FOCUS ON ENERGY

ENVIRONMENTAL AND ECONOMIC RESEARCH AND DEVELOPMENT

WISCONSIN BUILDING CODE ANALYSIS:
IDENTIFYING LOW-COST, HIGH-IMPACT MEASURES

INTERIM REPORT

April 10, 2015

PREPARED BY:

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EXECUTIVE SUMMARY

Date of Report: April 10, 2015

Title of Project: Wisconsin Building Code Analysis: Identifying Low-cost, High-impact Measures

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Research Question: "What changes to Wisconsin building codes would offer the most cost-effective savings to the Focus program at the lowest cost and inconvenience to the owner/builder?"

Project Period: December 19, 2013 to April 30, 2015

Research Objectives:

- Produce a database of building energy models using current Wisconsin building and energy codes for at least four (4) building types
- Determine the energy savings achieved, if any, with upgrading the baseline energy models to IECC 2012, and examine, incrementally, the savings associated with individual measures
- Conduct a simple payback analysis using incremental first costs to identify the cost-effectiveness of building upgrades
- Prepare a Final Report with quantitative analysis showing which areas of the current Wisconsin building codes would produce the most cost-effective savings to Focus on Energy

Summary of Results:

A database of building energy models was created to represent Wisconsin building stock in form, function, and energy usage. Six baseline models were created: a single family home, a K-12 school, a retail store, and three sizes of office building. These models were tailored to conform to current Wisconsin building code, and were calibrated to CBECS (EIA 2003) and RECS (EIA 2009) expected energy consumption in energy use intensity (EUI) and distribution (i.e., end use).

International Energy Conservation Code (IECC) versions released since the last Wisconsin building code update were investigated. Four (4) residential measures and six (6) commercial measures were selected for study inclusion. These represent all concrete (i.e., not geometry or occupancy dependent) IECC 2012 code updates (Appendix A), and a handful of added measures stemming from successful Focus on Energy incentive programs.

Individual and combined code upgrades were implemented in the models, and resulting changes in energy use were tracked. Incremental first costs were estimated for each measure and used to evaluate the cost effectiveness of the investigated measures, resulting in projected simple payback timescales. IECC 2012 compliance was evaluated along with a proposed Focus Standard set of upgrades. Site EUI savings percentages and payback timescale are given in Table 1 for each of these packages.

Table 1. Code Upgrade Summary Results

	IECC 2012		FOCUS STANDARD	
	EUI SAVINGS [%]	SIMPLE PAYBACK [Years]	EUI SAVINGS [%]	SIMPLE PAYBACK [Years]
RESIDENTIAL	16.3%	16.1	24.7%	10.9
COMMERCIAL [AVERAGE]	16.4%	6.9	28.0%	6.7

Though cost estimates can vary significantly due to frequent market changes, our results suggest that both IECC 2012 and Focus Standard code upgrades provide cost-effective compliance options for building owners in the state of Wisconsin.

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MOTIVATION

Building codes have a surprisingly long history. They can be said to date back to the Code of Hammurabi in 1772 BC, which stated "If a builder build a house for someone…if then the walls seem toppling, the builder must make the walls solid from his own means". The Bible (Deuteronomy 22:8) also stipulates that parapets must be constructed on all houses to prevent people from falling off. More modern versions in the United States were enacted in the mid-19th and early-20th centuries, also primarily motivated by safety issues.

The 1970s energy crisis inspired the original version of ASHRAE Standard 90.1 "Energy Standard for Buildings Except Low-Rise Residential Buildings" (ASHRAE, 1975), however, it was not until 1998 that the first International Energy Conservation Code (IECC; International Code Council, 1998) was created and the energy consumption of buildings began to be addressed by code requirements in earnest. Since then there have been seven additional versions of the IECC, each incrementally more stringent with respect to energy efficiency measures.

In Wisconsin, Act 141 (2005) encourages Wisconsin to enact IECC codes within three years of their date of publication, so Wisconsin building codes should continue to progress with respect to energy conservation requirements as well. Three or more years are, however, a relatively long timescale in comparison to the rapidity with which energy efficient technologies are developed and improved upon. The years that pass between the publication of an updated IECC code and its adoption provide an invaluable opportunity for achieving energy savings that might not otherwise have been realized. If building owners could be encouraged to meet updated codes prior to their official state adoption, resultant energy savings could be obtained immediately.

This study aims to investigate the potential benefits of instituting such a program. Changes in building code efficiency requirements can involve a number of building aspects: envelope properties, equipment, lighting, controls, etc. The main objective of this work is to identify which areas of the Wisconsin building code could be enhanced to provide the most cost-effective energy savings to building owners.

METHODOLOGY

The most direct way to estimate energy savings from individual building code changes is to employ building energy simulation. Energy models take a set of detailed inputs (e.g., floor plans, envelope construction, lighting, mechanical information, occupancy schedules) and simulate building performance over a one year period using specified hourly weather files. These simulations can produce a great deal of output information; for the purposes of this study the most useful are total annual electric and gas consumption.

As individual code upgrades are implemented in the models, resulting changes in energy use can be tracked. Combining this information with incremental first cost data results in estimations of energy savings per cost investment for each efficiency measure studied. Because energy efficiency measures interact, their savings are not directly additive; therefore the models are also used to investigate energy savings attributable to conglomerate sets of code upgrades as well.

Whole building energy simulation tools have been available since 1972. The main simulation engines currently in use are TRACE (1972; e.g., Trane, 1992) TRNSYS (1975; e.g., Klein, 1976), DOE-2 (1979; e.g., Winkelmann et al., 1993) and EnergyPlus (2001; e.g., Crawley, 2001). This project utilizes the most up-to-date U.S. Department of Energy building simulation engine, Energy Plus. Building models were developed using the front-end DesignBuilder Version 4 (DesignBuilder Software Ltd, 2005-2015), and exported for further text-editor and command-line processing.

BUILDING SAMPLE SELECTION

According to the Commercial Building Energy Consumption Database (EIA 2003), office, retail, and education spaces together consume nearly 50% of the total energy used by commercial buildings in the U.S. Therefore, to maximize the energy impact of this study, those were the three commercial building types chosen for investigation.

In total, six baseline models were created. Four different building types were simulated: a single family home, a K-12 school, a retail store, and an office. Three sizes of office building were also constructed to investigate code improvements to buildings which use different types of HVAC systems.

MODEL CALIBRATION

Code stretching measures are designed to impact real world energy performance; therefore it is crucial that baseline models accurately reflect the typical energy consumption characteristics of Wisconsin buildings. Two metrics were defined to provide this comparison, one based on overall building energy use and another based on the distribution of energy end uses within the building.

Overall building energy use is measured in terms of energy use intensity (EUI) which is defined as kBtu per square foot. This unit provides a convenient method of comparing energy performance between buildings of different sizes. In Table 2 example EUIs are given for typical Wisconsin buildings. These numbers represent the average energy use for both residential and commercial structures. Values for this table were obtained from the US Department of Energy's Residential Energy Consumption Survey (RECS) and Commercial Building Energy Consumption Survey (CBECS) data (EIA, 2009; EIA 2003).

The second energy performance metric is the distribution of energy end uses. These end uses refer to the amount of energy utilized for a specific function within the building, such as heating, cooling, or lighting. The share of energy used for each end use is expressed as a percentage of the total energy consumed. The values shown in Table 2 represent the typical share of energy for each end use in Wisconsin climate conditions.

Table 2. RECS/CBECS Wisconsin Averages

	RECS	CBECS
EUI (KBTU/FT^2)	39.6	108.1
HEATING	57%	51%
COOLING	1%	3%
VENTILATION	NA	6%
LIGHTING	28%	17%
DHW	16%	6%
MISC	NA	17%

CBECS end use percentages are averaged over all Wisconsin building types (e.g., schools, offices, etc.). CBECS also provides end use distributions for individual building types, however these are drawn from a geographically diverse building sample and therefore do not accurately represent Wisconsin climate conditions.

To estimate target end use distributions specific to both Wisconsin climate and building type, the following procedure was followed. General (all building types and climates) end use distribution was compared to building-type specific (all climates) end use distribution to determine building-type specific correction factors. These correction factors were then applied to the general (all building types) end use distribution of Wisconsin buildings, resulting in target distributions for individual Wisconsin building types.

Calibration of baseline models was then performed by incrementally adjusting unconstrained factors within baseline models (such as exterior lighting power density, miscellaneous plug loads, temperature set points, and schedules) until energy use came into alignment with expected EUI and end use targets. In addition to producing a more realistic overall comparison to actual buildings, the process of model calibration also ensures that individual model elements such as mechanical systems and building envelopes perform as expected. In this sense, model calibration served as both a quality control measure and as validation for real world comparison.

MEASURE SELECTION

Multiple resources were utilized in the process of selecting individual energy efficiency measures to study. Expertise and professional opinions were contributed by engineers. Program experience and market knowledge were offered by Focus on Energy representatives. The code stretch programs of other states were investigated (e.g., Massachusetts, Oregon, California) and use was made of the thought and study that underlies each IECC code upgrade.

These resources were combined to help identify the most cost-effective measures for residential and commercial buildings. Four (4) residential measures and six (6) commercial measures were ultimately identified for study inclusion. These represent all concrete (i.e., not geometry or occupancy dependent) IECC 2012 code updates (Appendix A), and a handful of added measures stemming from successful Focus on Energy incentive programs. Final measures are listed below in Table 3.

Table 3. Investigated Efficiency Measures

	RESIDENTIAL	COMMERCIAL
ENVELOPE	Window, wall and roof upgrades consistent with IECC 2012	Window, wall, and roof upgrades consistent with IECC 2012
	Attic Insulation upgrades	--
	Air sealing consistent with IECC 2012	Air sealing consistent with IECC 2012
LIGHTING	--	LPD 80% of IECC 2009 allowance
	--	Lighting occupancy sensors
MECHANICAL	95% efficient ECM furnace	95% efficient condensing, modulating boiler
EXTERIOR	--	LED parking lights

SAVINGS ESTIMATION

Baseline energy models (i.e., Wisconsin building code compliant) were created and calibrated in DesignBuilder, then exported to EnergyPlus input files. A parametric processing pipeline was developed using Excel, Cygwin, and Python, which ran a separate model for each code upgrade and then compared energy use results to baseline consumption. This pipeline was run for each building type.

COST / BENEFIT ANALYSIS

Operational cost savings for each efficiency measure were estimated using average electric and gas rates (Table 4) obtained for Wisconsin from the U.S. Energy Information Administration (EIA 2015). Additional first cost estimates for each measure were obtained from literature sources and/or local field contacts (please see Appendix C for details). These estimates were then divided by projected measure cost savings to produce simple payback timescales for each scenario.

Table 4. Electric and Gas Rates

	RESIDENTIAL	COMMERCIAL
ELECTRICITY [$/kWh]	$0.1310	$0.1034
NATURAL GAS [$/Therm]	$0.8650	$0.7070

BASELINE BUILDING MODELS

Six baseline models were created in compliance with existing Wisconsin building code. The modeled building types are listed in Table 5 along with some of their general characteristics. Energy consumptions of all simulated buildings fall within 5% of projected energy use. Details on each building model are given in the sections below, and in Appendix B. This set of models provides the basis for later parametric analysis investigating the effects of specific building code upgrades on energy use in Wisconsin buildings.

Table 5. Building Types and Energy Use Parameters

	RESIDENCE	SCHOOL	RETAIL	SMALL OFFICE	MED. OFFICE	LARGE OFFICE
SQUARE FOOTAGE	2,700	73,212	112,500	24,400	73,200	146,400
OPERATING HOURS	Typical Residence	Typical WI School Year	93 hrs/wk	55 hrs/wk	55 hrs/wk	55 hrs/wk
# OCCUPANTS	Single Family	500 students / 56 staff	Variable	261	785	1569
HVAC SYSTEM / PLANT TYPE	Split system – DX, gas furnace	VAV – DX, hot water	CAV – DX, gas	CAV – DX, gas	VAV – DX, hot water	VAV – chilled water, hot water
EXTERIOR LIGHTING [W]	400	12,000	5,000	13,000	55,000	130,000
EUI[1] [KBTU/FT^2]	**37.7**	**155.4**	**216.9**	**195.5**	**223.8**	**249.2**

Notes: 1 – Source EUI for commercial buildings, site EUI for residence.

RESIDENCE

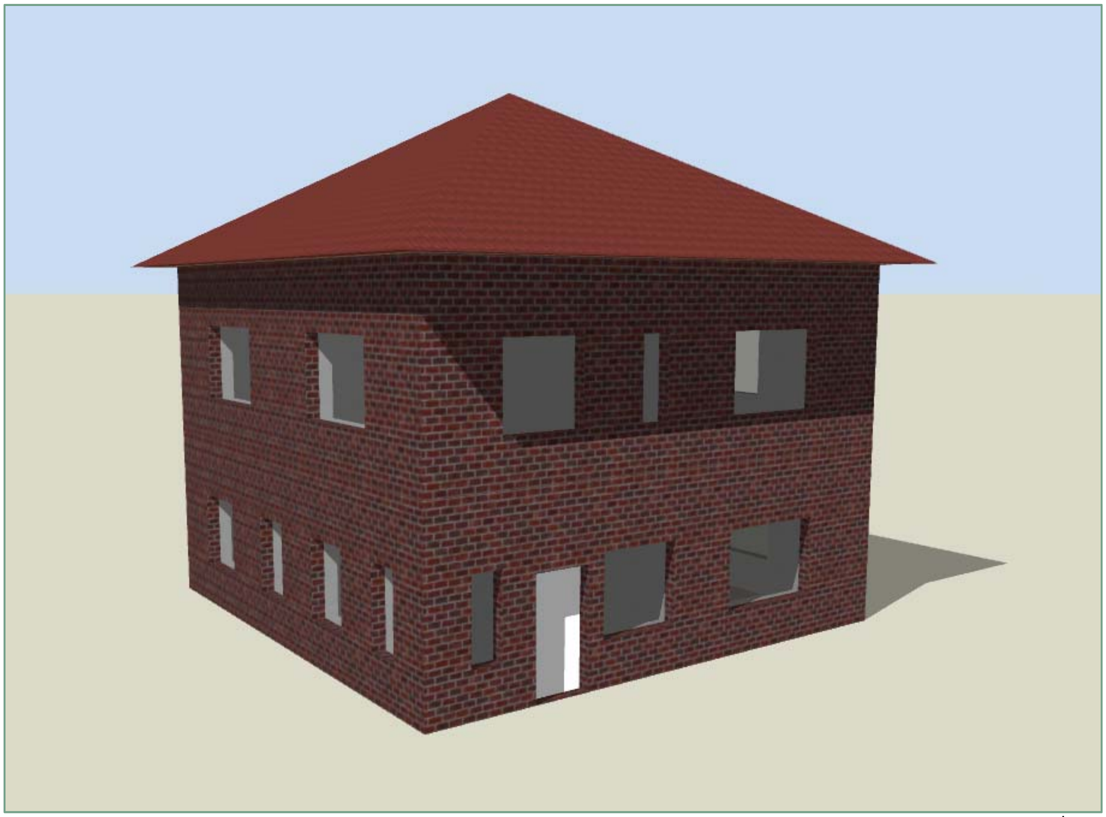

Figure 1. Single Residence Model. Shading represents solar position at 3pm on July 15th.

Physical characteristics of the modeled residence were based on measured data from the 2009 Residential Energy Consumption Survey (RECS) sponsored by the US Energy Information Administration (EIA, 2009). Our Energy Plus model of the home, located in Madison, is shown in Figure 1. The average size of a Wisconsin residence is 2,605 ft2, including basement; our modeled 2-story home is 2,700 ft2.

The first story contains a living room, dining room, kitchen, bathroom, storage, and combined entry/hallway/staircase (Figure 2). The second floor contains a master bedroom, two additional bedrooms, bathroom, and hallway/staircase (Figure 3). The heated basement was modeled as a single zone.

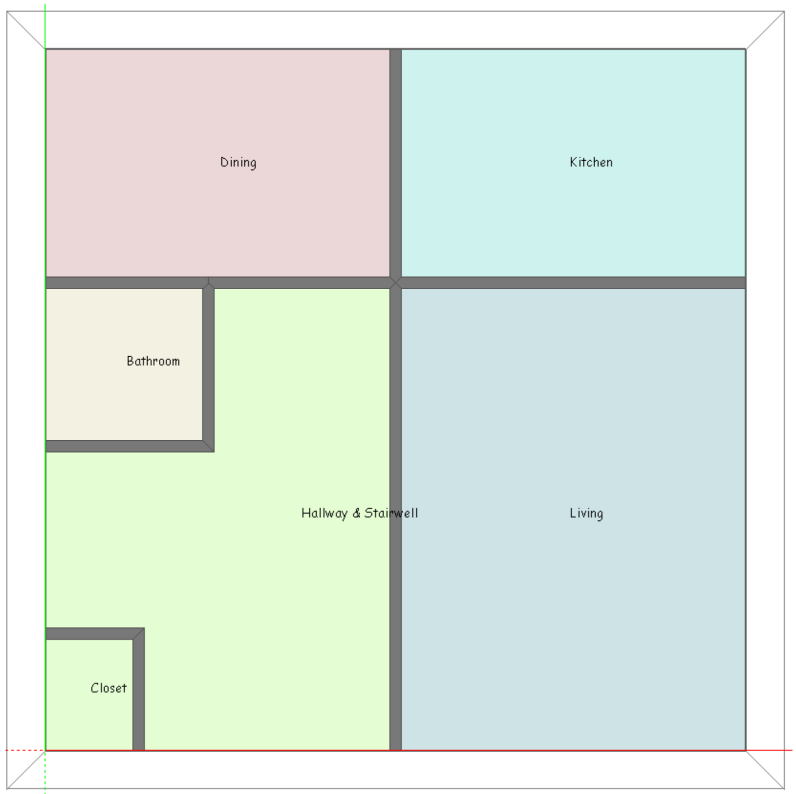

Figure 2. Residence Ground Floor Plan. Different colors represent different space type classifications.

Figure 3. Residence Second Floor Plan

The residential model was constructed in accordance with Wisconsin Residential Codes SPS 322 (Energy) and SPS 323 (HVAC). The HVAC system is a standard warm air gas furnace with split system air conditioning. The occupancy schedule of the house is set to match typical periods of residential use (i.e., weekday mornings/evenings and weekends). Specific modeling details such as U-values and equipment efficiencies are given in Table B-1 (Appendix B).

The model was adjusted to meet typical Wisconsin energy use via the calibration procedure discussed above. According to RECS, the average energy use intensity (EUI) of a Wisconsin home is 39.6 kBtu/ft^2. Our code-minimum model has an EUI of 37.7, within 5% of median energy use. The energy end use distribution closely matches expectations as well, with fan energy included in the heating category. Table 6 lists expected energy use and modeled energy use, Table 7 gives specific electric and gas use along with estimated annual utility costs.

Table 6. Energy Calibration Results for Residence Model

	RECS - WISCONSIN	MODELED
EUI (KBTU/FT^2)	**39.6**	**37.7**
HEATING	**57%**	**52%**
COOLING	**1%**	**3%**
VENTILATION	**NA**	**NA**
LIGHTING	**28%**	**29%**
DHW	**16%**	**16%**
MISC	**NA**	**NA**

Table 7. Modeled Energy Use and Cost for Residence

	RESIDENCE
ELECTRIC [kWh]	13,235
GAS [Therms]	615.5
ANNUAL COST [$]	$2,266

SCHOOL

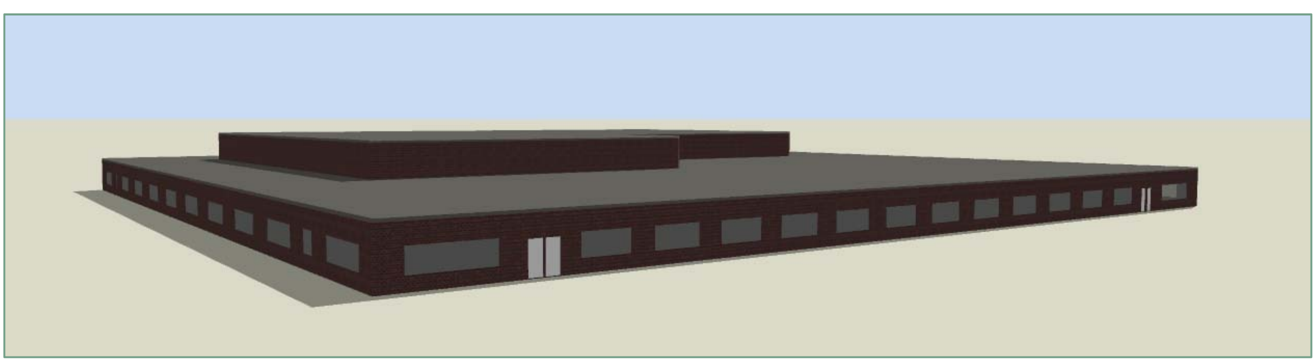

Figure 4. Middle School Model.

The school model was sized based on average Wisconsin middle school enrollments of 450-500 students (U.S. Department of Education, 2000). Using a local estimate of 150-170 ft^2 per student (EUA, 2012) resulted in a ~73,000 ft^2 facility. The Energy Plus model of the school is shown in Figure 4.

Occupancy schedules are based on a typical Wisconsin school year, with no use during summer months. The model was designed to be independent of orientation by creating a square building with classrooms located on all four exterior walls. The school includes the following space types: classrooms, kitchen, administrative areas, bathrooms, 15,000 ft^2 gymnasium, locker room, cafeteria/auditorium, and mechanical room. The school floor plan is shown in Figure 5.

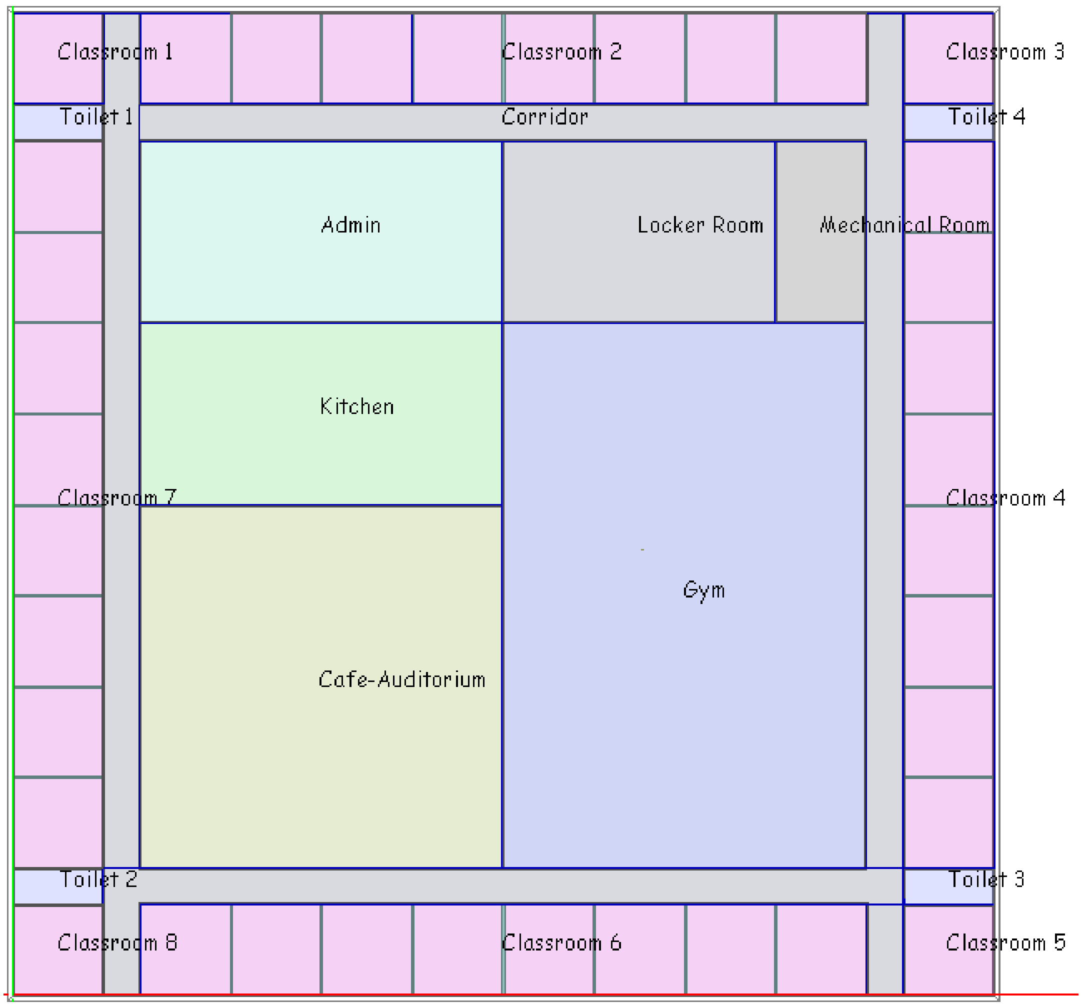

Figure 5. School Floor Plan.

The model is in compliance with Wisconsin Commercial Codes SPS 363 (Energy) and SPS 364 (HVAC). The school is served by a Variable Air Volume (VAV) HVAC system with a Direct Expansion (DX) cooling coil and hot water reheat in individual zones. A Constant Air Volume (CAV) system serves the gymnasium. Specific modeling details such as U-values and equipment efficiencies are given in Table B-1 (Appendix B).

The school model was calibrated to a combination of typical Wisconsin energy use and typical educational energy end use distribution using CBECS data. Compared to the average obtained using combined building types, educational buildings use more heating, cooling, and ventilation and less lighting, hot water, and miscellaneous plug loads. Entering specific model characteristics into the ENERGY STAR Target Finder tool, the resulting median energy use intensity (EUI) of a similar Wisconsin middle school is 155.6 kBtu/ft2. Our code-minimum model has a source EUI of 155.4, within 1% of median energy use. The energy end use distribution is also well matched. Table 8 lists target estimation data, expected energy consumption and modeled energy use, Table 7 gives specific electric and gas use along with estimated annual utility costs.

Table 8. Energy Calibration Results for K-12 School Model

	SCHOOL ADJUSTMENT CALCULATION			TARGET ESTIMATION		MODEL
	ALL U.S. BUILDINGS	U.S. SCHOOLS	SCHOOL ADJUSTMENT	WI AVERAGE	**WI SCHOOL TARGET**	**MODELED SCHOOL**
EUI ($KBTU/FT^2$)	--	--	--	--	**155.6**	**155.4**
HEATING	38%	47%	19%	51%	**61%**	**60%**
COOLING	7%	10%	30%	3%	**4%**	**4%**
VENTILATION	7%	10%	30%	6%	**8%**	**9%**
LIGHTING	20%	14%	(-30%)	17%	**12%**	**12%**
DHW	8%	7%	(-13%)	6%	**5%**	**5%**
MISC	21%	12%	(-43%)	17%	**10%**	**10%**

Table 9. Modeled Energy Use and Cost for School

	SCHOOL
ELECTRIC [kWh]	651,039
GAS [Therms]	41,138
ANNUAL COST [$]	$96,402

Figure 6. Retail Store Model

A local Kohl's store was used as a general guide for the retail model (at West Towne Mall in Madison). Google Earth was used to measure the facility, which resulted in a 112,500 ft^2 model. An Energy Plus rendering of the retail store model is shown in Figure 6.

Occupancy schedules are based on Kohl's opening hours: 9am-10pm Mon-Thurs, 9am-11pm Fri, 8am-11pm Sat, and 9am-9pm Sun (93 hours/week total). The building contains a retail space, stock room, bathrooms, hallway, offices, and employee break room. The simulated retail floor plan is shown in Figure 7.

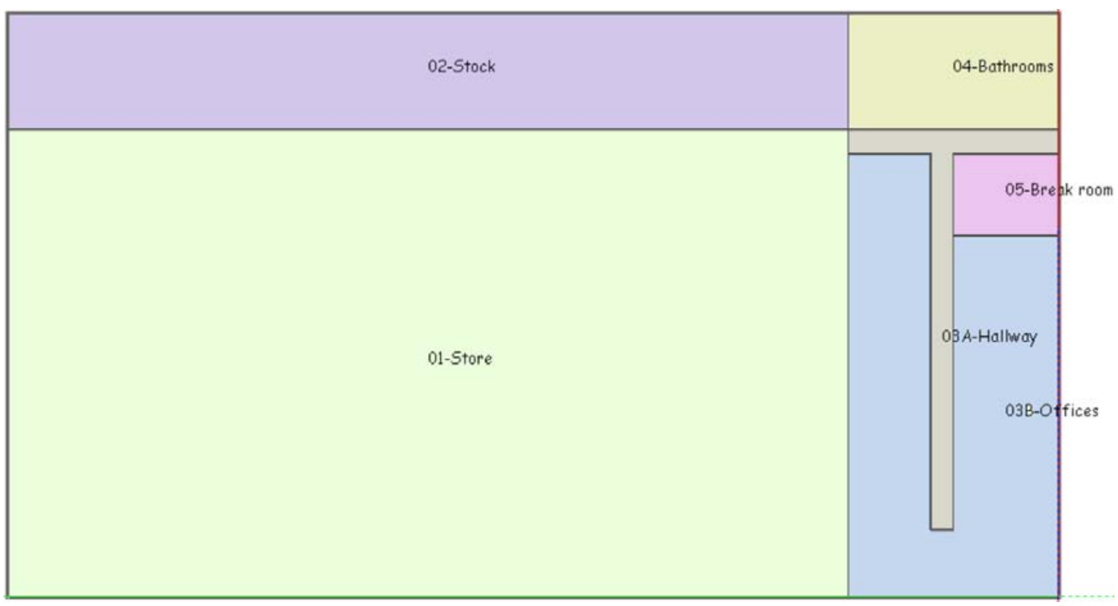

Figure 7. Retail Store Floor Plan

The retail model is in compliance with Wisconsin Commercial Codes SPS 363 (Energy) and SPS 364 (HVAC). The store is served by multiple rooftop CAVs with DX cooling coils and gas heating. Detailed modeling parameters are listed in Table B-1 (Appendix B).

Calibration of the retail model proceeded similarly to previous cases. Retail buildings use comparatively more energy on lighting and cooling, and less energy in the other end use categories, hot water in particular. Using the ENERGY STAR Target Finder tool coupled with model characteristics, the median source energy use intensity (EUI) of a similar Wisconsin retail building is 213.4 kBtu/ft^2. Our model has a source EUI of 216.9, within 2% of median energy use. The target energy end use distribution is also well represented, with the exception that our model uses a CAV system; therefore fan energy is higher and heating energy is lower in the model, as expected. Table 10 lists target energy use and modeled energy use, Table 7 gives specific electric and gas use along with estimated annual utility costs.

Table 10. Energy Calibration Results for Retail Model

	RETAIL ADJUSTMENT CALCULATION			TARGET ADJUSTMENT		MODEL
	ALL U.S. BUILDINGS	U.S. RETAIL	RETAIL ADJUSTMENT	WI AVERAGE	**WI RETAIL TARGET**	**MODELED RETAIL**
EUI (KBTU/FT^2)	--	--	--	--	**213.4**	**216.9**
HEATING	38%	33%	(-13%)	51%	**44%**	**43%**
COOLING	7%	8%	13%	3%	**3%**	**4%**
VENTILATION	7%	5%	(-29%)	6%	**4%**	**14%**
LIGHTING	20%	35%	43%	17%	**24%**	**24%**
DHW	8%	2%	(-75%)	6%	**2%**	**2%**
MISC	21%	17%	(-19%)	17%	**14%**	**14%**

Table 11. Modeled Energy Use and Cost for Retail

	RETAIL
ELECTRIC [kWh]	175,3970
GAS [Therms]	50,124
ANNUAL COST [$]	$216,798

OFFICES

Office models were designed to represent common office layouts and span a range of building sizes. Peak occupancy schedules are based on a traditional 9am-5pm Monday through Friday workweek, with the building open from 7am-6pm on week days and no use on weekends or holidays. The model was designed to be independent of orientation by creating a square building with offices located on all four exterior walls. The office floor plan template includes the following space types: offices, break rooms, copy rooms, bathrooms, conference rooms, storage, data center, and mechanical room. The office floor plan is shown in Figure 8.

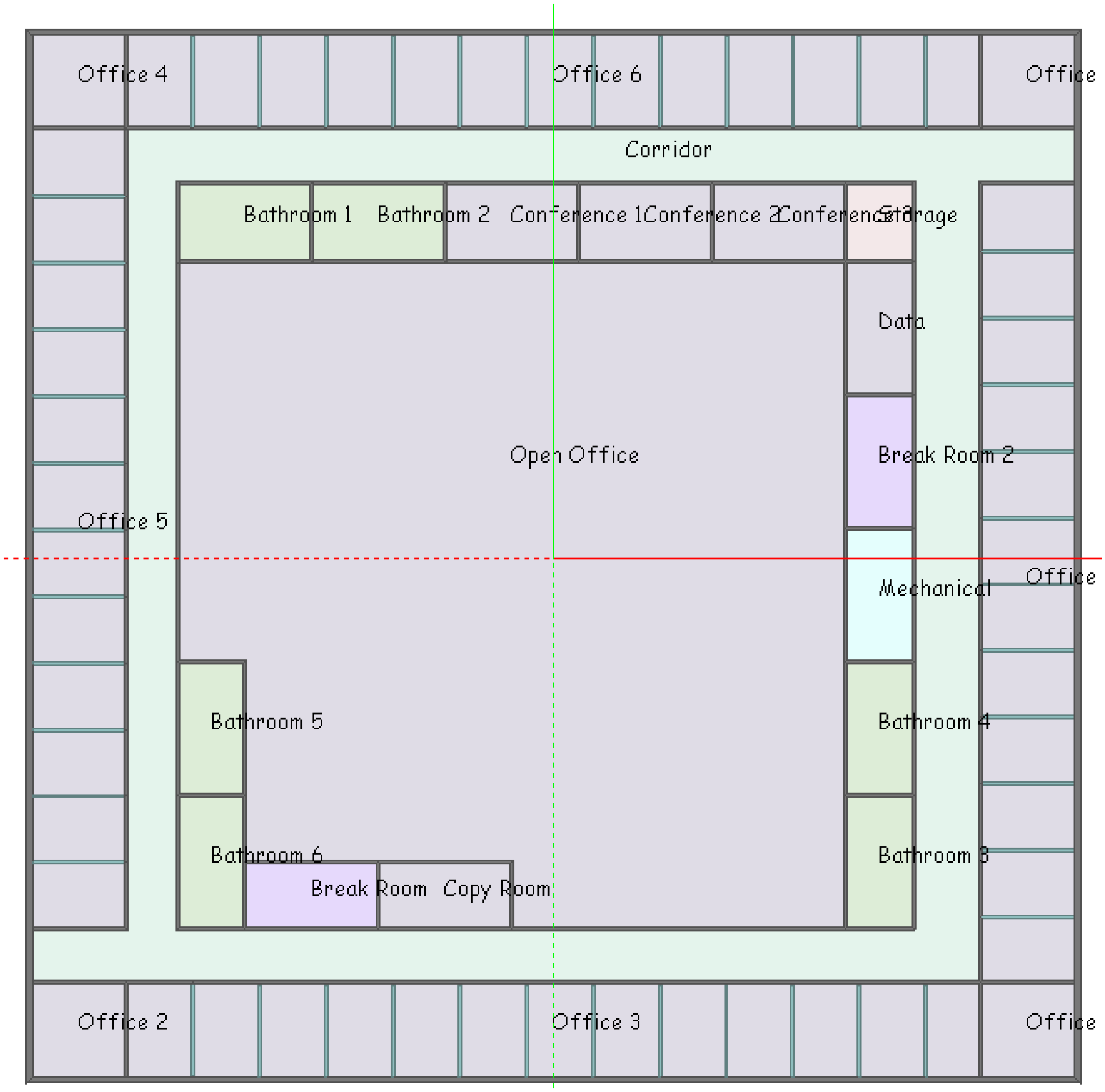

Figure 8. Office Floor Plan

In order to explore the effects of code stretching on buildings served by a broad range of common HVAC system types, we modeled three different sizes of office building. Each falls within a different ASHRAE building size category, and therefore has a different designated HVAC system for baseline modeling. The small building (<25,000 ft^2) uses a CAV system, the medium office (25,000 to 150,000 ft^2) uses a VAV system with hot water reheat, and the large office (approximately 150,000 ft^2) uses a chilled water VAV system with hot water reheat. Individual calibration results for the three simulated office buildings are discussed in the following sections.

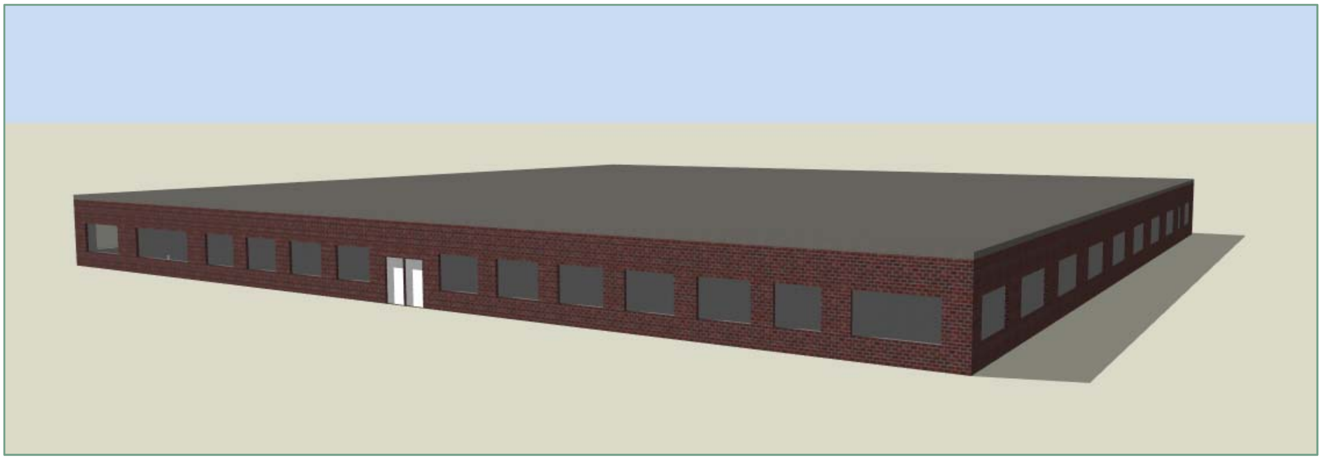

Figure 9. Small Office Model

The Energy Plus model of the 24,400 ft^2 small office is shown in Figure 9. Model parameters are in accordance with Wisconsin Commercial Codes SPS 363 (Energy) and SPS 364 (HVAC). The small office has a CAV system with DX cooling and natural gas heating. Specific modeling details for all three office buildings can be found in Table B-2 (Appendix B).

The code-minimum small office model has a source EUI of 195.5. According to ENERGY STAR Target Finder, the median EUI of a similar Wisconsin office building is 195.8 kBtu/ft^2, within 1% of modeled energy use. The energy end use distribution is also well matched, again with the exception that the CAV system uses more fan energy and less heating energy than averaged system types. Table 12 lists expected energy use and modeled energy use, Table 7 gives specific electric and gas use along with estimated annual utility costs.

Table 12. Energy Calibration Results for Small Office

	OFFICE ADJUSTMENT CALCULATION			TARGET ADJUSTMENT		MODEL
	ALL U.S. BUILDINGS	U.S. OFFICE	OFFICE ADJUSTMENT	WI AVERAGE	**WI OFFICE TARGET**	**MODELED OFFICE**
EUI (KBTU/FT^2)	--	--	--	--	**195.8**	**195.5**
HEATING	38%	35%	(-8%)	51%	**47%**	**46%**
COOLING	7%	10%	30%	3%	**4%**	**4%**
VENTILATION	7%	6%	(-14%)	6%	**5%**	**11%**
LIGHTING	20%	25%	20%	17%	**20%**	**20%**
DHW	8%	2%	(-75%)	6%	**2%**	**2%**
MISC	21%	22%	4.5%	17%	**18%**	**18%**

Table 13. Modeled Energy Use and Cost for Small Office

	SMALL OFFICE
ELECTRIC [kWh]	335,536
GAS [Therms]	10,518
ANNUAL COST [$]	$42,131

MEDIUM OFFICE

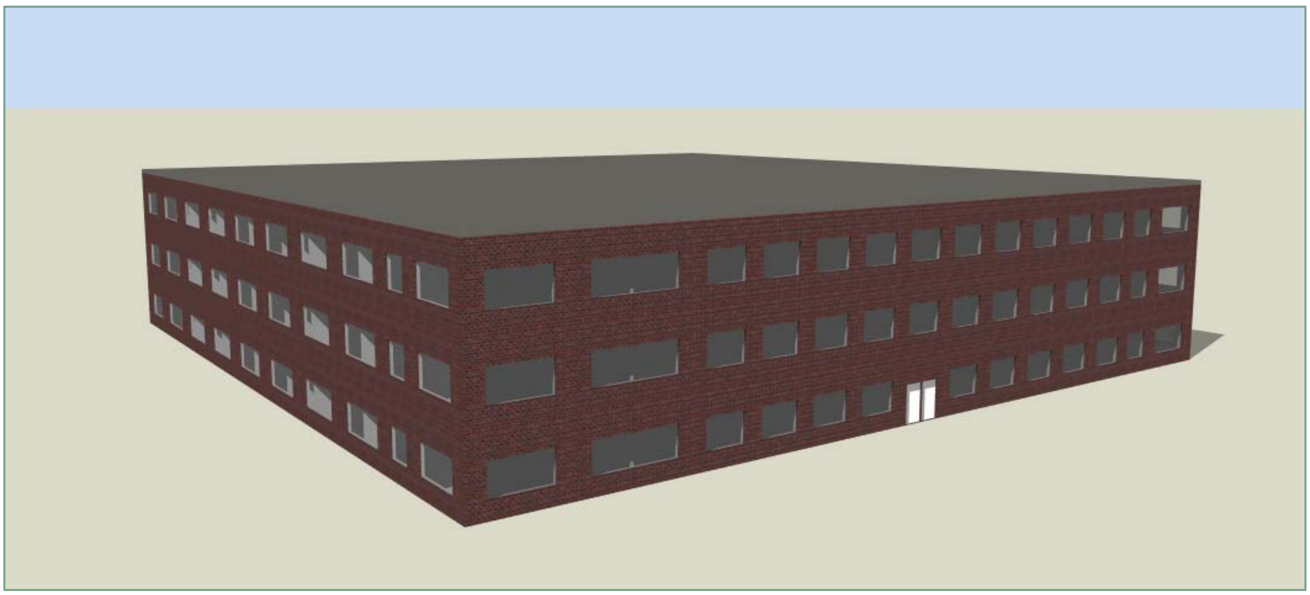

Figure 10. Medium Office Model

Figure 10 shows the 73,200 ft^2 medium office Energy Plus model. Model parameters follow Wisconsin Commercial Codes SPS 363 (Energy) and SPS 364 (HVAC). The medium office is conditioned with a VAV system with DX cooling and hot water reheat in individual zones. Specific modeling details for the medium office are listed in Table B-2 (Appendix B).

The baseline medium office model has a source EUI of 223.8. ENERGY STAR Target Finder gives a median EUI for similar buildings as 228.9 kBtu/ft^2, which falls within 3% of modeled energy use. End use distributions are also well matched. Table 14 lists target and modeled energy use, Table 7 gives specific electric and gas use along with estimated annual utility costs.

Table 14. Energy Calibration Results for Medium Office

	CBECS				TARGET	MODEL
	ALL U.S. BUILDINGS	U.S. OFFICE	% CHANGE	WI AVERAGE		
EUI (KBTU/FT^2)	--	--	--	--	**228.9**	**223.8**
HEATING	38%	35%	(-8%)	51%	**47%**	**50%**
COOLING	7%	10%	30%	3%	**4%**	**6%**
VENTILATION	7%	6%	(-14%)	6%	**5%**	**4%**
LIGHTING	20%	25%	20%	17%	**20%**	**20%**
DHW	8%	2%	(-75%)	6%	**2%**	**2%**
MISC	21%	22%	4.5%	17%	**18%**	**18%**

Table 15. Modeled Energy Use and Cost for Medium Office

	MEDIUM OFFICE
ELECTRIC [kWh]	1,104,159
GAS [Therms]	40,569
ANNUAL COST [$]	$142,852

LARGE OFFICE

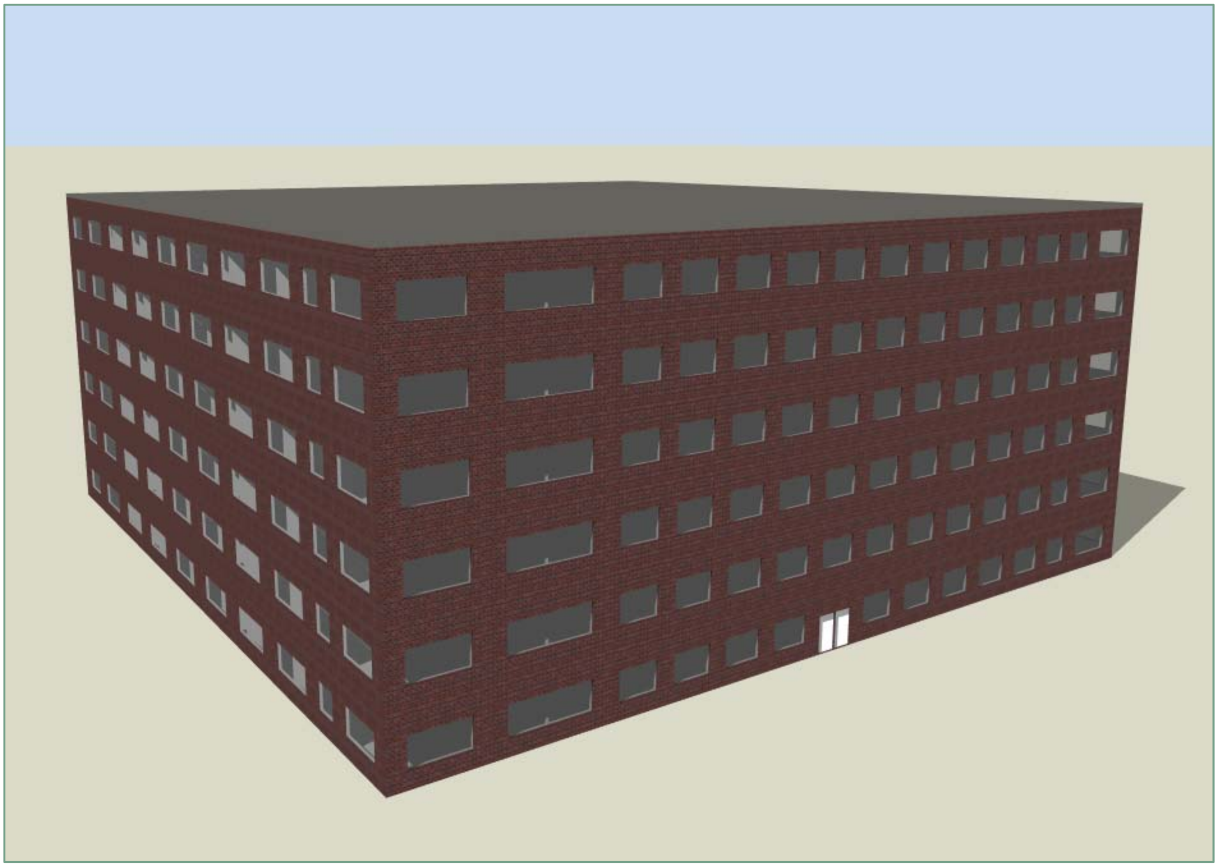

Figure 11. Large Office Model

The Energy Plus model of the 146,400 ft^2 large office is shown in Figure 11. Model parameters are in accordance with Wisconsin Commercial Codes SPS 363 (Energy) and SPS 364 (HVAC). The large office is served by a VAV system with chilled water coils and hot water zone reheat. Large office modeling parameters are given in Table B-2 (Appendix B).

The code-minimum large office model has a source EUI of 249.2. The median EUI of a similar Wisconsin office reported by ENERGY STAR Target Finder is 249.8 kBtu/ft^2, within 1% of modeled energy use. The energy end use distribution is also well matched. Table 16 lists expected energy consumption and modeled energy use, Table 7 gives specific electric and gas use along with estimated annual utility costs..

Table 16. Energy Calibration Results for Large Office

	CBECS				TARGET	MODEL
	ALL U.S. BUILDINGS	U.S. OFFICE	% CHANGE	WI AVERAGE		
EUI (KBTU/FT^2)	--	--	--	--	**249.8**	**249.2**
HEATING	38%	35%	(-8%)	51%	**47%**	**50%**
COOLING	7%	10%	30%	3%	**4%**	**5%**
VENTILATION	7%	6%	(-14%)	6%	**5%**	**5%**
LIGHTING	20%	25%	20%	17%	**20%**	**20%**
DHW	8%	2%	(-75%)	6%	**2%**	**2%**
MISC	21%	22%	4.5%	17%	**18%**	**18%**

Table 17. Modeled Energy Use and Cost for Large Office

	LARGE OFFICE
ELECTRIC [kWh]	2,472,237
GAS [Therms]	89,314
ANNUAL COST [$]	$318,774

CODE UPGRADE ANALYSIS

The portions of the current Wisconsin building code that address energy efficiency are based on the 2009 version of the International Energy Conservation Code (IECC). Since 2009, two updates have been released, IECC 2012 and IECC 2015. The main elements of each code and how they have changed over the last three iterations are listed in Appendix A in Table A-1 (residential) and Table A-2 (commercial).

IECC code changes were combined with commonly incentivized energy efficiency measures to create a pool of potential code upgrades. Measures and combinations selected for further investigation are listed below.

Residential Energy Conservation Measures / Combinations

1) Window, wall, and roof U-values consistent with IECC 2012
2) Attic Insulation R-50
3) Air Sealing consistent with IECC 2012 (3 ACH @ 50 Pa)
4) ECM furnace, 95% efficiency
5) IECC 2012 –Measures 1 and 3
6) Proposed Focus Standard - Measures 1 through 4

Commercial Energy Conservation Measures / Combinations

1) Window, wall, roof value consistent with IECC 2012
2) Air sealing consistent with IECC 2012 (<0.40 cfm/sf @ 75 Pa)
3) Lighting power density (LPD) 0.8 W/ft^2
4) Lighting Occupancy Sensors
5) Condensing, modulating boiler, 95% efficiency
6) LED parking lights
7) IECC 2012 –Measures 1, 2, 3*, and 4
8) Proposed Focus Standard – Measures 1 through 6

*Includes reduced LPD, but at values consistent with IECC 2012 (e.g., 0.9 W/ft^2 for office spaces)

The following sections describe the energy savings attributable to these measures for each of the building types modeled in the study.

RESIDENTIAL

ENVELOPE

Residential envelope upgrades reduce total site EUI by 3.9% over the course of a year. Increased U-values in windows and walls save homeowners approximately $50/year in utility costs. First costs for this measure are marginally higher in Wisconsin than warmer regions, due to IECC 2012 requirements for R-20 cavity insulation plus R-5 continuous insulation in climate zones 6 through 8. Calculated payback timescale is long for this measure, however it represents an upper limit as additional energy savings from infiltration reduction are expected. (Total savings resulting from improved air sealing are evaluated in an independent measure.)

ATTIC INSULATION

Improved attic insulation by itself produces approximately 1% EUI savings, and has a very long payback timescale. In practice this measure is often associated with attic air sealing, which would produce additional savings. For the purposes of this study improved air sealing was treated as an independent code upgrade.

AIR SEALING

Improved air sealing is one of the most cost-efficient measures available to homeowners. It reduces total BTU consumption by 12.7%, and saves almost $140/year in utility costs. Incremental first cost for this measure in new homes is modest, resulting in a short payback time of less than 6 years.

ECM FURNACE

Residential furnaces with electronically commutated motors (ECMs) save energy by reducing fan speed when less heating is required; therefore this measure primarily reduces electricity use. Gas consumption is also lessened due to higher furnace efficiency (95% vs. 90%). This measure is the most cost-effective of any studied here, with a payback of just under 1 year. Annual cost savings resulting from this measure are estimated at approximately $350/year.

IECC 2012 COMPLIANCE

Three residential code updates are included in IECC 2012: 1) window U-value, 2) wall U-value, and 3) improved air sealing. Implementation of all three measures results in approximately $200/year utility savings and a 16.1 year simple payback.

FOCUS RESIDENTIAL STANDARD

The combination of all residential code upgrades investigated in this study constitute a set of priority measures that are being reviewed for inclusion in a possible Focus on Energy Residential

Building Standard. When evaluated together, these measures produce 24.7% EUI savings, ~$500/year utility cost savings for homeowners, and pay themselves back in 10.9 years.

Table 18. Residential Code Upgrade Results

	ENVELOPE	ATTIC R-50	ATTIC R-60	AIR SEALING	ECM FURNACE	IECC 2012	FOCUS STANDARD
SITE EUI SAVINGS [%]	3.9%	0.7%	1.1%	12.7%	9.1%	16.3%	24.7%
ELECTRIC SAVINGS [kWh]	62	11	17	61	2,593	117	2,771
GAS SAVINGS [Therms]	39	7	11	134	8	170	168
ANNUAL COST SAVINGS [$]	$42	$7	$12	$124	$347	$162	$508
INCREMENTAL FIRST COST	$2,619	$1,831	$2,114	$810	$290	$2,619	$5,550
SIMPLE PAYBACK [Years]	62.6	244.3	180.0	6.5	0.8	16.1	10.9

COMMERCIAL

ENVELOPE

Commercial envelope upgrades affect the conductance of roofs, doors, and windows. The impact of these measures on energy use in commercial buildings is reported in Table 19. Envelope EUI savings span a range of 1-3%. As seen in the progression from small to large office buildings, more savings are realized for buildings that have a comparatively higher ratio of surface area to interior space (i.e., 1-story buildings). Simple payback timescales for envelope upgrades range from 14 to 32 years.

Table 19. Commercial Envelope Results

	SCHOOL	RETAIL	SMALL OFFICE	MEDIUM OFFICE	LARGE OFFICE
SITE ENERGY SAVINGS [%]	2.8%	2.2%	2.7%	1.8%	1.0%
ELECTRIC SAVINGS [kWh]	10,904	24,347	5,255	3,476	4,510
GAS SAVINGS [Therms]	1,424	1,625	404	1,261	1,573
ANNUAL COST SAVINGS [$]	$2,134	$3,666	$829	$1,251	$1,578
INCREMENTAL FIRST COST	$32,009	$52,393	$13,556	$28,188	$49,765
SIMPLE PAYBACK [Years]	15.0	14.3	16.4	22.5	31.5

AIR SEALING

Similarly to the residential case, commercial building air sealing is a very cost-effective measure, producing significant electric and gas savings. EUI reductions from this measure range from 9-18% for the building types investigated, with associated payback times of 2.5-7.3 years. Table 20 gives a breakdown of savings by building and fuel type.

Table 20. Commercial Air Sealing Results

	SCHOOL	RETAIL	SMALL OFFICE	MEDIUM OFFICE	LARGE OFFICE
SITE ENERGY SAVINGS [%]	17.9%	16.3%	8.9%	12.9%	13.6%
ELECTRIC SAVINGS [kWh]	79,760	130,315	10,709	22,701	72,335
GAS SAVINGS [Therms]	8,608	13,518	1,582	3,929	21,131
ANNUAL COST SAVINGS [$]	$14,333	$23,032	$2,226	$5,125	$22,419
INCREMENTAL FIRST COST	$37,500	$56,500	$12,500	$37,500	$75,000
SIMPLE PAYBACK [Years]	2.6	2.5	5.6	7.3	3.3

LIGHTING POWER DENSITY

According to the commercial building code, different types of spaces are assigned different lighting power density (LPD) allowances. For example, IECC 2009 specifies an allowance of 1.0 W/ft^2 for office buildings, and an allowance of 1.2 W/ft^2 for educational buildings. Because of these variations, it makes more sense to investigate the effects of reducing the power allowance by a given percentage than it does to specify a single LPD for all buildings to attempt to achieve.

Table 21 lists the energy savings attributable to reducing LPD by 20% from allowed values for each building type. This results in an LPD of 0.8 W/ft^2 for offices, 0.96 W/ft^2 for schools, and 1.76 W/ft^2 for the retail model. Incremental first costs associated with this measure assume an upgrade from T-8 to a combination of T-8 and T-5 lighting, resulting in a modest 10% decrease in overall lumens. Lumens could comfortably be reduced significantly more while still maintaining recommended minimum IES illumination for each building type (Illuminating Engineering Society, 2011) therefore first costs for this measure effectively represent an upper limit. Reducing lumens to minimum recommended IES values would save building owners on both first costs and utility bills, reducing the payback timescale on this measure to zero.

Total EUI savings range from 0.4-1.8%, and are predictably largest for the retail model. Negative gas savings are the result of greater heating requirements, as lower-power bulbs heat the surrounding space slightly less. Upper limits on payback timescales are in the approximate range of 7-13 years, while the lower limit on payback goes to zero.

Table 21. Commercial Lighting Power Density Results

	SCHOOL	RETAIL	SMALL OFFICE	MEDIUM OFFICE	LARGE OFFICE
SITE ENERGY SAVINGS [%]	0.9%	1.8%	1.2%	0.4%	0.6%
ELECTRIC SAVINGS [kWh]	20,693	78,788	9,564	28,406	57,583
GAS SAVINGS [Therms]	-163	-720	-70	-652	-921
ANNUAL COST SAVINGS [$]	$2,024	$7,638	$939	$2,476	$5,303
INCREMENTAL FIRST COST	$25,894	$68,202	$6,458	$19,373	$38,745
SIMPLE PAYBACK [Years]	12.8	8.9	6.9	7.8	7.3

LIGHTING OCCUPANCY SENSORS

The cost of lighting occupancy sensors has decreased in the last few years, rendering them a relatively cost-efficient energy saving measure. IECC 2012 stipulates that certain space types be outfitted with lighting occupancy sensors. These include meeting rooms, restrooms, locker rooms, classrooms, private offices, and storage rooms.

Although occupancy sensors provide modest overall savings (<1% of site EUI) they have a quick payback (<8 years) and are therefore recommended as a code upgrade measure.

Table 22. Commercial Lighting Occupancy Sensor Results

	SCHOOL	RETAIL	SMALL OFFICE	MEDIUM OFFICE	LARGE OFFICE
SITE ENERGY SAVINGS [%]	0.4%	0.3%	0.3%	--	--
ELECTRIC SAVINGS [kWh]	7,398	12,836	3,001	9,395	18,432
GAS SAVINGS [Therms]	21	-134	-48	-317	-567
ANNUAL COST SAVINGS [$]	$780	$1,233	$276	$747	$1,505
INCREMENTAL FIRST COST	$2,178	$335	$1,843	$5,528	$11,057
SIMPLE PAYBACK [Years]	2.8	0.3	6.7	7.4	7.3

CONDENSING MODULATING BOILER

Condensing boilers take advantage of the latent energy in water vapor. For each pound of water vapor forced into a liquid state, 1,000 BTU of latent energy is released. In a condensing boiler, this energy can be returned to the hot water loop, and therefore raise the efficiency of the boiler significantly.

Modulation refers to the ability of a boiler to match firing rate (heat input) to heating demand (output). Conventional boilers have only one firing rate, 100%. Modulating boilers can have turndown ratios of 3:1, 4:1 or even 20:1 (i.e., operate at 5% of maximum capacity). Operation at part-load uses less energy, contributing further to the efficiency of these types of boilers.

This study investigated condensing modulating boilers with efficiencies of 90% and 95%. It is more common to find 95% condensing, modulating boilers in the market, and they have a slightly shorter payback than the 90% option, therefore we focus here on the 95% efficiency results. Three of the six buildings modeled use a hot water loop as part of their HVAC system, and three do not. For that reason this measure is restricted to the school, medium office, and large office.

Overall, condensing modulating boilers reduce site EUI by 10-15%. Savings are greater in Wisconsin than they would be in a warmer climate, since Wisconsin buildings are in heating much of the year. This also explains why savings are highest in the school; most of its operating hours are during heating season. Simple payback on these boilers ranges from 4 to 7 years, making this one of the most promising commercial code upgrades studied.

Table 23. Commercial Boiler Upgrade Results

	SCHOOL	MEDIUM OFFICE	LARGE OFFICE
SITE ENERGY SAVINGS [%]	15.6%	14.8%	11.3%
GAS SAVINGS [Therms]	9,868	11,565	19,640
ANNUAL COST SAVINGS [$]	$6,977	$8,176	$13,885
INCREMENTAL FIRST COST	$37,772	$37,772	$94,430
SIMPLE PAYBACK [Years]	5.4	4.6	6.8

LED PARKING LIGHTS

Using LEDs to illuminate parking lots has become a more common practice in the last few years. The price of LED lighting continues to drop, and because LEDs produce significant energy savings, their payback timescale has become shorter as well.

Table 24 lists the savings attributable to lighting parking lots with LEDs. This analysis assumes a factor of two reduction in total parking lot wattage. Payback timescales are consistent between building types, as expected, at approximately 9 years.

Table 24. Commercial LED Parking Light Results

	SCHOOL	RETAIL	SMALL OFFICE	MEDIUM OFFICE	LARGE OFFICE
SITE ENERGY SAVINGS [%]	1.4%	0.3%	4.4%	5.2%	5.6%
ELECTRIC SAVINGS [kWh]	26,154	10,894	28,334	119,873	283,335
ANNUAL COST SAVINGS [$]	$2,704	$1,126	$2,930	$12,395	$29,297
INCREMENTAL FIRST COST	$24,174	$10,021	$26,048	$110,658	$261,324
SIMPLE PAYBACK [Years]	8.9	8.9	8.9	8.9	8.9

IECC 2012 COMPLIANCE

Of the commercial code updates included in IECC 2012, six are applicable to all building types (i.e., not geometry or occupancy dependent). These include: 1) roof U-value, 2) window U-value, 3) door U-value, 4) reduced LPD, 5) lighting occupancy sensors, and 6) improved air sealing. Costs of reduced LPD for IECC 2012 compliance were estimated by dropping LPD but maintaining lumens. LPD allowance for schools was unchanged in IECC 2012.

Implementation of all six measures results in approximately 12-21% site EUI savings and simple paybacks of approximately 4-10 years. Table 25 lists the results of the IECC 2012 code compliance savings analysis.

Table 25. Commercial IECC 2012 Compliance Results

	SCHOOL	RETAIL	SMALL OFFICE	MEDIUM OFFICE	LARGE OFFICE
SITE ENERGY SAVINGS [%]	21.0%	17.9%	12.6%	15.3%	15.3%
ELECTRIC SAVINGS [kWh]	99,090	129,200	26,277	59,752	147,069
GAS SAVINGS [Therms]	9,907	15,272	1,862	9,971	21,630
ANNUAL COST SAVINGS [$]	$17,250	$24,157	$4,033	$13,228	$30,499
INCREMENTAL FIRST COST	$71,687	$156,140	$38,278	$102,353	$198,095
SIMPLE PAYBACK [Years]	4.2	6.5	9.5	7.7	6.5

FOCUS COMMERCIAL STANDARD

The combination of all commercial code upgrades investigated in this study constitute a set of priority measures that are being reviewed for inclusion in a possible Focus on Energy Commercial Building Standard. When evaluated together, these measures produce 18-35% EUI savings, significant annual utility cost savings for building owners, and pay themselves back in 5-9 years.

Table 26. Focus Commercial Standard Results

	SCHOOL	RETAIL	SMALL OFFICE	MEDIUM OFFICE	LARGE OFFICE
SITE ENERGY SAVINGS [%]	35%	21.5%	17.9%	33.9%	31.7%
ELECTRIC SAVINGS [kWh]	180,347	271,346	62,168	203,383	480,456
GAS SAVINGS [Therms]	16,025	14,390	1,801	19,598	38,733
ANNUAL COST SAVINGS [$]	$29,978	$38,231	$7,701	$34,886	$77,063
INCREMENTAL FIRST COST	$159,527	$187,451	$60,404	$295,677	$530,320
SIMPLE PAYBACK [Years]	5.3	4.9	7.8	8.5	6.9

SUMMARY

A database of building energy models was created to represent Wisconsin building stock in form, function, and energy usage. Six baseline models were created: a single family home, a K-12 school, a retail store, and three sizes of office building. These models were tailored to conform to current Wisconsin building code, and were calibrated to CBECS (EIA 2003) and RECS (EIA 2009) expected energy consumption in energy use intensity (EUI) and distribution (i.e., end use).

One important caveat to mention is that the CBECS database which was used as a resource for commercial energy model calibration was compiled from a sample of existing buildings in 2003. Because buildings constructed to IECC 2009 should be more efficient than that sample, commercial energy savings estimates for this project are expected to run slightly high.

International Energy Conservation Code (IECC) versions released since the last Wisconsin building code update were investigated. Four (4) residential measures and six (6) commercial measures were selected for study inclusion. These represent all concrete (i.e., not geometry or occupancy dependent) IECC 2012 code updates (Appendix A), and a handful of added measures stemming from successful Focus on Energy incentive programs.

Individual and combined code upgrades were implemented in the models, and resulting changes in energy use were tracked. Incremental first costs were estimated for each measure and used to evaluate the cost effectiveness of the investigated measures, resulting in projected simple payback timescales. IECC 2012 compliance was evaluated along with a proposed Focus Standard set of upgrades. Site EUI savings percentages and payback timescale are given in Table 27 for each of these packages.

Table 27. Code Upgrade Summary Results

	IECC 2012		FOCUS STANDARD	
	EUI SAVINGS [%]	SIMPLE PAYBACK [Years]	EUI SAVINGS [%]	SIMPLE PAYBACK [Years]
RESIDENTIAL	16.3%	16.1	24.7%	10.9
COMMERCIAL [AVERAGE]	16.4%	6.9	28.0%	6.7

Though cost estimates can vary significantly due to frequent market changes, our results suggest that both IECC 2012 and Focus Standard code upgrades provide cost-effective compliance options for building owners in the state of Wisconsin.

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APPENDIX A – IECC CODE CHANGES

Table A-1. Residential Energy Code

RESIDENTIAL ENERGY CODE			
BUILDING PARAMETER	**IECC 2009 (CURRENT WI CODE)**	**IECC 2012 (MN 2015 CODE)**	**IECC 2015**
FENESTRATION	U-0.35	U-0.32	--
ATTIC FLOOR	U-0.026, R-49	--	--
FRAME WALL	U-0.057 (e.g., R-20 cavity)	U-0.048 (e.g., R-20 cavity, R-5 continuous)	U-0.045
FLOOR	U-0.033	--	--
BASEMENT WALL	U-0.050	--	--
AIR BARRIERS / INFILTRATION LEVELS	7 ACH @ 50 Pa (~0.4 ACH)	3 ACH @ 50 Pa (~0.2 ACH)	--
AC SPLIT SYSTEM EFFICIENCY	13 EER, COP = 3.81	--	--
NATURAL GAS FURNACE EFFICIENCY	90% AFUE	--	--
DOMESTIC HOT WATER BOILER EFFICIENCY	80%	--	--

Table A-2. Commercial Energy Code

COMMERCIAL ENERGY CODE			
BUILDING PARAMETER	IECC 2009 (CURRENT WI CODE)	IECC 2012 (MN 2015 CODE)	IECC 2015
ROOF	U=0.048, R-20 ci	U=0.032, R-30ci	--
WALL	U=0.064, R-13 + R-7.5ci	--	--
BELOW GRADE WALL	C=0.119, R-7.5ci	--	--
FLOOR	U=0.033, R-30	--	--
SLAB-ON-GRADE	F=0.540, R-10 for 24”	--	--
FENESTRATION	<40% by area U-0.55, SHGC 0.4	<30% by area U-0.36 (same SHGC)	SHGC South 0.40 SHGC North 0.53
DOORS	U-0.80, SHGC 0.4	U-0.77 (same SHGC)	--
AIR BARRIER / INFILTRATION	--	<0.40 cfm/sf @ 75 Pa	--
DX AC (240 kBTUH to 760 kBTUH)	9.8 EER (2.87 COP)	--	--
WATER COOLED AC (>240 kBTUH)	11.5 EER (3.37 COP)	>760 kBTU/h - 12.0 EER (3.52 COP)	--
WARM AIR FURNACES	80% Efficiency	>2,500 kBTU/h - 82%	--
WATER COOLED CHILLER <300 tons	COP 5.55	--	<150 tons, COP 5.76
DEMAND CONTROLLED VENTILATION (DCV)	>500 sf, 40 people/1,000 sf, OSA>1,200 cfm, supply>1,200 cfm	>500 sf, 25 people/1,000 sf, OSA>1,200 cfm, supply>1,200 cfm	--
ENERGY RECOVERY VENTILATION (ERV)	>5,000 cfm, >70% OSA	>1,000 cfm 70-80% OSA to >5,500 cfm 30-40% OSA	>1,000 cfm 70-80% OSA to >26,000 cfm 10-20% OSA
VAV REQUIREMENTS	>10 hp, turndown to 30%	>7.5 hp, turndown to 30%	Multizone systems, turndown to 30%
BOILER MODULATION	1 boiler >500 kBTUH	--	for >1,000 kBTUH total system
HOT WATER	80% Efficiency	--	80% or if > 1,000 kBTUH, 90%
LIGHTING OCCUPANCY SENSORS	--	Specific space types plus any spaces <300 sf	--
LIGHTING POWER DENSITY (LPD, W/ft^2)	1.0 (office)	0.9 (office)	0.82 (office)
AUTOMATIC DAYLIGHTING CONTROLS	--	OPTIONAL: When primary sidelighted area > 250 sf, 100%, 70%, 35% (not retail)	For window area > 24 sf and VT > 0.20, continuous dimming for some spaces

APPENDIX B – BASELINE BUILDING PARAMETERS

Table B-1. Residential, School, and Retail Model Parameters

		RESIDENCE		K-12 SCHOOL		RETAIL	
CATEGORY	PARAMETER	SUB-PARAMETER	MODELED	SUB-PARAMETER	MODELED	SUB-PARAMETER	MODELED
General	Climate Zone	6A-Dane County	-	6A-Dane County	-	6A-Dane County	-
General	Weather File	Madison TMY3	-	Madison TMY3	-	Madison TMY3	-
General	Design Conditions	1% Values for Madison: Winter: -4.9°F; Summer: Dry Bulb 87.1°F, Wet Bulb 72.1°F	from ASHRAE Fundamentals 2005, as required by SPS 322.40	Winter: -15°F; Summer: Dry Bulb 87°F, Wet Bulb 75°F	per SPS 363	Winter: -15°F; Summer: Dry Bulb 87°F, Wet Bulb 75°F	per SPS 363
General	Area	2,700 ft²	Two above ground floors, heated basement	73,212 ft²	One Floor, plus tall ceilings in gym and cafeteria	112,500 ft²	One Floor. Large open retail area, stock rooms, offices.
Insulation	Roof	For All Insulation, reference SPS 322.32	Attic Floor U-Factor, U=0.026	Insulation entirely above deck	U=0.048	Insulation entirely above deck	U=0.048
Insulation	Wall	Wood Frame Wall	U=0.06	Metal Frame	U=0.064	Metal Frame	U=0.064
Insulation	Wall	Basement and Crawl Space U-Factor	U = 0.065	Below Grade	C=0.119	Below Grade	C=0.119
Insulation	Floor	Floor U-Factor	U = 0.033	Joist/Framing	U=0.033	Joist/Framing	U=0.033
Insulation	Slab-on-Grade Floors	Unheated	F=0.540	Unheated	F=0.540	Unheated	F=0.540
Fenestration	Window to Wall Percentage	No maximum in SPS 322	20%	40% Maximum	30%	40% Maximum	30%, plus Two larger storefront windows.
Fenestration	U-factor	Fenestration U-Factor	U=0.35	Metal Framing, All other U-Factor	U=0.55	Metal Framing, All other U-Factor	U=0.55
Fenestration	Solar Heat Gain Coefficient	No Requirement in SPS 322	Set SHGC=0.4	SHGC=0.4	-	SHGC=0.4	-

		RESIDENCE		K-12 SCHOOL		RETAIL	
CATEGORY	PARAMETER	SUB-PARAMETER	MODELED	SUB-PARAMETER	MODELED	SUB-PARAMETER	MODELED
Fenestration	Projection Factor	-	PF is zero, no overhang	Per Code, PF must be less than 0.25	PF is zero, no overhang	Per Code, PF must be less than 0.25	PF is zero, no overhang
Fenestration	Door	Fenestration U-Factor	U=0.35	Entrance Door U-Factor	U=0.80	Entrance Door U-Factor	U=0.80
Infiltration	Air Changes per Hour	Maximum 0.5 ACH	0.4 ACH	Maximum 0.5 ACH	0.5 ACH	Maximum 0.5 ACH	0.5 ACH
HVAC System	System type	-	Warm Air Furnace with Split System Air Conditioning	-	ASHRAE 90.1-2007 Appendix G - System 5 - Packaged VAV with hot water reheat, System 3 - CAV for Gym	-	ASHRAE 90.1-2007 Appendix G - System 3 - PSZ-A, One system per zone
HVAC System	System Parameters	N/A	-	Packaged rooftop VAV with hot water reheat	One system per building. Appendix G allows model to group floors with identical Thermal Blocks.	-	Packaged Rooftop Air Conditioner
HVAC System	Air Conditioner	Split System	13 EER, COP = 3.81	Air Cooled, Table 503.2.3(1)	10 EER, COP = 2.92	Air Cooled	10 EER, COP = 2.92
HVAC System	Fan Control	-	Constant Volume	-	VAV	-	CAV
HVAC System	Cooling Type	-	DX	-	DX	-	DX
HVAC System	Heat Rejection	-	N/A	-	N/A	-	N/A
HVAC System	Heating Type	Warm Air Furnace, Natural Gas	Thermal Efficiency: 90%	2 hot-water fossil fuel boilers, Gas Fired	Thermal Efficiency: 80%	Fossil Fuel Furnace	80% efficient
HVAC System	Multistage Boiler	Not required	-	Multistage or Modulating boiler required for systems > 500,000 Btu/h	Yes, modulation required	N/A	-

		RESIDENCE		K-12 SCHOOL		RETAIL	
CATEGORY	**PARAMETER**	**SUB-PARAMETER**	**MODELED**	**SUB-PARAMETER**	**MODELED**	**SUB-PARAMETER**	**MODELED**
HVAC System	Setpoint Overlap Restriction	None	-	Provide 5°F Deadband	-	Provide 5°F Deadband	-
HVAC System	Minimum Temperature Setpoint	70 F	-	Heating season- setback 55°F, Cooling season - setback 85°F	Setbacks above minimum	Heating season- setback 55°F, Cooling season - setback 85°F	Setbacks above minimum
VAV Fan Control	Required?	N/A	-	VSD required when Fan Power > 10 HP	-	N/A	-
Water Loop Control	Reset Required?	N/A	-	Yes. Required for hydronic systems with load greater than 300,000 Btu/h.	Using OA reset from 180 to 150 F water, based on OA varying from 20 F to 50 F	N/A	-
Heat Rejection Fan Control	Control required?	N/A	-	Yes. Fan Speed Control required for all fans > 7.5 hp	-	N/A	-
VAV Turndown Ratio	Required?	N/A	-	Yes. Required for AHUs serving more than one zone.	Set to 30%, per IECC 503.4.4	N/A	-
Supply Air Reset	Required?	N/A	-	N/A	-	N/A	-
Ventilation	Source	SPS 323.04 - No mechanical ventilation required for zones with operable windows	-	SPS 364, Table 364.0403, Education Occupant Density	-	SPS 364, Table 364.0403, Retail Occupant Density	-

		RESIDENCE		K-12 SCHOOL		RETAIL	
CATEGORY	PARAMETER	SUB-PARAMETER	MODELED	SUB-PARAMETER	MODELED	SUB-PARAMETER	MODELED
Ventilation	Space Type 1	No Ventilation Modelled, all ventilation delivered as infiltration	-	Classrooms: 50 people per 1000 ft². Assume same for Admin Areas	.05 people/ft²	Retail: 8 people per 1000 ft²	.008 people/ft²
Ventilation	Space Type 2	Toilet: per SPS 323, 20 CFM continuous exhaust in bathrooms	-	Auditorium: 150 people per 1000 ft²	.15 people/ft²	Office Spaces: 7 people per 1000 ft²	.007 people/ft²
Ventilation	Space Type 3	N/A	-	Gym aka "Playing Floor": 30 people per 1000 ft²	.03 people/ft²	Stockroom (Warehouse): Not Required	-
Ventilation	Space Type 4	N/A	-	Kitchen: 20 people per 1000 ft²	.02 people/ft²	Other, not listed spaces: Used DB default	-
Ventilation	Space Type 5	N/A	-	Locker Room: 0.5 CFM/ft² area exhaust	-	Toilet: 75 CFM/ft²/Toilet Fixture. Assume 6 TF per bathroom	-
Ventilation	Space Type 6	N/A	-	Mechanical Room: 2 CFM/ft² area exhaust	-	-	-
Ventilation	Space Type 7	N/A	-	Toilet: 75 CFM/ft²/Toilet Fixture. Assume 6 TF per bathroom	450 CFM exhaust per bathroom	N/A	-
Ventilation	Space Type 8	N/A	-	Other, not listed spaces	Used DB defaults	N/A	-
Ventilation	Per Person CFM	N/A	-	7.5 CFM/person, default rate from SPS 364.0403.5.a	-	7.5 CFM/person, default rate from SPS 364.0403.5.a	-

		RESIDENCE		K-12 SCHOOL		RETAIL	
CATEGORY	PARAMETER	SUB-PARAMETER	MODELED	SUB-PARAMETER	MODELED	SUB-PARAMETER	MODELED
Economizer	Enabled?	N/A	-	Required for all systems with Cooling Load > 30,000 Btu/h	Chose high limit shutoff of 70°F DB per Appendix G	Required for all systems with Cooling Load > 30,000 Btu/h	Chose high limit shutoff of 70°F DB per Appendix G
Energy Recovery Ventilation	Enabled?	N/A	-	Required for systems w/ >5000 CFM supply and 70% of supply is OA	Not Required	Required for systems w/ >5000 CFM supply and 70% of supply is OA	Not Required
Fan Power Allowed	Level	-	DOE prescribed pressure rise: 0.5 inches H_2O	Calculated in spreadsheet per ASHRAE 90.1-2007	DB default Pressure rise: 2.4 inches H_2O (within allowance)	Calculated in spreadsheet per ASHRAE 90.1-2007	DB default Pressure rise: 2.4 inches H_2O (within allowance)
Service Water Heating	Spaces	Available to all spaces	-	Available to all spaces	-	Available to all spaces	-
Service Water Heating	Level	Gas Storage Water Heater	80% Efficient	Gas Storage Water Heater	80% Efficient	Gas Storage Water Heater	80% Efficient
Service Water Heating	Pump	N/A	-	Circulating Pump can turn off (504.6), selected "intermittent" pump control	-	Circulating Pump can turn off (504.6), selected "intermittent" pump control	-
Interior Lighting	Control	N/A	-	Automatic Shutoff required, either scheduled or occupancy sensor	Scheduled On during operating hours, Off otherwise	Automatic Shutoff required, either scheduled or occupancy sensor	Scheduled On during operating hours, Off otherwise
Interior Lighting	Power Density	-	07 W/sq ft	School, 1.2 W/ft²	1.2 W/ft²	Retail: 1.5 W/ft² plus Additional Allowance of 1.4 W/ft² for Retail Area 3 (Clothing, Cosmetics, etc.)	2.2 W/ft²

		RESIDENCE		K-12 SCHOOL		RETAIL	
CATEGORY	**PARAMETER**	**SUB-PARAMETER**	**MODELED**	**SUB-PARAMETER**	**MODELED**	**SUB-PARAMETER**	**MODELED**
Exterior Lighting	Control	On at Night, Off Dawn to Dusk	-	Exterior Lighting - only operate dawn to dusk	-	Exterior Lighting - only operate dawn to dusk	-
Exterior Lighting	Power Density	-	400 W	Minimum 750 W for Zone 3	12,000 W	Minimum 750 W for Zone 3	5,000 W
Internal Equipment Gains	Power Density	-	0.4 W/ sq ft	-	1.5 W/ft^2	-	1.0 W/ft^2

Table B-2. Small, Medium, and Large Office Model Parameters

		SMALL OFFICE		MEDIUM OFFICE		LARGE OFFICE	
CATEGORY	**PARAMETER**	**SUB-PARAMETER**	**MODELED**	**SUB-PARAMETER**	**MODELED**	**SUB-PARAMETER**	**MODELED**
General	Climate Zone	6A-Dane County	-	6A-Dane County	-	6A-Dane County	-
General	Weather File	Madison TMY3	-	Madison TMY3	-	Madison TMY3	-
General	Design Conditions	Dane County: Winter: -15°F; Summer: Dry Bulb 87°F, Wet Bulb 75°F	per SPS 363	Dane County: Winter: -15°F; Summer: Dry Bulb 87°F, Wet Bulb 75°F	per SPS 363	Dane County: Winter: -15°F; Summer: Dry Bulb 87°F, Wet Bulb 75°F	per SPS 363
General	Area	24,400 ft^2	Single story	73,200 ft^2	Three stories	146,374 ft^2	Six stories
Insulation	Roof	Insulation entirely above deck	U=0.048	Insulation entirely above deck	U=0.048	Insulation entirely above deck	U=0.048
Insulation	Wall	Metal Frame	U=0.064	Metal Frame	U=0.064	Metal Frame	U=0.064
Insulation	Wall	Below Grade	C=0.119	Below Grade	C=0.119	Below Grade	C=0.119
Insulation	Floor	Joist/Framing	U=0.033	Joist/Framing	U=0.033	Joist/Framing	U=0.033
Insulation	Slab-on-Grade Floors	Unheated	F=0.540	Unheated	F=0.540	Unheated	F=0.540
Fenestration	Window to Wall Percentage	40% Maximum	30%	40% Maximum	30%	40% Maximum	30%
Fenestration	U-factor	Metal Framing, All other U-Factor	U=0.55	Metal Framing, All other U-Factor	U=0.55	Metal Framing, All other U-Factor	U=0.55
Fenestration	Solar Heat Gain Coefficient	SHGC=0.4	-	SHGC=0.4	-	SHGC=0.4	-
Fenestration	Projection Factor	PF<0.25	PF is zero, no overhang	PF<0.25	PF is zero, no overhang	PF<0.25	PF is zero, no overhang
Fenestration	Door	Entrance Door U-Factor	U=0.80	Entrance Door U-Factor	U=0.80	Entrance Door U-Factor	U=0.80
Infiltration	Air Changes per Hour	Maximum 0.5 ACH	0.5 ACH	Maximum 0.5 ACH	0.5 ACH	Maximum 0.5 ACH	0.5 ACH
HVAC System	System type	ASHRAE 90.1-2007 Appendix G - System 3 - PSZ-AC	-	ASHRAE 90.1-2007 Appendix G - System 5 - Packaged VAV with Reheat	-	ASHRAE 90.1-2007 Appendix G - System 7 - VAV with Reheat	-

		SMALL OFFICE		MEDIUM OFFICE		LARGE OFFICE	
CATEGORY	**PARAMETER**	**SUB-PARAMETER**	**MODELED**	**SUB-PARAMETER**	**MODELED**	**SUB-PARAMETER**	**MODELED**
HVAC System	System Parameters	Packaged Rooftop Air Conditioner	-	Packaged rooftop VAV with hot water reheat	One system per building. Appendix G allows you to group floors with identical Thermal Blocks.	VAV with hot water reheat	One system per building. Appendix G allows you to group floors with identical Thermal Blocks.
HVAC System	Air Conditioner	Air Cooled	10 EER, COP = 2.93	Air Cooled, Table 503.2.3(1)	10 EER, COP = 2.93	N/A	-
HVAC System	Fan Control	Constant Volume	-	VAV	-	VAV	-
HVAC System	Cooling Type	Direct Expansion	-	Direct Expansion	-	Chilled Water, two chillers	Load: 137 tons. Minimum COP for Full Load is 5.5
HVAC System	Heat Rejection	N/A	-	N/A	-	Cooling Tower, two speed axial fan	-
HVAC System	Heating Type	Fossil Fuel Furnace, 80% efficient	Calculated Total Load: 670,000 Btu/hr	Two hot-water fossil fuel boilers, Gas Fired	Thermal Efficiency: 80%	Two hot-water fossil fuel boilers, Gas Fired	Thermal Efficiency: 80%
HVAC System	Multistage Boiler	N/A	-	Multistage or Modulating boiler required for systems > 500,000 Btu/h	Yes, modulation required	Multistage or Modulating boiler required for systems > 500,000 Btu/h	Yes, modulation required
HVAC System	Setpoint Overlap Restriction	Provide 5°F Deadband	-	Provide 5°F Deadband	-	Provide 5°F Deadband	-
HVAC System	Minimum Temperature Setpoint	Heating season-Setback 55°F, Cooling season - setback 85°F	-	Heating season-setback 55°F, Cooling season - setback 85°F	-	Heating season-setback 55°F, Cooling season - setback 85°F	-
VAV Fan Control	Required?	N/A	-	Yes, VSD required when Fans Power > 10 HP	-	Yes, VSD required when Fans Power > 10 HP	-

		SMALL OFFICE		MEDIUM OFFICE		LARGE OFFICE	
CATEGORY	**PARAMETER**	**SUB-PARAMETER**	**MODELED**	**SUB-PARAMETER**	**MODELED**	**SUB-PARAMETER**	**MODELED**
Water Loop Control	Reset Required?	N/A	-	Yes. Required for hydronic systems with load greater than 300,000 Btu/h.	Using OA reset from 180 to 150 F water, based on OA varying from 20 F to 50 F	Yes. Required for hydronic systems with load greater than 300,000 Btu/h. Both hot water and chilled water loop.	Hot Water: Reset from 180 to 150 F water, based on OA varying from 20 F to 50 F. Chilled Water: Reset water from 54 to 44 °F as OA varies from 60 to 80 °F
Heat Rejection Fan Control	Control required?	N/A	-	N/A	-	Required for heat rejection fans > 7.5 hp, operate at 2/3 of full speed or less	In DB, part load operation is modeled as an interpolation between fan on and off over a period of time
VAV Turndown Ratio	Required?	N/A	-	Yes. Required for AHUs serving more than one zone.	Set to 30%, per IECC 503.4.4	Yes. Required for AHUs serving more than one zone.	Set to 30%, per IECC 503.4.4
Supply Air Reset	Required?	N/A	-	Yes, must reset to 25% of difference between design room and supply temperature	Reset: as outdoor air varies from 32 to 60 °F, SA varies from 60 to 55 °F	Yes, must reset to 25% of difference between design room and supply temperature	Reset: as outdoor air varies from 32 to 60 °F, SA varies from 60 to 55 °F
Ventilation	Source	SPS 364, Table 364.0403, Office Occupant Density	-	SPS 364, Table 364.0403, Office Occupant Density	-	SPS 364, Table 364.0403, Office Occupant Density	-
Ventilation	Space Type 1	Conference Rooms: 50 people per 1000 ft²	.05 people/ft². Assume same for Break Room	Conference Rooms: 50 people per 1000 ft²	.05 people/ft². Assume same for Break Room	Conference Rooms: 50 people per 1000 ft²	.05 people/ft². Assume same for Break Room
Ventilation	Space Type 2	Office Spaces: 7 people per 1000 ft²	.007 people/ft²	Office Spaces: 7 people per 1000 ft²	.007 people/ft²	Office Spaces: 7 people per 1000 ft²	.007 people/ft²

		SMALL OFFICE		MEDIUM OFFICE		LARGE OFFICE	
CATEGORY	PARAMETER	SUB-PARAMETER	MODELED	SUB-PARAMETER	MODELED	SUB-PARAMETER	MODELED
Ventilation	Space Type 3	Reception Areas: 60 people per 1000 ft^2	.06 people/ft^2	Reception Areas: 60 people per 1000 ft^2	.06 people/ft^2	Reception Areas: 60 people per 1000 ft^2	.06 people/ft^2
Ventilation	Space Type 4	Telecommunication centers and data entry: 60 people per 1000 ft^2	.06 people/ft^2	Telecommunication centers and data entry: 60 people per 1000 ft^2	.06 people/ft^2	Telecommunication centers and data entry: 60 people per 1000 ft^2	.06 people/ft^2
Ventilation	Space Type 5	Other, not listed spaces	Used DB defaults	Other, not listed spaces	Used DB defaults	Other, not listed spaces	Used DB defaults
Ventilation	Space Type 6	SPS 364: Bathroom: 75 CFM/ft^2/Toilet Fixture. Assume 6 TF per bathroom	450 CFM exhaust per bathroom	SPS 364: Bathroom: 75 CFM/ft^2/Toilet Fixture. Assume 6 TF per bathroom	450 CFM exhaust per bathroom	SPS 364: Bathroom: 75 CFM/ft^2/Toilet Fixture. Assume 6 TF per bathroom	450 CFM exhaust per bathroom
Ventilation	Space Type 7	N/A	-	N/A	-	N/A	-
Ventilation	Space Type 8	N/A	-	N/A	-	N/A	-
Ventilation	Per Person CFM	7.5 CFM/person, default rate from SPS 364.0403.5.a	-	7.5 CFM/person, default rate from SPS 364.0403.5.a	-	7.5 CFM/person, default rate from SPS 364.0403.5.a	-
Economizer	Enabled?	Required for all systems with Cooling Load > 30,000 Btu/h	Chose high limit shutoff of 70°F DB per Appendix G	Required for all systems with Cooling Load > 30,000 Btu/h	Chose high limit shutoff of 70°F DB per Appendix G	Required for all systems with Cooling Load > 30,000 Btu/h	Chose high limit shutoff of 70°F DB per Appendix G
Energy Recovery Ventilation	Enabled?	Required for systems w/ <5000 CFM supply and 70% of supply is OA	Not Required	Required for systems w/ <5000 CFM supply and 70% of supply is OA	Not Required	Required for systems w/ <5000 CFM supply and 70% of supply is OA	Not Required
Fan Power Allowed	Level	Calculated in spreadsheet per ASHRAE 90.1-2007	Pressure rise: 1 inch H_2O (within allowed range)	Calculated in spreadsheet per ASHRAE 90.1-2007	Used DB default Pressure rise: 2.4 inches H_2O (within allowed range)	Calculated in spreadsheet per ASHRAE 90.1-2007	Used DB default Pressure rise: 2.4 inches H_2O (within allowed range)
Service Water Heating	Spaces	Available to all spaces	-	Available to all spaces	-	Available to all spaces	-
Service Water Heating	Level	Gas Storage Water Heater	80% Efficient	Gas Storage Water Heater	80% Efficient	Gas Storage Water Heater	80% Efficient

		SMALL OFFICE		MEDIUM OFFICE		LARGE OFFICE	
CATEGORY	**PARAMETER**	**SUB-PARAMETER**	**MODELED**	**SUB-PARAMETER**	**MODELED**	**SUB-PARAMETER**	**MODELED**
Service Water Heating	Pump	Circulating Pump can turn off (504.6), selected "intermittent" pump control	-	Circulating Pump can turn off (504.6), selected "intermittent" pump control	-	Circulating Pump can turn off (504.6), selected "intermittent" pump control	-
Interior Lighting	Control	Automatic Shutoff required, either scheduled or occupancy sensor	Scheduled On during operating hours, Off otherwise	Automatic Shutoff required, either scheduled or occupancy sensor	Scheduled On during operating hours, Off otherwise	Automatic Shutoff required, either scheduled or occupancy sensor	Scheduled On during operating hours, Off otherwise
Interior Lighting	Power Density	-	For Office, this is 1.0 W/ft²	-	For Office, this is 1.0 W/ft²	-	For Office, this is 1.0 W/ft²
Exterior Lighting	Control	Exterior Lighting - only operate dawn to dusk, use photosensor	-	Exterior Lighting - only operate dawn to dusk, use photosensor	-	Exterior Lighting - only operate dawn to dusk, use photosensor	-
Exterior Lighting	Power Density	-	13,000 W	Minimum 750 W for Zone 3	55,000 W	Minimum 750 W for Zone 3	130,000 W
Internal Equipment Gains	Power Density	-	1.3 W/ft²	-	1.5 W/ft²	-	1.7 W/ft²

APPENDIX C – INCREMENTAL FIRST COSTS

RESIDENTIAL

ENVELOPE

Table C- 1. Residential Envelope Costs

Parameter	Baseline	Proposed	Unit Cost over Baseline	Source
Fenestration	IECC 2006 (CURRENT WI RES CODE) U-0.35	IECC 2012 (MN 2015 CODE) U-0.32	$0.18/ft²$	Mendon et al. 2012
Frame Wall	IECC 2006 (CURRENT WI RES CODE) U-0.057 (e.g., R-20 cavity)	IECC 2012 (MN 2015 CODE) U-0.048 (e.g., R-20 cavity, R-5 continuous)	$0.79/ft²$	Mendon et al. 2012

ATTIC INSULATION

Table C- 2. Residential Attic Insulation Costs

Parameter	Baseline	Proposed	Unit Cost over Baseline	Source
Attic Floor R-50	IECC 2006 (CURRENT WI RES CODE) U-0.026 (R-38)	U-0.02 (R-50)	$1,831	RSMeans Online Proposed: R-38 + R-13 = R-51 (assume stacked blankets)
Attic Floor R-60	IECC 2006 (CURRENT WI RES CODE) U-0.026 (R-38)	U-0.017 (R-60)	$2,114	RSMeans Online Proposed: R-38 + R-19 = R-57 (assume stacked blankets)

AIR SEALING

Table C- 3. Residential Air Sealing Costs

Parameter	Baseline	Proposed	Unit Cost over Baseline	Source
Air Sealing	IECC 2006 (CURRENT WI RES CODE) 7 ACH @ 50 Pa (~0.4 ACH)	IECC 2012 (MN 2015 CODE) 3 ACH @ 50 Pa (~0.2 ACH)	$0.25/ft² for envelope sealing $135/dwelling unit for envelope testing during construction	Envelope Sealing: U.S. EPA 2011. Envelope Testing: Mendon et al

ECM FURNACE

Table C- 4. Residential Furnace Costs

Parameter	Baseline	Proposed	Unit Cost over Baseline	Source
ECM Furnace	90% AFUE, Single Stage Compressor, Constant Volume Fan	95% Efficient, Modulating Burner, Multistage Compressor, ECM Fan	$290	SupplyHouse.com Baseline: Goodman 80,000 BTU 92% Efficiency, Multi-Speed Blower Proposed: Goodman 90,000 BTU 95% Efficiency, Two Stage Burner, Multi-Speed Blower

COMMERCIAL

ENVELOPE

Table C- 5. Commercial Envelope Costs

Parameter	Baseline	Proposed	Unit Cost over Baseline	Source
Roof	IECC 2009 (CURRENT WI COMM CODE) U=0.048 (R-20 ci)	IECC 2012 (MN 2015 CODE) U=0.032 (R-31ci)	\$0.28/ft² (roof area)	RSMeans Online Item: Polyiso R-7.5/in Baseline: 3 in required for R-20 Proposed: 4 in required for R-30
Fenestration	IECC 2009 (CURRENT WI COMM CODE) U=0.55, SHGC=0.4	IECC 2012 (MN 2015 CODE) U-0.36 (same SHGC)	\$3.40/ft² (window area)	RSMeans Online Item: Aluminum Window, Picture Unit Baseline: Standard Glass (average price) Proposed: Insulated Glass (average price)

AIR SEALING

Table C- 6. Commercial Air Sealing Costs

Parameter	Baseline	Proposed	Unit Cost over Baseline	Source
Air Sealing	0.5 ACH (Calibrated to CBECS)	IECC 2012 (MN 2015 CODE) <0.4 cfm/ft² @ 75 Pa	\$0.50/ft² (floor area)	Thornton et al. 2013

LIGHTING POWER DENSITY

Table C- 7. Commercial Lighting Costs

Parameter	Baseline	Proposed	Unit Cost Over Baseline	Source
Lighting Power Density	IECC 2009 (CURRENT WI COMM CODE) Code Maximum Lighting Allowance Office: 1.0 W/ft² School: 1.2 W/ft² Retail: 2.2 W/ft² T8 Fixtures	80% of Code Maximum Lighting* Allow 10% footcandle reduction Mixture of T5 and T8 fixtures *for IECC 2012, proposed lighting is 90% of maximum	T8 (baseline) $0/fixture T5 $43/fixture LED $54/fixture	**T8 Fixture** 32 W/lamp (48 in length) 89 lum/W (RPI page) Ballast Factor: 0.88 (Benya) Pricing: Bees Lighting Product: Lithonia 2x4 2AV Fluorescent T8 Volumetric Troffer **T5 Fixtures** 28 W/lamp (48 in length) 95 lum/W (Benya) Ballast Factor: 0.95 (Benya) Pricing: Bees Lighting and private communication Product: Lithonia 2x4 2AV Fluorescent T5 Volumetric Troffer **LED Fixtures** 110 lum/W (Lithonia) 39 W/fixture (Lithonia) Pricing: Bees Lighting and PKK private communication Product: Lithonia VT Series Volumetric LED Troffer 2VTL 40L

LIGHTING OCCUPANCY SENSORS

Table C- 8. Lighting Occupancy Sensor Costs

Parameter	Baseline	Proposed	Unit Cost over Baseline	Source
Lighting Occupancy Sensors	None	IECC 2012 requires occ sensors in some spaces	$167.53 each	Proposed: RSMeans Item: Occupancy sensors, passive infrared ceiling mounted

CONDENSING MODULATING BOILER

Table C- 9. Commercial Boiler Costs

Parameter	Baseline	Proposed	Unit Cost over Baseline	Source
Condensing Boiler, 90% Efficient	IECC 2009 (CURRENT WI COMM CODE) 80% Thermal Efficiency # of Boilers: Medium Office: 2 Large Office: 5 School: 2	90% Thermal Efficiency Boiler Two models: FBN1500 and FBN3500 # of Boilers: Medium Office: 2xFBN1500 Large Office: 2xFBN3500 School: 2xFBN1500	Total premium Medium Office: $35,284 Large Office: $72,412 School: $35,284	ETNA Supply Baseline: LOCHINVAR CBN2066 COPPER-FIN BOILER - NAT 2065000 BTU/HR INPUT / 1672650 BTU/H Proposed: LOCHINVAR FBN1500 CREST BOILER, 60-1500 MBH INPUT (92% efficient) LOCHINVAR FBN3500 CREST BOILER, 200-3500 MBH INPUT (92% efficient)
Condensing Boiler, 95% Efficient	Same as 90% Option	95% Thermal Efficiency Boiler # of Boilers: Medium Office: 2 Large Office: 5 School: 2	Total premium Medium Office: $37,772 Large Office: $94,430 School: $37,772	ETNA Supply Baseline: same as above Proposed: LOCHINVAR SBN1500 SYNC BOILER 150-1500 MBH INPUT (96% efficient)

LED PARKING LIGHTS

Table C- 10. Parking Lot Lighting Costs

Parameter	Baseline	Proposed	Unit Cost Over Baseline	Source
Exterior Lighting Power	Metal Halide Fixtures Wattage calibrated to CBECS	Replace each Metal Halide Fixture with LED Fixture Achieve 50% wattage savings	$158/fixture	**Metal Halide Fixture** 47 lum/W (Benya) 400 W/fixture Pricing: Western Extralite and PKK private communication Product: Lumark WPP40 **LED Fixture** 81 lum/W (Benya) 79 W/fixture Pricing: Western Extralite and PKK private communication Product: Lumark XTOR9A

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