7,673	0	0.3444	138,114	0
		2	3891					
	Room AC	1	3875	7,673	0	0.3083	138,114	0
		2	3892					
Electric furnace	Central AC	1	3876	9,958	0	0.3444	179,244	0
		2	3893					
Electric baseboard	None	1	3877	6,981	0	-1.1622	125,658	0
		2	3894					
Natural gas furnace	Central AC	N/A	5022	-3,193	466	0.3444	-57,474	8,388
Natural gas boiler	Central AC	N/A	5023	-3,193	463	0.3444	-57,474	8,334

Assumptions

The 18 SEER and 9.0 HSPF requirements are based on Wisconsin-specific market data obtained from EERD research conducted by Tetra Tech (2016)[4] and corroborated by trade ally surveys.

Full-load cooling hours were reduced by 10% from the 410 hours found in the *Wisconsin Deemed Savings Review*,[6] producing 369 hours based on an assessment of assumed EFLH for ductless heat pumps in other states.

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial HVAC Measures*. Table A-2, "Residential Heating and Cooling." June 2007. http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/interiores/ilumina%E7%E3o%20industrial/measure_life_GDS.pdf
   The table shows 18 years as the median measure life from multiple heat pump sources.
2. Illinois Energy Efficiency Stakeholder Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 8.0, Volume 3*. October 17, 2019. p. 142. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_01-01-20_v8.0_Vol_3_Res_10-17-19_Final.pdf
   Full install cost for 10.0 HSPF to 10.9 HSPF units is $1,605 per ton. With a cooling capacity of 21,193 / 12,000 = 1.77 tons was used. $1,605 * 1.77 = $2,835.
3. Pennsylvania Public Utility Commission. *Technical Reference Manual*. June 2016. Section 2.2.3, p. 53. http://www.puc.pa.gov/pcdocs/1350348.docx
4. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. 2020. Average AHRI-rated capacities and efficiencies for 489 installations in 2020. For heating capacity, the average of the capacites at 17°F and 47°F was used.

5. Hours of use calculated by comparing TMY average weather data from four Wisconsin cities (Green Bay, La Crosse, Madison, and Milwaukee) to aggregate meter data collected by Cadmus from 70 cold-climate ductless heat pumps in Vermont, and evaluated against Vermont run-time variance to determine hours of use at various external temperatures.
6. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
7. Cadmus. *2016 Potential Study for Focus on Energy.* Data maintained by Cadmus and Wisconsin PSC. Based on site visit data from 103 single family homes in Wisconsin. Only three sites had boilers; 80% is an engineering assumption.

Revision History

Version Number	Date	Description of Change
01	05/2016	Initial TRM entry
02	01/2020	Added natural gas heating baseline
03	01/2021	Updated capacities, efficiencies, and cost

Air Source Heat Pump

	Measure Details
Measure Master ID	Air-Source Heat Pump, ≥16 SEER, 2992 Air-Source Heat Pump Replacing Gas Furnace and CAC, 5163 Air-Source Heat Pump Replacing Gas Furnace and No CAC, 5164
Workpaper ID	W0237
Measure Unit	Per heat pump
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Other
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	Varies by measure
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	18[1]
Incremental Cost ($/unit)	Varies by measure[2]

Measure Description

This measure is a residential-sized air-source heat pump with an input capacity of ≤65,000 Btu/hour.[2] Heat pumps that replace natural gas furnaces produce a large increase in electricity usage and a large decrease in natural gas usage, reducing the overall net energy use. Heat pumps that do not replace natural gas furnaces use a less efficient heat pump as the baseline.

Description of Baseline Condition

For heat pumps not installed with a natural gas furnace, the baseline measure is a federal standard baseline air-source heat pump of SEER 14 and HSPF 8.2.[3] For heat pumps installed with a natural gas furnace, the baseline is a furnace with or without central air conditioning.

Description of Efficient Condition

For heat pumps not installed with a natural gas furnace, the efficient measure is a residential-sized air-source heat pump of SEER 16 and HSPF 8.5. For heat pumps that replace a natural gas furnace, the efficient measure is a natural gas furnace with a residential-sized air-source heat pump of at least SEER 15 and HSPF 8.5.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{HEAT} + kWh_{COOL}$

$kWh_{HEAT} = CAP_{HEAT} * EFLH_{HEAT} * (HPH_{BASE} / HPSF_{BASE} – 1 / HSPF_{EE}) / 1{,}000$

$kWh_{COOL} = CAP_{COOL} * EFLH_{COOL} * (Cooling_{BASE} / SEER_{BASE} – 1 / SEER_{EE}) / 1{,}000$

$Therms_{SAVED} = Gas_{BASE} * CAP_{HEAT} * EFLH_{HEAT} / (AFUE_{BASE} * 100{,}000)$

Where:

CAP_{HEAT} = Capacity (= 33,528 Btu/hour)[4]
$EFLH_{HEAT}$ = Equivalent full-load heating hours (= 1,890)[5]
HPH_{BASE} = Factor indicating whether the baseline case is heat pump heat (= 1 if baseline is heat pump heat, = 0 if baseline is natural gas furnace heat)
$HSPF_{BASE}$ = Baseline heating seasonal performance factor (= 8.2)[3]
$HSPF_{EE}$ = Efficient measure heating seasonal performance factor (= 9.3)[4]
1,000 = Kilowatt conversion factor
CAP_{COOL} = Capacity (= 33,494 Btu/hour)[4]
$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 356; see Assumptions)[5]
$Cooling_{BASE}$ = Factor indicating whether baseline case had cooling (= 1 if baseline cooling, = 0 if no baseline cooling)
$SEER_{BASE}$ = Baseline seasonal energy efficiency ratio (= 13 for baseline natural gas heat, = 14 for baseline air-source heat pump heat)[3]
$SEER_{EE}$ = Efficient measure seasonal energy efficiency ratio (= 17.1)[4]
Gas_{BASE} = Factor indicating whether baseline case had natural gas heat (= 1 if natural gas furnace baseline, = 0 if heat pump baseline)
$AFUE_{BASE}$ = Furnace baseline AFUE (= 91.4%)[6]
100,000 = Conversion factor from Btu to therms

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = CAP_{COOL} * (Cooling_{BASE} / EER_{BASE} – 1 / EER_{EE}) / 1{,}000 * CF$

Where:

EER_{BASE} = Baseline energy efficiency ratio (= 10.5 for baseline natural gas heat, = 11 for baseline air-source heat pump heat)[7]
EER_{EE} = Efficient energy efficiency ratio (= 11.5)[4]
CF = Coincidence factor (= 0.68)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (=18 years)[1]

Assumptions

The capacity of residential heat pumps is assumed to be 2.79 tons for equipment installed in the Wisconsin market, based on analysis of 88 air-source heat pumps installed between 2018 and 2020 through the Focus on Energy Residential Prescriptive program. The assumed average capacity is 33,356 Btu/hr for cooling and 33,414 Btu/hr for heating.[4]

Supporting inputs for heating load hours in several Wisconsin cities are shown in the table below.

Equivalent Full-Load Heating Hours by Location

Location	$EFLH_{HEAT}$[5]
Green Bay	1,852
La Crosse	1,966
Madison	1,934
Milwaukee	1,883
Wisconsin Average	1,909
Weighted Average	**1,890**

Cooling hours are based on an air conditioner in the Deemed Savings Report,[6] adjusted for the larger capacity system (410 hours at 2.425 tons is equivalent to 357 hours at 2.79 tons).

Deemed Savings and Costs

Deemed Savings and Costs

MMID	Annual		kW	Lifecycle		Cost
	kWh	Therms		kWh	Therms	
2992	1,073	0	0.0900	19,314	0	$724.00
5163	-6,590	693	0.1886	-118,620	12,474	$1,920.91
5164	-7,507	693	-1.9805	-135,126	12,474	$1,920.91

Sources

1. GDS Associates. *Measure Life Report, Residential and Commercial/Industrial HVAC Measures*. June 2007. https://library.cee1.org/content/measure-life-report-residential-and-commercialindustrial-lighting-and-hvac-measures
   Table A-2, “Residential Heating and Cooling,” gives 18 years as a median measure life found from multiple heat pump sources.
2. Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 8.0, Volume 3*. pp. 66 and 79. October 17, 2019.

https://ilsag.s3.amazonaws.com/IL-TRM_Effective_01-01-20_v8.0_Vol_3_Res_10-17-19_Final.pdf
The air-source heat pump baseline has an incremental cost of $724.00 for a time-of-sale 17 SEER unit versus a less-efficient heat pump. For the furnace baseline, the heat pump is installed instead of an air conditioner, with a full cost of $1,381 * 2.79 tons + $724 = $4,576.99. The baseline cost is deemed at $952 per ton, which is an approximation for a 13 SEER air conditioner, or $952 * 2.79 = $2,656.08. This leads to a total cost of $4,576.99 - $2,656.08 = $1,920.91.

3. Electronic Code of Federal Regulations. Title 10, Chapter II, Subpart C, § 430.32. https://www.govinfo.gov/content/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf
4. Wisconsin Focus on Energy. Historical project data obtained from SPECTRUM. Average capacities and efficiencies of 88 units from January 2018 to November 2020.
5. U.S. Environmental Protection Agency and U.S. Department of Energy. “Life Cycle Cost Estimate for ENERGY STAR Qualified Air Source Heat Pump(s).” April 2009. https://www.energystar.gov/sites/default/uploads/buildings/old/files/ASHP_Sav_Calc.xls
Several Cadmus metering studies reveal that the ENERGY STAR calculator effective full-load heating hours are overestimated by 25%. The $EFLH_{HEAT}$ was adjusted by population-weighted heating degree days and TMY3 values.
6. Cadmus. 2016 Potential Study for Focus on Energy. Data maintained by Cadmus and Wisconsin PSC. Data includes information from 103 single family sites and 92 multifamily units.
7. Opinion Dynamics and Cadmus. Residential HVAC Metering Study Results. Recommendation 5a. February 28, 2018.
https://ilsag.s3.amazonaws.com/AIC_HVAC_Metering_Study_Memo_FINAL_2018-02-28.pdf
This value is also used in the Illinois TRM.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2015	Updated EFLH
03	12/2018	Updated EFLH for heating
04	2/2021	Updated workpaper based on SPECTRUM data and added natural gas furnace baseline measures

Ground Source Heat Pump, Residential, Natural Gas and Electric Backup

	Measure Details
Measure Master ID	Ground Source Heat Pump, No Gas Service, 5320 Ground Source Heat Pump, With Gas Service, 5321
Workpaper ID	W0244
Measure Unit	Per heat pump
Measure Type	Prescriptive
Measure Group	Renewable Energy
Measure Category	Geothermal
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	Varies
Annual Therm Savings (Therms)	Varies
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	Varies
Water Savings (gal/year)	0
Effective Useful Life (years)	20[1]
Incremental Cost ($/unit)	Based on actual program data in current year

Measure Description

This measure is installing residential-sized geothermal (ground source) heat pump systems in residential applications. Geothermal heat pump systems use the earth as a source of heating and cooling by installing an exterior underground loop that works in combination with an interior heat pump unit. The measure provides sites with a centralized heating and cooling system similar to that of a standard air-source heat pump.

Description of Baseline Condition

For systems installed in a home without natural gas service, the baseline measure is deemed to be a federal standard air-source heat pump with a SEER of 14 and HSPF of 8.2. For systems installed in a home with natural gas service, the baseline is a 91.4% AFUE furnace with 13 SEER central air conditioning. This matches assumptions made in the air source heat pump workpaper, W0237.

Description of Efficient Condition

A qualifying product must be an ENERGY STAR listed unit with a minium efficiency of:

- 17.1 EER / 3.6 COP for Water-to-Air systems
- 16.1 EER / 3.1 COP for for Water-to-Water systems
- 16.0 EER / 3.6 COP for Direct Ground Exchange (DGX) systems

EER and COP are based on a closed loop system but Focus on Energy will accept program applications for open or closed loop systems. Additionally, the procedures followed to install the equipment must conform to the ACCA Standard 5 Quality Installation requirements. Savings are based on average efficiency of actual installations.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{HEAT} + kWh_{COOL}$

$kWh_{HEAT} = CAP_{HEAT} * EFLH_{HEAT} * [HPH_{BASE} / HSPF_{BASE} - 1 / (COP_{EE} * 3.412)] / 1{,}000$

$kWh_{COOL} = CAP_{COOL} * EFLH_{COOL} * [1 / SEER_{BASE} - 1 / EER_{EE}] / 1{,}000$

$Therms_{SAVED} = Gas_{BASE} * CAP_{HEAT} * EFLH_{HEAT} / (AFUE_{BASE} * 100{,}000)$

Where:

CAP_{HEAT} = Heating output capacity of the equipment, Btu/h (= 48,205)[3]

$EFLH_{HEAT}$ = Equivalent full-load heating hours (= 1,890)[2]

HPH_{BASE} = Factor indicating whether the baseline case is heat pump heat (= 1 for no gas service, = 0 if with gas service)

$HSPF_{BASE}$ = Heating seasonal performance factor of baseline equipment, kBtu/kWh (= 8.2 for no gas service)[4]

COP_{EE} = Coefficient of performance (= 4.05)[3]

3.412 = Conversion from watts to Btu

1,000 = Kilowatt conversion factor

CAP_{COOL} = Cooling capacity of equipment, Btu/h (= 48,205)[3]

$EFLH_{COOL}$ = Equivalent full-load cooling hours (= 410)[2]

$SEER_{BASE}$ = Seasonal energy efficiency ratio of baseline equipment (= 13 for homes with gas service, = 14 for homes with no gas service)[4]

EER_{EE} = Energy efficiency ratio of efficient equipment, kBtu/kWh (= 22.3)[3]

Gas_{BASE} = Factor indicating whether baseline case is assumed to have had natural gas heat (= 0 for no gas service, = 1 for with gas service)

$AFUE_{BASE}$ = Furnace baseline AFUE (= 91.4% for single family[5])

100,000 = Conversion factor from Btu to therms

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Btu/h_{COOL} * (1 / EER_{BASE} - 1 / EER_{EE})) / 1{,}000 * CF$

Where:

EER_{BASE} = Energy efficiency ratio of baseline equipment (= 11 for no gas service, = 10.5 for gas service)[7]

CF = Coincidence factor (= 0.5)[6]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 20 years)[1]

Deemed Savings

Annual and Lifecycle Savings

Measure	MMID	Annual		kW	Lifecycle	
		kWh	Therms		kWh	Therms
Ground Source Heat Pump:						
No Gas Service	5320	5,043	0	1.1103	100,860	0
With Gas Service	5321	-5,959	997	1.2146	-119,180	19,940

Assumptions

This system life expectancy is generally constrained by the heat pump exchanger and compressor equipment. The actual ground loop installation itself often has a much longer life expectancy.

Supporting inputs for load hours in several Wisconsin cities are shown in the table below.[2]

Equivalent Full-Load Cooling and Heating Hours by City

Location	$EFLH_{COOL}$[2]	$EFLH_{HEAT}$[2]
Green Bay	344	1,852
La Crosse	323	1,966
Madison	395	1,934
Milwaukee	457	1,883
Wisconsin Average	380	1,909
Weighted Average	**410**	**1,890**

Sources

1. GDS Associates, Inc. *Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures.* June 2007. https://library.cee1.org/system/files/library/8842/CEE_Eval_MeasureLifeStudyLights%2526HVACGDS_1Jun2007.pdf

Indoor equipment EUL is likely 15 years, but ground equipment will have a much longer life. An EUL of 20 years is deemed.

2. Several Cadmus metering studies reveal that the ENERGY STAR calculator EFLHs are over-estimated by 30% for cooling and by 25% for heat pump heating hours. The heating and cooling EFLH values used are adjusted by population-weighted CDD and HDD TMY3 values.
3. Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 112 systems for MMID 2820 and 20 systems for MMID 2821, from January 2020 through June 2021.
4. U.S. Code of Federal Regulations. 10 CFR Ch. 11, §430.32. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32
5. Cadmus. *2016 Potential Study for Focus on Energy.* Data maintained by Cadmus and Wisconsin Public Service Commission.
   Data includes information 120 single family sites and 92 multifamily units.
6. Energy Center of Wisconsin. *Update of Geothermal Analysis*. p. 19–21. August 31, 2009. http://www.ecw.org/sites/default/files/249-1.pdf.
7. Opinion Dynamics and Cadmus. Residential HVAC Metering Study Results. Recommendation 5a. February 28, 2018.
   https://ilsag.s3.amazonaws.com/AIC_HVAC_Metering_Study_Memo_FINAL_2018-02-28.pdf
   This value is also used in the Illinois TRM.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	01/2015	Updated EFLH
03	05/2018	Updated based on evaluation findings
04	08/2020	Updated based on evaluation findings
05	12/2021	Updated with gas baseline, updated capacities and efficiencies

Residential Air Conditioning Tune Up - Coil Cleaning and Filter Replacement

	Measure Details
Measure Master ID	Residential AC Tune-Up, 4838
Workpaper ID	W0211
Measure Unit	Per air conditioner or air-source heat pump
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Air Conditioner – Residential
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	78.80
Peak Demand Reduction (kW)	0.1492
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	157.59
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	2[6]
Incremental Cost ($/unit)	$122.48[1]

Measure Description

This measure is for cleaning the condensing coil and replacing the filter on a central air conditioning or heat pump unit in a residence. This increases the operating efficiency of the unit. There are several service requirements:

- Clean condensing coil
- Check/replace filter
- Check line loads
- Measure temperature drop
- Maintain condenser fan and motor
- Verify thermostat operation is in accordance with manufacturer recommendations
- Confirm proper operation of the system

Description of Baseline Condition

The baseline condition is an air conditioner or air-source heat pump system that has not been maintained in the last two years.

Description of Efficient Condition

The efficient equipment is an air conditioner or air-source heat pump that has had a coil cleaning and filter changed as part of a tune up.

Annual Energy-Savings Algorithm

kWh_{SAVED} = CAP * 12 * EFLH / [SEER * (1 - SF)] * SF

Where:

CAP = Unit capacity (= 2.425 tons)[2]
12 = Conversion from tons to kBtuh
EFLH = Equivalent full load cooling hours (= 410)[2]
SEER = Seasonal energy efficiency ratio (= 12.1)[3]
SF = Savings factor (= 7.4%)[4]

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = CAP * 12 * EFLH / [EER * (1 - SF)] * SF * CF

Where:

EER = Energy efficiency ratio (= 10.6)[5]
CF = Coincidence factor (= 0.68)[2]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED} * EUL

Where:

EUL = Effective useful life (= 2 years)[6]

Assumptions

Only the savings from cleaning the condenser coil are used even though an additional adjustment (filter change) is completed—the study referenced[4] does not clarify the additive effects of these two adjustments.

Sources

1. Average cost based on responses from 12 residential HVAC contractors in Wisconsin. Costs ranged from $98 to $150. January 2019.
2. Wisconsin Focus on Energy. *Deemed Savings Report*. October 27, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf
3. Cadmus. Findings from the 2016 potential study audit. Based on site visit data from 103 single family homes and 92 units at 88 multifamily sites in Wisconsin.

4. Seventhwave. *Improving Installation and Maintenance Practices for Minnesota Residential Furnaces, Air Conditioners and Heat Pumps*. Table 11. September 30, 2016. https://www.cards.commerce.state.mn.us/CARDS/security/search.do?documentId=%7B881DD1B7-1FE4-495A-9FC0-F74A54B99CB6%7D
5. Wassmer, M. “A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations.” Masters Thesis, University of Colorado at Boulder. 2003.
6. EUL reflects engineering judgement, and the baseline condition requirement that the system has not been maintained in the last two years.

Revision History

Version Number	Date	Description of Change
01	12/17/2018	Initial TRM entry

Furnace Tune-Up, Single Family

	Measure Details
Measure Master ID	Furnace Tune-Up, Single Family, 4660
Workpaper ID	W0212
Measure Unit	Per tune-up
Measure Type	Prescriptive
Measure Group	HVAC
Measure Category	Tune-up / Repair / Commissioning
Sector(s)	Residential- single family
Annual Energy Savings (kWh)	0
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	14
Lifecycle Energy Savings (kWh)	0
Lifecycle Therm Savings (Therms)	28
Water Savings (gal/yr)	0
Effective Useful Life (years)	2[1]
Measure Incremental Cost ($/unit)	$150[2]

Measure Description

A tune-up of a residential furnace that provides space heating will improve efficiency. The tune-up involves cleaning the burners, combustion chamber, and burner nozzles; adjusting airflow if needed; and ensuring proper temperature rise. The tune-up may also include adjustments to the burner and gas inputs. The tune-up includes a check of venting, safety controls, and combustion air intake. Combustion efficiency is to be measured before and after tune-up using an electronic flue gas analyzer.

Description of Baseline Condition

The baseline measure is a 91% AFUE furnace, operating at a lower efficiency from lack of maintenance.

Description of Efficient Condition

The efficient condition is a furnace that is tuned up to nameplate efficiency by a technician. The incentive is available once in a 24-month period.

Annual Energy-Savings Algorithm

$\text{Therm}_{SAVED} = \text{CAP} * \text{SF} * \text{EFLH}_{HEAT} / (\text{AFUE}_{PRE} * 100)$

Where:

CAP = Size of the boiler being tuned (= 70.7 MBh)[3]

SF = Savings factor (= 1.6%)[4]

EFLH_{HEAT} = Equivalent full-load hours (= 1,158)[5]

$AFUE_{PRE}$ = AFUE of boiler prior to tune-up (= 91%)[3]

100 = Conversion factor from MBh to therm

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$Therms_{LIFECYCLE} = Therms_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 2 years)[1]

Sources

1. Illinois Energy Efficiency Statewide Advisory Group. *Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 6.0*. Volume 3. p. 148. February 8, 2017. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_3_Res_020817_Final.pdf
2. CLEAResult. Informal survey of four Wisconsin Trade Allies. December 2017.
3. Cadmus. 2016 potential study audit.
   Based on site visit data from 103 single family homes in Wisconsin.
4. PA Consulting Group. "Wisconsin *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*." p. 4-11. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
5. Cadmus. *Focus on Evaluated Energy Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Revision History

Version Number	Date	Description of Change
01	05/2018	Initial TRM entry

Laundry

ENERGY STAR Multifamily Common Area Clothes Washers

	Measure Details
Measure Master ID	Clothes Washer, Common Area, ENERGY STAR, Electric, 2756 Clothes Washer, Common Area, ENERGY STAR, Natural Gas, 2757
Workpaper ID	W0213
Measure Unit	Per clothes washer
Measure Type	Prescriptive
Measure Group	Laundry
Measure Category	Clothes Washer
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by fuel source
Peak Demand Reduction (kW)	Varies by fuel source
Annual Therm Savings (Therms)	Varies by fuel source
Lifecycle Energy Savings (kWh)	Varies by fuel source
Lifecycle Therm Savings (Therms)	Varies by fuel source
Water Savings (gal/year)	13,978
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	$325.40[4]

Measure Description

ENERGY STAR is a standard for energy-efficient consumer appliances. This standard increases savings for clothes washers in multifamily buildings, which are derived from factors such as hot water fuel, dryer type, and location (in-unit or common area).

This measure describes clothes washers in common areas. For washers installed in individual units of a multifamily building, see the residential single-family clothes washer measure.

Description of Baseline Condition

The baseline condition is a non-ENERGY STAR commercial clothes washer.

Description of Efficient Condition

The efficient condition is an ENERGY STAR commercial clothes washer.

Annual Energy-Savings Algorithm

Clothes Washer with Electric DHW

$kWh_{SAVED} = [\Delta kWh(EG) * \%EG + \Delta kWh(EE) * \%EE + \Delta kWh(EnD) * \%EnD] * Cycles/year$

$Therm_{SAVED} = [\Delta Therm(EG) * \%EG] * Cycles/year$

Clothes Washer with Natural Gas DHW

$kWh_{SAVED} = [\Delta kWh(GE) * \%GE + \Delta kWh(GG) * \%GG + \Delta kWh(GnD) * \%GnD] * Cycles/year$

$Therm_{SAVED} = [\Delta Therm(GG) * \%GG + \Delta Therm(GE) * \%GE + \Delta Therm(GnD) * \%GnD] * Cycles/year$

Where:

Mix of dryers for clothes washers with electric DHW[2]

EG = Electric DHW and natural gas dryer (= 8.0%)

EE = Electric DHW and electric dryer (= 92.0%)

EnD = Electric DHW with no dryer (= 0.0%)

Cycles/year = Wash cycles per year (= 1,241)[2]

Mix of dryers for clothes washers with natural gas DHW[2]

GG = Natural gas DHW and natural gas dryer (= 26.5%)

GE = Natural gas DHW and electric dryer (= 74.5%)

Gnd = Natural gas DHW with no dryer (=0.0%)

Cycles/year = Wash cycles per year (= 1,241)[2]

Electric and natural gas savings for mixes of dryer and DHW types[2]

$\Delta kWh(GE)$ = Electric savings per cycle in kWh (= 1.45)

$\Delta kWh(EG)$ = Electric savings per cycle in kWh (= 0.25)

$\Delta kWh(EE)$ = Electric savings per cycle in kWh (= 1.70)

$\Delta kWh(EnD)$ = Electric savings per cycle in kWh (=1.70)

$\Delta Therm(GG)$ = Natural gas savings per cycle in therms (= 0.066)

$\Delta Therm(GE)$ = Natural gas savings per cycle in therms (= 0.011)

$\Delta Therm(EG)$ = Natural gas savings per cycle in therms (= 0.055)

$\Delta Therm(GnD)$ = Natural gas Savings per cycle in therms (= 0.011)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / (Cycles/year * Hours/cycle) * CF$

Where:

Hours/cycle = 1 (estimated)

CF = Coincidence factor (= 0.045)[2]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

$Therm_{LIFECYCLE} = Therm_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Deemed Savings by Measure

	CAE (MMID 2756)	CAG (MMID 2757)
Annual Deemed Electricity Savings (kWh)	1,971	1,331
Deemed Summer Peak Electricity Demand Reduction (kW)	0.071	0.048
Lifecycle Deemed Electricity Energy Savings (kWh)	21,681	14,641
Annual Deemed Natural Gas Energy Savings (therms)	5.3	31.9
Lifecycle Deemed Natural Gas Energy Savings (Therms)	58	351
Annual Demand Water Savings (gallons)	13,978	13,978
Lifecycle Deemed Water Savings (gallons)	195,692	195,692

Sources

1. Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances: U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Program, Navigant Consulting, Inc. 2009. http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/commercial_appliances_report_12-09.pdf
2. California Public Utilities District. *Res Retro HIM Evaluation Report*. Weighted by quantity of each efficiency level from MESP SPECTRUM.
3. RECs Database - Wisconsin Multifamily unit counts.
4. Illinois Technical Reference Manual. p. 141. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry

Electric Clothes Dryer, ENERGY STAR

	Measure Details
Measure Master ID	Electric Clothes Dryer, ENERGY STAR, 4038
Workpaper ID	W0214
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Laundry
Measure Category	Dryer
Sector(s)	Residential- upstream
Annual Energy Savings (kWh)	160
Peak Demand Reduction (kW)	0.0170
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	1,920
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$224.91[1]

Measure Description

An electric clothes dryer is a cabinet-like appliance designed to dry fabrics in a tumble-type drum with forced air circulation. The heat source is electricity and the drum and blower(s) are driven by an electric motor or motors. This measure consists of ENERGY STAR-certified electric clothes dryer units that meet the ENERGY STAR Version 1.0 requirements.[1]

Description of Baseline Condition

The baseline condition is non-ENERGY STAR-certified electric clothes dryer units with a combined energy factor (CEF) of 3.11 lbs/kWh according to a modified 2015 Federal Standard.[2]

Description of Efficient Condition

The efficient condition is standard-sized (equal to or larger than 4.4 cubic feet) ventless or vented electric ENERGY STAR-certified clothes dryer units that meet ENERGY STAR Version 1.0 requirements of CEF of 3.93 lbs/kWh.[1]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = UEC_{BASE} - UEC_{EE}$

Where:

UEC_{BASE} = Annual unit energy consumption of baseline unit (= 768.92 kWh)[1]

UEC_{EE} = Annual unit energy consumption of measure unit (= 608.49 kWh)[1]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (kWh_{SAVED} / Hours) * CF$

Where:

Hours = Assumed annual run hours of clothes dryer (= 283; Ncycles * 1 Hour)

CF = Coincidence factor (= 2.9%)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 12 years)[1]

Sources

1. ENERGY STAR. "Retail Products Platform: Product Analysis for Clothes Dryers." RPP Product Analysis_5-25-16.xlsx. Updated May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U
   ENERGY STAR assumes 12 years based on: Appliance Magazine. "U.S Appliance Industry: Market Value, Life Expectancy & Replacement Picture."
   ENERGY STAR assumes $224.91 Ventless or Vented Electric, Standard Clothes Dryer; this is based on: the Dryer TSD Life-Cycle Cost and Payback Analysis "2011-04-18_TSD_Chapter_8_Life-Cycle_Cost_and_Payback_Period_Analyses.pdf" 8.2.9 Vented Dryer, Electric, Standard: Consumer Product Costs, Installation Costs, and Total Installed Costs in 2014.
2. U.S. Department of Energy. "10 CFR Part 431. Docket Number EERE–2014-BT-STD-0058. Energy Conservation Program: Energy Conservation Standards for Residential Clothes Dryers." Table II-6. March 23, 2015. Accessed November 16, 2016. http://energy.gov/sites/prod/files/2015/03/f20/Clothes%20Dryer%20Standards_RFI.pdf
3. Prepared by Shelter Analytics; Facilitated and Managed by Northeast Energy Efficiency Partnership. "Mid-Atlantic Technical Reference Manual Version 4.0." Clothes washer measure, p. 184. June 2014. http://www.neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V4_FINAL.pdf

Revision History

Version Number	Date	Description of Change
01	06/24/2016	Initial TRM entry

Natural Gas Clothes Dryer, ENERGY STAR

	Measure Details
Measure Master ID	Natural Gas Clothes Dryer, ENERGY STAR, 4039
Workpaper ID	W0215
Measure Unit	Per dryer
Measure Type	Prescriptive
Measure Group	Laundry
Measure Category	Dryer
Sector(s)	Residential- upstream
Annual Energy Savings (kWh)	8
Peak Demand Reduction (kW)	0.0008
Annual Therm Savings (Therms)	5
Lifecycle Energy Savings (kWh)	96
Lifecycle Therm Savings (Therms)	60
Water Savings (gal/year)	0
Effective Useful Life (years)	12[1]
Incremental Cost ($/unit)	$270.16[1]

Measure Description

A natural gas clothes dryer is a cabinet-like appliance designed to dry fabrics in a tumble-type drum with forced air circulation. The heat source is a natural gas and the drum and blower(s) are driven by an electric motor(s). This measure consists of ENERGY STAR-certified natural gas clothes dryer units that meet the ENERGY STAR Version 1.0 requirements.[2]

Description of Baseline Condition

The baseline condition is non-ENERGY STAR-certified, vented, natural gas clothes dryers that meet the 2015 federal standard combined energy factor (CEF) of 2.84 lbs/kWh.[1]

Description of Efficient Condition

The efficient condition is ENERGY STAR-certified, vented, natural gas clothes dryers that meet the ENERGY STAR Version 1.0 requirements of CEF of 3.48 lbs/kWh.[2]

Annual Energy-Savings Algorithm

$\text{Therm}_{\text{SAVED}} = \text{UEC}_{\text{BASE}} - \text{UEC}_{\text{EE}}$

$\text{kWh}_{\text{SAVED}} = \text{UEC}_{\text{BASE}} - \text{UEC}_{\text{EE}}$

Where:

UEC_{BASE} = Annual unit energy consumption of baseline unit (42.1 kWh/year, 27.2 therm/year)[1]

UEC_{EE} = Annual unit energy consumption of measure unit (34.36 kWh/year, 22.2 therm/year)[1]

Summer Coincident Peak Savings Algorithm

$\text{kW}_{\text{SAVED}} = (\Delta\text{kWh}/\text{Hours}) * \text{CF}$

Where:

ΔkWh = Annual unit energy savings (= 7.74 kWh, rounded to 8 kWh)

Hours = Annual hours of use (= 283)[1]

CF = Coincidence factor (= 2.9%)[3]

Lifecycle Energy-Savings Algorithm

$\text{Therm}_{\text{LIEFCYCLE}} = \text{Therm}_{\text{SAVED}} * \text{EUL}$

$\text{kWh}_{\text{LIFECYCLE}} = \text{kWh}_{\text{SAVED}} * \text{EUL}$

Where:

EUL = Effective useful life (= 12 years)[1]

Sources

1. ENERGY STAR. “Retail Products Platform: Product Analysis for Clothes Dryers.” Updated May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U
   ENERGY STAR assumes 12 years based on: Appliances Magazine. “U.S Appliance Industry: Market Value, Life Expectancy & Replacement Picture.”
   ENERGY STAR assumes $270.16 Ventless or Vented Gas, Standard Clothes Dryer; this is based on: the Dryer TSD Life-Cycle Cost and Payback Analysis "2011-04-18_TSD_Chapter_8_Life-Cycle_Cost_and_Payback_Period_Analyses.pdf" Table 8.2.12 Vented Dryer, Gas, Standard: Consumer Product Costs, Installation Costs, and Total Installed Costs in 2014.
   The workbook cites a CEF of 2.84 as the 2015 Federal Standard.
   Baseline energy consumption is based on a modified 2015 Federal Standard (10 CFR Part 431, discussed in Subpart B, Appendix D2). Calculations assume 283 cycles per year and an 8.45 lb load for standard sized dryers (≥ 4.4 cubic foot capacity).

2. ENERGY STAR. “Product Specifications & Partner Commitments Search.” https://www.energystar.gov/products/spec/clothes_dryers_specification_version_1_0_pdf
3. Prepared by Shelter Analytics; Facilitated and Managed by Northeast Energy Efficiency Partnership. “Mid-Atlantic Technical Reference Manual Version 4.0.” Clothes washer measure, p. 184. June 2014. http://www.neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V4_FINAL.pdf

Revision History

Version Number	Date	Description of Change
01	06/24/2016	Initial TRM entry

Lighting

Interior Lighting Controls, CALP

	Measure Details
Measure Master ID	Lighting Controls, Interior, CALP, 3969
Workpaper ID	W0216
Measure Unit	Per watt controlled
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Controls
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	3
Peak Demand Reduction (kW)	0.0003
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	24
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost ($/unit)	$0.92[2]

Measure Description

Interior lighting controls (also known as occupancy sensors) reduce energy consumption by reducing the operating hours for lighting equipment in low occupancy areas, such as hallways, storage rooms, and restrooms. Occupancy sensors automatically turn lights off a preset time after people leave a space, and turn lights on automatically when movement is detected. Occupancy sensors feature a delay adjustment that determines the time that lights are on after no occupancy is detected, as well as a sensitivity adjustment that determines the magnitude of the signal required to trigger the occupied status.

The two primary technologies used for occupancy sensors are passive infrared (PIR) and ultrasonic. PIR sensors determine occupancy by detecting the difference in heat between a body and the background. Ultrasonic sensors detect people using volumetric detectors and broadcast sounds above the range of human hearing, then measure the time it takes the waves to return.

Description of Baseline Condition

The baseline condition is no occupancy sensor, with lighting fixtures being controlled by manual wall switches.

Description of Efficient Condition

The efficient condition is a hard-wired, fixture-, wall-, or ceiling-mounted occupancy sensor, where lighting fixtures are controlled by the sensors based on detected occupancy.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = Watts / 1,000 * SF * HOU$

Where:

Watts = Controlled lighting wattage (provided for each project)

1,000 = Kilowatt conversion factor

SF = Savings factor, deemed (= 41%)[3]

HOU = Hours of use (= 6,614)[4]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Watts * SF /1,000 * CF$

Where:

CF = Coincidence factor (= 0.77)[5]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 8 years)[1]

Deemed Savings

Annual Savings (per watt controlled)

Measure	MMID	Multifamily	
		kWh	kW
Lighting Controls, Interior, CALP	3969	3	0.0003

Lifecycle Savings (per watt controlled)

Measure	MMID	Multifamily
Lighting Controls, Interior, CALP	3969	24

Sources

1. PA Consulting Group. *Focus on Energy, Business Programs: Measure Life Study Final Report*. Appendix B. August 25, 2009. https://focusonenergy.com/sites/default/files/bpmeasurelifestudyfinal_evaluationreport.pdf
2. Average incremental costs from 2016 CALP LED SPECTRUM measure master IDs 3605, 3606, 3201 and 3202, converted to dollars per watt.
3605: Similar to MMID 2474. WESCO Distribution Pricing ($70.00) + Labor ($25.00) = $95.00

3606: Similar to MMID 2474. WESCO Distribution Pricing ($70.00) + Labor ($25.00) = $95.00
3201: WESCO Distribution Pricing ($18.75) + Labor ($16.25) = $35.00 for Wall Mount. WESCO Distribution Pricing, 2013 + Labor = $120.00 for Ceiling Mount. $77.50 is the average.
3202: WESCO Distribution Pricing ($18.75) + Labor ($16.25) = $35.00 for Wall Mount. WESCO Distribution Pricing, 2013 + Labor = $120.00 for Ceiling Mount. $77.50 is the average.

3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. March 22, 2010. Table 4-161. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Historical Focus on Energy project data, January 1, 2015 through November 15, 2016. Weighted average of 12-hour versus 24-hour fixture replacements under MMIDs 3199, 3197, 3198, 3735, 3603, 3604, 3200, 3196 and 3195. Forty-nine percent of replaced fixtures operated 12 hours or more and 51% operated 24 hours
5. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	11/15/2016	Initial TRM entry

8-Foot Linear Fluorescent T8 Replacement System Parking Garage

	Measure Details
Measure Master ID	T8 2-Lamp, 4-Foot, HPT8 or RWT8: Replacing T12HO 1-Lamp, 8-Foot, BF > 1.00, Parking Garage, 3148 T8 4-Lamp, 4-Foot, HPT8 or RWT8: Replacing T12HO 2-Lamp, 8-Foot, 0.78 < BF < 1.00, Parking Garage, 3152 Replacing T12HO 2-Lamp, 8-Foot, BF ≤ 0.78, Parking Garage, 3153
Workpaper ID	W0219
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Fluorescent, Linear
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	Varies by measure, see Appendix D

Measure Description

This measure is high performance and reduced wattage 4-foot linear fluorescent lighting fixtures that use low ballast factors, high wattage lamps, or reduced wattage lamps are an energy-efficient alternative to 8-foot standard wattage T12, T12HO, and T12VHO linear fluorescent fixtures commonly found in parking garages within multifamily buildings. These products can be installed on a two-to-one basis to replace 1-lamp or 2-lamp T12 luminaires without sacrificing lighting quality.

Description of Baseline Condition

For existing building parking garages, the baseline measure is 8-foot, 1-lamp or 2-lamp, standard T12, T12HO, and T12VHO linear fluorescent fixtures.

Description of Efficient Condition

The efficient measure is 2-lamp or 4-lamp, 4-foot, high performance T8 fixtures with normal and low ballast factor, and reduced wattage, 25-watt and 28-watt T8s with high, normal, and low ballast factors.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{8'\ T12} - kWh_{HP/RW}$

Where:

$kWh_{8' T12}$ = Annual electricity consumption of an 8-foot, T12, T12HO, or T12VHO lamp linear fluorescent fixture

$kWh_{HP/RW}$ = Annual electricity consumption of a 4-foot linear fluorescent high performance or reduced wattage fixture

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = Wattage / 1,000 * CF

Where:

Wattage = Wattage used

1,000 = Kilowatt conversion factor

CF = Coincidence factor (= 1.0) [3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED}$ * EUL

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Annual Deemed Savings for 8-Foot Linear Fluorescent T8 Replacement System Parking Garage

Measure	MMID	Existing Building	
		kWh	kW
T8 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 1-Lamp, 8-Foot, BF > 1.00, Parking Garage	3148	473	0.0541
T8 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 2-Lamp, 8-Foot, 0.78 < BF < 1.00, Parking Garage	3152	1,083	0.1236
T8 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 2-Lamp, 8-Foot, BF ≤ 0.78, Parking Garage	3153	1,191	0.136

Lifecycle Deemed Savings for 8-Foot Linear Fluorescent T8 Replacement System Parking Garage

Measure	MMID	Existing Building (kWh)
T8 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 1-Lamp, 8-Foot, BF > 1.00, Parking Garage	3148	7,095
T8 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 2-Lamp, 8-Foot, 0.78 < BF < 1.00, Parking Garage	3152	16,245
T8 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 2-Lamp, 8-Foot, BF ≤ 0.78, Parking Garage	3153	17,865

Measure Costs for 8-Foot Linear Fluorescent T8 Replacement System Parking Garage[2]

Measure	MMID	Existing Building Cost
T8 2-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 1-Lamp, 8-Foot, BF > 1.00, Parking Garage	3148	$41.00
T8 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 2-Lamp, 8-Foot, 0.78 < BF < 1.00, Parking Garage	3152	$66.00
T8 4-Lamp, 4-Foot, HPT8 or RWT8 Replacing T12HO 2-Lamp, 8-Foot, BF ≤ 0.78, Parking Garage	3153	$66.00

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/
2. Michigan Master Measure Database. 2011 baselines. Updated May 26, 2011.
3. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
4. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

Revision History

Version Number	Date	Description of Change
01	12/31/2012	Initial TRM entry
02	01/2019	Removed MMIDs 3144—3147, 3149—3151, and 3154-3156

Reduced Wattage 8-Foot T8 Lamps Replacing 8-Foot Standard T8 Lamps

	Measure Details
Measure Master ID	Reduced Wattage 8-Foot T8 Lamps Replacing 8-Foot Standard T8 Lamps, 2665
Workpaper ID	W0222
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Fluorescent, Linear
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by wattage
Peak Demand Reduction (kW)	Varies by wattage
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by wattage
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$4.33[4]

Measure Description

Reduced wattage 8-foot standard wattage T8 lamps save energy by reducing the total input wattage of the luminaires where installed. Reduced wattage 8-foot T8 lamps can be installed in place of existing 59-watt 8-foot T8 lamps where the tasks that take place in the space do not require the light level provided by the existing lamps.

Description of Baseline Condition

The baseline equipment is standard 59-watt 8-foot T8 lamps.

Description of Efficient Condition

The efficient equipment is 49-watt, 50-watt, 51-watt, or 54-watt 8-foot T8 lamps.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{59wattT8} - kWh_{RWLamp}$

Where:

$kWh_{59wattT8}$ = Annual electricity consumption of standard 59-watt 8-foot T8 lamp

kWh_{RWLamp} = Annual electricity consumption of reduced wattage 8-foot T8 lamp

Summer Coincident Peak Savings Algorithm

kW_{SAVED} = Wattage / 1,000 * CF

Where:

Wattage = Wattage of installed fixture; (= ballast factor * lamp wattage)

1,000 = Kilowatt conversion factor

CF = Coincidence factor (= 0.77)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = ($kWh_{59wattT8}$ - kWh_{RWLamp}) * EUL

Where:

EUL = Effective useful life (= 15 years)[1]

Assumptions

An average of 25% each of 49-watt, 50-watt, 51-watt, and 54-watt 8-foot T8 lamps was used to generate the new measure wattage.

Sources

1. California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” February 4, 2014. http://www.deeresources.com/
Rated ballast life of 70,000 hours. Not rated on bulb life. Capped at 15 years.
2. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf
3. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.
4. 2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.

Revision History

Version Number	Date	Description of Change
01	12/2012	Updated savings values

LED, Omnidirectional, Connected Lighting Pack

	Measure Details
Measure Master ID	Connected Lighting Pack, Hub-Based, 4432 Connected Lighting Pack, Non-Hub, 4433
Workpaper ID	W0223
Measure Unit	Per kit
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure and sector
Peak Demand Reduction (kW)	Varies by measure and sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure and sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15 (see Assumptions)
Incremental Cost ($/unit)	$65.33 for MMID 4432;[1] $79.98 for MMID 4433[2]

Measure Description

Connected lighting products are retail lighting products that allow users to control the lights remotely, using a mobile app or web user interface. Basic features include the ability to remotely turn the light on and off and adjust its brightness and to set a schedule for the light. More advanced features are also available, such as motion and daylight sensing.

The technology leads to a reduction in energy consumption by providing dimming capabilities to otherwise non-dimmable sockets, as well as a reduction in hours of use by allowing users to turn off lights from anywhere and to schedule lights they would not otherwise put on a timer. Some connected lighting products use a hub to facilitate wireless communication with the lights, which requires additional power and therefore reduces total savings. Other connected lighting products do not use a hub. Although total savings from non-hub products are also reduced as a result of bulb standby power draw associated with the lights being turned off via the application interface, the decrease in total savings is smaller than the decrease associated with using a hub.

Savings values provided are derived from a study conducted in the summer of 2017,[3] in which two-lamp Philips Hue hub-based connected lighting kits were supplied for free and metered in more than 90 homes across Wisconsin.

Description of Baseline Condition

The baseline equipment is a general service 43-watt halogen light bulb.

Description of Efficient Condition

The efficient equipment is a connected light that can communicate either through a hub or directly with users via a readily available short-range telecommunication protocol.

Annual Energy-Savings Algorithm

$$kWh_{SAVED} = (\Delta kWh_{LED} * ISR_{LED}) + (\Delta kWh_{APP} * ISR_{APP}) + (\Delta kWh_{HUB} * ISR_{HUB})$$

$$\Delta kWh_{LED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * HOU * N_{LAMPS}$$

$$\Delta kWh_{APP} = (\Delta kWh_{DIM} + \Delta kWh_{HOU} - \Delta kWh_{STBY}) * N_{LAMPS}$$

$$\Delta kWh_{DIM} = Watts_{EE} / 1{,}000 * \%\Delta Watts_{DIM} * [HOU * (1 - \%\Delta HOU)]$$

$$\Delta kWh_{HOU} = [Watts_{EE} * (1 - \%\Delta Watts_{DIM})] / 1{,}000 * HOU * \%\Delta HOU$$

$$\Delta kWh_{STBY} = Watts_{STBY} / 1{,}000 * HOU_{STBY}$$

$$\Delta kWh_{HUB} = Watts_{HUB} / 1{,}000 * 8{,}760$$

Where:

ΔkWh_{LED} = Reduction in annual energy consumption from upgrading a single bulb

ISR_{LED} = Installation rate for two bulbs (= 90%, see Assumptions)[3]

ΔkWh_{APP} = Reduction in annual energy consumption from using all connected lighting features and standby and hub energy usage

ISR_{APP} = Usage rate of the smart lighting app (= 75%, see Assumptions)[3]

ΔkWh_{HUB} = Increase in annual energy consumption from hub power

ISR_{HUB} = Installation rate for hubs (= 75% for MMID 4432, see Assumptions;[3] = 0 for MMID 4433)

$Watts_{BASE}$ = Baseline wattage (= 43 watts, see Assumptions)

$Watts_{EE}$ = Efficient wattage (= 9.5 watts for MMID 4432;[4] = 11 watts for MMID 4433[5])

1,000 = Conversion from watts to kilowatts

HOU = Hours of use (= 829 hours for single family, 734 hours for multifamily)[6]

N_{LAMPS} = Number of lamps installed (= 2, see Assumptions)

ΔkWh_{DIM} = Reduction in annual energy consumption from app-induced dimming

ΔkWh_{HOU} = Reduction in annual energy consumption from app-induced HOU reduction

ΔkWh_{STBY} = Increase in annual energy consumption from standby power

$\%\Delta Watts_{DIM}$ = Average app-induced percentage decrease in power (= 11%)[3]

$\%\Delta HOU$ = Average app-induced percentage decrease in HOU (= 4%)[3]

$Watts_{STBY}$ = Bulb standby wattage (= 0.3 watts for MMID 4432;[3] = 0.5 watts for MMID 4433,[5] see Assumptions)

HOU_{STBY} = Bulb standby hours of use (= 160 hours)[3]

$Watts_{HUB}$ = Hub wattage (= 1.6 watts for MMID 4432;[3] = 0 watts for MMID 4433)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (\Delta kW_{LED} * ISR_{LED}) + (\Delta kW_{APP} * ISR_{HUB})$

$\Delta kW_{LED} = (Watts_{BASE} - Watts_{EE}) / 1{,}000 * CF * N_{LAMPS}$

$\Delta kW_{APP} = (\Delta kW_{DIM} - \Delta kW_{STBY}) * N_{LAMPS} - \Delta kW_{HUB}$

$\Delta kW_{DIM} = Watts_{EE} * \%\Delta Watts_{DIM} * CF / 1{,}000$

$\Delta kW_{STBY} = Watts_{STBY} * CF_{STBY} / 1{,}000$

$\Delta kW_{HUB} = Watts_{HUB} / 1{,}000$

Where:

CF = Coincidence factor for bulb usage time (= 12%)[3]

CF_{STBY} = Coincidence factor for bulb standby time (= 2%)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years, see Assumptions)

Deemed Savings

Savings for Pack-Based Connected Lighting Bulbs

Measure	MMID	Sector	Annual Savings (kWh)	Demand Reduction (kW)	Lifecycle Savings (kWh)
Connected Lighting Pack, Hub-Based	4432	Single family	41	0.0062	615
		Multifamily	35	0.0062	525
Connected Lighting Pack, Non-Hub	4433	Single family	50	0.0071	750
		Multifamily	44	0.0071	660

Assumptions

The savings are based on data used in a study conducted by Cadmus on behalf of the Wisconsin Focus on Energy program.[3] The connected lighting used by the study was the Philips Hue bulb, which uses a hub-based communication network. The power consumption of two baseline lights was metered, then the power consumption of two connected lights that replaced the baseline lights was metered. Participants were asked to change the lights on the summer solstice, so that both conditions occurred with the same average amount of sunlight per day. Most meters logged data from mid-May through early to late August. Most participants received meters in the mail, which they were instructed to connect in series with the lamp where the connected lights would be set up. They then received the kits in the mail in June, and were asked to install on June 21. Participants were asked to return the meters by mail. Data was retrieved from 109 participants in Wisconsin, 95 of which were confirmed to have used the technology.

The coincidence factor was calculated as the percentage of connected lighting runtime during Wisconsin's peak period, and did not receive any adjustment based on dimming during the peak times. The standby coincidence factor was calculated as the percentage of time the bulbs were in standby mode during the peak period. The $\%\Delta Watts_{DIM}$ represents the average percentage reduction in wattage due to dimming, calculated as the difference between the maximum observed wattage and the average observed wattage for each household, divided by the maximum observed wattage. The $\%\Delta HOU$ was calculated similarly, as the difference between the observed hours of use before and after the connected lighting was installed, divided by the observed hours of use before it was installed.

The study revealed that 90% of participants installed both bulbs that came with the kit, 0% installed only one bulb, and 10% installed no bulbs. The study also revealed that 75% of participants installed and used the hub along with the light bulbs.

The maximum output of a Philips Hue bulb is 840 lumens,[4] and it is 1,100 lumens for LIFX bulbs.[5] In accordance with the lumen equivalence method as specified in the *Uniform Methods Project*,[7] a Philips Hue bulb would replace a 43-watt halogen bulb and a LIFX bulb would replace a 52-watt halogen bulb. However, it is assumed that LIFX bulbs will generally be kept as dim as Philips bulbs, and therefore LIFX bulbs will generally replace 43-watt halogen bulbs as well.

The study revealed 2.21 hours of use per day on average for connected lighting bulbs (808 hours per year), but this value holds only for the summer study period, rather than the entire year. Therefore, this workpaper used the previously measured value of 829 hours for single family residents and 734 hours for multifamily residents.[6] The value for $\%\Delta HOU$, derived from the study, is maintained as a percentage rather than an absolute.

The study revealed an average Philips Hue standby wattage of 0.3. The study did not examine LIFX bulbs, but the LIFX website[5] lists a standby wattage of < 0.5, and this workpaper uses a value of 0.5 watts.

The claimed lifetime is 25,000 hours for both LIFX[5] and Philips Hue[4] bulbs. With an HOU of 829, the calculated lifetime is 30 years. However, a 15-year EUL cap has been deemed for most residential screw-base LED measures, as a result of measure persistence concerns[8] and LED lifetime cap practices of other programs (in CT, DC, IL, MA, MN, RI, and VT). While connected lighting products are less susceptible to persistence issues, they also have many more electronic components than standard LED products and are therefore likely more subject to early failure.[9] Therefore, the 15-year EUL cap is maintained for these measures.

Sources

1. Wisconsin Focus on Energy. Quote from Philips for two-bulb Hue kit.
2. Wisconsin Focus on Energy. Quote from LIFX for two A19 LIFX bulbs.
3. Iaccarino, Joseph, C. Kelly, S. Cofer, J. Fontaine. *Only as Smart as Its Owner: A Connected Device Study.* August 2018. https://cadmusgroup.com/papers-reports/only-as-smart-as-its-owner-a-connected-device-study/
4. Philips Hue. "Specifications of the Hue White Starter Kit." https://www2.meethue.com/en-us/p/hue-white-starter-kit-e26/046677455286/specifications
5. LIFX. "LIFX Color A19 LED Smart Bulb." https://www.lifx.com/products/lifx
6. Cadmus. "Focus on Energy Evaluated Deemed Savings Changes." November 26, 2013. https://focusonenergy.com/sites/default/files/FOC_XC_Deemed_WriteUp_12122013%20%282%29.pdf
7. National Renewable Energy Laboratory. *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*. "Chapter 21: Residential Lighting Evaluation Protocol." NREL/SR-7A40-63205. Table 2. February 2015. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf
8. NEEP. *Residential Lighting Deep Dive Brief: A Comparison of Savings Assumptions across the Northeast and Mid-Atlantic*. January 2016. http://www.neep.org/sites/default/files/resources/ResLightingDeeperDiveFINAL1.pdf
9. Next Generation Lighting Industry Alliance. *LED Luminaire Lifetime: Recommendations for Testing and Reporting*. September 2016. https://energy.gov/sites/prod/files/2015/01/f19/led_luminaire_lifetime_guide_sept2014.pdf

Revision History

Version Number	Date	Description of Change
01	01/2018	Initial TRM entry
02	04/2018	Added multifamily sector

LED, Pack-Based, Standard Bulb

	Measure Details
Measure Master ID	LED, Pack-Based, 9 Watt, 4277 LED, Pack-Based, 11 Watt, 4278
Workpaper ID	W0224
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	5[1]
Incremental Cost ($/unit)	9 watt = $0.09 (MMID 4277); 11 watt = $0.82 (MMID 4278)[2]

Measure Description

This measure is the installation of a general purpose, ENERGY STAR-qualified, screw-in LED A-lamp in place of an incandescent screw-in bulb. Pack-based measures assume the lamp was provided as part of a package, so an installation rate less than 100% is applied.

Description of Baseline Condition

The *Uniform Methods Project* (UMP) provides guidelines, based on EISA and the lumen output of the bulb and bulb type, for determining globe bulb baselines.[5] The 9-watt lamp is a TCP model LED9A19D27K, with output ranging from 825 lumens to 850 lumens. According to the *Uniform Methods Project*,[5] this corresponds to a baseline of 43 watts. The 11-watt lamp is a TCP model L11A19D2527K, with output ranging from 1,150 lumens to 1,225 lumens. According to the *Uniform Methods Project*, this corresponds to a baseline of 53 watts.

Description of Efficient Condition

The pack-based bulb models described above consume 9 watts and 11 watts, respectively.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * HOU * IR$

Where:

$Watts_{BASE}$ = Baseline wattage (= 43 watts for MMID 4277; = 53 watts for MMID 4278; see Description of Baseline Condition)

$Watts_{EE}$ = Efficient wattage (= 9 watts for MMID 4277; = 11 watts for MMID 4278)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= 829 for single family, 734 for multifamily)[3]

IR = Installation rate (= 96% for 9W,= 95% for 11W)[4]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1{,}000 * CF * IR$

Where:

CF = Coincidence factor (= 0.075 for single family, 0.055 for multifamily)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 years, see Assumptions)[1]

Deemed Savings

Single Family Savings

$Watts_{EE}$	MMID	Sector	Annual kWh_{SAVED}	kW_{SAVED}	Lifecycle $kWh_{LIFECYCLE}$
9	4277	Single Family	27	0.0024	135
		Multifamily	24	0.0018	120
11	4278	Single Family	33	0.0030	165
		Multifamily	29	0.0022	145

Assumptions

As demonstrated by data from the Consortium for Retail Energy Efficiency Data (CREED), LED market share has been rising steadily in recent years.[6] In a 2019 LED market forecast,[7] the U.S. DOE estimates that LEDs will comprise a majority of installed lamps by 2030. The 15 or 20 year technical life of an LED encompasses approximately four or five halogen lamp lifetimes, each of which is a theoretical opportunity for an LED replacement. Therefore even aside from future lighting code uncertainty,[6] the

LED lifetimes used to estimate program impacts should recognize the likelihood that a socket filled by a program lamp may have an LED installed within a few years even in the absence of the program.

For the 2022 program year, Focus on Energy estimated screw-base LED lifetime by combining current and Wisconsin-specific CREED data with LED market projections. This process produced lifetimes of five years for standard A-line bulbs, eight years for standard globe and decorative bulbs, four years for reflector bulbs, 11 years for income-qualified A-line bulbs, and 10 years for income-qualified globe, decorative, and reflector bulbs. These lifetimes will be revisited yearly in light of updated market forecasts and lighting code futures.

Sources

1. Apex Analytics and Cadmus. Analysis combining data from the Consortium for Retail Energy Efficiency Data with LED market projections to produce effective program lifetimes of screw-base LED bulbs.
2. Pack-based LED bulbs are provided free to customers, but they displace retail purchases that would have happened otherwise. The incremental cost is therefore the full bulk pricing cost of the bulb to Focus on Energy, minus the bulb baseline cost. The efficient costs are $1.41 for the 9 watt bulb and $2.33 for the 11 watt bulb. The baseline costs are deemed to be the same as for 310-749 lumen lamps and 750-1,049 lumen lamps in W0228, $1.32 and $1.51, from Consortium for Retail Energy Efficiency Data. $1.41 - $1.32 = $0.09, and $2.33 - $1.51 = $0.82.
3. Cadmus. *Focus on Energy Deemed Savings Changes*. September 12, 2016. https://focusonenergy.com/sites/default/files/2016%20Deemed%20Savings%20Review.pdf
4. Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report Volume II. p. 17. May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf*
5. National Renewable Energy Laboratory. "The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures." Chapter 21: Residential Lighting Evaluation Protocol. NREL/SR-7A40-63205. February 2015. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf
6. Apex Analytics. *COVID-19 and EISA Challenges Lead to Uncertainty in the Lighting Market: LED Market Update, Analysis, and Implications for Energy Efficiency Programs*. May 1, 2020. http://www.creedlighttracker.com/wp-content/uploads/2020/05/Spring-2020-Lighting-Update_050520_PDF.pdf
7. U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. "Energy Savings Forecast of Solid-State Lighting in General Illumination Applications." December 2019. https://www.energy.gov/sites/prod/files/2019/12/f69/2019_ssl-energy-savings-forecast.pdf. Table 4.13

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	01/2018	Updated sourcing, added 9-watt and 11-watt models
03	04/2018	Added multifamily sector
04	02/2020	Updated cost
05	01/2021	Updated EUL and cost
07	09/2021	Updated ISRs, EUL and lifecycle savings, cost

LED, Pack-Based, 5 Watt Globe G25 Lamp

	Measure Details
Measure Master ID	LED, Pack-Based, 5 Watt, G25 Lamp, 3896
Workpaper ID	W0225
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	16 for single family, 14 for multifamily
Peak Demand Reduction (kW)	0.0014 for single family, 0.0010 for multifamily
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	128 for single family, 112 for multifamily
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost	$0.77[2]

Measure Description

ENERGY STAR-rated LED replacement globe lamps save energy by reducing the total input wattage of the luminaire as compared to standard wattage incandescent globe lamps. This measure provides an energy-efficient alternative to using incandescent globe lamps in individual units. Pack-based measures assume the lamp was provided as part of a package, so an installation rate of 92% is applied.

Description of Baseline Condition

The Uniform Methods Project provides guidelines, based on EISA and on the lumen output of the bulb and the bulb type, for determining globe bulb baselines. The pack-based bulb model is a TCP LED5G25D27KF and has an output of 300 lumens (baseline of 25 watts).[3]

Description of Efficient Condition

The efficient equipment is an ENERGY STAR-rated G25 LED lamp of 5 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000 * IR$

Where:

$Watts_{BASE}$ = Power consumption of baseline incandescent fixtures (= 25 watts)[3]

$Watts_{EE}$ = Power consumption of efficient LED product (= 5 watts)

HOU = Hours of use (= 829 for single family, = 734 for multifamily)[4]

1,000 = Kilowatt conversion factor

IR = Installation rate (= 94%)[5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) / 1,000 * CF * IR$

Where:

CF = Coincidence factor (= 0.075 for single family, = 0.055 for multifamily)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 8 years, see Assumptions)[1]

Deemed Savings

Average Annual Deemed Savings for LED G25 Lamp

Measure	MMID	Sector	Annual		Lifecycle
			kWh	kW	kWh
Pack-Based 5-Watt LED Lamp Replacing Incandescent G25 Lamp	3896	Single family	16	0.0014	128
		Multifamily	14	0.0010	112

Assumptions

As demonstrated by data from the Consortium for Retail Energy Efficiency Data (CREED), LED market share has been rising steadily in recent years.[6] In a 2019 LED market forecast,[7] the U.S. DOE estimates that LEDs will comprise a majority of installed lamps by 2030. The 15 or 20 year technical life of an LED encompasses approximately four or five halogen lamp lifetimes, each of which is a theoretical opportunity for an LED replacement. Therefore even aside from future lighting code uncertainty,[6] the LED lifetimes used to estimate program impacts should recognize the likelihood that a socket filled by a program lamp may have an LED installed within a few years even in the absence of the program.

For the 2022 program year, Focus on Energy estimated screw-base LED lifetime by combining current and Wisconsin-specific CREED data with LED market projections. This process produced lifetimes of five years for standard A-line bulbs, eight years for standard globe and decorative bulbs, four years for reflector bulbs, 11 years for income-qualified A-line bulbs, and 10 years for income-qualified globe, decorative, and reflector bulbs. These lifetimes will be revisited yearly in light of updated market forecasts and lighting code futures.

Sources

1. Apex Analytics and Cadmus. Analysis combining data from the Consortium for Retail Energy Efficiency Data with LED market projections to produce effective program lifetimes of screw-base LED bulbs.
2. Pack-based LED bulbs are provided free to customers, but they displace retail purchases that would have happened otherwise. The incremental cost is therefore the full bulk pricing cost of the globe bulb to Focus on Energy, $2.27, minus the baseline cost. The baseline cost is deemed to be the same as for globe lamps in W0229, $1.50 from Consortium for Retail Energy Efficiency Data. $2.27 - $1.50 = $0.77.
3. National Renewable Energy Laboratory. *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*. “Chapter 21: Residential Lighting Evaluation Protocol.” NREL/SR-7A40-63205. Table 3. February 2015. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf
4. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. June 10, 2016. https://www.focusonenergy.com/sites/default/files/2016%20Deemed%20Savings%20Review.pdf
5. Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report Volume II. p. 17. May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf*
6. Apex Analytics. *COVID-19 and EISA Challenges Lead to Uncertainty in the Lighting Market: LED Market Update, Analysis, and Implications for Energy Efficiency Programs*. May 1, 2020. http://www.creedlighttracker.com/wp-content/uploads/2020/05/Spring-2020-Lighting-Update_050520_PDF.pdf
7. U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. “Energy Savings Forecast of Solid-State Lighting in General Illumination Applications.” December 2019. https://www.energy.gov/sites/prod/files/2019/12/f69/2019_ssl-energy-savings-forecast.pdf. Table 4.13

Revision History

Version Number	Date	Description of Change
01	10/13/2015	Initial TRM entry
02	05/10/2016	Added pack-based measure
03	10/2017	Updated effective useful life for MMID 3734
04	04/2018	Added multifamily sector, updated single family savings, and removed direct install measure
05	01/2021	Updated EUL and cost
07	09/2021	Updated ISRs, EUL and lifecycle savings

LED, Pack-Based, 5 Watt, B11, Decorative Candelabra Base

	Measure Details
Measure Master ID	LED, Pack-Based, 5 Watt, B11, 4042
Workpaper ID	W0226
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	26 for single family, 23 for multifamily
Peak Demand Reduction (kW)	0.0024 for single family, 0.0018 for multifamily
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	208 for single family, 184 for multifamily
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	8[1]
Incremental Cost	$1.43[2]

Measure Description

ENERGY STAR-rated LED replacement candelabra base (B11) lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent candelabra base lamps. This measure provides an energy-efficient alternative to incandescent candelabra base lamps in individual units. Pack-based measure savings are based on lamps provided as part of a package, so an installation rate of 91% is applied.[5]

Description of Baseline Condition

The Uniform Methods Project provides guidelines, based on EISA and the lumen output of the bulb and bulb type, for determining globe bulb baselines.[3] The pack-based bulb model is a TCP LED5E12B1127K with an output of 300 lumens (or a baseline of 40 watts).

Description of Efficient Condition

The pack-based bulb model is a TCP LED5E12B1127K, which consumes 5 watts.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) * HOU / 1,000 * IR$

Where:

$Watts_{BASE}$ = Power consumption of baseline incandescent fixtures (= 40 watts; see Assumptions)

$Watts_{EE}$ = Power consumption of efficient LED product (= 5 watts)

HOU = Hours of use (= 829 for single family, = 734 for multifamily)[4]

1,000 = Kilowatt conversion factor

IR = Installation rate (= 91% for pack-based bulbs)[5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) / 1,000 * CF * IR$

Where:

CF = Coincidence factor (= 0.075 for single family, = 0.055 for multifamily)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 8 years, see Assumptions)[1]

Assumptions

The baseline of 40 watts for pack-based bulbs is based on bulb models and UMP guidelines.[3]

Deemed Savings

Average Annual Deemed Savings for LED Candelabra Base (E12) Lamp

Measure	MMID	Sector	Annual Savings		Lifecycle Savings
			kWh	kW	kWh
LED, Pack-Based, 5 Watt, B11	4042	Single family	26	0.0024	208
		Multifamily	23	0.0018	184

Assumptions

As demonstrated by data from the Consortium for Retail Energy Efficiency Data (CREED), LED market share has been rising steadily in recent years.[6] In a 2019 DOE LED market forecast,[7] the U.S. DOE estimates that LEDs will comprise a majority of installed lamps by 2030. The 15 or 20 year technical life of an LED encompasses approximately four or five halogen lamp lifetimes, each of which is a theoretical opportunity for an LED replacement. Therefore even aside from future lighting code uncertainty,[6] the LED lifetimes used to estimate program impacts should recognize the likelihood that a socket filled by a program lamp may have an LED installed within a few years even in the absence of the program.

For the 2022 program year, Focus on Energy estimated screw-base LED lifetime by combining current and Wisconsin-specific CREED data with LED market projections. This process produced lifetimes of five years for standard A-line bulbs, eight years for standard globe and decorative bulbs, four years for reflector bulbs, 11 years for income-qualified A-line bulbs, and 10 years for income-qualified globe, decorative, and reflector bulbs. These lifetimes will be revisited yearly in light of updated market forecasts and lighting code futures.

Sources

1. Apex Analytics and Cadmus. Analysis combining data from the Consortium for Retail Energy Efficiency Data with LED market projections to produce effective program lifetimes of screw-base LED bulbs.
2. Pack-based LED bulbs are provided free to customers, but they displace retail purchases that would have happened otherwise. The incremental cost is therefore the full bulk pricing cost of the reflector bulb to Focus on Energy, $2.22, minus the baseline cost. The baseline cost is deemed to be the same as for decorative lamps in W0229, $0.79 from Consortium for Retail Energy Efficiency Data. $2.22 - $0.79 = $1.43
3. National Renewable Energy Laboratory. *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*. "Chapter 21: Residential Lighting Evaluation Protocol." NREL/SR-7A40-63205. February 2015. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf
4. Cadmus. *Focus on Energy Evaluated Deemed Savings*. June 10, 2016. https://focusonenergy.com/sites/default/files/2016%20Deemed%20Savings%20Review.pdf
5. Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report Volume II. p. 17. May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf*Apex Analytics. *COVID-19 and EISA Challenges Lead to Uncertainty in the Lighting Market: LED Market Update, Analysis, and Implications for Energy Efficiency Programs*. May 1, 2020. http://www.creedlighttracker.com/wp-content/uploads/2020/05/Spring-2020-Lighting-Update_050520_PDF.pdf
6. U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. "Energy Savings Forecast of Solid-State Lighting in General Illumination Applications." December 2019. https://www.energy.gov/sites/prod/files/2019/12/f69/2019_ssl-energy-savings-forecast.pdf. Table 4.13

Revision History

Version Number	Date	Description of Change
01	10/13/2015	Initial TRM entry
02	05/10/2016	Added pack-based bulbs
03	10/2017	Updated EUL
04	04/2018	Removed direct install measure and added multifamily sector for pack-based measure
05	01/2021	Updated EUL and cost
07	09/2021	Updated ISR, EUL and lifecycle savings

LED, Pack-Based, 8 Watt, BR30

	Measure Details
Measure Master ID	LED, Pack-Based, 8 Watt BR30, 4276
Workpaper ID	W0227
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	43 for single family, 38 for multifamily
Peak Demand Reduction (kW)	0.0039 for single family, 0.0029 for multifamily
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	172 for single family, 152 for multifamily
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	4[1]
Incremental Cost ($/unit)	$0.00[2]

Measure Description

ENERGY STAR-rated LED replacement BR30 lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent or halogen BR30 lamps. This measure provides an energy-efficient alternative to using incandescent or halogen BR30 lamps in several applications. Pack-based measure savings assume that the lamp was provided as part of a package, so an installation rate less than 100% is applied.

Description of Baseline Condition

The baseline equipment is a 65-watt incandescent BR30 reflector lamp, which is the most common reflector lamp installed in residential recessed can applications. BR30 shaped lamps are exempt from EISA lumen per-watt standards, and instead follow standards set forth in a 2009 Lamps Ruling.[3]

Description of Efficient Condition

The efficient equipment is an 8-watt, ENERGY STAR-rated BR30 LED lamp provided as part of an energy efficiency pack (pack-based).

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{EE}) / 1,000 * HOU * IR$

Where:

$Watts_{BASE}$ = Power consumption of baseline fixture (= 65 watts)

$Watts_{EE}$ = Power consumption of efficient LED product (= 8 watts)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= 829 for single family, = 734 for multifamily)[4]

IR = Installation rate (= 92%)[5]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) / 1,000 * CF * IR$

Where:

CF = Coincidence factor (= 0.075 for single family, = 0.055 for multifamily)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 7 years, see Assumptions)[1]

Deemed Savings

Deemed Savings for LED BR30 Lamp

Measure	MMID	Sector	kW	Annual kWh	Lifecycle kWh
Pack-Based 8-Watt LED BR30 Lamp Replacing BR30 Incandescent	4276	Single Family	0.0039	43	172
		Multifamily	0.0029	38	152

Assumptions

As demonstrated by data from the Consortium for Retail Energy Efficiency Data (CREED), LED market share has been rising steadily in recent years.[6] In a 2019 LED market forecast,[7] the U.S. DOE estimates that LEDs will comprise a majority of installed lamps by 2030. The 15 or 20 year technical life of an LED encompasses approximately four or five halogen lamp lifetimes, each of which is a theoretical opportunity for an LED replacement. Therefore even aside from future lighting code uncertainty,[6] the LED lifetimes used to estimate program impacts should recognize the likelihood that a socket filled by a program lamp may have an LED installed within a few years even in the absence of the program.

For the 2022 program year, Focus on Energy estimated screw-base LED lifetime by combining current and Wisconsin-specific CREED data with LED market projections. This process produced lifetimes of five years for standard A-line bulbs, eight years for standard globe and decorative bulbs, four years for reflector bulbs, 11 years for income-qualified A-line bulbs, and 10 years for income-qualified globe, decorative, and reflector bulbs. These lifetimes will be revisited yearly in light of updated market forecasts and lighting code futures.

Sources

1. Apex Analytics and Cadmus. Analysis combining data from the Consortium for Retail Energy Efficiency Data with LED market projections to produce effective program lifetimes of screw-base LED bulbs.
2. Pack-based LED bulbs are provided free to customers, but they displace retail purchases that would have happened otherwise. The incremental cost is therefore the full bulk pricing cost of the reflector bulb to Focus on Energy, $2.25, minus the bulb baseline cost. The baseline cost is deemed to be the same as for reflector lamps in W0229, $2.90 from Consortium for Retail Energy Efficiency Data. $2.25 - $2.90 = -$0.65. Because the incremental cost would be negative, it is deemed to be $0.00.
3. U.S. Department of Energy. “10 CFR Part 430 Energy Conservation Program: Energy Conservation Standards and Test Procedures for General Service Fluorescent Lamps and Incandescent Reflector Lamps; Final Rule.” July 14, 2009. https://www.gpo.gov/fdsys/pkg/FR-2009-07-14/pdf/E9-15710.pdf
4. Cadmus. *Focus on Energy Evaluated Deemed Savings*. June 10, 2016. https://focusonenergy.com/sites/default/files/2016%20Deemed%20Savings%20Review.pdf
5. Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report Volume II. p. 17. May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf*Apex Analytics. *COVID-19 and EISA Challenges Lead to Uncertainty in the Lighting Market: LED Market Update, Analysis, and Implications for Energy Efficiency Programs*. May 1, 2020. http://www.creedlighttracker.com/wp-content/uploads/2020/05/Spring-2020-Lighting-Update_050520_PDF.pdf
6. U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. “Energy Savings Forecast of Solid-State Lighting in General Illumination Applications.” December 2019. https://www.energy.gov/sites/prod/files/2019/12/f69/2019_ssl-energy-savings-forecast.pdf. Table 4.13

Revision History

Version Number	Date	Description of Change
01	10/13/2015	Initial TRM entry
02	05/10/2016	Added pack-based measures
03	06/10/2017	Updated wattage
04	04/19/2018	Added multifamily sector
05	02/2020	Updated cost
06	01/2021	Updated EUL and cost
08	09/2021	Updated ISR, EUL and lifecycle savings, cost

LED, Omnidirectional, Upstream, Online Store, Pop-Up, and Income Qualified

	Measure Details
Measure Master ID	LED, Omnidirectional, Retail Store Markdown, 310-749 Lumens, 3553 LED, Omnidirectional, Retail Store Markdown, 750-1,049 Lumens, 4308 LED, Omnidirectional, Retail Store Markdown, 1,050-1,489 Lumens, 4310 LED, Omnidirectional, Retail Store Markdown, 1,490-2,600 Lumens, 4312 LED, Omnidirectional, Retail Store Markdown, 2,601-5,000 Lumens, 5133 LED, Omnidirectional, Online Store, 310-749 Lumens, 5134 LED, Omnidirectional, Online Store, 750-1,049 Lumens, 5135 LED, Omnidirectional, Online Store, 1,050-1,489 Lumens, 5136 LED, Omnidirectional, Online Store, 1,490-2,600 Lumens, 5137 LED, Omnidirectional, Online Store, 2,601-5,000 Lumens, 5138 LED, Omnidirectional, Income Qualified, 310-749 Lumens, 5139 LED, Omnidirectional, Income Qualified, 750-1,049 Lumens, 5140 LED, Omnidirectional, Income Qualified, 1,050-1,489 Lumens, 5141 LED, Omnidirectional, Income Qualified, 1,490-2,600 Lumens, 5142 LED, Omnidirectional, Income Qualified, 2,601-5,000 Lumens, 5143 LED, Omnidirectional, Pop-Up Retail, 310-749 Lumens, 5299 LED, Omnidirectional, Pop-Up Retail, 750-1,049 Lumens, 5300 LED, Omnidirectional, Pop-Up Retail, 1,050-1,489 Lumens, 5301 LED, Omnidirectional, Pop-Up Retail, 1,490-2,600 Lumens, 5302 LED, Omnidirectional, Pop-Up Retail, 2,601-5,000 Lumens, 5303
Workpaper ID	W0228
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- upstream, Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Standard track = 5 (MMIDs 3553, 4308, 4310, and 4312, 5299 through 5303, and 5133 through 5138); Income Qualified = 11 (MMIDs 5139 through 5143)[1]
Incremental Cost ($/unit)	Varies by measure

Measure Description

This measure is installing an ENERGY STAR–certified omnidirectional LED bulb that was purchased through a retail outlet or the Focus on Energy Online Store to replace an incandescent or halogen bulb. It assumes a time-of-sale purchase for installation in a residential location.

Income-qualified measures are purchased through retail or other distribution method that has a majority income-qualified customer base. These include thrift stores, dollar stores, and other store types located in predominantly income-qualified areas that serve income-qualified customers. Single family or multfamily sector assumptions are applied to all Online Store purchases based on customer self-reported housing type.

Description of Baseline Condition

The baseline equipment is a general service incandescent light bulb (standard or EISA compliant halogen). The wattage of the baseline bulb is determined by the lumens equivalence method.[2]

Description of Efficient Condition

The efficient equipment is an ENERGY STAR–certified omnidirectional LED bulb. Typical values are used in this workpaper, but the actual wattage of the installed bulb is used to calculate savings for the evaluation.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \Delta Watts * HOU / 1{,}000 * ISR$

Where:

ΔWatts = Change in wattage, calculated by subtracting efficient bulb wattage from baseline wattage determined from its lumen bin (= varies by lumen bin; see table below)[3]

Wattage Reduction by Lumen Bin[3]

Lumen Bin	MMIDs	Base Watts	Efficient Watts	Gross ΔWatts
310-749 lumens	3553, 5134, 5139, 5299	29.0	5.7	23.3
750-1,049 lumens	4308, 5135, 5140, 5300	43.0	9.1	33.9
1,050-1,489 lumens	4310, 5136, 5141, 5301	53.0	10.8	42.2
1,490-2,600 lumens	4312, 5137, 5142, 5302	57.5	12.8	56.3
2,601-5,000 lumens	5133, 5138, 5143, 5303	61.3	9.1	96.8

HOU = Hours of use (= 996 for standard upstream, = 829 for single family, = 734 for multifamily,[4] = 782 for income qualified; see Assumptions)

1,000 = Kilowatt conversion factor

ISR = In-service rate (= see Installation Rates table and Assumptions)

Installation Rates

Measure Name	MMID	Sector	ISR	Source
LED, Omnidirectional, Retail Store Markdown	3553, 4308, 4310, 4312, 5133	SF/MF	87%	5
LED, Omnidirectional, Pop-Up Retail	5299	SF/MF	90%	9
LED, Omnidirectional, Pop-Up Retail	5300	SF/MF	92%	9
LED, Omnidirectional, Pop-Up Retail	5301	SF/MF	90%	9
LED, Omnidirectional, Pop-Up Retail	5302	SF/MF	88%	9
LED, Omnidirectional, Pop-Up Retail	5303	SF/MF	90%	9
LED, Omnidirectional, Online Store	5134-5138	SF/MF	84%	9
LED, Omnidirectional, Income Qualified	5139-5143	SF/MF	78%	see Assumptions

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = \Delta Watts * CF / 1{,}000 * ISR$

Where:

CF = Coincidence factor (= 0.1162 for upstream, = 0.075 for single family, = 0.055 for multifamily,[4] = 0.065 for income qualified; see Assumptions)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 5 for standard track, = 11 for income qualified; see Assumptions)[1]

Deemed Savings

Deemed Savings

Delivery / Sector		Lumen Bin	MMID	Annual Savings (kWh)	Annual Savings (kW)	Lifecycle Savings (kWh)
Standard upstream		310-749	3553	20	0.0024	100
		750-1,049	4308	29	0.0034	145
		1,050-1,489	4310	37	0.0043	185
		1,490-2,600	4312	49	0.0057	245
		2,601-5,000	5133	84	0.0098	420
Online Store	SF	310-749	5134	16	0.0015	80
	MF			14	0.0011	70
	SF	750-1,049	5135	24	0.0021	120
	MF			21	0.0016	105
	SF	1,050-1,489	5136	29	0.0027	145
	MF			26	0.0019	130

Delivery / Sector		Lumen Bin	MMID	Annual Savings (kWh)	Annual Savings (kW)	Lifecycle Savings (kWh)
	SF	1,490-2,600	5137	39	0.0035	195
	MF			35	0.0026	175
	SF	2,601-5,000	5138	67	0.0061	335
	MF			60	0.0045	300
Income qualified		310-749	5139	14	0.0006	154
		750-1,049	5140	21	0.0008	231
		1,050-1,489	5141	26	0.0010	286
		1,490-2,600	5142	34	0.0014	374
		2,601-5,000	5143	59	0.0024	649
Pop-Up Retail		310-749	5299	17	0.0015	84
		750-1,049	5300	26	0.0023	129
		1,050-1,489	5301	31	0.0028	154
		1,490-2,600	5302	41	0.0036	203
		2,601-5,000	5303	71	0.0064	357

Assumptions

The HOU and CF values were calculated using the cross-sector sales weighting shown in the table below.[4]

Standard Upstream HOU and CF Weighting

Sector	Residential Fraction	Overall Fraction	HOU per Day	HOU per Year	CF
Multifamily	25.3%	23.6%	2.01	734	0.055
Single family	74.7%	69.8%	2.27	829	0.075
Commercial	N/A	6.6%	10.20	3,723	0.770
Overall upstream				**996**	**0.1162**

Income qualified delivery is assumed to have a reduced ISR. Based on Cadmus preliminary findings comparing standard upstream LEDs to food bank giveaways this reduction is about 10%. Therefore, the income qualified ISR is deemed to be 87% * 90% = 78%.

As demonstrated by data from the Consortium for Retail Energy Efficiency Data (CREED), LED market share has been rising steadily in recent years.[6] In a 2019 LED market forecast,[7] the U.S. DOE estimates that LEDs will comprise a majority of installed lamps by 2030. The 15 or 20 year technical life of an LED encompasses approximately four or five halogen lamp lifetimes, each of which is a theoretical opportunity for an LED replacement. Therefore, even aside from future lighting code uncertainty,[6] the LED lifetimes used to estimate program impacts should recognize the likelihood that a socket filled by a program lamp may have an LED installed within a few years even in the absence of the program.

For the 2022 program year, Focus on Energy estimated screw-base LED lifetimes by combining current and Wisconsin-specific CREED data with LED market projections. This process produced lifetimes of five years for standard A-line bulbs, eight years for standard globe and decorative bulbs, four years for reflector bulbs, 11 years for income-qualified A-line bulbs, and 10 years for income-qualified globe, decorative, and reflector bulbs. These lifetimes will be revisited yearly in light of updated market forecasts and lighting code futures.

Incremental Costs

Base costs for each lumen bin were estimated for the Wisconsin market using data from the Consortium for Retail Energy Efficiency Data.[6] Efficient costs for each lumen bin are calculated from the delivered population of upstream bulbs. Income-qualified measures may have a slightly different efficient cost, and this may be examined in future years.

Measure Costs[8]

Lumen Bin	MMIDs	Base Cost	Efficient Cost	Incremental Cost
310-749	3553,5299 5134, 5139	$1.32	$3.02	$1.70
	5299		$2.75	$1.43
750-1,049	4308,5300 5135, 5140	$1.51	$2.74	$1.23
	5300		$3.58	$2.07
1,050-1,489	4310,5301 5136, 5141	$1.35	$3.67	$2.32
	5301		$4.00	$2.65
1,490-2,600	4312,5302 5137, 5142	$1.89	$4.90	$3.01
	5302		$4.00	$2.11
2,601-5,000	5133,5303 5138, 5143	$3.74	$7.25	$3.51
	5303		$12.00	$8.26

Pop-Up Retail Sector Split

For Pop-Up Retail measures, savings are weighted by approximate single family / multifamily participant counts, from 2020 program year Pop-Up Retail Survey results. Nine out of 120 respondents (7.5%) receiving an Energy and Water Savings Kit (containing showerheads, aerators, bulbs, pipe wrap, and a DHW turndown card) were multifamily participants. Nine out of 147 respondents receiving an LED Starter Kit, containing omnidirectional bulbs and a desk lamp, were multifamily participants. A rounded value of 7% is applied for these types of Pop-Up Retail measures, including pipe insulation.

Sources

1. Apex Analytics and Cadmus. Analysis of combining data from the Consortium for Retail Energy Efficiency Data with LED market projections to produce effective program lifetimes of screw-base LED bulbs.
2. National Renewable Energy Laboratory. *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*. "Chapter 21: Residential Lighting Evaluation Protocol." NREL/SR-7A40-63205. Table 3. February 2015. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf
3. Cadmus. *Focus on Energy Calendar Year 2019 Evaluation Report: Volume II*. Table 115. June 2, 2020. https://www.focusonenergy.com/sites/default/files/Annual_Report-CY_2019_Volume_II_0.pdf
   Omnidirectional delta watts values reflect omnidirectional, globe, decorative, and three-way bulbs. Values used here reflect only omnidirectional bulbs. Values for the 2,601 to 5,000 lumen bin reflect an average lumen value of 3,000 and a linear extrapolation.
4. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. Table 12 and Table 14. September 12, 2016. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2016_v1%207.pdf
5. Cadmus. *Focus on Energy Calendar Year 2017 Evaluation Report: Volume II*. Table 126. May 22, 2018. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202017%20Volume%20II%20FINAL.pdf
6. Apex Analytics. *COVID-19 and EISA Challenges Lead to Uncertainty in the Lighting Market: LED Market Update, Analysis, and Implications for Energy Efficiency Programs*. May 1, 2020. http://www.creedlighttracker.com/wp-content/uploads/2020/05/Spring-2020-Lighting-Update_050520_PDF.pdf
7. U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. "Energy Savings Forecast of Solid-State Lighting in General Illumination Applications." Table 4.13. December 2019. https://www.energy.gov/sites/prod/files/2019/12/f69/2019_ssl-energy-savings-forecast.pdf
8. Apex Analytics and Cadmus. Base costs derived from data from the Consortium for Retail Energy Efficiency Data. Efficient costs for Retail Store Markdown, Online Store, and Income Qualified

bulbs calculated from delivered bulbs for the 2019 program year. Efficient costs for Pop-Up Retail reflect bulk pricing to Focus for the bulbs, i.e. the discount plus the customer out-of-pocket price.

9. Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report Volume II. pp. 14,22. May 21, 2021.* *https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf*
10. Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report Volume II. p. 14 and p. 22. May 21, 2021.* *https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf*

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	01/2017	Updated HOU, CF, and delta watts per 2016 *Focus on Energy Deemed Savings Changes* report.[4] Corrected EUL to 20 years per ENERGY STAR requirements.[1]
03	11/2017	Added long lifetime measures
04	12/2018	Updated incremental cost, added ISR, and updated EUL
05	05/2019	Corrected listed incremental cost for MMIDs 4312 and 4313
06	02/2020	Updated incremental cost values, differentiating by lifetime
07	01/2021	Adjusted EUL, removed long lifetime measures, added Online Store and income-qualified measures, updated cost
09	09/2021	Updated EULs, ISRs, added MMIDs and costs for Pop-Up Retail measures

LED, Specialty, Upstream, Online Store, Pop-Up, and Income Qualified

	Measure Details
Measure Master ID	LED, Reflector, Retail Store Markdown, 5144 LED, Reflector, Online Store, 5145 LED, Reflector, Income Qualified, 5146 LED, Reflector, Pop-Up Retail, 5304 LED, Globe, Retail Store Markdown, 5147 LED, Globe, Online Store, 5148 LED, Globe, Income Qualified, 5149 LED, Globe, Pop-Up Retail, 5305 LED, Decorative, Retail Store Markdown, 5150 LED, Decorative, Online Store, 5151 LED, Decorative, Income Qualified, 5152 LED, Decorative, Pop-Up Retail, 5306 LED, Three-Way, Retail Store Markdown, 5153 LED, Three-Way, Online Store, 5154 LED, Three-Way, Income Qualified, 5155 LED, Three-Way, Pop-Up Retail, 5307
Workpaper ID	W0229
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- upstream, Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Standard track = 4 for reflectors (MMIDs 5144 through 5146 and 5304) and8 for other specialty lamps (MMIDs 5147 through 5152 and 5305 through 5307); Income Qualified = 10 (MMIDs 5153 through 5155)[1]
Incremental Cost ($/unit)	Varies by measure

Measure Description

This measure is installing an ENERGY STAR–certified LED reflector or recessed downlight or a globe, decorative, or three-way lamp that was purchased through a retail outlet or the Focus on Energy Online

Store to replace an incandescent or halogen bulb. The savings are based on a time-of-sale purchase for installation in a residential location.

Income-qualified measures are purchased through a retail or other distribution method that has a majority income-qualified customer base. These include food banks, pantries, thrift stores, and other community organizations that serve income-qualified customers. Single family or multfamily sector assumptions are applied for all Online Store purchases based on customer self-reported housing type.

Description of Baseline Condition

The baseline is an incandescent or halogen reflector, globe, decorative, or three-way lamp. Baselines for reflectors are exempt from EISA lumen per-watt standards, and instead follow standards set forth in a 2009 Lamps Ruling.[2] Baselines for other specialty bulbs follow the lumen equivalence method detailed in the *Uniform Methods Project*, Chapter 21.[3] For three-way bulbs, the highest lumen output is used.

Description of Efficient Condition

The efficient equipment is a standard screw-based ENERGY STAR–certified LED reflector or recessed downlight or a globe, decorative, or three-way lamp. Typical values are used in this workpaper, but the actual wattage of the installed bulb is used to calculate savings for the evaluation.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = \Delta Watts * HOU / 1{,}000 * ISR$

Where:

ΔWatts = Change in wattage, calculated by subtracting efficient bulb wattage from baseline wattage determined from its lumen bin (= varies by lamp type; see table below)[4]

Wattage Reduction by Bulb Type[4]

Bulb Type	MMIDs	Baseline Watts	Efficient Watts	Gross ΔWatts
Reflector	5144, 5145, 5146, 5304	61.34	9.07	52.3
Globe	5147, 5148, 5149, 5305	39.46	4.91	34.5
Decorative	5150, 5151, 5152,5306	45.27	4.20	41.1
Three-Way	5153, 5154, 5155, 5307	60.63	14.74	45.9

HOU = Hours of use (= 996 for standard upstream, = 829 for single family, = 734 for multifamily,[5] 782 for income qualified; see Assumptions)

1,000 = Kilowatt conversion factor

ISR = In-service rate (= see Installation Rates table and Assumptions)

Installation Rates

Measure Name	MMID	Sector	ISR	Source

LED, Standard Upstream	5144, 5147, 5150, 5153	SF/MF	87%	6
LED, Reflector, Pop-Up Retail	5304	SF/MF	90%	10
LED, Globe, Pop-Up Retail	5305	SF/MF	89%	10
LED, Decorative, Pop-Up Retail	5306	SF/MF	88%	10
LED, Three-Way, Pop-Up Retail	5307	SF/MF	88%	10
LED, Reflector, Online Store and Income Qualified	5145, 5146	SF/MF	89%	10
LED, Globe, Decorative, 3-Way, Online Store and Income Qualified	5148, 5149, 5151, 5152, 5154, 5155	SF/MF	84%	10

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = \Delta Watts * CF / 1{,}000 * ISR$

Where:

CF = Coincidence factor (= 0.1162 for upstream, = 0.075 for single family, = 0.055 for multifamily,[5] = 0.065 for income qualified)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 4 for reflectors, = 8 for other specialty lamps, = 10 for income qualified; see Assumptions)[1]

Deemed Savings

Deemed Savings

Bulb Type	Delivery / Sector		MMID	Annual Savings (kWh)	Annual Savings (kW)	Lifecycle Savings (kWh)
Reflector	Standard upstream		5144	45	0.0053	180
	Online Store	SF	5145	39	0.0035	156
		MF		34	0.0026	136
	Income qualified		5146	36	0.0030	396
	Pop-Up		5304	39	0.0035	156
Globe	Standard upstream		5147	30	0.0035	240
	Online Store	SF	5148	24	0.0022	192
		MF		21	0.0016	168
	Income qualified		5149	23	0.0019	253
	Pop-Up		5305	25	0.0023	199
Decorative	Standard upstream		5150	36	0.0042	288
	Online Store	SF	5151	29	0.0026	232
		MF		25	0.0019	200
	Income qualified		5152	27	0.0022	297
	Pop-Up		5306	30	0.0026	238
Three-Way	Standard upstream		5153	40	0.0046	320
	Online Store	SF	5154	32	0.0029	256
		MF		28	0.0021	224
	Income qualified		5155	30	0.0025	330
	Pop-Up		5307	33	0.0030	262

Assumptions

The HOU and CF were calculated using the cross-sector sales weighting shown in the table below.

Standard Upstream HOU and CF Weighting[6]

Sector	Residential Fraction	Overall Fraction	HOU per Day	HOU per Year	CF
Multifamily	25.3%	23.6%	2.01	734	0.055
Single family	74.7%	69.8%	2.27	829	0.075
Commercial	N/A	6.6%	10.20	3,723	0.770
Overall upstream				**996**	**0.1162**

For income-qualified delivery, it is assumed that there is a 0% commercial fraction.

As demonstrated by data from the Consortium for Retail Energy Efficiency Data (CREED), LED market share has been rising steadily in recent years.[7] In a 2019 LED market forecast,[8] the U.S. DOE estimates that LEDs will comprise a majority of installed lamps by 2030. The 15 or 20 year technical life of an LED encompasses approximately four or five halogen lamp lifetimes, each of which is a theoretical opportunity for an LED replacement. Therefore, even aside from future lighting code uncertainty,[7] the LED lifetimes used to estimate program impacts should recognize the likelihood that a socket filled by a program lamp may have an LED installed within a few years even in the absence of the program.

For the 2022 program year, Focus on Energy estimated screw-base LED lifetime by combining current and Wisconsin-specific CREED data with LED market projections. This process produced lifetimes of five years for standard A-line bulbs, eight years for standard globe and decorative bulbs, four years for reflector bulbs, 11 years for income-qualified A-line bulbs, and 10 years for income-qualified globe, decorative, and reflector bulbs. These lifetimes will be revisited yearly in light of updated market forecasts and lighting code futures.

Incremental Costs

Base costs for each lamp type were estimated for the Wisconsin market using data from the Consortium for Retail Energy Efficiency Data.[9] For Retail Store Markdown, Online Store, and Income-Qualified bulbs, efficient costs were calculated from the delivered population of upstream bulbs. Income-qualified measures may have a slightly different efficient cost, and this may be examined in future years. For Pop-Up Retail bulbs, efficient costs reflect the bulk cost of the bulb to the program, i.e. the discount plus the customer out-of-pocket price.

Measure Costs[9]

Lamp Type	MMIDs	Baseline Cost	Efficient Cost	Incremental Cost
Reflector	5144,5304 5145, 5146	$2.90	$5.84	$2.94
	5304		$3.15	$0.25
Globe	5147,5305 5148, 5149	$1.50	$3.31	$1.81
	5305		$2.83	$1.33
Decorative	5150,5306 5151, 5153	$0.79	$4.05	$3.26
	5306		$2.83	$0.00
Three-Way	5153,5307 5154, 5155	$2.90	$8.31	$5.41
	5307		$5.25	$0.00

Pop-Up Retail Sector Split

For Pop-Up Retail measures, savings are weighted by approximate single family / multifamily participant counts, from 2020 program year Pop-Up Retail Survey results. One out of of 96 respondents (1.0%) receiving a reflector LED pack was a multifamily participant, and ten out of 96 respondents (8.8%) receiving a globe LED pack and nine out of 112 respondents (8.0%) receiving a decorative were multifamily participants. Because there are generally more globe bulbs than decorative bulbs delivered, a rounded value of 9% is applied for Pop-Up Retail decorative, globe, and 3-way bulbs.

Sources

1. Apex Analytics and Cadmus. Analysis combining data from the Consortium for Retail Energy Efficiency Data with LED market projections to produce effective program lifetimes of screw-base LED bulbs.
2. U.S. Department of Energy. "10 CFR Part 430 Energy Conservation Program: Energy Conservation Standards and Test Procedures for General Service Fluorescent Lamps and Incandescent Reflector Lamps; Final Rule." July 14, 2009. https://www.gpo.gov/fdsys/pkg/FR-2009-07-14/pdf/E9-15710.pdf
3. National Renewable Energy Laboratory. *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*. "Chapter 21: Residential Lighting Evaluation Protocol." NREL/SR-7A40-63205. Table 3. February 2015. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf
4. Cadmus. *Focus on Energy Calendar Year 2019 Evaluation Report: Volume II*. Table 115. June 2, 2020. https://www.focusonenergy.com/sites/default/files/Annual_Report-CY_2019_Volume_II_0.pdf
   Omnidirectional delta watts values reflect omnidirectional, globe, decorative, and three-way bulbs. Values used here reflect individual types of specialty bulbs.
5. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. September 12, 2016. Table 12 and Table 14. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2016_v1%207.pdf
6. Cadmus. *Focus on Energy Calendar Year 2017 Evaluation Report: Volume II*. Table 126. May 22, 2018. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202017%20Volume%20II%20FINAL.pdf
7. Apex Analytics. *COVID-19 and EISA Challenges Lead to Uncertainty in the Lighting Market: LED Market Update, Analysis, and Implications for Energy Efficiency Programs*. May 1, 2020. http://www.creedlighttracker.com/wp-content/uploads/2020/05/Spring-2020-Lighting-Update_050520_PDF.pdf
8. U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. "Energy Savings Forecast of Solid-State Lighting in General Illumination Applications." Table 4.13. December 2019. https://www.energy.gov/sites/prod/files/2019/12/f69/2019_ssl-energy-savings-forecast.pdf
9. Apex Analytics and Cadmus. Base costs derived from data from the Consortium for Retail Energy Efficiency Data. Efficient costs for Retail Store Markdown, Online Store, and Income Qualified bulbs calculated from delivered bulbs for the 2019 program year. Efficient costs for Pop-Up Retail reflect bulk pricing to Focus for the bulbs, i.e. the discount plus the customer out-of-pocket price.

10. Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report Volume II. pp. 14,22. May 21, 2021. https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf*

Revision History

Version Number	Date	Description of Change
01	01/2015	Initial TRM entry
02	01/2017	Updated HOU, CF, and delta watts per 2016 *Focus on Energy Deemed Savings Changes* report. Corrected EUL to 20 years per ENERGY STAR requirements.
03	11/2017	Added long lifetime measures
04	12/2018	Updated incremental cost, added ISR, and updated EUL
05	02/2020	Updated incremental cost
06	01/2021	Adjusted EUL, removed long lifetime measures, added Online Store and income-qualified measures, added globe, decorative, and three-way bulbs that were previously included under the omnidirectional MMIDs, updated cost
08	09/2021	Updated EULs, ISRs, added MMIDs and costs for Pop-Up Retail measures

LED Fixture, Interior, Above 12 Hours to 24 Hours, CALP

	Measure Details
Measure Master ID	LED Fixture, Interior, 12 Hours, CALP, 3603 LED Fixture, Interior, 24 Hours, CALP, 3604
Workpaper ID	W0231
Measure Unit	Per fixture
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Varies by measure
Incremental Cost ($/unit)	$12.46[2]

Measure Description

This measure is installing hardwired LEDs to complete new fixtures. Incentives are only provided for replacing incandescent fixtures. LEDs provide the same or better light output than incandescent lamps while using significantly less energy.

Description of Baseline Condition

The baseline condition is a 1-lamp 72-watt, 65-watt, 43-watt, or 29-watt; a 2-lamp 43-watt or 29-watt; or a 3-lamp 29-watt incandescent fixture on a switch, photocell, or timer that is used for 12 or more hours per day up to 24 hours a day.

Description of Efficient Condition

LED incentives apply only to complete, new, hardwired fixtures that are ENERGY STAR or DLC qualified and meet the EISA lumen equivalency of their incandescent baselines. Incentives are only for replacing incandescent fixtures.

The contractor and/or Program Implementer verifies the hours of use during assessments and/or pre-installs. Typically, lights in the common areas are on for 24 hours, especially those in interior spaces and corridors, and are on for 12 to 16 hours on timers or photocells in the entries and/or lobbies with windows.

The effective useful life of this measure is based on the average rated hours for qualifying products, divided by 12 hours and 24 hours, then rounded.

Annual Energy-Savings Algorithm

$KWh_{SAVED} = (Watts_{INCANDESCENT} - Watts_{LED}) / 1{,}000 * HOU$

Where:

$Watts_{INCANDESCENT}$ = Power consumption of baseline measure (= 63.7 watts; see table below)[3]

Baseline Wattage

Baseline Bulb	Wattage	Weighting	Contribution to Baseline (watts)
1L EISA 100w incand	72	5%	3.60
1L 65w BR30 incand	65	25%	16.25
2L EISA 60w incand	86	25%	21.50
1L EISA 60w incand	43	25%	10.75
3L EISA 40w incand	87	5%	4.35
2L EISA 40w incand	58	10%	5.80
1L EISA 40w incand	29	5%	1.45
Total		**100%**	**63.70**

$Watts_{LED}$ = Power consumption of efficient measure (= 20.93 watts; see table below)[4]

Efficient Wattage

Bulb	Wattage	Weighting	Contribution to Efficient (watts)
LED (1,490-2,600 lumens) replacing 1L EISA 100w incand	32.14	5%	1.6000
LED (600-750 lumens) replacing 1L 65w BR30 incand	13.03	25%	3.
LED (750-1,049 lumens) replacing 2L EISA 60w incand	31.18	25%	7.7950
LED (750-1,049 lumens) replacing 1L EISA 60w incand	15.59	25%	3.8975
LED (310-749 lumens) replacing 3L EISA 40w incand	32.81	5%	1.6405
LED (310-749 lumens) replacing 2L EISA 40w incand	21.88	10%	2.1880
LED (310-749 lumens) replacing 1L EISA 40w incand	10.94	5%	0.5470
Total		**100%**	**20.9325**

1,000 = Kilowatt conversion factor

HOU = Average annual hours of use (= 4,380 for 12-hour use; = 8,760 for 24-hour use)

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{INCANDESCENT} - Watts_{LED}) / 1{,}000 * CF$

Where:

CF = Coincidence factor (= 0.0 to 1.0 for 24-hour use)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = (= 11 years for 12 hour fixtures; = 6 years for 24 hour fixtures)[1]

Deemed Savings

Annual Savings

Measure	MMID	Multifamily	
		kWh	kW
LED Fixture, Interior, 12 Hours, CALP	3603	187	0.0000
LED Fixture, Interior, 24 Hours, CALP	3604	375	0.0428

Lifecycle Savings

Measure	MMID	Multifamily (kWh)
LED Fixture, Interior, 12 Hours, CALP	3603	2,057
LED Fixture, Interior, 24 Hours, CALP	3604	2,250

Assumptions

Lamp weightings were developed through previous CALP workpapers and based on typical lamp wattages in common area light fixtures such as downlights, wall sconces, and flush/ceiling mounts, using typical lamping configuration data from manufacturers. This information was gathered from previous 12-hour and 24-hour use CFL fixture installations, field assessments in 2014, and data on currently available qualifying fixtures.

Sources

1. DesignLights Consortium. Qualified Product List. Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in LED fixture measures is 50,161 hours. With an HOU of 4,380, the EUL is 11 years for MMID 3603. With an HOU of 8,760, the EUL is 6 years for MMID 3604.
2. Online research. March 2016. Material cost is average sales price of LED downlight. https://www.1000bulbs.com/category/led-downlights/
3. EISA equivalent wattages for common incandescent lamps.
4. Average wattage of equivalent qualifying ENERGY STAR and DLC-listed LED fixtures as of January 30, 2015.

Revision History

Version Number	Date	Description of Change
01	01/30/2015	Initial TRM entry
02	03/30/2015	Revised and combined 12 hour and 24 hour workpapers
03	10/2017	Updated EUL

LED, ENERGY STAR, Replacing Incandescent > 40 Watts

	Measure Details
Measure Master ID	LED, ENERGY STAR, Replacing Incandescent > 40 Watts: In Unit, 3159 Common Area, 3160
Workpaper ID	W0232
Measure Unit	Per lamp
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	Varies by sector
Peak Demand Reduction (kW)	Varies by sector
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by sector
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	Varies by measure
Incremental Cost ($/unit)	$5.36[2]

Measure Description

ENERGY STAR-rated LED replacement lamps save energy by reducing the total input wattage of the luminaire as compared to the same luminaire operating with standard wattage incandescent lamps. This measure provides an energy-efficient alternative to incandescent lamps in several applications.

Description of Baseline Condition

The baseline measure is standard 60-watt, 65-watt, 75-watt, 90-watt, 100-watt, and 120-watt incandescent lamps.

Description of Efficient Condition

The efficient measure is an ENERGY STAR-rated LED.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{LED} - kWh_{INCANDESCENT}$

Where:

KWh_{LED} = Annual electricity consumption of ENERGY STAR-rated LED with a lumen output rating equivalent to a > 40-watt incandescent

$KWh_{INCANDESCENT}$ = Annual electricity consumption of standard 60-watt, 65-watt, 75-watt, 90-watt, 100-watt, or 120-watt incandescent lamp

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = Wattage / 1{,}000 * CF$

Where:

Wattage = Unit wattage

1,000 = Kilowatt conversion factor

CF = Coincidence factor (= 0.77 common area;[5] = 0.0825 in-unit)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years in unit;[1] = 4 years common area)[6]

Deemed Savings

Average Annual Deemed Savings for LED Lamp Replacing Incandescent Lamp > 40 Watts

Measure	MMID	Existing Building	New Construction
LED Replacing Incandescent Lamp > 40 Watts, In Unit	3159	58.0 kWh 0.0057 kW	43.0 kWh 0.0042 kW
LED Replacing Incandescent Lamp > 40 Watts, Common Area	3160	414.0 kWh 0.0536 kW	305.0 kWh 0.0395 kW

Average Lifecycle Deemed Savings for LED Lamp Replacing Incandescent Lamp > 40 Watts

Measure	MMID	Existing Building	New Construction
LED Replacing Incandescent Lamp > 40 Watts, In Unit	3159	870 kWh	645 kWh
LED Replacing Incandescent Lamp > 0 Watts, Common Area	3160	2,070 kWh	1,525 kWh

Assumptions

Existing Building/Common Area: Assumes 5,949.5 annual operating hours

- An average of 16.67% each of 60-watt, 65-watt, 75-watt, 90-watt, 100-watt, and 120-watt incandescent lamps was used to generate baseline usage
- An average of 33% each of 11.68-watt, 16.70-watt, and 17.81-watt ENERGY STAR-rated LEDs was used to generate new measure usage

Existing Building/In Unit: Assumes 839.5 annual operating hours

- An average of 16.67% each of 60-watt, 65-watt, 75-watt, 90-watt, 100-watt, and 120-watt incandescent lamps was used to generate baseline usage
- An average of 33% each of 11.68-watt, 16.70-watt, and 17.81-watt ENERGY STAR-rated LEDs was used to generate new measure usage

New Construction/Common Area: Assumes 5,939.5 annual operating hours

- An average of 16.67% each of 53-watt incandescent, 60-watt incandescent and halogen, 65-watt incandescent, 70-watt halogen, 72-watt halogen, and 80-watt halogen lamps was used to generate the baseline usage
- An average of 33% each of 11.68-watt, 16.70-watt, and 17.81-watt ENERGY STAR-rated LEDs was used to generate new measure usage

New Construction / In Unit: Assumes 839.5 annual operating hours

- An average of 16.67% each of 53-watt incandescent, 60-watt incandescent and halogen, 65-watt incandescent, 70-watt halogen, 72-watt halogen, and 80-watt halogen lamps was used to generate the baseline usage
- An average of 33% each 11.68-watt, 16.70-watt, and 17.81-watt ENERGY STAR-rated LEDs was used to generate new measure usage

Sources

1. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21787 hours. With an HOU of 829, the EUL is 26 years. However, a 15-year EUL cap has been deemed for most residential screw-base LED measures. This comes as a result of measure persistence concerns (http://www.neep.org/sites/default/files/resources/ResLightingDeeperDiveFINAL1.pdf) and LED lifetime cap practices of other programs (in Connecticut, Illinois, Massachusetts, Minnesota, Rhode Island, Vermont, and Washington DC).
2. August 2018 online lookups of four base and efficient models show an average efficient lamp price of $6.15 and base lamp price of $0.79, for an incremental cost of $5.36.
3. Tetra Tech. *ACES Deemed Savings Desk Review*. November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf
4. PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Coincidence Factor for Lighting in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

5. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.
6. ENERGY STAR Qualified Product List. Accessed July 2017. https://www.energystar.gov/productfinder/
   Average rated life of 3,453 omnidirectional and decorative LEDs is 21,787 hours. With an HOU of 5,950, the EUL is 4 years.

Revision History

Version Number	Date	Description of Change
01	12/26/2012	Initial TRM entry
02	10/2017	Updated EUL
03	12/2018	Updated incremental cost

LED Upgrades, CALP

	Measure Details
Measure Master ID	CALP Interior 12+ Hours, 3967 CALP Exterior, 3968
Workpaper ID	W0233
Measure Unit	Per watt reduced
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Residential- multifamily
Annual Energy Savings (kWh)	6.61 for MMID 3967; 4.38 for MMID 3968
Peak Demand Reduction (kW)	0.0008 for MMID 3967; 0 for MMID 3968
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	53 for MMID 3967; 48 for MMID 3968
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	CALP interior = 8 (MMID 3967); CALP exterior = 11 (MMID 3968)[1]
Incremental Cost ($/unit)	$1.20[2]

Measure Description

These measures are intended for the replacement of incandescent, HID, or fluorescent lighting technologies with more efficient LEDs, including complete exit signs. LEDs provide the same or better light output than incumbent technologies while using significantly less energy.

Description of Baseline Condition

The baseline condition is any incandescent, HID, or fluorescent fixtures, including complete exit signs.

Description of Efficient Condition

The efficient condition is any ENERGY STAR fixture or DesignLights Consortium-listed LED product. Exit signs must be LED and complete units. Retrofit kits are not eligible.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{REDUCED}) * HOU / 1,000 = Watts_{REDUCED} * HOU / 1,000$

Where:

$Watts_{REDUCED}$ = $Watts_{BASE}$ - $Watts_{LED}$

$Watts_{BASE}$ = Power consumption of currently installed lighting (= actual; provided by Trade Ally for each project)

$Watts_{LED}$ = Power consumption of efficient LED product (= actual; provided by Trade Ally for each project)

1,000 = Kilowatt conversion factor

HOU = Hours of use (= 6,614 for MMID 3967[3]; = 4,380 for MMID 3968)[4]

$Watts_{REDUCED}$ = Watts reduced

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (Watts_{BASE} - Watts_{LED}) /1{,}000 * CF$

Where:

CF = Coincidence factor (= 0.77 for MMID 3967[5]; = 0.00 for MMID 3968)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 3967 = 8 years, 3968 = 11 years)[1]

Deemed Savings

Annual Savings (per watt reduced)

Measure	MMID	Multifamily	
		kWh	kW
LED Interior 12+ Hours, CALP	3967	6.61	0.0008
LED Exterior, CALP	3968	4.38	0.0000

Lifecycle Savings (per watt reduced)

Measure	MMID	Multifamily
LED Interior 12+ Hours, CALP	3967	53
LED Exterior, CALP	3968	48

Sources

1. DesignLights Consortium. Qualified Product List. Accessed August 2017. https://www.designlights.org/lighting-controls/download-the-qpl/
   Average rated life of models participating in LED fixture measures is 50,161 hours. With an HOU of 6,614, the EUL is eight years for MMID 3967. With an HOU of 4,380, the EUL is 11 years for MMID 3968.
2. SPECTRUM. Average incremental costs. 2017. CALP LED measure master IDs 3735, 3603, 3604 and 3200, converted to dollars per watt saved.
   Online research. March 2016. https://www.1000bulbs.com/category/led-downlights/
   Material cost for MMIDs 3603, 3604, and 3735 is average sales price of LED downlight.
   Average sales price of LED Exit Signs for MMID 3200 on 1000bulbs.com = $26.43; RSMeans, 2015 labor cost for install of signs, interior electric exit sign, wall mounted, 6-inch = $72.00. [$26.43 (material cost) + $72.00 (labor cost) = $98.43].
3. Historical Focus on Energy project data from January 1, 2015 through November 15, 2016. Weighted average of 12-hour versus 24-hour fixture replacements under MMIDs 3199, 3197, 3198, 3735, 3603, 3604, 3200, 3196, and 3195 (where 49% of replaced fixtures operated 12 hours or more and 51% operated 24 hours).
4. U.S. Department of Commerce, National Oceanic & Atmospheric Administration. “NOAA Solar Calculator.” http://www.esrl.noaa.gov/gmd/grad/solcalc/
   This also includes the times when photocells turn on prior to exact sunset and turn off after exact sunrise, accounting for diminished outdoor lighting as well as time clock scheduled lighting.
5. Summit Blue Consulting. *Con Edison Callable Load Study*. May 15, 2008. https://uploads-ssl.webflow.com/5a08c6434056cc00011fd6f8/5a27177a5f89cb0001ea0c03_Schare%20Welch%20Edison%20Callable%20Load%20Study_Final%20Report_5-15-08.pdf
   Coincidence factor is within range of similar programs; report shows multifamily housing (in unit) CF of 65% to 89%.

Revision History

Version Number	Date	Description of Change
01	11/15/2016	Initial TRM entry
02	10/2017	Updated EUL

ENERGY STAR LED Porch Fixtures

	Measure Details
Measure Master ID	ENERGY STAR LED Porch Fixtures, 3157
Workpaper ID	W0235
Measure Unit	Per LED porch luminaire
Measure Type	Prescriptive
Measure Group	Lighting
Measure Category	Light Emitting Diode (LED)
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- multifamily
Annual Energy Savings (kWh)	Varies
Peak Demand Reduction (kW)	0
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	15[1]
Incremental Cost ($/unit)	$55.14[2]

Measure Description

ENERGY STAR-qualified LED porch lights are verified to meet both performance and efficiency thresholds, which ensures that an LED product’s performance is similar to other time-tested technologies used for the same applications and that it meets ENERGY STAR efficiency criteria.

Description of Baseline Condition

The baseline condition is standard, screw-based incandescent lamps/luminaires. Equal weighting of 60 watt, 75 watt, and 100 watt incandescents is assumed; see Assumptions for more details.

Description of Efficient Condition

The efficient equipment is an ENERGY STAR–rated LED porch light with a lumen output corresponding to that of 60 watt to 100 watt incandescent lamps.[3]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = (Watts_{BASE} – Watts_{LED}) / 1{,}000 * HOU$

Where:

$Watts_{BASE}$ = Wattage of baseline fixture (= 78.33 watts for existing buildings, = 61.67 watts for new construction; see Assumptions)

$Watts_{LED}$ = Wattage of efficient LED fixture (= 12.15 watts)[1]

HOU = Average annual run hours (= 1,131.5)[4]

Summer Coincident Peak Savings Algorithm

There are no peak savings for this measure.

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 15 years)[1]

Deemed Savings

Average Annual Deemed Savings for ENERGY STAR–Rated LED Porch Fixtures

Measure	Existing Building	New Construction
ENERGY STAR–Rated LED Porch Fixtures	75 kWh	56 kWh

Average Lifecycle Deemed Savings for ENERGY STAR–Rated LED Porch Fixtures

Measure	Existing Building	New Construction
ENERGY STAR–Rated LED Porch Fixtures	1,125 kWh	840 kWh

Assumptions

It was assumed that the annual operating hours are 1,131.5.[4]

For existing buildings, an average of 33% 60-watt, 33% 75-watt, and 33% 100-watt A-19 halogen and incandescent lamps that meet EISA 2007 as of January 1, 2013 were used to generate the baseline usage. For new construction, an average of 33% 53-watt, 33% 60-watt, and 33% 72-watt lamps were used to generate the baseline usage.

Sources

1. ENERGY STAR Qualified Fixtures Product List. Accessed February 2020. www.energystar.gov/productfinder/product/certified-light-fixtures/results
   Average rated life of 183 LED porch fixtures is 46,448 hours. With an annual HOU of 1,131.5, the EUL is 41 years. Lighting EULs are capped at 15 years.
   Average wattage for "Outdoor Porch Wall Mount" and "Porch (Wall Mounted)" fixture types where the technology is LED and the total light output is 700 to 1,700 lumens.
2. August 2018 online lookups of seven base and efficient models show an average efficient fixture price of $56.38 and base bulb price of $1.24, for an incremental cost of $55.14.
3. U.S. Department of Energy. Energy Saver website. Accessed February 2020. www.energy.gov/energysaver/save-electricity-and-fuel/lighting-choices-save-you-money/lumens-and-lighting-facts

4. PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation. ACES: Default Deemed Savings Review.” Final Report, Table 1-2. June 24, 2008. www.focusonenergy.com/sites/default/files/acesdeemedsavingsreview_evaluationreport.pdf

   Table 1-2 lists 3.1 hours per day for outdoor screw in lamps.

Revision History

Version Number	Date	Description of Change
01	12/26/2012	Initial release
02	10/2017	Updated EUL source
03	12/2018	Updated incremental cost
04	2/2020	Added additional sectors for eligibility, updated efficient LED wattage

Refrigeration

Freezer, ENERGY STAR

	Measure Details
Measure Master ID	Freezer, Chest, ENERGY STAR, 4036 Freezer, Upright, ENERGY STAR, 4037
Workpaper ID	W0242
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Refrigerator/Freezer
Sector(s)	Residential- upstream
Annual Energy Savings (kWh)	4 for chest freezer, 44 for upright freezer
Peak Demand Reduction (kW)	.0039 for chest freezer, 0.0071 for upright freezer
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	264 for chest freezer, 484 for upright freezer
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	11[1]
Incremental Cost ($/unit)	Chest freezer = $6.62 (MMID 4036) Upright freezer = $12.14 (MMID 4037)[2]
Important Comments	Measure under Retail Product Platform (RPP) Pilot

Measure Description

A freezer is a cabinet designed as a unit for freezing and storing food at temperatures of 0°F (-17.8°C) or below, and having a source of refrigeration requiring single phase, alternating current electric energy input only. These measures consist of chest and upright ENERGY STAR-certified freezer units that meet the ENERGY STAR Version 5.0 requirements. ENERGY STAR-certified units are at least 10% more efficient the federal minimum standard.[3]

Description of Baseline Condition

The baseline condition consists of non-ENERGY STAR-certified freezer units. Baseline energy consumption is based on the federal standard effective September 15, 2014.[2]

Description of Efficient Condition

The efficient condition is ENERGY STAR-certified freezer units that meet the ENERGY STAR V5.0 requirements.[3]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = UEC_{BASE} - UEC_{EE}$

Where:

UEC_{BASE} = Annual unit energy consumption of baseline unit in kWh (= based on unit type, see Annual Energy Savings table below)[1]

UEC_{EE} = Annual unit energy consumption of measure unit in kWh (= based on unit type, see Annual Energy Savings table below)[1]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = (kWh_{SAVED} / 8{,}760) * TAF * LSAF$

Where:

TAF = Temperature adjustment factor (= 1.23)[4]

LSAF = Load shape adjustment factor (= 1.15)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFE\text{-}CYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 11 years)[1]

Deemed Savings

Annual Energy Savings (kWh)

Unit Type and MMID	Baseline UEC[2]	Measure UEC[1]	Annual Savings (kWh)
Chest, 4036	239	215	24
Upright, 4037	439	395	44

Peak Demand Reduction (kW)

Unit Type and MMID	Demand Reduction (kW)
Chest, 4036	0.0039
Upright, 4037	0.0071

Lifecycle Energy Savings (kWh)

Unit Type and MMID	Annual Savings (kWh)	EUL (years)	Lifecycle Energy Savings (kWh)
Chest, 4036	24	11	264
Upright, 4037	44	11	484

Sources

1. ENERGY STAR. *Retail Products Platform: Product Analysis for Clothes Dryers*. Effective May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U
   For EUL, ENERGY STAR assumes 11 years based on Appliance Magazine, U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture for 2005-2012, 2011.
2. U.S. Department of Energy, Energy Efficiency and Renewable Energy Office. "Technical Support Document for Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers." Table 8.2.7. Accessed November 21, 2016. www.regulations.gov/contentStreamer?documentId=EERE-2008-BT-STD-0012-0128&disposition=attachment&contentType=pdf
   Incremental costs are based on the Freezer TSD Life-Cycle Cost and Payback Analysis.
3. ENERGY STAR. Program Requirements -Product Specification for Residential Refrigerators and Freezers Eligibility Criteria. Version 5. Accessed November 21, 2016. https://www.energystar.gov/sites/default/files/specs/private/ENERGY%20STAR%20Final%20Version%205.0%20Residential%20Refrigerators%20and%20Freezers%20Program%20Requirements.pdf
4. Prepared by Shelter Analytics; Facilitated and Managed by Northeast Energy Efficiency Partnership. "Mid-Atlantic Technical Reference Manual Version 4.0." June 2014. http://www.neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V4_FINAL.pdf
   Blasnik, Michael. "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study." p. 47. July 29, 2004.
   Temperature adjustment factor based on Blasnik and assuming 78% of refrigerators are in cooled space from [Mathew Greenwald & Associates. *Energy Use Survey, Report of Findings*. Prepared for Baltimore Gas & Electric. December 2005.] and 22% in uncooled space. Although this evaluation is based on refrigerators only, it is considered a reasonable estimate of the impact of cycling on freezers and gave exactly the same result as an alternative methodology based on Freezer eShape data. Daily load shape adjustment factor also based on Blasnik 2004 (page 48, extrapolated by taking the ratio of existing NEEP summer to existing annual profile for hours ending 15 through 18, and multiplying by new annual NEEP profile).

Revision History

Version Number	Date	Description of Change
01	06/24/2016	Initial TRM entry

Refrigerator and Freezer Recycling

	Measure Details
Measure Master ID	Refrigerator, Recycling and Replacement, 2955 Freezer, Recycling and Replacement, 2956
Workpaper ID	W0243
Measure Unit	Per unit recycled
Measure Type	Prescriptive
Measure Group	Refrigeration
Measure Category	Other
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	MMID 2955 = 827; MMID 2956 = 704
Peak Demand Reduction (kW)	MMID 2955 = 0.0954; MMID 2956 = 0.0868
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	MMID 2955 = 8,270; MMID 2956 = 7,040
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	10[1]
Incremental Cost ($/unit)	$110.00[4]

Measure Description

This measure involves removing an operable refrigerator or freezer from service prior to its natural end of life. The average age of a harvested unit is anticipated to be 20+ years. Savings are based on the estimated energy consumption during the remaining life of the unit, per unit characteristics at the time of removal.

Description of Baseline Condition

The baseline is an existing, inefficient unit in working order not being removed from service.

Description of Efficient Condition

The efficient condition is to remove an existing inefficient unit from circulation and send it for recycling.

Annual Energy-Savings Algorithm

kWh_{SAVED} = Unadjusted gross annual kWh savings/unit * Part_Use

Wisconsin Focus on Energy’s evaluation work for CY 2017 provides data to update both variables in the annual energy-savings equation. First, a modeling update in the CY 2017 report provides an estimate of the Wisconsin-specific gross annual savings, which results in a slight decrease in assumed savings for refrigerators and freezers. Second, the determined part-use factor for refrigerators is decreased from 0.875 to 0.86, and that for freezers is increased from 0.73 to 0.76.[2]

The annual energy savings is a deemed value based on an evaluation, measurement, and verification analyses,[2] with adjustments for the envisioned Wisconsin conditions as noted below.

Refrigerator and Freezer Variables

Metric	Refrigerators	Freezers
Unadjusted gross annual kWh savings/unit[2]	962	926
Part-use factor	0.86	0.76
Adjusted gross annual kWh savings/unit	827	704

Summary Coincident Peak Savings Algorithm

kW_{SAVED} = [(kWh savings/unit) / HOURS] * P *Part_Use

Where:

HOURS = Annual operating hours (= 8,760)

P = Peak intensity factor; this captures the increase in compressor cycling time in summer peak conditions relative to average annual conditions (= 1.01 for refrigerators; = 1.08 for freezers)[2]

Part_Use = Part-use factor determined by Evaluation Team (= 0.86 for refrigerators; = 0.76 for freezers)

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE}$ = kWh_{SAVED}* EUL

Where:

EUL = Effective useful life of replaced refrigerator (= 10 years)[1]

For this technology, ten years is technically the remaining useful life of the equipment; however, for consistency it is represented as the EUL.

Deemed Savings

Deemed Savings by Measure

	Refrigerator (MMID 2955)	Freezer (MMID 2956)
Annual Energy Savings (kWh)	827	704
Peak Demand Reduction (kW)	0.0954	0.0868
Lifecycle Energy Savings (kWh)	8,270	7,040

Assumptions

The per-unit deemed energy saving and demand reduction values quantify the early retirement of inefficient refrigerators and freezers. These values should be reviewed and updated every two or three years to quantify expected gradual improvements in the average unit efficiency (i.e., as reflected in lower kWh/unit).

Sources

1. Southern California Edison. *SCE's 2010-2012 Energy Efficiency Proposed Program Plan Workpapers (Amended)*. July 2, 2009. https://www.sce.com/wps/wcm/connect/d6b04314-457c-4338-8b0c-213d9a1ed779/A0807021EE_PP_PPP_Workpapers.pdf?MOD=AJPERES&ContentCache=NONE
2. Cadmus. *Focus on Energy Calendar Year 2017 Evaluation Report: Volume II.* May 22, 2018. https://focusonenergy.com/sites/default/files/WI%20FOE%20CY%202017%20Volume%20II%20FINAL.pdf
3. Cadmus. *Appliance Recycling Measure Savings Study*. Memo prepared for Michigan Evaluation Working Group. August 20, 2012.
4. Cost to implementer for appliance pick-up.

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	2015	Updated savings based on CY 2014 findings
03	04/2017	Updated savings based on CY 2015 findings
04	10/2017	Updated EUL source
05	12/2018	Updated savings based on CY 2017 findings, updated incremental cost

Renewable Energy

Solar Photovoltaic

	Measure Details
Measure Master ID	Solar PV, 2819
Workpaper ID	W0245-T229
Measure Unit	Per kWDC installed
Measure Type	Hybrid
Measure Group	Renewable Energy
Measure Category	Photovoltaics
Sector(s)	Commercial, Industrial, Agriculture, Schools & Government, Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by Type
Peak Demand Reduction (kW)	Varies by Type
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by Type
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	25[1]
Incremental Cost ($/unit)	Actual cost to be provided annually

Measure Description

PV systems generate DC electric current through the photovoltaic effect when exposed to light. The DC power in one or more series of PV modules, called strings, is converted to AC power by an inverter. Inverters can either be classified as string inverters, which are centrally located and combine the output of multiple modules or strings of modules, or as microinverters, which are installed at the module and convert each module's DC output to AC individually.

AC modules are growing in popularity. They provide AC output without the need for external inverters. Once the output of the PV system is converted into AC current that is compatible with the local utility grid, the system is interconnected to the residence wiring system.

The total system output is affected by the tilt and azimuth of the modules, module temperature, inverter efficiency, and shading factors. Ideal systems are designed to face south, have minimal shading, have a tilt close to the local latitude, and are installed in a safe area. The most common application is fixed-mounted panels on a south-facing rooftop, but other configurations can include ground-mounted or pole-mounted arrays and can be in fixed, manual, or automatic sun tracking configurations.

Panels may also be installed facing a direction other than South with reduced savings.

The average installed capacity of residential PV systems in Wisconsin was 6.6 kWDC for the 2016 program year.[2]

Description of Baseline Condition

The baseline for this measure is having no PV system installed at the site.

Description of Efficient Condition

South-facing PV arrays are designed to be installed within 45 degrees of due south (azimuth angle ≥ 135 degrees and ≤ 225 degrees). East-facing PV arrays may be installed within 45 degrees of straight east (azimuth angle ≥ 45 degrees and < 135 degrees). West-facing PV arrays may be within between 45 degrees of straight west (azimuth angle > 225 degrees and ≤ 315 degrees). North-facing systems may be installed within 45 degrees of due north (azimuth angle > 315 degrees and < 45 degrees). All panels are to be installed in a safe area, where there is 15% or less shading.

Arrays can have a tilt between 5 degrees and 50 degrees of the local latitude. A central inverter is typically installed in a mechanical room. In some cases, microinverters are used for one or two PV modules, which convert DC to AC power.

Annual Energy-Savings Algorithm

The energy savings from PV systems is calculated using PVWatts,[5] a tool that uses TMY3 solar radiation data, combined with user-entered capacity, array type, tilt, azimuth, and derate factor, to calculate hourly AC energy output and annual energy output. The table below summarizes the expected savings per kWDC installed by location. Note that these general calculations do not reflect the actual conditions at any site but are a general representation of typical PV systems installed in Wisconsin.

System Derate Factor = DerateFactor * (1 - ShadeFactor) * (1 - SnowFactor)

Where:

DerateFactor = Amount of power maintained in DC to AC conversion (= 88.6%; see Assumptions)

ShadeFactor = Percentage of time system is shaded (= 4.5%; see Assumptions)

SnowFactor = Percentage of time system in covered in snow (= 2% for 28° tilt)[3]

Installed Capacity by City

Reference City	Reference Zip Code	AC kWh/kWDC Installed Capacity			
		South Facing	East Facing	West Facing	North Facing
Milwaukee	53220	1,324	1,065	1,074	755
Madison	53706	1,310	1,048	1,054	738
Green Bay	54302	1,331	1,070	1,061	740
Average		**1,346**	**1,322**	**1,061**	**1,063**

Summer Coincident Peak Savings Algorithm

The peak period demand reduction is calculated by summarizing the modeled PV Watts kilowatt-hour output over the Focus on Energy peak period of 1 p.m. to 4 p.m. on weekdays in June, July, and August, then dividing by the number of hours in that period.

$kW_{SAVED} = kWh_{PEAK} / Hours_{PEAK}$

Where:

kWh_{PEAK} = Total kilowatt-hours generated during peak times

$Hours_{PEAK}$ = Total peak period hours (= 197.14; see Assumptions)

Installed Capacity by City

Direction	Reference City	Total Peak Period (kWh)	Amount Reduced (kW)
South	Milwaukee	87.8	0.45
	Madison	87.4	0.44
	Green Bay	87.3	0.44
	Average	**87.5**	**0.44**
East	Milwaukee	53.0	0.27
	Madison	53.9	0.27
	Green Bay	51.6	0.26
	Average	**52.8**	**0.27**
West	Milwaukee	100.3	0.51
	Madison	98.6	0.50
	Green Bay	98.9	0.50
	Average	**99.3**	**0.50**
North	Milwaukee	67.5	0.34
	Madison	67.1	0.34
	Green Bay	65.0	0.33
	Average	**66.5**	**0.34**

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 25 years)[1]

Assumptions

Throughout this document, kWDC is used to refer to the nameplate installed capacity of solar at standard test conditions of 25°C and 1,000 W/m^2 irradiance.

Generation estimates were made in accordance with PV system guidelines[3] or, where available, are Residential Rewards program-specific data:

- Array azimuth of 180° for south facing, 90° for east facing, 270° for west facing, 0° for north facing
- Fixed (non-tracking) array
- Array tilt of 28° (reference 6)

All results were normalized to installed kWDC capacity and can be scaled to actual installed capacity on a one-to-one basis (for example, a 2 kW system will produce twice the output and peak demand reduction of a 1 kW system).

A derate factor of 88.6% was used based on results produced by an updated version of PVWatts.[4]

A shade factor of 4.5% was used based on program year 2019 desktop reviews,[6] and reflect a higher permitted shading value. The 2019 desk reviews showed an average ShadeFactor of 1.0% for 10 nonresidential sites and 3.4% for 89 residential sites, an overall average of 3.2%. These values reflected a cutoff of 10% shading. For PY2022, installations have shading of up to 15%. Adding a rough projection of site counts from 10% to 15% shading, based on the existing 2019 trend in site counts observed from 0% to 10%, produces an average ShadeFactor of 4.5%.

The overall System Losses factor used in PV Watts is 1 - [System Derate Factor] = 1 - DerateFactor * (1 - ShadeFactor) * (1 - SnowFactor) = 1 - 88.6% * (1 - 4.5%) * (1 - 2%) = 1 - 84.4836% = 17.0793%.

Peak period hours were calculated as follows: there are 30 + 31 + 31 = 92 days in June, July, and August. Five out of every seven days are weekdays, with three peak hours per weekday. Therefore, $\text{Hours}_{\text{PEAK}}$ = 92 * (5 / 7) * 3 = 197.14.

Sources

1. National Renewable Energy Laboratory. “Useful Life.” Website. Accessed December 2018. https://www.nrel.gov/analysis/tech-footprint.html
   Site provides range of 25 to 40 years; bottom of range selected to account for uncertainties of lifetime measurement and consistency with historical program assumptions.
2. Cadmus. Analysis of 2016 Renewable Rewards program data for 24 funded PV systems.
3. Tetra Tech. *State of Wisconsin Public Service Commission Focus on Energy Evaluation: Standard Calculation Recommendations for Renewable Energy Systems.* January 18, 2011. https://focusonenergy.com/sites/default/files/standardcalculationrecommendationsCY10_evaluationreport.pdf
4. Cadmus. *Focus on Energy Evaluated Deemed Savings Changes*. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf

5. National Renewable Energy Laboratory. *PVWatts Calculator*. https://pvwatts.nrel.gov/pvwatts.php
6. Average tilt of 92 residential and 10 nonresidential Focus on Energy solar PV installations in program year 2019. Average ShadeFactor of 3.2% (with shading limit of 10%).

Revision History

Version Number	Date	Description of Change
01	08/2014	Initial TRM entry
02	05/2018	Updated savings based on evaluation findings
03	12/2018	Added east and west facing savings
04	12/2021	Added north facing, updated to 28 degree tilt and 4.5% Shadefactor

Vending & Plug Loads

Advanced Power Strip

	Measure Details
Measure Master ID	Advanced Power Strip, Pack-Based, APS Tier 1, 3895 Advanced Power Strip, APS Tier 1, Online Store, 4917 Advanced Power Strip, APS Tier 2, Online Store, 4918
Workpaper ID	W0246
Measure Unit	Per advanced power strip
Measure Type	Prescriptive
Measure Group	Vending & Plug Loads
Measure Category	Controls
Sector(s)	Residential- single family, Residential- multifamily
Annual Energy Savings (kWh)	Varies by measure
Peak Demand Reduction (kW)	Varies by measure
Annual Therm Savings (Therms)	0
Lifecycle Energy Savings (kWh)	Varies by measure
Lifecycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	6[1,2] (see Assumptions)
Incremental Cost	Tier 1 Online and Pack = $22.00 (MMIDs 4917);[3] Tier 2 Online = $50.00 (MMID 4918);[3]

Measure Description

This measure is the installation of a Tier 1 or Tier 2 advanced power strip (APS) in a home entertainment application. APSs differ from standard power strips because they have two sets of outlets—always on and switched outlets—with peripheral loads (such as a DVD player, gaming console, home theater, or printer) generally being plugged in to the switched outlets and main loads (such as a DVR, router, or clock) being plugged in to the always on outlets. Tier 1 APSs have the ability to automatically disconnect peripheral loads when the main load is off. Tier 2 APS have the additional ability to automatically disconnect peripheral loads when unit does not sense infrared remote control signals for a period of time. APS units are therefore able to reduce standby power loss and wasted energy from going to the switched outlets when the control device is off. Pack-based measure savings are based on the APS being provided as part of a package, so an installation rate less than 100% is applied.

Description of Baseline Condition

The baseline equipment is a standard power strip that does not control connected loads.

Description of Efficient Condition

The efficient condition is efficient use of an APS.

Annual Energy-Savings Algorithm

$kWh_{SAVED} = kWh_{BASE} * SF * ISR$

Where:

kWh_{BASE} = Baseline consumption (= 356)[4]

SF = Savings factor (= 19% for Tier 1;[5] see Assumptions, = 33% for Tier 2[4])

ISR = Installation rate (= 90% for Pack-Based Tier 1; = 93% for Online Store Tier 1, = 70% for Online Store Tier 2)[6]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} * CF / HOU$

Where:

CF = Coincidence factor (= 0.87; see Assumptions)[2]

HOU = Hours of use (= 6,588; see Assumptions)[5]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 6 years; see Assumptions)[1,2]

Deemed Savings

Deemed Savings by Measure

Delivery	APS Type	MMID	Annual Energy Savings (kWh)	Lifecycle Energy Savings (kWh)	Coincident Peak Demand Reduction (kW)
Pack-Based	Tier 1	3895	61	366	0.0081
Online Store	Tier 1	4917	63	378	0.0083
	Tier 2	4918	82	492	0.0108

Assumptions

It is assumed that Tier 1 and Tier 2 APSs have the same baseline consumption value of 356 kWh, derived from the ACEEE paper that examined sites in Wisconsin.[4] It is also assumed that single-family and multifamily sites have the same baseline consumption, savings factors, and installation rates.

A savings factor of 19% for Tier 1 APSs comes from an Illume study[5] showing 75 kWh of savings and 391.5 kWh of baseline consumption (75 / 391.5 = 19%).

Installation rates for all types of APS are updated based on 2020 participant survey results.[6]

For hours of use, the Illume whitepaper[5] cites a 2014 Nielsen study that reports an average daily television operation time of 5.95 hours. The APS is assumed to operate whenever the TV is not on, or 6,588 hours (8,760 – (365 * 5.95)).

The coincidence factor was calculated using the 2015 Vermont TRM[2] coincidence factor of 17.0% for televisions, which employs a peak period of four hours. Adjusting that value for the Wisconsin peak period of three hours yields 0.13 (0.17 * 3/4); therefore, the coincidence factor for a power strip is 0.87 (1 – 0.13).

The EUL of six years is an average of two values. A value of four years is from the Vermont 2015 TRM[2] and a value of eight years is from the 2017 Minnesota TRM.[1]

Sources

1. State of Minnesota. *Technical Reference User Manual (TRM) for Energy Conservation Improvement Programs.* p. 298. January 1, 2017. http://mn.gov/commerce-stat/pdfs/mn-trm-v2.0-041616.pdf
2. Efficiency Vermont. *Technical Reference User Manual (TRM): Measure Savings Algorithms and Cost Assumptions.* pp. 15, 16, and 391. March 16, 2015. http://puc.vermont.gov/sites/psbnew/files/doc_library/ev-technical-reference-manual.pdf
3. All packs are assumed to have no baseline, and therefore no baseline cost—the incremental cost is the full cost of the pack to Focus, whether it is a free pack or a discounted Online Store purchase. The cost of the Tier 1 APS to Focus is $22.00, and the cost of the Tier 2 APS is $50.00
4. Iaccarino, Joseph, C. Kelly, S. Cofer, and J. Fontaine. "Only as Smart as Its Owner: A Connected Device Study." July 2018. https://cadmusgroup.com/papers-reports/only-as-smart-as-its-owner-a-connected-device-study/
5. Illume. "Overview of the Tier 1 Advanced PowerStrip: Potential Savings and Programmatic Uses." Whitepaper. pp. 10 and 14. September 15, 2014. http://www.amconservationgroup.com/wp-content/uploads/2014/12/Illume-Advanced-Powerstrip-Case-Study.pdf
6. Cadmus. *Focus on Energy Calendar Year 2020 Evaluation Report Volume II.* p. 14, 17. May 21, 2021. *https://www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_II.pdf*

Revision History

Version Number	Date	Description of Change
01	09/2016	Initial TRM entry
02	02/2017	Created Tier 2 workpaper
03	04/2018	Merged Tier 1 and Tier 2 workpapers and added multifamily sector
04	01/2021	Added Online Store measures, updated cost
05	07/2021	Updated ISRs and removed unused retail and pack-based MMIDs

Room Air Cleaner, ENERGY STAR

	Measure Details
Measure Master ID	Room Air Cleaner, ENERGY STAR, 4034
Workpaper ID	W0238
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Vending & Plug Loads
Measure Category	Filtration
Sector(s)	Residential- upstream
Annual Energy Savings (kWh)	214
Peak Demand Reduction (kW)	0.0244
Annual Therm Savings (Therms)	0
Life-cycle Energy Savings (kWh)	1,926
Life-cycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	9[1]
Incremental Cost ($/unit)	$56.00[1]
Important Comments	Measure under Retail Product Platform (RPP) Pilot

Measure Description

A room air cleaner is a portable, electric appliance that removes fine particles, such as dust and pollen, from indoor air. This measure consists of ENERGY STAR-certified room air cleaner units that meet the ENERGY STAR Version 1.2 requirements. ENERGY STAR-certified units are 40% more efficient that non-qualified models.[2]

Description of Baseline Condition

The baseline condition consists of non-ENERGY STAR-certified room air cleaner units.

Description of Efficient Condition

The efficient condition consists of ENERGY STAR-certified room air cleaner units that meet ENERGY STAR Version 1.2 requirements.[2]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = UEC_{BASE} - UEC_{EE}$

Where:

UEC_{BASE} = Annual unit energy consumption of baseline unit (= 530.98 kWh)[1]

UEC_{EE} = Annual unit energy consumption of efficient unit (= 317.1 kWh)[1]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kWh_{SAVED} / Hours * CF$

Where:

Hours = Average hours of use per year (= 5,844)[3]

CF = Summer peak coincidence factor (= 66.7%)[3]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 9 years)[1]

Sources

1. ENERGY STAR. *Retail Products Platform: Product Analysis for Room Air Cleaners*. Effective May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U
ENERGY STAR assumes a nine-year useful life, based on: Lawrence Berkeley National Laboratory. *2008 Status Report - Savings Estimates for the ENERGY STAR Voluntary Labeling Program.* Accessed November 21, 2016. http://enduse.lbl.gov/Info/LBNL-56380(2008).pdf
2. *ENERGY STAR Version 1.2 Product Specification for Room Air Cleaners.* Accessed November 21, 2016. https://www.energystar.gov/sites/default/files/specs/private/Room_Air_Cleaners_Final_V1.2_Specification.pdf
Baseline and ENERGY STAR energy consumption are the weighted average of five product category sub types: 51-100 CADR, 101-150 CADR, 151-200 CADR, 201-250 CADR, and > 250 CADR. Wattages for all five product sub types are derived from Association of Home Appliance Manufacturers data. Duty cycle assumes 16 hours per day, 365 days per year based on filter replacement instructions.

3. *Illinois Technical Reference Manual*. 2016 Version 5.0. Accessed November 21, 2016. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_5/Almost_Final_PDF/IL_TRM_Effective_060116_Version_5.0_Vol_3_RES_012216_Clean.pdf
   Illinois TRM assumes that the purifier usage is evenly spread throughout the year (therefore the coincident peak is calculated as 5,844/8,766 = 66.7%).
   U.S Environmental Protection Agency and U.S. Department of Energy. “Savings Calculator for ENERGY STAR Qualified Appliances.” ENERGY STAR Qualified Room Air Cleaner Calculator. https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx
   Calculator assumes 16 hours per day (16 * 365.25 = 5,844).

Revision History

Version Number	Date	Description of Change
01	06/24/2016	Initial TRM entry

Soundbar, ENERGY STAR

	Measure Details
Measure Master ID	Soundbar, ENERGY STAR, 4033
Workpaper ID	W0241
Measure Unit	Per unit
Measure Type	Prescriptive
Measure Group	Vending & Plug Loads
Measure Category	Other
Sector(s)	Residential- upstream
Annual Energy Savings (kWh)	52
Peak Demand Reduction (kW)	0.0033
Annual Therm Savings (Therms)	0
Life-cycle Energy Savings (kWh)	364
Life-cycle Therm Savings (Therms)	0
Water Savings (gal/year)	0
Effective Useful Life (years)	7[1]
Incremental Cost ($/unit)	$0.00[1]

Measure Description

A soundbar is a special enclosure for a loudspeaker that creates a reasonable stereo effect from a single cabinet. Soundbars are much wider than they are tall, both for acoustical reasons and so they can be mounted above or below a display device, such as a computer monitor, television, or home theater screen. This measure consists of ENERGY STAR-certified soundbar units that meet efficiency levels 15% greater than the ENERGY STAR Version 3.0 audio visual product requirements.[3]

Description of Baseline Condition

The baseline condition consists of a market-based mix of both ENERGY STAR-certified and non-ENERGY STAR certified soundbar units.[4]

Description of Efficient Condition

The efficient condition consists of ENERGY STAR-certified soundbar units that meet efficiency standards 15% greater than ENERGY STAR Version 3.0 audio visual product requirements.[2]

Annual Energy-Savings Algorithm

$kWh_{SAVED} = UEC_{BASE} - UEC_{EE}$

Where:

UEC_{BASE} = Annual unit energy consumption of baseline unit (= 77 kWh)[1]

UEC_{EE} = Annual unit energy consumption of efficient unit (= 25 kWh)[1]

Summer Coincident Peak Savings Algorithm

$kW_{SAVED} = kW_{SAVED,\ ACTIVE} + kW_{SAVED,\ IDLE/SLEEP}$

$kW_{SAVED,\ ACTIVE} = (UEC_{BASE,\ ACTIVE} - UEC_{EE,\ ACTIVE}) / 8{,}760 * CF_{ACTIVE}$

$kW_{SAVED,\ IDLE/SLEEP} = (UEC_{BASE,\ IDLE/SLEEP} - UEC_{EE,\ IDLE/SLEEP}) / 8{,}760 * CF_{IDLE/SLEEP}$

Where:

$UEC_{BASE,\ ACTIVE}$ = Yearly baseline consumption in active mode (= 36.09 kWh, which is 4.3 * 8.62 * 2.65 * 365 / 1,000)[1]

$UEC_{EE,\ ACTIVE}$ = Yearly efficient consumption in active mode (=13.62 kWh, which is 4.3 * 8.62 * 365 / 1,000)[1]

CF_{ACTIVE} = Coincidence factor for the active condition (= 10%)[4]

8,760 = Hours per year

$UEC_{BASE,\ IDLE/SLEEP}$ = Yearly baseline consumption in idle and sleep modes (= 40.61 kWh, which is [2.0 * 8.42 * 2.65 + 17.7 * 1.42 * 2.65] * 365 / 1,000)[1]

$UEC_{EE,\ IDLE/SLEEP}$ = Yearly efficient consumption in idle and sleep modes (= 11.23 kWh, which is [0.4 * 8.42 + 19.3 * 1.42] * 365 / 1,000)[1]

$CF_{IDLE/SLEEP}$ = Coincidence factor for the idle and sleep conditions (= 90%)[4]

Lifecycle Energy-Savings Algorithm

$kWh_{LIFECYCLE} = kWh_{SAVED} * EUL$

Where:

EUL = Effective useful life (= 7 years)[1]

Sources

1. ENERGY STAR. "Retail Products Platform: Product Analysis for Sound Bars." Effective May 11, 2016. https://drive.google.com/open?id=0B9Fd3ckbKJp5OEpWSHg1eksyZ1U
   An efficient soundbar consumes 8.62 watts in active mode for 4.3 hours per day, 8.42 watts in idle mode for 0.4 hours per day, and 1.42 watts in sleep mode for 19.3 hours per day, for a total of 25 kWh per year. A baseline soundbar is in active mode for 4.3 hours per day, in idle mode for 2.0 hours per day, and in sleep mode for 17.7 hours per day. The power consumption during these periods is not specified, but increasing energy use of the efficient mode by a factor of 2.65 for the baseline case produces 77 kWh per year.
   There is no incremental cost. Additional market barriers are being investigated by ENERGY STAR.
2. *ENERGY STAR Version 3.0.* Specification for audio visual products. Accessed November 21, 2016. https://www.energystar.gov/ia/partners/prod_development/revisions/downloads/audio_video/Final_Version_3_AV_Program_Requirements.pdf?5442-a1e8.

3. Fraunhofer Center for Sustainable Energy Systems. “Energy Consumption of Consumer Electronics in U.S. Households.” 2010. Accessed November 21, 2016. http://www.cse.fraunhofer.org/publications/energy-consumption-of-consumer-electronics-us-households-2010
   Due to the high market penetration of ENERGY STAR-certified soundbars, a weighted average of the unit energy consumption of both non-ENERGY STAR and ENERGY STAR models was used to calculate savings estimates.
4. The coincidence factor for soundbars in active use is assumed to be 10%, based on engineering judgement. The coincidence factor for idle and sleep modes is therefore 100% - 10% = 90%.

Revision History

Version Number	Date	Description of Change
01	06/24/2016	Initial TRM entry

Appendix A: List of Acronyms

AC	Alternating current
	Air conditioning
AFUE	Annual Fuel Utilization Efficiency
ACH	Air changes per hour
Btu	British thermal units
CDD	Cooling degree day
CEE	Consortium for Energy Efficiency
CFL	Compact fluorescent light bulb
CMH	Ceramic metal halide
COP	Coefficient of performance
DC	Direct current
DDC	Direct digital control
DHW	Domestic hot water
DLC	Design Lights Consortium
DOE	U.S. Department of Energy
EBTU	Express Building Tune Up
ECM	Electronically commutated motor
EER	Energy efficiency ratio
EF	Energy factor
EFLH	Equivalent full-load hours
EISA	Energy Independence and Security Act
EM&V	Evaluation, measurement, and verification
ERV	Energy recovery ventilator
ETL	Intertek's ETL Mark
EUL	Effective useful life
FSTC	Food Service Technology Center
HDD	Heating degree day
HESCC	High-efficiency sealed combustion condensing
HESCCM	High-efficiency sealed combustion condensing modulating
HID	High-intensity discharge
HO	High output
HOU	Hours of use
hp	horsepower
HP	High performance
HSPF	Heating Season Performance Factor
IECC	International Energy Conservation Code
IPLV	Integrated part load volume
ISR	In-service rate
kWDC	Direct current kilowatts

LED	Light-emitting diode
NAIMA	North American Insulation Manufacturers Association
NPS	Nominal Pipe Size
NREL	National Renewable Energy Laboratory
NRTL	Nationally Recognized Testing Laboratory
OAT	Outside Air Temperature
PIR	Passive infrared
PSC	Public Service Commission of Wisconsin
	Permanent split capacitor
PSMH	Pulse-start metal halide
PTAC	Packaged terminal air conditioner
PTHP	Packaged terminal heat pump
PV	Photovoltaic
QPL	Qualified Product List
RCA	Refrigerant charge and airflow
RFP	Request for proposals
RH	Relative humidity
RTU	Rooftop unit
RW	Reduced wattage
SAM	System Advisor Model
SEER	Seasonal energy efficiency ratio
SP	Shaded pole
STC	Standard test conditions
SWH	Solar water heating
TE	Thermal efficiency
TMY	Typical meteorological year
TRC	Total Resource Cost
TRM	Technical Reference Manual
UL	Underwriters Laboratories
VAV	Variable air volume
VFD	Variable frequency drive
VHO	Very high output
VSD	Variable speed drive

Appendix B: Common Variables

Hours of use

Compressed Air

HOU = Average annual run hours (= 5,702)[3]

Commercial/Industrial Lighting

Commercial/Industrial Lighting HOU by Sector

Sector	HOU
Commercial	3,730
Industrial	4,745
Agriculture	4,698
Schools & Government	3,239

Source: PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Lighting Hours of Use in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

Multifamily Lighting (Daily HOU for In-Unit Room estimates)

HOU = Average annual run hours (= 5,950 for multifamily common areas)[4]

Multifamily Lighting Hours of use by Room Type

Room Type	HOU
Bathroom	2.26
Bedroom	1.32
Dining	2.34
Kitchen	2.92
Living Room	2.67
Other (Hall and Office)	0.51

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[3] Cadmus. Focus on Energy Evaluated Deemed Savings Changes. August 31, 2017. https://www.focusonenergy.com/sites/default/files/FoE_Deemed%20Savings%20Report_%20CY%2017_v1.7.pdf

[4] Tetra Tech. *ACES Deemed Savings Desk Review*. Multifamily Applications for Common Areas.November 3, 2010. https://www.focusonenergy.com/sites/default/files/acesdeemedsavingsdeskreview_evaluationreport.pdf

Single Family Residential Lighting (Daily HOU)

Single Family Lighting Hours of use by Room Type

Room Type	HOU
Bathroom	1.00
Bedroom	1.62
Dining	3.18
Kitchen	0.65
Living Room	2.17
Other	0.66
Average Daily Use	2.77

Source: Cadmus. *Focus on Energy Residential Single Family Lighting Hours of Use and Peak Coincidence Factor Findings Memo*. July 2, 2014.

Retail Lighting

Because retail lighting incentives are covered through retail price markdowns at the store level, the program does not collect participant-specific data for where purchased bulbs will be installed. General figures are calculated using the following weighting assumptions:

- Single Family Weighting, 74.7%[5]
- Multifamily Weighting, 25.3%[6]
- Single Family HOU, 2.27 hours per day[7]
- Multifamily HOU, 2.01 hours per day[8]
- Residential Weighting 93%[9]
- Commercial Weighting 7%[10]
- Residential HOU Average, 2.20
- Commercial HOU Average, 10.2[11]

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[5] U.S. Census Bureau. Percentage of Wisconsin housing stock that is single family. 2013 Estimates.

[6] U.S. Census Bureau. Percentage of Wisconsin housing stock that is multifamily. 2013 Estimates.

[7] Cadmus. Single family light logger study, 2013.

[8] Cadmus. Multifamily light logger study. 2013.

[9] Cadmus. In-store intercept surveys. 2012.

[10] Ibid.

[11] *Wisconsin Business Deemed Savings*. 2010.

- Single Family Coincidence Factor 7.5%[12]
- Multifamily Coincidence Factor 5.5%[13]
- Residential, Averaged, Coincidence Factor 6.99%
- Commercial Coincidence Factor 77%[14]

Average annual HOU based on weighting metrics outlined above = 1,011

Coincidence factor based on weighting metrics outline above = 0.1189

Coincidence Factors

Commercial/Industrial/Multifamily Lighting Coincidence Factors

Sector	CF
Commercial*	0.77
Industrial	0.77
Schools & Government	0.64
Agriculture	0.67
Multifamily Common Area	0.77
In-Residence**	0.055

* PA Consulting Group. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Table 3.2 Coincidence Factor for Lighting in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

** Cadmus. Field Study: Residential Lighting. October 18, 2013. (Report based on using CFL bulbs to replace incandescent bulbs. Since LEDs will initially be treated the same as CFLs, those values were used.)

Equivalent Full-Load Hours

Residential Natural Gas Measures

EFLH = 1,158 hours[15]

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[12] U.S. Census Bureau. Percentage of Wisconsin housing stock that is single family. 2013 Estimates.

[13] U.S. Census Bureau. Percentage of Wisconsin housing stock that is multifamily. 2013 Estimates.

[14] PA Consulting Group Inc. *Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0*. Lighting in Commercial Applications. March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf

[15] Cadmus. *Focus on Evaluated Energy Deemed Savings Changes*. November 14, 2014. https://focusonenergy.com/sites/default/files/FoE_Deemed_WriteUp%20CY14%20Final.pdf

Residential Heat Pumps and Split HVAC

Equivalent Full-Load Hours for Air Sealing, Air-Source Heat Pumps, Ground-Source Heat Pumps, and Split A/C System.

Equivalent Full-Load Hours

Location	$EFLH_{COOL}$	$EFLH_{HEAT}$	Weighting by Participant
Green Bay	344	1,852	22%
La Crosse	323	1,966	3%
Madison	395	1,934	18%
Milwaukee	457	1,883	48%
Wisconsin Average	380	1,909	9%
Overall	**410**	**1,890**	

* Full load hours calculated using an average from Illinois Statewide Technical Reference Manual, applied to Wisconsin CDDs.

Flow Rates

Faucet Aerators

$GPM_{EXISTING}$ = Baseline flow rate (= 2.2 GPM)[16]

Low-Flow Showerheads

$GPM_{EXISTING}$ = Baseline flow rate (= 2.5 GPM)[17]

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[16] Federal minimum at 80 psi.

[17] Federal minimum at 80 psi.

Temperature (Water)

Water Heaters

T_{WH} = Water heater temperature setpoint (= 125°F)[18]

$T_{ENTERING}$ = Temperature of water entering water heater (= 52.3°F)[19]

Faucet Aerators (Kitchen)

$T_{POINT\ OF\ USE}$ = Temperature of water at point of use (= 93°F)[20]

Faucet Aerators (Bathroom)

$T_{POINT\ OF\ USE}$ = Temperature of water at point of use (= 86°F)[20]

Low-Flow Showerheads

$T_{POINT\ OF\ USE}$ = Temperature of water at point of use (= 101°F)[20]

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[18] The water heater setpoint is assumed to be 125°F, as Wisconsin building code 704.06 requires landlords to set water heaters to 125°F: https://docs.legis.wisconsin.gov/statutes/statutes/704/06. Water heater setpoints typically range between 120°F and 140°F because temperatures below 120°F are susceptible to Legionella bacteria (which lead to Legionnaires Disease) and heaters set to temperatures above 140°F can quickly scald users: http://www.nrel.gov/docs/fy12osti/55074.pdf. Most TRMs assume water heater setpoints of 120°F, 125°F, or 130°F, though most of these are unsourced engineering assumptions. (Residential water heater setpoints include: Connecticut 2012 TRM PSD: 130°F for natural gas DWH and 125°F for tank wrap, HPWH, and temperature reduction; Mid- Atlantic TRM v3.0: 130°F for tank wrap and pipe insulation; Illinois TRM v2.0: 125°F for pipe insulation, natural gas water heater, HPWH, and tank wrap and 120°F for temperature reduction; and Indiana TRM v1.0: 130°F for pipe insulation.)

[19] U.S. Department of Energy. *Domestic Hot Water Scheduler.* Average water main temperature of all locations measured in Wisconsin by scheduler, weighted by city populations.

[20] Cadmus. *Showerhead and Faucet Aerator Meter Study*. Memo to Michigan Evaluation Working Group. June 2013.

Outside Air Temperature Bin Analysis

Bin Analysis

Bin	Max of Bin	Midpoint	GREEN BAY	LA CROSSE	MADISON	MILWAUKEE	MINOCQUA	RICE LAKE	WAUSAU	Average Hours for WI	Note
95 to 100	100	97.5	0	2	0	3	0	0	0	1	
90 to 95	95	92.5	22	51	25	18	22	4	29	24	
85 to 90	90	87.5	62	121	86	59	36	22	91	68	
80 to 85	85	82.5	275	355	339	225	222	213	335	281	
75 to 80	80	77.5	398	445	486	400	397	398	532	437	
70 to 75	75	72.5	445	489	447	497	413	508	420	460	
65 to 70	70	67.5	675	762	723	692	555	693	666	681	
60 to 65	65	62.5	871	746	770	936	852	810	699	812	
55 to 60	60	57.5	647	583	605	545	680	673	502	605	
50 to 55	55	52.5	420	510	470	547	557	541	423	495	Boiler enabled
45 to 50	50	47.5	527	549	618	603	515	557	586	565	Boiler enabled
40 to 45	45	42.5	579	597	510	723	554	477	718	594	Boiler enabled
35 to 40	40	37.5	777	826	905	883	589	632	619	747	Boiler enabled
30 to 35	35	32.5	820	719	741	720	669	675	792	734	Boiler enabled
25 to 29	30	27.5	507	425	396	423	424	366	539	440	Boiler enabled
20 to 25	25	22.5	579	457	439	531	506	365	551	490	Boiler enabled
15 to 20	20	17.5	443	319	353	390	478	420	406	401	Boiler enabled
10 to 15	15	12.5	265	227	212	228	475	367	252	289	Boiler enabled
5 to 10	10	7.5	157	174	117	97	315	296	247	200	Boiler enabled
0 to 5	5	2.5	111	144	152	116	203	286	138	164	Boiler enabled
-5 to 0	0	-2.5	81	106	157	61	136	182	115	120	Boiler enabled
-10 to -5	-5	-7.5	83	109	105	57	90	177	84	101	Boiler enabled
-15 to -10	-10	-12.5	9	23	70	6	40	69	16	33	Boiler enabled
-20 to -15	-15	-17.5	7	9	21	0	24	24	0	12	Boiler enabled
-25 to -20	-20	-22.5	0	6	9	0	8	5	0	4	Boiler enabled
-30 to -25	-25	-27.5	0	6	4	0	0	0	0	1	Boiler enabled
-35 to -30	-30	-32.5	0	0	0	0	0	0	0	0	Boiler enabled
			5365	5206	5279	5385	5583	5439	5486	5392	Boiler enabled total

Heating and Cooling Degree Days

Heating and Cooling Degree Days for Residential Applications*

Location	HDD	CDD
Milwaukee	7,276	548
Green Bay	7,725	516
Wausau	7,805	654
Madison	7,599	630
La Crosse	7,397	729
Minocqua	8,616	423
Rice Lake	8,552	438
Statewide Weighted	**7,616**	**565**

* Cadmus. *Michigan Water Meter Study.* 2012.

Appendix C: Effective Useful Life Table

The workpapers above define savings and EULs for a vast majority of active measures. This appendix defines effective useful life values for measures that are not described in the workpapers above.

MMID	Measure Name	EUL
598	Greenhouse Climate Controls, Hybrid	10
1989	Water Heater, Electric, EF 0.93 or greater	15
2139	Low-flow Showerhead, 1.5 gpm, Gas	10
2145	Low-flow Showerhead, 1.5 gpm, Electric MF	10
2211	Boiler Tune-up - service buy down	1
2494	Pre-Rinse Sprayer, <=.65 gpm, Electric	5
2495	Pre-Rinse Sprayer, <=.65 gpm, NG	5
2556	T8 1L-4 ft Reduced Wattage with CEE Ballast - 25 Watts (Low BF)	15
2557	T8 1L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)	15
2558	T8 1L 4', 28W, CEE, BF > 0.78	15
2564	T8 2L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)	15
2565	T8 2L-4 ft Reduced Wattage with CEE Ballast - 28 Watts	15
2571	T8 3L-4 ft Low Watt with CEE Ballast - 25 Watts (Low BF)	15
2573	T8 3L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)	15
2574	T8 3L 4', 28W, CEE, BF > 0.78	15
2579	T8 4L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)	15
2580	T8 4L 4', 28W, CEE, BF > 0.78	15
2590	T8 Low Watt Relamp - 25 Watts	15
2591	T8 Low Watt Relamp - 28 Watts	15
2602	Thermal Curtain, Poly Film Walls and Ceiling, Under Bench Heating	5
2603	Thermal Curtain, Single Pane Glass Walls and Ceiling, Overhead Heating	5
2608	Unit Heater, >= 90% thermal efficiency, per input MBh, for retrofit	15
2635	Agricultural Exhaust Fan, High Efficiency - 55"	16
2637	Agricultural Exhaust Fan, High Efficiency - 60"	16
2651	Storage Water Heater EF >0.67	10
2711	Insulation, Project Based, Attic	35
2712	Insulation, Sidewall, Foam	25
2713	Insulation, Foundation - Interior	20
2714	Insulation, Sill Box	20
2764	Furnace, with ECM fan motor, for space heating (AFUE >= 95%)	18
2902	Water Heater, Power Vented, EF = .67-.82, Storage, NG	15
3022	Split System A/C	15
3121	Programmable Thermostat, RTU Optimization Standard	8
3266	Demand Control Ventilation, RTU Optimization	15
3586	Water Heater, Electric, EF of 0.93 or greater, Claim Only	15

MMID	Measure Name	EUL
3587	Water Heater, >= 0.67 EF, Storage, NG, Claim Only	10
3588	Water Heater, >= 0.82 EF, Tankless, Residential, NG, Claim Only	13
3761	A/C Split or Packaged System, High Efficiency, Multifamily	15
3767	Circulation Fan, HS/HE, 36"-47", Ag	15
3768	Circulation Fan, HS/HE, 48"-52", Ag	15
3769	Circulation Fan, HS/HE, ≥ 53", Ag	15
3770	Ventilation Fan, HS/HE, 24"-35", Ag	16
3771	Ventilation Fan, HS/HE, 36"-47", Ag	16
3772	Ventilation Fan, HS/HE, 48"-52", Ag	16
3773	Ventilation Fan, HS/HE, ≥ 53", Ag	16
3785	Insulation, Tier 2, Project Based, Attic	35
3786	Insulation, Tier 2, Project Based, Foundation	20
3787	Insulation, Tier 2, Project Based, Sillbox	20
3788	Insulation, Tier 2, Project Based, Wall	25
3799	T8 2L 4', HPT8, CEE, BF <= 0.78, Agriculture	15
3806	LED Fixture, <155 Watts, Replacing 250 Watt HID, High Bay, Agriculture	14
3807	LED Fixture, <250 Watts, Replacing 400 Watt HID, High Bay, Agriculture	14
3810	LED Fixture, <250 Watts, Replacing 320-400 Watt HID, High Bay, Agriculture	14
3831	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 320-400 Watt HID, Exterior, Agriculture	15
3834	Lighting Controls, Photocell with Internal Timer or Wireless Schedule, Exterior, Agriculture	8
3842	Air Sealing, Tier 2, Project Based	20
3861	LED, 10 Watt, Pack-based	15
3897	LED, Pack-based, 10 Watt, BR30	15
3984	Refrigeration System Tune-Up Without Milk Pre-Cooler	5
3985	Refrigeration System Tune-Up With Milk Pre-Cooler	5
3986	Refrigeration System Tune-Up With Milk Pre-Cooler and VFD Milk Pump	5
4052	TLED Trial, Replacement of 4' T8 Lamps utilizing existing ballast	15

Appendix D: Incremental Costs

The workpapers above define savings and incremental costs for a vast majority of active measures. This appendix defines incremental cost values for measures that are not described in the workpapers above. These are in the Non-Workpaper Measure Costs table.

Non-Workpaper Measure Costs

MMID	Measure Name	Incremental Cost	Source
598	Greenhouse Climate Controls, Hybrid	$0.11	Historical Project Data, 2016. Agriculture, Schools and Government Program; 4 Projects, 01/2016 to 06/2016. Average Cost is $0.11 per square foot.
1989	Water Heater, Electric, EF 0.93 or greater	$25.16	California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/index.php/ex-ante-databaseRSMeans. Facilities Construction Cost Data. 2011.
2139	Low-flow Showerhead, 1.5 gpm, Gas	$5.00	$5.00 = WESCO Distribution Pricing ($3.11) + Labor ($1.89)
2145	Low-flow Showerhead, 1.5 gpm, Electric MF	$5.00	$5.00 = WESCO Distribution Pricing ($3.11) + Labor ($1.89)
2211	Boiler Tune-up - service buy down	$0.83	Illinois Technical Reference Manual. p. 185. 2013. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf
2494	Pre-Rinse Sprayer, <=.65 gpm, Electric	$51.74	Midwest program data suggests $35.00 incremental cost.California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” June 2, 2008. http://www.deeresources.com/index.php/ex-ante-database. An installation cost of $16.74 can be estimated from DEER 2008, assuming cost of installing a showerhead is equivalent to a pre-rinse sprayer.
2495	Pre-Rinse Sprayer, <=.65 gpm, NG	$51.74	
2556	T8 1L-4 ft Reduced Wattage with CEE Ballast - 25 Watts (Low BF)	$2.45	2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.
2557	T8 1L-4 ft Reduced Wattage with CEE	$2.07	

MMID	Measure Name	Incremental Cost	Source
	Ballast - 28 Watts (Low BF)		
2558	T8 1L 4', 28W, CEE, BF > 0.78	$2.07	
2564	T8 2L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)	$4.13	
2565	T8 2L-4 ft Reduced Wattage with CEE Ballast - 28 Watts	$4.13	
2571	T8 3L-4 ft Low Watt with CEE Ballast - 25 Watts (Low BF)	$7.35	2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.
2573	T8 3L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)	$6.20	
2574	T8 3L 4', 28W, CEE, BF > 0.78	$6.20	
2579	T8 4L-4 ft Reduced Wattage with CEE Ballast - 28 Watts (Low BF)	$8.27	
2580	T8 4L 4', 28W, CEE, BF > 0.78	$8.27	
2590	T8 Low Watt Relamp - 25 Watts	$2.45	
2591	T8 Low Watt Relamp - 28 Watts	$2.07	
2602	Thermal Curtain, Poly Film Walls and Ceiling, Under Bench Heating	$1.50	Work Paper PGECOAGR101 Greenhouse Thermal Curtains. 2008. https://www.socalgas.com/regulatory/documents/a-08-07-022/amendedWorkpapers/SW-AgB/Greenhouse%20Thermal%20Curtains%20PGECOAGR101%20R0.pdf
2603	Thermal Curtain, Single Pane Glass Walls and Ceiling, Overhead Heating	$1.50	

MMID	Measure Name	Incremental Cost	Source
2608	Unit Heater, >= 90% thermal efficiency, per input MBh, for retrofit	$18.00	Actual Program Data, 2015-2016. 49 projects with average actual cost of $18.00 per MBh.
2635	Agricultural Exhaust Fan, High Efficiency - 55"	$1,139.00	Similar to measure 2634. Historical Focus on Energy project data, 2012-2013. 12 projects, 289 fans; fan average total cost is $1,139.00.
2637	Agricultural Exhaust Fan, High Efficiency - 60"	$2,010.00	Historical Focus on Energy project data, 2012-2013. 3 projects, 141 fans; fan average total cost is $2,010.00.
2651	Storage Water Heater EF >0.67	$400.00	U.S. Department of Energy. Water Heater Market Profile. p. 15. September 2009. https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/Water_Heater_Market_Profile_Sept2009.pdf
2711	Insulation, Project Based, Attic	$2.69	Illinois Technical Reference Manual. p. 141. 2013. This measure includes air sealing costs. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf
2712	Insulation, Sidewall, Foam	$0.94	California Energy Commission and California Public Utilities Commission. “Database for Energy Efficient Resources.” Revised Measure Cost Summary. June 2, 2008. http://www.deeresources.com/. Cost for Wall 2x6 R-19 Batts + R-5 Rigid.
2713	Insulation, Foundation - Interior	$2.93	Illinois Technical Reference Manual. p. 141. 2013. This measure includes air sealing costs. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf
2714	Insulation, Sill Box	$5.97	
2764	Furnace, with ECM fan motor, for space heating (AFUE >= 95%)	$1,667.84	NEEP Regional Evaluation, Measurement & Verification Forum, A Report on Costs in Six Northeast & Mid-Atlantic Markets. 2011. Navigant Consulting. Navigant study completed 15 interviews for this measure. http://www.neep.org/Assets/uploads/files/emv/emv-products/Incremental%20Cost_study_FINAL_REPORT_2011Sep23.pdf
2902	Water Heater, Power Vented, EF = .67-.82, Storage, NG	$400.00	U.S. Department of Energy. Water Heater Market Profile. p. 15. September 2009. https://www.energystar.gov/ia/partners/prod_development/

MMID	Measure Name	Incremental Cost	Source
			new_specs/downloads/water_heaters/Water_Heater_Market_Profile_Sept2009.pdf
3022	Split System A/C	$82.34	Northeast Energy Efficiency Partnerships. "Incremental Cost Study Phase Three Final Report." Table 10. May 2014. http://www.neep.org/incremental-cost-study-phase-3. Average of CEE Tier 2 values ($126.84 and $37.83)
3121	Programmable Thermostat, RTU Optimization Standard	$150.00	California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/
3266	Demand Control Ventilation, RTU Optimization	$2,130.68	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 131 projects and 247 units from January 2018 to May 2020 is $2,130.68. Base cost of $0.00 from October 2019 lookups of 0 32 watt T8 lamps, average of 3x and 4x. $2,130.68 - $0.00 = $2,130.68.
3586	Water Heater, Electric, EF of 0.93 or greater, Claim Only	$25.16	California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." June 2, 2008. http://www.deeresources.com/index.php/ex-ante-databaseRSMeans. Facilities Construction Cost Data. 2011.
3587	Water Heater, >= 0.67 EF, Storage, NG, Claim Only	$400.00	U.S. Department of Energy. Water Heater Market Profile. p. 15. September 2009. https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/Water_Heater_Market_Profile_Sept2009.pdf
3588	Water Heater, >= 0.82 EF, Tankless, Residential, NG, Claim Only	$605.00	Ohio TRM. p. 123. 2010. Tankless DHW EF > 0.82 incremental cost is $605.00 per water heater. http://s3.amazonaws.com/zanran_storage/amppartners.org/ContentPages/2464316647.pdf
3761	A/C Split or Packaged System, High Efficiency, Multifamily	$100.00	Based on a review of TRM incremental cost assumptions from Vermont (Vermont Technical Reference Manual. August 2013. and California Municipal Utilities (CMUA Savings Estimation Technical Reference Manual). 2014. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf; http://cmua.org/energy-efficiency-technical-reference-manual
3767	Circulation Fan, HS/HE, 36"-47", Ag	$150.00	Illinois Energy Efficiency Stakeholder Advisory Group. "Illinois Technical Reference Manual." Version 4.0. p. 62 referencing

MMID	Measure Name	Incremental Cost	Source
3768	Circulation Fan, HS/HE, 48"-52", Ag	$150.00	'Act on Energy Commercial Technical Reference Manual No. 2010-4.' January 22, 2016. http://www.ilsag.info/il_trm_version_4.html
3769	Circulation Fan, HS/HE, ≥ 53", Ag	$150.00	
3770	Ventilation Fan, HS/HE, 24"-35", Ag	$150.00	
3771	Ventilation Fan, HS/HE, 36"-47", Ag	$150.00	
3772	Ventilation Fan, HS/HE, 48"-52", Ag	$150.00	
3773	Ventilation Fan, HS/HE, ≥ 53", Ag	$150.00	
3785	Insulation, Tier 2, Project Based, Attic	$2.69	Illinois Technical Reference Manual. p. 141. 2013. This measure includes air sealing costs. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf
3786	Insulation, Tier 2, Project Based, Foundation	$0.94	California Energy Commission and California Public Utilities Commission. "Database for Energy Efficient Resources." Revised Measure Cost Summary. June 2, 2008. http://www.deeresources.com/. Cost for Wall 2x6 R-19 Batts + R-5 Rigid.
3787	Insulation, Tier 2, Project Based, Sillbox	$2.93	Illinois Technical Reference Manual. p. 141. 2013. This measure includes air sealing costs. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_3/Final_Draft/Illinois_Statewide_TRM_Effective_060114_Version_3%200_021414_Final_Clean.pdf
3788	Insulation, Tier 2, Project Based, Wall	$5.97	
3799	T8 2L 4', HPT8, CEE, BF <= 0.78, Agriculture	$15.40	2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. There is no additional cost for ballasts.
3806	LED Fixture, <155 Watts, Replacing 250 Watt HID, High Bay, Agriculture	$204.99	Online research. March 2016. Average cost of LED round high bay fixtures under 155-watt replacement. https://www.1000bulbs.com/category/round-high-bays/
3807	LED Fixture, <250 Watts, Replacing 400	$387.82	

MMID	Measure Name	Incremental Cost	Source
	Watt HID, High Bay, Agriculture		
3810	LED Fixture, <250 Watts, Replacing 320-400 Watt HID, High Bay, Agriculture	$387.82	
3831	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 320-400 Watt HID, Exterior, Agriculture	$290.00	2015 Implementer assessment of measure cost.
3834	Lighting Controls, Photocell with Internal Timer or Wireless Schedule, Exterior, Agriculture	$101.56	Actual cost from 2015-16 program data, 7 applications.
3842	Air Sealing, Tier 2, Project Based	$0.00	Implementer findings
3861	LED, 10 Watt, Pack-based	$5.90	Evaluator Online Cost research from www.1000bulbs.com Lowes, and HomeDepot. Research conducted March 2016 for ENERGY STAR®. Weighted Average of 29 to 43 Watt LEDs.
3897	LED, Pack-based, 10 Watt, BR30	$7.85	Home Depot. Website. Accessed May 15, 2016. www.homedepot.com Menards. Website. Accessed May 15, 2016. www.menards.com Pack incremental cost is the average price of BR30 LED – Incandescent replacement
3984	Refrigeration System Tune-Up Without Milk Pre-Cooler	$260.86	"Ag Dairy Refrigeration Tune-Up Supplemental Data."Dairy Tune-Up tab shows historical data (54 projects) average of May 2013 through July 2015 approved application kWh savings and project cost data. WI Dairy Statistics tab shows USDA-reported annual data from: U.S. Department of Agriculture. "Milk Production Per Cow, Wisconsin." https://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Dairy/Historical_Data_Series/mkpercow.pdf
3985	Refrigeration System Tune-Up With Milk Pre-Cooler	$260.86	
3986	Refrigeration System Tune-Up With Milk Pre-Cooler and VFD Milk Pump	$260.86	
4052	TLED Trial, Replacement of 4' T8 Lamps utilizing existing ballast	$4.10	Cost for particular product for the TLED Trial special offering, per accepted proposal. Price valid through December 31, 2017.

Workpaper Measure Costs

MMID	Measure Name	Incremental Cost	Source
2280	Dishwasher, Low Temp, Door Type, Energy Star, Energy Star, Electric	$662.00	ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. October 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
2281	Dishwasher, High Temp, Electric Booster, Door Type, Energy Star, Electric	$662.00	
2282	Dishwasher, High Temp, Electric Booster, Door Type, Energy Star, NG	$995.00	
2283	Dishwasher, High Temp, Electric Booster, Multi Tank Conveyor, Energy Star, Electric	$970.00	
2284	Dishwasher, High Temp, Electric Booster, Multi Tank Conveyor, Energy Star, NG	$970.00	ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. October 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
2285	Dishwasher, High Temp, Electric Booster, Single Tank Conveyor, Energy Star, Electric	$2,050.00	
2286	Dishwasher, High Temp, Electric Booster, Single Tank Conveyor, Energy Star, NG	$2,050.00	
2287	Dishwasher, High Temp, Electric Booster, Under Counter, Energy Star, Electric	$2,025.00	
2288	Dishwasher, High Temp, Electric Booster, Under Counter, Energy Star, NG	$2,025.00	
2289	Dishwasher, High Temp, Gas Booster, Door Type, Energy Star, NG	$995.00	
2290	Dishwasher, High Temp, Gas Booster, Multi Tank	$970.00	

MMID	Measure Name	Incremental Cost	Source
	Conveyor, Energy Star, NG		
2291	Dishwasher, High Temp, Gas Booster, Single Tank Conveyor, Energy Star, NG	$2,050.00	
2292	Dishwasher, High Temp, Gas Heat, Gas Booster, Under Counter, Energy Star, NG	$2,025.00	
2293	Dishwasher, Low Temp, Door Type, Energy Star, NG	$662.00	
2294	Dishwasher, Low Temp, Multi Tank Conveyor, Energy Star, Electric	$970.00	ENERGY STAR. "Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment." Calculator. October 2016. https://www.energystar.gov/sites/default/files/asset/document/commercial_kitchen_equipment_calculator_0.xlsx
2295	Dishwasher, Low Temp, Multi Tank Conveyor, Energy Star, NG	$970.00	
2296	Dishwasher, Low Temp, Single Tank Conveyor, Energy Star, Electric	$0.00	
2298	Dishwasher, Low Temp, Under Counter, Energy Star, Electric	$234.00	
2299	Dishwasher, Low Temp, Under Counter, Energy Star, NG	$234.00	
3136	Dishwasher, High Temp, Electric Booster, Pots/Pans Type, Energy Star, Electric	$1,710.00	
3137	Dishwasher, High Temp, Electric Booster, Pots/Pans Type, Energy Star, NG	$1,710.00	
3138	Dishwasher, High Temp, Gas Booster, Pots/Pans Type, Energy Star, NG	$1,710.00	

MMID	Measure Name	Incremental Cost	Source
4514	Dishwasher, Low Temp, Single Tank Conveyor, Energy Star, NG, SBP	$0.00	
4515	Dishwasher, Low Temp, Under Counter, Energy Star, Electric, SBP	$234.00	
3139	Dishwasher, Low Temp, Pots/Pans Type, Energy Star, Electric	$1,710.00	
3140	Dishwasher, Low Temp, Pots/Pans Type, Energy Star, NG	$1,710.00	
2471	Occupancy Sensors - Ceiling Mount <= 500 Watts	$120.00	WESCO Distribution Pricing, 2013 ($95.00)+ Labor ($25.00) = $120.00
2472	Occupancy Sensors - Ceiling Mount >= 1001 Watts	$120.00	
2473	Occupancy Sensors - Ceiling Mount 501-1000 Watts	$120.00	
2474	Occupancy Sensors - Fixture Mount <= 200 Watts	$95.00	WESCO Distribution Pricing. 2013. ($70.00) + Labor ($25.00) = $95.00
2475	Occupancy Sensors - Fixture Mount > 200 Watts	$95.00	
2483	Occupancy Sensors - Wall Mount <= 200 Watts	$35.00	WESCO Distribution Pricing, 2013 ($18.75) + Labor ($16.25) = $35.00
2484	Occupancy Sensors - Wall Mount >= 201 Watts	$35.00	
3201	Occupancy Sensor, Wall or Ceiling Mount <=200 Watts, CALP	$77.50	WESCO Distribution Pricing ($18.75) + Labor ($16.25) = $35.00 for Wall Mount. WESCO Distribution Pricing, 2013 + Labor = $120.00 for Ceiling Mount. $77.50 is the average.
3605	Occupancy Sensor, Fixture Mount, <=200 Watts, CALP	$115.00	Similar to MMID 2474. WESCO Distribution Pricing ($70.00) + Labor ($25.00) = $95.00

MMID	Measure Name	Incremental Cost	Source
3606	Occupancy Sensor, Fixture Mount, >200 Watts, CALP	$115.00	
3619	Occupancy Sensor, Fixture Mount, ≤ 60 Watts, SBP Package	$200.00	Similar to MMID 3561. Mid-Atlantic Technical Reference Manual Version 5.0. p.302. April 2015. http://www.neep.org/sites/default/files/resources/Mid-Atlantic_TRM_V5_FINAL_5-26-2015.pdf
3621	Occupancy Sensor, Fixture Mount, ≤ 60 Watts, SBP After A La Carte	$200.00	
3122	T8 2L 4', HPT8 or RWT8, Replacing T12 1L 8', 0.78 < BF < 1.00	$4.90	2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.
3123	T8 2L 4', HPT8 or RWT8, Replacing T12 1L 8', BF <= 0.78	$4.90	
3124	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', 0.78 < BF < 1.00	$4.90	
3125	T8 2L-4ft High Performance HBF Replacing T12HO 1L-8 ft	$4.90	
3126	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', BF > 1.00	$4.90	
3127	T8 4L-4-4ft High Performance Replacing T12 2L-8 ft	$9.80	
3128	T8 4L 4', HPT8 or RWT8, Replacing T12 2L 8', BF <= 0.78	$9.80	
3129	T8 4L-4ft High Performance Replacing T12HO 2L-8 ft -	$9.80	
3130	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', BF <= 0.78	$9.80	
3131	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', BF > 1.00	$9.80	

MMID	Measure Name	Incremental Cost	Source
3132	T8 4L-4ft High Performance Replacing T12HO/VHO 2L-8 ft	$9.80	
3133	T8 4L 4', HPT8 or RWT8, Replacing T12VHO 2L 8', BF <= 0.78	$9.80	
3134	T8 4L 4', HPT8 or RWT8, Replacing T12VHO 2L 8', BF > 1.00	$9.80	2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.
3801	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', 0.78 < BF < 1.00, Agriculture	$4.90	
3802	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', BF > 1.00, Agriculture	$4.90	
3803	T8 4L 4', HPT8 or RWT8, Replacing T12 2L 8', 0.78 < BF < 1.00, Agriculture	$9.80	
3804	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', 0.78 < BF < 1.00, Agriculture	$9.80	
3805	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', BF > 1.00, Agriculture	$9.80	
3097	LED Fixture, Bilevel, Stairwell and Passageway	$215.15	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 1,939 units over 101 projects, from 2016 to 2018.
3251	Lighting Controls, Bilevel, Exterior and Parking Garage Fixtures, Dusk to Dawn	$81.41	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 800 units over 38 projects, from 2016 to 2018.
3252	Lighting Controls, Bilevel, Parking Garage Fixtures, 24 Hour	$47.54	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average cost of 5,321 units over 21 projects, from 2016 to 2018.
2276	DELAMPING, DIRECT INSTALL, 4 FOOT LAMP	$51.75	Actual program cost from 2015-16 program data, where available, 23 applications.
2277	Delamping, T8 to T8	$11.59	

MMID	Measure Name	Incremental Cost	Source
3320	Delamping, T12 to T8, 8', SBP A La Carte	$10.80	Mid-Atlantic TRM Version 6.0. p. 323. http://www.neep.org/mid-atlantic-technical-reference-manual-v6
3099	LED Fixture, Replacing 150-175 Watt HID, Exterior	$257.06	Full cost of $267.15 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 12,545 fixtures over 1,706 projects, from 2016 to 2018. Online lookups of 6 baseline lamps on www.1000bulbs.com show a baseline cost of $10.09 per replacement bulb. The incremental cost is therefore $257.06.
3102	LED Fixture, Replacing 250 Watt HID, Exterior	$340.05	Wisconsin Focus on Energy. Historical project data, obtained from SPECTRUM. Average unit cost of 608 projects and 3,948 units from April 2018 to September 2019 is $349.67. Base cost of $9.62 from August 2018 online lookups of 6 base models. $349.67 - $9.62 = $340.05.
3107	LED Fixture, Replacing 400 Watt HID, Exterior	$461.62	Full cost of $473.61 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 16,097 fixtures over 2,029 projects, from 2016 to 2018. Online lookups of 6 baseline lamps on www.1000bulbs.com show a baseline cost of $11.98 per replacement bulb. The incremental cost is therefore $461.62.
3108	LED Fixture, Replacing 70-100 Watt HID, Exterior	$214.57	Full cost of $223.18 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 7,721 fixtures over 1,070 projects, from 2016 to 2018. Online lookups of 6 baseline lamps on www.1000bulbs.com show a baseline cost of $8.61 per replacement bulb. The incremental cost is therefore $214.57.
3824	LED Fixture, Replacing 150-175 Watt HID, Exterior, Agriculture	$328.01	Full cost of $338.10 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 72 fixtures over 26 projects, from 2016 to 2018. Online lookups of 6 baseline lamps on www.1000bulbs.com show a baseline cost of $10.09 per bulb. The incremental cost is therefore $328.01.
3825	LED Fixture, Replacing 250 Watt HID, Exterior, Agriculture	$371.94	Full cost of $371.94 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 182 fixtures over 53 projects, from 2016 to 2018. Online lookups of 6 baseline lamps on www.1000bulbs.com show a baseline cost of $9.62 per bulb. The incremental cost is therefore $371.94.

MMID	Measure Name	Incremental Cost	Source
3826	LED Fixture, Replacing 320-400 Watt HID, Exterior, Agriculture	$94.27	Actual cost from 2015-16 program data = $337.33. 283 applications, primary fixture types are a mixture of architectureal floods, pole/arm mounted and wall packs. Less average price from 1000bulbs.com search for "320 Watt HID, Exterior = $243.06. Incremental Cost is $408-$243.06 =$164.94. Incremental Cost is $337.33 - $243.06 = $94.27
3827	LED Fixture, Replacing 400 Watt HID, Exterior, Agriculture	$404.66	Full cost of $416.64 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 28 fixtures over 9 projects, from 2016 to 2018. Online lookups of 6 baseline lamps on www.1000bulbs.com show a baseline cost of $11.98 per bulb. The incremental cost is therefore $404.66.
3828	LED Fixture, Replacing 70-100 Watt HID, Exterior, Agriculture	$259.73	Full cost of $268.34 is based on Wisconsin Focus on Energy historical project data obtained from SPECTRUM, average cost of 17 fixtures over 7 projects, from 2016 to 2018. Online lookups of 6 baseline lamps on www.1000bulbs.com show a baseline cost of $8.61 per bulb. The incremental cost is therefore $259.73.
3811	T8 4L Replacing 250-399 W HID, Agriculture	$129.00	2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013.
3812	T8 6L Replacing 400-999 W HID, Agriculture	$327.12	
3813	T5HO 4L Replacing 400-999 W HID, Agriculture	$163.16	
3814	T5HO 6L Replacing 400-999 W HID, Agriculture	$210.22	
3084	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 320 Watt HID, Exterior	$340.00	2015 Implementer assessment of measure cost.
3829	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 150-175 Watt HID, Exterior, Agriculture	$284.48	Actual cost from 2015-16 program data, 8 applications.
3830	Induction, PSMH/CMH, or Linear Fluorescent,	$244.76	Actual cost from 2015-16 program data, 15 applications.

MMID	Measure Name	Incremental Cost	Source
	Replacing 250 Watt HID, Exterior, Agriculture		
3832	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 400 Watt HID, Exterior, Agriculture	$316.61	Actual cost form 2015-16 program data, 15 applications.
3833	Induction, PSMH/CMH, or Linear Fluorescent, Replacing 70-100 Watt HID, Exterior, Agriculture	$50.00	2015 Implementer assessment of measure cost.
3815	Induction, PSMH/CMH, Replacing 250 Watt HID, High Bay	$100.00	Actual cost from 2015-16 program data, 1 application.
3816	Induction, PSMH/CMH, <=250 Watt, Replacing 320-400 Watt HID, High Bay, Agriculture	$290.00	2015 Implementer assessment of measure cost.
3817	Induction, PSMH/CMH, <=250 Watt, Replacing 400 Watt HID, High Bay, Agriculture	$159.74	Online research. March 2016. and Program Data. 2015. warehouse-lighting.com. Baseline measure is 16" Aluminum (400-watt High Bay Light Fixture, High Pressure Sodium, 120-277v); cost is $181.26. Efficient measure average cost is $341.00 from 2015 Focus on Energy Program application data.
1988	Water Heater, Indirect	$988.50	New York Statewide Residential Gas High Efficiency Heating Equipment Programs: Evaluation of 2009-2011 Programs. Average of mean and median costs using both approaches, Table 1-4. http://www.coned.com/energyefficiency/PDF/EEPS%20CY1%20NY%20HEHE%20Evaluation%20Report%20FINAL%20APPROVED%202014-08-21.pdf
3585	Water Heater, Indirect, Claim Only	$1,294.00	NEEP Regional Evaluation, Measurement & Verification Forum, A Report on Costs in Six Northeast & Mid-Atlantic Markets. 2011. Navigant Consulting. p. 11. Mid-sized (60 MBh and 48 gals) Residential Indirect Water Heater Incremental Cost Results ($ per unit) Non-Regional Specific.
3784	Water Heater, Indirect, Tier 2	$988.50	New York Statewide Residential Gas High Efficiency Heating Equipment Programs: Evaluation of 2009-2011 Programs. Average of mean and median costs using both approaches, Table 1-4.

MMID	Measure Name	Incremental Cost	Source
			http://www.coned.com/energyefficiency/PDF/EEPS%20CY1%20NY%20HEHE%20Evaluation%20Report%20FINAL%20APPROVED%202014-08-21.pdf
3148	T8 2L 4', HPT8 or RWT8, Replacing T12HO 1L 8', BF > 1.00, Parking Garage	$9.80	2014 Focus on Energy Program Data; verified with average price of lamps on 1000bulbs.com (2014). Evaluator estimate for labor duration, labor cost from RSMeans, 2013. Assumes T8 and CEE ballast as baseline.
3152	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', 0.78 < BF < 1.00, Parking Garage	$9.80	
3153	T8 4L 4', HPT8 or RWT8, Replacing T12HO 2L 8', BF <= 0.78, Parking Garage	$9.80	