CADMUS

Focus on Energy

2021 Rooftop Solar Potential Study Report

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Prepared for:

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Acknowledgments

Cadmus would like to thank project stakeholders and National Renewable Energy Laboratory staff for their active engagement throughout the study (project stakeholders include renewable energy advocates, rooftop solar installers, local government representatives, Focus on Energy staff, and others). The input and guidance provided by these project stakeholders contributed significantly to the success of this study.

Cadmus leveraged the National Renewable Energy Laboratory's Distributed Generation Market Demand Model to estimate the technical potential and simulated market adoption potential of rooftop solar PV for this study. NREL staff provided valuable assistance to Cadmus throughout the project, supporting us to run the model and helping us to troubleshoot technical issues.

Acronyms

ATB: *Annual Technology Baseline*

dGen: Distributed Generation Market Demand

GWh: Gigawatt hours

ITC: Investment Tax Credit

kWh: Kilowatt-hour

mTRC: Modified Total Resource Cost test

MW: Megawatt

MWh: Megawatt-hour

NREL: National Renewable Energy Laboratory

PSC: Public Service Commission of Wisconsin

SEA: *Final Strategic Energy Assessment*

Executive Summary

The Public Service Commission of Wisconsin (PSC) contracted with Cadmus to complete a rooftop solar photovoltaic (PV) potential assessment, timed to provide information to the PSC and stakeholders in planning for the 2023–2026 quadrennium of Focus on Energy. Cadmus produced estimates of the statewide rooftop solar PV potential over a 12-year period, from 2023 through 2034. This study is a companion to the 2021 *Energy Efficiency Potential Study*, which was published in September 2021.[1]

Study Objectives and Approach

There were four primary objectives for this potential study:

- Inform program planning by assessing rooftop solar PV potential under business-as-usual conditions, as well as four economic scenarios. While the potential study does not provide a target for program planning, the research was timed to provide input on quadrennial planning for Focus on Energy programs.
- Conduct research about barriers to and opportunities for delivering programs to promote rooftop solar PV adoption in the income-qualified population segment, and estimate the rooftop solar PV potential for income-qualified customers.
- Compare the cost-effectiveness of rooftop solar PV to energy efficiency measures.
- Engage and consult with project stakeholders throughout the study.

Through the study, Cadmus produced energy efficiency estimates for the residential and commercial sectors, as well as for the income-qualified population segment of the residential sector[2].

	RESIDENTIAL (STANDARD AND INCOME QUALIFIED)	Single-family and manufactured homes for standard and income-qualified population segments
	COMMERCIAL	Commercial offices, retail stores, healthcare facilities (hospitals and outpatient centers), lodging, schools, restaurants, warehouses, and multifamily buildings.

Cadmus produced two types of potential estimates using the National Renewable Energy Laboratory's (NREL) Distributed Generation Market Demand (dGen) model.[3] This study was designed to assess

1 Cadmus. September 10, 2021. *2021 Focus on Energy Energy Efficiency Potential Study Report.* Prepared for Public Service Commission of Wisconsin. https://focusonenergy.com/sites/default/files/inline-files/2021%20Focus%20on%20Energy%20Energy%20Efficiency%20Potential%20Study%20Report.pdf

2 Cadmus considered multifamily buildings as part of commercial sector, given that typically the building owner, not individual tenants, makes the decision to invest in rooftop solar projects.

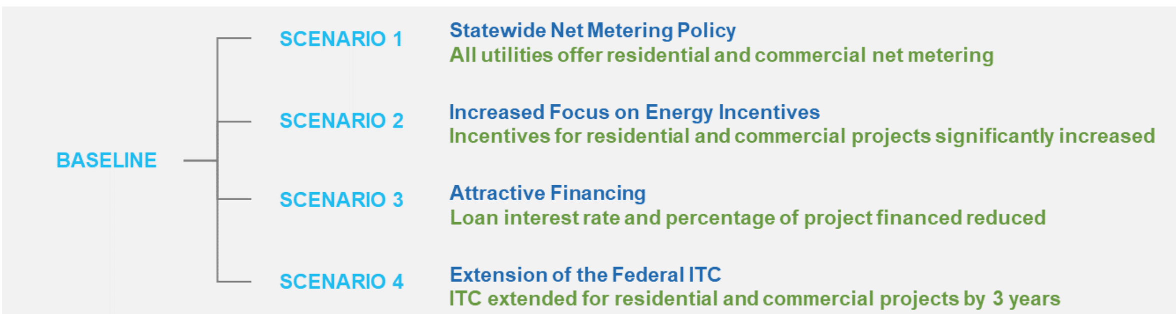
3 National Renewable Energy Laboratory (Benjamin Sigrin, Michael Gleason, Robert Preus, Ian Baring-Gould, and Robert Margolis). February 2016. "The Distributed Generation Market Demand Model (dGen): Documentation."

rooftop solar potential; estimates of ground-mounted solar resources fall outside of the scope of this work.

TECHNICAL POTENTIAL represents the theoretical maximum rooftop solar PV that can be achieved in terms of capacity (nameplate) and production, accounting for available rooftop square footage including shading, solar PV panel production per square foot, and solar irradiation.

SIMULATED MARKET ADOPTION POTENTIAL represents the amount of rooftop solar PV capacity and electric production that is projected to be developed given an assumed set of economic parameters that affect the financial attractiveness from a customer perspective.

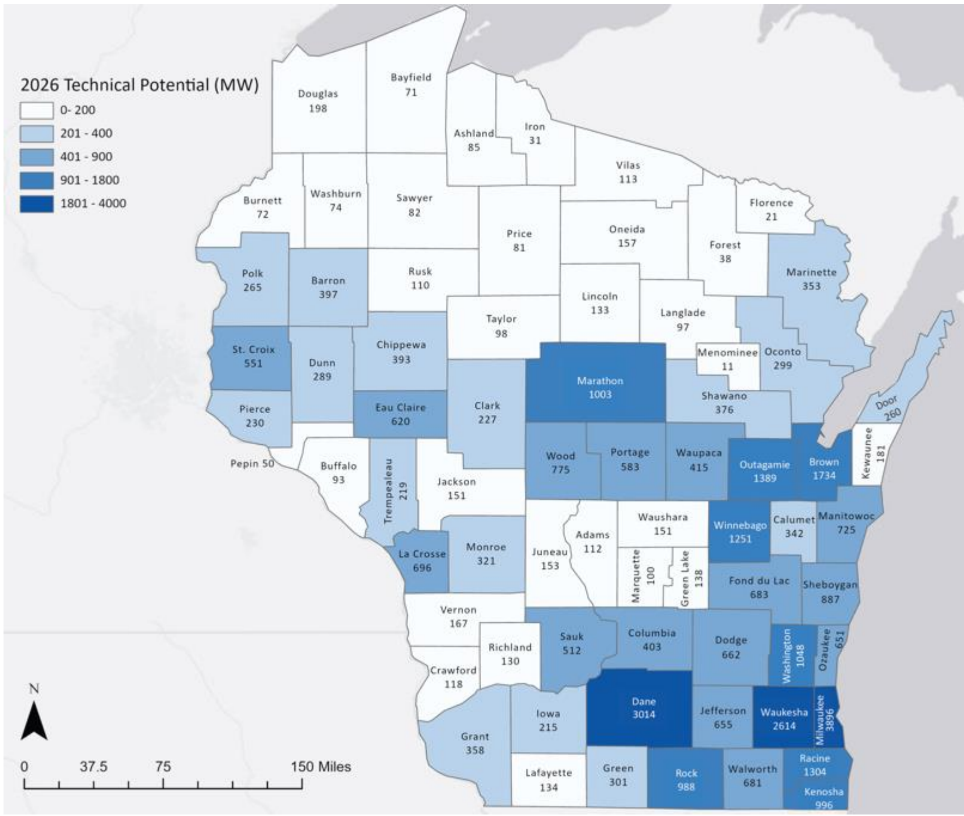
Cadmus conducted sensitivity analyses to determine the impacts of four economic scenarios on market adoption: changes to utility net metering policies, increases in Focus on Energy incentives, more attractive project financing, and a three-year extension of the federal Investment Tax Credit (ITC).



Rooftop Solar Potential Study Results

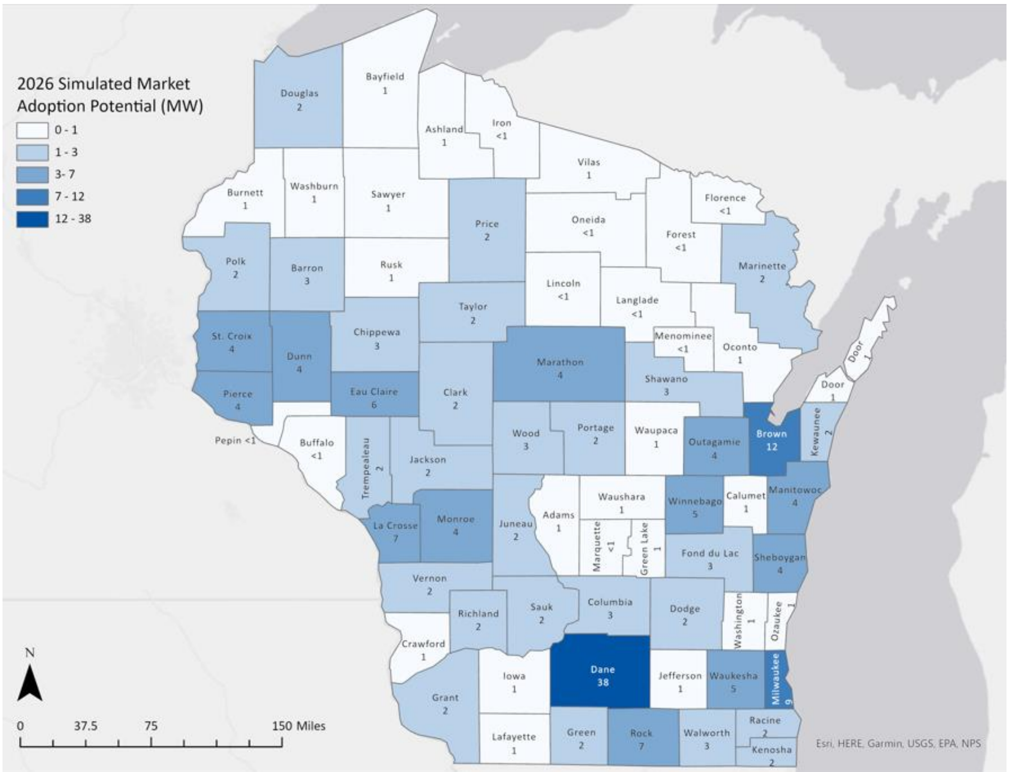
Cadmus estimated technical and simulated market adoption potential for Wisconsin by county. Below is a map of the county-level estimates of technical potential in 2026. Cadmus found nearly 37 GW of technically feasible rooftop solar PV nameplate capacity in 2026. Milwaukee is the largest contributing county, making up 11% of the total technical potential.

Statewide County-Level Rooftop Solar PV Technical Potential – 2026 (MW)



Cadmus found 207 MW of nameplate capacity simulated market adoption potential for rooftop solar PV in 2026. The map below shows that Dane County has the greatest simulated market adoption potential, contributing to 19% of the 2026 Wisconsin simulated market adoption potential.

Statewide County-Level Rooftop Solar PV Simulated Market Adoption Potential – 2026 (MW)



By the twelfth year of the study, Cadmus found almost 39 GW of technically available nameplate capacity in Wisconsin. Of the technically available capacity in 2034, 1.6% is simulated to be adopted given an assumed set of economic parameters. Because the study focuses on rooftop solar installations, technical potential is highest in areas with the most homes and businesses, which are correlated with more population-dense areas.

Statewide Rooftop Solar PV Potential Estimates

POTENTIAL TYPE	2026 MW	2026 MWh	2034 MW	2034 MWh
TECHNICAL POTENTIAL	36,734	44,182,839	38,898	46,784,762
SIMULATED MARKET ADOPTION POTENTIAL	207	250,397	623	751,160

The residential sector contributes the greatest amount of nameplate capacity to the simulated market adoption potential. In 2034,[4] the residential standard-income customer sector makes up nearly 50% of the total simulated market adoption potential capacity, followed by the commercial sector (29%) and the residential income-qualified sector (23%). This differs from the technical potential distribution, in

4 The technical potential increases from 2026 to 2034 due to load growth projections and efficiency improvements of solar systems.

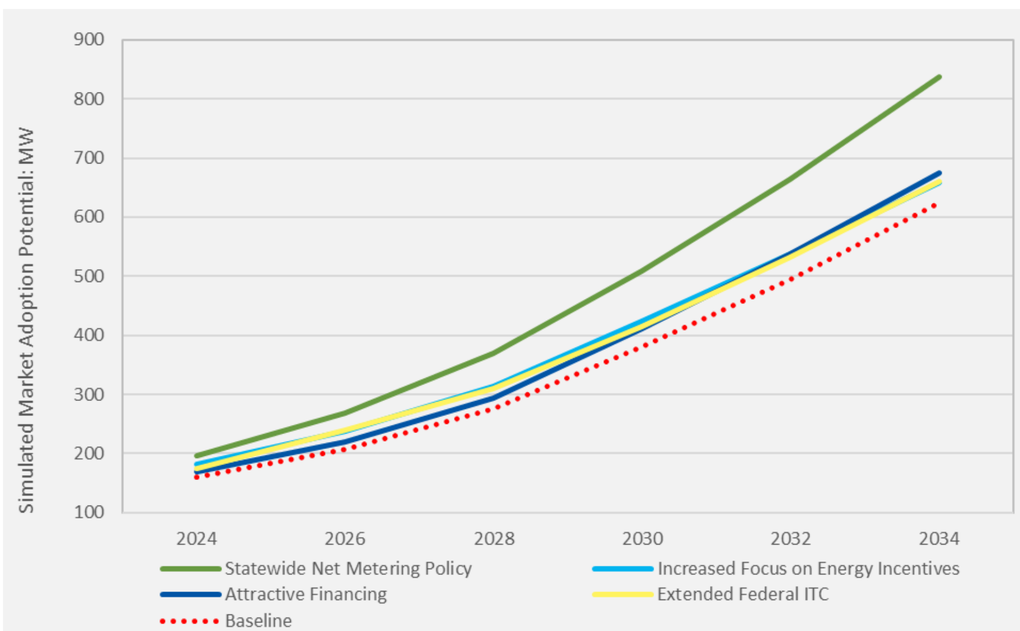
which the residential standard-income customer capacity makes up 42% of the technical potential, followed by the commercial sector (37%) and the residential income-qualified sector (22%).

Sector Rooftop Solar PV Simulated Market Adoption Potential Estimates

POTENTIAL TYPE	2026 MW	2026 MWh	2034 MW	2034 MWh
STANDARD INCOME	90	108,567	304	365,617
INCOME QUALIFIED	40	48,538	142	170,838
COMMERICAL	77	93,291	178	214,705

In addition to simulating market adoption under the current market standards, Cadmus ran four additional scenarios: transitioning the entire Wisconsin market to net metering–based customer compensation, increasing Focus on Energy incentives, providing attractive financing (reducing the project financing interest rate by 1% and requiring no down payment), and extending the federal ITC by three years. The statewide net metering scenario policy scenario produced the biggest increase in simulated market adoption.

Rooftop Solar PV Potential Scenarios – MW (Nameplate)



Cadmus used the capacity estimates for the simulated market adoption potential to determine the average peak period generation capacity (in MW) over the summer season that Focus on Energy could achieve through rooftop solar PV adoption. Cadmus used Focus on Energy's current peak period definition of June through August between 1 p.m. and 4 p.m. to estimate the peak period generation capacity, shown in the table below.[5] The peak period generation capacity in the base scenario of simulated market adoption potential is 257 MW in 2034. The peak period generation capacity represents roughly 41% of rated nameplate capacity across all scenarios.

Rooftop Solar PV Simulated Market Adoption Potential Scenarios – Peak Period Generation Capacity MW

ECONOMIC SCENARIO	2026 PEAK PERIOD GENERATION CAPACITY MW	2034 PEAK PERIOD GENERATION CAPACITY MW
BASELINE	86	257
STATEWIDE NET METERING POLICY	111	344
INCREASED FOCUS ON ENERGY INCENTIVES	98	271
ATTRACTIVE FINANCING	90	278
EXTENDED FEDERAL ITC	99	272

The PSC requested that Cadmus conduct research on barriers to solar PV adoption for income-qualified residents in Wisconsin. Cadmus identified best practices for overcoming barriers to encourage a wider adoption of solar among income-qualified communities. Cadmus conducted primary and secondary research about barriers and opportunities for delivering programs that promote rooftop solar PV adoption in the income-qualified population segment.

MARKET BARRIERS	CONSIDERATIONS
UPFRONT COST BURDEN	• Ensure that incentives are available for upfront costs including panel/construction costs and other costs, such as health and safety repairs or permits • Provide grants and incentives, rather than loans, to minimize the debt burden for participants • Consider avenues for third-party ownership while ensuring that consumer protections are in place for ongoing costs • Establish a standardized rule for net metering to maximize benefits for solar development across the state
HOME READINESS FOR SOLAR INSTALLATION	• Provide incentives for more than just the cost of installation (such as roof repairs) • Encourage energy efficiency upgrades in addition to solar installation
LIMITATIONS FOR MULTIFAMILY RESIDENTS	• Design programs that incent both property owners and tenants • Use virtual net metering as a means for allocating solar benefits to property owners and tenants in master-metered buildings

Cadmus synthesized these findings on barriers along with 12 equity program best practices to develop an equity framework that provides guiding principles and questions for stakeholders to consider as they develop approaches to drive the adoption of solar systems by income-qualified customers.

5 This definition presents Focus on Energy's current peak period. If this definition changes, the impact of solar PV's peak period generation capacity would be different. For example, if the peak period definition changes to later in the day, solar PV's peak period generation capacity would decrease.

Cost-Effectiveness Comparison

Cadmus calculated the modified Total Resource Cost test (mTRC), represented as a benefit-to-cost ratio, for a representative sample of residential and commercial solar projects based on inputs and methods described in the *Cost-Effectiveness Comparison* methodology section. Cadmus then selected electric energy efficiency measures with high installation costs from the *2021 Focus on Energy Potential Study* to serve as comparison points. When drawing these comparisons, it is important to consider that, for energy efficiency measures, both the cost and energy savings are incremental to baseline equipment assumptions, while for rooftop solar PV projects there is no baseline condition from which to calculate net cost or net savings. It is also noteworthy that the mTRC presents one of multiple potential cost-effectiveness perspectives.

RESIDENTIAL TECHNOLOGY	mTRC
RESIDENTIAL ROOFTOP SOLAR PV PROJECT	0.88
HEAT PUMP - AIR-SOURCE ENERGY STAR	1.34
HEAT PUMP - AIR-SOURCE ADVANCED	0.82
HEAT PUMP WATER HEATER - ENERGY STAR	1.12
CARBON DIOXIDE HEAT PUMP WATER HEATER	0.20

COMMERCIAL TECHNOLOGY	mTRC
COMMERCIAL ROOFTOP SOLAR PV PROJECT	1.48
WATER HEATER LE 55 GALLON - HEAT PUMP - ENHANCED EFFICIENCY	3.53
DIRECT EXPANSION PACKAGE 240 TO 760 KBTUh - PREMIUM EFFICIENCY	3.35
WATER HEATER LE 55 GALLON - HEAT PUMP WATER HEATER - ADVANCED EFFICIENCY	3.14
CHILLERS >300 TONS (CENTRIFUGAL) - ADVANCED EFFICIENCY (WATER COOLED)	1.25

Conclusions

CONCLUSION 1	Rooftop solar PV systems represent a sizable energy resource in terms of technical potential capacity; approaching 70% of statewide 2019 generation by 2034. However, only a small fraction of what is technically available is projected to be adopted by 2034.
CONCLUSION 2	Rooftop solar PV technical and simulated market adoption potential are primarily concentrated on single-family homes, which make up approximately 62% of technical rooftop potential.
CONCLUSION 3	Homes owned or rented by income-qualified customers represent an appreciable fraction of statewide single-family homes and subsequently a sizable portion of rooftop solar technical potential. Yet these households face significant challenges, such as upfront costs, home readiness, and limitations due to multifamily housing, in adopting rooftop solar systems.
CONCLUSION 4	Despite barriers, several avenues exist to increase adoption by income-qualified households, such as third-party ownership, reducing upfront costs through rebates and incentives, virtual net metering, and net metering.
CONCLUSION 5	The most efficacious strategy for accelerating the adoption of rooftop solar systems is through implementation of a statewide net metering policy.
CONCLUSION 6	Residential and commercial rooftop solar systems are comparable to high-cost, electric energy efficiency measures from a cost-effectiveness perspective.
CONCLUSION 7	Rooftop solar PV generation overlaps with the summer peak period, with 42% of the average summer daily solar generation capacity being captured during the peak hours.

Potential Study Approach

The PSC contracted with Cadmus to complete a rooftop solar PV potential assessment, designed to produce estimates of the potential rooftop solar PV capacity and production in Wisconsin over a 12-year period, from 2023 through 2034.

Study Objectives

Though this potential study, a companion study to the 2021 Energy Efficiency Potential Study,[6] does not provide a target for program planning, research was timed so Cadmus could provide input on quadrennial planning for Focus on Energy programs. Results from this study provide foundational information to the PSC and stakeholders in assessing the appropriate goals, priorities, and measurable targets for the 2023–2026 quadrennium of Focus on Energy. There were four study objectives:

- Inform program planning by assessing rooftop solar PV potential under business-as-usual conditions, as well as four economic scenarios.
- Conduct research about barriers and opportunities for delivering programs to promote rooftop solar PV adoption in the income-qualified population segment, and estimate the potential for income-qualified customers.
- Compare the cost-effectiveness of rooftop solar PV to energy efficiency measures.
- Engage and consult with project stakeholders throughout the study.

The study does not characterize all considerations that factor into customers' decisions to adopt solar PV systems, nor the mechanisms by which a consumer could engage with solar installers or Focus on Energy programs. There are program considerations that are outside of the scope of this study that decisions makers and program administrators should consider when planning to implement programs.

Scope of Assessment

This section provides an overview of Cadmus' scope of work and methodology.

Market Sectors

Cadmus analyzed the two sectors and population segments shown in Table 1. We considered multifamily buildings as part of commercial sector, given that typically the building owner, not individual tenants, makes the decision to invest in rooftop solar projects, and because of the similarity of adoption decisions for multifamily buildings and commercial segment buildings.[7]

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6 Cadmus. September 10, 2021. *2021 Focus on Energy Energy Efficiency Potential Study Report.* Prepared for Public Service Commission of Wisconsin. focusonenergy.com/sites/default/files/inline-files/2021%20Focus%20on%20Energy%20Energy%20Efficiency%20Potential%20Study%20Report.pdf

7 Though the study made the treatment adjustment for multifamily buildings, the model does not distinguish adoption between owners and renters of single-family and manufactured homes (see *Study Limitations and Considerations* section in this report).

Table 1. Sectors and Segments Covered in 2021 Rooftop Solar PV Potential Study

	RESIDENTIAL (STANDARD AND INCOME QUALIFIED)	Single-family and manufactured homes for standard and income-qualified population segments
	COMMERCIAL	Commercial offices, retail stores, healthcare facilities (hospitals and outpatient centers), lodging, schools, restaurants, warehouses, and multifamily buildings.

The income-qualified segment represents customers whose income is 80% or less of the Wisconsin median income, in line with Focus on Energy's qualification criteria for Tier 2 incentives.

Types of Potential Estimates

This section describes the two types of potential Cadmus estimated in the 2021 study: technical and simulated market adoption rooftop solar potential. Table 2 briefly describes these potential estimate types. These do not include ground-mounted solar PV systems.

Table 2. Types of Potential Estimated

Rooftop Area Not Suitable for Development	**TECHNICAL POTENTIAL** Theoretical maximum system (nameplate) capacity deployed and energy produced accounting for available rooftop square footage including shading, solar PV panel production per square foot, and solar irradiation.	
Rooftop Area Not Suitable for Development	Not Adopted by Building Owners	**SIMULATED MARKET ADOPTION POTENTIAL** Rooftop solar capacity deployed and energy produced based on simulations and economic parameters that affect the financial attractiveness from a customer perspective.

Technical Potential

Technical potential represents the theoretical maximum, developable rooftop solar PV capacity given the statewide rooftop square footage. Technical capacity potential excludes rooftop areas that are not suitable for development,[8] and it is measured in kilowatts, megawatts, or gigawatts. Technical energy production potential accounts for varying solar irradiation across Wisconsin and is measured in kilowatt-hours, megawatt-hours, or gigawatt-hours.

Technical potential is calculated by the dGen model using light detection and ranging data to calculate rooftop obstructions, rooftop azimuth, and rooftop tilt. The model also assumes that a percentage of the building stock is not suitable for rooftop solar development based on rooftop orientation or pitch. Finally, the model mines statewide solar irradiation levels to calculate technical potential. Technical potential does not account for barriers to adoption, such as roof age, structural suitability, or electric code compliance.

[8] To be considered suitable for development, a roof plane is required to have at least 80% unshaded, and it cannot be oriented to the northwest, north, or northeast. The dGen model does not account for changes in shading over time.

Simulated Market Adoption Potential

Simulated market adoption potential represents the simulated rooftop solar PV adoption on residential and commercial buildings and is based on three parameters:

- Existing rooftop solar deployment in an area of interest
- The assumed maximum market adoption based on the economic attractiveness of solar PV systems
- The technology diffusion rate throughout the population

Existing rooftop solar deployment refers to the historically adopted system capacity in Wisconsin, by sector, through 2020. Economic attractiveness is a function of a range of model inputs, including technology costs, federal and state incentives, project financing, and utility compensation mechanisms (net metering or net billing). The technology diffusion rate throughout the population refers to the rate of adoption of rooftop solar PV and is determined by a Bass diffusion curve.

The Bass diffusion curve is determined by Bass diffusion coefficients, a key input used to simulate technology diffusion. NREL has calibrated Bass diffusion coefficients for residential and commercial rooftop solar adoption based on historical adoption data from the Lawrence Berkeley National Laboratory's Tracking the Sun dataset and from Stanford University's DeepSolar Project dataset.[9] The calibrated residential coefficients simulate a longer time to peak adoption compared to the commercial coefficients. Based on this calibration, the commercial sector will reach maximum market saturation more quickly than the residential sector.

Another key input impacting adoption is the maximum market adoption curve, used to provide the relationship between the maximum percentage of the market that adopts solar and the payback period

Simulated market adoption potential is a subset of technical potential, determined by the adoption parameters described above and limited by the amount of solar potential that can technically be installed given suitable rooftop space.

Methodology

This section describes the methodology and model inputs Cadmus used to estimate technical and simulated market adoption potential, as well as our methods for conducting cost-effectiveness comparisons and research on income-qualified barriers and opportunities.

[9] The Sun dataset is available online at https://emp.lbl.gov/tracking-the-sun.
The Stanford University's DeepSolar Project dataset is also available online at http://web.stanford.edu/group/deepsolar/deepsolar_tract.csv.

NREL dGen Model

To model technical and simulated market adoption rooftop solar PV potential, Cadmus used NREL's dGen model, which simulates the market adoption of rooftop solar PV systems. The model and underlying state-level datasets are available to the public. The dGen model uses a particular approach to estimate market adoption:

1. Generates agents and assigns representative attributes based on population data.[10]
2. Applies technical resource characteristics—such as solar irradiance, rooftop square footage, rooftop pitch and orientation, and obstruction data—to each agent.
3. Conducts economic calculations using cashflow analysis. The economic analysis incorporates project costs, electric rates, net-metering or net billing considerations, and state and federal incentives.
4. Calculates market adoption based on Bass diffusion and project economics.[11]

NREL has made the model publicly available and provides the opportunity to adjust model inputs and underlying assumptions, as well as model logic. Cadmus reviewed the model inputs in detail and adjusted data inputs and model programming as appropriate. Details about the model mechanics can be found in the dGen documentation as well as on the NREL website at www.nrel.gov/analysis/dgen.

The dGen model provides market adoption results at the county, utility, and state levels. The model also produces estimates by sector and building segment through 2050.[12] Because model inputs can be varied, adoption scenarios can be generated by changing key inputs.

Approach for Technical Potential

The dGen model uses light detection and ranging data inputs to estimate the total rooftop area suitable for solar projects and calculates system capacity factors based on additional data inputs such rooftop orientation and solar irradiance. However, the model does not directly report technical potential estimates; rather, its outputs can be used to calculate the amount of capacity that could be deployed and amount of energy that could be produced. To calculate technical potential, Cadmus applied the system capacity per square footage model input assumption (see *Baseline Model Inputs* section) to the

10 An agent represents a group of customers with similar characteristics for the purpose of estimating solar adoption. Agents are statistically weighted together to represent commercial and residential populations.

11 National Renewable Energy Laboratory (Benjamin Sigrin, Michael Gleason, Robert Preus, Ian Baring-Gould, and Robert Margolis). February 2016. "The Distributed Generation Market Demand Model (dGen): Documentation."

12 While aggregate outputs are available at various levels of granularity, these cannot necessarily be provided at any special resolution due to the sampling approach taken to generate population files. For example, building sector resolution is not available at the county level because not all counties include all building sectors in the sample-based population file.

estimated developable rooftop.[13] The technical system capacity changes over time based on assumed increases in solar panel efficiency and load growth associated with new buildings. To calculate technical generation potential, Cadmus applied the modeled system capacity factors to the calculated technical system capacity.

Approach for Income-Qualified Potential

The dGen model does not simulate market adoption for income-qualified populations and does not characterize agents (representative customers) by income level. To generate income-qualified estimates, Cadmus segmented the residential population into standard and income-qualified groups using data from the U.S. Census Bureau's American Community Survey. Cadmus used 80% of state median income as the threshold for this segmentation, consistent with Focus on Energy tiered incentives for income-qualifying customers.

Cadmus then reviewed the model variables that could be adjusted to simulate economic barriers that income-qualified customers might face when adopting solar potential. These variables included the relationship between payback period and maximum market adoption, the discount rate, and the down payment fraction.[14] Cadmus also inquired about these variables as part of the income-qualified research component of this project. Based on feedback received during the interviews, Cadmus adjusted the discount rate for income-qualified populations. Detailed findings about the interviews can be found in the *Income-Qualified Research* section. Details about the model inputs for the income qualified population are in Table 3.

Approach for Multifamily Potential

The dGen model simulates the adoption of rooftop solar PV on multifamily buildings as a unit occupant decision in its residential model, rather than a building owner decision. For this study Cadmus assumed that multifamily building rooftop solar potential is part of the commercial sector, given that building owners, rather than unit occupants, are the most likely adopters of rooftop solar systems. To estimate multifamily rooftop solar adoption, Cadmus calculated multifamily building technical potential, then applied an adoption rate from the commercial sector.

Model Inputs

The dGen model contains a large volume of data inputs, including utility rates, customer populations, customer loads, project costs, financing conditions, and many others. Cadmus presented a set of key model inputs to stakeholders during the project, received important feedback on them, and made several adjustments. The tables below present a selection of key model inputs for baseline and scenario simulations; however, they are not a comprehensive list of all adjustable model data.

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13 NREL does not account for roof age, structural suitability, or electric code compliance. These factors can create barriers to solar adoption, especially for income-qualified customers.

14 The dGen model does not account for different adoption patterns by home-owners and renters. See *Study Limitations and Considerations*, below.

Baseline Model Inputs

Table 3 provides key dGen model inputs for the commercial and residential baseline models. For the income-qualified residential model, Cadmus adjusted one variable and kept the other residential inputs constant. The dGen model provides prepopulated tables with the model inputs. These model inputs are applied universally to all members of the population; however, Focus on Energy cannot provide incentives for 100% of rooftop PV installations. Therefore, the simulated market adoption potential may be higher than what can realistically be achieved based on current funding levels.

Table 3. Baseline Model Inputs

Model Input	Value	Notes/Source
Residential		
Federal ITC	2020–2022: 26%; 2023: 22%; after 2023: 0%	U.S. Department of Energy
Focus on Energy incentives	$500 per project	Focus on Energy
Loan term	20 years	Modified from NREL 2020 *Annual Technology Baseline* (ATB) assumption following stakeholder discussions
Interest rate	3.5%	NREL 2020 ATB
Discount rate	3.7%	NREL 2020 ATB
Down payment fraction	20%	Modified from NREL 2020 ATB assumption following stakeholder discussion
Net metering	Xcel Energy, Madison Gas and Electric, public utilities	Maximum capacity limit varies by utility; all other utilities set to net billing[a]
Solar costs (2020)	$2,972 per kilowatt	2020 costs are based on historical Focus on Energy program costs. Costs decline according to NREL 2020 ATB “moderate” estimates
Coefficient: *p* (innovation)	0.00011	dGen model Bass market diffusion coefficients used to simulate market adoption over time
Coefficient: *q* (imitation)	0.20001	
Residential Income-Qualified Adjustment		
Discount rate	5.4%	Modified from NREL 2020 ATB assumption following income-qualified research
Commercial		
Federal ITC	2020–2022: 26%; 2023: 22%; after 2023: 10%	U.S. Department of Energy
Focus on Energy incentives	$0.10 per watt installed and $50,000 maximum per project	Focus on Energy currently offers tiered incentives; the dGen model does not process tiered incentives and the input represents a proxy for the current offering
Loan term	10 years	Modified from NREL 2020 ATB assumption following stakeholder discussions
Interest rate	3.5%	NREL 2020 ATB
Discount rate	3.7%	NREL 2020 ATB
Down payment fraction	26%	NREL 2020 ATB
Net metering	Xcel Energy, Madison Gas and Electric, public utilities	Maximum capacity limit of 100 kW; all other utilities set to net-billing
Solar costs (2020)	$1,701 per kilowatt	2020 costs are based on NREL 2020 ATB reporting. Costs decline according to NREL 2020 ATB “moderate” estimates

Model Input	Value	Notes/Source
Coefficient: *p* (innovation)	0.0020	dGen model Bass market diffusion coefficients used to simulate market adoption over time
Coefficient: *q* (imitation)	0.4000	

[a] The primary difference between net billing and net metering arrangements is how excess customer generation is valued. Under a net billing scenario, dGen assumes that each month's excess generation is valued at the wholesale power rate. Under the net metering arrangement, excess generation is carried over as credits to following months, which can be applied to reduce the customer utility bill. The dGen model limits system sizing to not produce more energy annually than is consumed by a customer. Therefore, the investigated net metering scenario effectively reflects an annual true-up.

Another modeling consideration is the distributed rooftop system adoption that has been historically deployed. These data provide a starting point for future simulated rooftop adoption. A key consideration is that each utility has specific starting points for solar adoption, these then set the starting point for future growth within that utility service area.

To estimate historical adoption, Cadmus relied on the PSC's *Final Strategic Energy Assessment, 2020-2026*[15] (SEA) for the total statewide distributed solar adoption. Because the SEA does not provide sector- or utility-specific adoption, Cadmus used residential and commercial system data from the U.S. Energy Information Administration Form 861,[16] which provides historical utility-level system adoption, to calibrate values from the SEA to the residential and commercial sectors, as well as to the utility level. The residential sector historical capacity was divided into standard and income-qualified capacity based on the system load forecast for residential income-qualified and standard-income customers in the 2021 Focus on Energy *Energy Efficiency Potential Study*.

Additionally, Cadmus reviewed annual reports filed by individual investor-owned utilities on the PSC's E-Services portal (apps.psc.wi.gov/ARS/annualReports/content/listingIOU.aspx). These data also do not contain sector-specific solar adoption and do not include reported customer-owned distributed energy resource capacity for Madison Gas and Electric. Therefore, Cadmus relied on the approach to use the SEA and Form 861 information. Collection of utility-specific solar adoption, including at the utility and sector levels, could improve the study's ability to simulate future market adoption. However, this study did not have sufficient time to make a data request for this information from Wisconsin utilities.

Because the dGen model produces inputs in two-year increments and the SEA provides data for 2019, Cadmus escalated the 2019 estimate by the historical annual growth of 20% cited in the SEA to estimate 2020 solar capacity.

Table 4 shows the 2020 distributed residential and commercial solar adoption in Wisconsin and the associated utility electric load (as modeled by dGen). Some utilities have relatively strong adoption while others have less historical adoption, and historical adoption is not directly correlated with utility load. Madison Gas and Electric's territory, for example, contains approximately 16% of existing solar adoption

15 Public Service Commission of Wisconsin. October 2020. *Final Strategic Energy Assessment: 2020-2026.* Docket 5-ES-110. https://apps.psc.wi.gov/ERF/ERFview/viewdoc.aspx?docid=397611

16 U.S. Energy Information Administration. August 3, 2021. "Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files." www.eia.gov/electricity/data/eia861

but has only 5% of the statewide electric load. On the other hand, Wisconsin Electric Power Company has 45% of the statewide load, but it has only 15% of the adopted statewide solar adoption. These differences in distribution indicate that economics, policy, and other factors in a service area may have a strong influence on adoption of rooftop solar systems.

Table 4. Historical Distributed Solar Adoption in Wisconsin

Utility	Residential [a]		Commercial	
	2020 Starting Distributed Solar Adoption (MW)	2020 Utility Electric Load (MWh)[b]	2020 Starting Distributed Solar Adoption (MW)	2020 Utility Electric Load (MWh)[b]
Madison Gas and Electric	5.01	519,494	12.05	1,562,989
Wisconsin Electric Power Company	11.54	7,085,414	3.72	10,930,910
Wisconsin Power and Light	8.88	2,820,426	8.67	2,555,341
Wisconsin Public Service	4.91	3,196,154	7.22	2,042,417
Xcel Energy	9.60	1,834,543	6.33	1,490,809
Others	23.03	4,643,331	3.54	1,480,445
Total	**62.98**	**20,099,362**	**41.53**	**20,062,911**

[a] Cadmus segmented this adoption into standard and income-qualified segments based on American Community Survey income data.

[b] Source: NREL dGen model data based on historical Energy Information Administration Residential Energy Consumption Survey and Commercial Building Energy Consumption Surveys. Load growth used to determine 2020 estimates is based on the Annual Energy Outlook 2018 reference case forecast (by sector and NERC region). Further documentation on load data in the dGen model can be found in the model documentation: National Renewable Energy Laboratory (Benjamin Sigrin, Michael Gleason, Robert Preus, Ian Baring-Gould, and Robert Margolis). February 2016. "The Distributed Generation Market Demand Model (dGen): Documentation." See https://www.nrel.gov/docs/fy16osti/65231.pdf.

Calculating Peak Period Generation Capacity Impacts

To estimate the nameplate capacity, Cadmus relied strictly on the dGen model, whereas for the peak period generation capacity calculation Cadmus relied on solar irradiance in Wisconsin that correspond to the Focus on Energy defined peak period (1 p.m. to 4 p.m., June through August). The peak period generation capacity is a subset of the nameplate capacity based on the average system set up (tilt and azimuth) and the historical typical amount of solar irradiance available at any given hour of the year. Cadmus used the NREL PVWatts Calculator (https://pvwatts.nrel.gov/) to determine the hourly solar irradiance and associated system output for Wisconsin.[17] As an input to the PVWatts Calculator, Cadmus determined the average azimuth and tilt of residential and commercial rooftop solar PV systems based on the average for each of the sectors in 2020 from the dGen model.

Cadmus developed residential and commercial hourly system capacity values from the PVWatts Calculator, then calibrated the results using the ratio of annual nameplate capacity to annual kilowatt-hour generation from solar technology in each year for each sector within the dGen model. Once

[17] Cadmus used Madison, Wisconsin, as the location to gather solar irradiance data.

calibrated, Cadmus was able to determine the peak period generation capacity values during the peak period.[18]

Economic Scenario Inputs

To estimate market adoption for four economic scenarios, Cadmus adjusted selected dGen model inputs, including utility-level net-metering compensation and maximum capacity limits, Focus on Energy incentive levels, project interest rates and down payment levels, and the duration of the federal ITC. We developed the investigated scenarios and their associated dGen inputs in close collaboration with project stakeholders. Table 5 shows the scenario-specific model adjustments Cadmus made to estimate simulated market adoption potential.

Table 5. Economic Scenario Model Inputs

Model Input	Notes
Scenario 1: Statewide Net Metering	
Net-metering for all utilities. Net-metering capacity limit	Maximum capacity limit: 500 kW.
Scenario 2: Increased Focus on Energy Incentives	
Residential Standard Income: $0.90 per watt and maximum of $4,500 per project **Residential Income Qualified**: $1.50 per watt and maximum of $10,500 per project	Focus on Energy currently offers tiered incentives. The dGen model does not process tiered incentives and the input represents a proxy for the current offering.
Commercial: $0.30 per watt installed and $180,000 maximum per project	
Scenario 3: Attractive Financing	
Residential: Interest rate: 2.5%; down payment fraction: 0%	No adjustment made to loan term. Made adjustments to reflect potential financing support that Focus on Energy or other organizations could offer to entities considering installing solar projects.
Commercial: Interest rate: 2.5%; down payment fraction: 0%	
Scenario 4: Extension of the Federal ITC	
Residential: 2020–2026: 26%; 2027: 22%; after 2027: 0%	Extends the current federal ITC rates and schedule by an additional three years.
Commercial: 2020–2026: 26%; 2027: 22%; after 2027: 10%	

Cost-Effectiveness Comparison

Cost-effectiveness tests are used to compare the benefits of an action or resource to its costs. The specific benefits and costs included in a given test depend on the perspective of the selected stakeholder of interest. The most frequently used cost-effectiveness tests compare the benefits and costs accrued to utilities, ratepayers and society. The total resource cost test compares the energy savings benefits of a program or resource (i.e., avoided energy) to its equipment and installation costs, plus any added administrative costs.

Wisconsin's primary cost-effectiveness metric is the modified total resource cost test (mTRC), which also includes reduced or avoided emissions as a benefit. Cadmus used the mTRC to compare the cost-

18 Focus on Energy's current peak period definition is weekdays in June through August from 1 p.m. to 4 p.m. Cadmus did not include day-type when averaging over the solar peak capacity values, because solar irradiance is not day-type dependent.

effectiveness of representative solar PV projects with selected measures from the 2021 Focus on Energy *Energy Efficiency Potential Study*. Because this study determined the mTRC for each building segment and construction vintage of a measure uniquely (e.g., where a commercial federal standard heat pump might have a different mTRC for existing warehouses than it does for new offices), Cadmus weighted the mTRC for all permutations of a measure together based on the per-unit savings of the permutations.

To make these comparisons and calculate mTRC benefit-cost ratios, Cadmus used the same costs and benefits for the representative solar projects as the energy efficiency measures shown in Table 6.

Table 6. Summary of Costs and Benefit Components

Type	Component
Costs	Incremental equipment and labor cost
	Administrative adder
Benefits	Present value of avoided energy supply benefits
Discount rate	2.0%
Non-energy benefits	$15 per ton of avoided carbon emissions

These components can be further explained as follows:

- ***Incremental equipment and labor cost.*** For the energy efficiency study, Cadmus considered the incremental equipment and labor costs relative to a standard or baseline equipment measure required to purchase a measure and sustain savings over each measure's effective useful life. For the representative solar projects, we used the same capital and operations and maintenance costs that had been used for baseline model inputs.
- ***Administrative adder.*** Cadmus assumed these costs were equal to 21% of incremental costs for residential energy efficiency measures and 18% of incremental costs for commercial energy efficiency measures, informed by Focus on Energy's historical delivery and administration charges from the Focus on Energy 2019 annual report. For solar projects, the administrative adder was 13% of incentive cost for commercial projects and 15% of incentive cost for residential projects. Cadmus calculated this ratio based on 2020 Focus on Energy program data.
- ***Present value of avoided energy supply benefits.*** Cadmus estimated avoided energy and deferred generation capacity benefits based on energy cost forecasts provided by Focus on Energy. For avoided electric costs Cadmus used $0.031/kWh and $128/kW in 2021. These avoided costs escalate over the project's lifetime.
- ***Non-energy benefits***. Cadmus accounted for benefits from reduced emissions. Reduced emissions reflect the economic value of avoided greenhouse gas emissions, including carbon dioxide, nitrous oxides, and sulfur oxides. Non-energy benefits were valued at $0.013/kWh.

In addition to each benefit and cost detailed above, Focus on Energy provided standard line loss factors and discount rates for this study. Cadmus applied discount rates from the energy efficiency study to this solar PV study. Table 7 shows the assumptions Cadmus made to model representative residential and commercial projects.

Table 7. Representative Project System Characteristics

System Characteristic	Value		Source/Description
	Commercial	Residential	
2020 Capital Costs ($/kW)	1,701	2,972	Aligns with dGen model assumption
Operations and Maintenance Costs ($/kW/year)	12	12	Aligns with dGen model assumption
Project Lifetime (years)	25	25	Aligns with dGen model assumption
System Size (kW)	65	7	2020 Focus on Energy average
System Capacity Factor	0.14	0.13	dGen model output

Income-Qualified Research

In addition to determining income-qualified technical potential for solar PV, Cadmus conducted several research tasks, including benchmarking, policy review, and stakeholder interviews. These tasks allowed us to further explore how to provide income-qualified residents of Wisconsin with opportunities to receive benefits from solar.

Exemplary Program Benchmarking

Cadmus conducted a literature review to benchmark exemplary rooftop solar adoption programs that target income-qualified residents, and to determine best practices. (Sources can be found in *Appendix F.)* We started by reviewing known equity guides, presentations, and other research that might include best practices for income-qualified rooftop solar installation. We then conducted a general web search to identify solar rooftop programs across the country that were either designed for income-qualified residents or that included special considerations for income-qualified residents.

Out of this general search, Cadmus chose five programs that target all income-qualified housing and implement the best practices and principles of an equitable rooftop solar program. Table 8 shows the programs we benchmarked and the program elements that stood out as exemplary.

Table 8. Exemplary Income-Qualified Solar Programs Benchmarked

Program Name	Program Sponsor	Program Region	Exemplary Program Elements
Solar for Your Home/ Solar within Reach	Energy Trust of Oregon	Northwest	Effectively reduces financial burden; partners with community organizations; designed with input from community organizations; education efforts
Illinois Solar for All	Illinois Power Agency	Midwest	Eliminates financial burden; partners with community organizations; includes multifamily and community organization incentives; provides consumer protections; education efforts
Solar Rewards	Xcel Energy (Minnesota)	Midwest	Effectively reduces financial burden; will include disadvantaged communities (not just income-based eligibility); promotes energy efficiency alongside solar; includes multifamily incentives; provides consumer protections; education efforts
Washington DC Solar for All	DC Department of Energy and Environment	Mid-Atlantic	Eliminates financial burden; partners with community organizations; education efforts
Multifamily Affordable Solar Housing	California Public Utilities Commission	West	Effectively reduces financial burden; includes multifamily incentives; promotes energy efficiency alongside solar; education efforts; co-benefits (such as job training)

Energy and Solar Policy Review

Cadmus reviewed Wisconsin energy and solar policies to understand if there is existing legislation that might inadvertently create barriers for income-qualified solar adoption. In addition to web articles surrounding solar policy in Wisconsin, Cadmus reviewed state legislature and tariffs directly. These included utility tariffs, energy administration codes, and regulation on renewable energy systems. A full list of the legislation we reviewed can be found in *Appendix F*.

Stakeholder Interviews

Cadmus conducted eight stakeholder interviews, which we designed to supplement the findings of the benchmarking and policy review activities described above. During these interviews, Cadmus further explored best practices, lessons learned from program administrators of low-income solar programs, and ways to anticipate and identify barriers and opportunities for low-income solar adoption. We also asked Wisconsin stakeholders if they had knowledge about Wisconsin-specific barriers, such as policy barriers. Our specific research objectives and research questions are outlined in Table 9.

Table 9. Low-Income Stakeholder Interview Research Objectives

Research Objectives	Research Questions
Understand best practices and lessons learned from other low-income solar programs	• What have other programs learned from implementing a low-income solar program? • What were the biggest successes of the program? • What were the biggest challenges of the program?
Identify barriers to and opportunities for low-income solar adoption	• Are there existing policy barriers to low-income solar adoption? • What kind of barriers and opportunities exist for multifamily buildings? • What prevents low-income solar adoption? • Where in Wisconsin are there opportunities for low-income solar adoption? • What kind of sensitivity do low-income individuals have to payback periods?
Understand how to engage multiple stakeholders, such as solar installers [a]	• Are solar installers willing to partner with a low-income solar adoption program? • What barriers have solar installers faced when working with low-income customers?

[a] Cadmus attempted to interview Wisconsin-based solar installers but was unable to complete an interview.

Ultimately, Cadmus interviewed three Wisconsin stakeholders and five out-of-state program administrators, as shown in Table 10.

Table 10. Solar Stakeholder Interviewees

Organization	State/Region	Role
Wisconsin State Energy Office	Wisconsin	Stakeholder
West CAP	Wisconsin	Solar Program Administrator/Stakeholder
RENEW Wisconsin	Wisconsin	Solar Program Administrator/Stakeholder
Xcel Energy (Minnesota)	Midwest	Solar Program Administrator
Illinois Power Agency	Midwest	Solar Program Administrator
Xcel Energy (Colorado)	Midwest	Solar Program Administrator
Washington DC Department of Energy and Environment	Mid-Atlantic	Solar Program Administrator
Energy Trust of Oregon	Northwest	Solar Program Administrator

Equity Framework

Cadmus synthesized findings from the primary and secondary research to develop an equity framework that provides guiding principles and questions for stakeholders to consider as they develop approaches to drive the adoption of solar systems by income-qualified customers. The framework can be used at the start of program design, during design and implementation, and during performance reviews or evaluations. It guides the reader through four sets of questions about how participants will be engaged, the program beneficiaries, details about program design and policy considerations, and how burdens of participation or solar installation are being relieved. Finally, the equity framework also contains a list of potential program outcomes that can be used as key performance indicators throughout the lifetime of the program.

Stakeholder Involvement

Cadmus engaged with project stakeholders throughout the course of this study. Project stakeholders include advocacy organizations, industry professionals, local government organizations, Focus on Energy staff, and utilities. To engage with stakeholders, Cadmus and the PSC facilitated three online presentations and discussion sessions and solicited feedback by email. Stakeholders provided input on model parameters and assumptions, and delivered feedback on the draft report. Table 11 provides details on the three stakeholder engagement sessions. Recordings of these sessions, as well as presentation slides, are posted to the Focus on Energy website: focusonenergy.com/about/2021-Potential-Study-Documents.

Table 11. Key Stakeholder Engagement Activities

Meeting	Key Discussion Items and Stakeholder Input
1st Stakeholder Meeting May 27, 2021	Cadmus and PSC staff introduced the potential study objectives, timeline, stakeholder engagement process, and overview of the methodology. Stakeholders provided feedback on the methodology.
2nd Stakeholder Meeting June 30, 2021	Cadmus presented dGen model inputs and potential economic scenarios. Stakeholders provided feedback on model inputs and preferences for scenarios. Cadmus and PSC followed up with stakeholders after the meeting by email.
3rd Stakeholder Meeting August 26, 2021	Cadmus presented preliminary study finding to stakeholders.
4th Stakeholder Meeting Fall 2021	The final meeting will recap results, discuss the conclusions in detail, provide a discussion of stakeholder comments received, and next steps for Quadrennial Planning (this meeting had not occurred at time this report was published).

Study Limitations and Considerations

While this study provides insights regarding the market adoption potential in Wisconsin under a variety of economic scenarios, this information is meant to inform—not set—program targets. In addition to the descriptions of potential noted above, several other considerations regarding the dGen modeling tool should be considered:

- ***Treatment of renters versus owners:*** While the dGen model distinguishes between homes that are occupied by owners and homes that are occupied by renters, the model does not take a distinct approach for modeling solar simulated market adoption potential by ownership class. It is likely that market uptake among homeowners is different from uptake among renters, but dGen is not able to distinguish any differences in the uptake rate. For this potential study, Cadmus is reporting adoption for both owners and renters together.
- ***Rooftop system sizing:*** The dGen model optimizes rooftop solar PV project size to maximize the project net present value given specific economic and energy production inputs and constrained by available rooftop space and customer load. The model varies both the system size and the number of installed systems based on various economic parameters. However, in reality, system sizes may be less variable annually than the dGen model assumes. The dGen model constrains system sizes to produce, at a maximum, the energy required to offset customer loads.
- ***Income-qualified adoption:*** Income-qualified populations face specific barriers to adopting rooftop solar PV systems, including home readiness, income, access to capital, awareness, and others. However, the dGen model does not currently provide income class–specific inputs or modeling assumptions. Cadmus' approach to modeling income-qualified potential is noted above, in the *Approach for Income-Qualified Potential* section.

- ***Multifamily adoption:*** Building owners, rather than unit residents, are more likely to invest in rooftop solar PV projects. dGen currently models the uptake of individual tenant-owned systems of shared multifamily building rooftop space. Cadmus' approach to model multifamily rooftop solar PV adoption as a building owner decision is described above, in the *Approach for Multifamily Potential* section.
- ***Global incentive application:*** The incentive assumptions for each sector are applied universally to all members of the population; however, Focus on Energy cannot provide incentives covering 100% of rooftop PV installations. Therefore, the simulated market adoption potential may be higher than what can realistically be achieved based on current funding levels.
- ***Non-economic factors of adoption:*** The dGen model simulates solar adoption based on economic attractiveness, maximum market share parameters, and Bass diffusion coefficients. While economic variables differ by utility, maximum market share parameters and Bass diffusion coefficients are standard across the state. However, historical utility adoption trends suggest that economic attractiveness is not the only driver of adoption. The study does not account for non-economic parameters, such as population's environmental values, that may vary by geography in estimating the market adoption potential.
- ***Granularity of model outputs:*** The model relies on a sampled set of agents (representative customers) as the basis for simulating market adoption. The agent database combines utility rates, compensation policies, customer characteristics (such as load and rooftop characteristics), and building segment (such as manufactured home or warehouse) to simulate adoption for a defined set of customers. Due to this sampling approach, model output granularity is dependent on the level of reporting. For example, building segment adoption is not accessible at the county or utility levels, rather is available in state aggregate.
- ***Granularity of Load Growth Estimation:*** The dGen model uses load growth estimates from the Annual Energy Outlook's 2019 Reference Case to predict population increases that affect solar potential over time.[19] Load growth estimates vary by sector (commercial, residential, and industrial) and by North American Electric Reliability Council (NERC) region. Therefore, the model does not account for changes in load at the utility or county level.
- ***Focus on Rooftop Solar Potential:*** In this potential study Cadmus estimated only the potential for solar systems sited on homes and business rooftops, which is the only potential that can be analyzed in the NREL dGen model. Estimating ground-mounted solar PV potential would require a separate study. Though Focus on Energy currently does not formally track if systems receiving incentives are rooftop or ground-mounted systems, the implementation team estimates that approximately 90% of systems not installed on farms are rooftop systems, and that most systems installed on farms are ground-mounted.

[19] U.S. Energy Information Administration. "Annual Energy Outlook 2019." https://www.eia.gov/outlooks/archive/aeo19/

Technical Potential

Technical potential represents the theoretical maximum developable rooftop solar PV capacity, given the rooftop square footage that is suitable for development and solar panel efficiency. Cadmus determined technical potential estimates for 2026 and 2034, corresponding with the four-year PSC planning horizon and the 12-year study period. While technical potential is relatively stagnant, it is affected by several variables that change over time: the degradation of existing systems, improvements in panel efficiency, and population growth (that is, an increase in rooftop square footage).

The estimated total statewide technical potential for Wisconsin in 2026 is 44,182,839 MWh of generation and 36,734 MWs of capacity. This level of rooftop solar PV generation represents approximately 70% of 2019 statewide energy production (in megawatt-hours). This level of rooftop solar PV capacity represents 265% of statewide 2019 nameplate capacity (in megawatts).[20]

Utility and Statewide Technical Potential

Technical rooftop solar potential is concentrated in the state's largest utilities, as shown in Table 12. Wisconsin Electric Power Company has the largest technical potential capacity, accounting for approximately 38% of the 2026 technical potential. Utilities with the largest customer base, such as Wisconsin Electric Power Company, contain the most rooftop area, and therefore represent the largest technical rooftop solar PV potential. Table 12 also shows the 2020 historical adoption. Comparing the historical adoption distribution by utility to the technical potential distribution by utility shows that historical adoption in a utility service territory is not directly correlated with technical potential.

Table 12. Utility and Statewide Technical Potential

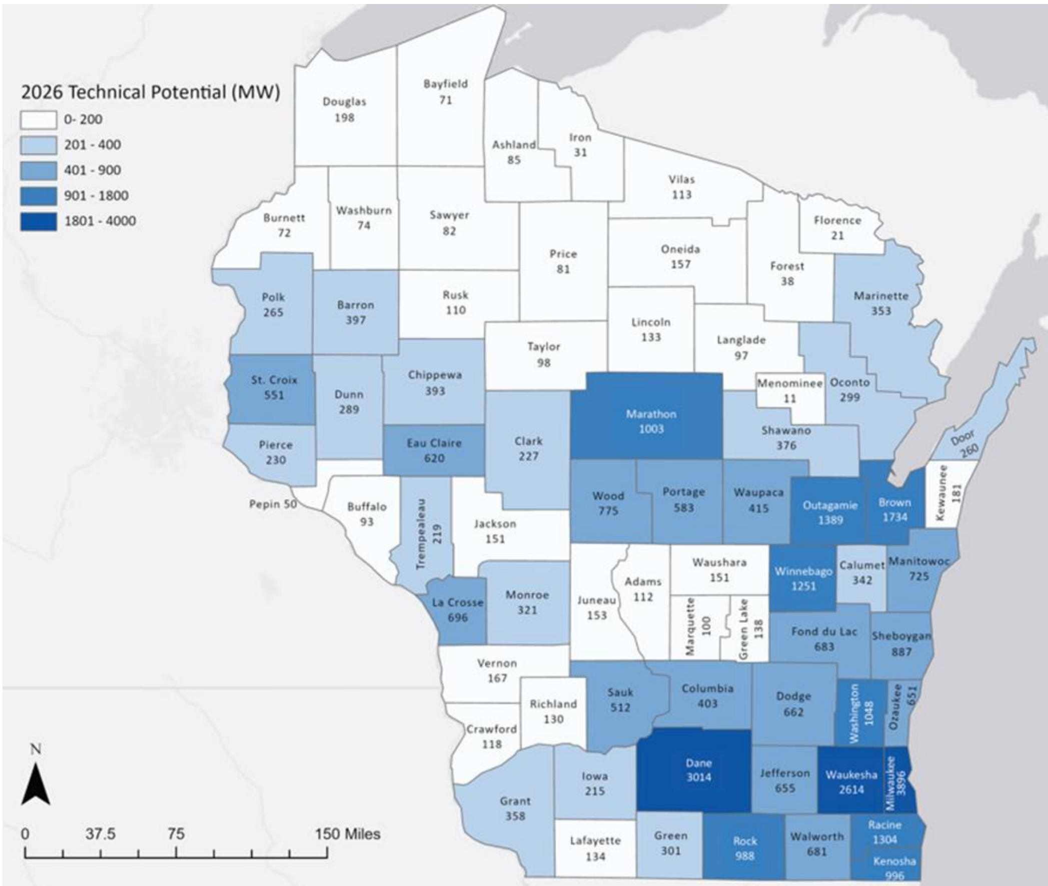
Utility	2020 Capacity Adopted	2026 Technical Potential			2034 Technical Potential		
	% of Total	MW	MWh	% of Total (MW)	MW	MWh	% of Total (MW)
Madison Gas and Electric	16%	1,583	1,955,863	4%	1,679	2,075,125	4%
Wisconsin Electric Power Company	15%	14,017	16,982,057	38%	14,834	17,970,647	38%
Wisconsin Power and Light	17%	6,201	7,511,871	17%	6,566	7,953,572	17%
Wisconsin Public Service	12%	5,635	6,671,420	15%	5,964	7,061,304	15%
Xcel Energy	15%	2,935	3,499,122	8%	3,121	3,720,572	8%
Others	25%	6,363	7,562,506	17%	6,734	8,003,542	17%
Total	**100%**	**36,734**	**44,182,839**	**100%**	**38,898**	**46,784,762**	**100%**

As with utility disaggregation, technical generation and capacity potential is primarily based on developable rooftop square footage. As shown in the Figure 1, technical capacity is concentrated in

20 The 2019 generation and capacity estimates are from: U.S. Energy Information Administration. U.S. Energy Information Administration. August 3, 2021. "Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files." https://www.eia.gov/electricity/data/eia861/

population-dense areas of Wisconsin, where more rooftop square footage is available for solar PV system installation.

Figure 1. Statewide Rooftop Solar PV Technical Potential by County – 2026 (MW)



Residential Technical Potential

As shown in Table 13, rooftop solar PV technical potential in the residential sector is primarily found on standard-income single-family homes. Income-qualified homes make up approximately 33% of the total single family home technical potential, roughly proportional to the percentage of income-qualified households in Wisconsin, according to American Community Survey data. Manufactured homes make up a relatively small percentage of technical potential, given their comparatively low total rooftop square footage in Wisconsin.

Table 13. Residential Technical Potential by Segment

Residential Segment	2026		2034	
	MW	MWh	MW	MWh
Standard Income Single Family	15,157	18,273,486	15,928	19,203,076
Standard Income Manufactured	289	336,015	304	353,109
Total Standard Income	**15,447**	**18,609,501**	**16,232**	**19,556,184**
Income-Qualified Single Family	7,525	8,972,043	7,908	9,428,460
Income-Qualified Manufactured	452	580,083	475	609,592
Total Income-Qualified	**7,977**	**9,552,126**	**8,383**	**10,038,052**
Total Residential	**23,424**	**28,161,627**	**24,615**	**29,594,236**

Commercial Technical Potential

Table 14 shows the commercial technical potential by building segment. As shown, commercial rooftop solar PV technical potential is primarily concentrated on warehouses, retail buildings, and schools, all of which have large rooftop areas, a large number of buildings, or both. The other segments, such as restaurants and lodging, make up a relatively small proportion of the technical potential.

Table 14. Commercial Technical Potential

Commercial Segment	2026		2034	
	MW	MWh	MW	MWh
Healthcare	461	552,836	495	593,274
Lodging	223	266,419	240	286,381
Multifamily	627	776,819	658	816,337
Office	652	786,413	701	844,336
Restaurant	211	253,505	227	272,542
Retail	3,601	4,322,980	3,867	4,642,322
School	1,881	2,254,920	2,022	2,423,697
Warehouse	5,654	6,807,319	6,073	7,311,637
Total Commercial	**13,311**	**16,021,212**	**14,283**	**17,190,526**

Baseline Simulated Market Adoption Potential

This section presents the results of simulated market adoption potential based on the dGen model inputs described in the *Baseline Model Inputs* section above. Simulated market adoption potential can be described as simulated market adoption that accounts for existing utility adoption, economic attractiveness, and general market diffusion. Simulated market adoption potential represents a fraction of technical potential. Overall, the 2026 simulated rooftop PV capacity adoption is 0.56% of technical potential and, despite more than tripling in 2034, remains only 1.6% of statewide technical potential.

Utility and Statewide Simulated Market Adoption Potential

Table 15 and Figure 2 show the simulated rooftop solar PV market adoption capacity for the residential and commercial sectors for Wisconsin utilities. This simulation builds on and includes the base of existing 2020 rooftop deployment, which was outlined above in the *Baseline Model Inputs* section. Three drivers of simulated adoption are the relative historical adoption starting points, overall market size, and utility area–specific characteristics, such as customer profiles, electric rates, and compensation policies.

Table 15. Utility and Statewide Simulated Market Adoption Potential (MW)

Utility	2024	2026	2028	2030	2032	2034
Madison Gas and Electric	22.55	27.35	34.49	44.59	53.58	61.98
Wisconsin Electric Power Company	20.13	25.16	34.02	50.15	72.32	101.49
Wisconsin Power and Light	26.51	35.13	47.62	66.04	84.94	104.15
Wisconsin Public Service	19.67	26.29	35.87	51.72	67.13	82.75
Xcel Energy	26.61	34.79	46.49	62.74	80.79	100.53
Other	44.97	58.38	77.82	104.64	136.26	172.54
Total	**160.44**	**207.10**	**276.32**	**379.86**	**495.02**	**623.44**

Figure 2. Utility and Statewide Simulated Market Adoption Potential (MW)

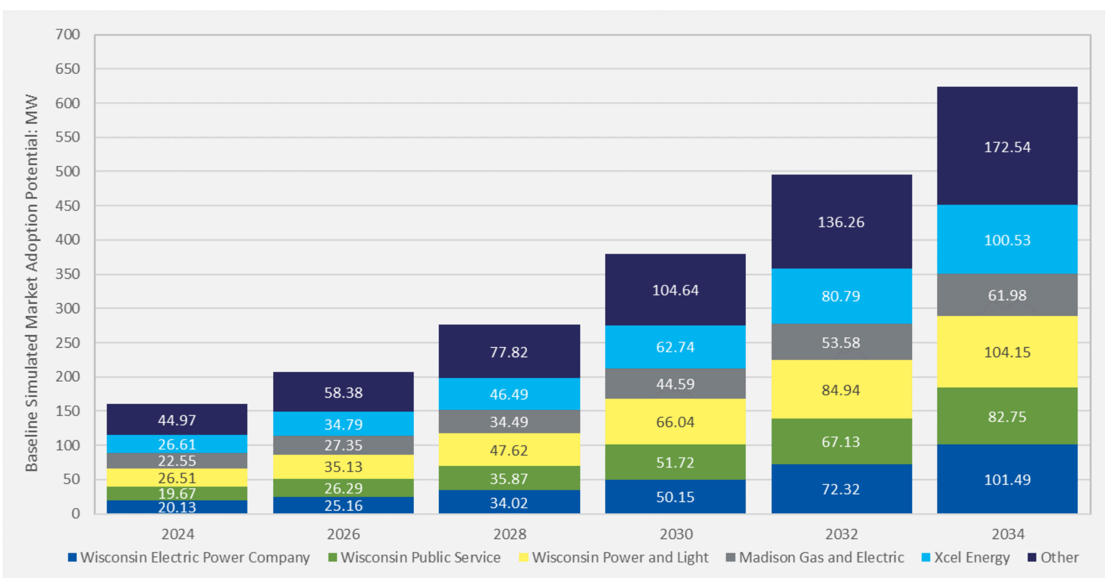
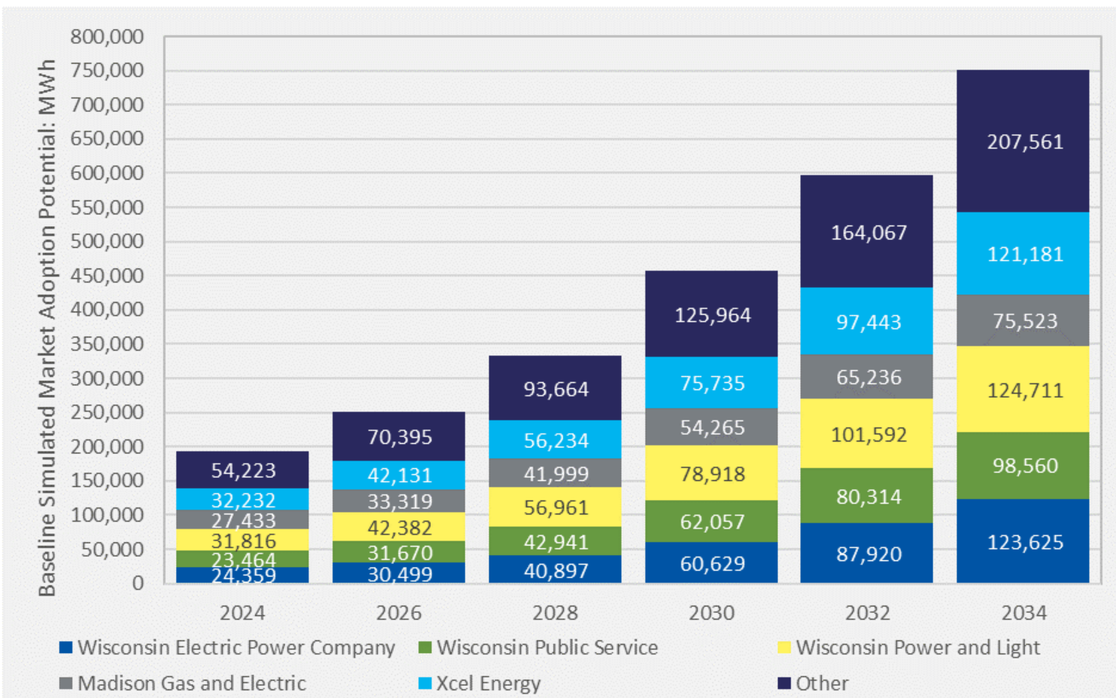


Table 16 and Figure 3 show the simulated rooftop solar PV market adoption energy production for the combined residential and commercial sectors for Wisconsin utilities. The simulated energy production estimates are roughly proportional to the simulated capacity estimate.

Table 16. Utility and Statewide Simulated Market Adoption Potential (MWh)

Utility	2024	2026	2028	2030	2032	2034
Madison Gas and Electric	27,433	33,319	41,999	54,265	65,236	75,523
Wisconsin Electric Power Company	24,359	30,499	40,897	60,629	87,920	123,625
Wisconsin Power and Light	31,816	42,382	56,961	78,918	101,592	124,711
Wisconsin Public Service	23,464	31,670	42,941	62,057	80,314	98,560
Xcel Energy	32,232	42,131	56,234	75,735	97,443	121,181
Other	54,223	70,395	93,664	125,964	164,067	207,561
Total	**193,528**	**250,397**	**332,696**	**457,567**	**596,571**	**751,160**

Figure 3. Utility and Statewide Simulated Market Adoption Potential (MWh)



In addition to disaggregating total market capacity potential by utility, Cadmus simulated market capacity potential at the county level. As shown in Figure 4 and Figure 5, market capacity is concentrated in population-dense areas of Wisconsin, where more rooftop square footage is available for solar PV system installation.

Figure 4. Statewide Rooftop Solar PV Simulated Market Adoption Potential by County – 2026 (MW)

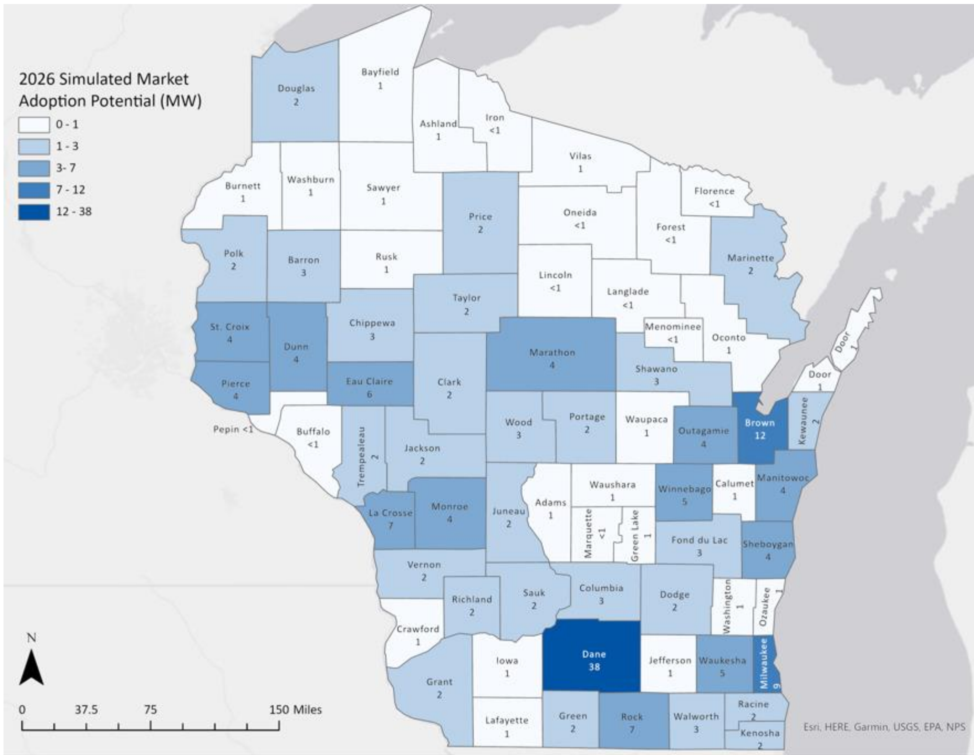


Figure 5. Statewide Rooftop Solar PV Simulated Market Adoption Potential by County – 2034 (MW)

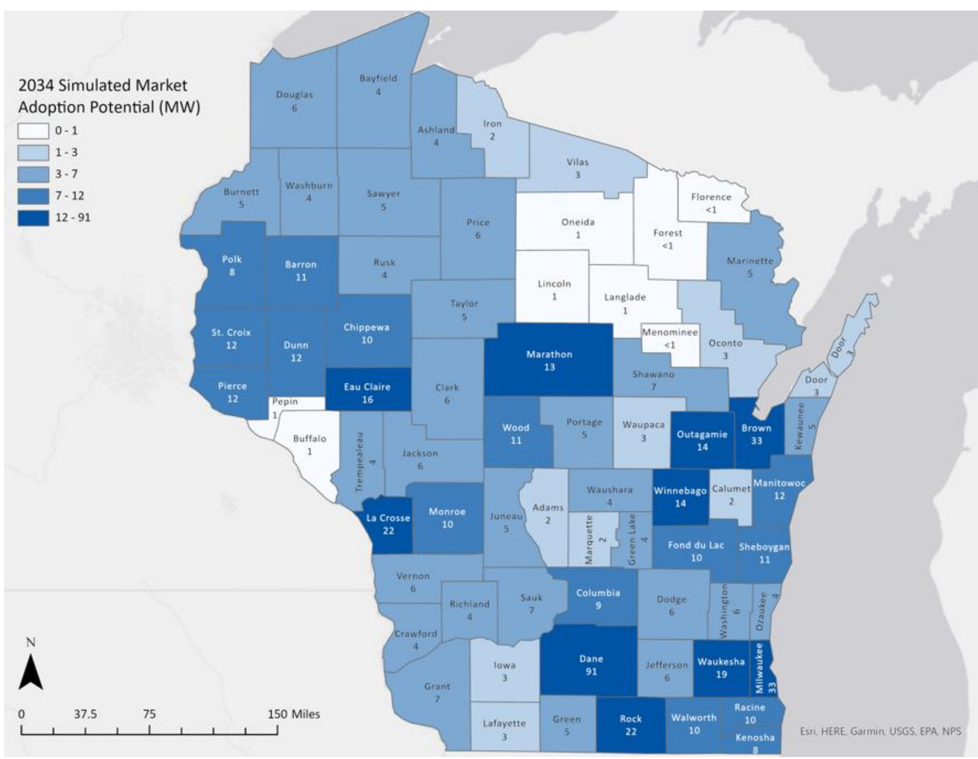


Table 17 and Figure 6 show the simulated rooftop solar PV market capacity for the residential (standard income and income qualified) and commercial sectors. The residential simulated market adoption potential rises at a more aggressive rate than the simulated commercial adoption. This difference is primarily due to the model assumptions about the diffusion of solar PV technology between the two sectors. Solar PV technology diffuses through the population of commercial sector adopters more quickly than it does through the population of residential sector adopters. Simulated standard-income market adoption rises more quickly than income-qualified market adoption, owing to the higher discount rate applied to that population segment, which results in a lower modeled payback period.

Table 17. Sector Simulated Market Adoption Potential (MW)

Utility	2024	2026	2028	2030	2032	2034
Residential Standard Income	68.99	89.82	121.82	170.46	231.07	303.57
Residential Income Qualified	30.57	40.11	55.11	77.90	106.66	142.02
Commercial	60.88	77.18	99.39	131.50	157.28	177.85
Total	**160.44**	**207.10**	**276.32**	**379.86**	**495.02**	**623.44**

Figure 6. Sector Simulated Market Adoption Potential (MW)

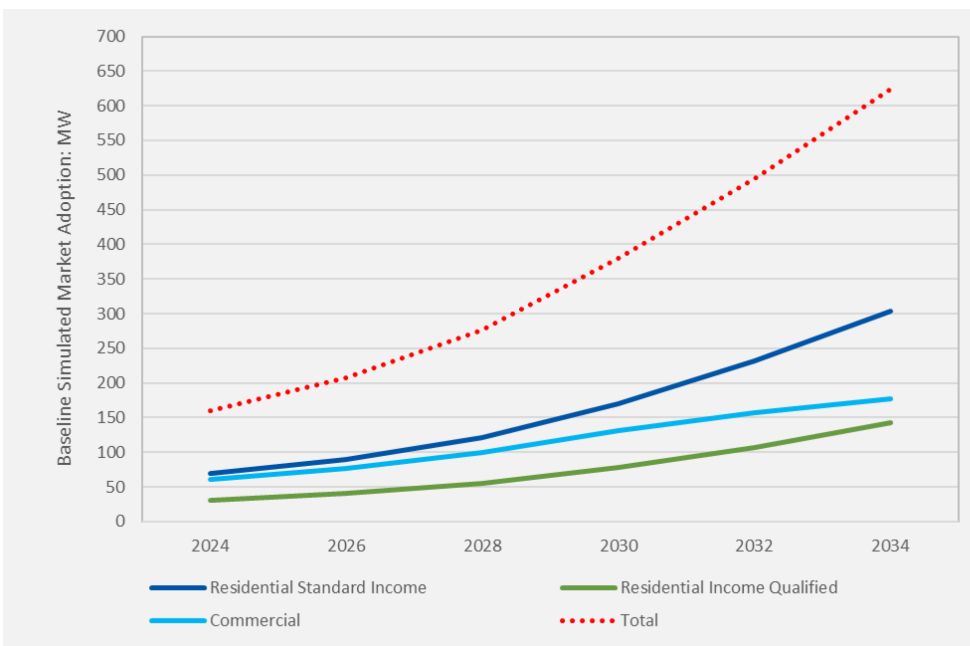
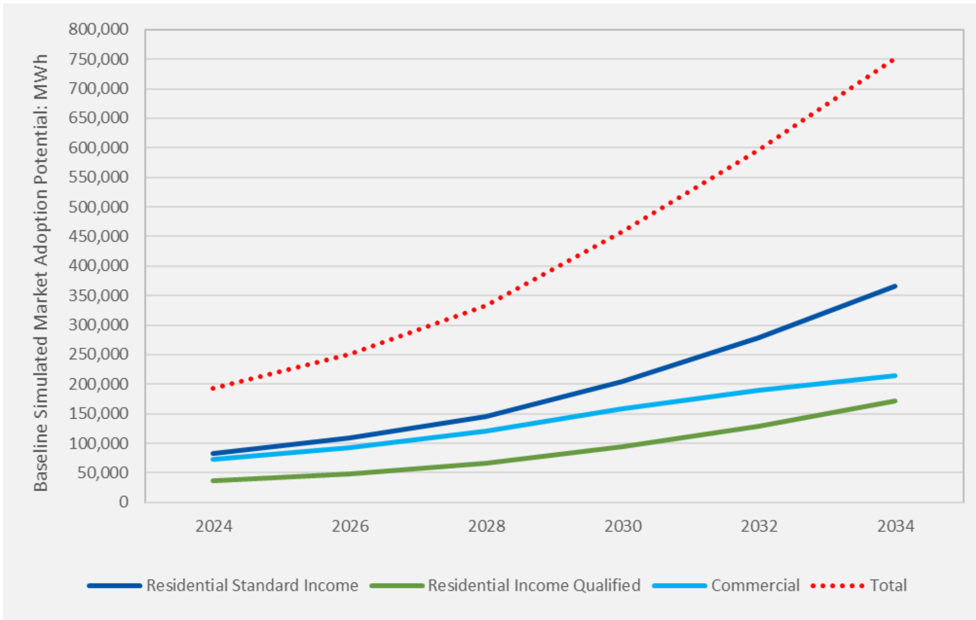


Table 18 and Figure 7 show the simulated rooftop solar PV market energy production for the residential and commercial sectors. The simulated energy production estimates are roughly proportional to the simulated capacity estimate.

Table 18. Sector Simulated Market Adoption Potential (MWh)

Utility	2024	2026	2028	2030	2032	2034
Residential Standard Income	82,994	108,567	145,804	205,046	278,308	365,617
Residential Income Qualified	36,898	48,538	66,841	93,747	128,390	170,838
Commercial	73,636	93,291	120,051	158,774	189,873	214,705
Total	**193,528**	**250,397**	**332,696**	**457,567**	**596,571**	**751,160**

Figure 7. Sector Simulated Market Adoption Potential (MWh)



Residential Simulated Market Adoption Potential

Residential simulated market adoption potential is primarily concentrated in the single-family homes of the standard-income population segment. However, income-qualified single-family homes also make up a sizeable portion of the residential simulated market adoption potential. Manufactured homes, both in the standard-income and income-qualified population segments, make up a relatively small fraction of the market.[21] Table 19 and Table 20 show the simulated residential capacity and energy production potential.

[21] Solar PV adoption in manufactured homes may include barriers that are not accounted for in the dGen model. These barriers may include different levels of home readiness, metering issues, costs, and feasibility.

Table 19. Residential Simulated Market Adoption Potential (MW)

Segment	2024	2026	2028	2030	2032	2034
Standard Income Single Family	66.24	86.25	117.07	164.02	222.63	292.86
Standard Income Manufactured	2.75	3.56	4.75	6.45	8.44	10.71
Total Standard Income	**68.99**	**89.82**	**121.82**	**170.46**	**231.07**	**303.57**
Income-Qualified Single Family	27.81	36.29	49.78	70.41	96.49	128.56
Income-Qualified Manufactured	2.75	3.82	5.33	7.49	10.17	13.46
Total Income-Qualified	**30.57**	**40.11**	**55.11**	**77.90**	**106.66**	**142.02**
Total Residential	**99.56**	**129.92**	**176.93**	**248.36**	**337.74**	**445.59**

Table 20. Residential Simulated Market Adoption Potential (MWh)

Segment	2024	2026	2028	2030	2032	2034
Standard Income Single Family	79,527	104,173	139,901	197,017	267,901	352,304
Standard Income Manufactured	3,467	4,394	5,902	8,029	10,408	13,313
Total Standard Income	**82,994**	**108,567**	**145,804**	**205,046**	**278,308**	**365,617**
Income-Qualified Single Family	33,483	43,717	60,258	84,453	115,742	154,256
Income-Qualified Manufactured	3,415	4,821	6,583	9,294	12,648	16,582
Total Income-Qualified	**36,898**	**48,538**	**66,841**	**93,747**	**128,390**	**170,838**
Total Residential	**119,891**	**157,106**	**212,645**	**298,793**	**406,698**	**536,455**

Commercial Simulated Market Adoption Potential

In the commercial sector, retail business, warehouses, offices, and schools make up most of the simulated market adoption potential (see Table 21 and Table 22). Although warehouses, due to their large square footage, make up significant proportion of the technical potential, their contribution to simulated market adoption potential is relatively modest. This is a result of the relatively smaller loads for the warehouse building segment, which constrain the dGen model maximum system adoption (systems are designed to offset customer loads).

Table 21. Commercial Simulated Market Adoption Potential (MW)

Segment	2024	2026	2028	2030	2032	2034
Healthcare	3.34	4.05	5.08	6.62	7.76	8.65
Lodging	0.92	1.19	1.56	2.11	2.55	2.88
Multifamily	1.08	1.35	1.76	2.42	3.03	3.55
Office	8.59	10.91	13.93	17.98	21.17	23.73
Restaurant	3.04	3.88	5.01	6.50	7.68	8.56
Retail	25.78	33.48	43.75	58.22	69.21	77.54
School	8.41	10.09	12.31	15.59	18.11	20.20
Warehouse	9.72	12.21	15.98	22.06	27.77	32.75
Total Commercial	**60.88**	**77.18**	**99.39**	**131.50**	**157.28**	**177.85**

Table 22. Commercial Simulated Market Adoption Potential (MWh)

Segment	2024	2026	2028	2030	2032	2034
Healthcare	4,074	4,932	6,168	8,037	9,411	10,488
Lodging	1,114	1,434	1,885	2,546	3,069	3,466
Multifamily	1,343	1,679	2,184	3,000	3,762	4,410
Office	10,354	13,160	16,803	21,691	25,542	28,640
Restaurant	3,672	4,676	6,020	7,813	9,225	10,276
Retail	31,247	40,537	52,909	70,345	83,588	93,617
School	10,130	12,161	14,836	18,780	21,804	24,312
Warehouse	11,703	14,712	19,246	26,563	33,473	39,496
Total Commercial	**73,636**	**93,291**	**120,051**	**158,774**	**189,873**	**214,705**

Economic Scenarios

Cadmus developed economic scenarios to test the sensitivity of simulated market adoption potential to four discrete financial influences: transitioning the entire Wisconsin market to net metering–based customer compensation, increasing incentives, providing attractive financing (reducing the project financing interest rate by 1% and requiring no down payment), and extending the federal ITC by three years.

In the net metering scenario, Cadmus assumed that all utilities in Wisconsin would offer net metering compensation, compared to the baseline assumption where some utilities offered net metering compensation and other utilities compensate customers for excess generation through net billing. Another change in the net metering scenario was to adjust the size limits on net-metered systems. In the baseline assumption net metering size limits varied by utility, and in the net metering scenario all system size limits were set to 500kW. Table 23 shows the baseline and net metering scenario assumptions for each utility.

Table 23. Baseline and Net Metering Scenario Assumptions for Utilities

Utility	Baseline (if not net metering)	Baseline Size Limit (kW)		Net Metering Scenario Size Limit (kW)	
		Commercial	Residential	Commercial	Residential
Madison Gas and Electric		100	100	500	500
Wisconsin Electric Power Company	Net billing	300	300	500	500
Wisconsin Power and Light	Net billing	20	20	500	500
Wisconsin Public Service	Net billing	20	20	500	500
Xcel Energy		100	100	500	500
Other		20	20	500	500

The primary difference between the dGen model treatment of utility customers under a net billing and net metering arrangement is in how generation that is produced in excess of customer direct consumption is valued. Under a net billing scenario dGen assumes that each month's excess generation is valued at the wholesale power rate. Under the net metering arrangement, any excess generation is carried over as credits to following months, where those credits can be applied to reduce the customer utility bill should customer demand exceed rooftop solar production in that month. Customer net energy production consumption is trued up annually. The dGen model limits systems to not produce more energy annually than is consumed by a customer. Because net metering allows excess generation to be valued as offset electric purchases at the utility retail rate and net billing compensates excess generation at the electric wholesale rate (and electric retail rates are higher than wholesale rates), net metering arrangements are more financially attractive from a customer perspective.

In the increased Focus on Energy incentives scenario, Cadmus assumed that commercial incentives per watt would triple relative to the baseline, to be $0.30 per watt. In the residential sector, incentives differed between standard-income and income-qualified customers, to be $0.90 per watt and $1.50 per watt, respectively. Although the scenario values are based on Focus on Energy incentives, the model is agnostic to the provider of the incentives and results do not differ if funding is provided by other entities. For further detail around these assumptions, see Table 5.

In the attractive financing scenario, Cadmus assumed that the residential and commercial sector both have a down payment fraction of 0% and interest rate of 2.5%. In the baseline, the customer is held to a down payment fraction of 20% and the interest rate is 3.5%. Finally, we modeled the extended ITC scenario under the assumption that the current ITC schedule is extended for three more years, such that the ITC is expired after 2027 for residential customers and is reduced to 10% for commercial customer after 2027.

As illustrated in Table 24 and Figure 8, all economic scenarios lead to a simulated increase in market adoption. However, the statewide net metering scenario, in which all utilities would compensate customers for excess generation based on utility rates, would have the greatest impact. The increase in potential capacity adoption from the baseline scenario to the statewide net metering scenario is driven by three of Wisconsin's utilities (Wisconsin Electric Power Company, Wisconsin Public Service Commission, and Wisconsin Power and Light) switching from net billing to net metering.

Table 24. Economic Scenario Simulated Market Adoption Potential (MW)

Scenario	2024	2026	2028	2030	2032	2034
Baseline	**160.44**	**207.10**	**276.32**	**379.86**	**495.02**	**623.44**
Statewide Net Metering Policy	196.15	268.33	369.48	508.20	663.11	837.26
Increased Focus on Energy Incentives	181.97	237.69	313.91	423.85	538.16	658.88
Attractive Financing	168.96	219.33	293.88	410.45	537.25	674.43
Extended Federal ITC	174.37	240.13	310.35	415.50	531.62	660.22

Figure 8. Total Economic Scenario Simulated Market Adoption Potential (MW)

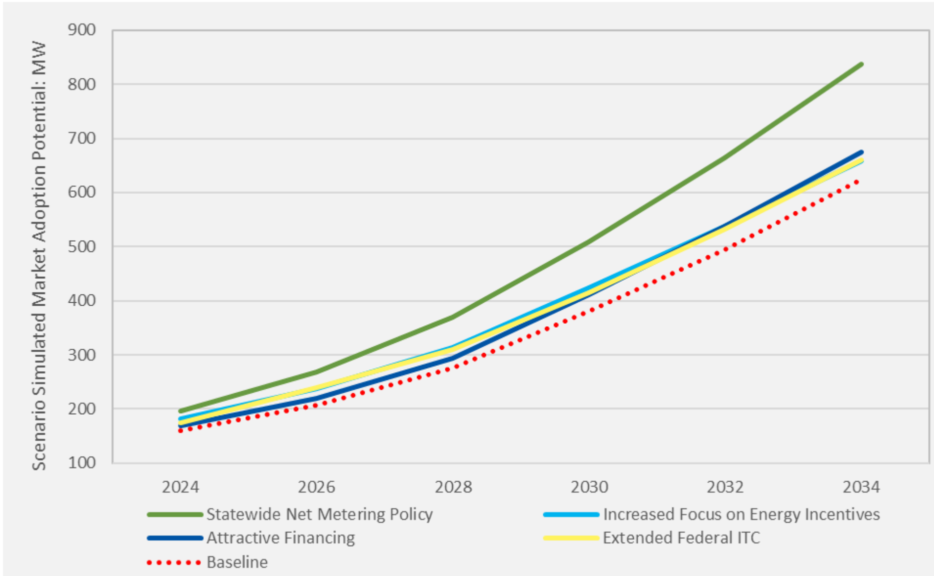


Table 25 shows the economic scenarios' simulated market energy production. The results are roughly proportional to the capacity estimates shown above.

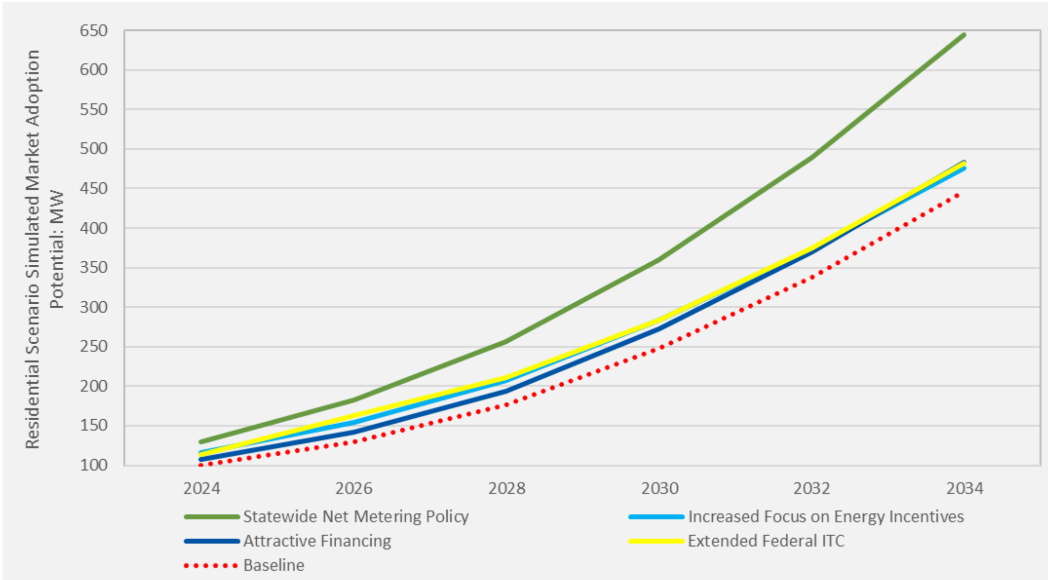
Table 25. Economic Scenario Simulated Market Adoption Potential (MWh)

Scenario	2024	2026	2028	2030	2032	2034
Baseline	**193,528**	**250,397**	**332,696**	**457,567**	**596,571**	**751,160**
Statewide Net Metering Policy	236,774	323,838	445,417	612,429	798,805	1,008,003
Increased Focus on Energy Incentives	219,599	285,884	377,092	510,478	648,439	793,203
Attractive Financing	204,205	263,980	353,960	495,566	648,955	814,082
Extended Federal ITC	209,660	289,346	373,046	500,029	640,288	795,112

The simulated scenario market adoption results for the residential sector (standard-income and income-qualified segments combined) are shown in Figure 9. As illustrated, switching to a statewide net metering policy would have the biggest impact on capacity adoption. However, increased Focus on Energy incentives, attractive financing, and an extension of the federal ITC all lead to increased simulated rooftop solar PV adoption, although their effects are more muted compared to the impacts of the net metering scenario.

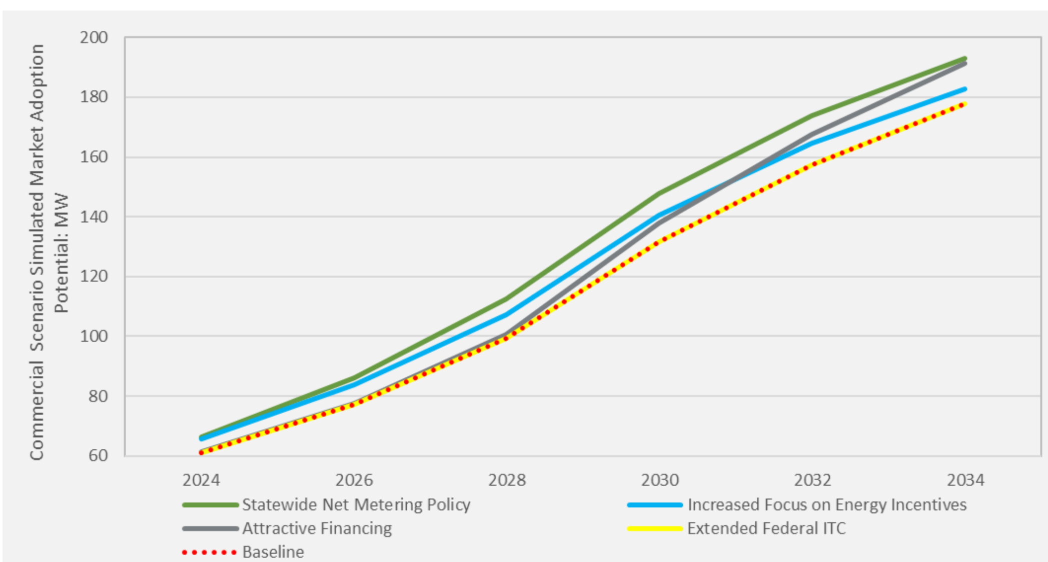
Within the residential sector, the attractive financing and increased Focus on Energy incentives scenarios has a relatively larger impact in the income-qualified population segment compared to the standard-income segment. The increased Focus on Energy incentives scenario is the second-most impactful scenario for the income-qualified customers, while for standard-income customers the total simulated results for this scenario are slightly less than the simulated adoption in the extended federal ITC and attractive financing scenarios.

Figure 9. Residential Scenario Simulated Market Adoption Potential



The simulated scenario market adoption results for the commercial sector are shown in Figure 10. As illustrated, switching to a statewide net metering policy would have the biggest impact on capacity adoption. However, attractive financing would have a strong impact on simulated market adoption potential as well. The simulated longer-run effects of increased Focus on Energy incentives and extended federal ITC, which does not increase simulated market adoption potential, are muted compared to the other scenarios.

Figure 10. Commercial Scenario Simulated Market Adoption Potential



In addition to estimating simulated market adoption potential nameplate capacity, Cadmus used weather data from NREL's PVWatts Calculator to determine how the adoption of solar technology relates to the summer peak period in Wisconsin. Cadmus used Focus on Energy's current peak period definition of weekdays in June through August between 1 p.m. and 4 p.m. Figure 11 shows the normalized 2019 load and 2034 solar generation for an average weekday in the summer (June through August). The peak period is shaded in light blue on the graph. As illustrated in Figure 11, the 2019 historical peak load overlaps with a large portion (42%) of the solar generation on an average summer weekday.

Figure 11. Normalized Summer Weekday Solar Generation and Historical Load

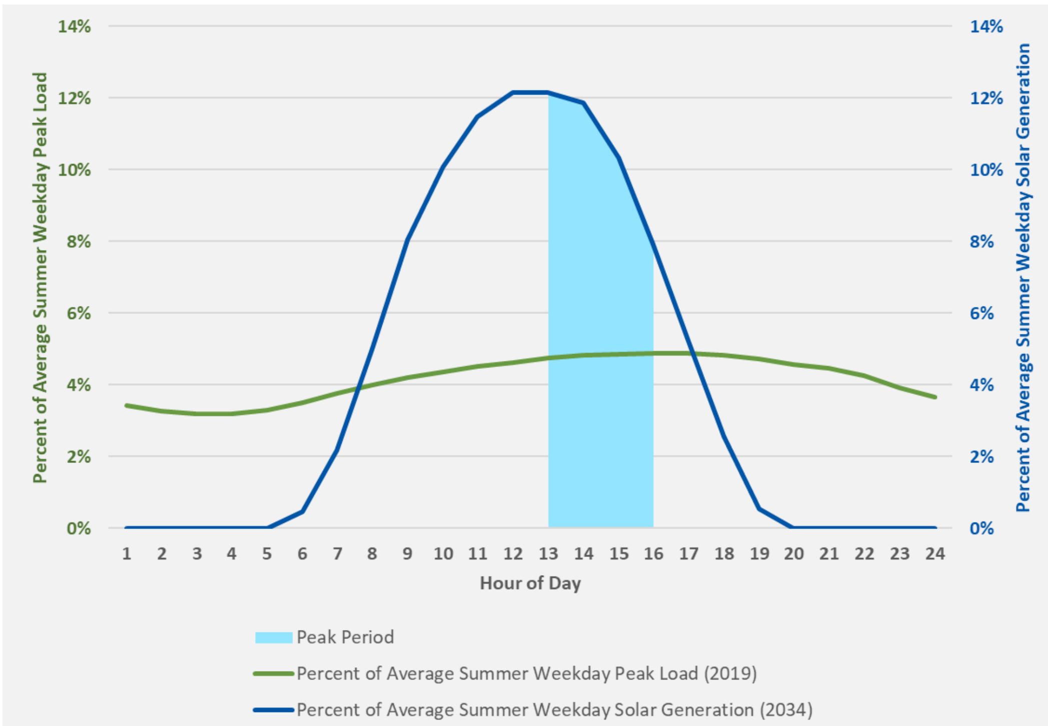


Table 26 shows the residential peak period generation capacity associated with simulated market adoption potential. In the baseline scenario, the residential solar PV peak generation capacity in 2034 is 181 MW. The net metering scenario provides the greatest amount of peak period generation capacity, at 262 MWs in 2034.

Table 26. Residential Solar PV Potential Scenarios – Peak Period Generation Capacity MW

Economic Scenario	2024	2026	2028	2030	2032	2034
Baseline	**41**	**53**	**72**	**101**	**138**	**181**
Statewide Net Metering Policy	53	74	105	147	199	262
Increased Focus on Energy Incentives	47	62	84	115	152	194
Attractive Financing	44	58	79	111	151	197
Extended Federal ITC	46	66	86	115	152	196

Table 27 shows the commercial peak period generation capacity associated with the capacity adopted through the simulated market adoption potential for each economic scenario. The scenario showing the greatest peak period generation capacity in 2034 is the statewide net metering policy, with 82 MW of reduction. The baseline and extended federal ITC are slightly lower, accounting for an 82 MW peak period generation capacity in 2034.

Table 27. Commercial Solar PV Potential Scenarios – Peak Period Generation Capacity MW

Economic Scenario	2024	2026	2028	2030	2032	2034
Baseline	**26**	**33**	**42**	**56**	**67**	**75**
Statewide Net Metering Policy	28	36	48	63	74	82
Increased Focus on Energy Incentives	28	36	45	60	70	77
Attractive Financing	26	33	43	58	71	81
Extended Federal ITC	26	33	42	56	67	75

Cost-Effectiveness Comparison

Cost-effectiveness tests are used to compare the benefits of an action or resource to its costs. A benefit-to-cost ratio above one indicates that the benefits exceed the costs, for that particular test. The specific benefits and costs that are included in a given test depend on the perspective of the selected stakeholder of interest. The most frequently used cost-effectiveness tests compare the benefits and costs accrued to several different types of stakeholders, such as participants, utilities, and society. The total resource cost test compares the energy savings benefits of a program or resource (i.e., avoided energy) to its equipment and installation costs, plus any added administrative costs.

Wisconsin's primary cost-effectiveness metric is the modified total resource cost test (mTRC), which also includes reduced or avoided emissions as a benefit. Cadmus calculated the mTRC cost-effectiveness ratio for a representative residential and commercial solar project based on inputs and methods described in the *Cost-Effectiveness Comparison* methodology section above. Cadmus then selected energy efficiency measures from the *2021 Focus on Energy Potential Study* to serve as comparison points.

We chose comparison measures based on their similarities in installation cost and measure type (equipment), also selecting those that use the same fuel (electric). Cadmus focused on high-cost electric measures, rather than lower cost measures (such as lightbulbs) or portfolio-wide energy efficiency in general, in order to compare systems with similar customer considerations, such as high upfront costs. Comparisons between the cost-effectiveness of solar PV systems and low-cost or otherwise ill-matched measures would have been less informative and could easily be misinterpreted.

The mTRC cost-effectiveness test is designed to measure the overall impacts of the benefits and costs of energy efficiency and distributed solar projects on the state of Wisconsin. As some of the project-related costs and benefits are not neutral between parties, such as incentives or avoided electric payments, not all costs and benefits are included in this test. Additional tests can explore cost-effectiveness from different perspectives and include other costs and benefits, such as incentives. A full description of the various standard cost-effectiveness test can be found in Appendix H of the 2020 Focus on Energy Evaluation report.[22]

When drawing these comparisons it is important to consider that, for energy efficiency measures, both the cost and energy savings are calculated as incremental to baseline equipment assumptions. In other words, the mTRC cost associated with an efficient air conditioner, is the difference between the price of a standard (or baseline) air conditioner and the more efficient model. For rooftop solar PV projects there is no baseline condition from which to calculate incremental costs or savings.

[22] Cadmus, Focus on Energy Calendar Year 2020 Evaluation Report VOLUME III APPENDICES, May 21, 2021. www.focusonenergy.com/sites/default/files/inline-files/Evaluation_Report-2020-Volume_III.pdf

Residential mTRC Comparison

The mTRC cost-effectiveness ratio for a representative residential rooftop solar PV project is 0.88. This ratio is higher than some high-cost energy efficiency measures, such as advanced air-source heat pumps (those that are similar to the most efficient ENERGY STAR options) or carbon dioxide heat pump water heaters, but it is lower than ENERGY STAR (base efficiency model) air-source heat pumps or heat pump water heaters. One primary driver of the lower-cost-effectiveness result for residential rooftop solar PV relates to the installed equipment costs. In comparison to commercial rooftop solar PV costs, residential installed costs were roughly 80% higher in 2020. The higher installed costs have a direct correlation to lower mTRC results, since incremental measure costs typically comprise the largest portion of costs under the mTRC test.

Table 28. Residential mTRC Comparison

Measure Name	mTRC
Residential Rooftop Solar PV Project	0.88
Heat Pump - Air-Source Advanced	0.82
Heat Pump Water Heater – ENERGY STAR	1.12
Heat Pump - Air-Source ENERGY STAR	1.34
Carbon Dioxide Heat Pump Water Heater	0.20

Commercial mTRC Comparison

The mTRC cost-effectiveness ratio for a representative commercial rooftop solar PV project is 1.48. This ratio is higher than for the representative residential project given the lower commercial project costs. The representative commercial rooftop solar PV cost is lower than many high-cost commercial equipment measures, although it is higher than advanced efficiency chillers.

Table 29. Commercial mTRC Comparison

Measure Name	mTRC
Commercial Solar Rooftop Solar Project	1.48
Chillers >300 tons (centrifugal) - Advanced Efficiency (Water Cooled)	1.25
Direct Expansion Package 240 to 760 kBtuh - Premium Efficiency	3.35
Water Heater LE 55 Gal - Heat Pump - Enhanced Efficiency	3.53
Water Heater LE 55 Gal - Heat Pump Water Heater - Advanced Efficiency	3.14

Income-Qualified Research

Cadmus identified best practices for overcoming barriers to encourage a wider adoption of solar among income-qualified communities. Cadmus conducted primary and secondary research about barriers and opportunities for delivering programs that promote rooftop solar PV adoption in the income-qualified population segment.

Best Practices for Driving Solar Adoption in Income-Qualified Communities

In a report prepared for the Urban Sustainability Directors Network,[23] Cadmus identified 12 principles of equitable clean energy program design, as shown in Table 30. To determine how these principles should be considered specifically for rooftop solar adoption in Wisconsin, Cadmus benchmarked five exemplary rooftop solar programs, reviewed Wisconsin energy and solar policies to understand how existing legislation may create barriers or opportunities for income-qualified solar adoption and interviewed eight solar program stakeholders.

Table 30. Guiding Equity Principles for Increased Solar Adoption

Equity Program Best Practices	Considerations
Listen and respond	Stakeholders designing programs that target income-qualified populations should first listen to the communities they seek to serve. Program design should be as responsive as possible to the needs expressed by community members, and stakeholders designing programs should be transparent about their resources. Ideally, community engagement would build from preexisting connections and help define program goals. One interviewed solar program administrators said their organization, "did a lot of brainstorming with community-based organizations" to design their income-qualified solar program. The interviewee said the approach was different from how they had approached designing solar programs in the past, when they "would partner primarily with installers, and so the challenges we anticipated were based on only that perspective. For the income-qualified solar program, we asked community-based organizations to submit for grant funding requests to research LMI [low- and moderate-income] solar adoption [trends] and used their findings to guide [the] design."
Partner with trusted community organizations	Stakeholders should work with community organizations to design and deliver programs and, where applicable, should help build the capacity of community organizations through the partnership. One of the interviewed solar program administrators stated, "part of the legislation that mandated our income-qualified solar program included funding for grassroots organizations. We elevated contracts with community organizations to increase education efforts. The community organizations plant the seeds and ideas about solar adoption [in income-qualified communities]. There's also a trust issue. Ours is a new program, solar is new [to these communities], and now [the income-qualified residents] are being approached by commercial entities [solar developers and/or utilities]. That's another role of the grassroots organization education: to build up a level of trust in the program."
Recognize structural racism	Programs targeting income-qualified households will not necessarily serve all disadvantaged populations. Racial analysis and baseline data must be part of an inclusive program design process to understand and address structural barriers that exist beyond income.

[23] Cadmus. September 2018. *A Guidebook on Equitable Clean Energy Program Design for Local Government and Partners*. Prepared for Urban Sustainability Directors Network.

Equity Program Best Practices	Considerations
Prioritize efficiency first	Programs should be designed to ensure that income-qualified households can access energy efficiency benefits as a key step to reducing energy burden and increasing household health and comfort. Partner with local utilities and state agencies that offer weatherization and other efficiency program benefits to income-qualified households. One interviewed solar program administrator indicated that income-qualified participants of their solar program are required to also participate in the utility's weatherization program.
Reduce financial burden	Programs should not add financial burden to income-qualified households and should aim to reduce financial and other burdens.
Increase benefits	Programs should seek to deliver services beyond clean energy technologies and to capitalize on co-benefits, such as job creation or community resilience for people of color, indigenous communities, and other historically underserved and underrepresented populations. One interviewed solar program administrator said, "our income-qualified solar program offers solar installation funding for community action agencies. We are investing in the CAAs [community action agencies] so they can do more within their communities." Another interviewed solar program administrator said, "throwing money at [income-qualified residents for solar installation] isn't going to completely solve the issues around solar adoption. There are other barriers, such as education, trust, and time available to participate. Programs must make sure they're throwing money at the right thing—such as roof replacement and other repairs."
Make it easy	Program participation should be as easy as possible for any household with effective, efficient, and culturally competent program design, outreach, and delivery. One interviewed solar program administrator said their program tried to streamline the enrollment process by, "not having any formal income verification process. Participants just have to sign a document confirming they are eligible. We didn't want to add red tape to burden [of the installation process]. We trust our customers and contractors making the decisions."
Integrate with other services	Wherever possible, programs should align with other services for income-qualified households. An interviewed stakeholder in Wisconsin indicated, "one of the main ways to best make income-qualified individuals aware of new programs [including solar] is through energy assistance programs. The word gets out pretty widely for energy assistance, so these avenues could be leveraged to increase awareness and education."
Protect consumers and workers	Programs should carefully consider consumer and workforce protection elements and include consumer education to avoid unintended consequences. Since income-qualified communities generally have not been targeted for clean energy investments in the past, clearly communicating the long-term benefits can be challenging.[a] One of the interviewed solar program administrators said high-quality installation is a form of consumer protection, "we inspect the first five projects of any installer, and then inspect 20% of every installer's projects moving forward."
Go beyond carve-outs	Programs should do more than set aside a small portion of benefits for income-qualified households and, where possible, should center the needs of income-qualified households and other historically underserved communities in program design and delivery.
Track progress	Programs should establish and assess against baseline equity data—both quantitative and qualitative—to inform program design, establish metrics, and track progress.
Make a long-term commitment	Programs should provide support for income-qualified households beyond installing a clean energy technology, and should include structures for helping with technology service, upkeep, and repair. Third-party ownership of clean energy systems transfers the burden of ongoing maintenance costs away from the resident.

[a] National Renewable Energy Laboratory. n.d. "Low- and Moderate-Income Solar Policy Basics." https://www.nrel.gov/state-local-tribal/lmi-solar.html

Barriers and Solar Adoption Opportunity for Income-Qualified Customers

For income-qualified households, common barriers to rooftop solar include the high upfront costs, home readiness deferrals, and limited accessibility for multifamily residents. The following sections provide insights to overcome these barriers and create opportunities to encourage a greater adoption of solar among income-qualified communities.

Minimize Cost Burden

> "If you're struggling to pay your energy bill each month, in what world are you going to even consider the costs of installing solar?" – Solar Program Administrator

Solar programs typically offer incentives for upfront costs, provide ongoing incentives, or both. Upfront incentives help residents cover the initial costs of the project while ongoing incentives are typically to provide money—either in the form of on-bill credits or checks—based on system size and performance to incent for the solar credits generated through the system. Rooftop solar PV can have significant upfront costs, and high credit scores are often necessary for no-money down loan or leasing program models.

Interviewed stakeholders agreed that the largest barrier for income-qualified residents to install rooftop solar is the upfront cost. Between potential repair, installation, and permitting costs, the upfront cost of installing a solar panel system can often be too much for an income-qualified resident to even consider. In addition, rooftop solar presents ongoing maintenance costs for the life of the solar panels. A solar program meant to increase equity in adoption must include considerations for all of these costs and be designed for income-qualified residents. In its research, the Lawrence Berkley National Laboratory found evidence that programs with non-targeted income-qualified incentives do not increase equitable adoption.[24] To ensure that the incentive structure of a rooftop solar program is well-suited for income-qualified individuals, consider two options:

- ***Ensure that incentives are available for the upfront costs.*** Even if a program typically only offers ongoing incentives, consider allowing income-qualified participants to forgo the ongoing incentive to receive the maximum amount to put towards the upfront cost of their system. This way, customers' energy bills are reduced since they are using less energy from the grid, and they are able to reduce the upfront cost burden of installation.
- ***Provide grants or incentives rather than loans.*** Loans do not relieve the cost burden of installation—only delay it. This does not help make solar access equitable since income-qualified residents would still have to pay off the debt.

The benchmarked exemplary programs provided a range of incentives for customers, as shown in Table 31. For income-qualified residents, programs that cover 100% of upfront project costs are ideal.

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[24] Lawrence Berkley National Laboratory. December 3, 2020. "The Impact of Policies and Business Models on Income Equity in Rooftop Solar Adoption." Presentation at the Clean Energy States Alliance. https://www.cesa.org/event/the-impact-of-policies-and-business-models-on-income-equity-in-rooftop-solar-adoption/

However, in order to serve a sizable number of residents, it may not be possible to cover 100% of project costs for each participant. A program must consider this trade-off when determining its goals.

Additionally, a program also must consider if cost-effectiveness requirements will impact the design or goals of the program, because programs can often be constrained by cost-effectiveness requirements. However, income-qualified-focused programs typically have more lenient cost-effectiveness requirements than market rate programs, and some states do not require income-qualified programs to be cost-effective at all. This principle could be applied to income-qualified solar programs as well. One program administrator interviewee mentioned that their income-qualified program does not take on cost-effective projects, since the income-qualified program is meant to support projects that could otherwise not receive support.

Table 31. Benchmarked Program Incentive Types

Program Name	Program Sponsor	Incentive Structure	Percentage Upfront Cost Covered
Solar for Your Home/ Solar within Reach	Energy Trust of Oregon	Offers ongoing incentive/solar credit based on capacity size with increased incentives for income-qualified residents. Income-qualified residents may forgo the ongoing incentive to receive the maximum per-household incentive amount upfront.	30% to 50%
Illinois Solar for All	Illinois Power Agency	Incentives/renewable energy credits go to approved installers/developers for each project, so the customer does not incur any upfront costs for installing the system. Protections are in place for participants so the cost of ongoing utility bill payments do not exceed the solar credits generated from the system.	100% for the resident
Solar Rewards	Xcel Energy (Minnesota)	Offers ongoing incentive based on capacity size. Income-qualified residents receive a capacity-based upfront incentive as well.	40% to 70% for single family homes; 20% to 35% for multifamily properties [a]
Washington DC Solar for All	DC Department of Energy and Environment	Installs the solar PV system at no cost to the resident; resident benefits from decreased utility bills and excess energy goes back to the grid.	100% for the resident; about 50% to developers/installers

[a] This is based on the average per-watt cost being $3 to $5.

The solar potential study model Cadmus developed also assumed that 50% of standard-income customers would adopt a rooftop solar system with a six-year payback period; three interviewees said this assumption is likely reasonable for income-qualified customers as well. However, four interviewees said upfront cost is a higher priority metric than payback period for income-qualified customers' decision-making. Similarly, three interviewees specifically indicated that income-qualified customers value money now more than money later.[25] Income-qualified customers do not typically have much

[25] Standard-income customers and income-qualified customers apply different implicit discount rates when making investment decisions; in other words, income-qualified customers value dollars they will receive later less than dollars they have to spend immediately.

disposable income, so paying upfront for something (such as a solar system) means they are sacrificing the payment of something else.

Wisconsin does not currently permit third-party ownership of solar PV,[26] but interviewees said that this type of legislation encourages third-party sponsorship of rooftop solar offerings through power purchase agreements.[27] The largest benefit of third-party ownership is the elimination of initial upfront costs; however, for programs targeting income-qualified households, a contract agreement should ensure that a customer's savings from energy generated would exceed lease or power purchase agreement payments. According to the Lawrence Berkeley National Laboratory, leasing agreements are a proven, effective intervention for increasing adoption equity for low- and moderate-income residents.[28]

"Our underlying value is that there are consumer protections in place. We follow the 'do no harm' model to make sure we're not establishing something that would inadvertently get people who are already struggling into a situation where [solar] is going to hurt them. There can be all sorts of financial structures [in a program], but at no time is there a point that someone would be paying more for electricity than they are now." – Solar Program Administrator

Three of the benchmarked exemplary programs allow for third-party ownership, with varying policies:

- ***Illinois Power Agency Illinois Solar for All program:*** Includes protection agreements for participants that choose third-party ownership by making the third party agree that the resident's monthly energy payment will not exceed 50% of the value of the energy produced in a given month.
- ***Xcel Energy Solar Rewards program:*** Allows third-party installers to receive the renewable energy credits or excess energy benefits from the system while the resident still receives the benefit of having lower utility bills.
- ***DC Department of Energy and Environment Washington DC Solar for All program:*** Covers 100% of project costs and allows the resident to benefit from lower energy bills while sending all excess energy back to the grid. Developers and installers receive 50% reimbursement of project costs from the program and receive payback through renewable energy credits.

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26 NC Clean Energy Technology Center and U.S. Department of Energy Office of Energy Efficiency & Renewable Energy. March 2018. "3rd Party Solar PV Power Purchase Agreement." PowerPoint presentation. http://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2018/03/DSIRE_3rd-Party-PPA_March_2018.pdf

27 Through power purchase agreements, a third party installs solar on a home and the resident pays the installer for the energy produced by the system, typically on either a per-kilowatt-hour or a monthly basis.

28 Lawrence Berkley National Laboratory. December 3, 2020. "The Impact of Policies and Business Models on Income Equity in Rooftop Solar Adoption." Presentation at the Clean Energy States Alliance. https://www.cesa.org/event/the-impact-of-policies-and-business-models-on-income-equity-in-rooftop-solar-adoption/

Similarly, Wisconsin has not adopted administrative rules for net metering.[29] Net metering laws enable customers with rooftop solar to be credited for feeding excess electricity generated back to the grid. Interviewees said that the lack of standardized net metering rules makes it hard for installers, program administrators, and property owners to understand what they can and cannot do related to solar development in the state. One interviewee said a standardized rule regarding net metering would help solar advocates to explain net metering benefits to those who may be interesting in pursuing solar and would encourage more solar development programs in Wisconsin.

Support Home Readiness

Home readiness challenges, such as updating electric systems and making roof repairs, can present a burden to income-qualified residents who are interested in rooftop solar. Since income-qualified housing typically has health and safety concerns, it is possible that residents will incur repair costs before solar panels can even be installed.[30] To overcome some of these additional cost constraints, consider two options:

- ***Provide incentives for more than just the cost of installation.*** Though a program should cover part (or all) of the installation costs for income-qualified individuals, there should be funds available to help cover the costs of any repairs that need to be made to the building to allow for the installation, as well as for any permitting, connection, or insurance costs that may be associated with installing solar PV. A program administrator interviewee noted that if the program structure does not allow for direct funds for these additional costs, they could consider incorporating them in the payback structure to justify a higher incentive for income-qualified residents.
- ***Encourage energy efficiency upgrades in addition to solar installation.*** Saving energy is less expensive than producing energy. Partner with programs that offer energy efficiency upgrades to decrease the payback period for the system overall (thus decreasing installation costs covered by program incentives). Net metering becomes more advantageous when a resident uses less energy.

Consider Participation Options for Multifamily Residents

Rooftop solar programs typically target single-family homeowners. However, according to NREL, income-qualified communities generally have lower rates of homeownership and are more likely to live in multifamily and affordable housing units, which translates into having less control over decisions about rooftop solar.[31]

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[29] NC Clean Energy Technology Center. November 30, 2018. "DSIRE: Net Metering." https://programs.dsireusa.org/system/program/detail/235

[30] Cadmus. September 2018. *A Guidebook on Equitable Clean Energy Program Design for Local Government and Partners*. Prepared for Urban Sustainability Directors Network.

[31] National Renewable Energy Laboratory. n.d. "Low- and Moderate-Income Solar Policy Basics." https://www.nrel.gov/state-local-tribal/lmi-solar.html

For multifamily housing, rooftop solar programs can be designed to incentivize building owners to share savings with income-qualified tenants. Interviewees said there is a lot of potential for solar on multifamily properties in Wisconsin, but programs have to offer property owners enough of an incentive to make the payback period enticing. One example of overcoming this barrier is the Solar on Multifamily Affordable Housing program in California, in which the program uses upfront rebates to reduce the cost of installing solar and requires that tenants receive the full economic benefit of solar credits.[32]

"Generally, one of the areas of greatest potential is retrofitting existing multifamily buildings: 99% of them don't have [solar or energy-efficient upgrades]. A program [to fill this gap] would be huge! There are millions of these units in Wisconsin."
– Wisconsin Solar Stakeholder

The Illinois Solar for All program offered by the Illinois Power Agency is open to multifamily properties with income-eligible residents as well, allowing for property owners to enter leasing or power purchase agreements rather than having to pay to install the panels upfront. Xcel Energy's Minnesota Solar Rewards program also includes an upfront incentive based on the capacity of the solar array for multifamily properties.

For solar PV to provide maximum benefits to tenants and landlords, submetering needs to be possible.[33] Multifamily properties constructed in Wisconsin after March 1, 1980, are required to use electric submeters; however, converting an older, master-metered building to submeters can be very expensive, which increases the payback period for a solar system. A Wisconsin stakeholder interviewee indicated that virtual net metering can be a cost-effective solution to sub-metering retrofits. Virtual net metering is a utility rate structure or a tariff arrangement that enables a property owner to allocate the overall property's solar system energy credits to individual tenants and to the property owner's account. Through virtual net metering, instead of the solar feeding directly into the building's common area or units, it goes back to the grid. The partnering utility tracks the energy generated and credits the landlord and tenant accounts in accordance with a pre-arranged allocation agreement (determined at the time of installation), allowing both tenants and property owners to receive decreased utility bill benefits.

Equity Framework

Cadmus synthesized the findings from the income-qualified research to develop an equity framework that provides guiding principles and questions for stakeholders to consider as they develop approaches to drive the adoption of solar systems by income-qualified customers. The equity framework is included below.

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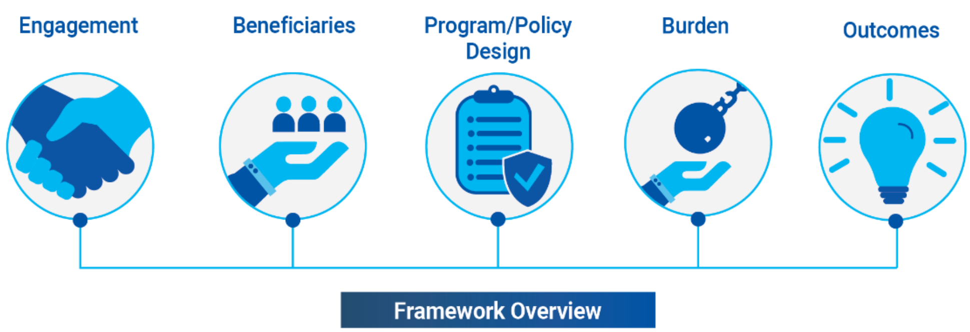
32 Low-Income Solar Policy Guide. 2016–2021. "California." https://www.lowincomesolar.org/best-practices/multi-family-california/

33 Wisconsin allows landlords and property managers to install submetering systems and bill residents for individualized utility usage: Wisconsin State Legislature. May 2019. "Chapter PSC 113: Service Rules for Electrical Utilities." https://docs.legis.wisconsin.gov/code/admin_code/psc/113/VIII/0802/3

Equity Framework for Income-Qualified Rooftop Solar Program Design



The questions below provide a framework for program stakeholders to use to embed equity into planning for and implementing rooftop solar programs that target income-qualified communities.

Engagement

DESIGN

- Did the program engage local, community organizations to help understand the target population and establish trust?
- Was the program developed based on data/outreach gathered regarding the needs of the target population?
- Does the program include funds to educate the market (consumers/workforce)?

IMPLEMENTATION

- Who are the parties involved in the implementation of the program and what are their roles?
- How is the program going to engage participants?
- Does the program's recruitment strategy include varying channels to accommodate for populations with disabilities, who speak a primary language other than English, or who have a technological illiteracy.

Beneficiaries

WHO

- Who is the program advocating on behalf of?
- Who is eligible for the program?
  - Who is the target population?
  - What housing types are eligible?
  - Who is not included?

HOW

- How will eligibility be verified?
- Does the program make efforts to target multilingual participants (such as with multilingual applications, program staff, and marketing materials)?
- What languages, other than English, will the program accommodate?
- Does the program benefit a workforce, supply chain, or another area of the market?

Program/Policy Design

PROGRAM

- What is the program advocating for? Why?
- What is the program offering to participants?
- Will the program initially launch as a pilot?
- What are the available ownership structures through the program?
- What incentives does the program offer?
    - Who are incentives paid to?

- Does the program:
    - Have consumer/workforce protections in place?
    - Partner with other available energy and housing programs?
    - Encourage energy-efficiency prior to participation?
    - Ensure high-quality installation and ongoing maintenance for participants?

POLICY

- To what extent does local policy allow for:
    - Net metering?
    - Virtual net metering?

Burden

FINANCIAL

- Does the program minimize participant costs (without increased debt burden)?
    - Installation costs?
    - Insurance/permitting costs?
    - Structural or safety repair costs?
    - Metering changes or connection fees?
    - Ongoing panel/system maintenance costs?
- Does the program offer ongoing incentives to participants?
    - Net metering?
    - Solar credits?

ADMINISTRATIVE

- Does the program provide the following support to participants:
    - Understanding the application/enrollment process?
    - Choosing a qualified solar installer with a competitive bid?
    - Finding/selecting a contractor for any structural/safety improvements?
    - Securing landlord approval to participate (if eligible)?
    - Securing supplemental incentives/funding sources to further minimize upfront cost (if needed)?

Outcomes

- What are the short-term outcomes of the program?
- What are the long-term outcomes of the program?
- What are the consequences if the program does not have the intended outcomes?
- What are the metrics to measure program success?

Potential Key Performance Indicators:

- Percentage of income-qualified population with rooftop solar
- Achievement of participation targets
- Percentage of participants who transition out of arrears or off bill assistance (if eligible)
- Participant satisfaction
- Greenhouse gas reductions
- Non-energy benefits

Equity Program Development Process

Source:

Cadmus. September 2018. *A Guidebook on Equitable Clean Energy Program Design for Local Government and Partners*. Prepared for Urban Sustainability Directors Network.

Conclusions

Rooftop solar PV systems represent a sizable energy resource from a technical potential standpoint, but only a small fraction of what is technically available is projected to be adopted by 2034. In 2026, Wisconsin rooftops can accommodate approximately 37 GWs of solar capacity and produce 44,183 GWh of electricity, nearly 70% of the statewide generation in 2019. However, despite model simulation indicating an average baseline market adoption growth of 30% annually, only a small fraction of this technical potential is simulated to be actualized by 2034.

Rooftop solar PV technical and simulated market adoption potential are primarily concentrated on single family homes. While there is opportunity in the commercial sector, especially on warehouses, retail businesses, and schools, single family homes make up approximately 62% of technical rooftop potential. Additionally, adoption simulation suggests that the commercial market will reach market saturation well before the residential sector. This is a result of the market diffusion assumptions used by the dGen model to estimate the rate of solar PV adoption in the residential and commercial sectors.

Homes owned or rented by income-qualified households represent a significant fraction of statewide single-family homes. Yet these households face sizeable barriers to adopting rooftop solar systems. Approximately one-third of the single-family technical potential is found in homes owned or rented by income-qualified households. These households, however, face challenges associated with upfront costs, home readiness, and split incentives in multifamily buildings when installing rooftop solar projects. Successful income-qualified rooftop solar programs offer empirical insights on effective approaches to address these key market barriers.

Despite barriers, several options exist to increase income-qualified rooftop solar adoption. Research conducted for this study suggests that Wisconsin solar and energy policies could encourage the adoption of rooftop solar among income-qualified residents with specifications around third-party ownership, reducing upfront costs through rebates and incentives net metering, and virtual net metering.

The most efficacious strategy for accelerating the adoption of rooftop solar systems is through implementation of a statewide net metering policy. While extending the federal ITC, increasing incentives, and offering attractive financing options do lead to increased solar adoption, simulation modeling indicates that a statewide net metering policy would have the largest impact. Modeling results suggest that a statewide net metering policy would primarily increase adoption in the residential sector in utility territories where net billing compensation is not currently offered and where significant rooftop solar potential is concentrated. Net metering is a more attractive compensation scheme from a customer perspective compared to net billing because retail electric rates are higher than wholesale electric rates. Under net metering excess customer generation is valued at retail rates while under net billing excess generation is valued at wholesale electric rates.

Residential and commercial rooftop solar systems are comparable to high-cost, electric energy efficiency measures from an mTRC perspective. While a representative residential rooftop solar project does not pass the mTRC test, its mTRC ratio is comparable to other high-cost, electric energy efficiency measures in the residential sector. A representative commercial rooftop solar project passes the mTRC due to lower costs, but has a value lower than several high-cost commercial energy efficiency measures.

Rooftop solar PV generation overlaps significantly with the summer peak period. During weekdays in June through August, 42% of the average daily solar generation capacity occurs during the peak period of 1 p.m. to 4 p.m. This alignment indicates that the adoption of solar technology would not only reduce overall load, but would also have an impact on the demand during the Focus on Energy peak period.

Appendix A. County-Level Technical Potential

Table A-1. County by County Technical Potential

County	2026		2034	
	MW	MWh	MW	MWh
Adams	112	135,102	119	142,781
Ashland	85	103,202	90	108,452
Barron	397	456,628	425	488,791
Bayfield	71	78,368	74	82,354
Brown	1,734	2,144,736	1,835	2,268,798
Buffalo	93	112,106	99	119,370
Burnett	72	88,296	76	92,788
Calumet	342	402,670	363	426,532
Chippewa	393	460,743	418	489,926
Clark	227	267,453	242	285,592
Columbia	403	474,054	426	501,758
Crawford	118	145,063	125	153,525
Dane	3,014	3,761,038	3,191	3,980,629
Dodge	662	803,253	702	851,040
Door	260	284,842	275	302,192
Douglas	198	245,638	208	258,134
Dunn	289	352,318	308	374,221
Eau Claire	620	706,113	658	749,395
Florence	21	22,228	22	23,359
Fond du Lac	683	781,568	723	826,999
Forest	38	42,048	40	44,187
Grant	358	443,377	380	469,575
Green	301	359,973	319	381,628
Green Lake	138	162,149	147	171,634
Iowa	215	259,247	228	275,144
Iron	31	34,986	33	36,766
Jackson	151	189,033	161	201,457
Jefferson	655	794,427	694	841,506
Juneau	153	185,409	162	196,121
Kenosha	996	1,199,960	1,053	1,268,708
Kewaunee	181	218,691	192	232,145
La Crosse	696	819,192	739	869,837
Lafayette	134	161,226	142	170,978
Langlade	97	115,661	101	121,545
Lincoln	133	154,206	140	162,050
Manitowoc	725	882,400	769	935,186
Marathon	1,003	1,169,862	1,063	1,239,708
Marinette	353	405,346	374	429,370
Marquette	100	116,854	106	123,478
Menominee	11	13,034	12	13,697
Milwaukee	3,896	4,810,151	4,121	5,088,714
Monroe	321	401,300	339	424,194
Oconto	299	360,958	316	382,117

County	2026		2034	
	MW	MWh	MW	MWh
Oneida	157	183,223	165	192,544
Outagamie	1,389	1,666,166	1,472	1,765,706
Ozaukee	651	790,478	688	836,219
Pepin	50	59,736	54	63,702
Pierce	230	279,874	244	297,056
Polk	265	295,713	281	314,434
Portage	583	645,376	618	684,896
Price	81	106,340	85	111,750
Racine	1,304	1,524,189	1,379	1,612,332
Richland	130	153,037	138	162,101
Rock	988	1,199,084	1,044	1,266,762
Rusk	110	134,967	117	143,753
Sauk	512	605,095	542	641,010
Sawyer	82	91,172	86	95,810
Shawano	376	427,815	399	454,258
Sheboygan	887	1,072,701	939	1,135,462
St. Croix	551	641,489	586	681,955
Taylor	98	121,615	103	127,802
Trempealeau	219	252,401	233	269,489
Vernon	167	206,670	177	218,419
Vilas	113	141,428	119	148,622
Walworth	681	823,592	721	871,307
Washburn	74	90,268	78	94,860
Washington	1,048	1,285,003	1,110	1,360,581
Waukesha	2,614	3,173,523	2,764	3,356,229
Waupaca	415	490,201	440	519,634
Waushara	151	173,849	159	183,954
Winnebago	1,251	1,472,746	1,325	1,559,256
Wood	775	950,179	823	1,008,476

Appendix B. County-Level Simulated Market Adoption Potential

Table B-1. County by County Simulated Market Adoption Potential

County	2026		2034	
	MW	MWh	MW	MWh
Adams	0.56	685	2.11	2,614
Ashland	1.23	1,492	4.35	5,269
Barron	3.49	4,074	11.32	12,874
Bayfield	1.15	1,300	4.05	4,543
Brown	11.50	13,937	33.35	40,340
Buffalo	0.47	594	1.43	1,811
Burnett	1.29	1,588	4.59	5,651
Calumet	0.78	921	2.45	2,896
Chippewa	3.49	4,130	9.96	11,692
Clark	1.74	2,097	5.58	6,688
Columbia	2.79	3,326	8.58	10,275
Crawford	1.27	1,595	3.67	4,566
Dane	38.37	46,897	95.22	115,620
Dodge	1.95	2,375	6.27	7,505
Door	1.20	1,397	3.48	3,971
Douglas	2.48	3,105	6.49	8,229
Dunn	4.20	5,117	12.10	14,686
Eau Claire	5.65	6,631	16.17	18,845
Florence	0.11	122	0.46	524
Fond du Lac	3.29	3,853	10.05	11,494
Forest	0.11	127	0.41	461
Grant	2.10	2,594	6.86	8,624
Green	2.12	2,586	5.16	6,095
Green Lake	1.26	1,479	3.75	4,455
Iowa	1.20	1,444	3.40	4,111
Iron	0.48	540	1.59	1,792
Jackson	2.36	3,009	6.11	7,778
Jefferson	1.50	1,854	6.48	8,201
Juneau	1.58	1,975	4.94	6,173
Kenosha	2.03	2,478	7.91	9,798
Kewaunee	2.06	2,546	4.93	6,018
La Crosse	7.45	9,131	21.65	26,514
Lafayette	0.97	1,216	2.74	3,463
Langlade	0.25	304	1.04	1,242
Lincoln	0.25	307	1.01	1,174
Manitowoc	3.50	4,318	12.17	14,995
Marathon	3.73	4,451	13.14	15,443
Marinette	1.56	1,880	5.16	6,115
Marquette	0.49	573	1.93	2,244
Menominee	0.11	141	0.39	460
Milwaukee	9.19	11,243	33.61	41,213
Monroe	3.38	4,248	10.08	12,652
Oconto	1.42	1,654	3.02	3,469

County	2026		2034	
	MW	MWh	MW	MWh
Oneida	0.34	406	1.36	1,484
Outagamie	4.05	4,913	13.60	16,460
Ozaukee	0.88	1,070	3.62	4,354
Pepin	0.46	568	1.44	1,745
Pierce	4.00	4,867	12.18	14,809
Polk	2.43	2,734	7.69	8,736
Portage	1.49	1,744	5.39	6,212
Price	2.30	3,036	6.31	8,331
Racine	2.40	2,784	10.11	11,961
Richland	1.73	2,004	4.23	4,884
Rock	6.56	8,078	21.94	26,799
Rusk	1.39	1,711	4.22	5,208
Sauk	2.30	2,704	6.66	7,674
Sawyer	1.45	1,599	5.08	5,719
Shawano	2.84	3,143	7.45	8,171
Sheboygan	4.23	5,015	11.29	13,875
St. Croix	4.44	5,188	12.20	14,262
Taylor	1.85	2,288	5.32	6,583
Trempealeau	1.71	1,967	3.75	4,482
Vernon	2.45	3,063	6.15	7,618
Vilas	0.75	943	3.19	3,995
Walworth	3.30	3,959	10.38	11,918
Washburn	1.35	1,694	4.10	5,077
Washington	1.30	1,598	5.71	7,061
Waukesha	5.10	6,072	19.29	23,596
Waupaca	0.94	1,129	3.04	3,470
Waushara	0.88	1,017	3.55	4,063
Winnebago	4.79	5,750	14.30	16,992
Wood	3.27	4,019	10.73	13,036

Appendix C. Segment-Level Simulated Market Adoption Potential

Table C-1. Residential Segment-Level Simulated Market Adoption Potential

Segment	2026		2034	
	MW	MWh	MW	MWh
Standard Income Single Family	86	104,173	293	352,304
Standard Income Manufactured	4	4,394	11	13,313
Total Standard Income	90	108,567	304	365,617
Income Qualified Single Family	36	43,717	129	154,256
Income Qualified Manufactured	4	4,821	13	16,582
Total Income Qualified	40	48,538	142	170,838
Total Residential	**130**	**157,106**	**446**	**536,455**

Table C-2. Commercial Segment-Level Simulated Market Adoption Potential

Segment	2026		2034	
	MW	MWh	MW	MWh
Healthcare	4	4,932	9	10,488
Lodging	1	1,434	3	3,466
Multifamily	1	1,679	4	4,410
Office	11	13,160	24	28,640
Restaurant	4	4,676	9	10,276
Retail	33	40,537	78	93,617
School	10	12,161	20	24,312
Warehouse	12	14,712	33	39,496
Total Commercial	**77**	**93,291**	**178**	**214,705**

Appendix D. Scenario Results

Statewide Net Metering Policy

Table D-1. Statewide Net Metering Policy Simulated Market Adoption Potential (MW)

Utility	2024	2026	2028	2030	2032	2034
Residential Standard Income	89.65	124.80	174.78	243.89	329.72	432.65
Residential Income Qualified	40.32	57.44	82.15	116.59	159.64	211.67
Commercial	66.19	86.09	112.55	147.72	173.76	192.94
Total	**196.15**	**268.33**	**369.48**	**508.20**	**663.11**	**837.26**

Table D-2. Statewide Net Metering Policy Simulated Market Adoption Potential (MWh)

Utility	2024	2026	2028	2030	2032	2034
Residential Standard Income	108,026	150,483	210,267	293,679	396,877	520,472
Residential Income Qualified	48,736	69,371	99,331	140,576	192,427	254,930
Commercial	80,012	103,985	135,819	178,174	209,502	232,602
Total	**236,774**	**323,838**	**445,417**	**612,429**	**798,805**	**1,008,003**

Increased Focus on Energy Incentives

Table D-3. Increased Focus on Energy Incentives Simulated Market Adoption Potential (MW)

Utility	2024	2026	2028	2030	2032	2034
Residential Standard Income	77.29	101.81	136.76	187.92	248.30	316.98
Residential Income Qualified	39.07	52.06	69.95	95.38	125.19	159.18
Commercial	65.61	83.81	107.20	140.56	164.67	182.72
Total	**181.97**	**237.69**	**313.91**	**423.85**	**538.16**	**658.88**

Table D-4. Increased Focus on Energy Incentives Simulated Market Adoption Potential (MWh)

Utility	2024	2026	2028	2030	2032	2034
Residential Standard Income	93,175	121,942	163,862	226,047	299,011	381,185
Residential Income Qualified	47,110	62,645	83,721	114,679	150,552	191,353
Commercial	79,315	101,297	129,510	169,752	198,876	220,665
Total	**219,599**	**285,884**	**377,092**	**510,478**	**648,439**	**793,203**

Attractive Project Financing

Table D-5. Attractive Project Financing Simulated Market Adoption Potential (MW)

Utility	2024	2026	2028	2030	2032	2034
Residential Standard Income	73.10	96.20	131.03	184.50	249.50	324.78
Residential Income Qualified	34.41	45.54	62.29	88.01	120.08	158.22
Commercial	61.45	77.60	100.55	137.94	167.67	191.44
Total	**168.96**	**219.33**	**293.88**	**410.45**	**537.25**	**674.43**

Table D-6. Attractive Project Financing Simulated Market Adoption Potential (MWh)

Utility	2024	2026	2028	2030	2032	2034
Residential Standard Income	88,355	115,239	157,613	222,689	301,279	391,717
Residential Income Qualified	41,539	54,943	74,895	106,295	145,214	191,245
Commercial	74,310	93,799	121,452	166,581	202,462	231,120
Total	**204,205**	**263,980**	**353,960**	**495,566**	**648,955**	**814,082**

Extended Federal ITC

Table D-7. Extended Federal ITC Simulated Market Adoption Potential (MW)

Utility	2024	2026	2028	2030	2032	2034
Residential Standard Income	77.92	111.97	144.66	194.51	255.85	328.48
Residential Income Qualified	35.57	50.99	66.31	89.48	118.49	153.90
Commercial	60.88	77.18	99.39	131.50	157.28	177.85
Total	**174.37**	**240.13**	**310.35**	**415.50**	**531.62**	**660.22**

Table D-8. Extended Federal ITC Simulated Market Adoption Potential (MWh)

Utility	2024	2026	2028	2030	2032	2034
Residential Standard Income	93,343	134,692	172,824	233,749	307,948	395,415
Residential Income Qualified	42,680	61,363	80,171	107,506	142,467	184,992
Commercial	73,636	93,291	120,051	158,774	189,873	214,705
Total	**209,660**	**289,346**	**373,046**	**500,029**	**640,288**	**795,112**

Appendix E. dGen Model Documentation

There are three classes of dGen inputs that each represent a different level of complexity for making changes:

- ***Scenario Inputs*** are a series of Microsoft Excel workbooks designed to easily adjust pre-defined scenarios.
- ***Database Inputs*** are SQL schemas stored in a SQL database. Some of the SQL tables for the model are pure inputs, while others pull calculations from the Scenario Inputs tables or other Database Inputs tables. While the Database Inputs tables can be modified, they are not designed to be adjusted.
- ***Agent Files*** are two Python pickle files (residential and commercial) that contain representative model agents. These agents are statistically weighted entities that together represent the population of residential and commercial actors who can adopt solar installations. These files include various key parameters as columns that are used to calculate solar potential. These files can only be altered using Python and must be adjusted keeping in mind overall population weighting.

Useful Links

See details in the following links about the database and what each input class represents:

- GitHub. 2021. "dGen Data: Distributed Generation Market Demand (dGen) Model." https://github.com/openEDI/documentation/blob/main/dGen.md
- National Renewable Energy Laboratory. 2020. "Welcome to the Open Source dGen Model Documentation!" https://nrel.github.io/dgen/

Scenario Inputs

Scenario Inputs are controlled by an Excel-based workbook where users can adjust key model parameters. Each input that can be adjusted has a corresponding Excel workbook. The input worksheet is shown in Figure E-1 and each of the linked input workbooks, as well as a few additional workbooks, are described below.

Figure E-1. Scenario Inputs Worksheet

Scenario Options	Value	User Defined File
Scenario Name	mxblsdl_com	
Technology	Solar + Storage	
Agent File	Use pre-generated Agents	agent_df_base_com_wi_revised
Region to Analyze	Wisconsin	
Markets	Only Commercial	
Analysis End Year	2034	
Load Growth Scenario	AEO2019 Low Growth	
Retail Electricity Price Escalation Scenario	User Defined	ATB19_Mid_Case_retail
Wholesale Electricity Price Scenario	User Defined	ATB19_Mid_Case_wholesale
PV Price Scenario	User Defined	pv_price_atb19_mid
PV Technical Performance Scenario	User Defined	pv_tech_performance_defaultFY19
Storage Cost Scenario	User Defined	batt_prices_FY20_mid
Storage Technical Performance Scenario	User Defined	batt_tech_performance_SunLamp17
PV + Storage Cost Scenario	User Defined	pv_plus_batt_prices_FY20_mid
Financing Scenario	User Defined	financing_atb_FY19
Depreciation Scenario	User Defined	deprec_sch_FY19
Value of Resiliency Scenario	User Defined	vor_FY20_mid
Carbon Intensity Scenario	User Defined	carbon_intensities_FY19
Random Generator Seed	1	

Save Scenario

Load Growth (dGen name: *experimental load growth*). These data provide load growth by census region from 2014 through 2050 by sector. Input allows the user to select from various growth scenarios rooted in the U.S. Energy Information Administration data forecast.

Retail Electricity Price Escalation (dGen name: *elec_prices* [folder]). Multiple scenario files represent retail electric prices for residential, commercial, and industrial customers. Data are shown from 2014 through 2050 for a number of balancing authorities.

Wholesale Electricity Price (dGen name: *wholesale_electricity_prices* [folder]). One scenario file represents whole electric from 2014 through 2050 for a number of balancing authorities.

PV Price (dGen name: *PV_prices* [folder]). These files provide system capital and operations and maintenance costs for each sector from 2014 through 2050. The user can choose one of three scenarios.

PV Technical Performance (dGen name: *pv_tech_performance* [folder]). Two files for 2017 and 2019 provide residential, commercial, and industrial kilowatts per square foot and a degradation factor of 0.005. Data are provided for 2014 through 2050. All sectors currently have the same performance per year.

Financing (dGen name: *financing_terms* [folder]). A single worksheet provides inputs on system lifetimes, loan terms, loan interest rates (residential and commercial), the down payment fraction, and real discount rates (residential and commercial).

Depreciation (dGen name: *depreciation_schedules* [folder]). A single worksheet provides a depreciation schedule for the commercial and industrial sectors.

Observed Solar Deployment (dGen name: *installed_capacity_MW_by_state_sector* and *observed_deploment_by_state_sector_2020*). Two worksheets provide solar installation in Wisconsin for 2014–2018, biannually).

Database Inputs

The following Database Inputs are in SQL database format. While these were not created with the intention for users to make modifications, Cadmus was able to make updates to some of the schemas listed below to align with Focus on Energy's service territory.

Load Profiles (dGen name: *comstock_load_profiles* and *comstock_load_profiles*). Two SQL tables with 8760 load profiles for residential and commercial buildings. Maps to the buildings in the agent data files.

Solar Irradiation (dGen name: *solar_resource_hourly*). SQL table with solar irradiation data by geo-coordinate. Maps to the geographic identity in the agent data files.

Retail Electric Prices (dGen name: *ATB19_Mid_Case_Retail*). SQL table with electric price multipliers by county identifier, year, and sector. Retail prices can be adjusted in scenario inputs.

Rate Escalations (dGen name: *AEO_rate_escaltions*). SQL table with escalation multipliers by North American Electric Reliability Corporation region, year, and sector. Cadmus is unclear about the function of this table. Retail prices can be adjusted in scenario inputs.

Utility Lookup Table (dGen name: *default_res_rate_lkup_2020*). SQL table with utility names and mapping to U.S. Energy Information Administration ID and rate ID.

Investment Tax Credit (dGen name: *inputs_main_ict_solar*). SQL table with ITC fraction for 2008 through 2050 for each sector. This table was updated with current federal ITC design and to show the simulated market adoption potential scenario.

Incentive Options (dGen name: *input_main_dsire_incentive_options_raw*). SQL table with date. Cadmus is unclear how this table pulls in actual incentive values. Incentive values can be adjusted in other tables (see below).

Incentive Fraction (dGen name: *input_main_incentives_raw*). SQL table with the maximum incentive fraction set to 1. Cadmus is unclear what this does. Incentive values can be adjusted in other tables (see below).

Inflation (dGen name: *input_main_market_inflation*). SQL table with inflation setpoint.

Net Energy Metering Scenario (dGen name: *input_main_nem_selected_scenario*). SQL table with scenario set to business as usual. There does not appear to be other scenario options.

Net Energy Metering Details (dGen name: *input_main_nem_user_defined*). SQL table with PV limit, sunset year, and compensation style by state.

Net Energy Metering State Limits (dGen name: *inputs_solar_bass_com*). SQL table maximum percentage cumulative capacity by state.

Bass Diffusion Coefficients (dGen name: *nem_state_limits_2019*). SQL table with Bass diffusion coefficients by state.

Maximum Market Share (dGen name: *max_market_share*). SQL table that provides a relationship between calculated payback period and maximum market adoption, which is key for modeling simulated market adoption potential. There is a curve for residential and commercial maximum market share. NREL assumes a commercial curve that is more sensitive to payback period. Cadmus adjusted the commercial curve to align with the residential curve.

Net Metering BAU Definition (dGen name: *nem_scenorio_bau_2019*). SQL table that defines maximum PV limits, compensation style (net metering or net billing), and sunset year by state and sector. For Wisconsin, the PV limit is currently set to 20 for the residential and commercial sector.

Net Metering Utility Data (dGen name: *nem_scenario_bau_by_utility_2019*). SQL table with utility name mapped to the U.S. Energy Information Administration ID. Table provides maximum PV limits, compensation style (net billing or net metering), a sell value, and a sunset date. Net billing rates have sell values, while net metering values do not.

Starting Capacities (dGen name: *starting_capacities_mw_2012_q4_us*). SQL table by state with megawatt capacity and system count by sector.

State Incentives (dGen name: *state_incentives_2019*). SQL table by state with incentive type, maximum size (kilowatts), maximum incentive, investment-based incentive percentage, annual incentive cap, start and end dates, and other variables.

Agent File

The model contains two Agent Files, one for the residential sector and one for the commercial sector. Agent Files are Python pickle files that contain representative model agents. These agents are statistically weighted entities that together represent the population of residential and commercial actors who can adopt solar installations. These files include various key parameters, some of which are listed below. There are 6,233 commercial agents and 456 residential agents.

Agent ID (dGen name: *agent_id*). Each agent has a unique identifier.

Census Tract (dGen name: *tract_id*). Maps to census tract.

Customers (dGen name: *customer_bin_initial*). Reflects the number of customers each agent represents.

Per Customer Load (dGen name: *load_kwh_per_customer_in_bin_initial*). Reflects the per-customer annual load for each agent.

Maximum Customer Demand (dGen name: *max_demand_kw*). Reflects the maximum customer demand.

Per Customer Average Monthly Load (dGen name: *avg_monthly_kwh*). Reflects the per-customer monthly load for each agent.

Customer Building/Business Type (dGen name: *crb_model*). Designation that reflects the building type or business type of the agent.

Ownership Status (dGen name: *owner_occupancy_status*). Designation that reflects whether the users is an owner or a renter.

Solar Production Factors (Multiple dGen names: *solar_re_9809_gid, tilt, azimuth, developable_roof_sqft, pct_of_bldgs_developable*). Designation that reflects the average developable rooftop square footage for each building type (shown in Table E-1).

Table E-1. Average Developable Roof Square Footage by Building Type

Sector	Building Type	Average of Developable Roof Square Footage
Commercial	Full Service Restaurant	3,448
	Hospital	74,096
	Large Hotel	9,350
	Large Office	9,584
	Medium Office	10,716
	Outpatient	14,569
	Primary School	47,347
	Quick Service Restaurant	2,385
	Retail	17,880
	Secondary School	74,124
	Small Hotel	18,995
	Small Office	3,847
	Strip Mall	10,781
	Warehouse	33,990
Residential	Mobile Home	404
	Multifamily with Two to Four Units	315
	Multifamily with Five or More Units	135
	Single-Family Attached	174
	Single-Family Detached	588

Percentage of Buildings Suitable for Solar (dGen name: *pct_of_bldgs_developable*). Shows the percentage of buildings that are suitable for rooftop development for each agent.

Building Size (dGen name: *bldg_size_class*). Breaks buildings into size classes (small, medium, large).

RTO (dGen name: *rto*). Maps agent to wholesale rates based on regional transmission organization.

Tariff Name (dGen name: *tariff_name*). Used to identify a tariff for an agent.

Tariff ID (dGen name: *tariff_id*). Used to identify specific rates for an agent

EIA ID (dGen name: *eia_id*). Corresponds to a utility identity.

Appendix F. Resources Consulted for Income-Qualified Research

Solar Programs Review

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Appendix G. Income-Qualified Interview Guide

Focus on Energy Low-Income Solar Potential

2021 Stakeholder Interview Guide

Interviewee Name:
Interviewee Organization:
Date of Interview:
Interviewer:

Research Objectives	Research Questions	Corresponding Guide Questions
Understand best practices and lessons learned from other low-income solar programs	• What have other programs learned from implementing a low-income solar program? • What were the biggest successes of the program? • What were the biggest challenges of the program?	B1–B12
Identify barriers to and opportunities for low-income solar adoption	• Are there existing policy barriers to low-income solar adoption? • What kind of barriers and opportunities exist for multifamily buildings? • What prevents low-income solar adoption? • Where in Wisconsin are there opportunities for low-income solar adoption? • What kind of sensitivity do low-income individuals have to payback periods?	D1–D12
Understand how to engage multiple stakeholders, such as solar installers	• Are solar installers willing to partner with a low-income solar adoption program? • What barriers have solar installers faced when working with low-income customers?	C1–C7

Note for reviewers: Cadmus intends to conduct up to eight interviews for this study with different stakeholder organizations. The expected list of interviewees is shown in the table below. Due to the differences in type of interviewee, not all questions in this guide will be asked to all participants. In order to determine what solar program administrators to interview, Cadmus used the findings from the benchmarking task that was also completed as part of this low-income solar potential study.

Potential Interviewees

Organization	Type of Interviewee	Located in Wisconsin?
Division of Energy, Housing, and Community Resources at the Department of Administration	Solar Stakeholder	Yes
Energy Trust of Oregon	Solar Program Administrator	No
Illinois Power	Solar Program Administrator	No
Xcel Energy (Minnesota)	Solar Program Administrator	No
DC Department of Energy and Environment	Solar Program Administrator	No
All Energy Solar	Solar Installer	Yes
Renew Wisconsin	Solar Stakeholder	Yes

A. Interviewee and Company Information (all interviewees)

A1. What is your role at **[ORGANIZATION]**?

B. Program Administrator Questions

B1. It is my understanding that the **[PROGRAM] [worked/works]** like **[SHORT DESCRIPTION OF PROGRAM].** Is that about right? **[TAKE NOTE OF ANY DETAILS/ADJUSTMENTS THAT NEED TO BE MADE]**

B2. What motivated the launch of this program? **[IF NEEDED: Regulatory, corporate, or market pressures? Customer/client needs?]**

B3. What **[were/are]** the most notable successes about the program?

B4. What were the biggest challenges in implementing this program? **[PROBE for challenges regarding installation partners, regulatory and policy barriers, or problems encountered during launch]**

B5. How **[was/is]** the program funded?

B6. How did you decide what kind and level of assistance/incentive the program would provide to eligible participants?

B7. How did you decide on your method of determining eligibility? **[IF APPLICABLE, PROBE why they use area median income versus federal poverty level/other established threshold]**

B8. What marketing or outreach strategies **[did you try/are you trying]**?
   i. What **[was/is]** the most successful strategy?

B9. Do you have any insights on what challenges participants face(d)? If so, what?

B10. What would you say were the lessons learned coming out of this program so far? **[PROBE for lessons learned regarding designing and launching the program]**

B11. What advice do you have for an organization looking to include equity in solar adoption program design?

B12. **[IF PROGRAM IS NO LONGER RUNNING]** Why did you decide to stop the program?

C. Solar Installer Questions

C1. What kind of customer are you most hired by? **[IF NEEDED: Individual residential customers, low-income customers, municipalities, utilities, companies?]**

C2. What kind of funding or financing opportunities do you commonly promote?
- Do these suggestions differ when working with low-income customers?
- Are there specific financing challenges for low-income communities?

C3. How often are you installing systems that serve/benefit low income customers or low-income communities?
- What are the differences in these projects compared to others?

C4. What are challenges for your company when serving low-income customers?

C5. **[IF COMPANY WORKS IN WI]** Through Focus on Energy, the PSC is considering options for solar adoption programs. In particular, they are interested in programs that equitably serve all residents of Wisconsin, which may mean targeted initiatives geared toward low-income and disadvantaged communities. How interested would you be in partnering with a program like this, as an installer?
- What would be benefits to your company for participating in a program like this?
- What would make it most likely for you to want to be a partner?
- **[IF NO]** What makes you not want to partner with the program?

C6. **[IF COMPANY WORKS IN MULTIPLE STATES]** What makes it more or less difficult to install solar in Wisconsin compared to other states?

C7. Do you do any work on multifamily buildings?
- **[IF YES]** Did any of the buildings specifically serve low-income residents?
- **[IF YES]** Who typically pays for the project? **[PROBE for situations where tenants initiate/fund the project and potential split-incentives between tenants and landlords]**
- **[IF YES]** Are the arrays that are installed typically sized to meet the needs of all tenant unit and common spaces?
  - **[IF YES]** What are the biggest challenges for a multifamily solar installation project?
  - **[IF NO]** Why not? **[PROBE for potential challenges to installation and/or lack of market demand]**

D. General Questions (All Interviewees, excluding questions that were already answered above)

D1. **[IF WISCONSIN BASED]** Are you aware of any regulatory or policy barriers in Wisconsin that might make it harder for a low-income individual to install solar on their home?
- Are there policy improvements that could be made to make it easier for low-income individuals to install solar on their home?

D2. **[IF NOT SOLAR INSTALLER OR COVERED ABOVE]** What do you think are opportunities for multifamily rooftop solar, particularly within disadvantaged and low-income communities? **[PROBE for common spaces only versus including tenant units]**

D3. **[IF NOT SOLAR INSTALLER OR COVERED ABOVE]** Conversely, what would be the barriers to installing rooftop solar on multifamily buildings, particularly within disadvantaged and low-income communities?

D4. **[IF NOT COVERED ABOVE]** What do you think motivates landlords or multifamily property owners to install solar on their buildings?

D5. **[IF NOT PROGRAM ADMINISTRATOR OR COVERED ABOVE]** What do you think is the biggest barrier that low-income individuals face when trying to install solar on their homes?

- How can the PSC and Focus on Energy help overcome these barriers?

D6. What do you think most motivates low-income individuals to install solar on their homes?

D7. What do you think would be the best ways to make low-income individuals aware of assistance that may be available to them when considering installing solar on their homes?

D8. **[IF WISCONSIN BASED]** What low-income solar programs or projects in Wisconsin are you aware of, whether it be rooftop, community solar, or something else?

- **[IF YES]** What about the program was successful?
- **[IF YES]** Do you know about any challenges the program may have faced?

D9. What are the best practices a solar adoption program should include to best serve disadvantaged and low-income individuals? **[IF NEEDED: For example, what kind of rebate or incentive structure is most equitable and useful? Community solar versus rooftop solar?]**

D10. To model solar uptake we are assuming that for standard income customers, about 40% of the project is financed by the customer. Is this a reasonable assumption? **[IF NEEDED: This estimate is based on the NREL annual technology baseline assessment.]**

- Do you believe this is reasonable for low-income customers as well? **[PROBE why and if different, how different]**

D11. We know that sensitivity to payback periods can influence adoption rate. For example, with a six-year payback period, we estimate that about 50% of the available standard residential market could be captured. How do you think sensitivity to payback periods compares for low-income individuals considering solar? **[PROBE why and if different, how different]**

D12. As we project adoption rates for rooftop solar, we are trying to understand how customers value their investment decision is over the entire project period. We are seeking to understand if standard income customers and low-income customers apply different implicit discount rates when making investment decisions—in other words, do they value dollars they will receive *later* compared to the dollars they have to spend *immediately* on the system differently? Do you think low-income individuals apply the same or a different discount rate compared to standard-income individuals? **[PROBE why and if different, how different]**

E. Closing

E1. Those are all my questions today! Is there anything else you would like to mention that we have not already covered?

Thank you so much again for your time, we really appreciate it. Have a great rest of your day!