Electric Energy Waste Reduction Potential Study

2021-2040

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This report is a deliverable submitted to Consumers Energy as part of a multiyear, independent evaluation contract to conduct impact, process, and market assessment studies of residential energy waste reduction and demand response programs administered by Consumers Energy. The independent evaluation team includes the following firms:

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CADMUS

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Acronyms and Abbreviations

Acronym	Definition
CBECS	Commercial Building Energy Consumption Survey
CEE	Consortium for Energy Efficiency
DEER	California Database of Energy Efficient Resources
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Technology (U.S. Department of Energy)
EIA	U.S. Energy Information Administration
EISA	Energy Independence and Security Act
EUL	Effective useful life
EWR	Energy waste reduction
IRP	Integrated resource plan
MEMD	*Michigan Energy Measures Database*
MPSC	Michigan Public Service Commission
NPV	Net present value
RECS	Residential Energy Consumption Survey
TLED	Tubular LED
TRM	Technical reference manual
UCT	Utility cost test

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Executive Summary

Consumers Energy contracted with an independent evaluation firm, Cadmus, to conduct electric energy waste reduction (EWR) and demand response market potential studies. Cadmus and subcontractor Demand Side Analytics (collectively known as the Cadmus team) completed the two studies in parallel, incorporating a high degree of coordination with Consumers Energy program staff and system planners. This report presents the results of the electric EWR potential study; the results of the demand response potential study are presented in a separate companion report.

The Cadmus team designed the EWR potential study to provide a foundation for continuing utility-administered electric EWR programs in the Consumers Energy service area and for determining the remaining opportunities for cost-effective electric EWR in the residential and business sectors. This study presents the technical, economic, maximum achievable, and program achievable potential for each sector, as well as annual costs comprised of different EWR measures for the Consumers Energy Resource Planning team to use in its *2021 Integrated Resource Plan* (IRP). Figure 1 describes these types of potential in more detail.

Figure 1. Types of Potential Estimates

Technical Potential includes all technically feasible EWR measures, regardless of costs and market barriers, that are commercially available at the time of the study. The Cadmus team used a hybrid top-down, bottom-up approach to analyze energy waste reduction measures.

Economic Potential represents a subset of technical potential and consists of all EWR measures meeting the study's cost-effectiveness criteria using the Utility Cost Test, consistent with the Michigan's Clean and Renewable Energy and Waste Reduction Act (PA 342).

Achievable Potential represents the portion of economic potential that might be reasonably achievable, after accounting for market barriers that may impede customer adoption, including limitations in customers' willingness to adopt EWR measures. For this study, the Cadmus team considered two achievable potential scenarios:

- Maximum achievable includes estimates of gross savings potential including EWR measures not currently offered by Consumers Energy and an expanded distribution of home energy reports.
- Program achievable includes estimates of net savings potential for EWR measures that are offered or have potential to be offered by Consumers Energy over the 20-year study horizon.

Research Objectives

This report addresses three primary research objectives:

- Using the most recent, updated, and available market data, develop annual estimates of EWR electric potential for Consumers Energy to incorporate into its 2021 IRP.
- Using detailed measure-level incentives and program-level administrative costs, develop the most realistic estimates of the annual EWR potential acquisition costs for Consumers Energy to use in its 2021 IRP.

- Using forward-looking (emerging) technologies to examine savings potential to determine the potential for a transformational technology scenario to meet Consumers Energy's long-term EWR goals.

Research Approach

To address the research objectives, the Cadmus team conducted several distinct research activities for the 2020 Consumers Energy EWR potential study:

- Created a baseline end-use energy forecast that assumed no future, planned EWR, based on Consumers Energy customer data and forecasts
- Characterized a comprehensive set of electric EWR measures for the potential study, drawing primarily from the 2020 *Michigan Energy Measures Database* (MEMD)[1]
- Incorporated impacts from federal codes and standards into the modeling framework
- Modeled four levels of EWR potential: technical, economic, maximum achievable, and program achievable
- Developed detailed, annual acquisition costs of EWR for the maximum achievable and program achievable potentials
- Compiled and characterized a transformational technology scenario that includes an expansive set of emerging technologies, based on nascent commercially available technologies as well as technologies under research and development

The Cadmus team prepared 20-year forecasts of electric EWR and peak demand reduction potential for each measure. The team considered various building sectors and multiple vintages (new and existing), distinguished between lost opportunity and retrofit measures, and accounted for building energy codes and future federal equipment standards. Figure 2 outlines the three sectors analyzed in this study.

Figure 2. Study Sectors

[1] Michigan Public Service Commission (supplied by Morgan Marketing Partners). Accessed 2020 version. "Michigan Energy Measures Database." https://www.michigan.gov/mpsc/0,9535,7-395-93309_94801_94808_94811---,00.html

Summary of Potential Study Results

For this potential study, the Cadmus team quantified the amount of electric EWR and demand reduction from EWR achievable within Consumers Energy's service territory from 2021 to 2040. Table 1 lists the cumulative electric resources of technical, economic, maximum achievable, and program achievable potential identified for five- and 20-year horizons. Electric EWR potential, representing nearly 6,714 GWh of maximum achievable potential and 5,740 GWh of program achievable potential, could produce approximately 1,374 MW and 1,027 MW of coincident summer peak demand reduction, respectively. All electric potential estimates in this report are presented at the customer site, meaning they do not include line losses that occur from the point of generation.

Table 1. Summary of Electric Energy Savings and Demand Reduction Potential: Cumulative 2025 and 2040

Electric Resource	Technical Potential	Economic Potential	Maximum Achievable Potential	Program Achievable Potential
2025				
Energy (MWh)	4,599,596	4,542,218	2,770,694	2,394,909
Peak Demand (MW)	1,064	1,058	485	383
2040				
Energy (MWh)	10,527,202	10,333,188	6,714,807	5,739,614
Peak Demand (MW)	2,481	2,462	1,374	1,027

Table 2 lists the sector-level cumulative electric technical, economic, maximum achievable, and program achievable potential estimated through the study. As shown in the table, there is over 10,527 GWh of cumulative technically feasible electric EWR potential by 2040, with cost-effective measures producing approximately 10,333 GWh of economic potential. Of Consumers Energy's forecasted 2040 sales, technical and economic potential each represent approximately 26%, equating to 1.5% of forecasted sales on an annual basis. As a percentage of total technical potential, the economic potential represents 98%.

For the 20-year maximum achievable potential, the residential sector accounted for 27% of the residential sector sales forecast, followed by the commercial sector (19%) and the industrial sector (15%). The maximum achievable and program achievable potential equated to 16.5% and 14.1% of forecasted annual electric sales in 2040, respectively.

Table 2. Electric Energy Waste Reduction Potential by Sector—Energy: Cumulative 2040

Sector	Baseline Sales (MWh)	Technical Potential		Economic Potential		Maximum Achievable Potential		Program Achievable Potential	
		MWh	%[a]	MWh	%[a]	MWh	%[a]	MWh	%[a]
Residential	14,861,197	5,515,726	37.1%	5,429,686	36.5%	2,262,348	15.2%	1,737,912	11.7%
Commercial	14,528,160	3,112,498	21.4%	3,061,027	21.1%	2,765,511	19.0%	2,483,449	17.1%
Industrial	11,204,888	1,898,978	16.9%	1,842,475	16.4%	1,686,948	15.1%	1,518,253	13.5%
Total[b]	**40,594,246**	**10,527,202**	**25.9%**	**10,333,188**	**25.5%**	**6,714,807**	**16.5%**	**5,739,614**	**14.1%**

[a] These columns are a percentage of baseline sales.

[b] May not equal sum of rows due to rounding.

The study identified electric EWR maximum achievable potential on both a cumulative and incremental basis, as shown in Table 3.

Table 3. Electric Energy Waste Reduction Potential by Sector—Energy: Cumulative and Incremental Maximum Achievable Potential 2040

Sector	Baseline Sales (MWh)	Maximum Achievable Potential – Total Cumulative Potential		Maximum Achievable Potential – Total Annual Incremental Potential	
		MWh	% [a]	MWh	% [a]
Residential	14,861,197	2,262,348	15.2%	4,723,600	31.8%
Commercial	14,528,160	2,765,511	19.0%	4,421,914	30.4%
Industrial	11,204,888	1,686,948	15.1%	2,359,759	21.1%
Total [b]	**40,594,246**	**6,714,807**	**16.5%**	**11,505,273**	**28.3%**

[a] These columns are a percentage of baseline sales.

[b] May not equal sum of rows due to rounding.

Cumulative potential accounts for measures that are converted during early years of the analysis but reach the end of their effective useful life before the end of the 20-year study timeframe. Cumulative potential assumes these measures are re-installed with a like-for-like technology and accumulated no additional savings compared to the baseline forecast. The cumulative savings are consistent with the EWR savings modeled by Consumers Energy for its Integrated Resource Plan as these represent the expected reduction in the baseline forecast.

Incremental potential assumes that, for measures that are converted during early years of the analysis and are re-installed with a like-for-like technology before the end of the study timeframe, the re-installation savings accumulate using the same per-unit savings as the original installation. Unlike cumulative savings, incremental savings serve as the basis for Consumers Energy's EWR Plan filings and targets, consistent with industry best practices and the recommendations of the National Action Plan for Energy Efficiency.[2]

Figure 3 illustrates the cumulative annual maximum achievable potential available in each sector. The slight change in slope depends on the rate in which discretionary resources and lost opportunity resources are acquired. Discretionary resources represent savings from measures that affect existing buildings or equipment that can be retrofitted at any time. Lost opportunity resources are savings from new buildings or equipment where, if energy efficiency is not incorporated upfront, it may not be available until the buildings undergo renovation or the equipment is replaced. For example, most discretionary resources will be acquired within the first 10 years (2021 and 2030), and the majority of the remaining potential after 2030 will be achieved through lost opportunity resources.

[2] Environmental Protection Agency. November 2007. *Guide for Conducting Energy Efficiency Potential Studies: A Resource of the National Action Plan for Energy Efficiency.* https://www.epa.gov/sites/production/files/2015-08/documents/potential_guide_0.pdf

Figure 3. Electric Energy Waste Reduction Potential by Year-Energy: Cumulative

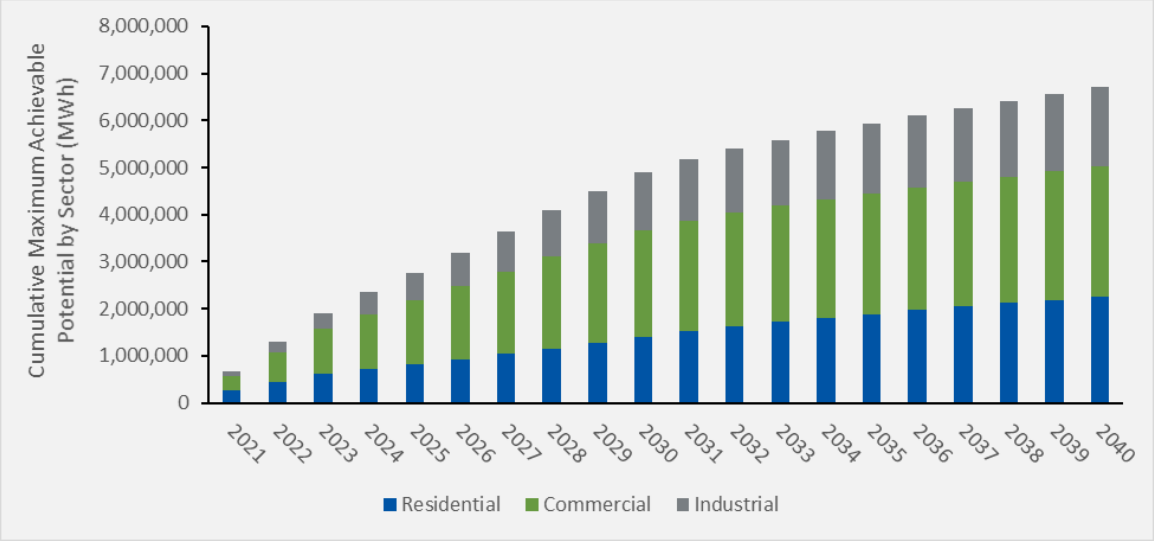


Table 4 shows the cumulative technical, economic, maximum achievable, and program achievable electric coincident peak demand reduction potential for Consumers Energy from 2021 through 2040. Over 99% of the technical electric coincident peak demand reduction is cost-effective. EWR measures provide substantial coincident peak demand reduction from EWR, with maximum achievable and program achievable potential equivalent to approximately 17% and 13% of forecast peak demand in 2040, respectively.[3]

Table 4. Electric Energy Waste Reduction Potential by Sector—Demand: Cumulative 2021 through 2040

Sector	Technical Potential (MW)	Economic Potential (MW) MW	Maximum Achievable Potential (MW)	Program Achievable Potential (MW)
Residential	1,661	1,654	672	397
Commercial	517	515	434	388
Industrial	304	294	269	242
Total [a]	**2,481**	**2,462**	**1,374**	**1,027**

The maximum and program achievable EWR potential estimated by the study provides considerable net economic benefits across the 20-year study horizon. Table 5 shows the net present value (NPV) of the 20-year maximum and program achievable potential benefits and costs, respectively, and the resulting utility cost test (UCT) benefit/cost ratios. The benefits shown in Table 5 include adjusted lifetime savings for residential and commercial screw-based lighting, consistent with the current policy in Michigan and

[3] The Cadmus team developed a peak load forecast for the companion demand response report that subtracted peak load impacts from existing EWR, conservation voltage reduction, retail open access customers, and the effects of a planned transition to default residential summer time-of-use rates from a base, unadjusted peak load forecast provided by Consumers Energy. The peak load forecast we developed equates to approximately 8,000 MW in 2040.

with the MEMD. The commercial and industrial sectors are combined into a single business sector in Table 5 because some Consumers Energy programmatic costs cannot be allocated directly to industrial and commercial customers.

Table 5. Maximum and Program Achievable Potential Utility Cost Test Benefits and Costs

Sector	Maximum Achievable Potential			Program Achievable Potential		
	NPV Benefits	NPV Costs	Benefit/ Cost Ratio	NPV Benefits	NPV Costs	Benefit/ Cost Ratio
Residential	$1,557,936,171	$813,573,354	1.91	$1,077,603,284	$629,154,475	1.71
Business	$3,468,808,813	$839,706,101	4.13	$3,115,968,648	$735,624,244	4.24
Total [a]	**$5,026,744,984**	**$1,653,279,455**	**3.04**	**$4,193,571,932**	**$1,364,778,719**	**3.07**

[a] May not equal sum of rows due to rounding.

Cadmus also calculated the customer electric bill savings across the study horizon associated with the maximum achievable potential results. The bill savings also incorporate a forecast of retail rates at the sector level.[4] Table 6 shows the customer bill savings associated with the maximum achievable potential, in 2040 in nominal dollars.

Table 6. Maximum Achievable Potential Customer Bill Savings, in 2040

Sector	Maximum Achievable Potential
	Customer Bill Savings
Residential	$576,600,156
Business	$809,272,244
Total	**$1,385,872,400**

In support of Consumers Energy's aggressive goals, Cadmus developed a transformational technology scenario that looked at expanded EWR potential that includes new and emerging technologies. The transformation technology scenario shows increased savings opportunities if key actions to further develop and demonstrate technologies, engage trade allies and consumers, and facilitate regulatory review and acceptance.

Table 7 shows the cumulative technical, economic, and maximum achievable potential when transformational technology measures are included in the potential estimation process. Overall, the transformational technology scenario represents a 63% increase over the initial estimate of maximum achievable potential.

[4] The forecast of retail rates by sector is included in Appendix B.

Table 7. Transformational Technology Scenario Electric Energy Waste Reduction Potential by Sector—Energy: Cumulative 2040

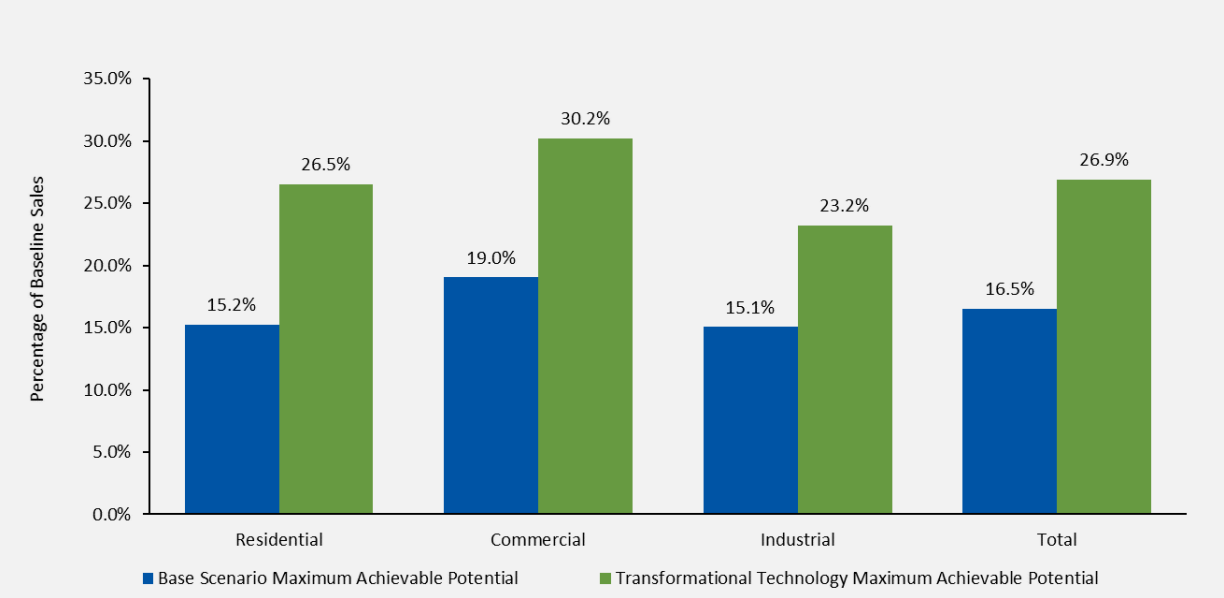
Sector	Baseline Sales (MWh)	Technical Potential		Economic Potential		Maximum Achievable Potential	
		MWh	% [a]	MWh	% [a]	MWh	% [a]
Residential	14,861,197	9,808,564	66.0%	6,943,146	46.7%	3,938,701	26.5%
Commercial	14,528,160	4,827,870	33.2%	4,773,253	32.9%	4,387,185	30.2%
Industrial	11,204,888	2,799,606	25.0%	2,754,011	24.6%	2,599,612	23.2%
Total [b]	**40,594,246**	**17,436,040**	**43.0%**	**14,470,410**	**35.6%**	**10,925,499**	**26.9%**

[a] These percentages are of baseline sales.

[b] May not equal sum of rows due to rounding.

Figure 4 compares the 2040 cumulative maximum achievable potential by sector, as a percentage of baseline sales, to the transformational technology scenario.

Figure 4. Comparison of Percentage of Baseline Sales for Maximum Achievable Potential in Transformational Scenario and Base Scenario – Electric Energy: Cumulative 2040



Conclusions

There are several key conclusions for Consumers Energy to consider in translating this study's estimates of EWR potential into its 2021 IRP:

- ***LED standard screw-based lighting represents significant EWR potential savings in the residential and commercial sectors in 2021, 2022, and 2023.*** Despite the U.S. Department of Energy's (DOE) December 27, 2019, final rule and determination that effectively rescinded the Energy Independence and Security Act (EISA) 2020 backstop standard, substantial uncertainty remains regarding the future of that standard and the effect of DOE's final rule on energy savings potential for LEDs within EWR programs. The general service LED lighting potential

savings account for approximately 8% of the total 20-year electric maximum achievable potential for residential homes.

- ***Specialty LED lighting, including lamps that are exempt from the EISA 2020 backstop standard, represent significant EWR savings potential.*** For this study, the Cadmus team assumed a market shift to LED specialty lamps as a baseline technology, starting by the end of 2024. These lamps account for almost 8% of the total 20-year electric maximum achievable potential for residential homes.
- ***Advanced and emerging residential measures offer substantial long-run, cost-effective EWR potential.*** Advanced Tier 4 central air conditioners, with a SEER rating of 21, demonstrate cost-effective EWR and peak demand potential in the early years of the study and after the 2023 central air conditioning federal standard takes effect. One emerging technology measure included in the study, heat pump dryers, represents a significant savings opportunity for this ubiquitous residential end use, as nearly 96% of single family homes have an electric dryer. Combined, these two measures account for approximately 6% of the total 20-year electric maximum achievable potential for residential homes.
- ***Appliance recycling measures contribute significant, cost-effective EWR potential.*** The refrigerator and freezer recycling measures combined account for 46% of the total, 20-year maximum achievable electric EWR potential. With nearly 1.4 refrigerators and 0.6 stand-alone freezers per single family home, 1.2 refrigerators and 0.6 stand-alone freezers per manufactured home, and 1.2 refrigerators and 0.1 stand-alone freezers per multifamily home, appliance recycling measures contribute meaningful, cost-effective electric EWR potential in Consumers Energy service territory. Two additional appliance recycling measures—room air conditioners and dehumidifiers—contribute approximately 0.1% of the total 20-year maximum achievable potential for residential homes.
- ***Residential behavioral energy measures—including home energy reports—offer opportunities and substantial energy savings potential.*** The potential study revealed that home energy report measures will offer substantial savings opportunities in the future, but only after lifting program participation caps. Home energy reports could contribute up to 4% of the total, 20-year maximum achievable electric EWR potential in the residential sector.
- ***Commercial and industrial lighting opportunities contribute significant, cost-effective EWR potential.*** While the data collected by TRC (formerly EMI Consulting) for Consumers Energy's 2019 *Commercial and Industrial Market Assessment* revealed dramatically increased LED penetration across all commercial segments compared with data collected in 2015, there is still a large potential across all LED applications (linear, high-bay, screw-base, and exterior). Combined, commercial and industrial lighting end-use savings account for approximately 48% of the total 20-year nonresidential maximum achievable potential.
- ***Commercial lighting controls contribute significant, cost-effective EWR potential.*** The potential study revealed that lighting controls represent 18% of commercial maximum achievable potential from control technologies such as occupancy sensors, dimming controls, bi-level controls, and advanced network occupancy and daylighting controls.

- ***Industrial process measures contribute significant, cost-effective EWR potential.*** The industrial sector, which represents 28% of 2040 forecasted baseline sales, represents significant cost-effective EWR potential, led by a wide range of process measures across all manufacturing facilities. Process measures account for 39% of the total, 20-year industrial maximum achievable potential and 15% of total nonresidential savings.

To achieve long-term EWR goals, there are several key conclusions for Consumers Energy to consider when pursuing potential identified in the transformational technology scenario:

- ***Transformational technology potential provides a pathway to achievable long-term EWR goals.*** By incorporating dozens of emerging and innovative technologies in various stages of development, Consumers Energy can begin strategically planning initiatives through demonstration projects, pilots, outreach, and regulatory collaboration.
  - **Technology development and demonstration.** This may include investment in research and development, lab testing, or engagement of early adopters to install and use new technologies and to provide feedback that will help further development and determine applicability.
  - **Delivery strategy optimization.** Determination of the most effective market interventions to encourage adoption of emerging technologies at scale; this may include pilots and market forecasting to assess changes in cost as technologies are commercialized.
  - **Customer and trade ally outreach.** Lack of awareness and knowledge are significant barriers to adoption of a new technology; outreach to and education of consumers helps to build interest and demand while trade ally engagement ensures that there is a qualified workforce to install and service new technologies.
  - **Regulatory review and acceptance.** Educating Michigan Public Service Commission (MPSC) staff about emerging technologies and working collaboratively to demonstrate energy saving potential and path to market adoption.
- ***Transformational technology potential requires key actions to achieve long-term potential.*** While this study conducted aggressive research and outreach to industry experts on promising emerging technologies, limited data exists regarding the long-term viability of some of these technologies. This will require Consumers Energy to continue to research, pursue, and promote viable technologies as more data becomes available in coordination with industry partners.
- ***Many of the most impactful transformational technology measures exhibit more long-run potential; however, several provide savings in the study's first five years.*** Advanced commercial HVAC and refrigeration equipment, industrial processes and refrigeration, and expanded residential web portal offerings, advanced furnace fans, radiant panels, and smart vents represent technologies which Consumers Energy should begin monitoring and tracking.

Report Organization

We organized this report as follows:

- Comparison of this study's results to the EWR projections in Consumers Energy's 2018 IRP
- Summary of Consumers Energy electric EWR transformational technology scenario potential results
- General approach and methodology overview
- Detailed findings from several activities:
  - Baseline forecast
  - Electric EWR technical and economic potential
  - Electric EWR maximum achievable potential
  - Electric EWR program achievable potential
- Summary of methodologies
- Consumers Energy electric EWR transformational technology scenario potential
- Appendix A. Baseline forecast data
- Appendix B. Economic Inputs
- Appendix C. Emerging technology descriptions

Comparison to Consumers Energy's 2018 Integrated Resource Plan

The EWR potential values adopted in the Consumers Energy 2018 IRP were based on a statewide EWR potential study for 2017 through 2036, prepared by GDS Associates,[5] which was later adapted for Consumers Energy's service territory.

Table 8 shows a comparison of the 20-year cumulative maximum achievable and program achievable potential identified in this 2020 EWR market potential study, expressed as a percentage of baseline sales, compared to the achievable and constrained achievable potential identified in the 2017 GDS study. Overall, for this 2020 potential study, the Cadmus team identified lower levels of residential, commercial, and industrial potential, for maximum achievable potential compared to the 2017 GDS study's achievable potential, but higher levels of program achievable potential when program budgets are not limited to 2% of revenue.

Table 8. Maximum Achievable and Program Achievable Potential Comparison to 2017 GDS Study: Cumulative 20-Year Potential

Study	2020 Maximum Achievable Potential and 2017 Achievable Potential				2020 Program Achievable Potential and 2017 Constrained Achievable Potential			
	Percentage of Baseline Sales			MWh	Percentage of Baseline Sales			MWh
	Residential	Commercial	Industrial	Total	Residential	Commercial	Industrial	Total
2020 Cadmus	15.2%	19.0%	15.1%	6,714,807	11.7%	17.1%	13.5%	5,739,614
2017 GDS	19.2%	25.0%	17.6%	7,684,742	10.7%	10.5%	10.1%	3,934,680

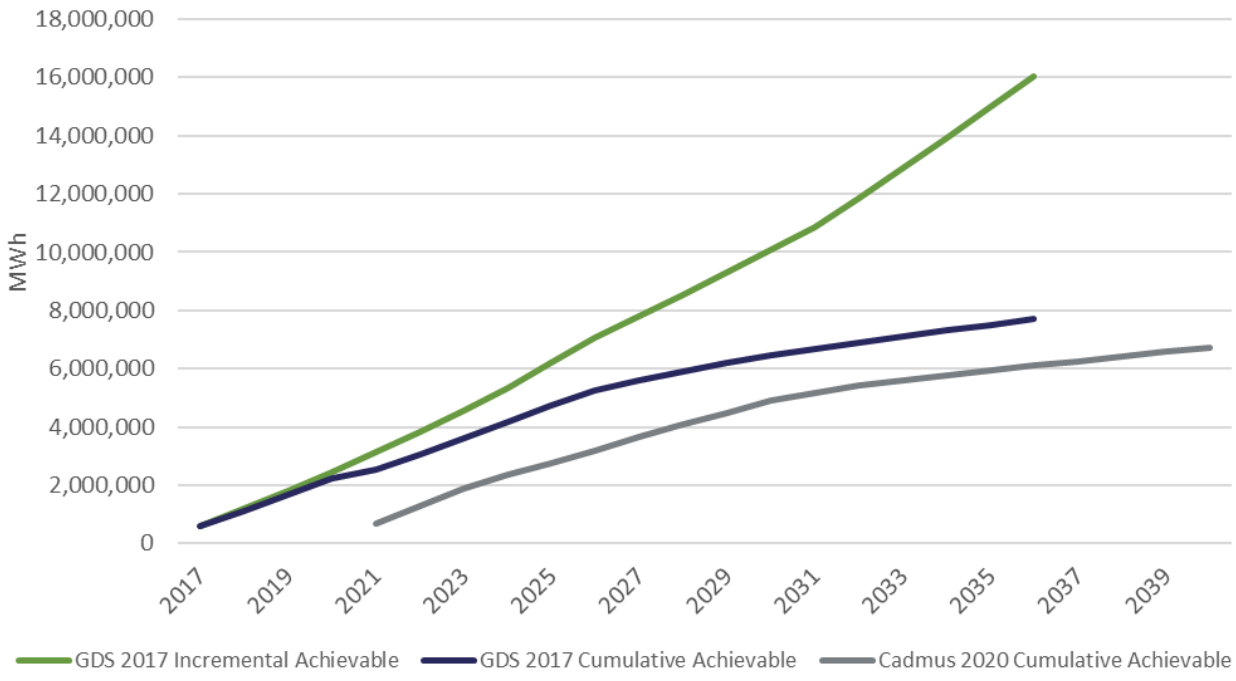
For this study, the Cadmus team incorporated several changes compared to the 2018 IRP and to the 2017 GDS study:

- Developed a baseline end-use energy forecast, relying on Consumers Energy's most recent electric energy and customer forecasts.
- Estimated both incremental and cumulative EWR potential; however, whereas the 2018 IRP relied on the 2017 GDS study's approach of incorporating incremental potential, the Cadmus team provided cumulative potential for Consumers Energy's 2021 IRP in order to better account for EWR's effect on Consumers Energy's grid and forecasted loads. Whereas the incremental approach is applicable to setting program and portfolio targets—as these more accurately characterize how programs count savings—applying incremental potential to forecast loads in an IRP context overstates the effect on the grid by double-counting savings from EWR measure re-installations at the end of their useful lifetimes. Figure 5 shows a comparison of the 2017 GDS study incremental and cumulative achievable potential to the cumulative maximum achievable potential from this study.
- Used updated market data collected from site visits in 2019, showing the acceleration of LED adoption by Consumers Energy's commercial and industrial customers.

[5] GDS Associates. March 20, 2017. *Consumers Energy Electric Energy Efficiency Potential Study.* Prepared for Consumers Energy.

- Employed updated information on changes in federal appliance standards and regulatory treatment of screw-based LED lighting that gradually phases out general service lamp savings from 2021 through 2024.
- This study provides estimates of maximum achievable and program achievable potential. The key outputs of the 2017 GDS study were "Achievable Potential UCT" and "Constrained Achievable Potential UCT." The proposed course of action in Consumers Energy's 2018 IRP was based on the Achievable Potential UCT. A key difference between this study and the 2017 GDS study is that the Cadmus team included both variable program administration and incentive costs. The 2017 GDS study assumed flat rates for administrative and incentive costs, whereas the Cadmus team employed measure-level incentive assumptions and applied administrative costs at the program level, consistent with values from Consumers Energy's most recent EWR plan filing.

Figure 5. Comparison of 2017 GDS Incremental and Cumulative Achievable Potential to 2020 Study Cumulative Maximum Achievable Potential



Summary of Consumers Energy Electric EWR Transformational Technology Potential Results

Per Consumers Energy's request (and as a supplement to the primary EWR potential study), the Cadmus team examined savings potential using a more aggressive set of assumptions to determine the transformational technology potential specific to Consumers Energy. The research had three primary analysis objectives:

- Identify an expanded estimate of EWR potential that could support Consumers Energy's ambitious EWR goals
- Investigate forward-looking technology and market scenarios that are the most likely to support Consumers Energy's longer-term EWR goals, particularly from 2031 to 2040 (the second half of the electric potential study time horizon)
- Provide insights on actions that may be required to fully capture the available potential from emerging measures, which could include investing in technology research and providing demonstrations, educating and building awareness of new and emerging measures, and building regulatory support with the Michigan Public Service Commission (MPSC)

Table 9 summarizes the 20-year transformational cumulative technical, economic, and maximum achievable potential in each sector. Of the total technical potential (17,436 GWh), 83% is considered economic (14,470 GWh). The maximum achievable potential is 10,925 GWh, which is 24% lower than the economic potential.

Table 9. Transformational Electric Energy Waste Reduction Potential by Sector—Energy: Cumulative 2040

Sector	Baseline Sales (MWh)	Technical Potential		Economic Potential		Maximum Achievable Potential	
		MWh	% [a]	MWh	% [a]	MWh	% [a]
Residential	14,861,197	9,808,564	66.0%	6,943,146	46.7%	3,938,701	26.5%
Commercial	14,528,160	4,827,870	33.2%	4,773,253	32.9%	4,387,185	30.2%
Industrial	11,204,888	2,799,606	25.0%	2,754,011	24.6%	2,599,612	23.2%
Total [b]	**40,594,246**	**17,436,040**	**43.0%**	**14,470,410**	**35.6%**	**10,925,499**	**26.9%**

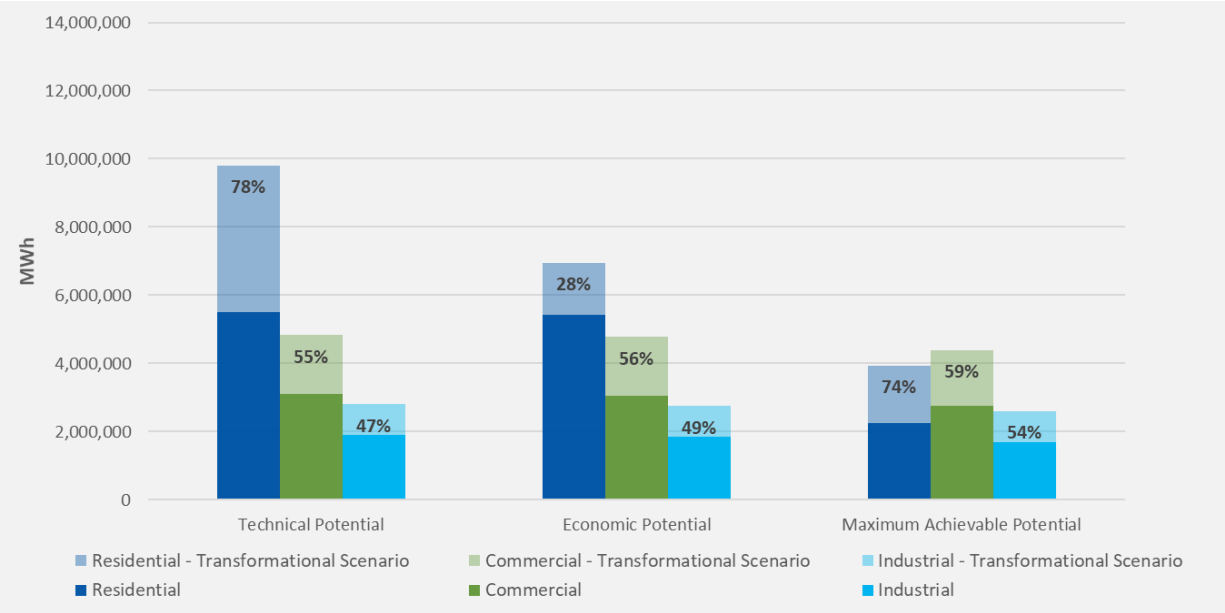
[a] These percentages are of baseline sales.

[b] May not equal sum of rows due to rounding.

Figure 6 shows the 20-year cumulative transformational potential relative to the primary study results. The percentages represent the increase in cumulative 20-year potential in the transformational technology scenario for each sector. The total, cumulative maximum achievable potential increases by 63% when including transformational measures. Most of the additional savings potential comes from the residential sector, which increases by 74%, followed by the commercial (59%) and industrial (54%) sectors. Figure 7 shows the different peak demand values from the transformational potential and the primary results, with the percentage values representing the percentage increase in peak demand within a sector from the primary potential results to the transformational potential results. The transformational residential and commercial sector peak demand potential increases at a higher rate

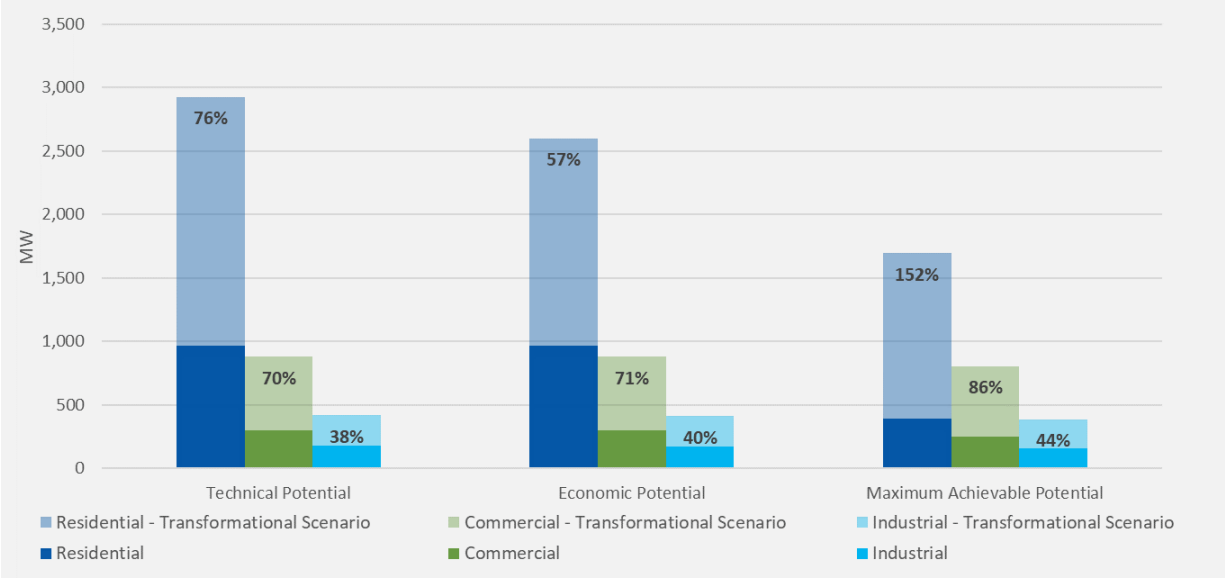
than the energy savings potential because many of the transformational technology measures incorporate HVAC efficiency improvements that are coincident to Consumers Energy's summer system peak demand.

Figure 6. Transformational Scenario Electric EWR Potential-Energy: Cumulative 2040



The percentages represent the increase in cumulative 20-year potential in the transformational technology scenario for each sector.

Figure 7. Transformational Scenario Electric EWR Potential—Demand: Cumulative 2040



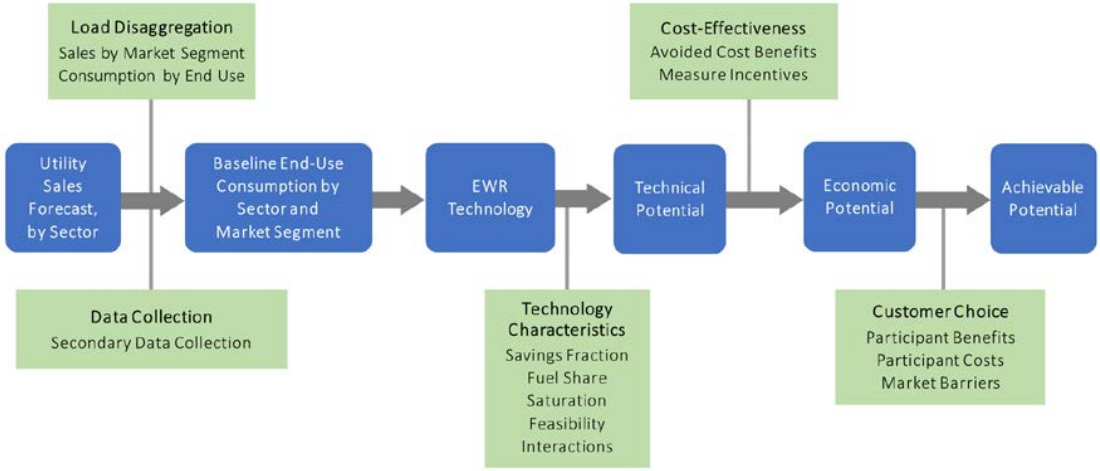
The percentages represent the increase in cumulative 20-year potential in the transformational technology scenario for each sector.

General Approach: Methodology Overview

The Cadmus team's general methodology was a combined top-down/bottom-up approach. For the top-down component, the team began with the most current sales forecasts—excluding future, planned EWR savings and adjusting for building codes, equipment efficiency standards, and market trends that the forecast did not account for—and disaggregated this information into customer sectors, customer segments, and end-use components. For the bottom-up component, the team considered the potential technical impacts of various EWR measures on each end use, then estimated impacts based on engineering calculations and accounting for fuel shares, current market saturations, technical feasibility, and costs.

The Cadmus team followed specific primary steps to model EWR: (1) created a baseline forecast of energy use by end use, (2) conducted measure research to understand where, how, and at what cost EWR potential can be achieved, and (3) modeled EWR based on the defined set of measures. Figure 8 illustrates the process we used to estimate the technical, economic, and achievable potential.

Figure 8. General Methodology for Assessing Energy Waste Reduction Potential



The Cadmus team developed a baseline forecast by determining 20-year future energy use by sector, market segment, and end use. The team calibrated the base year (2020) to Consumers Energy's forecasted sector loads. Baseline forecasts in this report include estimates of naturally occurring potential (such as energy savings due to building energy codes and federal equipment standards); therefore, the EWR potential estimates presented in the report represent only additional savings achievable through programs.

As part of this study, the team leveraged recently collected primary data in the nonresidential sectors (commercial and industrial building stock) within Consumers Energy's service territory, using 255 site

visits across all nonresidential building types.[6] The collected data provide Consumers Energy-specific baseline data on building characteristics, demographics, and energy-consuming end uses (such as fuel type, equipment type, and estimated equipment age). For the residential sector, the Cadmus team primarily relied on data collected for the Consumers Energy *Residential Appliance Saturation and Home Characteristics Study*, dated October 2018.

Next, the Cadmus team developed a comprehensive measure database of technical and market data that applied to all end uses in various market segments, as well as the estimated costs, savings, and applicability for a comprehensive set of EWR measures. The primary measure data source was the Michigan Energy Measures Database (MEMD), as well as Consumers Energy workpapers and regional technical reference manuals (TRMs). The *Measure Characterization* section in the *Summary of Methodologies* chapter details the data sources we used for this study.

The Cadmus team assessed four types of potential:

- ***Technical potential*** assumes that all technically feasible EWR measures generally available at the time of the study will be implemented, regardless of their cost or other market barriers. We estimated this theoretical upper bound of available conservation potential after accounting for technical constraints. For EWR resources, there are three classes of technical potential:
  - Retrofit opportunities in existing buildings
  - Equipment replacements in existing buildings
  - New construction

  Customers can theoretically implement retrofits in the current building stock at any point in the planning horizon. Examples of retrofit measures, which reduce the use of end-use equipment without modifying or replacing that equipment, include insulation, faucet aerators, and lighting controls. However, end-use equipment turnover rates and new construction rates dictate the timing of equipment replacements and new construction. The *Baseline End-Use Forecast* section in the *Summary of Methodologies* chapter details the data sources we used to estimate these technical constraints for individual measures.
- ***Economic potential*** represents a subset of technical potential and consists only of measures meeting the cost-effectiveness criteria, set to be consistent with the primary cost-effectiveness test adopted under Michigan Public Acts 295 and 342. Michigan set requirements for Consumers Energy where the primary benefit/cost test includes benefits and cost from the viewpoint of the utility, referred as the UCT. For each EWR measure, the Cadmus team structured the benefit/cost test as the ratio of NPVs for the measure's benefits and costs, using the benefit and cost inputs from Consumers Energy. We identified only measures with a benefit/cost ratio of 1.0 or greater as cost-effective. The *Economic Potential* section in the *Summary of Methodologies* chapter details the benefits and costs considered.

[6] These data were collected by EMI Consulting in 2019 as part of a Consumers Energy commercial and industrial market assessment.

- ***Maximum achievable potential*** represents the portion of economic potential that might be achieved after accounting for market barriers that impede customer adoption, including limitations in customers' willingness to adopt EWR measures. The maximum achievable potential does not consider any limits to savings achievement that currently constrain home energy report programs; to determine the maximum achievable potential, we assumed that 60% of eligible single family electric service customers would receive home energy reports. A comprehensive set of EWR measures—including technologies not currently offered by Consumers Energy programs spanning the residential, commercial, and industrial sectors—comprised the maximum achievable potential. This report expresses gross maximum achievable savings potential at the meter.
- ***Program achievable potential*** consists of the subset of economic potential for measures currently offered and measures that have potential to be offered during the study horizon by Consumers Energy. This report expresses program achievable potential in net savings, accounting for the most current net-to-gross factors used to determine Consumers Energy program cost-effectiveness.

The Cadmus team did not attempt to predict or incorporate new, non-commercially available technologies that may emerge in future years in the core estimate of potential but did include those in the transformational technology scenario. The team did make assumptions regarding future market conditions and federal and state policies based on informed projections, which may or may not precisely match actual conditions. Therefore, these study results should not serve as the final word on savings that can be achieved by Consumers Energy; rather, they should help to guide future program planning, design, funding, and goal setting. The following sections detail study considerations and limitations of the potential study.

Additional Study Methodological Considerations

The Cadmus team took special considerations in reporting results within this study.

Incremental and Cumulative Potential

EWR potential studies of this type typically produce two sets of savings potential outputs—incremental and cumulative—for each type of potential (technical, economic, maximum achievable, and program achievable). Except where noted, tables within this report present potential estimates on a cumulative basis. EWR measures converted during early analysis years (but reaching the end of their effective useful life [EUL] during the 20-year study horizon) remain eligible for future installations.

Incremental savings include additional savings at the end of these measures' EULs—consistent with EWR program practices—while cumulative savings do not. Cumulative potential includes savings from new measure installations only during the 20-year study horizon and assumes like-for-like replacement of efficient measures when EWR measure lifetimes expire.

Screw-Based Lighting

Despite the DOE's December 27, 2019 final rule and determination that effectively rescinded the EISA 2020 backstop standard,[7] the screw-based LED lighting market continues to transform. To address this transformation within the potential study, the Cadmus team followed Consumers Energy's adopted assumptions (accepted by the MPSC) for screw-based LED lighting program design. This included adjusting the measure life of LED standard and specialty bulbs to coincide with the transformed market (standard LED in 2023 and specialty LED in 2024) projections.

Maximum achievable potential and program achievable potential include savings potential from standard and specialty LED screw-based lamps; however, the baselines for standard LED and specialty LED screw-based lamps will change in 2024 and 2025, respectively, from an incandescent/halogen mix to a market LED baseline, significantly reducing the per-unit savings potential for these lamps. Any remaining potential for screw-based LEDs after these baseline changes is due to the difference between the market LED baseline per-unit energy use assumption and Consortium for Energy Efficiency (CEE) Tier 2 LEDs.

Home Energy Reports

The Cadmus team relied on the *Michigan Behavior Resource Manual* to provide the basis for energy savings, as well as on Consumers Energy's existing EWR behavioral program.[8] The team applied similar savings percentage estimates from the *Michigan Behavior Resource Manual* to single family customers with electric service from Consumers Energy. Generally, the manual calculated savings as a percentage of total home load values, which vary based on the level of total home energy use and the year. These savings percentages ranged from 0.77% for a home with annual use less than 7,000 kWh in the first year a customer receives a report to 2.27% for a home with annual energy use between 7,000 kWh and 8,999 kWh in in the third year a customer receives a report.

Beginning in 2026 and continuing through the end of the study, the Cadmus team deviated from the *Michigan Behavior Resource Manual* by lowering the savings percentages from 2.73% and 2.20% (for single family homes with annual energy use greater than and less than 9,000 kWh, respectively) to 1.5%, after consulting with Consumers Energy's home energy report program vendor, who recommended the lower level of savings based on their experience implementing home energy report programs for utilities across the United States.

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7 U.S. Department of Energy. December 27, 2019. "Energy Conservation Program: Energy Conservation Standards for General Incandescent Service Lamps." https://federalregister.gov/documents/2019/12/27/2019-27515/energy-conservation-program-energy-conservation-standards-for-general-service-incandescent-lamps

8 Michigan Public Service Commission. December 17, 2018. *Michigan Behavior Resource Manual.* https://michigan.gov/mpsc/0,9535,7-395-93309_94801_94808_94812---,00.html

In developing estimates of maximum achievable and program achievable potential, the Cadmus team assumed a significant expansion of the home energy report program to 60% of the eligible single family electric customer population.

To support these assumptions, the Cadmus team reviewed secondary data (including program evaluations and the E Source tracking database) to determine which other, vertically integrated investor-owned utilities in the United States achieved similarly high levels of home energy report customer participation. The research showed that several utilities, including Baltimore Gas and Electric and Pepco in Maryland, both exceeded the 60% customer participation threshold in 2019, with Baltimore Gas and Electric reaching approximately 80% of its residential customer population, based on values in its 2019 fourth-quarter evaluation report and U.S. Energy Information Administration (EIA) Form 861 data.

Michigan Energy Measures Database

The Cadmus team used the MEMD as the primary source of measure data to estimate the savings potential. The MEMD includes measure-level deemed or modeled (nominal) savings that the team used to inform its end-use potential study model.[9] It may not be appropriate to apply nominal saving calculations across all building types and vintages due to differences in baseline use when compared to the baseline use of the prototypical building type; therefore, where possible, the Cadmus team adjusted underlying generic assumptions, e.g., number of people per home, to reflect building and occupancy characteristics collected from primary data (specifically, from the Consumers Energy 2018 *Residential Appliance Saturation and Home Characteristics Study* and the Consumers Energy's 2019 *Commercial and Industrial Market Assessment*).[10]

In addition, nominal savings within the MEMD in some cases exceed the Cadmus team's prototypical baseline end-use consumptions. This may be due to multiple factors, but typically reflects the nominal savings baseline being far less efficient than the prototypical baseline. For example, an MEMD measure of residential attic insulation may represent savings from R-0 to R-49, but the team's prototypical home (representing all insulated and non-insulated homes) has an R-19 value. Since the MEMD savings would overestimate potential within the Cadmus team's calibrated end-use model, the team adjusted the MEMD values by embedding applicability and feasibility constraints or by applying the MEMD's underlining percentage savings assumptions (instead of the nominal saving values).

Industrial Measures

While our residential and commercial methodology represents a bottom-up/top-down approach, the Cadmus team assessed the industrial sector primarily using top-down approach due to the diverse nature of industrial facilities. The unique processes and variations within industrial facilities make it

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9 The MEMD consists of a "Deemed Database" and a "Weighting Tool" of measure-level deemed savings, measure incremental costs, and measure lifetimes.

10 TRC (EMI Consulting). Summer 2020. *2019 Commercial and Industrial Market Assessment.* Prepared for Consumers Energy.

infeasible to develop bottom-up end-use loads; therefore, the team estimated EWR potential for this sector using a wide range of measures culled from multiple sources, including Consumers Energy's industrial sales and customer databases, combined with the EIA *Manufacturing Energy Consumption Survey*[11] and DOE *Industrial Assessment Center Database*,[12] as well as lighting data collected from Consumers Energy's 2019 *Commercial and Industrial Market Assessment*.

While the process end-use potential accounts for the largest end-use category in terms of savings, the characterized process improvements may be underestimated because they are often specialized custom improvements and difficult to estimate across an entire industry. As a result, this study may not reflect the total maximum achievable potential, as it does not account for Consumers Energy's experience with developing process measures for highly specialized, specific industrial applications on a facility-by-facility basis.

Limitations for Program Design

This study provides insights into which measures Consumers Energy can offer in future programs by informing future load reduction from EWR in an IRP context. Several considerations regarding the potential study design may cause future program plans to differ from the study results:

- ***Potential study estimates account for interactions between cost-effective measures.*** When installing two interactive measures (such as ceiling insulation and windows), the combined interactive savings are lower than the sum of stand-alone savings for the two measures. Sometimes called measure stacking, such interactive effects can produce lower savings than what is estimated, and program plans may not include all measures considered within the potential study.
- ***The potential study uses broad assumptions about the adoption of EWR measures with different incentive levels.*** Different market potential estimates are meant to be directional (where, given a certain increase or decrease in incentives, there is a corresponding increase or decrease in measure adoption and resulting savings). This approach provides a realistic range of estimates given a range of incentive levels. Program design, however, requires a more detailed examination of historical participation and incentive levels on a measure-by-measure basis. The potential study can be used to inform planning for measures that Consumers Energy has not historically offered.
- ***The potential study cannot accurately predict all market changes over time, whereas programs are able to address market changes dynamically, in real time.*** While this study accounts for planned changes in codes and standards, the Cadmus team cannot predict upcoming changes in policies, pending codes and standards, and new technologies that will become commercially available during the 20-year study horizon. For example, past potential

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[11] U.S. Energy Information Administration. 2014. *Manufacturing Energy Consumption Survey.* https://eia.gov/consumption/manufacturing/data/2014/

[12] U.S. Department of Energy. 2019. *Industrial Assessment Center Database.* https://energy.gov/eere/amo/industrial-assessment-centers-iacs

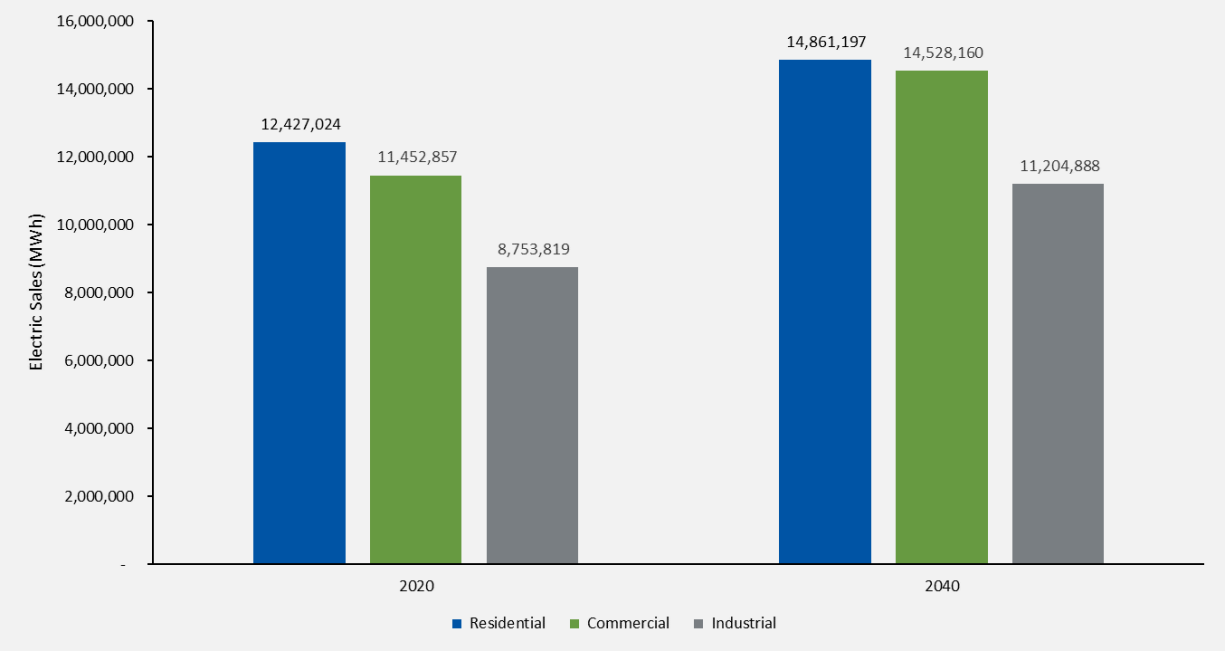
studies may not have accurately predicted the speed and magnitude of recent LED technology adoption. Consumers Energy's programs are not static, providing the flexibility to rapidly address changes in the marketplace. This flexibility was demonstrated in 2020 as Consumers Energy responded to the COVID-19 pandemic with program modifications and innovative measure offerings.

- ***The potential study does not attempt to forecast or otherwise predict future changes in EWR measure costs.*** Although this study includes a thorough estimate of incremental EWR measure costs, including for equipment and labor, it does not attempt to forecast changes to these costs during the study timeline. As a result, incremental costs for some emerging technologies, which may decrease with increased adoption, could be overstated relative to actual costs in later study years.
- ***The potential study incorporated primary data collected within the commercial sector, with findings that provide a probable view of the current commercial stock but may not fully represent Consumers Energy's diverse customer base.*** The commercial baseline market characterization study provided critical inputs for the potential study, such as building characteristics and equipment saturations for each building type. While the baseline study limited the uncertainty through weighting strategies and sample design, all data collection and recruitment efforts produce some level of uncertainty. As a result, the potential study represents the best available data but does not provide a complete and conclusive estimate.
- ***The potential study relies on specified measures and may not include highly customized program measures.*** While this study includes a large variety of EWR measures, it is difficult to characterize highly customized measures that may be designed specifically for a single project or building. For example, while the Cadmus team reviewed a number of measures related to defined technologies used in industrial facilities, we did not capture all the potential from industrial facility custom-process measures specific to *individual* manufacturing processes or facility designs.
- ***The transformational potential relies on technologies in various stages of development to estimate the magnitude, timing, and costs of savings potential with limited data to support measure inputs.*** While this study conducted aggressive research and outreach to identify and characterize promising technologies, limited data are available surrounding these emerging technologies. Significant expert judgement had to be applied when technologies will be commercially available, likely cost trajectories, and estimated savings potential.

Detailed Findings: Baseline Forecast

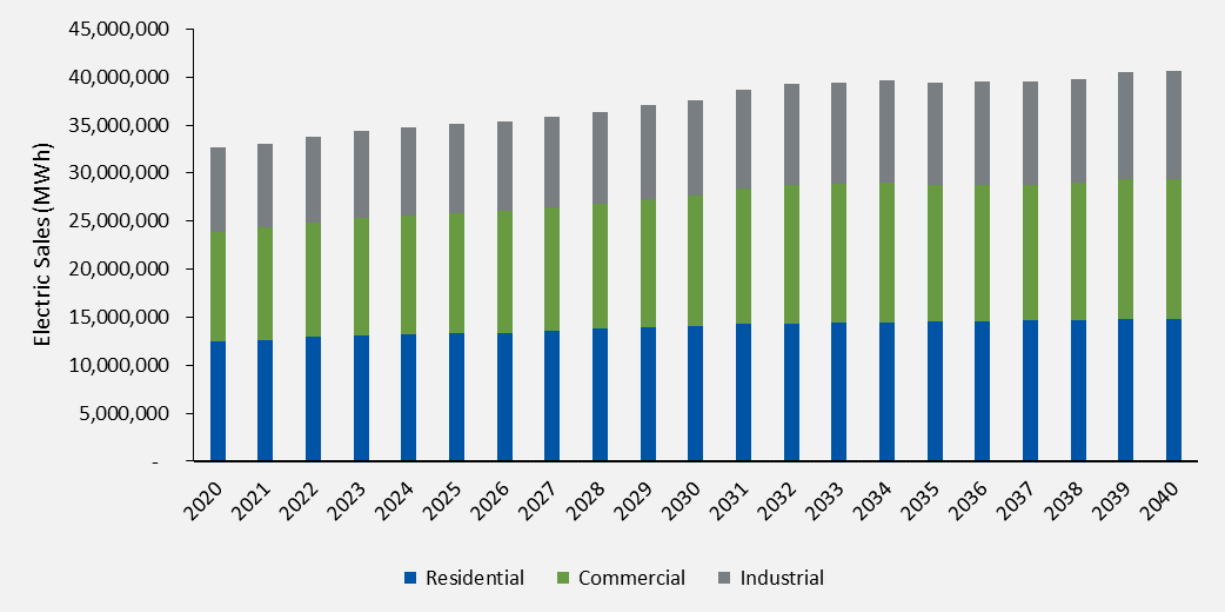
The annual electricity sales in 2020 for the Consumers Energy residential, commercial, and industrial sectors totaled approximately 32,634 GWh. As shown in Figure 9, in 2020 the residential sector accounts for approximately 38% of annual energy sales, while the commercial and industrial sectors combined account for 62% of total sales. The figure also shows the projected 2040 baseline sales of electricity by sector, representing approximately 40,594 GWh. The baseline accounts for naturally occurring potential (such as for changes in codes and standards), as well as for changes in Consumers Energy's customer forecast. *Appendix A* contains additional baseline characterization assumptions for each sector.

Figure 9. Electric Sales by Sector: 2020 and 2040



The baseline forecast in Figure 10 represents the likely future sales in absence of planned efficiency programs. All EWR potentials characterized in this report are referenced and compared to this baseline forecast.

Figure 10. Electricity Baseline Forecast by Sector



Residential Baseline Forecast

For the residential sector, Figure 11 represents the 2020 baseline and 2040 projected baseline sales by segment. Single family baseline sales contribute to approximately 87% in 2020 and 86% in 2040 (all incomes) of the residential electric sales and 33% and 31%, respectively, of all Consumers Energy electricity sales. Overall, low income segments represent 27% of residential sales in 2020 and 2040, while the single family low income segment contributes the majority of low-income sales (82%).

Figure 11. Residential Baseline Electric Sales by Segment: 2020 and 2040

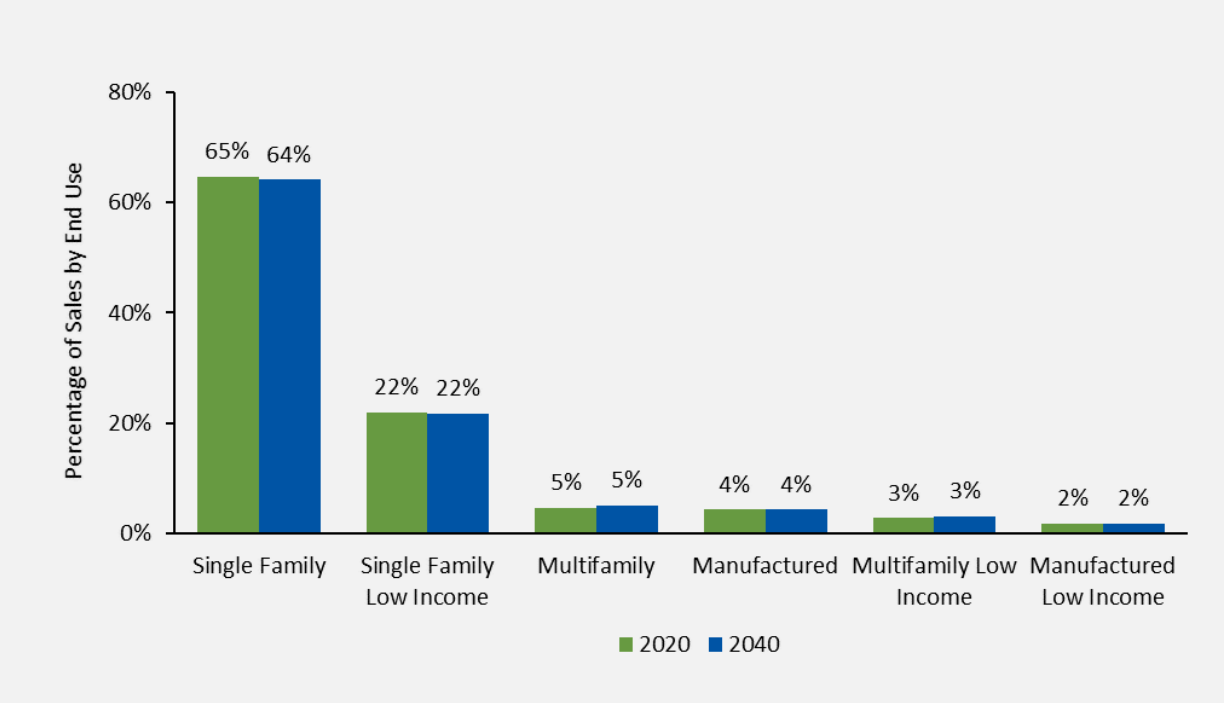


Figure 12 shows the residential baseline forecast by primary end use for 2020 and 2040 as a percentage of baseline sales. Residential lighting represents the predominant end use in 2020 (18% of all residential sales) but reduces to 11% in 2040 due to assumptions regarding changes in lighting market baselines.

Figure 12. Residential Baseline Electric Forecast by End Use: 2020 and 2040

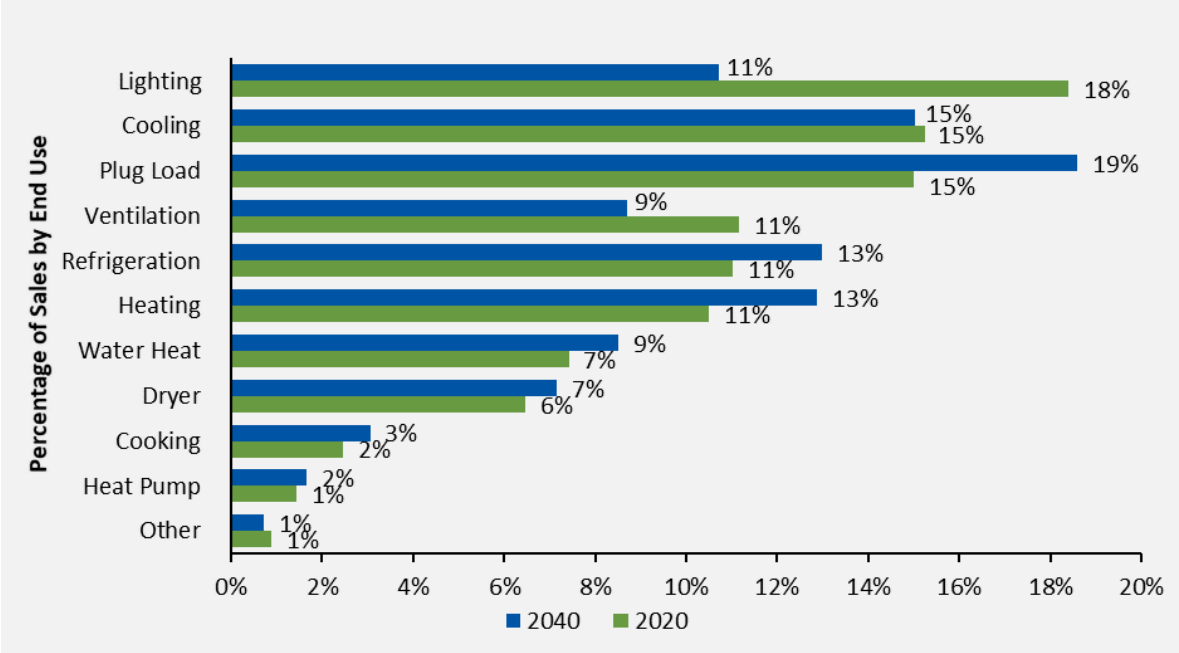


Table 10 shows the 2040 baseline sales by segment and end use.

Table 10. Residential Baseline Electric Sales by Segment and End Use: 2040 (MWh)

End Use Group	Single Family	Single Family Low Income	Multifamily	Multifamily Low Income	Manufactured	Manufactured Low Income	Total [a]
Lighting	1,118,630	335,507	30,594	15,548	66,189	25,432	**1,591,901**
Cooling	1,753,054	317,321	71,510	29,073	46,352	14,514	**2,231,824**
Plug Load	1,879,135	574,285	101,636	46,623	120,043	41,834	**2,763,556**
Ventilation	792,590	322,938	50,064	23,266	73,892	30,497	**1,293,248**
Refrigeration	1,253,519	438,664	79,861	33,349	90,680	34,440	**1,930,514**
Heating	767,530	437,308	306,863	266,464	94,481	39,603	**1,912,250**
Water Heat	649,182	412,053	56,460	25,709	69,962	52,500	**1,265,866**
Dryer	707,948	246,479	23,184	4,693	58,272	21,697	**1,062,274**
Cooking	277,528	111,044	25,796	12,033	21,095	6,676	**454,172**
Heat Pump	213,879	26,414	-	6,605	-	-	**246,898**
Other	108,695	-	-	-	-	-	**108,695**
Total [a]	**9,521,692**	**3,222,014**	**745,967**	**463,363**	**640,968**	**267,194**	**14,861,197**

[a] May not equal sum of rows/columns due to rounding.

Commercial Baseline Forecast

Figure 13 shows the commercial sector 2020 and 2040 projected baseline sales by segment. In 2040 the office building type represents the largest segment, at 23% of the commercial electric sales, followed by retail (19%), other (14%), warehouse (12%), and education (10%). The remaining 21% of commercial electric sales in 2040 contain building segments with less than 10% each: health (8%), restaurant (6%), grocery (4%), and lodging (2%).

Figure 13. Commercial Baseline Electric Sales by Segment: 2020 and 2040

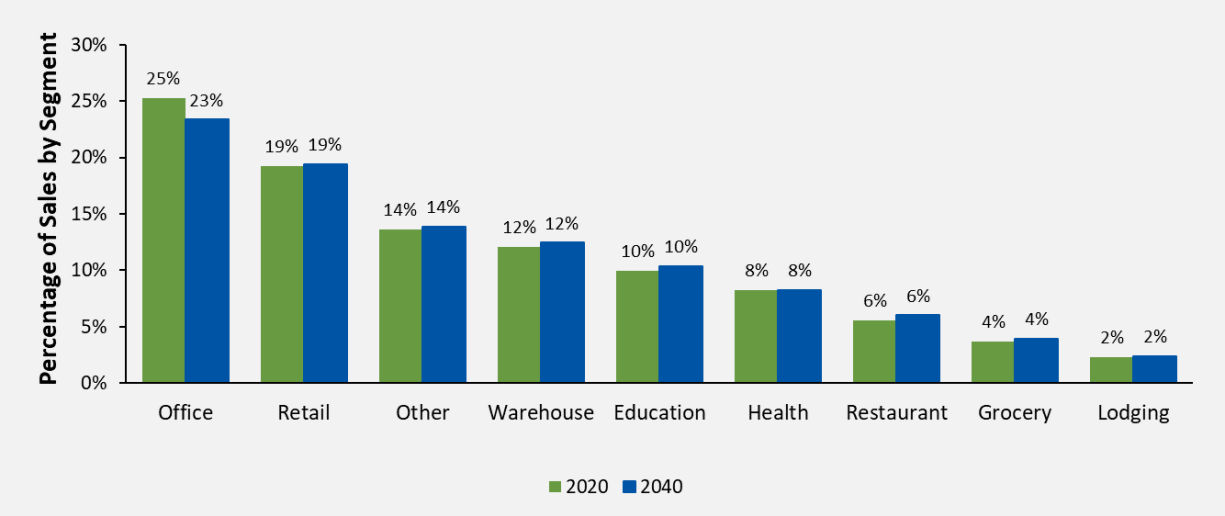


Figure 14 shows the commercial baseline forecast by primary end use for 2020 and 2040 as a percentage of baseline sales. Lighting represents the largest end use in 2020 (41% of all commercial sales) and in 2040 (36% of all commercial sales).

Figure 14. Commercial Baseline Electric Forecast by End Use: 2020 and 2040

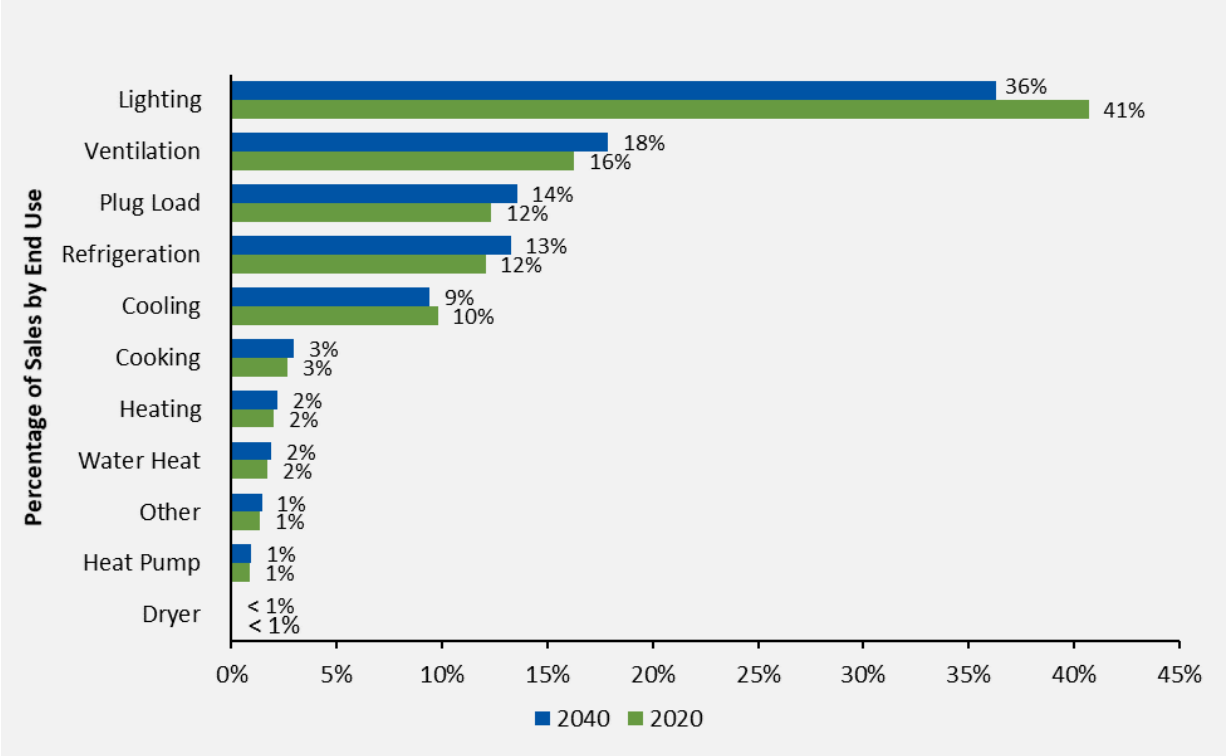


Table 11 shows the 2020 baseline sales by segment and end use.

Table 11. Commercial Baseline Electric Sales by Segment and End Use: 2020 (MWh)

	Education	Grocery	Health	Lodging	Office	Other	Restaurant	Retail	Warehouse	Total [a]
Lighting	440,721	58,765	300,462	47,533	1,258,099	676,161	92,338	900,950	885,146	**4,660,177**
Ventilation	171,958	26,566	194,412	34,024	705,771	174,416	74,464	393,251	88,072	**1,862,935**
Plug Load	188,242	15,492	170,481	74,970	438,646	283,976	51,756	138,990	51,991	**1,414,544**
Refrigeration	107,310	294,380	57,076	19,970	76,055	125,885	226,884	422,399	52,452	**1,382,409**
Cooling	166,269	6,711	120,713	10,705	312,710	213,386	34,868	167,331	92,280	**1,124,972**
Cooking	16,377	16,289	27,887	24,768	624	27,462	146,903	48,138	-	**308,448**
Heating	10,644	957	2,155	39,382	8,771	20,776	5,676	35,419	106,049	**229,831**
Water Heat	21,153	417	47,956	7,436	34,503	20,556	3,943	41,628	22,341	**199,934**
Other	1,738	358	619	558	7,739	16,912	196	44,623	84,335	**157,078**
Heat Pump	14,838	2,498	19,467	1,614	50,329	-	3,323	12,346	-	**104,415**
Dryer	2,627	-	2,160	586	-	2,741	-	-	-	**8,114**
Total [a]	**1,141,878**	**422,432**	**943,389**	**261,547**	**2,893,248**	**1,562,272**	**640,351**	**2,205,075**	**1,382,665**	**11,452,857**

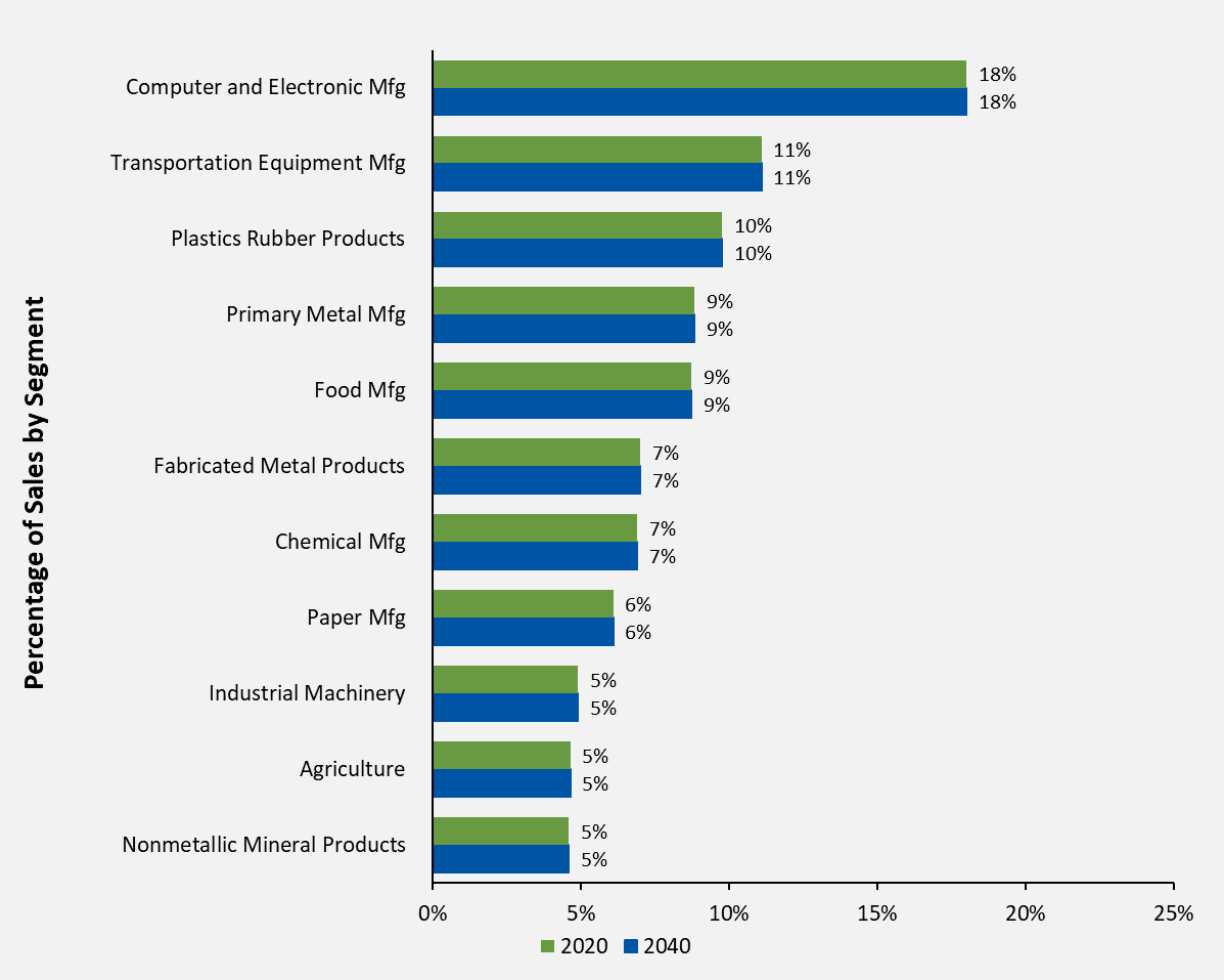
[a] May not equal sum of rows/columns due to rounding.

Industrial Baseline Forecast

Figure 15 shows the industrial sector 2020 and 2040 projected baseline sales by segment. Computer and electronic manufacturing (18%), transportation equipment manufacturing (11%), plastics rubber products manufacturing (10%), primary metal manufacturing (9%), food manufacturing (9%), fabricated

metal products manufacturing (7%), and chemical manufacturing (7%) represent 70% of all industrial electric sales. The agriculture sector, included within the industrial sector, represents 5% of the 2040 industrial sales (approximating 1% of sales across all sectors). Whereas changes to the end-use allocation of forecasted electric energy use in the residential and commercial sectors considers both codes and standards and the natural replacement of old, inefficient equipment, the unique characteristics of the industrial sector and the top-down method employed to disaggregate sector-level loads to segment and end use loads means that these do not vary over time in the baseline forecast.

Figure 15. Industrial Baseline Electric Sales by Segment: 2020 and 2040



Note: The remaining 10% of 2020 and 2040 baseline electric sales are from wood product manufacturing, furniture manufacturing, electrical equipment manufacturing, printing-related support, miscellaneous manufacturing, mining, wastewater, textile mills, textile product mills, leather manufacturing, petroleum coal products, apparel, and water, beverage, and tobacco manufacturing.

Figure 16 shows the industrial baseline forecast by primary end use for 2020 and 2040 as a percentage of baseline sales. Industrial process represents the largest end use in 2020 and in 2040 (both 37% of all industrial sales).

CADMUS

Figure 16. Industrial Baseline Electric Forecast by End Use: 2020 and 2040

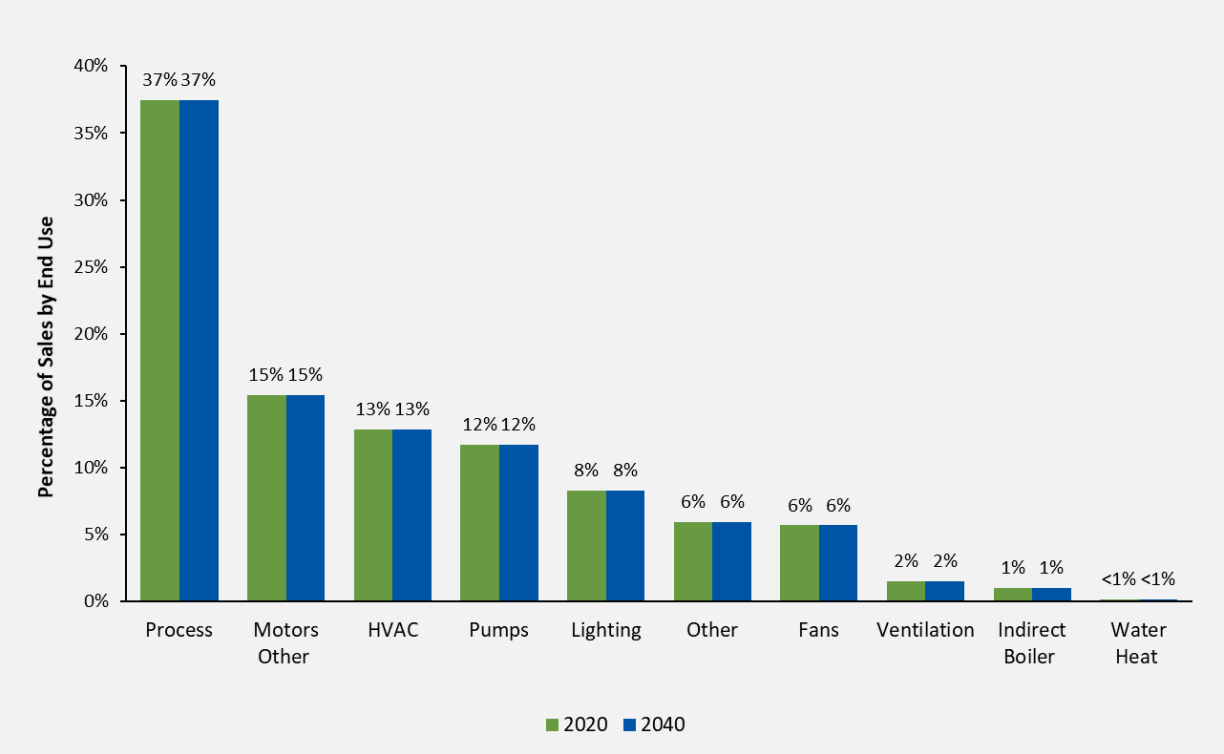


Table 12 shows the 2020 baseline sales by segment and end use.

Table 12. Industrial Baseline Electric Sales by Segment and End Use: 2020 (MWh)

Segment/Type of Manufacturing	Fans	HVAC	Indirect Boiler	Lighting	Motors Other	Other	Process	Pumps	Ventilation	Water Heat	Total [a]
Computer and Electronic	71,148	383,819	14,018	145,990	140,859	147,671	559,313	112,831	-	-	**1,575,651**
Transportation Equipment	44,551	181,056	8,010	120,668	99,958	78,620	340,171	97,337	-	-	**970,371**
Plastics Rubber Products	62,299	86,802	4,136	81,066	177,346	23,214	305,866	112,774	-	-	**853,502**
Primary Metal	31,412	26,728	2,681	25,323	126,468	26,552	515,373	17,862	-	-	**772,398**
Food	24,653	63,243	21,940	56,008	128,194	39,074	377,036	53,907	-	-	**764,056**
Fabricated Metal Products	36,745	95,289	-	58,156	104,604	27,249	223,768	66,517	-	-	**612,328**
Chemical	39,696	43,821	9,567	28,156	89,066	21,495	285,628	86,731	-	-	**604,160**
Paper	78,419	23,452	14,369	21,582	155,254	11,306	104,581	124,361	-	-	**533,325**
Industrial Machinery	25,010	87,525	4,135	59,325	71,197	20,209	115,003	45,274	-	-	**427,677**
Agriculture	-	-	-	38,162	-	44,136	7,028	172,953	131,845	11,596	**405,719**
Nonmetallic Mineral Products	28,938	26,017	3,588	19,864	82,379	8,267	180,850	52,385	-	-	**402,289**
Wood Product	13,744	10,237	1,503	8,112	39,124	4,383	33,164	24,879	-	-	**135,146**
Furniture	8,978	26,482	1,558	21,862	25,558	6,099	23,801	16,252	-	-	**130,589**
Electrical Equipment	3,696	18,350	513	10,865	8,294	3,276	56,228	8,076	-	-	**109,298**
Printing Related Support	8,010	18,405	916	9,171	22,802	4,229	28,534	14,500	-	-	**106,566**
Miscellaneous	5,143	26,341	1,491	15,084	20,708	6,203	28,074	2,925	-	-	**105,969**
Mining	10,706	-	-	-	43,105	9,050	10,006	6,088	-	-	**78,955**
Water	-	-	-	-	-	-	62,042	-	-	-	**62,042**
Beverage and Tobacco	1,722	4,170	537	3,298	4,901	4,717	12,170	3,116	-	-	**34,631**
Wastewater	-	-	-	-	-	33,978	-	-	-	-	**33,978**
Textile Mills	1,040	1,909	264	934	2,960	302	3,503	1,882	-	-	**12,794**
Textile Product Mills	623	1,120	423	912	1,774	426	2,257	1,128	-	-	**8,662**
Leather	742	832	54	885	2,113	215	2,265	1,344	-	-	**8,450**
Petroleum Coal Products	360	111	25	79	1,023	84	750	651	-	-	**3,082**
Apparel	120	638	48	375	343	92	346	218	-	-	**2,180**
Total [a]	**497,755**	**1,126,346**	**89,775**	**725,877**	**1,348,030**	**520,846**	**3,277,755**	**1,023,992**	**131,845**	**11,596**	**8,753,819**

[a] May not equal sum of rows/columns due to rounding.

Detailed Findings: Technical and Economic Potential

This study included a comprehensive set of EWR measures from Consumers Energy's programs and the MEMD, supplemented by additional measures not currently offered by Consumers Energy or included in the MEMD. We began our analysis by assessing the technical potential for hundreds of unique EWR measures. As discussed in the *Measure Characterization* section, we considered measure savings and costs separately for each measure permutation across applicable sector, segment, end use, and construction vintage. As shown in Table 13, the Cadmus team considered 7,314 EWR measure permutations and 471 unique measures across all sectors and fuels.

Table 13. Energy Waste Reduction Measure Counts and Permutations

Sector	Unique Electric Measures	Electric Permutations
Residential	122	2,179
Commercial	230	3,851
Industrial	119	1,284
Total	**471**	**7,314**

The study identified more than 10,527 GWh of cumulative technically feasible electric EWR potential by 2040, with cost-effective measures producing approximately 10,333 GWh. Economic potential represents 26% of forecasted 2040 sales. On an annual basis, the 20-year technical and economic potential savings each correspond to 1.5% of sales. Table 14 summarizes electric technical and economic potential for each sector. The residential sector accounts for 52.6% of the total economic electric potential, followed by commercial and industrial, at 29.6% and 17.8%, respectively.

Table 14. Energy Waste Reduction Technical and Economic Potential by Sector-Energy: Cumulative 2040

Sector	Baseline Sales (MWh)	Technical Potential		Economic Potential		Economic Potential Percentage of Technical Potential
		MWh	Percentage of Baseline Sales	MWh	Percentage of Baseline Sales	
Residential	14,861,197	5,515,726	37.1%	5,429,686	36.5%	98.4%
Commercial	14,528,160	3,112,498	21.4%	3,061,027	21.1%	98.3%
Industrial	11,204,888	1,898,978	16.9%	1,842,475	16.4%	97.0%
Total [a]	**40,594,246**	**10,527,202**	**25.9%**	**10,333,188**	**25.5%**	**98.2%**

[a] May not equal sum of rows due to rounding.

Table 15 provides the corresponding electric peak demand reduction potential.

Table 15. Energy Waste Reduction Technical and Economic Potential by Sector-Demand: Cumulative 2040

Sector	20-Year Technical Potential (MW)	20-Year Economic Potential (MW)	Economic Potential Percentage of Technical Potential
Residential	1,661	1,654	99.6%
Commercial	517	514	99.5%
Industrial	304	294	96.9%
Total [a]	**2,481**	**2,462**	**99.2%**

[a] May not equal sum of rows/columns due to rounding.

Detailed Findings: Maximum Achievable Potential

Estimating technical and economic potentials fundamentally remains an engineering and accounting endeavor, whereas estimating maximum achievable and program achievable potential requires a prediction of customer behavior related to adopting EWR measures. This chapter provides the maximum achievable potential results.

The Cadmus team estimated maximum achievable potential as a subset of economic potential that assumes EWR measure-specific ramp rates, using market research and our recent program experience, as well as using current incentive, implementation, and administration costs for each EWR measure from Consumers Energy programs. The maximum achievable potential also includes EWR measures not currently offered and includes a higher volume of home energy reports than offered through the current program. The Cadmus team closely calibrated our findings to the existing levels of Consumers Energy's incentives (expressed as a percentage of either incremental costs or total measure costs). The Detailed Measure Results workpaper contains additional measure characterization assumptions and potential by measure within each sector.

The savings within the maximum achievable potential also represent gross savings and do not consider savings attribution for any particular program. Maximum achievable potential represents an enhanced portfolio of measures compared to Consumers Energy existing programs, and also accounts for future market impacts such as from codes and standards. The maximum achievable potential spreads discretionary and lost opportunity savings over the study horizon using a ramp-rate selection, based on Consumers Energy's recent measure-level EWR program achievements.

The maximum achievable potential includes energy savings and demand reduction for each measure. Table 16 shows the annual maximum achievable potential EWR program expenditures for incentives and administrative costs, in 2020 dollars. Administrative costs include Consumers Energy's program implementation, marketing, direct install, and administration costs. The year-over-year total expenditures follow market impacts, such as in years 2023 to 2024, when the large drop in expenditures is directly related to the absence of residential LED lighting measures. Another decline starts in 2031, representing when nonresidential LED market adoption has no remaining potential.

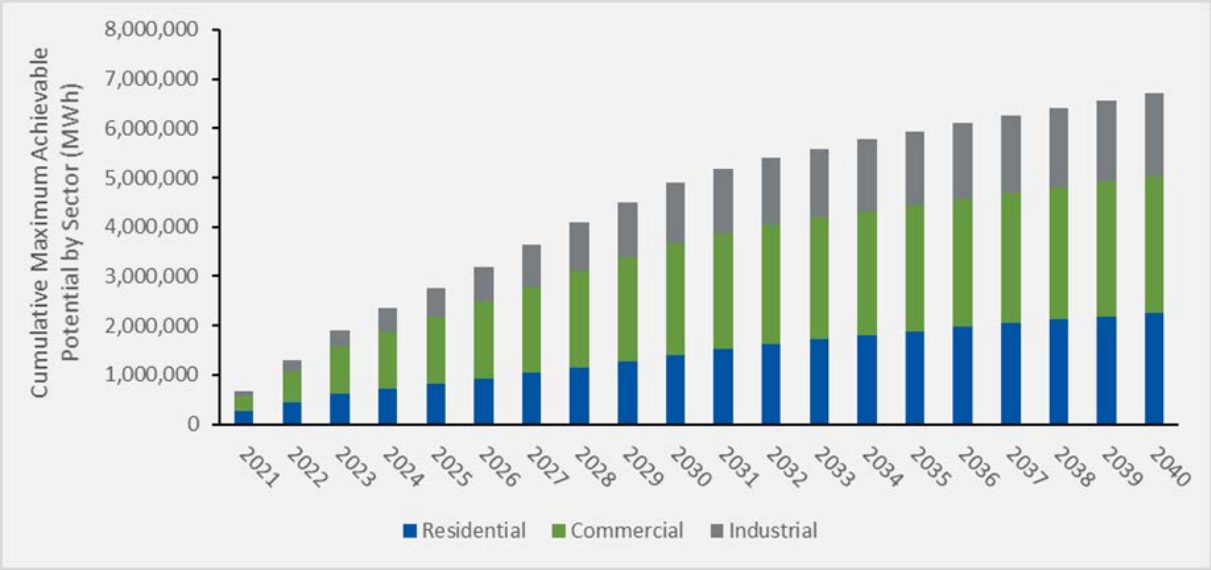
Table 16. Maximum Achievable Potential Energy Waste Reduction Program Expenditures Assumptions

Year	Cost (Million USD)		
	Incentives	Administrative	Total [a]
2021	$73.18	$92.41	**$165.59**
2022	$76.24	$96.95	**$173.19**
2023	$74.85	$96.10	**$170.95**
2024	$61.58	$78.40	**$139.98**
2025	$69.84	$78.63	**$148.47**
2026	$69.85	$79.38	**$149.23**
2027	$71.93	$86.03	**$157.96**
2028	$72.75	$91.82	**$164.56**
2029	$71.12	$92.63	**$163.75**
2030	$74.73	$100.23	**$174.96**
2031	$61.44	$92.50	**$153.95**
2032	$58.86	$89.47	**$148.33**
2033	$54.06	$82.48	**$136.54**
2034	$52.76	$81.07	**$133.83**
2035	$51.98	$80.17	**$132.15**
2036	$66.76	$83.89	**$150.65**
2037	$70.25	$86.91	**$157.16**
2038	$72.52	$87.27	**$159.78**
2039	$70.54	$93.18	**$163.72**
2040	$76.12	$95.34	**$171.46**

[a] May not equal sum of columns due to rounding.

Figure 17 presents the 20-year cumulative maximum achievable EWR potential in megawatt-hours.

Figure 17. Cumulative Maximum Achievable Potential by Sector



Residential

Residential customers in Consumers Energy service territory accounted for 37% of electric baseline forecast sales in 2040—approximately 14,861 GWh. This sector—divided into single family, single family low income, manufactured, manufactured low income, multifamily, and multifamily low income—presents a variety of potential savings sources, including general and specialty LED lighting, air-source and ductless heat pumps, behavior measures, and removing secondary refrigerators.

Based on the resources we assessed, the Cadmus team estimated residential cumulative maximum achievable potential of approximately 2,262,348 MWh over 20 years, corresponding to a 15.2% reduction in residential baseline sales by 2040. This also corresponds to annual savings of 0.8% of sales. Table 17 shows cumulative, 20-year residential electric conservation potential by residential segment.

Table 17. Residential Maximum Achievable Potential by Segment-Energy: Cumulative 2040

Segment	Baseline Sales by Segment	MWh Savings	Percentage of Baseline Sales	MW Savings
Single Family	9,521,692	1,453,901	15.3%	456
Single Family Low Income	3,222,014	551,242	17.1%	145
Manufactured	640,968	86,171	13.4%	26
Multifamily	745,967	79,682	10.7%	23
Multifamily Low Income	463,363	47,333	10.2%	10
Manufactured Low Income	267,194	44,018	16.5%	12
Total or Average [a]	**14,861,197**	**2,262,348**	**15.2%**	**672**

[a] May not equal sum of rows due to rounding.

Table 18 shows cumulative 20-year residential electric conservation potential for the residential segment by end uses and relative to baseline sales. The table shows that the behavior (46%), refrigeration (18%), lighting (16%), heating (5%), and cooling (4%) end uses combined account for 89% of electric residential, cumulative maximum achievable potential. The heating end use only represented 5% because most customers have non-electric heating. The large behavioral savings represents the unconstrained potential from behavior-based changes.

Table 18. Residential Maximum Achievable Potential by End Use-Energy: Cumulative 2040

End Use	Baseline Sales by End Use	MWh Savings	Percentage of Baseline Sales	MW Savings
Refrigeration	1,930,514	731,267	37.9%	86
Lighting	1,591,901	641,698	40.3%	188
Heating	1,912,250	191,430	10.0%	0
Cooling	2,231,824	172,482	7.7%	189
Water Heat	1,265,866	155,823	12.3%	79
Plug Load	2,763,556	123,472	4.5%	66
Dryer	1,062,274	107,848	10.2%	38
Behavior [b]	NA	88,697	NA	10
Heat Pump	246,898	30,783	12.5%	3
Cooking	454,172	18,376	4.0%	11
Other	108,695	473	0.4%	0
Ventilation	1,293,248	0	0.0%	0
Total [a]	**14,861,197**	**2,262,348**	**15.2%**	**672**

[a] May not equal sum of rows due to rounding.
[b] Behavior savings cross all end uses.

Figure 18 shows electric residential cumulative maximum achievable potential by end use in 2025 and 2040.

Figure 18. Residential Maximum Achievable Potential by End Use-Energy: Cumulative

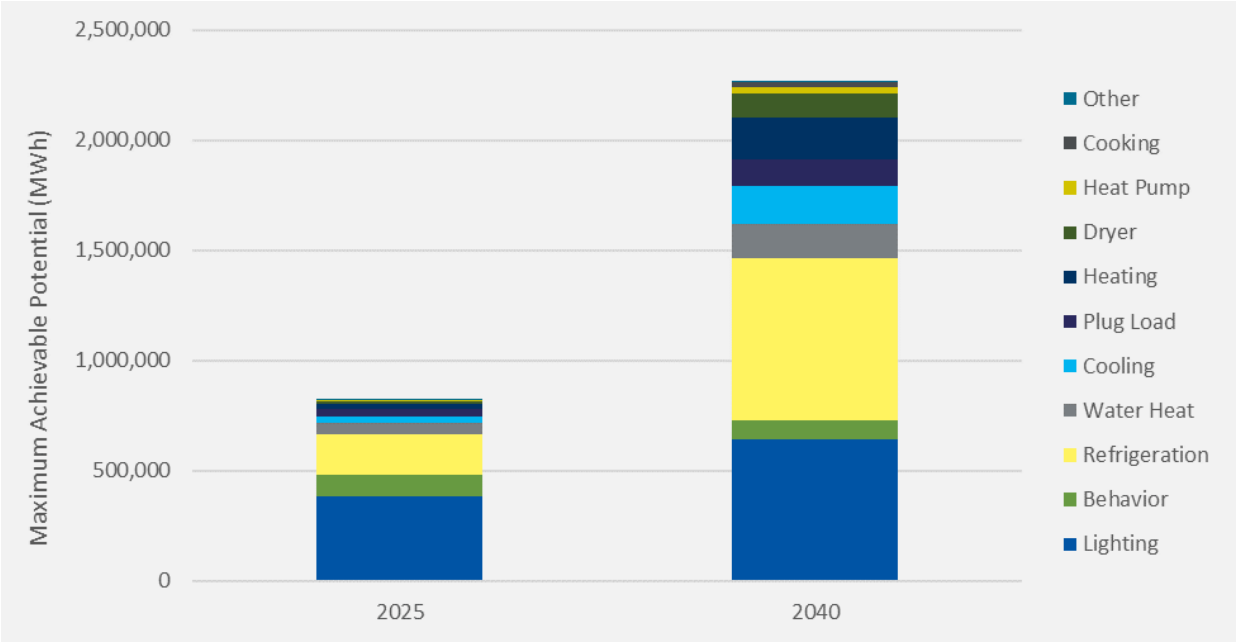


Table 19 lists the top 15 saving electric residential measures that passed the UCT benefit/cost screen. Refrigerator and freezer recycling create the most EWR residential electric maximum achievable potential, LED lighting, home energy reports, windows, heat pump dryers, and lighting controls. Collectively, these top savings measures accounted for 89% of the 20-year residential maximum achievable potential.

Table 19. Top Residential Maximum Achievable Potential Measures: Cumulative 2025 and 2040

Measure Name	Maximum Achievable Potential			
	Cumulative 5-Year (MWh)	Percentage of 5-Year Residential Potential	Cumulative 20-Year (MWh)	Percentage of 20-Year Residential Potential
Home Energy Reports	99,648	12%	88,697	4%
Refrigerator - Removal of Secondary	93,524	11%	726,548	32%
Lighting General Service Lamp - CEE Tier 2	83,360	10%	181,618	8%
Freezer - Removal of Stand-Alone	79,772	10%	319,087	14%
Lighting Specialty Lamp - CEE Tier 2	72,016	9%	173,146	8%
Linear Fluorescent Lamp - TLED	20,088	2%	62,234	3%
Low-Flow Showerhead	17,596	2%	44,937	2%
Interior Lighting Controls	17,025	2%	68,884	3%
Central Air Conditioner - Tier 4	15,755	2%	58,881	3%
Refrigerator - CEE Tier 3	11,289	1%	35,642	2%
Exterior Lighting Controls	9,268	1%	37,498	2%
Dryer - Heat Pump Dryer	9,140	1%	79,168	3%
Ceiling Fan - ENERGY STAR	9,139	1%	37,165	2%
Windows	8,075	1%	85,604	4%
Ceiling / Attic Insulation	2,451	0%	42,157	2%

Commercial

Consumers Energy's commercial sector accounted for 36% of forecasted baseline sales in 2040—approximately 14,528 GWh. The Cadmus team estimated potential for the nine commercial segments listed in Table 20, which summarizes 20-year cumulative maximum achievable potential and the same potentials as a percentage of sales. The available maximum achievable potential for the commercial sector represents 19% of the total 2040 forecasted sales, which corresponds to annual savings of 1.1% of sales. The table shows that offices, retail buildings, warehouses, and other commercial buildings representing 25%, 19%, 16%, and 13%, respectively, of the cumulative 2040 commercial maximum achievable potential.

Table 20. Commercial Maximum Achievable Potential by Segment-Energy: Cumulative 2040

Segment	Baseline Sales by Segment	MWh Savings	Percentage of Baseline Sales	MW Savings
Office	3,392,646	696,975	20.5%	125
Retail	2,817,591	526,321	18.7%	81
Warehouse	1,807,509	445,451	24.6%	64
Other	2,015,616	349,412	17.3%	54
Education	1,503,735	272,055	18.1%	45
Health	1,201,677	204,106	17.0%	33
Restaurant	872,417	133,420	15.3%	17
Grocery	572,090	84,996	14.9%	8
Lodging	344,878	52,777	15.3%	6
Total	**14,528,160**	**2,765,511**	**19.0%**	**434**

[a] May not equal sum of rows due to rounding.

Table 21 shows cumulative 20-year maximum achievable potential for the commercial sector by end use. Lighting (67%), refrigeration (9%), cooling (9%), and ventilation (4%) end uses have the highest 20-year maximum achievable potential in the commercial sector.

Table 21. Commercial Maximum Achievable Potential by End Use-Energy: Cumulative 2040

End Use	Baseline Sales by End Use	MWh Savings	Percentage of Baseline Sales	MW Savings
Lighting	5,276,623	1,852,460	35.1%	285
Refrigeration	1,927,013	259,140	13.4%	20
Cooling	1,366,558	243,037	17.8%	84
Ventilation	2,598,798	120,101	4.6%	12
Heating	320,614	69,817	21.8%	0
Water Heat	278,909	69,253	24.8%	3
Plug Load	1,969,685	41,543	2.1%	4
Heat Pump	138,375	43,422	31.4%	14
Cooking	430,286	41,499	9.6%	7
Other	211,405	24,439	11.6%	4
Dryer	9,895	801	8.1%	0
Total [a]	**14,528,160**	**2,765,511**	**19.0%**	**434**

[a] May not equal sum of rows due to rounding.

Figure 19 shows commercial cumulative maximum achievable potential by end use in 2025 and 2040.

Figure 19. Commercial Maximum Achievable Potential by End Use-Energy: Cumulative

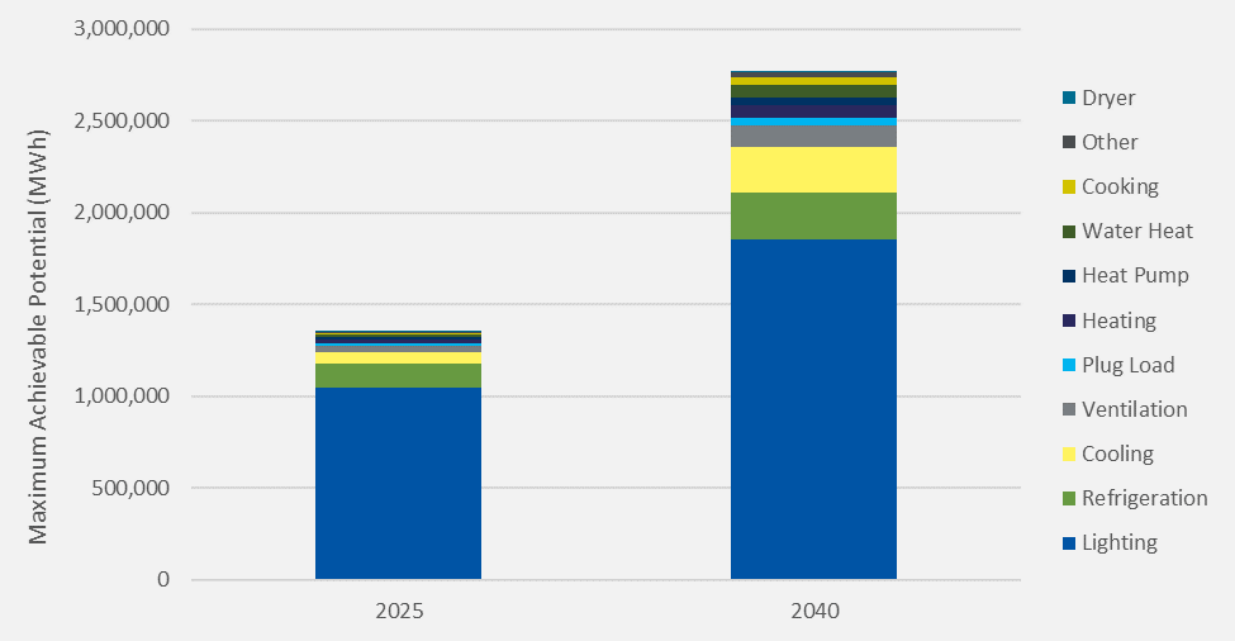


Table 22 lists the top 15 saving commercial measures. The top commercial measures collectively represent 69% of the 20-year commercial maximum achievable potential.

Table 22. Top Commercial Maximum Achievable Potential Measures: Cumulative 2025 and 2040

Measure Name	Maximum Achievable Potential			
	Cumulative 5-Year (MWh)	Percentage of 5-Year Commercial Potential	Cumulative 20-Year (MWh)	Percentage of 20-Year Commercial Potential
Lighting Interior - Screw Base LED - Above Standard	416,107	31%	462,341	17%
Lighting Interior - TLED / LED Panel - Above Standard	204,005	15%	418,602	15%
Occupancy Sensor Control	84,827	6%	212,066	8%
LED Exterior Wall Pack	71,129	5%	115,015	4%
Dimming, Fluorescent Fixtures	54,940	4%	109,879	4%
Advanced Network Occupancy and Daylighting Controls	54,894	4%	109,788	4%
Exterior Occupancy Sensor	43,064	3%	107,660	4%
LED Exterior Flood Lights	37,649	3%	60,878	2%
Bi-Level Control, Stairwell Lighting	29,393	2%	59,196	2%
Walk-in Economizer	29,216	2%	59,184	2%
Lighting Interior - High Bay LED - Above Standard	22,768	2%	46,809	2%
LED Exterior Pole Mount Fixture	21,455	2%	34,692	1%
New Construction Lighting Package - Advanced Efficiency	17,520	1%	43,855	2%
Wall Insulation	10,346	1%	41,384	1%
Direct Digital Control System-Installation	8,699	1%	34,796	1%

Industrial

Consumers Energy's industrial sector accounted for 28% of baseline sales in 2040—approximately 11,205 GWh. The Cadmus team estimated potential for the 25 industrial segments (including agriculture) listed in Table 23, which summarizes 20-year cumulative maximum achievable potential and the same potentials as a percentage of sales. Available maximum achievable potential for the industrial sector represents 15% of the total 2040 forecasted load, which corresponds to annual savings of 0.8% of sales. The table shows that the top five industries represent 59% of cumulative 2040 maximum achievable potential.

Table 23. Industrial Maximum Achievable Potential by Segment-Energy: Cumulative 2040

Segment/Type of Manufacturing	Baseline Sales by Segment	MWh	Percentage of Baseline Sales	MW
Computer and Electronic	2,016,833	331,227	16.4%	48
Transportation Equipment	1,242,074	224,735	18.1%	32
Plastics Rubber Products	1,092,482	172,212	15.8%	25
Food	977,991	145,880	14.9%	21
Fabricated Metal Products	783,780	127,435	16.3%	18
Primary Metal	988,669	118,140	11.9%	17
Chemical	773,325	101,709	13.2%	15
Industrial Machinery	547,426	91,310	16.7%	13
Paper	682,656	77,648	11.4%	11
Nonmetallic Mineral Products	514,930	74,862	14.5%	11
Agriculture	519,321	67,888	13.1%	35
Furniture	167,154	28,467	17.0%	4
Wood Product	172,987	24,612	14.2%	4
Miscellaneous	135,641	24,097	17.8%	3
Electrical Equipment	139,902	23,114	16.5%	3
Printing Related Support	136,405	21,510	15.8%	3
Mining	101,062	8,771	8.7%	1
Beverage and Tobacco	44,328	6,630	15.0%	1
Wastewater	43,491	5,336	12.3%	1
Water	79,414	4,560	5.7%	1
Textile Mills	16,376	2,494	15.2%	0
Textile Product Mills	11,088	1,681	15.2%	0
Leather	10,816	1,629	15.1%	0
Petroleum Coal Products	3,946	501	12.7%	0
Apparel	2,791	498	17.8%	0
Total [a]	**11,204,888**	**1,686,948**	**15.1%**	**269**

[a] May not equal sum of rows due to rounding.

Table 24 shows cumulative 20-year electric conservation potential for the industrial sector by end use. Process load savings represent the highest potential savings (39%) by end use.

Table 24. Industrial Maximum Achievable Potential by End Use-Energy: Cumulative 2040

End Use	Baseline Sales by End Use	MWh	Percentage of Baseline Sales	MW
Process	4,195,527	661,075	15.8%	96
HVAC	1,441,723	312,997	21.7%	45
Lighting	929,122	287,205	30.9%	42
Motors Other	1,725,479	153,934	8.9%	22
Pumps	1,310,710	134,885	10.3%	42
Fans	637,127	63,086	9.9%	9
Other	666,683	36,401	5.5%	5
Ventilation	168,762	31,462	18.6%	7
Indirect Boiler	114,912	5,772	5.0%	1
Water Heat	14,843	132	0.9%	0
Total [a]	**11,204,888**	**1,686,948**	**15.1%**	**269**

[a] May not equal sum of rows due to rounding.

Figure 20 shows the industrial cumulative maximum achievable potential by end use in 2025 and 2040.

Figure 20. Industrial Maximum Achievable Potential by End Use-Energy: Cumulative

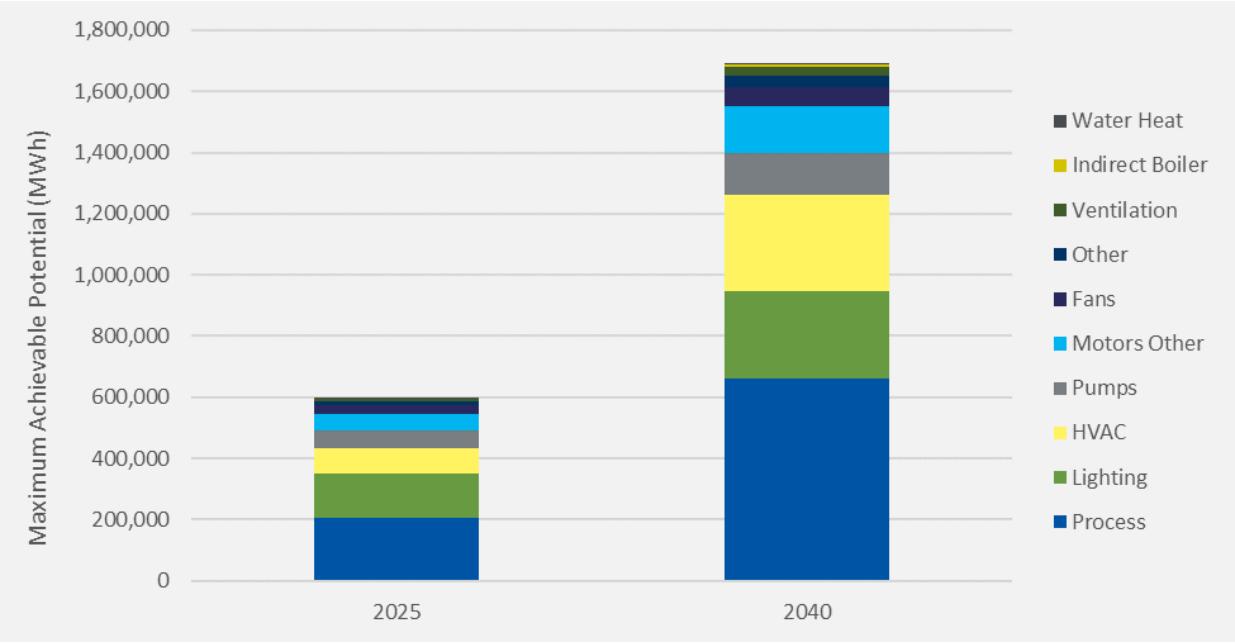


Table 25 lists the top 15 saving electric industrial measures, which collectively represent approximately 54% of the sector's total maximum achievable potential. LED lighting measures accounted for approximately 9% of the industrial electric maximum achievable savings potential.

Table 25. Top Industrial Maximum Achievable Potential Measures: Cumulative 2025 and 2040

Measure Name	Maximum Achievable Potential			
	Cumulative 5-Year (MWh)	Percentage of 5-Year Industrial Potential	Cumulative 20-Year (MWh)	Percentage of 20-Year Industrial Potential
Lighting - Linear LED Packages	51,814	4%	103,629	6%
Optimize Lighting System - Install Skylights And Use Daylighting	27,585	2%	55,170	3%
Equipment Upgrade - Replace Existing Chiller With High Efficiency Model	26,622	2%	66,556	4%
Cooling Tower Operation And Maintenance	25,851	2%	64,627	4%
Lighting - High Bay LED Packages	25,769	2%	51,537	3%
Upgrade Equipment - Replace Existing HVAC Unit With High Efficiency Model	24,687	2%	98,748	6%
Install Adjustable Frequency Drive to Replace Existing System - Pumps	23,686	2%	47,372	3%
Equipment Upgrade - Air Compressor	20,010	2%	50,026	3%
Optimize Chiller and Refrigeration Systems	19,992	2%	49,980	3%
Thermal Systems Recover Heat And Use For Preheating, Space Heating, Power Generation, Steam Generation, Transformers, Exhausts, Engines, Compressors, Dryers, Waste Process Heat, etc.	18,357	2%	73,428	4%
Optimize Motor Systems With Right Sizing	17,967	2%	44,917	3%
Install Compressor Controls	17,909	2%	44,771	3%
Thermal Systems Add Insulation to Equipment	12,958	1%	51,831	3%
Building Envelope Insulation and Window/Door Improvements	12,233	1%	48,932	3%
Building Duct System Improvements	11,392	1%	45,568	3%

Detailed Findings: Program Achievable Potential

The Cadmus team estimated program achievable potential as a subset of maximum achievable potential based on Consumers Energy paying incentive levels (as a percentage of incremental or total measure costs) that are closely calibrated to historical levels, subject to any overall program- or customer class-specific spending constraints. The team mapped program achievable potential incentive levels to those currently offered by Consumers Energy. For instances where we were unable to identify a direct, current incentive for an EWR measure, we used a similar technology and incentive level as a proxy. In addition, the team modeled increased distribution of home energy reports within the residential sector as an expansion to the existing Consumers Energy program.

The savings within the program achievable potential also represent net savings and measures currently offered through Consumers Energy programs and measures with potential to be offered within the study horizon, while also accounting for future market impacts (such as federal standards). The program achievable potential spreads discretionary and lost opportunity savings over the study horizon using a ramp-rate selection based on Consumers Energy's recent, measure-level EWR program achievements.

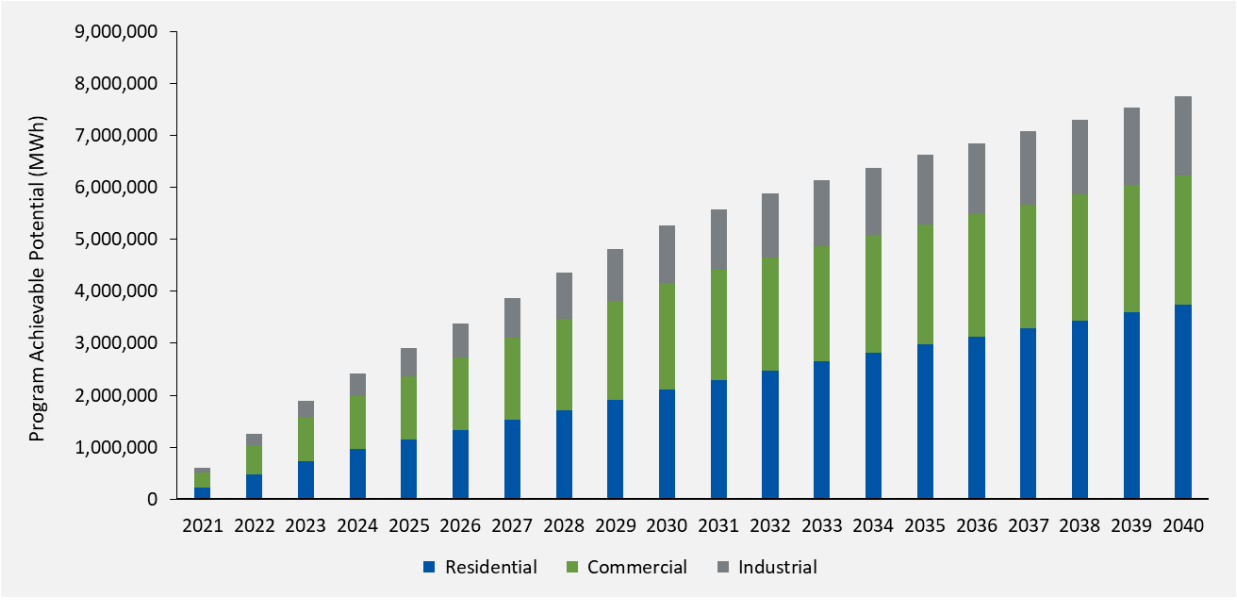
The Cadmus team used various budget assumptions to develop program achievable potential, based on anticipated levels of programmatic spending by Consumers Energy. Table 26 shows the yearly expenditures for administrative and incentive costs. In a pattern similar to that for the estimated maximum achievable potential spending, the budget reflects market impacts from changes such as a decline in spending after 2023, when the LED measures no longer have potential due to changing lighting standards.

Table 26. Program Achievable Potential Energy Waste Reduction Program Expenditures Assumptions

Year	Cost (Million USD)		
	Incentives	Administrative	Total
2021	$60.19	$86.27	**$146.45**
2022	$62.98	$90.57	**$153.55**
2023	$62.04	$90.59	**$152.64**
2024	$53.04	$75.19	**$128.23**
2025	$60.33	$75.18	**$135.50**
2026	$60.55	$76.29	**$136.84**
2027	$62.84	$83.41	**$146.25**
2028	$63.40	$88.75	**$152.14**
2029	$61.82	$89.66	**$151.48**
2030	$64.79	$96.66	**$161.46**
2031	$52.76	$93.90	**$146.66**
2032	$50.78	$91.42	**$142.20**
2033	$47.21	$85.66	**$132.87**
2034	$45.92	$83.44	**$129.36**
2035	$45.02	$81.71	**$126.72**
2036	$58.19	$85.32	**$143.52**
2037	$61.42	$88.14	**$149.56**
2038	$63.75	$88.90	**$152.65**
2039	$60.45	$94.37	**$154.82**
2040	$65.74	$96.62	**$162.36**

Figure 21 presents the 20-year cumulative program achievable EWR potential in megawatt-hours.

Figure 21. Cumulative Program Achievable Potential by Sector



Residential

Based on resources included in this assessment, the Cadmus team estimated residential cumulative program achievable potential of 1,737,9112 MWh over 20 years, corresponding to a 25% reduction in residential baseline sales. Table 27 displays cumulative 20-year residential electric conservation for each segment in the residential sector.

Table 27. Residential Program Achievable Potential by Segment-Energy: Cumulative 2040

Segment	Baseline Sales by Segment	MWh	Percentage of Baseline Sales	MW
Single Family	9,521,692	1,055,697	11%	250
Single Family Low Income	3,222,014	480,932	15%	101
Manufactured	640,968	61,247	10%	16
Multifamily	745,967	57,986	8%	14
Multifamily Low Income	463,363	42,881	9%	7
Manufactured Low Income	267,194	39,169	15%	9
Total [a]	**14,861,197**	**1,737,912**	**12%**	**397**

[a] May not equal sum of rows due to rounding.

Table 28 shows cumulative 20-year residential electric energy waste reduction potential for the residential segment by end uses and relative to baseline sales. The table shows that more than one-third of the available program achievable potential comes from refrigeration (37%). The other end uses with significant amounts of potential are refrigeration (42%), heating (9%), and cooling (7%).

Table 28. Residential Program Achievable Potential by End Use-Energy: Cumulative 2040

End Use	Baseline Sales by End Use	MWh	Percentage of Baseline Sales	MW
Refrigeration	1,930,514	649,187	34%	76
Lighting	1,591,901	423,172	27%	50
Heating	1,912,250	159,482	8%	0
Cooling	2,231,824	138,499	6%	163
Water Heat	1,265,866	126,414	10%	53
Dryer	1,062,274	99,924	9%	36
Behavior	NA	70,957	NA	8
Plug Load	2,763,556	45,607	2%	8
Heat Pump	246,898	24,244	10%	3
Other	108,695	426	0%	0
Cooking	454,172	0	0%	0
Ventilation	1,293,248	0	0%	0
Total [a]	**14,861,197**	**1,737,912**	**12%**	**397**

[a] May not equal sum of rows due to rounding.

Figure 22 shows electric residential cumulative program achievable potential by end use in 2025 and 2040

Figure 22. Residential Program Achievable Potential by End Use-Energy: Cumulative

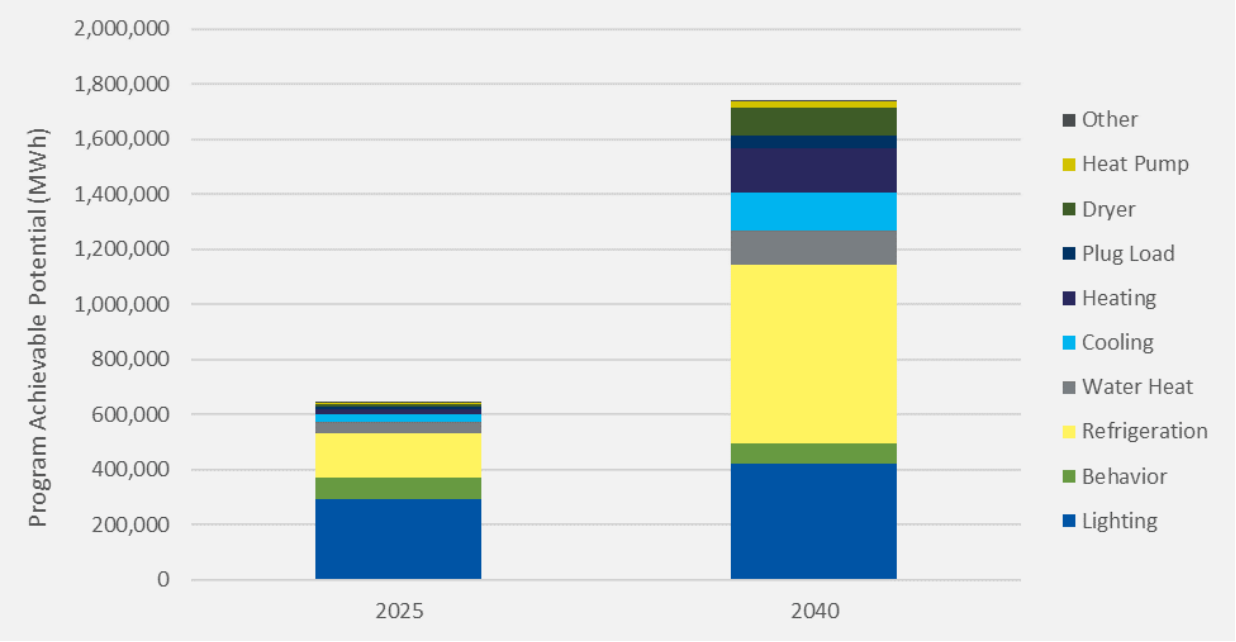


Table 29 lists the top 15 saving electric residential measures that passed the UCT benefit/cost screen. Secondary refrigerator and freezer removal are large contributors, collectively making up 37% of the 20-year residential program achievable potential.

Table 29. Top Residential Program Achievable Potential Measures: Cumulative 2025 and 2040

Measure Name	Program Achievable Potential			
	Cumulative 5-Year (MWh)	Percentage of 5-Year Residential Potential	Cumulative 20-Year (MWh)	Percentage of 20-Year Residential Potential
Refrigerator - Removal of Secondary	85,601	13%	342,402	20%
Home Energy Reports	79,718	12%	70,957	4%
Freezer - Removal of Stand-Alone	73,632	11%	294,527	17%
Lighting General Service Lamp - CEE Tier 2	60,025	9%	124,908	7%
Lighting Specialty Lamp - CEE Tier 2	56,080	9%	124,175	7%
Low-Flow Showerhead	16,739	3%	42,748	2%
Central Air Conditioner - Tier 4	14,432	2%	53,932	3%
Refrigerator - CEE Tier 3	11,289	2%	35,642	2%
Dryer - Heat Pump Dryer	8,469	1%	73,352	4%
Windows	7,518	1%	79,704	5%
Advanced Power Strip - Tier 2	7,293	1%	29,659	2%
Dryer - CEE Advanced Tier	3,414	1%	28,679	2%
Wall Insulation	3,337	1%	35,286	2%
Ceiling / Attic Insulation	2,304	0%	39,611	2%
ENERGY STAR Door	1,453	0%	24,850	1%

Commercial

The Cadmus team estimated potential for the nine commercial segments listed in Table 30, which summarizes 2040 forecast sales, 20-year cumulative program achievable potential, and the same potential as a percentage of sales. The table shows that the commercial sector has 2,483,449 MWh of available program achievable potential and 388 MW of demand reduction. The energy savings for commercial program achievable potential aggregates to 17% of the 2040 commercial baseline sales, with individual segments ranging between 13% and 22%. Offices make up 25% of the energy savings, the greatest proportion, with retail buildings (19%) and warehouses (16%) also making up a sizable amount. This trend is reflected in the demand reduction as well.

Table 30. Commercial Program Achievable Potential by Segment-Energy: Cumulative 2040

Segment	Baseline Sales by Segment	MWh	Percentage of Baseline Sales	MW
Office	3,392,646	625,179	18%	111
Retail	2,817,591	472,770	17%	73
Warehouse	1,807,509	400,217	22%	58
Other	2,015,616	313,834	16%	48
Education	1,503,735	244,237	16%	40
Health	1,201,677	183,344	15%	30
Restaurant	872,417	120,017	14%	16
Grocery	572,090	76,447	13%	7
Lodging	344,878	47,402	14%	5
Total	**14,528,160**	**2,483,449**	**17%**	**388**

[a] May not equal sum of rows due to rounding.

Table 31 shows cumulative 20-year program achievable potential at the end use level for the commercial sector. The table shows the greatest potential for lighting (67%), followed by refrigeration (9%), cooling (9%), and ventilation (4%).

Table 31. Commercial Program Achievable Potential by End Use-Energy: Cumulative 2040

End Use	Baseline Sales by End Use	MWh	Percentage of Baseline Sales	MW
Lighting	5,276,623	1,664,734	32%	256
Refrigeration	1,927,013	233,226	12%	18
Cooling	1,366,558	217,440	16%	74
Ventilation	2,598,798	108,091	4%	10
Water Heat	278,909	62,328	22%	3
Heating	320,614	62,308	19%	0
Plug Load	1,969,685	36,735	2%	4
Heat Pump	138,375	38,523	28%	12
Cooking	430,286	37,349	9%	6
Other	211,405	21,995	10%	4
Dryer	9,895	720	7%	0
Total	**14,528,160**	**2,483,449**	**17%**	**388**

[a] May not equal sum of rows due to rounding.

Figure 23 shows the cumulative program achievable potential by end use for the commercial sector in 2025 and 2040. The figure shows that lighting savings grow significantly in the first few years of the study, then plateau (as LED measures do not obtain potential in the latter half of the study).

Figure 23. Commercial Program Achievable Potential by End Use-Energy: Cumulative

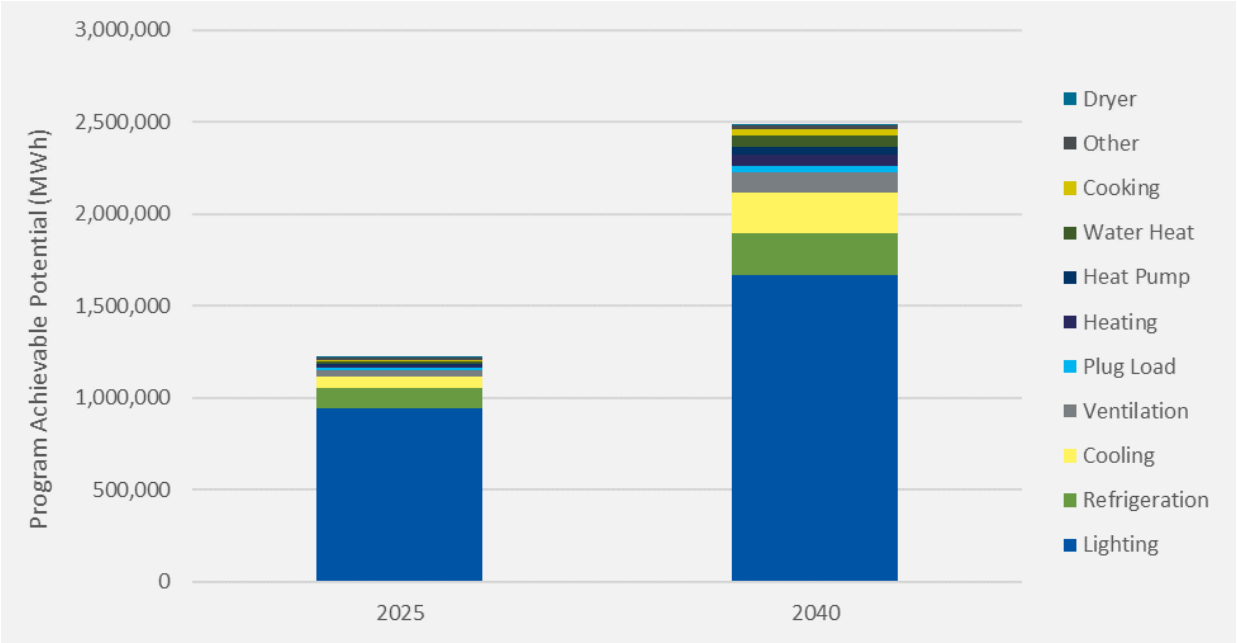


Table 32 lists the top 15 saving commercial measures that passed the UCT benefit/cost screen. Above-standard LED/TLED panel interior lighting accounts for 15% of the 20-year commercial program achievable potential, followed by several other retrofit and equipment lighting measures. Collectively, the top 15 measures make up 67% of the 20-year commercial program achievable potential.

Table 32. Top Commercial Program Achievable Potential Measures: Cumulative 2025 and 2040

Measure Name	Program Achievable Potential			
	Cumulative 5-Year (MWh)	Percentage of 5-Year Commercial Potential	Cumulative 20-Year (MWh)	Percentage of 20-Year Commercial Potential
Lighting Interior - Screw Base LED - Above Standard	182,395	330,990	27%	367,766
Lighting Interior - TLED / LED Panel - Above Standard	330,990	182,395	15%	374,261
Occupancy Sensor Control	76,344	76,344	6%	190,860
LED Exterior Wall Pack	64,016	64,016	5%	103,514
Dimming, Fluorescent Fixtures	49,446	49,446	4%	98,891
Advanced Network Occupancy and Daylighting Controls	49,404	49,404	4%	98,809
Exterior Occupancy Sensor	38,758	38,758	3%	96,894
LED Exterior Flood Lights	33,884	33,884	3%	54,791
Bi-Level Control, Stairwell Lighting	26,453	26,453	2%	53,277
Walk-in Economizer	26,294	26,294	2%	53,265
Lighting Interior - High Bay LED - Above Standard	20,491	20,491	2%	42,128
LED Exterior Pole Mount Fixture	15,768	19,309	2%	31,223
New Construction Lighting Package - Advanced Efficiency	9,311	15,768	1%	39,470
Wall Insulation	7,829	9,311	1%	37,246
Direct Digital Control System-Installation	19,309	7,829	1%	31,317

Industrial

The Cadmus team estimated program achievable potential for the 25 industrial segments listed in Table 33. The table summarizes the 20-year cumulative program achievable potential and the same potential as a percentage of sales. There are 1,518,253 MWh of overall industrial EWR available as a part of the program achievable potential, which is 14% of the 2040 industrial baseline sales. Additionally, there are 242 MW of demand reduction available. Computer and electronic manufacturing provides the greatest opportunity for energy savings and demand reduction based on current Consumers Energy program offerings, followed by transportation equipment manufacturing and plastic rubber product manufacturing.

Table 33. Industrial Program Achievable Potential by Segment-Energy: Cumulative 2040

Segment/Type of Manufacturing	Baseline Sales by Segment	MWh	Percentage of Baseline Sales	MW
Computer and Electronic	2,016,833	298,104	15%	43
Transportation Equipment	1,242,074	202,262	16%	29
Plastics Rubber Products	1,092,482	154,991	14%	22
Food	977,991	131,292	13%	19
Fabricated Metal Products	783,780	114,692	15%	17
Primary Metal	988,669	106,326	11%	15
Chemical	773,325	91,538	12%	13
Industrial Machinery	547,426	82,179	15%	12
Paper	682,656	69,884	10%	10
Nonmetallic Mineral Products	514,930	67,376	13%	10
Agriculture	519,321	61,099	12%	31
Furniture	167,154	25,620	15%	4
Wood Product	172,987	22,151	13%	3
Miscellaneous	135,641	21,688	16%	3
Electrical Equipment	139,902	20,803	15%	3
Printing Related Support	136,405	19,359	14%	3
Mining	101,062	7,894	8%	1
Beverage and Tobacco	44,328	5,967	13%	1
Wastewater	43,491	4,803	11%	1
Water	79,414	4,104	5%	1
Textile Mills	16,376	2,245	14%	< 1
Textile Product Mills	11,088	1,513	14%	< 1
Leather Mfg	10,816	1,466	14%	< 1
Petroleum Coal Products	3,946	451	11%	< 1
Apparel	2,791	448	16%	< 1
Total	**11,204,888**	**1,518,253**	**14%**	**242**

[a] May not equal sum of rows due to rounding.

Table 34 shows cumulative 20-year electric conservation potential for the industrial sector by end use. The table shows that process measures make up the greatest amount of the industrial program achievable potential (39%), followed by HVAC (19%), and lighting (17%).

Table 34. Industrial Program Achievable Potential by End Use-Energy: Cumulative 2040

End Use	Baseline Sales by End Use	MWh	Percentage of Baseline Sales	MW
Process	4,195,527	594,967	14%	86
HVAC	1,441,723	281,698	20%	41
Lighting	929,122	258,484	28%	38
Motors Other	1,725,479	138,540	8%	20
Pumps	1,310,710	121,396	9%	38
Fans	637,127	56,777	9%	8
Other	666,683	32,761	5%	5
Ventilation	168,762	28,316	17%	6
Indirect Boiler	114,912	5,195	5%	1
Water Heat	14,843	118	1%	0
Total [a]	**11,204,888**	**1,518,253**	**14%**	**242**

[a] May not equal sum of rows due to rounding.

Figure 24 shows the annual cumulative program achievable potential by end use for industrial sector in 2025 and 2040.

Figure 24. Industrial Program Achievable Potential by End Use-Energy: Cumulative

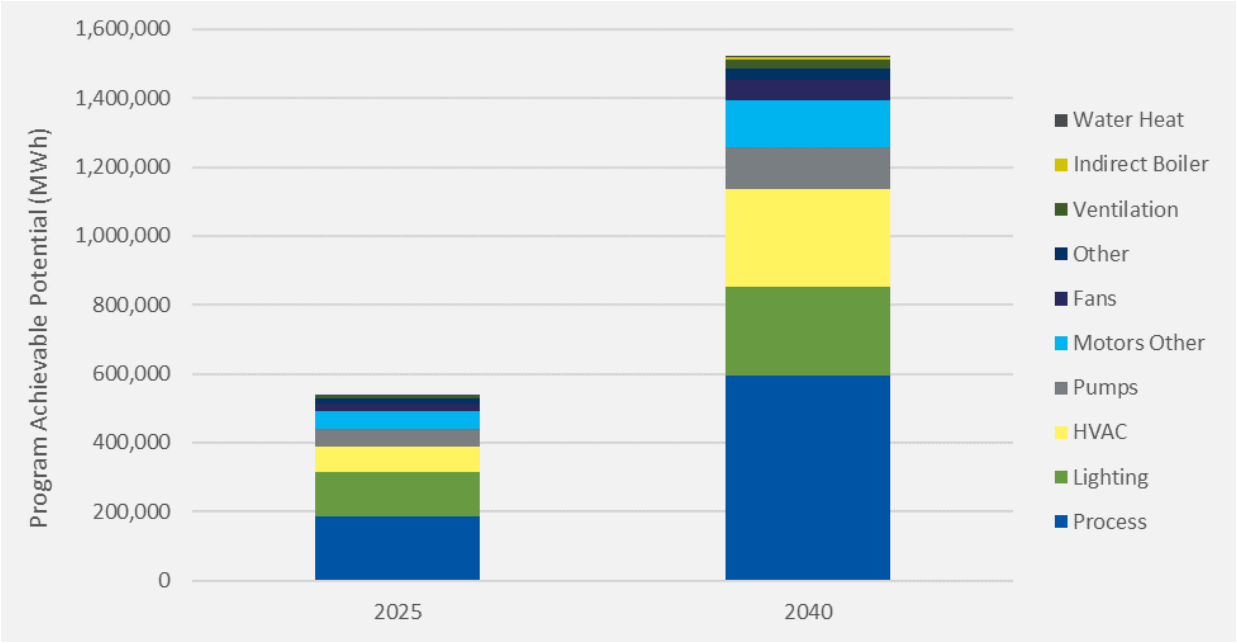


Table 35 lists the top 15 saving electric industrial measures that passed the UCT benefit/cost screen. These top 15 measures collectively accounted for 53% of the 20-year industrial achievable potential. The individual measure with the largest 20-year program achievable potential is the linear lighting LED package, with over 93,000 MWh of program achievable potential.

Table 35. Top Industrial Program Achievable Potential Measures: Cumulative 2025 and 2040

Measure Name	Program Achievable Potential			
	Cumulative 5-Year (MWh)	Percentage of 5-Year Industrial Potential	Cumulative 20-Year (MWh)	Percentage of 20-Year Industrial Potential
Lighting - Linear LED Packages	46,633	4%	93,266	6%
Optimize Lighting System - Install Skylights And Use Daylighting	24,826	2%	49,653	3%
Equipment Upgrade - Replace Existing Chiller With High Efficiency Model	23,960	2%	59,900	4%
Cooling Tower Operation And Maintenance	23,266	2%	58,164	4%
Lighting - High Bay LED Packages	23,192	2%	46,384	3%
Upgrade Equipment - Replace Existing HVAC Unit With High Efficiency Model	22,218	2%	88,874	6%
Install Adjustable Frequency Drive to Replace Existing System - Pumps	21,317	2%	42,635	3%
Equipment Upgrade - Air Compressor	18,009	2%	45,023	3%
Optimize Chiller and Refrigeration Systems	17,993	2%	44,982	3%
Thermal Systems Recover Heat And Use For Preheating, Space Heating, Power Generation, Steam Generation, Transformers, Exhausts, Engines, Compressors, Dryers, Waste Process Heat, etc.	16,521	2%	66,085	4%
Optimize Motor Systems With Right Sizing	16,170	2%	40,425	3%
Install Compressor Controls	16,118	2%	40,294	3%
Thermal Systems Add Insulation to Equipment	11,662	1%	46,648	3%
Building Envelope Insulation and Window/Door Improvements	11,010	1%	44,039	3%
Building Duct System Improvements	10,253	1%	41,011	3%

Summary of Methodologies

The Cadmus team relied on industry best practices, analytic rigor, and flexible and transparent tools to accurately estimate the long-term electric EWR potential for energy savings and peak demand reduction in Consumers Energy's territory from 2021 to 2040. This chapter describes the team's methods for each step in the assessment process.

Baseline End-Use Forecast

To assess EWR, the Cadmus team first determined an accurate and Consumers Energy-specific representation of baseline energy use by sector and segment. We established customer counts and sales, as well as forecasts, and disaggregated the baseline year (2020) sales and customer counts using 2019 sales data, applying primary and secondary data to further disaggregate.

To create a baseline forecast, the team used multiple data inputs to accurately characterize energy use within Consumers Energy's service area:

- Electric energy sales and customer forecasts
- Major customer segments (residential dwelling types, nonresidential business types)
- End-use saturations (the percentage of an end use, such as an air conditioner, present in a building)
- Equipment saturations (average number of units in a building)
- Fuel shares (proportion of units using electricity versus natural gas)
- Efficiency shares (the percentage of equipment below, at, and above standard)
- Annual end-use estimates by efficiency levels

Data specific to Consumers Energy's service territory not only provided the basis for baseline calibration, but also supported the team's estimate of technical potential. Table 36 lists the key data sources used.

Table 36. Baseline Forecast Data Sources

Data	Residential	Commercial	Industrial
Baseline Sales and Customers	Consumers Energy Customer Databases, Actual	Consumers Energy Customer Databases, Actual	Consumers Energy Customer Databases, Actual
Forecasted Sales and Customers	Consumers Energy Load Forecasts	Consumers Energy Load Forecasts	Consumers Energy Load Forecasts
Percentage of Sales by Building Type	Consumers Energy Customer Databases	Consumers Energy Customer Databases	Consumers Energy Customer Databases
End-Use Energy Use	Consumers Energy Load Forecasts, 2020 MEMD, EIA 2015 *Residential Energy Consumption Survey* (RECS), ENERGY STAR, Cadmus team research	Consumers Energy Load Forecasts, Consumers Energy *2019 Commercial and Industrial Market Assessment*, 2020 MEMD, EIA 2012 *Commercial Building Energy Consumption Survey* (CBECS), ENERGY STAR, Cadmus team research	Consumers Energy Load Forecasts, Consumers Energy *2019 Commercial and Industrial Market Assessment* EIA 2018 *Manufacturing Energy Consumption Survey*, 2020 MEMD, Cadmus team research
Saturations and Fuel Shares	Consumers Energy 2018 *Residential Appliance Saturation and Home Characteristics Study*, EIA RECS, Cadmus team research	*2019 Commercial and Industrial Market Assessment*, EIA CBECS, Cadmus team research	*2019 Commercial and Industrial Market Assessment*, DOE *Industrial Assessment Center Database*, EIA *Manufacturing Energy Consumption Survey*, Cadmus team research
Efficiency Shares	Consumers Energy 2018 *Residential Appliance Saturation and Home Characteristics Study*, EIA RECS, ENERGY STAR unit shipment reports, Cadmus team research	*Nonresidential Baseline Study*, EIA CBECS, Cadmus team research	*Nonresidential Baseline Study*, DOE *Industrial Assessment Center Database*, EIA *Manufacturing Energy Consumption Survey*, Cadmus team research

The Cadmus team followed these steps to create the baseline forecast:

- ***Step 1. Establish Utility Sales and Customer Counts.*** The team requested Consumers Energy's residential, commercial, and industrial customer counts and sales data, sales and customer forecasts, and peak demand by sector and segment. These data served as the foundation for establishing the level of EWR potential available in Consumers Energy territory over the 20-year study period. The initial data request included several additional details:
  - The number of customers and weather-normalized actual electric sales for 2019 (as a historical base year) and for a forecast period.
  - Forecast sales absent future, planned EWR (to avoid double-counting savings future potential savings).

  These customer data were intended to represent the number of buildings or dwellings, but the team used accounts and premises as a proxy where available and necessary.
- ***Step 2. Disaggregate Market Results.*** To disaggregate Consumers Energy's customer counts and electric sales, the team reviewed Consumers Energy's electric sales and demand forecasts for a

20-year period (2021 through 2040), along with one full year of customer billing data. After analyzing the customer billing databases, the team determined the distribution of energy use and demand by sector and segment in 2019. Within each segment, the team analyzed two vintages—existing construction and new construction—within the following market-sector and segment classifications:

- ***Sectors:*** residential, commercial, industrial
- ***Segments:*** Residential (single family, single family low income, multifamily, multifamily low income, manufactured, manufactured low income) and commercial and industrial (both based on business type, typically by North American Industry Classification System code, as shown in Table 37).

- ***Step 3: Develop Baseline End-Use Profiles.*** The Cadmus team further divided each market sector into major end-use shares using a combination of primary and secondary data sources.

Table 37. Segments Modeled

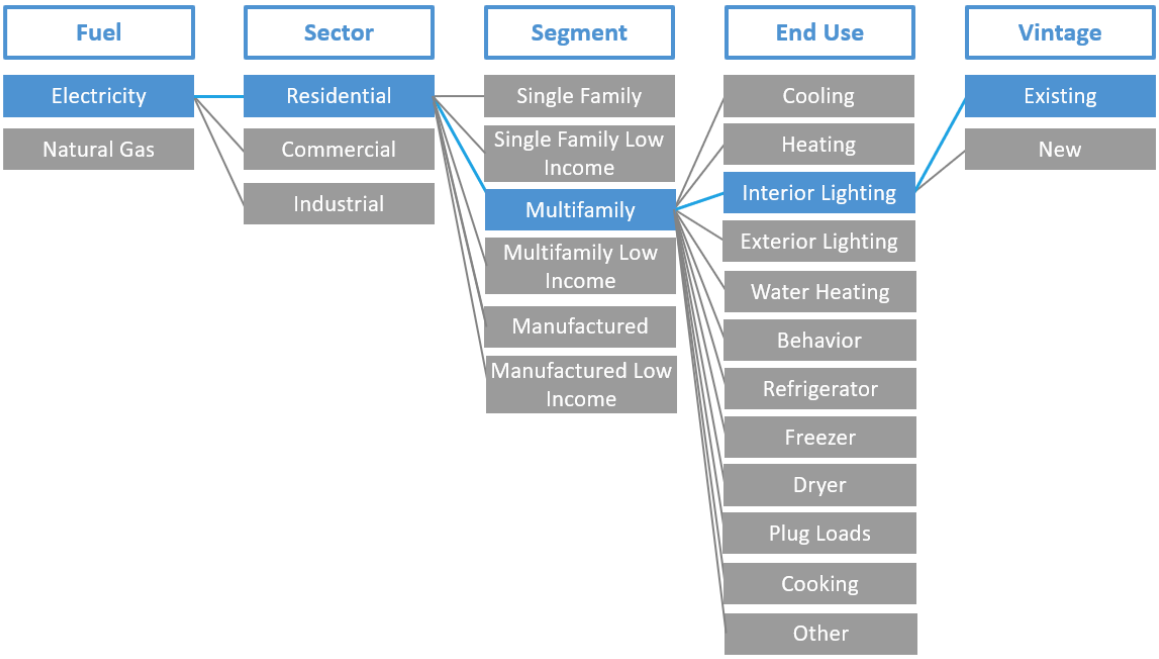
Residential	Commercial	Industrial
• Single Family • Multifamily • Manufactured • Single Family Low Income • Multifamily Low Income • Manufactured Low Income	• Office • Retail • Education • Grocery • Restaurant • Health • Lodging • Warehouse • Miscellaneous	• Agriculture • Apparel Manufacturing • Beverage and Tobacco Manufacturing • Chemical Manufacturing • Computer Electronics Manufacturing • Electrical Equipment Manufacturing • Fabricated Metal Product Manufacturing • Food Manufacturing • Furniture Manufacturing • Industrial Machinery Manufacturing • Leather Manufacturing • Mining • Miscellaneous Manufacturing • Nonmetallic Mineral Product Manufacturing • Paper Manufacturing • Petroleum and Coal Products • Plastics Rubber Manufacturing • Primary Metal Manufacturing • Printing-Related Support • Textile Mills • Textile Product Mills • Transportation Equipment Manufacturing • Wastewater • Water • Wood Product Manufacturing

Figure 25 illustrates how the team applied this data using an example that pertains to residential lighting. The team used information about end-use saturations (the percentage of homes with lighting) and penetrations (the average number of light bulbs per home), as well as fuel shares (the percentage of homes with electric lighting) and home vintage (the number of existing homes), drawn from primary

data provided from Consumers Energy's *2018 Residential Appliance Saturation and Home Characteristics Study* and 2019 *Commercial and Industrial Market Assessment*, supplemented with regional datasets.

Using each dataset, the team estimated average fuel shares and end-use saturations by sector and by segment to develop end-use load profiles. The team identified all relevant end uses by sector including, but not limited to, interior and exterior lighting, HVAC, building shell, refrigeration, cooking, freezer, dryer, water heating, plug loads, processes, data centers, and motors.

Figure 25. Simple Load Disaggregation Example – Residential Lighting



With the disaggregation process complete, the team applied per-unit end-use energy use—sometimes called unit energy use for a residential forecast and energy-use intensity for a commercial forecast—to develop the end-use forecasts. We used an equation to specify the forecast for each end use in the study:

$$EUSE_{ij} = \Sigma_e \; ACCTS_i * UPA_i * SAT_{ij} * FSH_{ij} * ESH_{ije} * EUI_{ije}$$

Where:

$EUSE_{ij}$ = Total energy use for end use 'j' in customer segment 'i'

$ACCTS_i$ = The number of accounts/customers in segment 'i'

UPA_i = The units per account in customer segment 'i'

SAT_{ij} = The share of customers in customer segment 'i' with end use 'j'

FSH_{ij} = The share associated with electric or natural gas in end use 'j' in customer segment 'i'

ESH_{ije} = The market share of efficiency level 'e' equipment for customer segment 'ij'

EUI_{ije} = End-use intensity or unit energy use for the equipment configuration 'ije'

The Cadmus team summed the end-use forecast within each segment, sector, and fuel type combination to determine the overall sales forecast.

Measure Characterization

It was critical to characterize EWR measure impacts specific to Consumers Energy's service territory. To develop an initial list of measures, the Cadmus team used research from both the 2020 MEMD and from the weather-sensitive database for the residential and commercial high-impact measures (such as lighting, HVAC equipment, and insulation). The team also used several additional sources:

- eTracker (to account for measures currently included in Consumers Energy's programs, including the supporting workpaper)
- 2017 GDS electric energy efficiency potential study
- Efficiency tiers from the Consortium for Energy Efficiency (CEE) and ENERGY STAR
- Cadmus' extensive database, including measures in regional or national databases (such as the California *Database of Energy Efficient Resources* [DEER][13] and other TRMs)
- Selected behavioral measures

Upon identifying measures, the team compiled all measure characterization inputs into a master Excel database to estimate potential. We then used this database to populate the potential study model to estimate technical, economic, maximum, and program achievable potential. The database included technical and market data that applied to all end uses in various market segments, as well as estimated costs, savings, and applicability for a comprehensive set of EWR measures. Through this process, the team calculated measure savings as unit energy savings or measure percentage savings to estimate the present end-use savings. These measure end-use percentage savings, when applied to the baseline end-use forecast, produced estimates of EWR potential.

MEMD Methodology

The MEMD includes measure-level deemed or modeled (nominal) savings, which the team used to inform the end-use potential study model. The MEMD includes two databases:

- ***MEMD Master Database.*** This dataset includes measure-level deemed savings, measure costs, and useful life [EUL]assumptions. To understand the underlining deemed assumptions, Consumers Energy provided supporting files of the MEMD's "Deemed Database" that contained Microsoft Word and Excel measure-specific documentation.
- ***MEMD Master with Weather-Sensitive Weighting Tool.*** This dataset includes measure savings that are affected directly by weather, as simulated through building modeling software. The tool weights measure results by segment and region, as well as by equipment characteristics. In

[13] California Public Utilities Commission. 2020. *Database of Energy Efficient Resources.* https://cpuc.ca.gov/general.aspx?id=2017

addition, the Cadmus team used the modeling MEMD "Deemed Database" documentation that contained additional context on model inputs and system efficiencies.

Using the underlying MEMD "Deemed Database" documentation, the team adjusted generic assumptions to better reflect Consumers Energy's service territory, such as number of people per home. The team used specific characteristics collected from primary data (specifically, from the Consumers Energy 2018 *Residential Appliance Saturation and Home Characteristics Study* and the EMI Consulting 2019 *Commercial and Industrial Market Assessment,* prepared for Consumers Energy).

The MEMD weighting tool provided the flexibility to adjust (weight) the climate zones across Michigan to best represent the Consumers Energy electric service territory. Using residential customer accounts by zip code, the Cadmus team mapped zip codes to MEMD climate zones to create a distribution of Consumers Energy customers across MEMD weather locations. In addition, the team relied on the weighting tool to inform differences between standard and income-qualified residential homes by varying the MEMD vintage age for weatherization measures. This allowed us to characterize income-qualified homes as being less efficient than standard homes.

Considering the very specific measure iterations within the MEMD, the Cadmus team may have combined iterations or only selected certain iterations to avoid complexity. For example, the MEMD may have included various equipment configurations (such as single door, side-by-side, top freezer, and bottom freezer options for ENERGY STAR refrigerators). In a few cases, the Cadmus team found inconsistent results between MEMD HVAC equipment efficiency iterations (which were non-linear across efficiency tiers). After comparing this inconsistency with prior potential study results, other regional TRMs, and the EIA RECS, the team identified the most appropriate MEMD efficiency tier and re-calculated energy use across the other equipment efficiency tiers.

While the MEMD provided a robust measure-level dataset, it can be challenging to incorporate deemed values within a bottom-up calibrated end use. The Cadmus team made best efforts to align with the MEMD, but nominal savings in some cases may have exceeded the team's prototypical baseline end uses. This may have been due to multiple factors, and typically reflects the nominal savings baseline being far less efficient than the prototypical baseline. For example, an MEMD measure of residential attic insulation may represent savings from R-0 to R-49, but the team's prototypical home (representing all insulated and non-insulated homes) has an R-19 value. Since the MEMD savings would overestimate potential within the Cadmus team's end-use model, the team adjusted the MEMD values by embedding applicability and feasibility constraints or by applying the MEMD's underlining percentage savings assumptions (instead of using the nominal saving values).

Measure Data Sources

Table 38 lists the study's key EWR measure data sources.

Table 38. Key Measure Data Sources

Input	Residential	Commercial	Industrial
Energy Savings	Consumers Energy 2018 *Residential Appliance Saturation and Home Characteristics Study*, 2020 MEMD, *Michigan Behavior Resource Manual*, Consumers Energy workpapers, Consumers Energy *2020-2023 EWR Plan*, DOE/EERE technical support documents, [a] EIA RECS, ENERGY STAR calculators, state TRMs, Cadmus team research	Consumers Energy 2019 *Commercial and Industrial Market Assessment,* 2020 MEMD, Consumers Energy *2020-2023 EWR Plan*, ENERGY STAR calculators, DOE/EERE technical support documents, [a] EIA CBECS, state TRMs, Cadmus team research	Consumers Energy 2019 *Commercial and Industrial Market Assessment,*2020 MEMD, DOE *Industrial Assessment Center Database*, DOE/EERE technical support documents, [a] state TRMs, Cadmus team research
Equipment and Labor Costs	2020 MEMD, Consumers Energy workpapers, Consumers Energy *2020-2023 EWR Plan*, DOE/EER technical support documents, [a] ENERGY STAR, Northeast Energy Efficiency Partnerships incremental cost reports, RSMeans "Database for Cost Estimation," [c] state TRMs, Cadmus team research	2020 MEMD, Consumers Energy *2020-2023 EWR Plan*, DOE/EERE technical support documents, [a] ENERGY STAR, Northeast Energy Efficiency Partnerships incremental cost reports, RSMeans "Database for Cost Estimation," [c] state TRMs, Cadmus team research	2020 MEMD, Consumers Energy *2020-2023 EWR Plan,* DOE *Industrial Assessment Center Database*, DOE/EERE technical support documents, [a] state TRMs, Cadmus team research
Measure Life	2020 MEMD, Consumers Energy workpapers, Consumers Energy *2020-2023 EWR Plan*, ENERGY STAR, DOE/EERE technical support documents, [a] state TRMs, Cadmus team research	2020 MEMD, ENERGY STAR, DOE/EERE technical support documents, [a] state TRMs, Cadmus team research	2020 MEMD, DOE's Industrial Technologies Program, DOE/EERE technical support documents, [a] state TRMs, Cadmus team research
Technical Feasibility	Consumers Energy 2019 *Residential Appliance Saturation and Home Characteristics Study*, EIA RECS, Cadmus team research	Consumers Energy 2019 *Commercial and Industrial Market Assessment,* 2020 MEMD Commercial Database, Cadmus team research	Consumers Energy 2019 *Commercial and Industrial Market Assessment*, Cadmus team research
Percentage Incomplete	Consumers Energy 2019 *Residential Appliance Saturation and Home Characteristics Study*, ENERGY STAR, Cadmus team research, third-party research	Consumers Energy 2019 *Commercial and Industrial Market Assessment,* ENERGY STAR, Cadmus team research, third-party research	Consumers Energy 2019 *Commercial and Industrial Market Assessment,* Cadmus team research, third-party research

[a] U.S. Department of Energy, Office of Energy Efficiency and Renewable Technology (EERE). n.d. "Standards and Test Procedures."

[b] Regional Technical Forum. 2020. "UES Measures." https://rtf.nwcouncil.org/measures

[c] RSMeans. 2020. "Comprehensive Database for Cost Estimation." https://rsmeans.com/products/online.aspx

Energy Savings

For each EWR measure, the Cadmus team estimated energy savings, both per unit (kilowatt-hours) and as a percentage of end use. These estimates also accounted for savings interactions and results across

end uses (for example, upon installing efficient lighting, cooling loads decrease due to the reduction of waste heat). The team relied on several key sources to develop savings estimates:

- ***Consumers Energy 2019 Commercial and Industrial Market Assessment and Consumers Energy 2018 Residential Appliance Saturation and Home Characteristics Study:*** This included data from nonresidential site visits and mail/web residential surveys. Primary data provided comprehensive information on building characteristics, energy-consuming end uses, and equipment efficiencies.
- ***2020 MEMD:*** The primary resource for determining measure savings was the 2020 MEMD that includes deemed and calculated savings values for residential and commercial weather sensitive and non-weather sensitive measures. For every measure in this study where an appropriate MEMD match was available, the team used the MEMD deemed savings values. Otherwise, where possible, the team used MEMD supporting methodologies to match study measure descriptions.
- ***Michigan Behavior Resource Manual:*** A resource for determining behavior energy savings that was used in combination with input from the program vendor.
- **Consumers Energy 2020-2023 EWR Plan and Workpapers:** Measure energy savings data within Consumers Energy's 2020-2023 EWR plan and measure workpapers supporting programs were used for program specific measures not within the MEMD.
- ***DOE/ Office of Energy Efficiency and Renewable Technology (EERE) technical support documents:*** The DOE technical support documents include estimates of equipment energy use for several types of energy-efficient equipment. The team leveraged these documents for input to our savings calculations, when necessary.
- ***U.S. Energy Information Administration (EIA) RECS and EIA CBECS:*** These assessments include building characteristics that the team may have used to inform estimates of energy savings. For example, number of commercial vending machines per building.
- ***Industrial Assessment Center Database:*** The team used U.S. DOE Industrial Assessment Centers' technical assessment data with specific details on energy savings and operational opportunities.
- ***ENERGY STAR calculators:*** The team used U.S. Environmental Protection Agency ENERGY STAR calculators to estimate per-unit savings for several measures, including efficient appliances (refrigerators, freezers, clothes washers) and efficient home electronics (televisions, computers, monitors).
- ***State technical reference manuals (TRMs):*** The team used various state TRMs including those from California, Illinois, Iowa, Minnesota, New York, Vermont, Wisconsin, and the NW Regional Technical Forum[14] for guidance on savings calculations, EULs, costs, and other key potential study inputs for EWR measures not included in the MEMD.

[14] Regional Technical Forum. 2020. "UES Measures." https://rtf.nwcouncil.org/measures

- ***Cadmus team research:*** The team used various third-party measure characterization reports, data conducted within prior potential studies, and online research to inform the energy savings, when applicable.

Equipment and Labor Costs

The Cadmus team estimated equipment and labor costs for each EWR measure and used these costs to calculate benefit/cost ratios and to estimate potential program expenditures. All costs were adjusted to 2020 dollars. The team relied on several key sources to develop cost estimates:

- ***2020 MEMD:*** The primary resource for determining measure costs was the 2020 MEMD that includes cost data for residential and commercial weather sensitive and non-weather sensitive measures . For every measure in this study where an appropriate MEMD match was available, the team used MEMD-listed costs. Otherwise, when possible, we adjusted MEMD supporting document methodologies to match study measure descriptions.
- **Consumers Energy 2020-2023 EWR Plan and Workpapers:** Measure cost data within Consumers Energy's 2020-2023 EWR plan and measure workpapers supporting programs were used for program specific measures not within the MEMD.
- ***DOE/EERE technical support documents:*** The DOE technical support documents include estimates of equipment and labor costs for several types of energy-efficient equipment. The team leveraged these documents for input to our savings calculations, when necessary.
- ***ENERGY STAR:*** The team used U.S. Environmental Protection Agency-provided equipment costs for a number of ENERGY STAR-rated technologies.
- ***RSMeans "Database for Cost Estimation":*** The team used construction cost data from RSMeans Online 2020, the most recent version, including costs for several home and business retrofits (water heater tank wrap, insulation, air sealing, other shell upgrades).
- ***Northeast Energy Efficiency Partnerships incremental cost reports:*** These studies show baseline and efficiency measure costs (labor, equipment) for the measures most commonly offered through utility sponsored EWR programs.
- ***State TRMs:*** The team used various state TRMs for guidance on savings calculations, EULs, costs, and other key potential study inputs for many EWR measures.
- ***Cadmus team research:*** The team continuously reviewed prices listed on manufacturer or retailer websites. While online retailers may not provide estimates of installation (labor) costs, they provide reliable equipment costs.

Measure Life

The Cadmus team used estimates of each measure's EUL to calculate the lifetime NPV benefits and costs for each EWR measure. Many data sources for measure savings and costs (described above) also

provided estimates for measure lifetimes. The team relied on several sources to develop measure life estimates:

- ***2020 MEMD:*** The primary resource for determining measure EUL was the 2020 MEMD. For every measure in this study where an appropriate MEMD match was available, the team used MEMD-listed EULs.
- **Consumers Energy 2020-2023 EWR Plan and Workpapers:** EUL data within Consumers Energy's 2020-2023 EWR plan and measure workpapers supporting programs. For example, Consumers Energy's program data and cost-effectiveness assumptions supporting residential lighting EULs to account for the rapid changes within the LED market.
- ***ENERGY STAR:*** The team used U.S. Environmental Protection Agency-provided equipment EULs for a number of ENERGY STAR-rated units.
- ***DOE/EERE technical support documents:*** The DOE technical support documents include estimates of EULs for several types of energy-efficient equipment. The team leveraged these documents for input to our savings calculations, when necessary.
- ***State TRMs:*** The team used various state TRMs for guidance on savings calculations, EULs, costs, and other key potential study inputs for many EWR measures.
- ***Cadmus team research:*** The team used various third-party measure characterization reports, data conducted within prior potential studies, and online research to inform the measure EUL, when applicable.

Technical Feasibility

Technical feasibility represents the percentage of homes or buildings that could feasibly install an EWR measure. Technical limitations include equipment capability or space limitations. For example, geothermal heat pumps could not be feasibly installed in all buildings, as some buildings do not have the required land to drill horizonal or vertical ground loops. The team relied on several key sources to develop feasibility estimates:

- ***Consumers Energy 2019 Commercial and Industrial Market Assessment and Consumers Energy 2018 Residential Appliance Saturation and Home Characteristics Study:*** The collected data provides building characteristics and equipment information that informs measure applicability. The team leveraged these documents for input to our savings calculations, when necessary.
- ***2020 MEMD:*** The MEMD Weather-Sensitive Database informed measure feasibility through classification measures applicable to specific market segments (large office versus small office).
- ***EIA RECS and EIA CBECS:*** These assessments include building characteristics that the team may have used to inform estimates of technical feasibility. For instance, some floor insulation measures require a basement or a crawlspace; using EIA RECS, the team determined the proportion of homes with a basement or crawlspace that could feasibly install this measure.
- ***Cadmus team research; third-party research (including the Federal Energy Management program, DOE, or Toolbase.org):*** The team used various third-party measure characterization reports that identify technical limitations for EWR measures. We used these assessments to

estimate the proportion of homes or businesses that could feasibly install each measure. In some instances, the team used engineering judgment to approximate technical constraints.

Percentage Incomplete

Percentage incomplete factors represent the percentage of remaining homes or businesses that have yet to install an EWR measure and is calculated as the total market size minus the current saturation of EWR measures. To account for Consumers Energy's program accomplishments, building energy codes and standards, and the natural adoption of efficiency measures, the team relied on three key sources to develop percentage incomplete estimates:

- ***Consumers Energy 2019 Commercial and Industrial Market Assessment and Consumers Energy 2018 Residential Appliance Saturation and Home Characteristics Study:*** Using recent primary data, this research informed the percentage of the market that has already achieved EWR technology.
- ***ENERGY STAR:*** National ENERGY STAR shipment data informed the penetration of ENERGY STAR products currently in the market.
- ***Cadmus team research:*** The team used various third-party measure characterization reports, data conducted within prior potential studies, and online research to inform the percentage of the market that already implemented the efficient technology.

Compiling Energy Waste Reduction Technology Measure Database

After creating a list of electric EWR measures applicable to Consumers Energy's service territory, the team classified EWR measures into two categories:

- ***Lost opportunity measures:*** These measures affect new buildings or equipment at the end of its useful life, incorporating energy efficiency at this point is most cost-effective. The lost opportunity measures in any given year are based on stock turnover and normal replacement patterns based on EULs.
- ***Discretionary measures (retrofit):*** These measures affect end uses without replacing end-use equipment (such as insulation). As such, these measures did not include timing constraints from equipment turnover and could be acquired at any point over the planning horizon.

For this study, the Cadmus team assumed that all high-efficiency equipment measures would be installed at the end of the existing equipment's remaining useful life, and therefore we did not assess EWR potential for early replacement.[15] In addition, most measures naturally turn over within the study horizon, and the long-run technical potential from early replacement measures equals savings from replace-on-burnout measures.

[15] The Cadmus team considered refrigerator, freezer, and room air conditioner recycling to estimate savings associated with the removal of below-standard secondary units. These measures, however, could not be considered early replacement, as they do not assume secondary units would be replaced with efficient units.

The team used several relevant inputs for each measure:

- Equipment and non-equipment measures:
  - Technical feasibility—the percentage of buildings where customers could install this measure, accounting for physical constraints
  - Energy savings—average annual savings attributable to installing the measure, in absolute and/or percentage terms
  - Equipment cost—full or incremental equipment cost, depending on the nature of the measure and the application
  - Labor cost—the expense of installing the measure, accounting for differences in labor rates by region and other variables
  - Measure life—the expected life for the equipment
- Non-equipment measures only:
  - Percentage incomplete—the percentage of buildings where customers had not installed the measure, but where it could technically (and feasibly) be installed
  - Measure competition—for mutually exclusive measures, accounting for the percentage of each measure likely installed to avoid double-counting savings (for example, 1.5 gallons per minute (gpm) and 2.0 gpm showerheads cannot both be installed in the same showerhead socket; therefore, only one permutation could possibly be installed, which would depend on technical feasibility for technical potential and would depend on both technical feasibility and cost-effectiveness for economic potential)

Incorporating Codes and Standards

The Cadmus team accounted for changes in codes and standards over the planning horizon. These changes will affect customers' energy-use patterns and behaviors and we used them to determine which EWR measures would continue to produce energy savings over minimum requirements. The team captured current efficiency requirements, including those enacted but not yet in effect.

The team did not, however, attempt to predict how federal standards might change in the future. Rather, we only factored in legislation that has already been enacted. Based on a strict interpretation of each standard, the team assumed that customers would replace affected equipment with more efficient alternatives, and that these alternatives would meet minimum federal standards. In other words, the team assumed complete compliance. Notably, we made one exception, for screw-based LEDs: instead of adhering to the DOE's December 27, 2019, final rule and determination that effectively rescinded the EISA 2020 backstop standard,[16] we followed Consumers Energy's adopted assumptions (accepted by the

[16] U.S. Department of Energy. December 27, 2019. "Energy Conservation Program: Energy Conservation Standards for General Incandescent Service Lamps." https://federalregister.gov/documents/2019/12/27/2019-27515/energy-conservation-program-energy-conservation-standards-for-general-service-incandescent-lamps

MPSC). This included adjusting the measure life of LED standard and specialty bulbs to coincide with the transformed market (standard LED in 2023 and specialty LED in 2024).

The Cadmus team explicitly accounted for several other pending federal standards. Table 39 lists the recently enacted or pending equipment standards the team accounted for in this study's commercial and residential sectors for electric and natural gas end uses. The team also incorporated standards that became effective for equipment prior to 2015 including:

- Commercial boilers (2013)
- Commercial clothes washer (2013)
- Commercial package terminal heat pumps (2012)
- Cooking ovens and ranges (2012)
- Dehumidifier (2013)
- Faucet aerators (1994)
- Pool heaters (2014)
- Residential dishwashers (2014)
- Residential refrigerators and freezers (2015)
- Room air conditioners (2015)
- Showerheads (1994)

For measures where a future standard will have a higher efficiency than a current standard market practice baseline, the team adjusted the baseline to the new federal standard.

Table 39. Current and Pending Electric Standards by End Use

Equipment Electric Type	Existing (Baseline) Standard	New Standard	Sectors Impacted	Study Effective Year
Appliances				
Automatic commercial ice maker	Federal standard 2010	Federal standard 2018	Nonresidential	2019 [a]
Clothes dryer	Federal standard 1994	Federal standard 2015	Residential/Nonresidential	2015
Clothes washer	Federal standard 2015	Federal standard 2018	Residential	2018
Vending machine	Federal standard 2012	Federal standard 2019	Nonresidential	2020 [a]
Cooking				
Microwave	Existing conditions (no federal standard)	Federal standard 2016	Residential	2017 [a]
HVAC				
Central air conditioner	Federal standard 2006	Federal standard 2015 and 2023	Residential	2015-2023
Heat pump (air source)	Federal standard 2006	Federal standard 2015 and 2023	Residential	2015-2023
Package terminal air conditioner	Federal standard 2012	Federal standard 2017	Nonresidential	2017
Small, large, and very large commercial package air conditioner and heat pump	Federal standard 2010	Federal standard 2018 and 2023	Nonresidential	2018-2023

Equipment Electric Type	Existing (Baseline) Standard	New Standard	Sectors Impacted	Study Effective Year
Lighting				
General service fluorescent lamp	Federal standard 2012	Federal standard 2018	Residential/Nonresidential	2019 [a]
Refrigeration				
Commercial display case	Federal standard 2012	Federal standard 2017	Nonresidential	2018 [a]
Commercial freezer	Federal standard 2012	Federal standard 2017	Nonresidential	2018 [a]
Commercial refrigerator	Federal standard 2012	Federal standard 2017	Nonresidential	2018 [a]
Walk-in cooler and freezer	Federal standard 2009	Federal standard 2017	Nonresidential	2018 [a]
Ventilation and Circulation				
Furnace fan	Existing conditions (no prior federal standard)	Federal standard 2019	Residential	2020 [a]
Motor	Federal standard 2010	Federal standard 2016	Nonresidential	2017 [a]
Pool pump	Existing conditions (no federal standard)	Federal standard 2021	Residential/Nonresidential	2021
Water Heat				
Pre-rinse spray valve	Federal standard 2006	Federal standard 2019	Nonresidential	2020 [a]
Water heater ≤55 gallons	Federal standard 2003 and 2004	Federal standard 2015 (test procedure update in 2017)	Residential/Nonresidential	2015-2017
Water heater >55 gallons	Federal standard 2003 and 2004	Federal standard 2015 (test procedure update in 2017)	Residential/Nonresidential	2015-2017

[a] To estimate potential, the Cadmus team assumed that standards taking effect mid-year would start on January 1 of the following year.

Naturally Occurring Conservation

The Cadmus team's baseline forecast included naturally occurring conservation, which refers to the reduction in energy use occurring due to normal market adoption of efficient technologies, improved energy codes and standards, and market transformation efforts. These impacts resulted in updated baseline sales, from which the team could estimate technical and achievable technical potential.

This analysis accounted for naturally occurring conservation in three ways:

- For the potential associated with certain energy-efficient measures, the team assumed a natural adoption rate, net of current saturation. For example, the total potential savings associated with ENERGY STAR appliances accounts for current trends in customer adoption. As such, the baseline energy forecast reflected the total technical savings potential from ENERGY STAR appliances.
- The team assumed gradual increases in efficiency due to retiring older equipment in existing buildings and homes that are replaced with units meeting or exceeding minimum standards at the time of replacement. For example, the existing single family residential building construction stock includes a number of central air conditioning units that do not meet current minimum

federal efficiency standards. As these units are replaced, the baseline forecast assumes replacement with a unit that meets minimum federal efficiency standards.

- The team accounted for pending improvements to equipment efficiency standards that will take effect during the planning horizon, as discussed above in the *Incorporating Codes and Standards* section. The team did not, however, forecast changes to standards yet to be passed.

Energy Waste Reduction Modeling

The Cadmus team used its demand-side management Excel Potential Model to estimate EWR potential using an end-use-based modeling approach. For modeling, the team separated measures into two classes: lost opportunity (equipment and new construction) and retrofit (non-equipment). The team characterized the technical, economic, maximum, and program achievable potential by sector, segment, end use, program, measure, and year for both fuel types in Consumers Energy's territory.

Technical Potential

The Cadmus team incorporated measure-level inputs and disaggregated baseline forecasts into its Excel Potential Model to estimate technical potential over the 20-year planning horizon. We accomplished this by creating an alternate forecast in which energy use is reduced by the installation of all technically feasible EWR measures. For each individual measure, the team estimated savings using a basic relationship:

$$SAVE_{ijm} = UEC_{ije} * PCTSAV_{ijem} * APP_{ijem}$$

Where:

$SAVE_{ijm}$	=	Annual energy savings for measure 'm' for end use 'j' in customer segment 'i'
UEC_{ije}	=	Calibrated annual end-use energy use for equipment 'e' for end use 'j' in customer segment 'i'
$PCTSAV_{ijem}$	=	The percentage savings of measure 'm' relative to the base use of equipment 'e' for end use 'j' in customer segment 'i'
APP_{ijem}	=	Measure applicability fraction that represents a combination of the technical feasibility, existing measure saturation, end-use interaction, and any adjustments to account for competing measures

The Cadmus team then subtracted this forecast from the baseline forecast to estimate the technical potential by sector, segment, building vintage, end use, year, and measure. The team accounted for the portion of load with no energy savings opportunity (for example, miscellaneous non-premise electrical loads such as communication towers, railway installations, and other non-building loads) where the baseline forecast will not have any EWR potential.

The team's goal for our analysis of each market segment and end-use combination was to estimate the cumulative effect of the bundle of eligible measures and incorporate all impacts into the end-use model as a percentage adjustment to the baseline end uses. Capturing all applicable measures requires examining instances in which multiple measures affect a single end use. To avoid overestimating savings,

the Cadmus team accounted for the interaction among measures using a technique called stacking. The team's Excel Potential Model conducted this stacking by establishing a rolling, reduced energy use baseline, which it applied iteratively as measures in the stack were assessed. For example, the model reduced central air conditioner savings after the addition of insulation reduced the baseline space cooling energy load.

The model prioritizes measures in the stacking list based on cost-effectiveness (first analyzing measures with the highest UCT results). The team also accounted for interactive effects between measure types by reducing the measure-level savings estimates of relevant measures (such as reduced LED savings because of increased space heating load).

Economic Potential

Economic potential represents a subset of technical potential, consisting only of measures meeting cost-effectiveness criteria. The Cadmus team used the UCT as the primary cost-effectiveness test for determining economic potential, consistent with consistent with the requirements of Michigan's Clean and Renewable Energy and Energy Waste Reduction Act (PA 342).[17] The UCT examines the cost and benefits of an EWR measure or program from the program implementor's perspective. For the purposes of this study, the Cadmus team included only utility incentive cost when screening measures on an individual basis. For determining total maximum achievable and program achievable annual budgets, we included all other non-incentive costs incurred by the utility, including program administration, support services, and marketing costs, consistent with the categories included in Consumers Energy's most recent EWR Plan.

Table 40 lists the inputs included in the calculation of cost-effectiveness, which we used to develop the economic potential, or the savings potential for measures that have benefits greater than zero or have a benefit/cost ratio greater than one. Specific values used in the analysis are listed in Appendix B.

Table 40. Cost-effectiveness Data Summary

Benefit/Cost Data Element	Benefits	Costs
Avoided Electric Energy Cost	X	
Avoided Electric Generation Capacity Cost	X	
Avoided or Deferred Transmission and Distribution Capacity Cost	X	
Supplemental Reserve Margin Adder	X	
Average Electric Transmission and Distribution Line Losses	X	
Avoided Natural Gas Costs	X	
Discount Rate	X	X
Utility Incentives and Program Administration Costs		X

The ***avoided electric and natural gas energy costs*** in the table reflect the direct (primary) and secondary energy savings benefits from installing EWR measures, respectively. The Cadmus team's end-use

[17] Michigan Legislature. April 20, 2017. "Act No. 342: Public Acts of 2016." http://www.legislature.mi.gov/documents/2015-2016/publicact/pdf/2016-PA-0342.pdf

modeling approach to estimating potential necessitated that each individual measure accounted for primary (electric) and secondary (natural gas) fuel energy savings. An example is the cost of R-60 ceiling insulation for a home with a natural gas furnace and electric cooling system. For the electric cooling system, the team characterized the energy savings that R-60 insulation produced for natural gas furnace, conditioned in the presence of an electric cooling system, as a secondary benefit in the electric EWR modeling.

Avoided energy costs used in the analysis are based on market prices for electricity and natural gas at delivery points within Michigan and forecasts that consider multiple scenarios and historical load and weather variation.

The ***avoided electric generation capacity cost*** and the ***avoided or deferred transmission and distribution capacity cost*** are based on the expected cost of adding new resources to meet increased demand. These are used to value reductions in peak-coincident electric demand from EWR measures. In addition to reductions in the need for new resources to meet demand, peak-coincident savings also reduce the need for ***supplemental reserve margin.***

Line losses represent energy lost from point of generation to the meter. A reduction in energy use in homes or businesses reduce those losses and are reflected in the ***average electric transmission and distribution line losses.***

Finally, the team calculated the NPV of cost and benefits accruing over the planning horizon using a 7.5% ***discount rate*** which represents the weighted average cost of capital, per data provided by Consumers Energy.

Additional Economic Potential Considerations

Economic potential for a given measure can exceed technical potential when a second measure, interacting with that measure, fails a cost-effectiveness screen. For instance, if a homeowner installs an efficient air conditioner that reduces baseline cooling use from 1,000 kWh to 900 kWh, then installs a weatherization measure that saves 10% off the baseline cooling use, this weatherization results in EWR savings, or technical potential, of 90 kWh (900 * 10%).

Had the efficient air conditioner not been installed first, the homeowner's baseline use would have been 1,000 kWh, and the weatherization measure would have resulted in energy savings, or economic potential, of 100 kWh (1,000 * 10%). In this case, the economic potential (100 kWh) exceeds the technical potential (90 kWh) for the weatherization measure.

Achievable Potential

The Cadmus team assessed EWR achievable potential under maximum achievable and program achievable scenarios. Both scenarios included similar estimates of per-unit measure incentives and programmatic administration costs. We based the maximum achievable potential on current measure offerings, plus an expanded Home Energy Reports program and several EWR measures not presently offered by Consumers Energy. For the program achievable potential, we also included measure-specific

net-to-gross values. Table 41 shows key differences between maximum and program achievable potential.

Table 41. Maximum and Program Achievable Potential Considerations

Treatment	Maximum Achievable Potential	Program Achievable Potential
Included measures not currently offered?	Yes	Yes
Home energy report participation eligibility [a]	60%	60%
Reported savings	Gross	Net

[a] This row applies to residential single family customers.

The Cadmus team employed a two-step approach to estimating market potential:

- ***Estimated long-term market penetration for maximum and program achievable potential.*** The team relied on secondary data to establish the long-run percentage of Consumers Energy customers who would adopt an efficient option. We developed unique penetration rates for key end uses and/or technology types as well as for miscellaneous categories.
- ***Apply ramp rates to measures, aligning savings acquisition opportunities with results likely to occur.*** Ramp rates are acquisition curves that indicate how long a measure will take to reach the long-term achievable market penetration rate from the previous step. To develop these ramp rates, the team relied on existing measure-level program data (such as participation counts by technology or end use by year, program, and customer class) from the 2016 through 2019 program years. We assigned shorter ramp rates to specific measures or groups of measures demonstrating significant, recent achievements within Consumers Energy EWR programs. The Cadmus team assigned a longer ramp rate for newer measures to factor in the time required for the technology or measure to reach a steady state of adoption.

For the maximum and program achievable potential scenarios, the team calculated potential as the sum of each measure's annual energy-savings estimate and the expected market saturation for each program year, and over the entire forecast period.

Consumers Energy Electric EWR Transformational Technology Scenario

The Cadmus team had three objectives for determining the transformational potential specific to Consumers Energy:

- Identify an expanded estimate of EWR potential that could support Consumers Energy's ambitious EWR goals (up to 2% of sales)
- Investigate forward-looking technology and market scenarios that are the most likely to support Consumers Energy's longer-term EWR goals, particularly from 2031 to 2040 (during the second half of the potential study horizon)
- Provide insights on actions that may be needed to fully capture the available potential from underused measures, which could include investing in technology and providing demonstrations, educating and building awareness of new and emerging measures, and building regulatory support with the MPSC

We identified the savings potential that Consumers Energy could capture by being even more aggressive and by strategically researching, supporting, and implementing emerging energy-efficiency technologies, alternative delivery strategies, and other new energy-efficiency opportunities. We envision the transformational potential as a countermeasure and initial roadmap of the path needed to fill a gap identified in the Cadmus team's and other firms' recent electric EWR potential studies showing reduced utility program EWR potential over the next 20 years.

The Cadmus team assessed several opportunities including:

- Expanded savings for measures that have historically been underused due to low market awareness or other key barriers, especially in the small and medium commercial customer sectors. We assumed that a concerted action would be required to address underuse issues, such as expanding customer education, conducting targeted outreach and marketing to specific customer segments, or increasing incentive levels.
- Currently available technologies that, to date, have been characterized by high costs and low cost-effectiveness (and therefore we did not include them in our calculation of achievable potential in the initial study). We made reasonable assumptions regarding the time periods during which the costs of identified technologies are likely to decline and market shares to increase.
- Incremental savings from smart, or Tier 3, thermostats for residential homes based on peer-reviewed research in other jurisdictions with broad adoption similar to that in Michigan. Currently the MEMD does not include a unique savings value for this measure because of unclear evaluation results. The MEMD set Tier 3 thermostat savings at the same level as standard programable thermostat savings; however, the MPSC has indicated a willingness to

incorporate this measure into the MEMD as soon as calibration research can be conducted using an industry-accepted evaluation methodology.[18]

- Potential savings opportunities that may be available from expanding behavior-based energy-efficiency programs including (but not limited to) traditional home energy reports programs through increased investment in marketing, alternative outreach strategies, and tools development. The MPSC currently limits savings that can be claimed from home energy report programs; however, Consumers Energy may be able to negotiate a relaxed cap over time through efforts to demonstrate veracity and persistence of savings.
- Sustained savings over a longer period from emphasizing (through increased and targeted marketing, incentives, education, and other efforts) equipment with measure lives of 20 years or more, such as chillers and air compressors.
- Expanded savings from certain measures—specifically commercial variable frequency drives and refrigeration, cooling, and ventilation measures—for which the Cadmus team's potential estimate may have been understated due to the MEMD's assignment of savings values to a subset of potentially viable building types.
- A less restrictive approach to modeling certain measures that could be expected to gain market acceptance and more widespread adoption under future conditions that emphasize decarbonization, a shift toward greater residential energy uses (a potential outcome of the Covid-19 pandemic), and increased proliferation of automation, real-time monitoring, and artificial intelligence-supported building systems. Such technologies may also become more economically feasible under shifting policy environments that emphasize integrated decarbonization over energy efficiency alone.
- Incorporation of additional emerging technology options identified by Consumers Energy staff, vendors, national research teams, and industry experts from across the country. The Cadmus team compiled, reviewed, and prioritized these emerging technologies that may be associated with varying degrees of technical, economic, market, or programmatic uncertainty.

As shown in Table 42, the transformational technology scenario incorporates 170 additional unique emerging technology measures that were assessed across 4,102 different permutations for various building types, vintages, and unique applications. These measures are described in more detail in *Appendix C*.

[18] The Uniform Methods Project, an effort by DOE to provide standard methods for determining energy savings for common measures and programs, is currently working to develop a Smart Thermostat Evaluation Protocol. https://www.nrel.gov/ump/index.html. The Energy Waste Reduction Collaborative will pursue calibration research when the protocol is available.

Table 42. Emerging Technology Measure Counts and Permutations

Sector	Unique Measures	Measure Permutations
Residential	59	1,656
Commercial	60	1,995
Industrial	51	451
Total	**170**	**4,102**

Technical Feasibility Updates

As part of the transformational potential assessment, the Cadmus team reviewed and updated a select set of the commercial sector measure values used to estimate potential in the primary results. This update addressed loosening a strict methodology that incorporated the structure and organization of the MEMD's building application assumptions. Specifically, many commercial measures listed in the MEMD are mapped to 18 individual building types; however not all measures are mapped to every building type. Using this approach to limit the technical feasibility of measure applications within buildings can be considered too rigid within the context of utility programs. Note that, although the update spanned multiple variables in the calculation of potential, technical feasibility changes had the largest impact on potential. We removed the building type weighting applicability (technical constraints) from the MEMD weighting tool and used engineering judgement (that aligns with prior Cadmus potential studies) to make the model inputs more realistic.

As shown in Table 43, the cumulative technical and economic potential both increased by 19% as a result of the technical feasibility updates. The maximum achievable potential increased by 18%.

Table 43. Technical Feasibility Update Impact on Commercial Energy Waste Reduction Potential: Cumulative 2040

Technical Potential			Economic Potential			Maximum Achievable Potential		
Initial Results (MWh)	Technical Feasibility Update (MWh) [a]	Change	Initial Results (MWh)	Technical Feasibility Update (MWh) [a]	Change	Initial Results (MWh)	Technical Feasibility Update (MWh) [a]	Change
3,112,498	3,703,772	19%	3,061,027	3,637,589	19%	2,765,511	3,253,317	18%

[a] This comparison does not include transformational technology measures.

Table 44 provides the end-use-level impacts of the technical feasibility updates. Ventilation, plug load, and refrigeration end uses have the largest percentage increase in maximum achievable potential as a result of the technical feasibility updates. On the other hand, the maximum achievable potential for dryers and water heaters decreased by 20% and 7%, respectively, due to the technical feasibility changes.

Table 44. Technical Feasibility Update 20-Year Commercial Energy Waste Reduction Potential by End Use: Cumulative 2040

End Use	Technical Potential			Economic Potential			Maximum Achievable Potential		
	Initial Results (MWh)	Technical Feasibility Update (MWh) [a]	Percentage Change	Initial Results (MWh)	Technical Feasibility Update (MWh) [a]	Percentage Change	Initial Results (MWh)	Technical Feasibility Update (MWh) [a]	Percentage Change
Lighting	1,852,767	1,831,613	-1%	1,852,767	1,831,613	-1%	1,852,460	1,831,326	-1%
Ventilation	144,319	600,949	316%	142,647	600,949	321%	120,101	509,657	324%
Plug Load	69,634	110,162	58%	56,073	91,416	63%	41,543	71,139	71%
Refrigeration	333,959	421,770	26%	306,570	380,144	24%	259,140	320,608	24%
Cooling	340,950	371,757	9%	338,327	370,993	10%	243,037	273,030	12%
Cooking	49,564	49,564	0%	49,564	49,564	0%	41,499	41,499	0%
Heating	100,044	100,172	0%	96,066	96,066	0%	69,817	69,817	0%
Water Heat	132,768	126,929	-4%	132,195	126,451	-4%	69,253	64,548	-7%
Other	29,696	29,696	0%	29,118	29,118	0%	24,439	24,439	0%
Heat Pump	57,002	59,824	5%	55,908	59,541	6%	43,422	46,366	7%
Dryer	1,794	1,603	-11%	1,794	1,603	-11%	801	644	-20%
Total [b]	**3,112,498**	**3,703,911**	**19%**	**3,061,027**	**3,637,458**	**19%**	**2,765,637**	**3,253,199**	**18%**

[a] This comparison does not include emerging technology measures.

[b] May not equal sum of rows due to rounding.

Technical and Economic Potential

After finalizing the emerging technology measure bundles, the Cadmus team estimated the technically viable savings from emerging technologies and the technologies included in the primary results. Once we finalized the technical potential, we used the UCT to screen for measures that would be economically feasible.

The cumulative, 20-year, sector-level results of this process are summarized in Table 45, showing 17,436 GWh of technically available savings. Of that technical potential, 83% is cost-effective (14,470 GWh) by 2040. On an annual basis, the 20-year technical and economic potential savings correspond to savings of 2.8% and 2.2% of sales, respectively. The residential sector accounts for 48% of the total economic electric potential, followed by commercial (33%) and industrial (19%).

Table 45. Transformational Scenario Energy Waste Reduction Technical and Economic Potential by Sector: Cumulative 2040

Sector	Baseline Sales (MWh)	Technical Potential		Economic Potential	
		MWh	Percentage of Baseline Sales	MWh	Percentage of Baseline Sales
Residential	14,861,197	9,808,564	66.0%	6,943,146	46.7%
Commercial	14,528,160	4,827,870	33.2%	4,773,253	32.9%
Industrial	11,204,888	2,799,606	25.0%	2,754,011	24.6%
Total [a]	**40,594,246**	**17,436,040**	**43.0%**	**14,470,410**	**35.6%**

[a] May not equal sum of rows due to rounding.

Table 46 provides the corresponding electric peak demand reduction potential.

Table 46. Transformational Technology Scenario Energy Waste Reduction Technical and Economic Potential by Sector-Demand: Cumulative 2040

Sector	20-Year Technical Potential (MW)	20-Year Economic Potential (MW)	Economic Potential Percentage of Technical Potential
Residential	2,926	2,600	89%
Commercial	879	878	100%
Industrial	419	412	98%
Total [a]	**4,224**	**3,890**	**92%**

[a] May not equal sum of rows due to rounding.

The above findings are based on measure characterizations and financial calculations alone. The following section describes the maximum achievable potential, which accounts for customer behavior such as their willingness to adopt given financial relief or have increased awareness through utility-provided incentives, marketing, and awareness initiatives.

Maximum Achievable Potential

After determining the amount of potential that was economically achievable, the Cadmus team identified the subset these savings that make up the maximum achievable potential assuming EWR measure-specific ramp rates. We used maximum achievable potential assumptions that are consistent with the primary results for non-emerging technology measures, and we used emerging technology measure characterization assumptions based on the research described in Appendix C. The emerging technology measures and certain non-emerging technology measures included in the maximum achievable potential are not currently offered by Consumers Energy's EWR programs.

Figure 26 presents the 20-year cumulative maximum achievable EWR potential in megawatt-hours.

Figure 26. Transformational Technology Scenario Cumulative Maximum Achievable Potential by Sector

Residential

Residential customers represent the largest percentage of 2040 cumulative baseline sales (37%). The Cadmus team and Consumers Energy identified 59 unique, residential emerging technologies that could provide savings within the framework of the 20-year study horizon. The resulting savings increased cumulative 20-year potential by 40%, to 3,939 GWh of maximum achievable potential. This corresponds to annual savings of 1.6% of sales. Behavioral web portal savings are a large driver in this increase, making up 10% of total cumulative 20-year horizon savings.

Table 47 shows cumulative 20-year residential electric conservation potential for the residential segment by end uses and relative to baseline sales. The table shows that cooling (20%), refrigeration (18%), lighting (17%), behavior (17%), and heating 11%) end uses combined account for 83% of residential electric cumulative maximum achievable potential. The large behavioral savings represents the unconstrained potential from behavior-based changes and the added web portal emerging technology measure savings.

Table 47. Transformational Technology Scenario 20-Year Cumulative Maximum Achievable Residential Potential by End Use

End Use	Baseline Sales by End Use	MWh	Percentage of 2040 Total End Use Baseline Sales	MW
Cooling	2,231,824	772,458	35%	831
Refrigeration	1,930,514	717,482	37%	85
Lighting	1,591,901	685,437	43%	283
Behavior	NA	657,213	NA [a]	75
Heating	1,912,250	444,623	23%	0
Water Heat	1,265,866	177,192	14%	131
Ventilation	1,293,248	145,991	11%	15
Plug Load	2,763,556	125,087	5%	68
Dryer	1,062,274	123,902	12%	181
Heat Pump	246,898	72,546	29%	16
Cooking	454,172	16,270	4%	10
Other	108,695	417	0%	0
Electric Vehicle	NA	83	NA [a]	0
Total [b]	**14,861,197**	**3,938,701**	**27%**	**1,695**

[a] The team calculated potential for the behavioral end use based on the aggregate of all other end use baseline sales, so it does not have a corresponding baseline sales value. Additionally, electric vehicles are an emerging technology that does not have a baseline.

[b] May not equal sum of rows due to rounding.

Figure 27 shows electric residential cumulative maximum achievable potential by end use in 2025 and 2040.

Figure 27. Transformational Technology Scenario Residential Maximum Achievable Potential by End Use-Energy: Cumulative

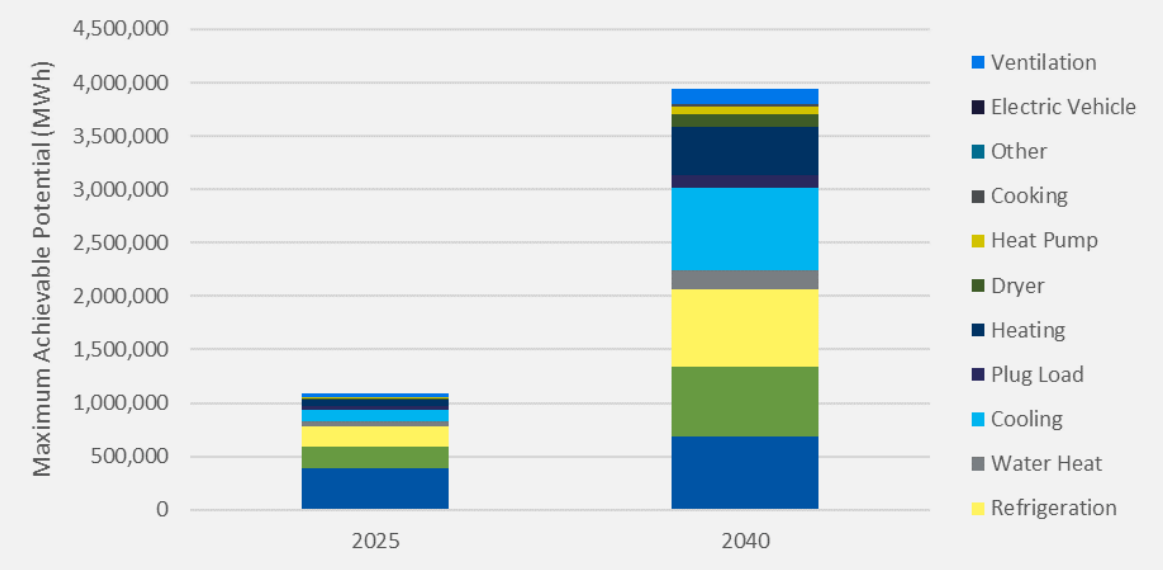


Table 48 provides the top five emerging technology measures based on their contribution to the cumulative maximum achievable potential. Web portal measures offer the largest emerging technology savings, followed by advanced furnace fans, wet bulb chillers, radiant panels, and smart vents. In total, these emerging technology measures account for 26% of the total residential maximum achievable potential. Some measures, like wet bulb chillers, are expected to take longer to develop and gain market acceptance so savings occur later in the planning period.

Table 48. Top Residential Maximum Achievable Potential Emerging Technology Measures: Cumulative 2025 and 2040

Measure Name		Maximum Achievable Potential		
	Cumulative 5-Year (MWh)	Percentage of 5-Year Residential Potential	Cumulative 20-Year (MWh)	Percentage of 20-Year Residential Potential
Emerging Technology - Web Portal	105,176	9%	568,516	14%
Emerging Technology - Advanced Furnace Fan	27,539	2%	142,392	4%
Emerging Technology - Residential-Sized Sub-Wet Bulb Chiller	-	0%	132,393	3%
Emerging Technology - Smart Vents	24,456	2%	130,228	3%
Emerging Technology - Radiant Panels	20,025	2%	106,574	3%

Commercial

Commercial customers represent the second largest percentage of 2040 cumulative baseline sales (36%). Of the 14,528 GWh of cumulative, commercial baseline sales, 30% are achievable (4,387 GWh). This is a 58% increase from the primary results for20-year cumulative commercial maximum achievable

potential and corresponds to annual savings of 1.8% of sales. The major contributing emerging technology measures are advanced motors and advanced dedicated outdoor air systems.

Table 49 shows the commercial, cumulative 20-year electric maximum achievable potential by end use and relative to baseline sales. The greatest energy savings category is lighting, with 45% of the total commercial maximum achievable potential. Ventilation and cooling provide a combined 32% of the 4,387 GWh of maximum achievable potential. These three end uses also make up 88% of the total peak demand reduction. Emerging technology measures for advanced motors, advanced dedicated outdoor air systems, and future lighting Perovskite LEDs are primary contributors to these end-use savings.

Table 49. Transformational Scenario 20-Year Cumulative Maximum Achievable Commercial Potential by End Use

End Use	Baseline Sales by End Use	MWh Savings	Percentage of 2040 Total End Use Baseline Sales	MW Savings
Lighting	5,276,623	1,955,500	37%	300
Ventilation	2,598,798	713,230	27%	31
Cooling	1,366,558	681,062	50%	376
Refrigeration	1,927,013	537,750	28%	42
Plug Load	1,969,685	165,244	8%	8
Heating	320,614	99,361	31%	2
Heat Pump	138,375	76,350	55%	25
Water Heat	278,909	71,293	26%	3
Cooking	430,286	55,293	13%	11
Other	211,405	30,703	15%	5
Dryer	9,895	1,399	14%	0
Total [a]	**14,528,160**	**4,387,185**	**30%**	**805**

[a] May not equal sum of rows due to rounding.

Figure 28 shows electric commercial cumulative maximum achievable potential by end use in 2025 and 2040.

Figure 28. Transformational Scenario Commercial Maximum Achievable Potential by End Use-Energy: Cumulative

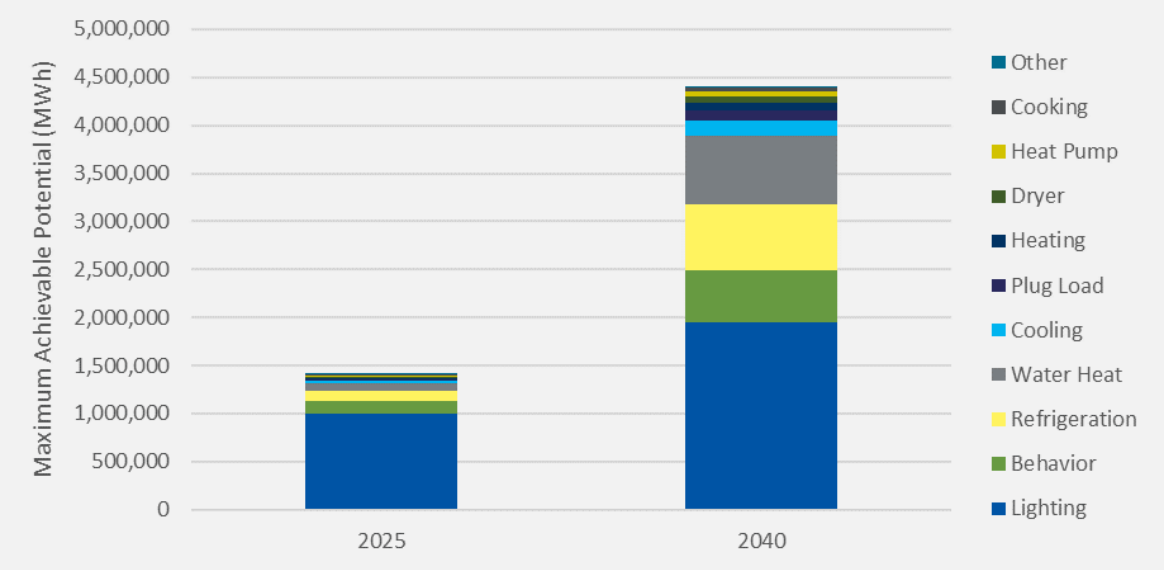


Table 50 lists the top five emerging technology savings measures. These measures all provide savings to the top four saving end uses: lighting, ventilation, cooling, and refrigeration. Combined, advanced motors, advanced dedicated outdoor air systems, aerofoils for open display cases, perovskite LEDs, and advanced refrigeration equipment make up 11% of the total cumulative, 20-year maximum achievable potential for the commercial sector.

Table 50. Top Commercial Maximum Achievable Potential Emerging Technology Measures: Cumulative 2025 and 2040

Measure Name	Maximum Achievable Potential			
	Cumulative 5-Year (MWh)	Percentage of 5-Year Commercial Potential	Cumulative 20-Year (MWh)	Percentage of 20-Year Commercial Potential
Emerging Technology - Advanced Motors	0	0%	128,001	3%
Emerging Technology - Advanced Dedicated Outdoor Air Systems	0	0%	96,684	2%
Emerging Technology - Aerofoils for Open Display Cases	18,150	1%	93,857	2%
Emerging Technology - Future Lighting - Perovskite LEDs	0	0%	89,940	2%
Emerging Technology - Advanced Refrigeration / CO2 Systems	0	0%	67,293	2%

Industrial

Industrial customers represent the smallest percentage of 2040 cumulative baseline sales (28%). Of the 20-year cumulative industrial baseline sales, the maximum achievable potential is 2,607 GWh, or 23% of baseline sales. The Cadmus team and Consumers Energy identified 51 unique, industrial emerging

technologies and savings acquisition approaches that could provide savings within the framework of the 20-year study horizon, increasing cumulative 20-year potential by 54%. This corresponds to annual savings of 1.3% of sales. The major contributors to the increase in maximum achievable potential are process improvements for refrigeration and cooling and future proxy process heating improvements. Proxy measure bundles represent unique energy-efficiency improvements in commercial and industrial applications, akin to custom measures, that may be acquired through program strategies such as standard offer or pay-for-performance.

Table 51 shows the industrial end-use distribution of 20-year cumulative maximum achievable potential. The end use with the greatest cumulative savings is process (44%). The emerging technology measures included in this category are for future process improvement. Other end uses with high cumulative achievable values include lighting (16%) and HVAC (14%).

Table 51. Transformational Scenario 20-Year Cumulative Maximum Achievable Industrial Potential by End Use

End Use	Baseline Sales by End Use	MWh	Percentage of 2040 Total End Use Baseline Sales	MW
Process	4,195,527	1,153,055	27%	167
Lighting	929,122	402,969	43%	58
HVAC	1,441,723	353,651	25%	50
Motors Other	1,725,479	257,365	15%	37
Pumps	1,310,710	222,170	17%	47
Fans	637,127	101,174	16%	15
Other	666,683	59,382	9%	8
Ventilation	168,762	38,544	23%	6
Indirect Boiler	114,912	5,772	5%	1
Plug Load [a]	0	4,045	NA [a]	0
Water Heat	14,843	1,486	10%	0
Total [b]	**11,204,888**	**2,599,612**	**23%**	**388**

[a] The plug load end use is made of emerging technology measures for indoor agriculture, which has no baseline.

[b] May not equal sum of rows due to rounding.

Figure 29 shows electric industrial cumulative maximum achievable potential by end use in 2025 and 2040.

Figure 29. Transformational Technology Scenario Industrial Maximum Achievable Potential by End Use-Energy: Cumulative

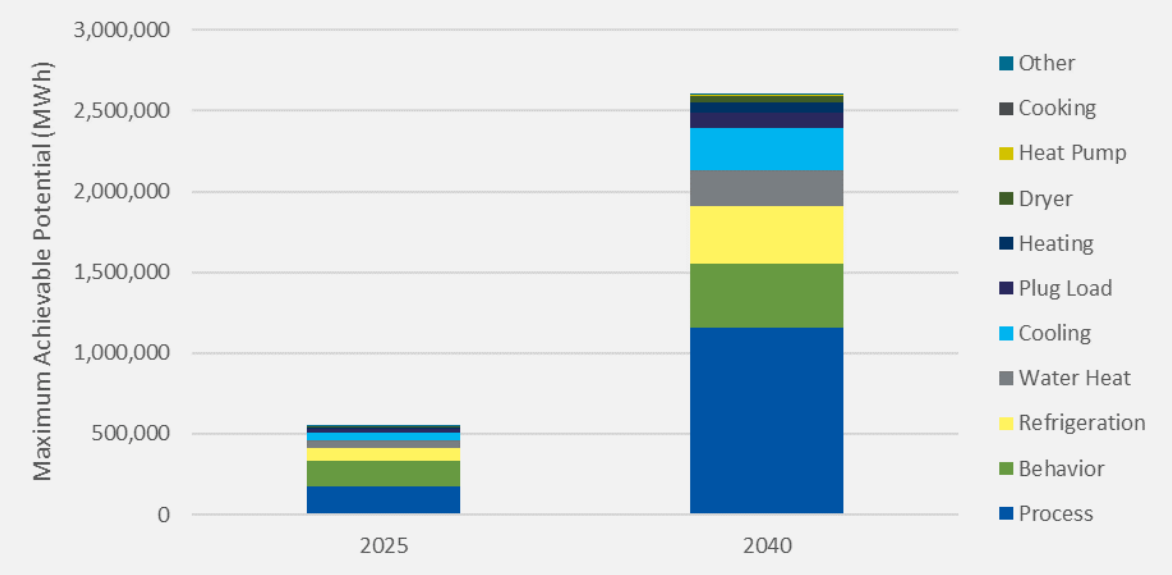


Table 52 provides the top five emerging technology savings measures and their cumulative five-year and 20-year maximum achievable potential, in addition to the percentage of total 20-year industrial maximum achievable potential. For the industrial sector, the emerging technology measures that had the greatest contributions (11% in total) are for process improvements in refrigeration and cooling and in heating. Advanced lighting controls and advanced motors contributed 5% of the industrial cumulative 20-year maximum achievable potential.

Table 52. Top Industrial Maximum Achievable Potential Emerging Technology Measures: Cumulative 2025 and 2040

Measure Name	Maximum Achievable Potential			
	Cumulative 5-Year (MWh)	Percentage of 5-Year Industrial Potential	Cumulative 20-Year (MWh)	Percentage of 20-Year Industrial Potential
Emerging Technology - Process Improvement - Refrigeration and Cooling	20,287	4%	109,659	4%
Emerging Technology - Future Proxy Process Improvement - Heat	0	0%	108,066	4%
Emerging Technology - Future Proxy Process Improvement - Refrigeration and Cooling	0	0%	86,130	3%
Emerging Technology - Advanced Lighting Controls	12,721	2%	68,761	3%
Emerging Technology - Advanced Motor - Motors Other	0	0%	56,893	2%

CADMUS

Appendix A. Baseline Forecast Data

This appendix provides baseline forecast data for the residential (Figure A-1, Figure A-2, and Table A-1), commercial (Figure A-3, Figure A-4, and Table A-2), and industrial (Figure A-5 and Figure A-6) sectors.

Residential Electric

Figure A-1. Residential Baseline Electric Forecast by Segment

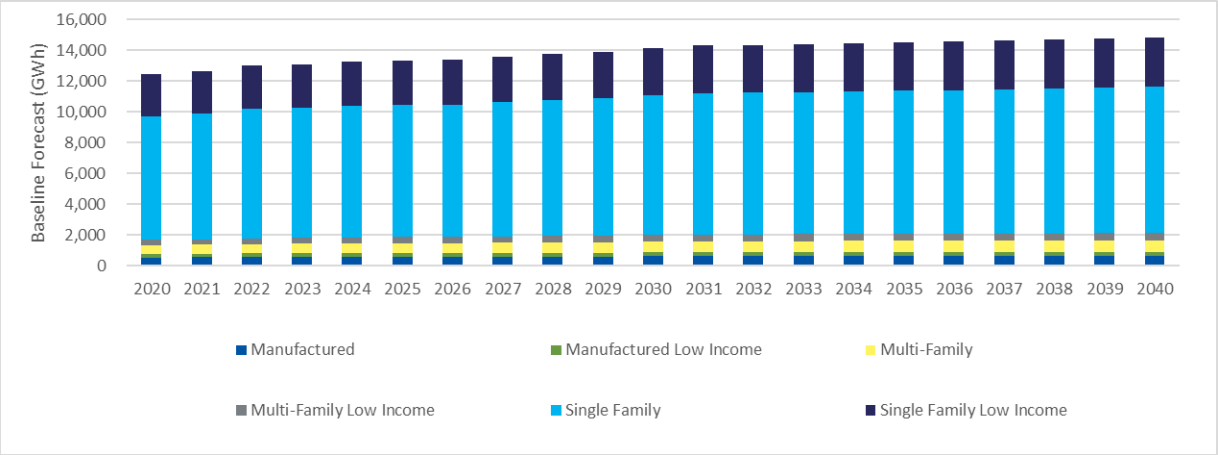


Figure A-2. Residential Baseline Electric Forecast by End Use

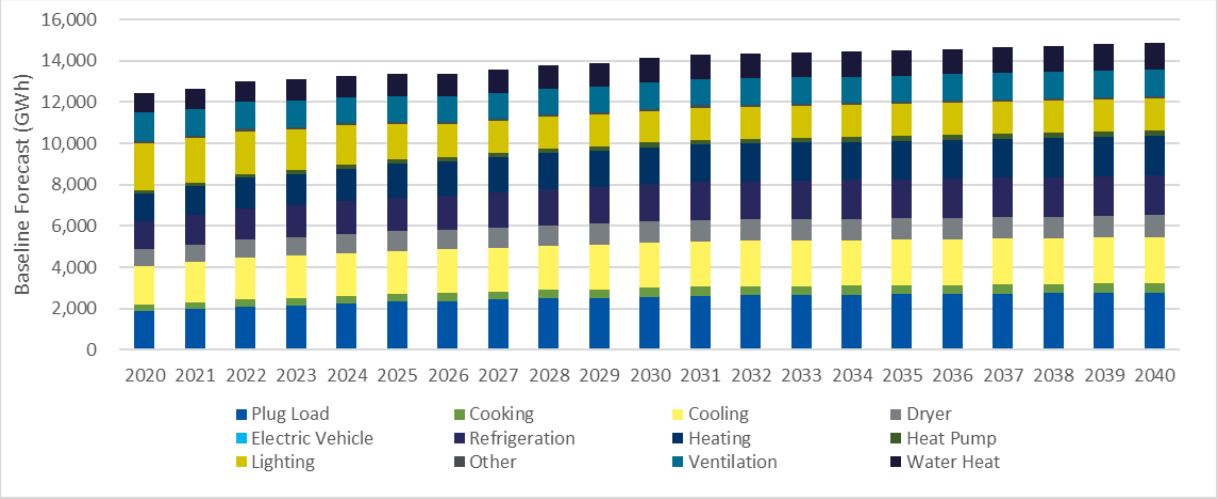


Table A-1. Residential Baseline Forecast Assumptions:
Electric Saturations Fuels Shares and Unit Energy Use

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Existing Construction			
Manufactured			
Air Purifier	6%	100%	890.21
Computer	99%	100%	60.68
Cooking Oven	86%	56%	174.17
Cooking Range	96%	96%	124.74
Cool Central	58%	100%	806.74
Cool Room	36%	100%	208.92
Dehumidifier	12%	100%	551.45
Dryer	96%	96%	670.49
Electric Vehicle	0%	100%	2,553.36
Freezer	55%	100%	524.30
Heat Central	5%	100%	17,670.97
Heat Pump	0%	100%	6,775.74
Heat Room	0%	100%	11,507.79
Lighting – Fluorescent	617%	100%	26.57
Lighting – Specialty	2032%	100%	31.42
Lighting – Standard	2818%	100%	20.47
Microwave	88%	100%	130.99
Monitor	40%	100%	28.92
Other	100%	100%	0.00
Plug Load Other	100%	100%	628.75
Refrigerator	116%	100%	527.13
Television	187%	100%	103.39
Ventilation and Circulation	99%	100%	1,118.04
Water Heater GT 55 Gallon	3%	41%	1,716.76
Water Heater LE 55 Gallon	95%	41%	1,710.26
Manufactured Low Income			
Air Purifier	2%	100%	890.21
Computer	82%	100%	60.68
Cooking Oven	100%	24%	174.17
Cooking Range	93%	93%	124.74
Cool Central	44%	100%	749.44
Cool Room	36%	100%	192.42
Dehumidifier	7%	100%	551.45
Dryer	91%	91%	670.49
Electric Vehicle	0%	100%	2,553.36
Freezer	46%	100%	524.30
Heat Central	5%	100%	15,887.25
Heat Pump	0%	100%	6,204.51
Heat Room	2%	100%	10,346.18
Lighting – Fluorescent	568%	100%	26.57
Lighting – Specialty	1872%	100%	34.98

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Lighting – Standard	2595%	100%	23.62
Microwave	79%	100%	130.99
Monitor	34%	100%	28.92
Other	100%	100%	0.00
Plug Load Other	100%	100%	548.56
Refrigerator	110%	100%	527.13
Television	165%	100%	103.39
Ventilation and Circulation	98%	100%	1,118.04
Water Heater GT 55 Gallon	3%	46%	2,808.96
Water Heater LE 55 Gallon	94%	46%	2,803.74
Multifamily			
Air Purifier	3%	100%	890.21
Computer	93%	100%	60.68
Cooking Oven	98%	66%	174.17
Cooking Range	88%	88%	124.74
Cool Central	59%	100%	1,071.31
Cool Room	45%	100%	201.01
Dehumidifier	8%	100%	551.45
Dryer	56%	56%	670.49
Electric Vehicle	0%	100%	2,553.36
Freezer	14%	100%	524.30
Heat Central	9%	100%	12,868.67
Heat Pump	0%	100%	6,159.80
Heat Room	16%	100%	8,380.41
Lighting – Fluorescent	131%	100%	26.57
Lighting – Specialty	202%	100%	27.31
Lighting – Standard	2195%	100%	16.06
Microwave	86%	100%	130.99
Monitor	18%	100%	28.92
Other	100%	100%	0.00
Plug Load Other	100%	100%	461.21
Refrigerator	115%	100%	527.13
Television	120%	100%	103.39
Ventilation and Circulation	58%	100%	1,118.04
Water Heater GT 55 Gallon	45%	46%	1,592.74
Water Heater LE 55 Gallon	45%	46%	1,585.36
Multifamily Low Income			
Air Purifier	8%	100%	890.21
Computer	79%	100%	60.68
Cooking Oven	99%	68%	174.17
Cooking Range	93%	93%	124.74
Cool Central	44%	100%	1,242.81
Cool Room	50%	100%	232.81
Dehumidifier	7%	100%	551.45
Dryer	38%	38%	670.49

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Electric Vehicle	0%	100%	2,553.36
Freezer	18%	100%	524.30
Heat Central	26%	100%	14,505.34
Heat Pump	2%	100%	7,345.66
Heat Room	14%	100%	9,446.25
Lighting – Fluorescent	151%	100%	26.57
Lighting – Specialty	234%	100%	31.24
Lighting – Standard	2543%	100%	17.97
Microwave	64%	100%	130.99
Monitor	15%	100%	28.92
Other	100%	100%	0.00
Plug Load Other	100%	100%	473.03
Refrigerator	106%	100%	527.13
Television	144%	100%	103.39
Ventilation and Circulation	62%	100%	1,118.04
Water Heater GT 55 Gallon	42%	45%	1,780.64
Water Heater LE 55 Gallon	42%	45%	1,776.63
Single Family			
Air Purifier	9%	100%	890.21
Computer	153%	100%	60.68
Cooking Oven	109%	56%	174.17
Cooking Range	98%	98%	124.74
Cool Central	71%	100%	2,455.89
Cool Room	23%	100%	304.09
Dehumidifier	46%	100%	551.45
Dryer	98%	98%	670.49
Electric Vehicle	0%	100%	2,553.36
Freezer	66%	100%	524.30
Heat Central	2%	100%	23,220.98
Heat Pump	2%	100%	10,972.27
Heat Room	1%	100%	15,122.09
Lighting – Fluorescent	898%	100%	26.57
Lighting – Specialty	2958%	100%	21.71
Lighting – Standard	4101%	100%	24.34
Microwave	85%	100%	130.99
Monitor	63%	100%	28.92
Other	100%	100%	0.00
Plug Load Other	100%	100%	750.76
Pool Pump	9%	100%	1,448.34
Refrigerator	137%	100%	527.13
Television	213%	100%	103.39
Ventilation and Circulation	92%	100%	1,118.04
Water Heater GT 55 Gallon	3%	22%	2,533.15
Water Heater LE 55 Gallon	96%	22%	2,526.91

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Single Family Low Income			
Air Purifier	5%	100%	890.21
Computer	96%	100%	60.68
Cooking Oven	110%	54%	174.17
Cooking Range	96%	96%	124.74
Cool Central	39%	100%	1,791.27
Cool Room	37%	100%	221.96
Dehumidifier	28%	100%	551.45
Dryer	90%	90%	670.49
Electric Vehicle	0%	100%	2,553.36
Freezer	55%	100%	524.30
Heat Central	4%	100%	16,832.99
Heat Pump	1%	100%	7,668.32
Heat Room	3%	100%	10,962.07
Lighting – Fluorescent	655%	100%	26.57
Lighting – Specialty	2159%	100%	26.13
Lighting – Standard	2993%	100%	27.32
Microwave	78%	100%	130.99
Monitor	39%	100%	28.92
Other	100%	100%	0.00
Plug Load Other	100%	100%	596.96
Refrigerator	118%	100%	527.13
Television	161%	100%	103.39
Ventilation and Circulation	91%	100%	1,118.04
Water Heater GT 55 Gallon	3%	31%	2,833.12
Water Heater LE 55 Gallon	96%	31%	2,828.28
New Construction			
Manufactured			
Air Purifier	6%	100%	843.03
Computer	99%	100%	60.68
Cooking Oven	86%	56%	174.17
Cooking Range	96%	96%	124.74
Cool Central	58%	100%	526.18
Cool Room	36%	100%	192.79
Dehumidifier	12%	100%	536.46
Dryer	96%	96%	583.43
Electric Vehicle	0%	100%	2,553.36
Freezer	55%	100%	479.17
Heat Central	5%	100%	11,658.21
Heat Pump	0%	100%	5,952.18
Heat Room	0%	100%	7,592.12
Lighting – Fluorescent	421%	100%	26.04
Lighting – Specialty	1386%	100%	31.42
Lighting – Standard	1922%	100%	20.47
Microwave	88%	100%	130.99

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Monitor	40%	100%	28.92
Other	100%	100%	0.00
Plug Load Other	100%	100%	628.75
Refrigerator	116%	100%	507.30
Television	187%	100%	103.39
Ventilation and Circulation	99%	100%	699.39
Water Heater GT 55 Gallon	3%	41%	740.56
Water Heater LE 55 Gallon	95%	41%	1,642.11
Manufactured Low Income			
Air Purifier	2%	100%	843.03
Computer	82%	100%	60.68
Cooking Oven	100%	24%	174.17
Cooking Range	93%	93%	124.74
Cool Central	44%	100%	484.61
Cool Room	36%	100%	177.56
Dehumidifier	7%	100%	536.46
Dryer	91%	91%	583.43
Electric Vehicle	0%	100%	2,553.36
Freezer	46%	100%	479.17
Heat Central	5%	100%	10,737.78
Heat Pump	0%	100%	5,407.19
Heat Room	2%	100%	6,992.71
Lighting – Fluorescent	388%	100%	26.04
Lighting – Specialty	1276%	100%	34.98
Lighting – Standard	1770%	100%	23.62
Microwave	79%	100%	130.99
Monitor	34%	100%	28.92
Other	100%	100%	0.00
Plug Load Other	100%	100%	548.56
Refrigerator	110%	100%	507.30
Television	165%	100%	103.39
Ventilation and Circulation	98%	100%	699.39
Water Heater GT 55 Gallon	3%	46%	1,211.71
Water Heater LE 55 Gallon	94%	46%	2,686.83
Multifamily			
Air Purifier	3%	100%	843.03
Computer	93%	100%	60.68
Cooking Oven	98%	66%	174.17
Cooking Range	88%	88%	124.74
Cool Central	59%	100%	883.65
Cool Room	45%	100%	185.92
Dehumidifier	8%	100%	536.46
Dryer	56%	56%	583.43
Electric Vehicle	0%	100%	2,553.36
Freezer	14%	100%	479.17

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Heat Central	9%	100%	10,504.95
Heat Pump	0%	100%	6,670.53
Heat Room	16%	100%	6,841.09
Lighting – Fluorescent	131%	100%	26.04
Lighting – Specialty	202%	100%	27.31
Lighting – Standard	2195%	100%	16.06
Microwave	86%	100%	130.99
Monitor	18%	100%	28.92
Other	100%	100%	0.00
Plug Load Other	100%	100%	461.21
Refrigerator	115%	100%	507.30
Television	120%	100%	103.39
Ventilation and Circulation	58%	100%	699.39
Water Heater GT 55 Gallon	45%	46%	706.63
Water Heater LE 55 Gallon	45%	46%	1,525.68
Multifamily Low Income			
Air Purifier	8%	100%	843.03
Computer	79%	100%	60.68
Cooking Oven	99%	68%	174.17
Cooking Range	93%	93%	124.74
Cool Central	44%	100%	1,023.46
Cool Room	50%	100%	215.34
Dehumidifier	7%	100%	536.46
Dryer	38%	38%	583.43
Electric Vehicle	0%	100%	2,553.36
Freezer	18%	100%	479.17
Heat Central	26%	100%	12,167.66
Heat Pump	2%	100%	7,930.96
Heat Room	14%	100%	7,923.89
Lighting - Fluorescent	151%	100%	26.04
Lighting - Specialty	234%	100%	31.24
Lighting - Standard	2543%	100%	17.97
Microwave	64%	100%	130.99
Monitor	15%	100%	28.92
Other	100%	100%	0.00
Plug Load Other	100%	100%	473.03
Refrigerator	106%	100%	507.30
Television	144%	100%	103.39
Ventilation and Circulation	62%	100%	699.39
Water Heater GT 55 Gallon	42%	45%	821.85
Water Heater LE 55 Gallon	42%	45%	1,709.22
Single Family			
Air Purifier	9%	100%	843.03
Computer	153%	100%	60.68
Cooking Oven	109%	56%	174.17

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Cooking Range	98%	98%	124.74
Cool Central	71%	100%	1,319.42
Cool Room	23%	100%	280.61
Dehumidifier	46%	100%	536.46
Dryer	98%	98%	583.43
Electric Vehicle	0%	100%	2,553.36
Freezer	66%	100%	479.17
Heat Central	2%	100%	12,672.03
Heat Pump	2%	100%	7,849.14
Heat Room	1%	100%	8,252.35
Lighting - Fluorescent	612%	100%	26.04
Lighting - Specialty	2017%	100%	21.71
Lighting - Standard	2797%	100%	24.34
Microwave	85%	100%	130.99
Monitor	63%	100%	28.92
Other	100%	100%	0.00
Plug Load Other	100%	100%	750.76
Pool Pump	9%	100%	955.26
Refrigerator	137%	100%	507.30
Television	213%	100%	103.39
Ventilation and Circulation	92%	100%	699.39
Water Heater GT 55 Gallon	3%	22%	1,097.41
Water Heater LE 55 Gallon	96%	22%	2,423.53
Single Family Low Income			
Air Purifier	5%	100%	843.03
Computer	96%	100%	60.68
Cooking Oven	110%	54%	174.17
Cooking Range	96%	96%	124.74
Cool Central	39%	100%	963.07
Cool Room	37%	100%	204.82
Dehumidifier	28%	100%	536.46
Dryer	90%	90%	583.43
Electric Vehicle	0%	100%	2,553.36
Freezer	55%	100%	479.17
Heat Central	4%	100%	9,250.11
Heat Pump	1%	100%	5,372.10
Heat Room	3%	100%	6,023.91
Lighting - Fluorescent	447%	100%	26.04
Lighting - Specialty	1472%	100%	26.13
Lighting - Standard	2042%	100%	27.32
Microwave	78%	100%	130.99
Monitor	39%	100%	28.92
Other	100%	100%	0.00
Plug Load Other	100%	100%	596.96
Refrigerator	118%	100%	507.30

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Television	161%	100%	103.39
Ventilation and Circulation	91%	100%	699.39
Water Heater GT 55 Gallon	3%	31%	1,238.55
Water Heater LE 55 Gallon	96%	31%	2,711.77

Commercial Electric

Figure A-3. Commercial Baseline Electric Forecast by Segment

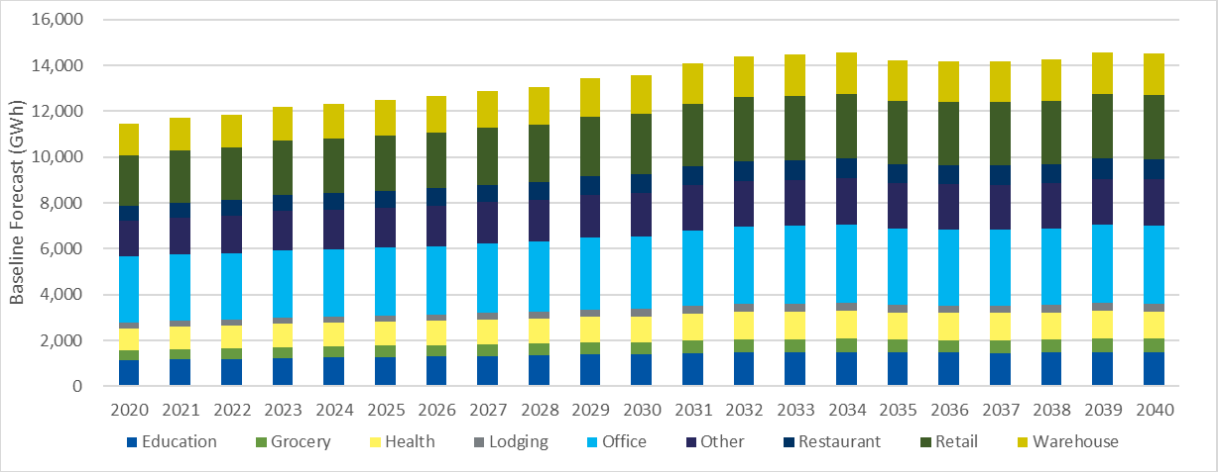


Figure A-4. Commercial Baseline Electric Forecast by End Use

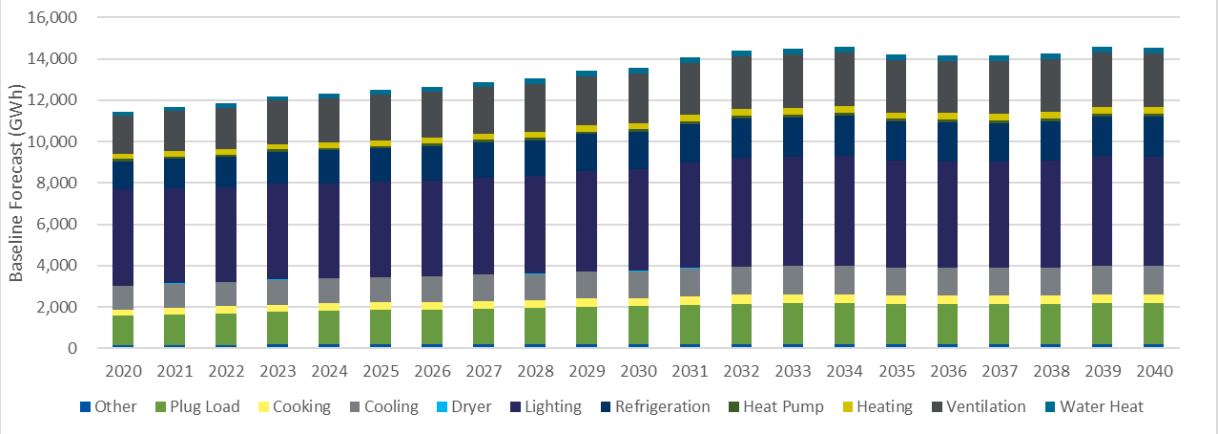


Table A-2. Commercial Baseline Forecast Assumptions:
Electric Saturation Fuel Shares and Unit Energy Use

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Existing Construction			
Education			
Compressed Air	100%	100%	0.00
Computer	100%	100%	0.11
Cooking	100%	33%	0.42
Cooling Chillers	29%	100%	0.88
Cooling Direct Expansion	66%	100%	1.70
Dryer	100%	92%	0.02
Extension Lighting	100%	100%	0.46
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.00
Heat Pump	3%	100%	4.51
Lighting Interior Fluorescent	100%	100%	1.27
Lighting Interior HID	100%	100%	0.13
Lighting Interior Other	100%	100%	0.09
Lighting Interior Screw Base	100%	100%	0.15
Monitor	100%	100%	0.07
Other	100%	100%	0.00
Other Plug Load	100%	100%	2.92
Package Terminal Air Conditioner	0%	100%	0.61
Package Terminal Heat Pump	0%	100%	1.47
Photo Copier	100%	100%	0.00
Pool Pump	100%	100%	0.01
Printer	100%	100%	0.02
Refrigeration	100%	100%	0.89
Refrigerator	100%	100%	0.02
Room Cool	4%	100%	0.62
Room Heat	12%	28%	2.76
Server	100%	100%	0.08
Space Heat	86%	0%	8.32
Vending Machine	100%	100%	0.03
Ventilation and Circulation	100%	100%	1.46
Water Heat GT 55 Gallon	50%	20%	0.55
Water Heat LE 55 Gallon	50%	20%	1.22
Grocery			
Compressed Air	100%	100%	0.05
Computer	100%	100%	0.03
Cooking	100%	41%	5.25
Cooling Chillers	0%	100%	0.85
Cooling Direct Expansion	100%	100%	0.88
Dryer	100%	0%	0.02
Extension Lighting	100%	100%	0.95
Fax Machine	100%	100%	0.00

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Freezer	100%	100%	0.01
Heat Pump	10%	100%	3.39
Lighting Interior Fluorescent	100%	100%	5.01
Lighting Interior HID	100%	100%	0.01
Lighting Interior Other	100%	100%	0.09
Lighting Interior Screw Base	100%	100%	1.84
Monitor	100%	100%	0.02
Other	100%	100%	0.00
Other Plug Load	100%	100%	1.69
Package Terminal Air Conditioner	0%	100%	0.69
Package Terminal Heat Pump	0%	100%	2.35
Photo Copier	100%	100%	0.01
Pool Pump	100%	100%	0.00
Printer	100%	100%	0.02
Refrigeration	100%	100%	38.75
Refrigerator	100%	100%	0.05
Room Cool	0%	100%	0.70
Room Heat	8%	0%	5.31
Server	100%	100%	0.11
Space Heat	82%	2%	8.07
Vending Machine	100%	100%	0.03
Ventilation and Circulation	100%	100%	3.50
Water Heat GT 55 Gallon	33%	30%	0.10
Water Heat LE 55 Gallon	67%	30%	0.22
Health			
Compressed Air	100%	100%	0.00
Computer	100%	100%	0.08
Cooking	100%	24%	2.89
Cooling Chillers	13%	100%	1.94
Cooling Direct Expansion	78%	100%	3.38
Dryer	100%	57%	0.10
Extension Lighting	100%	100%	0.70
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.00
Heat Pump	6%	100%	8.30
Lighting Interior Fluorescent	100%	100%	3.07
Lighting Interior HID	100%	100%	0.04
Lighting Interior Other	100%	100%	0.09
Lighting Interior Screw Base	100%	100%	0.68
Monitor	100%	100%	0.07
Other	100%	100%	0.00
Other Plug Load	100%	100%	6.99
Package Terminal Air Conditioner	0%	100%	1.82
Package Terminal Heat Pump	0%	100%	3.95
Photo Copier	100%	100%	0.01
Pool Pump	100%	100%	0.02

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Printer	100%	100%	0.04
Refrigeration	100%	100%	1.40
Refrigerator	100%	100%	0.04
Room Cool	9%	100%	1.83
Room Heat	1%	0%	6.83
Server	100%	100%	0.13
Space Heat	93%	0%	14.70
Vending Machine	100%	100%	0.03
Ventilation and Circulation	100%	100%	4.92
Water Heat GT 55 Gallon	20%	28%	2.22
Water Heat LE 55 Gallon	80%	28%	4.91
Lodging			
Compressed Air	100%	100%	0.01
Computer	100%	100%	0.02
Cooking	100%	53%	3.09
Cooling Chillers	16%	100%	0.52
Cooling Direct Expansion	33%	100%	1.01
Dryer	100%	41%	0.09
Extension Lighting	100%	100%	0.70
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.01
Heat Pump	1%	100%	2.80
Lighting Interior Fluorescent	100%	100%	0.29
Lighting Interior HID	100%	100%	0.01
Lighting Interior Other	100%	100%	0.09
Lighting Interior Screw Base	100%	100%	1.62
Monitor	100%	100%	0.01
Other	100%	100%	0.00
Other Plug Load	100%	100%	5.27
Package Terminal Air Conditioner	3%	100%	0.56
Package Terminal Heat Pump	5%	100%	1.42
Photo Copier	100%	100%	0.00
Pool Pump	100%	100%	0.03
Printer	100%	100%	0.01
Refrigeration	100%	100%	1.21
Refrigerator	100%	100%	0.09
Room Cool	47%	100%	0.57
Room Heat	40%	43%	2.76
Server	100%	100%	0.01
Space Heat	54%	74%	5.35
Vending Machine	100%	100%	0.03
Ventilation and Circulation	100%	100%	2.24
Water Heat GT 55 Gallon	82%	17%	2.42
Water Heat LE 55 Gallon	18%	17%	5.36

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Office			
Compressed Air	100%	100%	0.03
Computer	100%	100%	0.12
Cooking	100%	2%	0.15
Cooling Chillers	10%	100%	1.07
Cooling Direct Expansion	82%	100%	1.87
Dryer	100%	0%	0.03
Extension Lighting	100%	100%	0.70
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.00
Heat Pump	6%	100%	4.30
Lighting Interior Fluorescent	100%	100%	1.55
Lighting Interior HID	100%	100%	0.08
Lighting Interior Other	100%	100%	0.09
Lighting Interior Screw Base	100%	100%	1.72
Monitor	100%	100%	0.09
Other	100%	100%	0.00
Other Plug Load	100%	100%	4.69
Package Terminal Air Conditioner	0%	100%	1.19
Package Terminal Heat Pump	0%	100%	2.44
Photo Copier	100%	100%	0.01
Pool Pump	100%	100%	0.01
Printer	100%	100%	0.05
Refrigeration	100%	100%	0.38
Refrigerator	100%	100%	0.03
Room Cool	8%	100%	1.20
Room Heat	21%	1%	3.98
Server	100%	100%	0.26
Space Heat	72%	1%	7.20
Vending Machine	100%	100%	0.03
Ventilation and Circulation	100%	100%	3.91
Water Heat GT 55 Gallon	26%	63%	0.16
Water Heat LE 55 Gallon	74%	63%	0.35
Other			
Compressed Air	100%	100%	0.11
Computer	100%	100%	0.02
Cooking	100%	43%	0.42
Cooling Chillers	2%	100%	0.83
Cooling Direct Expansion	94%	100%	1.42
Dryer	100%	39%	0.05
Extension Lighting	100%	100%	0.70
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.00
Heat Pump	0%	100%	4.09
Lighting Interior Fluorescent	100%	100%	2.02
Lighting Interior HID	100%	100%	0.45

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Lighting Interior Other	100%	100%	0.09
Lighting Interior Screw Base	100%	100%	0.97
Monitor	100%	100%	0.02
Other	100%	100%	0.00
Other Plug Load	100%	100%	1.87
Package Terminal Air Conditioner	0%	100%	0.88
Package Terminal Heat Pump	0%	100%	2.27
Photo Copier	100%	100%	0.00
Pool Pump	100%	100%	0.00
Printer	100%	100%	0.02
Refrigeration	100%	100%	0.77
Refrigerator	100%	100%	0.04
Room Cool	4%	100%	0.89
Room Heat	42%	0%	4.43
Server	100%	100%	0.05
Space Heat	58%	3%	8.46
Vending Machine	100%	100%	0.03
Ventilation and Circulation	100%	100%	1.13
Water Heat GT 55 Gallon	43%	29%	0.27
Water Heat LE 55 Gallon	57%	29%	0.59
Restaurant			
Compressed Air	100%	100%	0.01
Computer	100%	100%	0.01
Cooking	100%	34%	24.54
Cooling Chillers	0%	100%	1.97
Cooling Direct Expansion	98%	100%	1.97
Dryer	100%	0%	0.49
Extension Lighting	100%	100%	2.30
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.01
Heat Pump	4%	100%	4.95
Lighting Interior Fluorescent	100%	100%	1.10
Lighting Interior HID	100%	100%	0.02
Lighting Interior Other	100%	100%	0.09
Lighting Interior Screw Base	100%	100%	1.60
Monitor	100%	100%	0.01
Other	100%	100%	0.00
Other Plug Load	100%	100%	2.82
Package Terminal Air Conditioner	0%	100%	1.69
Package Terminal Heat Pump	0%	100%	3.26
Photo Copier	100%	100%	0.00
Pool Pump	100%	0%	0.00
Printer	100%	100%	0.01
Refrigeration	100%	100%	12.71
Refrigerator	100%	100%	0.07
Room Cool	2%	100%	1.70

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Room Heat	7%	86%	5.02
Server	100%	100%	0.05
Space Heat	89%	0%	7.28
Vending Machine	100%	100%	0.01
Ventilation and Circulation	100%	100%	4.20
Water Heat GT 55 Gallon	38%	6%	2.15
Water Heat LE 55 Gallon	63%	6%	4.77
Retail			
Compressed Air	100%	100%	0.33
Computer	100%	100%	0.02
Cooking	100%	49%	0.81
Cooling Chillers	0%	100%	1.38
Cooling Direct Expansion	100%	100%	1.38
Dryer	100%	0%	0.04
Extension Lighting	100%	100%	0.95
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.00
Heat Pump	2%	100%	4.64
Lighting Interior Fluorescent	100%	100%	2.96
Lighting Interior HID	100%	100%	0.27
Lighting Interior Other	100%	100%	0.09
Lighting Interior Screw Base	100%	100%	1.53
Monitor	100%	100%	0.02
Other	100%	100%	0.00
Other Plug Load	100%	100%	2.61
Package Terminal Air Conditioner	0%	100%	0.96
Package Terminal Heat Pump	0%	100%	2.36
Photo Copier	100%	100%	0.00
Pool Pump	100%	100%	0.04
Printer	100%	100%	0.02
Refrigeration	100%	100%	3.46
Refrigerator	100%	100%	0.02
Room Cool	0%	100%	0.97
Room Heat	35%	19%	4.47
Server	100%	100%	0.06
Space Heat	63%	0%	7.93
Vending Machine	100%	100%	0.02
Ventilation and Circulation	100%	100%	3.24
Water Heat GT 55 Gallon	18%	69%	0.25
Water Heat LE 55 Gallon	82%	69%	0.55
Warehouse			
Compressed Air	100%	100%	0.35
Computer	100%	100%	0.01
Cooking	100%	0%	0.02
Cooling Chillers	3%	100%	0.39
Cooling Direct Expansion	90%	100%	0.39

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Dryer	100%	0%	0.04
Extension Lighting	100%	100%	0.95
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.00
Heat Pump	0%	100%	2.30
Lighting Interior Fluorescent	100%	100%	0.74
Lighting Interior HID	100%	100%	0.62
Lighting Interior Other	100%	100%	0.09
Lighting Interior Screw Base	100%	100%	0.13
Monitor	100%	100%	0.01
Other	100%	100%	0.00
Other Plug Load	100%	100%	1.28
Package Terminal Air Conditioner	0%	100%	0.24
Package Terminal Heat Pump	0%	100%	0.96
Photo Copier	100%	100%	0.00
Pool Pump	100%	100%	0.00
Printer	100%	100%	0.01
Refrigeration	100%	100%	0.20
Refrigerator	100%	100%	0.01
Room Cool	7%	100%	0.25
Room Heat	56%	34%	2.29
Server	100%	100%	0.04
Space Heat	44%	0%	4.60
Vending Machine	100%	100%	0.02
Ventilation and Circulation	100%	100%	0.37
Water Heat GT 55 Gallon	6%	55%	0.08
Water Heat LE 55 Gallon	94%	55%	0.18
New Construction			
Education			
Compressed Air	100%	100%	0.00
Computer	100%	100%	0.11
Cooking	100%	33%	0.42
Cooling Chillers	29%	100%	0.88
Cooling Direct Expansion	66%	100%	1.57
Dryer	100%	92%	0.02
Extension Lighting	100%	100%	0.46
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.00
Heat Pump	3%	100%	4.51
Lighting Interior Fluorescent	100%	100%	0.00
Lighting Interior HID	100%	100%	0.00
Lighting Interior Other	100%	100%	1.47
Lighting Interior Screw Base	100%	100%	0.00
Monitor	100%	100%	0.07
Other	100%	100%	0.00
Other Plug Load	100%	100%	2.92

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Package Terminal Air Conditioner	0%	100%	0.61
Package Terminal Heat Pump	0%	100%	1.47
Photo Copier	100%	100%	0.00
Pool Pump	100%	100%	0.00
Printer	100%	100%	0.02
Refrigeration	100%	100%	0.89
Refrigerator	100%	100%	0.02
Room Cool	4%	100%	0.62
Room Heat	12%	28%	2.76
Server	100%	100%	0.08
Space Heat	86%	0%	8.32
Vending Machine	100%	100%	0.02
Ventilation and Circulation	100%	100%	1.46
Water Heat GT 55 Gallon	50%	20%	0.55
Water Heat LE 55 Gallon	50%	20%	1.22
Grocery			
Compressed Air	100%	100%	0.05
Computer	100%	100%	0.03
Cooking	100%	41%	5.25
Cooling Chillers	0%	100%	0.85
Cooling Direct Expansion	100%	100%	0.78
Dryer	100%	0%	0.02
Extension Lighting	100%	100%	0.95
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.01
Heat Pump	10%	100%	3.39
Lighting Interior Fluorescent	100%	100%	0.00
Lighting Interior HID	100%	100%	0.00
Lighting Interior Other	100%	100%	5.98
Lighting Interior Screw Base	100%	100%	0.00
Monitor	100%	100%	0.02
Other	100%	100%	0.00
Other Plug Load	100%	100%	1.69
Package Terminal Air Conditioner	0%	100%	0.69
Package Terminal Heat Pump	0%	100%	2.35
Photo Copier	100%	100%	0.01
Pool Pump	100%	100%	0.00
Printer	100%	100%	0.02
Refrigeration	100%	100%	38.75
Refrigerator	100%	100%	0.05
Room Cool	0%	100%	0.70
Room Heat	8%	0%	5.31
Server	100%	100%	0.11
Space Heat	82%	2%	8.07
Vending Machine	100%	100%	0.02
Ventilation and Circulation	100%	100%	3.50

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Water Heat GT 55 Gallon	33%	30%	0.10
Water Heat LE 55 Gallon	67%	30%	0.22
Health			
Compressed Air	100%	100%	0.00
Computer	100%	100%	0.08
Cooking	100%	24%	2.89
Cooling Chillers	13%	100%	1.94
Cooling Direct Expansion	78%	100%	3.02
Dryer	100%	57%	0.08
Extension Lighting	100%	100%	0.70
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.00
Heat Pump	6%	100%	8.30
Lighting Interior Fluorescent	100%	100%	0.00
Lighting Interior HID	100%	100%	0.00
Lighting Interior Other	100%	100%	3.41
Lighting Interior Screw Base	100%	100%	0.00
Monitor	100%	100%	0.07
Other	100%	100%	0.00
Other Plug Load	100%	100%	6.99
Package Terminal Air Conditioner	0%	100%	1.82
Package Terminal Heat Pump	0%	100%	3.95
Photo Copier	100%	100%	0.01
Pool Pump	100%	100%	0.01
Printer	100%	100%	0.04
Refrigeration	100%	100%	1.40
Refrigerator	100%	100%	0.04
Room Cool	9%	100%	1.83
Room Heat	1%	0%	6.83
Server	100%	100%	0.13
Space Heat	93%	0%	14.70
Vending Machine	100%	100%	0.02
Ventilation and Circulation	100%	100%	4.92
Water Heat GT 55 Gallon	20%	28%	2.22
Water Heat LE 55 Gallon	80%	28%	4.91
Lodging			
Compressed Air	100%	100%	0.01
Computer	100%	100%	0.02
Cooking	100%	53%	3.09
Cooling Chillers	16%	100%	0.52
Cooling Direct Expansion	33%	100%	0.93
Dryer	100%	41%	0.08
Extension Lighting	100%	100%	0.70
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.01
Heat Pump	1%	100%	2.80

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Lighting Interior Fluorescent	100%	100%	0.00
Lighting Interior HID	100%	100%	0.00
Lighting Interior Other	100%	100%	1.32
Lighting Interior Screw Base	100%	100%	0.00
Monitor	100%	100%	0.01
Other	100%	100%	0.00
Other Plug Load	100%	100%	5.27
Package Terminal Air Conditioner	3%	100%	0.56
Package Terminal Heat Pump	5%	100%	1.42
Photo Copier	100%	100%	0.00
Pool Pump	100%	100%	0.01
Printer	100%	100%	0.01
Refrigeration	100%	100%	1.21
Refrigerator	100%	100%	0.09
Room Cool	47%	100%	0.57
Room Heat	40%	43%	2.76
Server	100%	100%	0.01
Space Heat	54%	74%	5.35
Vending Machine	100%	100%	0.03
Ventilation and Circulation	100%	100%	2.24
Water Heat GT 55 Gallon	82%	17%	2.42
Water Heat LE 55 Gallon	18%	17%	5.36
Office			
Compressed Air	100%	100%	0.03
Computer	100%	100%	0.12
Cooking	100%	2%	0.15
Cooling Chillers	10%	100%	1.07
Cooling Direct Expansion	82%	100%	1.67
Dryer	100%	0%	0.02
Extension Lighting	100%	100%	0.70
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.00
Heat Pump	6%	100%	4.30
Lighting Interior Fluorescent	100%	100%	0.00
Lighting Interior HID	100%	100%	0.00
Lighting Interior Other	100%	100%	2.51
Lighting Interior Screw Base	100%	100%	0.00
Monitor	100%	100%	0.09
Other	100%	100%	0.00
Other Plug Load	100%	100%	4.69
Package Terminal Air Conditioner	0%	100%	1.19
Package Terminal Heat Pump	0%	100%	2.44
Photo Copier	100%	100%	0.01
Pool Pump	100%	100%	0.00
Printer	100%	100%	0.05
Refrigeration	100%	100%	0.38

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Refrigerator	100%	100%	0.03
Room Cool	8%	100%	1.20
Room Heat	21%	1%	3.98
Server	100%	100%	0.26
Space Heat	72%	1%	7.20
Vending Machine	100%	100%	0.03
Ventilation and Circulation	100%	100%	3.91
Water Heat GT 55 Gallon	26%	63%	0.16
Water Heat LE 55 Gallon	74%	63%	0.35
Other			
Compressed Air	100%	100%	0.11
Computer	100%	100%	0.02
Cooking	100%	43%	0.42
Cooling Chillers	2%	100%	0.83
Cooling Direct Expansion	94%	100%	1.24
Dryer	100%	39%	0.04
Extension Lighting	100%	100%	0.70
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.00
Heat Pump	0%	100%	4.09
Lighting Interior Fluorescent	100%	100%	0.00
Lighting Interior HID	100%	100%	0.00
Lighting Interior Other	100%	100%	2.81
Lighting Interior Screw Base	100%	100%	0.00
Monitor	100%	100%	0.02
Other	100%	100%	0.00
Other Plug Load	100%	100%	1.87
Package Terminal Air Conditioner	0%	100%	0.88
Package Terminal Heat Pump	0%	100%	2.27
Photo Copier	100%	100%	0.00
Pool Pump	100%	100%	0.00
Printer	100%	100%	0.02
Refrigeration	100%	100%	0.77
Refrigerator	100%	100%	0.04
Room Cool	4%	100%	0.89
Room Heat	42%	0%	4.43
Server	100%	100%	0.05
Space Heat	58%	3%	8.46
Vending Machine	100%	100%	0.02
Ventilation and Circulation	100%	100%	1.13
Water Heat GT 55 Gallon	43%	29%	0.27
Water Heat LE 55 Gallon	57%	29%	0.59
Restaurant			
Compressed Air	100%	100%	0.01
Computer	100%	100%	0.01
Cooking	100%	34%	24.54

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Cooling Chillers	0%	100%	1.97
Cooling Direct Expansion	98%	100%	1.76
Dryer	100%	0%	0.42
Extension Lighting	100%	100%	2.30
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.01
Heat Pump	4%	100%	4.95
Lighting Interior Fluorescent	100%	100%	0.00
Lighting Interior HID	100%	100%	0.00
Lighting Interior Other	100%	100%	1.92
Lighting Interior Screw Base	100%	100%	0.00
Monitor	100%	100%	0.01
Other	100%	100%	0.00
Other Plug Load	100%	100%	2.82
Package Terminal Air Conditioner	0%	100%	1.69
Package Terminal Heat Pump	0%	100%	3.26
Photo Copier	100%	100%	0.00
Pool Pump	100%	0%	0.00
Printer	100%	100%	0.01
Refrigeration	100%	100%	12.71
Refrigerator	100%	100%	0.07
Room Cool	2%	100%	1.70
Room Heat	7%	86%	5.02
Server	100%	100%	0.05
Space Heat	89%	0%	7.28
Vending Machine	100%	100%	0.01
Ventilation and Circulation	100%	100%	4.20
Water Heat GT 55 Gallon	38%	6%	2.15
Water Heat LE 55 Gallon	63%	6%	4.77
Retail			
Compressed Air	100%	100%	0.33
Computer	100%	100%	0.02
Cooking	100%	49%	0.81
Cooling Chillers	0%	100%	1.38
Cooling Direct Expansion	100%	100%	1.23
Dryer	100%	0%	0.03
Extension Lighting	100%	100%	0.95
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.00
Heat Pump	2%	100%	4.64
Lighting Interior Fluorescent	100%	100%	0.00
Lighting Interior HID	100%	100%	0.00
Lighting Interior Other	100%	100%	3.92
Lighting Interior Screw Base	100%	100%	0.00
Monitor	100%	100%	0.02
Other	100%	100%	0.00

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Other Plug Load	100%	100%	2.61
Package Terminal Air Conditioner	0%	100%	0.96
Package Terminal Heat Pump	0%	100%	2.36
Photo Copier	100%	100%	0.00
Pool Pump	100%	100%	0.02
Printer	100%	100%	0.02
Refrigeration	100%	100%	3.46
Refrigerator	100%	100%	0.02
Room Cool	0%	100%	0.97
Room Heat	35%	19%	4.47
Server	100%	100%	0.06
Space Heat	63%	0%	7.93
Vending Machine	100%	100%	0.02
Ventilation and Circulation	100%	100%	3.24
Water Heat GT 55 Gallon	18%	69%	0.25
Water Heat LE 55 Gallon	82%	69%	0.55
Warehouse			
Compressed Air	100%	100%	0.35
Computer	100%	100%	0.01
Cooking	100%	0%	0.02
Cooling Chillers	3%	100%	0.39
Cooling Direct Expansion	90%	100%	0.35
Dryer	100%	0%	0.03
Extension Lighting	100%	100%	0.95
Fax Machine	100%	100%	0.00
Freezer	100%	100%	0.00
Heat Pump	0%	100%	2.30
Lighting Interior Fluorescent	100%	100%	0.00
Lighting Interior HID	100%	100%	0.00
Lighting Interior Other	100%	100%	1.40
Lighting Interior Screw Base	100%	100%	0.00
Monitor	100%	100%	0.01
Other	100%	100%	0.00
Other Plug Load	100%	100%	1.28
Package Terminal Air Conditioner	0%	100%	0.24
Package Terminal Heat Pump	0%	100%	0.96
Photo Copier	100%	100%	0.00
Pool Pump	100%	100%	0.00
Printer	100%	100%	0.01
Refrigeration	100%	100%	0.20
Refrigerator	100%	100%	0.01
Room Cool	7%	100%	0.25
Room Heat	56%	34%	2.29
Server	100%	100%	0.04
Space Heat	44%	0%	4.60
Vending Machine	100%	100%	0.01

End Use	Saturation	Fuel Share	Weighted Average Unit Energy Use (kWh/Unit)
Ventilation and Circulation	100%	100%	0.37
Water Heat GT 55 Gallon	6%	55%	0.08
Water Heat LE 55 Gallon	94%	55%	0.18

Industrial Electric

Figure A-5. Industrial Baseline Forecast by Segment - Electric

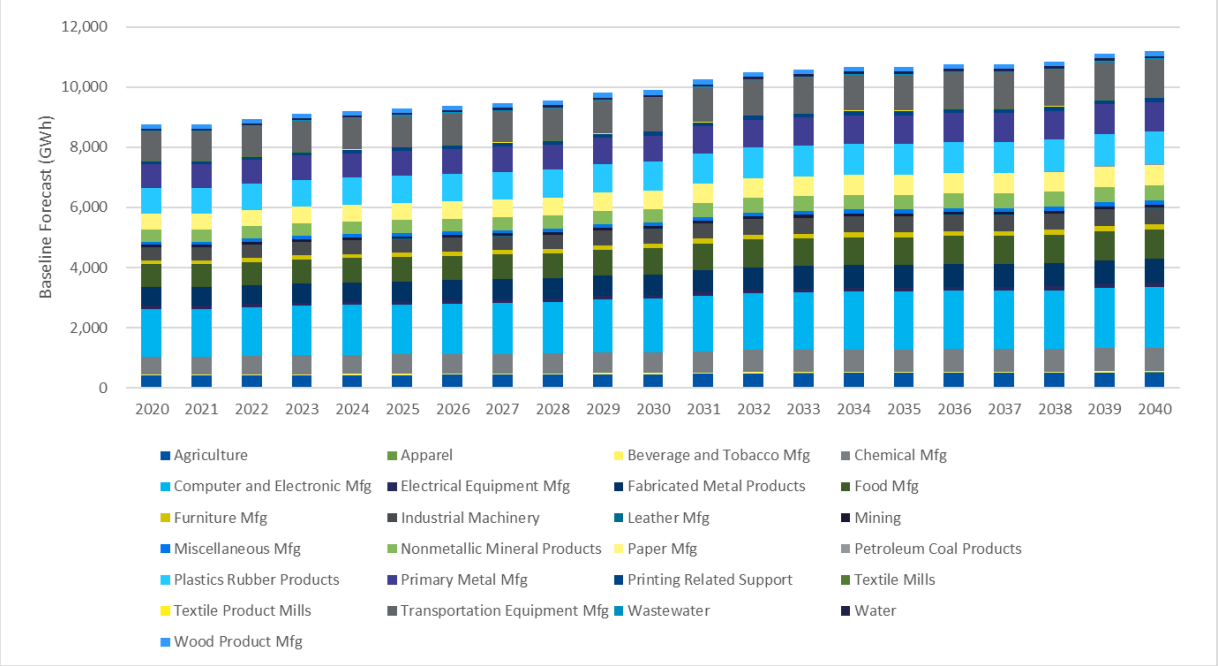
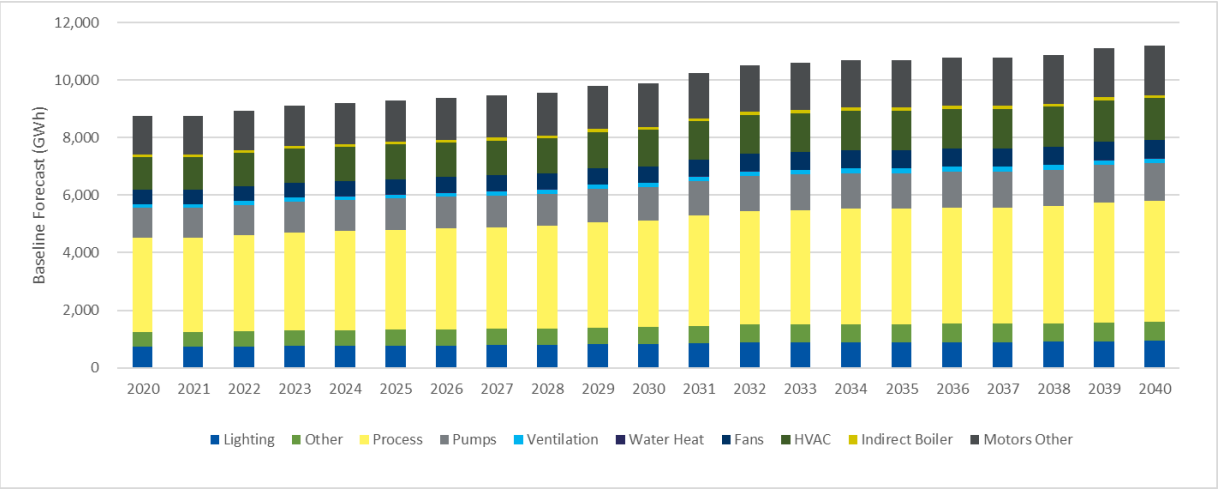


Figure A-6. Industrial Baseline Forecast by End Use - Electric



Appendix B. Economic Inputs

Table B-1 presents the avoided costs used for determining economic potential. These values are provided by Consumers Energy and are consistent with values used to estimate cost-effectiveness in the 2020–2023 EWR Plan.

Table B-1. Avoided Costs

Year	Avoided Electric Energy ($/kWh)	Avoided Generation Capacity ($/kW)	Avoided Transmission & Distribution ($/kW)	Avoided Natural Gas Energy ($/therm)
2021	$0.0370	$75.62	$22.03	$0.3251
2022	$0.0389	$77.44	$22.14	$0.3360
2023	$0.0406	$79.29	$22.68	$0.3555
2024	$0.0444	$81.20	$23.12	$0.3740
2025	$0.0461	$83.15	$23.76	$0.3924
2026	$0.0485	$85.14	$24.09	$0.4014
2027	$0.0501	$87.18	$24.59	$0.4109
2028	$0.0516	$89.28	$25.03	$0.4203
2029	$0.0542	$91.42	$25.45	$0.4301
2030	$0.0560	$93.61	$25.77	$0.4401
2031	$0.0589	$95.86	$26.24	$0.4506
2032	$0.0614	$98.16	$26.61	$0.4613
2033	$0.0639	$100.52	$26.99	$0.4722
2034	$0.0664	$102.93	$27.28	$0.4835
2035	$0.0690	$105.40	$27.76	$0.4949
2036	$0.0717	$107.93	$28.16	$0.5066
2037	$0.0744	$110.52	$28.56	$0.5185
2038	$0.0773	$113.17	$28.88	$0.5308
2039	$0.0801	$115.89	$29.41	$0.5435
2040	$0.0831	$118.67	$29.87	$0.5565

Table B-2 shows additional global economic assumptions.

Table B-2. Global Assumptions

Nominal Discount Rate	7.50%
Inflation Rate	2.10%
Reserve Margin Multiplier	7.84%
Electric Line Losses	7.73%

Table B-3 shows the retail rate forecast used to calculate potential customer bill savings from the maximum achievable potential.

Table B-3. Retail Rate Forecast by Sector

Year	Residential ($/kWh)	Commercial ($/kWh)	Industrial ($/kWh)
2021	$0.172	$0.133	$0.080
2022	$0.175	$0.135	$0.080
2023	$0.178	$0.135	$0.079
2024	$0.183	$0.137	$0.079
2025	$0.190	$0.142	$0.081
2026	$0.199	$0.147	$0.084
2027	$0.208	$0.154	$0.086
2028	$0.218	$0.160	$0.090
2029	$0.228	$0.167	$0.093
2030	$0.237	$0.172	$0.096
2031	$0.247	$0.179	$0.099
2032	$0.255	$0.184	$0.102
2033	$0.266	$0.192	$0.106
2034	$0.275	$0.197	$0.109
2035	$0.284	$0.204	$0.112
2036	$0.292	$0.208	$0.115
2037	$0.300	$0.213	$0.117
2038	$0.308	$0.217	$0.120
2039	$0.316	$0.222	$0.122
2040	$0.324	$0.227	$0.125

Appendix C. Emerging Technology Descriptions

To create the transformational technology scenario, the Cadmus team identified over 200 emerging measures, which we then characterized and incorporated into the energy-efficiency potential model. Ultimately, 170 unique measures were added to create the transformational technology scenario. The team aggregated these measures to create bundles focused on specific end uses. The measure bundles are described in Table C-1.

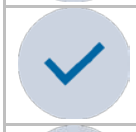
Table C-1. Emerging Technology Bundles

Residential	Commercial	Industrial
• Emerging HVAC • Online Services • Emerging Building Shell • Emerging Lighting • Emerging Domestic Hot Water • Other	• Emerging HVAC • Emerging Refrigeration • Emerging Lighting • Emerging DHW • Emerging Information Technology (IT) • Other • Proxy Measures (post-2036)	• Emerging Process • Emerging Lighting • Emerging Motors • Emerging Agriculture and Indoor Agriculture • Emerging Pumps and Fans • Other • Proxy Measures (2031-2036) • Proxy Measures (post-2036)

For each measure bundle, this appendix provides a high-level description that includes the identity of specific measures, applicability to segments or building types, measure energy savings and demand reduction, measure cost, EUL; the expected path to commercialization, and key resources used to characterize the measures or measure bundles.

The measure costs shown do not include necessary investments to drive innovation that may be undertaken by Consumers Energy or industry partners. The Cadmus team identified four key paths to realizing savings from emerging technologies, described in Table C-2. One or more paths may be pursued to support the availability and acceptance of a measure either in sequence or in parallel depending on specific barriers to measure development or adoption that may be faced.

Table C-2. Paths to Realizing Transformational Technology Savings

	**Technology development and demonstration**. This may include investment in research and development, lab testing, or engagement of early adopters to install and use new technologies and to provide feedback that will help further development and determine applicability
	**Delivery strategy optimization.** Determining the most effective market interventions to encourage the adoption of emerging technologies at-scale; this may include pilots and market forecasting to assess changes in cost as technologies are commercialized
	**Customer and trade ally outreach.** Lack of awareness and knowledge are significant barriers to adopting a new technology: providing outreach and education to customers helps to build interest and demand while trade ally engagement ensures that there is a qualified workforce to install and service new technologies.
	**Regulatory review and acceptance.** Educating MPSC staff and others about emerging technologies and working collaboratively to demonstrate energy saving potential and path to market adoption

The measure descriptions also include an estimate of the development timeline or year that measures may be available for widespread use. Generally, measures may be available in the short-term (2021 to 2025), mid-term (2026 to 2030), or long-term (2031 or later).

Finally, specific descriptions of proxy measures are not defined. Proxy measure bundles represent unique energy-efficiency improvements in commercial and industrial applications, akin to custom measures, that may be acquired through program strategies such as standard offer or pay-for-performance. The cost and size of proxy measure bundles varies based on the time period in which they are installed.

Residential Emerging Technology: Domestic Water Heaters

Domestic heat pump hot water heaters make up 1% of the 20-year residential portfolio achievable potential.

Bundle Measure Names and Residential Sector Applicability

Table C-3 shows the four measures in the domestic water heater bundle, as well as the residential sectors in which the measures can be installed.

Table C-3. Domestic Hot Water Heater Measure Names and Applicable Segments

Measure Name	Single Family	Single Family Low Income	Multifamily	Multifamily Low Income	Manufactured	Manufactured Low Income
Emerging Technology - Advanced Heat Pump Water Heater	X	X	X	X	X	X
Emerging Technology - Heat Pump Water Heater - CEE Advanced Tier			X	X		
Emerging Technology - Heat Pump Water Heater - ENERGY STAR Tier 4			X	X		
Emerging Technology - Pool Heat Pump Water Heater	X	X				

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-4 shows several characteristics for each measure: the percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, and measure life. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-4. Percentage Energy Savings over the Baseline Technology

Measure Name	Energy Savings (%)	Energy Savings (kWh)	Demand Reduction (kW)	Incremental Cost Per Home	Incremental Cost (Per Unit)	Units Per Home	Measure Life
Emerging Technology - Advanced Heat Pump Water Heater	1.5% - 3.4%	24 - 48	0.003 - 0.005	$129	$129/water heater	1	10 years
Emerging Technology - Heat Pump Water Heater - CEE Advanced Tier	20% - 46%	322 - 375	0.043	$1,063	$1,063/water heater	1	10 years
Emerging Technology - Heat Pump Water Heater - ENERGY STAR Tier 4	73% - 79%	1,555	0.153	$3,602	$3,602/water heater	1	10 years
Emerging Technology - Pool Heat Pump Water Heater	42% - 53%	283 - 314	0.832	$1,137	$314/pool heater	0.25	10 years

Path to Commercialization

All measures are expected to be commercially available by 2021; however, they face barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Incremental cost

Table C-5 shows the path to commercialization for each domestic water heater measure.

Table C-5. Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Advanced Heat Pump Water Heater	Near-Term 2020-2025			X	
Emerging Technology - Heat Pump Water Heater - CEE Advanced Tier	Near-Term 2020-2025		X	X	
Emerging Technology - Heat Pump Water Heater - ENERGY STAR Tier 4	Near-Term 2020-2025		X	X	
Emerging Technology - Pool Heat Pump Water Heater	Near-Term 2020-2025			X	X

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U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. November 2009. *Technical Support Document - Residential Water Heaters, Direct Heating Equipment, and Pooler Heaters.* Table 8.2.14.

Residential Emerging Technology: HVAC Cooling, Duct Sealing, and Thermostats

The emerging technology HVAC cooling, duct sealing, and smart thermostat measures make up 31% of the 20-year residential portfolio achievable potential for emerging technology measures. These are a subset of the HVAC measures bundle, which makes up 46% of the of the 20-year residential portfolio achievable potential for emerging technology measures.

Bundle Measure Names and Residential Sector Applicability

Table C-6 shows the 10 measures in the HVAC cooling, duct sealing, and thermostats bundle, as well as the residential sectors in which the measures can be installed.

Table C-6. HVAC Heating Measure Names and Applicable Segments

Measure Name	Single Family	Single Family Low Income	Multifamily	Multifamily Low Income	Manufactured	Manufactured Low Income
Emerging Technology - Aerosol-Based Duct Sealing	X	X	X	X	X	X
Emerging Technology - Communicating Electric Line Voltage Thermostat	X	X	X	X	X	X
Emerging Technology - Eco-Snap Air Conditioning	X	X	X	X	X	X
Emerging Technology - HVAC Economizer	X	X	X	X	X	X
Emerging Technology - Integrated HVAC Controls	X	X	X	X	X	X
Emerging Technology - Optimized Thermostat	X	X	X	X	X	X
Emerging Technology - Residential Indirect-Direct Evaporative Cooler	X	X	X	X	X	X
Emerging Technology - Residential-Sized Sub-Wet Bulb Chiller	X	X	X	X	X	X
Emerging Technology - Smart Vents	X	X	X	X	X	X
Emerging Technology - Solar-Assisted Air Conditioning	X	X	X	X	X	X

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-7 shows several characteristics for each measure: the annual percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, measure life, and commercial availability start year. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-7. Percentage Energy Savings over the Baseline Technology

Measure Name	Energy Savings (%)	Energy Savings (kWh)	Demand Reduction (kW)	Incremental Cost Per Home	Incremental Cost (Per Unit)	Units Per Home	Measure Life
Emerging Technology - Aerosol-Based Duct Sealing - Cool Central	15%	112 - 3,483	0.2 - 0.3	$347 - $617	$333 - $1,000/ building sq ft	1.04 - 1.85	18
Emerging Technology - Aerosol-Based Duct Sealing - Heat Central and Heat Pump	15%	924 - 2,651	0 - 0.2	$347 - $618	$333 - $1,000/ building sq ft	1.04 - 1.86	18
Emerging Technology - Communicating Electric Line Voltage Thermostat	6%	361 - 907	-	$100	$100/ thermostat	1	15
Emerging Technology - Eco-Snap Air Conditioning	22% - 38%	43 - 106	0.04 - 0.06	$80	$80/home	1	15
Emerging Technology - HVAC Economizer	10% - 10%	49 - 246	0.05 - 0.3	$399 - $630	$200/ central AC ton	1.99 - 3.15	20
Emerging Technology - Integrated HVAC Controls (cool room, cool central)	5%	10 - 133	-	$90 - $108	$90 - $108/ thermostat	1	9
Emerging Technology - Integrated HVAC Controls (heat central, heat pump, heat room)	5%	290 - 1,253	0.0 - 0.13	$90 - $109	$90 - $108/ thermostat	1	9
Emerging Technology - Optimized Thermostat	4%	7 - 859	-	$5	$5/ thermostat	1	1
Emerging Technology - Residential Indirect-Direct Evaporative Cooler	44% - 51%	249 - 1,080	0.1 - 0.4	($1,792) - ($1,134)	($1,792) - ($1,134)/ tonnage	1.99 - 3.15	15
Emerging Technology - Residential-Sized Sub-Wet Bulb Chiller	32% - 37%	180 - 782	0.2 - 0.8	$1,511 - $2,388	$1,511 - $2,388/ home	1	20
Emerging Technology - Smart Vents	20% - 20%	97 - 4,645	0.0 - 1.0	$1,219	$1,219/ home	1	10
Emerging Technology - Solar-Assisted Air Conditioning	30% - 30%	146 - 737	0.2 - 0.8	$533	$533/home	1	15

Path to Commercialization

The commercialization dates for the residential emerging HVAC cooling, duct sealing, and thermostats measures range from 2021 to 2031; however, they face barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Incremental cost

Table C-8 shows the path to commercialization for each measure.

Table C-8. Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Aerosol-Based Duct Sealing	Near-Term 2021-2025			X	X
Emerging Technology - Communicating Electric Line Voltage Thermostat	Near-Term 2021-2025			X	X
Emerging Technology - Eco-Snap Air Conditioning	Mid-Term 2026-2030	X		X	X
Emerging Technology - HVAC Economizer	Near-Term 2021-2025		X	X	X
Emerging Technology - Integrated HVAC Controls	Near-Term 2021-2025			X	X
Emerging Technology - Optimized Thermostat	Near-Term 2021-2025			X	X
Emerging Technology - Residential Indirect-Direct Evaporative Cooler	Near-Term 2021-2025			X	X
Emerging Technology - Residential-Sized Sub-Wet Bulb Chiller	Mid-Term 2026-2030	X	X	X	X
Emerging Technology - Smart Vents	Near-Term 2021-2025			X	X
Emerging Technology - Solar-Assisted Air Conditioning	Long-Term 2031-2035	X	X	X	X

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Residential Emerging Technology: HVAC Heating

The emerging technology HVAC heating measures makes up 15% of the 20-year residential portfolio achievable potential for emerging technology measures. The HVAC heating measures are a subset of the HVAC measures bundle, which makes up 46% of the 20-year residential portfolio achievable potential for emerging technology measures.

Bundle Measure Names and Residential Sector Applicability

Table C-9 shows the eight measures in the HVAC heating measures bundle, as well as the residential sectors in which the measures can be installed.

Table C-9. HVAC Heating Measure Names and Applicable Segments

Measure Name	Single Family	Single Family Low Income	Multifamily	Multifamily Low Income	Manufactured	Manufactured Low Income
Emerging Technology - Advanced Air-Source Heat Pump	X	X	X	X	X	X
Emerging Technology - Advanced Furnace Fan	X	X	X	X	X	X
Emerging Technology - Advanced Wall Heater	X	X	X	X	X	X
Emerging Technology - Electro Caloric Heat Pump	X	X	X	X	X	X
Emerging Technology - Heat Pump with Integrated Desuperheater	X	X	X	X	X	X
Emerging Technology - Horizontal Drainpipe Heat Exchanger	X	X	X	X	X	X
Emerging Technology - Radiant Panels	X	X	X	X	X	X
Emerging Technology - Well-Connected Geothermal Heat Pump	X	X				

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-10 shows several characteristics for each measure: the annual percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, measure life, and commercial availability start year. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-10. Percentage Energy Savings over the Baseline Technology

Measure Name	Energy Savings (%)	Energy Savings (kWh)	Demand Reduction (kW)	Incremental Cost Per Home	Incremental Cost (Per Unit)	Units Per Home	Measure Life
Emerging Technology - Advanced Air-Source Heat Pump	6% - 7%	358 - 680	0.07 - 0.1	$758 - $1,199	$381/heat pump ton	1.9 - 3.1	15
Emerging Technology - Advanced Furnace Fan	17% - 27%	188	0.02	$302	$302/ furnace fan	1	10
Emerging Technology - Advanced Wall Heater	30% - 31%	1,807 - 4,505	-	$78 - $139	$71.50/ 12,000 Btuh electric room heat	1.1 - 2.0	20
Emerging Technology - Electro Caloric Heat Pump	33%	1,791 - 3,657	0.8 - 1.6	$1,997 - $3,156	$1,003/heat pump ton	1.9 - 3.2	15
Emerging Technology - Heat Pump with Integrated Desuperheater	10% - 24%	170 - 318	0.02 - 0.04	1257.65	$1,258/ water heater	1	15
Emerging Technology - Horizontal Drainpipe Heat Exchanger	3% - 10%	50 - 170	0.008 - 0.03	$1,366	$1,366/ drainpipe heat exchanger	1	20
Emerging Technology - Radiant Panels (cool central)	30%	145 - 537	0.2 - 0.8	$28,180-50,018	$27/sq ft	1,271 - 1,352	20
Emerging Technology - Radiant Panels (heat pump, heat central)	30%	1,611 - 6,966	0.7 - 1.5	$28,180-50,019	$27/sq ft	1,271-1,352	20
Emerging Technology - Well-Connected Geothermal Heat Pump	26% - 48%	1,961 - 3,524	0.4 - 0.6	$12,654 - $17,337	$12,654 - $17,337/ home	1	15

Path to Commercialization

The commercialization dates for the residential emerging HVAC heating measures range from 2021 to 2026; however, they face barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Incremental cost

Table C-11 shows the path to commercialization for each measure.

Table C-11. Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Advanced Air-Source Heat Pump	Mid-Term 2026-2030	X		X	X
Emerging Technology - Advanced Furnace Fan	Short-Term 2021-2035			X	X
Emerging Technology - Advanced Wall Heater	Short-Term 2021-2035			X	X
Emerging Technology - Electro Caloric Heat Pump	Long-Term 2036-2040	X	X	X	X
Emerging Technology - Heat Pump with Integrated Desuperheater	Short-Term 2021-2035			X	X
Emerging Technology - Horizontal Drainpipe Heat Exchanger	Short-Term 2021-2035		X	X	X
Emerging Technology - Radiant Panels	Short-Term 2021-2035			X	X
Emerging Technology - Well-Connected Geothermal Heat Pump	Short-Term 2021-2035			X	X

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Residential Emerging Technology: Lighting

Emerging residential lighting measures make up 5% of the 20-year residential portfolio achievable potential.

Bundle Measure Names and Residential Sector Applicability

Table C-12 shows the seven measures in the emerging lighting bundle, as well as the residential sectors in which the measures can be installed.

Table C-12. Residential Emerging Lighting Measure Names and Applicable Segments

Measure Name	Single Family	Single Family Low Income	Multifamily	Multifamily Low Income	Manufactured	Manufactured Low Income
Emerging Technology - Advanced Daylighting	X	X	X	X	X	X
Emerging Technology - General Service Lamp - Advanced Lighting	X	X	X	X	X	X
Emerging Technology - General Service Lamp - Connected LED	X	X	X	X	X	X
Emerging Technology - Linear Lamp - Advanced Lighting	X	X	X	X	X	X
Emerging Technology - Linear Lamp - Connected TLED	X	X	X	X	X	X
Emerging Technology - Specialty Lamp - Advanced Lighting	X	X	X	X	X	X
Emerging Technology - Specialty Lamp - Connected LED	X	X	X	X	X	X

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-13 shows several characteristics for each measure: the annual percentage energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, measure life, and commercial availability start year. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-13. Percentage Energy Savings over the Baseline Technology

Measure Name	Energy Savings (%)	Energy Savings (kWh)	Demand Reduction (kW)	Incremental Cost Per Home	Incremental Cost (Per Unit)	Units Per Home	Measure Life
Emerging Technology - Advanced Daylighting	5%	0.80 - 1.8	0.000001	$6,784 - $12,041.60	$6.5/sq ft	1,044 - 1,852	15
Emerging Technology - General Service Lamp - Advanced Lighting	5%	9.0 - 90.0	0.00001 - 0.00007	$6,784 - $12,041.60	$6.5/sq ft	1,044 - 1,852	15
Emerging Technology - General Service Lamp - Connected LED	16% - 24%	4.3	0.005100	$8	$8.14/lamp	1	15
Emerging Technology - Linear Lamp - Advanced Lighting	10% - 16%	2.6 - 2.7	0.003200	$4	$3.88/lamp	1	15
Emerging Technology - Linear Lamp - Connected TLED	25% - 26%	6.7	0.008200	$218	$217.88/ lamp	1	18
Emerging Technology - Specialty Lamp - Advanced Lighting	15% - 16%	4.1 - 4.2	0.005000	$109	$108.88/ lamp	1	18
Emerging Technology - Specialty Lamp - Connected LED	8% - 13%	2.8	0.003300	$32	$32.19/ lamp	1	15
Emerging Technology - Advanced Daylighting	5% - 8%	1.7	0.002000	$15	$15.34/ lamp	1	15

Path to Commercialization

The commercialization dates for the emerging lighting residential measures range from 2021 to 2036; however, they face barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Incremental cost

Table C-14 shows the path to commercialization for each measure.

Table C-14. Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Advanced Daylighting	Mid-Term 2026-2030	X	X	X	X
Emerging Technology - General Service Lamp - Advanced Lighting	Long-Term 2036-2040	X		X	X
Emerging Technology - General Service Lamp - Connected LED	Short-Term 2021-2025		X	X	
Emerging Technology - Linear Lamp - Advanced Lighting	Long-Term 2036-2040	X		X	X
Emerging Technology - Linear Lamp - Connected TLED	Short-Term 2021-2025		X	X	
Emerging Technology - Specialty Lamp - Advanced Lighting	Long-Term 2036-2040	X		X	X
Emerging Technology - Specialty Lamp - Connected LED	Short-Term 2021-2025		X	X	

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Residential Emerging Technology: Online Services

The emerging technology online services measure makes up 32% of the 20-year residential portfolio achievable potential for emerging technology measures.

Bundle Measure Names and Residential Sector Applicability

Table C-185 shows the one measure in the online services bundle, as well as the residential sectors in which the measure can be installed.

Table C-15. Other Measure Names and Applicable Segments

Measure Name	Single Family	Single Family Low Income	Multifamily	Multifamily Low Income	Manufactured	Manufactured Low Income
Emerging Technology - Web Portal	X	X	X	X	X	X

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-16 shows several characteristics for the measure: the annual percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, measure life, and commercial availability start year. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-16. Percentage Energy Savings over the Baseline Technology

Measure Name	Energy Savings (%)	Energy Savings (kWh)	Demand Reduction (kW)	Incremental Cost Per Home	Incremental Cost (Per Unit)	Units Per Home	Measure Life
Emerging Technology - Web Portal	1.5% - 3.5%	131	0.0007 - 0.02	$2	$2/home	1	1

Path to Commercialization

The web portal measure will be commercially available in 2021; however, it faces barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer awareness of the offering
- Incremental cost (until enough customers enroll to make the offering cost-effective)

Table C-17 shows the path to commercialization for each web portal.

Table C-17. Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Web Portal	Short-Term 2021-2025		X	X	

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Residential Emerging Technology: Other Measures

Emerging technology other measures (other) make up 9% of the 20-year residential portfolio achievable potential for emerging technology measures.

Bundle Measure Names and Residential Sector Applicability

Table C-18 shows the four measures in the other bundle, as well as the residential sectors in which the measures can be installed.

Table C-18. Other Measure Names and Applicable Segments

Measure Name	Single Family	Single Family Low Income	Multifamily	Multifamily Low Income	Manufactured	Manufactured Low Income
Emerging Technology - Dryer - Ultrasonic Clothes Dryer	X	X	X	X	X	X
Emerging Technology - Integrated Design	X	X	X	X	X	X
Emerging Technology - Ozone Laundry System	X	X	X	X	X	X
Emerging Technology - Phase Change Material	X	X	X	X	X	X

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-19 shows several characteristics for each measure: the annual percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, measure life, and commercial availability start year. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-19. Percentage Energy Savings over the Baseline Technology

Measure Name	Energy Savings (%)	Energy Savings (kWh)	Demand Reduction (kW)	Incremental Cost Per Home	Incremental Cost (Per Unit)	Units Per Home	Measure Life
Emerging Technology - Dryer - Ultrasonic Clothes Dryer	9% - 11%	61.1	0.2	$148.91	$149.91/ dryer	1	12
Emerging Technology - Integrated Design (cool room, cool central)	50%	93 - 660	0.0001 - 0.0004	$26,094 - $$46,314	$25/sq ft	1,044 - 1,853	20
Emerging Technology - Integrated Design (heat room, heat pump, heat central)	50%	2,687 - 6,336	0 - 0.001	$26,094 - $$46,314	$25/sq ft	1,044 - 1,853	20
Emerging Technology - Integrated Design (lighting)	50%	9 - 16	0.0001 - 0.0002	$26,094 - $46,315	$25/sq ft	1,044 - 1,853	20
Emerging Technology - Integrated Design (ventilation and circulation)	50%	350	0.00002 - 0.00003	$26,094 - $46,315	$25/sq ft	1,044 - 1,853	20
Emerging Technology - Integrated Design (water heating)	50%	354 - 1,356	0.00003 - 0.0001	$26,094 - $46,315	$25/sq ft	1,044 - 1,853	20
Emerging Technology - Ozone Laundry System	5% - 35%	94.72 - 256.77	0.9	$109 - $297	$297/ system	0.37 - 1.0	5
Emerging Technology - Phase Change Material (cool room, cool central)	18% - 25%	36 - 595	0.06-0.6	$625 - $2,613	$625 - $2,613/ home	1	25
Emerging Technology - Phase Change Material (heat pump, heat room, heat central)	12% - 24%	768 - 5,347	0.0 - 1.1	$625 - $2,615	$625 - $2,613/ home	1	25

Path to Commercialization

The commercialization dates for the emerging lighting residential measures range from 2021 to 2031. They face barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Incremental cost

Table C-20 shows the path to commercialization for each measure.

Table C-20. Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Dryer - Ultrasonic Clothes Dryer	Mid-Term 2026-2030	X		X	X
Emerging Technology - Integrated Design	Long-Term 2031-2035	X	X	X	X
Emerging Technology - Ozone Laundry System	Short-Term 2021-2025			X	X
Emerging Technology - Phase Change Material	Short-Term 2021-2025	X	X	X	X

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Residential Emerging Technology: Shell Measures

Emerging technology shell measures make up 10% of the achievable potential for emerging technology measures.

Bundle Measure Names and Residential Sector Applicability

Table C-21 shows the 10 measures in the shell measures bundle, as well as the residential sectors in which the measures can be installed.

Table C-21. Shell Measure Names and Applicable Segments

Measure Name	Single Family	Single Family Low Income	Multifamily	Multifamily Low Income	Manufactured	Manufactured Low Income
Emerging Technology - Advanced Walls	X	X	X	X	X	X
Emerging Technology - Advanced Windows	X	X	X	X	X	X
Emerging Technology - Basement Wall Insulation - Nanoinsulation	X	X	X	X		
Emerging Technology - Belly Insulation - Nanoinsulation					X	X
Emerging Technology - Ceiling / Attic Insulation - Nanoinsulation	X	X	X	X	X	X
Emerging Technology - Crawlspace Insulation - Nanoinsulation	X	X	X	X	X	X
Emerging Technology - Floor Insulation - Nanoinsulation	X	X	X	X	X	X
Emerging Technology - Rim and Band Joist Insulation - Nanoinsulation	X	X				
Emerging Technology - Wall Insulation - Nanoinsulation	X	X	X	X	X	X
Emerging Technology - Window Cellular Shades	X	X	X	X	X	X

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-22 shows several characteristics for each measure: the annual percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, and measure life. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-22. Percentage Energy Savings over the Baseline Technology

Measure Name	Energy Savings (%)	Energy Savings (kWh)	Demand Reduction (kW)	Incremental Cost Per Home	Incremental Cost (Per Unit)	Units Per Home	Measure Life
Emerging Technology - Advanced Walls (cool central, cool room)	1% - 15%	7 - 27	0.07 - 0.11	$973 - $1,555	$973 - $1,555/ 1,000 sq ft wall area	0.94 - 1.51	25

Measure Name	Energy Savings (%)	Energy Savings (kWh)	Demand Reduction (kW)	Incremental Cost Per Home	Incremental Cost (Per Unit)	Units Per Home	Measure Life
Emerging Technology - Advanced Walls (heat room, heat pump, heat central)	2% - 13%	139 - 838	0.014 - 0.08	$973 - $1,556	$973 - $1,555/ 1,000 sq ft wall area	0.94 - 1.52	25
Emerging Technology - Advanced Windows	0% - 13%	1 - 889	0.0 - 0.1	$3,422 - $6,074	$3,422 - $6,074/per 100 sq ft window area	0.89 - 1.58	30
Emerging Technology - Basement Wall Insulation - Nanoinsulation	0% - 11%	0 - 673	0.0 - 0.0004	$1,233 - $1,421	$1,233 - $1,421/home	1	25
Emerging Technology - Belly Insulation - Nanoinsulation	2% - 36%	10 - 1,947	0.0 - 1.9	$243 - $264	$243 - $263.53/ home	1	25
Emerging Technology - Ceiling/Attic Insulation - Nanoinsulation (cool room, cool central)	1% - 29%	5 - 376	0.01 - 0.33	$2,155 - $10,454	$2,155 - $10,455/home	1	25
Emerging Technology - Ceiling/Attic Insulation - Nanoinsulation (heat room, heat pump heat central)	1% - 51%	73 - 3,974	0.0 - 0.3	$2,155 - $10,455	$2,155 - $10,455/home	1	25
Emerging Technology - Crawlspace Insulation - Nanoinsulation (cool central, cool room)	0.2% - 16%	0 - 120	0	$868 - $1,757	$868 - $1,758/ home	1	25
Emerging Technology - Crawlspace Insulation - Nanoinsulation (heat room, heat pump heat central)	3% - 67%	12- 1,141	(0.01) - (0.0001)	$868 - $1,758	$868 - $1,758/ home	1	25
Emerging Technology - Floor Insulation - Nanoinsulation	0% - 4%	0 - 418	-0.01	$868 - $1,669	$868 - $1,669/ home	1	25
Emerging Technology - Rim and Band Joist Insulation - Nanoinsulation	0.1% - 3%	2.3 - 76	0.0 - 0.04	$142 - $196	$142 - $197/ home	1	25
Emerging Technology - Wall Insulation - Nanoinsulation (cool room, cool central)	1.3% - 28%	14 - 50	0.01 - 0.2	$2,498 - $3,993	$2,498 - $3,993/home	1	25
Emerging Technology - Wall Insulation - Nanoinsulation (heat room, heat pump heat central)	3% - 25%	226 - 1,553	0 - 0.16	$2,498 - $3,994	$2,498 - $3,993/home	1	25
Emerging Technology - Window Cellular Shades (cool room, cool central)	0.06%	10.8 - 142.0	0.03 - 0.2	$1,412 - $2,506	$1,412 - $2,506/ window area sq ft	89.2 - 158.3	15

Measure Name	Energy Savings (%)	Energy Savings (kWh)	Demand Reduction (kW)	Incremental Cost Per Home	Incremental Cost (Per Unit)	Units Per Home	Measure Life
Emerging Technology - Window Cellular Shades (heat pump)	0.02%	107 - 464	0 - 0.04	$1,586 - $1,722	$1,412 - $2,506/ window area sq ft	89.2 - 158.4	15

Path to Commercialization

The commercialization dates for the emerging residential shell measures range from 2021 to 2026; however, they face barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Incremental cost

Table C-23 shows the path to commercialization for each measure.

Table C-23. Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Advanced Walls	Short-Term 2021-2025			X	X
Emerging Technology - Advanced Windows	Mid-Term 2026-2030	X		X	X
Emerging Technology - Basement Wall Insulation - Nanoinsulation	Mid-Term 2026-2030	X	X	X	X
Emerging Technology - Belly Insulation - Nanoinsulation	Mid-Term 2026-2030	X	X	X	X
Emerging Technology - Ceiling / Attic Insulation - Nanoinsulation	Mid-Term 2026-2030	X	X	X	X
Emerging Technology - Crawlspace Insulation - Nanoinsulation	Mid-Term 2026-2030	X	X	X	X
Emerging Technology - Floor Insulation - Nanoinsulation	Mid-Term 2026-2030	X	X	X	X
Emerging Technology - Rim and Band Joist Insulation - Nanoinsulation	Mid-Term 2026-2030	X	X	X	X
Emerging Technology - Wall Insulation - Nanoinsulation	Mid-Term 2026-2030	X	X	X	X
Emerging Technology - Window Cellular Shades	Short-Term 2021-2025			X	X

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Commercial Emerging Technology: Domestic Hot Water

Domestic hot water emerging technologies make up 6% of the 20-year commercial portfolio achievable potential.

Bundle Measure Names and Commercial Sector Applicability

Table C-24 shows the two measures within the domestic hot water bundle, as well as the commercial sectors in which the measures can be installed.

Table C-24. Domestic Hot Water Heater Measure Names and Applicable Segments

Measure Name	Education	Grocery	Health	Lodging	Office	Other	Restaurant	Retail	Warehouse
Emerging Technology - Advanced DHW	X	X	X	X	X	X	X	X	X
Emerging Technology - Multifamily Hot Water System Demand Recirculation Pumps and Controls						X			

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-25 shows several characteristics for each measure: the percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, and measure life. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-25. Percentage Energy Savings over the Baseline Technology

Measure Name	Unit	Energy Savings	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost	Measure Life
Emerging Technology - Advanced Domestic Hot Water - Cooling Direct Expansion	Per building sq ft	26% - 31%	0.10 - 0.93	0.0011 - 0.0013	$18.27	20 Years
Emerging Technology - Advanced Domestic Hot Water - Heat Pump	Per building sq ft	22% - 25%	0.51 - 2.18	0.00047 - 0.002	$18.27	20 Years
Emerging Technology - Advanced Domestic Hot Water - Space Heat	Per building sq ft	40%	1.84 - 5.88	0.00021 - 0.00067	$18.27	20 Years
Emerging Technology - Advanced Domestic Hot Water - Water Heat	Per building sq ft	10% - 22%	0.02 - 0.53	0.000002 - 0.000059	$18.27	20 Years
Emerging Technology - Multifamily Hot Water System Demand Recirculation Pumps and Controls - Water Heat	Per circulator	14%	357	0.0205	$4,662	15 Years

Path to Commercialization

Both measures included in the commercial domestic hot water category are expected to be commercially available by 2026; however, they face barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Lack of established design practices for combined HVAC and domestic hot water systems
- Lack of coordination between trade allies and design professionals across technology types

- Lack of contractor and distributor trust in and understanding of the technology
- Incremental cost

Table C-26 shows the path to commercialization for both commercial domestic hot water measures.

Table C-26. Development Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Advanced Domestic Hot Water	Mid-Term (2026-2030)	X	X	X	
Emerging Technology - Multifamily Hot Water System Demand Recirculation Pumps and Controls	Mid-Term (2026-2030)			X	

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Commercial Emerging Technology: HVAC

HVAC emerging technologies make up 33% of the 20-year commercial portfolio achievable potential.

Bundle Measure Names and Commercial Sector Applicability

Table C-27 shows the 11 measures within the HVAC bundle, as well as the commercial sectors in which the measures can be installed.

Table C-27. Emerging HVAC Names and Applicable Segments

Measure Name	Education	Grocery	Health	Lodging	Office	Other	Restaurant	Retail	Warehouse
Emerging Technology - Advanced Dedicated Outdoor Air System	X	X	X	X	X	X	X	X	X
Emerging Technology - Advanced Duct Sealing	X	X	X	X	X	X	X	X	X
Emerging Technology - Advanced Energy Management System	X	X	X	X	X	X	X	X	X
Emerging Technology - Advanced Envelope	X	X	X	X	X	X	X	X	X
Emerging Technology - Advanced HVAC Controls	X	X	X	X	X	X	X	X	X
Emerging Technology - Advanced HVAC Equipment	X	X	X	X	X	X	X	X	X
Emerging Technology - Advanced Windows	X	X	X	X	X	X	X	X	X
Emerging Technology - Eco-snap Air Conditioning and Do-it-Yourself Ductless Air Conditioning Units	X	X	X	X	X	X	X	X	X
Emerging Technology - Very High Efficiency Dedicated Outdoor Air System	X	X	X	X	X	X	X	X	X
Emerging Technology - Adsorbent Air Filtration	X	X	X	X	X	X	X	X	X
Emerging Technology - Biofeedback Thermostat	X	X	X	X	X	X	X	X	X

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-28 shows several characteristics for each measure: the percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, and measure life. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-28. Percentage Energy Savings over the Baseline Technology

Measure Name	Unit	Energy Savings	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost	Measure Life
Emerging Technology - Advanced Dedicated Outdoor Air System - Cooling Direct Expansion	Per building sq ft	63 - 65%	0.25 - 2.13	0 - 0.0032	$25.37[a]	15 Years
Emerging Technology - Advanced Dedicated Outdoor Air System - Heat Pump	Per building sq ft	52 - 61%	1.39 - 4.31	<0.00001	$25.37	15 Years
Emerging Technology - Advanced Dedicated Outdoor Air System - Space Heat	Per building sq ft	49 - 60%	2.77 - 7.27	0.00032 - 0.00083	$25.37	15 Years
Emerging Technology - Advanced Duct Sealing - Cooling Direct Expansion	Per building sq ft	1 - 4%	0.01 - 0.12	0 - 0.00016	$1.01[d]	10 Years
Emerging Technology - Advanced Duct Sealing - Heat Pump	Per building sq ft	2 - 12%	0.10 - 0.89	0 - 0.00092	$1.01	10 Years
Emerging Technology - Advanced Duct Sealing - Space Heat	Per building sq ft	2 - 14%	0.16 - 1.82	0 - 0.00021	$1.01	10 Years
Emerging Technology - Advanced Emergency Management System - Cooling Chillers	Per building sq ft	15%	0.10 - 0.30	0.000005 - 0.000028	$1.01	15 Years
Emerging Technology - Advanced EMS - Cooling DX	Per building sq ft	15%	0.05 - 0.51	0.00008 - 0.00077	$1.01	15 Years
Emerging Technology - Advanced EMS - Heat Pump	Per building sq ft	15%	0.36 - 1.29	0.00056 - 0.00129	$1.01	15 Years
Emerging Technology - Advanced EMS - Space Heat	Per building sq ft	15%	0.69 - 2.21	0.00008 - 0.00025	$1.01	15 Years
Emerging Technology - Advanced Envelope - Cooling	Per building sq ft	10%	0.02 - 0.30	0.000004 - 0.000458	$3.04	20 Years
Emerging Technology - Advanced Envelope - Heat Pump	Per building sq ft	10%	0.10 - 0.83	0 - 0.00036	$3.04	20 Years
Emerging Technology - Advanced Envelope - Heating	Per building sq ft	10%	0.23 - 1.47	0.000026 - 0.000168	$3.04	20 Years
Emerging Technology - Advanced HVAC Controls - Cooling Chillers	Per building sq ft	13%	0.05 - 0.26	<0.00001	$1.01	5 Years
Emerging Technology - Advanced HVAC Controls - Cooling Direct Expansion	Per building sq ft	13%	0.05 - 0.45	0.00008 - 0.00069	$1.01	5 Years
Emerging Technology - Advanced HVAC Controls - Heat Pump	Per building sq ft	13%	0.30 - 1.09	<0.00001	$1.01	5 Years
Emerging Technology - Advanced HVAC Controls - Space Heat	Per building sq ft	13%	0.60 - 1.91	0.000069 - 0.000218	$1.01	5 Years
Emerging Technology - Advanced HVAC Equipment - Cooling Chillers	Per building sq ft	24 - 29%	0.11 - 0.56	0.00001 - 0.00005	$3.04	15 Years
Emerging Technology - Advanced HVAC Equipment - Cooling Direct Expansion	Per building sq ft	19 - 24%	0.08 - 0.70	0.000095 - 0.000859	$3.04	15 Years
Emerging Technology - Advanced HVAC Equipment - Heat Pump	Per building sq ft	17 - 21%	0.38 - 1.64	0.00035 - 0.00150	$3.04	15 Years
Emerging Technology - Advanced Windows	Per building sq ft	12 - 16%	0.04 - 0.44	<0.00001	$9.74[m]	25 Years
Emerging Technology - Eco-snap Air Conditioner and Do-it-Yourself Ductless Air Conditioner Units - Room Cool	Per room AC (10,000 btuh)	13%	23 - 125	0.000002 - 0.000019	$901.2[p]	15 Years

Measure Name	Unit	Energy Savings	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost	Measure Life
Emerging Technology - Very High Efficiency Dedicated Outdoor Air System - Cooling Direct Expansion	Per building sq ft	39 - 40%	0.16 - 1.31	0.00024 - 0.00199	$15.22[s]	15 Years
Emerging Technology - Very High Efficiency Dedicated Outdoor Air System - Heat Pump	Per building sq ft	32 - 37%	0.85 - 2.65	0.00088 - 0.00274	$15.22	15 Years
Emerging Technology - Very High Efficiency Dedicated Outdoor Air System - Space Heat	Per building sq ft	30 - 37%	1.70 - 4.48	0.00019 - 0.00051	$15.22	15 Years
Emerging Technology - Adsorbent Air Filtration - Cooling Direct Expansion	Per building	15%	648 - 7,581	0.98 - 11.50	$329 - $3,847	15 Years
Emerging Technology - Adsorbent Air Filtration - Heat Pump	Per building	15%	2,696 - 134,151	2.79 - 20.79	$1,368 - $10,210	15 Years
Emerging Technology - Adsorbent Air Filtration - Space Heat	Per building	15%	3,965 - 247,476	14.87 - 139.19	$2,012 - $18,835	15 Years
Emerging Technology - Biofeedback Thermostat - Cooling Direct Expansion	Per thermostat	5%	177 - 1,150	0.27 - 1.74	$162.37	10 Years
Emerging Technology - Biofeedback Thermostat - Heat Pump	Per thermostat	5%	573 - 3,123	0.000004 - 0.000021	$162.37	10 Years
Emerging Technology - Biofeedback Thermostat - Space Heat	Per thermostat	5%	866 - 5,790	0.00	$162.37	10 Years

Path to Commercialization

All measures are expected to be commercially available by 2036. However, they face barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Lack of established design practices for complex HVAC systems
- Lack of coordination between trade allies and design professionals across technology types
- Lack of contractor and distributor trust in and understanding of the technology
- Lack of guidance on code compliance of alternative ventilation solutions
- Incremental cost

Table C-29 shows the path to commercialization for each commercial HVAC measure.

Table C-29. Development Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Advanced Dedicated Outdoor Air System	Long-Term (2031-2040)	X		X	
Emerging Technology - Advanced Duct Sealing	Mid-Term (2026-2040)			X	
Emerging Technology - Advanced Energy Management System	Mid-Term (2026-2040)	X		X	
Emerging Technology - Advanced Envelope	Mid-Term (2026-2040)	X		X	
Emerging Technology - Advanced HVAC Controls	Mid-Term (2026-2040)	X		X	
Emerging Technology - Advanced HVAC Equipment	Near-Term (2021-2040)			X	
Emerging Technology - Advanced Windows	Near-Term (2021-2040)			X	
Emerging Technology - Eco-snap Air Conditioning and Do-it-Yourself Ductless Air Conditioning Units	Near-Term (2021-2040)		X	X	
Emerging Technology - Very High Efficiency Dedicated Outdoor Air System	Near-Term (2021-2031)			X	
Emerging Technology - Adsorbent Air Filtration	Mid-Term (2026-2040)	X	X	X	X
Emerging Technology - Biofeedback Thermostat	Long-Term (2036-2040)	X	X	X	

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Commercial Emerging Technology: IT Systems

Domestic IT emerging technologies make up 3% of the 20-year commercial portfolio achievable potential.

Bundle Measure Names and Commercial Sector Applicability

Table C-30 shows the eight measures within the commercial emerging IT bundle, as well as the commercial sectors in which the measures can be installed.

Table C-30. Commercial Emerging IT System Measure Names and Applicable Segments

Measure Name	Education	Grocery	Health	Lodging	Office	Other	Restaurant	Retail	Warehouse
Emerging Technology - Future Server - Quantum Computing Servers/Data Centers	X	X	X	X	X	X	X	X	X
Emerging Technology - IT Systems - Decommissioning of Unused Servers	X				X	X			
Emerging Technology - IT Systems - Energy Efficient Data Storage Management	X				X	X			
Emerging Technology - IT Systems - Hot or Cold Aisle Configuration	X				X	X			
Emerging Technology - IT Systems - Hot or Cold Aisle Configuration with Containment	X				X	X			
Emerging Technology - IT Systems - Install Misters, Foggers, or Ultrasonic Humidifiers	X				X	X			
Emerging Technology - IT Systems - Server Virtualization/ Consolidation	X				X	X			
Emerging Technology - IT Systems - Uninterruptible Power Supply Upgrade	X				X	X			

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-31 shows several characteristics for each measure: the percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, and measure life. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-31. Percentage Energy Savings over the Baseline Technology

Measure Name	Unit	Energy Savings	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost	Measure Life
Emerging Technology - Future Server - Quantum Computing Servers/Data Centers	Per building	20%	39 - 454	0.007-0.769	$18.27	4 Years
Emerging Technology - IT Systems - Decommissioning of Unused Servers	Per MWh DC load	0.2 - 0.9%	67.1	0	$2.25	5 Years
Emerging Technology - IT Systems - Energy Efficient Data Storage Management	Per MWh DC Load	0.2 - 0.8%	55.8	0	$4.37	5 Years
Emerging Technology - IT Systems - Hot or Cold Aisle Configuration	Per MWh DC load	<0.1%	1.3	0	$0.24	10 Years
Emerging Technology - IT Systems - Hot or Cold Aisle Configuration with Containment	Per MWh DC load	<0.1%	2.6	0	$0.59	10 Years
Emerging Technology - IT Systems - Install Misters, Foggers, or Ultrasonic Humidifiers	Per MWh DC load	<0.1%	2.6	0	$1.04	10 Years
Emerging Technology - IT Systems - Server Virtualization/ Consolidation	Per MWh DC load	1.0% - 4.2%	301.1	0	$26.97	5 Years
Emerging Technology - IT Systems - Uninterruptible Power Supply Upgrade	Per MWh DC load	0.1% - 0.6%	44.3	0	$19.10	15 Years

Path to Commercialization

All the measures in the commercial emerging IT systems category, with the exception of quantum computing, are expected to be commercially available by 2021; however, they face barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Lack of contractor and distributor trust in and understanding of the technology
- Lack of established distribution channels to serve affected customers
- Incremental cost

Table C-32 shows the path to commercialization for each commercial emerging IT systems measure.

Table C-32. Development Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Future Server - Quantum Computing Servers/Data Centers	Long-Term (2031-2035)	X			
Emerging Technology - IT Systems - Decommissioning of Unused Servers	Near-Term (2021-2025)		X	X	

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - IT Systems - Energy Efficient Data Storage Management	Near-Term (2021-2025)			X	
Emerging Technology - IT Systems - Hot or Cold Aisle Configuration	Near-Term (2021-2025)			X	
Emerging Technology - IT Systems - Hot or Cold Aisle Configuration with Containment	Near-Term (2021-2025)			X	
Emerging Technology - IT Systems - Install Misters, Foggers, or Ultrasonic Humidifiers	Near-Term (2021-2025)			X	
Emerging Technology - IT Systems - Server Virtualization/ Consolidation	Near-Term (2021-2025)			X	
Emerging Technology - IT Systems - Uninterruptible Power Supply Upgrade	Near-Term (2021-2025)			X	

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Commercial Emerging Technology: Lighting

Emerging lighting technologies make up 9% of the 20-year commercial portfolio achievable potential.

Bundle Measure Names and Residential Sector Applicability

Table C-33 shows the two measures within the commercial emerging lighting bundle, as well as the commercial sectors in which the measures can be installed.

Table C-33. Commercial Emerging Lighting Measure Names and Applicable Segments

Measure Name	Education	Grocery	Health	Lodging	Office	Other	Restaurant	Retail	Warehouse
Emerging Technology - Advanced Daylighting Controls	X	X	X	X	X	X	X	X	X
Emerging Technology - Future Lighting - Perovskite LEDs	X	X	X	X	X	X	X	X	X

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-34 shows several measure characteristics for each measure: the percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, and measure life. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-34. Percentage Energy Savings over the Baseline Technology

Measure Name	Unit	Energy Savings	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost	Measure Life
Emerging Technology - Advanced Daylighting Controls	Per building sq ft	2% - 6%	0.15 - 1.05	0 - 0.0004	$3.04	30 Years
Emerging Technology - Future Lighting - Perovskite LEDs	Per building sq ft	14%	1.0	0.00018	$0.41	15 Years

Path to Commercialization

Both measures are expected to be commercially available by 2036; however, they face barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer awareness of the technology and understanding of the required integration of advanced lighting controls with other building systems
- Incremental cost and coordination required to maximize the benefits of advanced lighting controls

Table C-35 shows the path to commercialization for both commercial lighting measures.

Table C-35. Development Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Advanced Daylighting Controls	Mid-Term (2026-2030)		X	X	
Emerging Technology - Future Lighting - Perovskite LEDs	Long-Term (2036-2040)	X		X	

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Commercial Emerging Technology: Other Technologies

Commercial emerging other technologies make up 13% of the 20-year commercial portfolio achievable potential.

Bundle Measure Names and Commercial Sector Applicability

Table C-36 shows the seven measures within the other emerging technology bundle, as well as the commercial sectors in which the measures can be installed.

Table C-36. Commercial Emerging Other Technology Measure Names and Applicable Segments

Measure Name	Education	Grocery	Health	Lodging	Office	Other	Restaurant	Retail	Warehouse
Emerging Technology - Advanced Food Service	X	X	X	X	X	X	X	X	X
Emerging Technology - Advanced Laundry	X	X	X	X	X	X	X	X	X
Emerging Technology - Advanced Motors	X	X	X	X	X	X	X	X	X
Emerging Technology - CO2 Laundry - Front Loading	X	X	X	X	X	X	X	X	X
Emerging Technology - CO2 Laundry - Top Loading	X	X	X	X	X	X	X	X	X
Emerging Technology - Commercial Behavioral	X	X	X	X	X	X	X	X	X
Emerging Technology - Spring-Loaded Garage Door Hinges	X	X	X	X	X	X	X	X	X

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-37 shows several characteristics for each measure: the percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, and measure life. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-37. Percentage Energy Savings over the Baseline Technology

Measure Name	Unit	Energy Savings	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost	Measure Life
Emerging Technology - Advanced Food Service	Per cooking appliance	0.1 - 0.6%	525[a]	0.0969	$7,104[a]	12 Years
Emerging Technology - Advanced Laundry	Per dryer	29 - 33%	229.88	0.006	$882	12 Years
Emerging Technology - Advanced Motors	Per HP	11.8%	1,204.65	0.109	$304	15 Years
Emerging Technology - CO2 Laundry - Front Loading	Per commercial washer	0 - 19%	15,278	0.391	$142,072	10 Years
Emerging Technology - CO2 Laundry - Top Loading	Per commercial washer	0 - 16%	13,015	0.333	$142,072	10 Years

Measure Name	Unit	Energy Savings	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost	Measure Life
Emerging Technology - Commercial Behavioral (chillers, direct expansion, PTAC, room cool) [h]	Per commercial account	0.25%	7.48 - 126	0.002 - 0.027	$10.15	1 Year
Emerging Technology - Commercial Behavioral (room eat, space heat)	Per commercial account	0.25%	45.59 - 619	0.010 - 0.133	$10.15	1 Year
Emerging Technology - Commercial Behavioral (heat pump, PTHP)	Per commercial account	0.25%	29.51 - 336	0.006 - 0.072	$10.15	1 Year
Emerging Technology - Commercial Behavioral (exterior lighting, interior lighting)	Per commercial account	0.25%	0.09 - 218	0 - 0.047	$10.15	1 Year
Emerging Technology - Commercial Behavioral (other end uses)	Per commercial account	0.25%	0 - 880	0 - 0.189	$10.15	1 Year
Emerging Technology - Spring-Loaded Garage Door Hinges (heat pump, room heat, space heat)	Per garage door	1%	316 - 10,127	0 - 4	$200.70	20 Years

Path to Commercialization

All seven measures in the commercial emerging other technologies category are expected to be commercially available by 2031; however, they face barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Lack of contractor and distributor trust in and understanding of the technology
- Lack of established distribution channels to serve affected customers
- Lack of regulatory acceptance of behavioral savings
- Delivery cost considerations for behavioral savings
- Incremental cost

Table C-38 shows the path to commercialization for each commercial other measure.

Table C-38. Development Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Advanced Food Service	Near-Term (2021-2025)			X	
Emerging Technology - Advanced Laundry	Mid-Term (2026-2030)			X	
Emerging Technology - Advanced Motors	Mid-Term (2026-2030)			X	
Emerging Technology - CO2 Laundry - Front Loading	Near-Term (2021-2025)	X	X	X	
Emerging Technology - CO2 Laundry - Top Loading	Near-Term (2021-2025)	X	X	X	
Emerging Technology - Commercial Behavioral	Long-Term (2031-2035)		X		X
Emerging Technology - Spring-Loaded Garage Door Hinges	Near-Term (2021-2025)			X	

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Commercial Emerging Technology: Refrigeration

Commercial emerging refrigeration technologies make up 15% of the 20-year commercial portfolio achievable potential.

Bundle Measure Names and Commercial Sector Applicability

Table C-39 shows the two measures within the commercial emerging refrigeration bundle, as well as the commercial sectors in which the measures can be installed.

Table C-39. Commercial Emerging Refrigeration Measure Names and Applicable Segments

Measure Name	Education	Grocery	Health	Lodging	Office	Other	Restaurant	Retail	Warehouse
Emerging Technology - Advanced Refrigeration/CO2 Systems	X	X	X	X	X	X	X	X	X
Emerging Technology - Aerofoils for Open Display Cases	X	X	X	X		X	X	X	

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-40 shows several characteristics for each measure: the percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, and measure life. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-40. Percentage Energy Savings over the Baseline Technology

Measure Name	Unit	Energy Savings	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost	Measure Life
Emerging Technology - Advanced Refrigeration/CO2 Systems	Per building	12.5% [a]	310.9 - 4,4004	0.035 - 5.012	$13,263 - 108,660	20 Years
Emerging Technology - Aerofoils for Open Display Cases	Per refrigerated case	0.3 - 20.3%	4,588	0.3764	$311.54	10 Years

Path to Commercialization

Both measures included in the commercial refrigeration category are expected to be commercially available by 2021 or 2026; however, they face barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Lack of established design practices for combined HVAC and domestic hot water systems
- Lack of contractor and distributor trust in and understanding of the technology
- Lack of established distribution channels
- Incremental cost

Table C-41 shows the path to commercialization for each commercial refrigeration measure.

Table C-41. Development Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Advanced Refrigeration/CO2 Systems	Mid-Term (2026-2030)		X	X	
Emerging Technology - Aerofoils for Open Display Cases	Near-Term (2021-2025)			X	

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Industrial Emerging Technology: Agricultural

Industrial emerging agricultural technologies make up 5% of the 20-year industrial portfolio achievable potential.

Bundle Measure Names and Industrial Sector Applicability

Table C-42 shows the 13 measures within the emerging agricultural bundle, as well as the industrial sectors in which the measures can be installed.

Table C-42. Industrial Emerging Agricultural Measure Names and Applicable Segments

Measure Name	Apparel	Beverage and Tobacco	Chemical	Computer and Electronics	Electrical Equipment	Fabricated Metal Products	Food Manufacturing	Furniture Manufacturing	Industrial Machinery	Leather	Misc.	Nonmetallic Mineral	Paper Manufacturing	Petroleum Coal Products	Plastics Rubber Products	Primary Metal Manufacturing	Printing Related Support	Textile Mills	Textile Product Mills	Transportation Equipment Mfg.	Wood Product Manufacturing	Wastewater	Water	Mining	Agriculture
Emerging Technology - Future Dairy - Lighting Efficiency Improvement																									X
Emerging Technology - Future Dairy - Other Efficiency Improvement																									X
Emerging Technology - Future Dairy - Process Refrigeration and Cooling Efficiency Improvement																									X
Emerging Technology - Future Dairy - Pumps Efficiency Improvement																									X
Emerging Technology - Future Dairy - Ventilation Efficiency Improvement																									X
Emerging Technology - Future Dairy - Water Heat Efficiency Improvement																									X
Emerging Technology - Future Irrigation - Pumps Efficiency Improvement																									X

Measure Name	Apparel	Beverage and Tobacco	Chemical	Computer and Electronics	Electrical Equipment	Fabricated Metal Products	Food Manufacturing	Furniture Manufacturing	Industrial Machinery	Leather	Misc.	Nonmetallic Mineral	Paper Manufacturing	Petroleum Coal Products	Plastics Rubber Products	Primary Metal Manufacturing	Printing Related Support	Textile Mills	Textile Product Mills	Transportation Equipment Mfg.	Wood Product Manufacturing	Wastewater	Water	Mining	Agriculture
Emerging Technology - Future Miscellaneous Ag - Lighting Efficiency Improvement																									X
Emerging Technology - Future Miscellaneous Ag - Other Efficiency Improvement																									X
Emerging Technology - Future Miscellaneous Ag - Process Refrigeration and Cooling Efficiency Improvement																									X
Emerging Technology - Future Miscellaneous Ag - Pumps Efficiency Improvement																									X
Emerging Technology - Future Miscellaneous Ag - Ventilation Efficiency Improvement																									X
Emerging Technology - Future Miscellaneous Ag - Water Heat Efficiency Improvement																									X

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-43 shows several characteristics for each measure: the percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, and measure life. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-43. Percentage Energy Savings over the Baseline Technology

Measure Name	Unit	Energy Savings	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost	Measure Life
Emerging Technology - Future Dairy - Lighting Efficiency Improvement	Per site	20%	8,182,943	0	$3,272,177	10 Years
Emerging Technology - Future Dairy - Other Efficiency Improvement	Per site	20%	9,463,964	0	$3,785,586	10 Years
Emerging Technology - Future Dairy - Process Refrigeration and Cooling Efficiency Improvement	Per site	20%	1,506,902	0	$602,761	10 Years
Emerging Technology - Future Dairy - Pumps Efficiency Improvement	Per site	20%	37,086,150	0	$14,834,460	10 Years
Emerging Technology - Future Dairy - Ventilation Efficiency Improvement	Per site	20%	28,271,340	0	$11,308,536	10 Years
Emerging Technology - Future Dairy - Water Heat Efficiency Improvement	Per site	20%	2,486,543	0	$994,617	10 Years
Emerging Technology - Future Irrigation - Pumps Efficiency Improvement	Per site	20%	37,086,150	0	$14,834,460	10 Years
Emerging Technology - Future Miscellaneous Ag - Lighting Efficiency Improvement	Per site	20%	8,182,943	0	$3,273,177	10 Years
Emerging Technology - Future Miscellaneous Ag - Other Efficiency Improvement	Per site	20%	9,463,964	0	$3,785,586	10 Years
Emerging Technology - Future Miscellaneous Ag - Process Refrigeration and Cooling Efficiency Improvement	Per site	20%	1,506,902	0	$602,761	10 Years
Emerging Technology - Future Miscellaneous Ag - Pumps Efficiency Improvement	Per site	20%	37,086,150	0	$14,834,460	10 Years
Emerging Technology - Future Miscellaneous Ag - Ventilation Efficiency Improvement	Per site	20%	28,271,340	0	$11,308,536	10 Years
Emerging Technology - Future Miscellaneous Ag - Water Heat Efficiency Improvement	Per site	20%	2,486,543	0	$4994,617	10 Years

Path to Commercialization

All 13 measures included in the industrial agricultural measure technologies category are expected to be commercially available by 2031; however, they face barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Lack of established distribution channels to serve affected customers
- Incremental cost

Table C-44 shows the path to commercialization for each industrial agricultural measure.

Table C-44. Development Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Future Dairy - Lighting Efficiency Improvement	Long-Term (2031-2035)	X			
Emerging Technology - Future Dairy - Other Efficiency Improvement	Long-Term (2031-2035)	X			
Emerging Technology - Future Dairy - Process Refrigeration and Cooling Efficiency Improvement	Long-Term (2031-2035)	X			
Emerging Technology - Future Dairy - Pumps Efficiency Improvement	Long-Term (2031-2035)	X			
Emerging Technology - Future Dairy - Ventilation Efficiency Improvement	Long-Term (2031-2035)	X			
Emerging Technology - Future Dairy - Water Heat Efficiency Improvement	Long-Term (2031-2035)	X			
Emerging Technology - Future Irrigation - Pumps Efficiency Improvement	Long-Term (2031-2035)	X			
Emerging Technology - Future Miscellaneous Ag - Lighting Efficiency Improvement	Long-Term (2031-2035)	X			
Emerging Technology - Future Miscellaneous Ag - Other Efficiency Improvement	Long-Term (2031-2035)	X			
Emerging Technology - Future Miscellaneous Ag - Process Refrigeration and Cooling Efficiency Improvement	Long-Term (2031-2035)	X			
Emerging Technology - Future Miscellaneous Ag - Pumps Efficiency Improvement	Long-Term (2031-2035)	X			
Emerging Technology - Future Miscellaneous Ag - Ventilation Efficiency Improvement	Long-Term (2031-2035)	X			
Emerging Technology - Future Miscellaneous Ag - Water Heat Efficiency Improvement	Long-Term (2031-2035)	X			

Bibliography

PSE's PY2016/17 Commercial Rebate and New Construction Programs, Council (7th Plan) assumptions, Evan Mills (DOE), Manifest Mind report and other secondary sources. This data was also informed by communications with Brad Queen (CubeResourses) and Aaron Block (Allumia), as well as by one Colorado site visit and one survey response, plus one additional site visit and online survey conducted in Colorado. The team updated the customer account forecast for 2020 (no new customers), updated values to 2020 dollars with adjusted LED costs using 2021 Council data of LED cost forecast, and updated to the account level for PSE accomplishments.

Industrial Emerging Technology: Fans

Industrial emerging fan technologies make up 2% of the 20-year industrial portfolio achievable potential.

Bundle Measure Names and Industrial Sector Applicability

Table C-475 shows the one measure within the emerging fans bundle, as well as the industrial sectors in which the measure can be installed.

Table C-45. Industrial Emerging Technology Fan Measure Names and Applicable Segments

Measure Name	Apparel	Beverage and Tobacco	Chemical	Computer and Electronics	Electrical Equipment	Fabricated Metal Products	Food Manufacturing	Furniture Manufacturing	Industrial Machinery	Leather	Misc.	Nonmetallic Mineral	Paper Manufacturing	Petroleum Coal Products	Plastics Rubber Products	Primary Metal Manufacturing	Printing Related Support	Textile Mills	Textile Product Mills	Transportation Equipment Mfg.	Wood Product Manufacturing	Wastewater	Water	Mining	Agriculture
Emerging Technology - Advanced Motor - Fans	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-46 shows several characteristics for the measure: the percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, and measure life. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-46. Percentage Energy Savings over the Baseline Technology

Measure Name	Unit	Energy Savings	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost [a]	Measure Life
Emerging Technology - Advanced Motor - Fans	Per site	5%	0 - 5,166,509	0 - 746.939	$0 - 1,676710	20 Years

Path to Commercialization

The one measure in the industrial emerging fans category is expected to be commercially available by 2026; however, it faces barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Lack of contractor and distributor trust in and understanding of the technology
- Incremental cost

Table C-47 shows the path to commercialization for the industrial emerging fan measure.

Table C-47. Development Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Advanced Motor - Fans	Mid-Term (2026-2030)	X			

Bibliography

Minnesota Department of Commerce. January 1, 2020. "C/I Motors." *Minnesota Technical Reference Manual, Version 3.0.* https://mn.gov/commerce/industries/energy/utilities/cip/technical-reference-manual/

[a] For this value, the team assumed future advancement through either existing technology (just reconfigured) or emerging technologies improvements on process end uses. The team added emerging technology measures for transformational potential. Based on DNV GL conversations, process improvements will continually evolve and are unlikely to decline. These emerging technology bundles include both existing and new technologies that will advance process improvements. DNV GL indicated that process improvements combined will account for 50% of the Consumers Energy program savings.

Industrial Emerging Technology: Indoor Agricultural

Industrial indoor agricultural emerging technologies, that address multiple end-uses, make up 4% of the 20-year industrial portfolio achievable potential.

Bundle Measure Names and Industrial Sector Applicability

Table C-48 shows the 18 measures within the emerging indoor agricultural bundle, as well as the industrial sectors in which the measures can be installed.

Table C-48. Industrial Emerging Indoor Agricultural Measure Names and Applicable Segments

Measure Name	Apparel	Beverage and Tobacco	Chemical	Computer and Electronics	Electrical Equipment	Fabricated Metal Products	Food Manufacturing	Furniture Manufacturing	Industrial Machinery	Leather	Misc.	Nonmetallic Mineral	Paper Manufacturing	Petroleum Coal Products	Plastics Rubber Products	Primary Metal Manufacturing	Printing Related Support	Textile Mills	Textile Product Mills	Transportation Equipment Mfg.	Wood Product Manufacturing	Wastewater	Water	Mining	Agriculture
Emerging Technology - Future Indoor Agriculture - Production Facility Grower A - Dehumidification - Indoor Ag Efficiency Improvement																									X
Emerging Technology - Future Indoor Agriculture - Production Facility Grower A - HVAC - Indoor Ag Efficiency Improvement																									X
Emerging Technology - Future Indoor Agriculture - Production Facility Grower A - Lighting - Indoor Ag Efficiency Improvement																									X
Emerging Technology - Future Indoor Agriculture - Production Facility Grower B - Dehumidification - Indoor Ag Efficiency Improvement																									X

Measure Name	Apparel	Beverage and Tobacco	Chemical	Computer and Electronics	Electrical Equipment	Fabricated Metal Products	Food Manufacturing	Furniture Manufacturing	Industrial Machinery	Leather	Misc.	Nonmetallic Mineral	Paper Manufacturing	Petroleum Coal Products	Plastics Rubber Products	Primary Metal Manufacturing	Printing Related Support	Textile Mills	Textile Product Mills	Transportation Equipment Mfg.	Wood Product Manufacturing	Wastewater	Water	Mining	Agriculture
Emerging Technology - Future Indoor Agriculture - Production Facility Grower B - HVAC - Indoor Ag Efficiency Improvement																									X
Emerging Technology - Future Indoor Agriculture - Production Facility Grower B - Lighting - Indoor Ag Efficiency Improvement																									X
Emerging Technology - Future Indoor Agriculture - Production Facility Grower C - Dehumidification - Indoor Ag Efficiency Improvement																									X
Emerging Technology - Future Indoor Agriculture - Production Facility Grower C - HVAC - Indoor Ag Efficiency Improvement																									X
Emerging Technology - Future Indoor Agriculture - Production Facility Grower C - Lighting - Indoor Ag Efficiency Improvement																									X
Emerging Technology - Indoor Agriculture - Production Facility Grower A - Dehumidification System																									X
Emerging Technology - Indoor Agriculture - Production Facility Grower A - LED Lighting																									X
Emerging Technology - Indoor Agriculture - Production Facility Grower A - VRF Heat Pump																									X

Measure Name	Apparel	Beverage and Tobacco	Chemical	Computer and Electronics	Electrical Equipment	Fabricated Metal Products	Food Manufacturing	Furniture Manufacturing	Industrial Machinery	Leather	Misc.	Nonmetallic Mineral	Paper Manufacturing	Petroleum Coal Products	Plastics Rubber Products	Primary Metal Manufacturing	Printing Related Support	Textile Mills	Textile Product Mills	Transportation Equipment Mfg.	Wood Product Manufacturing	Wastewater	Water	Mining	Agriculture
Emerging Technology - Indoor Agriculture - Production Facility Grower B - Dehumidification System																									X
Emerging Technology - Indoor Agriculture - Production Facility Grower B - LED Lighting																									X
Emerging Technology - Indoor Agriculture - Production Facility Grower B - VRF Heat Pump																									X
Emerging Technology - Indoor Agriculture - Production Facility Grower C - Dehumidification System																									X
Emerging Technology - Indoor Agriculture - Production Facility Grower C - LED Lighting																									X
Emerging Technology - Indoor Agriculture - Production Facility Grower C - VRF Heat Pump																									X

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-49 shows several characteristics for each measure: the percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, and measure life. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-49. Percentage Energy Savings over the Baseline Technology

Measure Name	Unit	Energy Savings	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost	Measure Life
Emerging Technology - Future Indoor Agriculture - Production Facility Grower A - Dehumidification - Indoor Ag Efficiency Improvement	Per site	2%	377,486	0	$150,994	10 Years
Emerging Technology - Future Indoor Agriculture - Production Facility Grower A - HVAC - Indoor Ag Efficiency Improvement	Per site	2%	629,143	0	$251,657	10 Years
Emerging Technology - Future Indoor Agriculture - Production Facility Grower A - Lighting - Indoor Ag Efficiency Improvement	Per site	2%	1,384,115	0	$553,646	10 Years
Emerging Technology - Future Indoor Agriculture - Production Facility Grower B - Dehumidification - Indoor Ag Efficiency Improvement	Per site	1%	107,853	0	$43,141	10 Years
Emerging Technology - Future Indoor Agriculture - Production Facility Grower B - HVAC - Indoor Ag Efficiency Improvement	Per site	1%	179,755	0	$71,902	10 Years
Emerging Technology - Future Indoor Agriculture - Production Facility Grower B - Lighting - Indoor Ag Efficiency Improvement	Per site	1%	395,461	0	$158,185	10 Years
Emerging Technology - Future Indoor Agriculture - Production Facility Grower C - Dehumidification - Indoor Ag Efficiency Improvement	Per site	17%	2,660,377	0	$1,064,151	10 Years
Emerging Technology - Future Indoor Agriculture - Production Facility Grower C - HVAC - Indoor Ag Efficiency Improvement	Per site	17%	4,433,961	0	$1,773,584	10 Years
Emerging Technology - Future Indoor Agriculture - Production Facility Grower C - Lighting - Indoor Ag Efficiency Improvement	Per site	17%	9,754,715	0	$3,901,886	10 Years
Emerging Technology - Indoor Agriculture - Production Facility Grower A - Dehumidification System	Per site	2%	251,699	0	$39,620	10 Years
Emerging Technology - Indoor Agriculture - Production Facility Grower A - LED Lighting	Per site	5%	3,075,811	486.886	$1,256,642	4 Years

Measure Name	Unit	Energy Savings	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost	Measure Life
Emerging Technology - Indoor Agriculture - Production Facility Grower A - VRF Heat Pump	Per site	3%	913,736	0	$357,271	20 Years
Emerging Technology - Indoor Agriculture - Production Facility Grower B - Dehumidification System	Per site	1%	94,829	0	$15,544	10 Years
Emerging Technology - Indoor Agriculture - Production Facility Grower B - LED Lighting	Per site	2%	878,803	139.110	$359,041	4 Years
Emerging Technology - Indoor Agriculture - Production Facility Grower B - VRF Heat Pump	Per site	1%	261,067	0	$102,077	20 Years
Emerging Technology - Indoor Agriculture - Production Facility Grower C - Dehumidification System	Per site	30%	4,678,270	0	$285,569	10 Years
Emerging Technology - Indoor Agriculture - Production Facility Grower C - LED Lighting	Per site	38%	21,677,144	3,431.390	$8,856,337	4 Years
Emerging Technology - Indoor Agriculture - Production Facility Grower C - VRF Heat Pump	Per site	20%	5,246,151	0	$2,517,910	20 Years

Path to Commercialization

All 18 measures included in the industrial indoor agriculture category are expected to be commercially available by 2031; however, they face barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Lack of established distribution channels to serve affected customers
- Lack of customer trust in and understanding of the technology
- Incremental cost

Table C-50 shows the path to commercialization for each industrial indoor agriculture measure.

Table C-50. Development Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Future Indoor Agriculture - Production Facility Grower A - Dehumidification - Indoor Ag Efficiency Improvement	Long-Term (2031-2035)	X		X	
Emerging Technology - Future Indoor Agriculture - Production Facility Grower A - HVAC - Indoor Ag Efficiency Improvement	Long-Term (2031-2035)	X		X	
Emerging Technology - Future Indoor Agriculture - Production Facility Grower A - Lighting - Indoor Ag Efficiency Improvement	Long-Term (2031-2035)	X		X	
Emerging Technology - Future Indoor Agriculture - Production Facility Grower B - Dehumidification - Indoor Ag Efficiency Improvement	Long-Term (2031-2035)	X		X	
Emerging Technology - Future Indoor Agriculture - Production Facility Grower B - HVAC - Indoor Ag Efficiency Improvement	Long-Term (2031-2035)	X		X	
Emerging Technology - Future Indoor Agriculture - Production Facility Grower B - Lighting - Indoor Ag Efficiency Improvement	Long-Term (2031-2035)	X		X	
Emerging Technology - Future Indoor Agriculture - Production Facility Grower C - Dehumidification - Indoor Ag Efficiency Improvement	Long-Term (2031-2035)	X		X	
Emerging Technology - Future Indoor Agriculture - Production Facility Grower C - HVAC - Indoor Ag Efficiency Improvement	Long-Term (2031-2035)	X		X	
Emerging Technology - Future Indoor Agriculture - Production Facility Grower C - Lighting - Indoor Ag Efficiency Improvement	Long-Term (2031-2035)	X		X	
Emerging Technology - Indoor Agriculture - Production Facility Grower A - Dehumidification System	Near-Term (2021-2025)			X	
Emerging Technology - Indoor Agriculture - Production Facility Grower A - LED Lighting	Near-Term (2021-2025)			X	
Emerging Technology - Indoor Agriculture - Production Facility Grower A - VRF Heat Pump	Near-Term (2021-2025)			X	
Emerging Technology - Indoor Agriculture - Production Facility Grower B - Dehumidification System	Near-Term (2021-2025)			X	
Emerging Technology - Indoor Agriculture - Production Facility Grower B - LED Lighting	Near-Term (2021-2025)			X	

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Indoor Agriculture - Production Facility Grower B - VRF Heat Pump	Near-Term (2021-2025)			X	
Emerging Technology - Indoor Agriculture - Production Facility Grower C - Dehumidification System	Near-Term (2021-2025)			X	
Emerging Technology - Indoor Agriculture - Production Facility Grower C - LED Lighting	Near-Term (2021-2025)			X	
Emerging Technology - Indoor Agriculture - Production Facility Grower C - VRF Heat Pump	Near-Term (2021-2025)			X	

Bibliography

PSE's PY2016/17 Commercial Rebate and New Construction Programs, Council (7th Plan) assumptions, Evan Mills (DOE), Manifest Mind report and other secondary sources. This data was also informed by communications with Brad Queen (CubeResourses) and Aaron Block (Allumia), as well as by one Colorado site visit and one survey response, plus one additional site visit and online survey conducted in Colorado. The team updated the customer account forecast for 2020 (no new customers), updated values to 2020 dollars with adjusted LED costs using 2021 Council data of LED cost forecast, and updated to the account level for PSE accomplishments.

Industrial Emerging Technology: Lighting

Industrial emerging lighting technologies make up 8% of the 20-year industrial portfolio achievable potential.

Bundle Measure Names and Industrial Sector Applicability

Table C-51 shows the one measure within the industrial emerging lighting bundle, as well as the industrial sectors in which the measure can be installed.

Table C-51. Industrial Emerging Lighting Measure Names and Applicable Segments

Measure Name	Apparel	Beverage and Tobacco	Chemical	Computer and Electronics	Electrical Equipment	Fabricated Metal Products	Food Manufacturing	Furniture Manufacturing	Industrial Machinery	Leather	Misc.	Nonmetallic Mineral	Paper Manufacturing	Petroleum Coal Products	Plastics Rubber Products	Primary Metal Manufacturing	Printing Related Support	Textile Mills	Textile Product Mills	Transportation Equipment Mfg.	Wood Product Manufacturing	Wastewater	Water	Mining	Agriculture
Emerging Technology - Advanced Lighting Controls	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-52 shows several characteristics for the measure: the percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, and measure life. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-52. Percentage Energy Savings over the Baseline Technology

Measure Name	Unit	Energy Savings	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost	Measure Life
Emerging Technology - Advanced Lighting Controls	Per site	42%	0 - 80,790,515	0 - 11,680.143	$0 - 181,771,987	8 Years

Path to Commercialization

The one measure in the industrial emerging lighting category is expected to be commercially available by 2021; however, it faces barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Lack of contractor and distributor trust in and understanding of the technology
- Incremental cost

Table C-53 shows the path to commercialization for the industrial emerging lighting measure.

Table C-53. Development Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Advanced Lighting Controls	Near-Term (2021-2025)			X	

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Industrial Emerging Technology: Motors

Industrial motors emerging technologies make up 6% of the 20-year industrial portfolio achievable potential.

Bundle Measure Names and Industrial Sector Applicability

Table C-54 shows the one measure within the industrial motors bundle, as well as the industrial sectors in which the measure can be installed.

Table C-54. Industrial Motors Measure Names and Applicable Segments

Measure Name	Apparel	Beverage and Tobacco	Chemical	Computer and Electronics	Electrical Equipment	Fabricated Metal Products	Food Manufacturing	Furniture Manufacturing	Industrial Machinery	Leather	Misc.	Nonmetallic Mineral	Paper Manufacturing	Petroleum Coal Products	Plastics Rubber Products	Primary Metal Manufacturing	Printing Related Support	Textile Mills	Textile Product Mills	Transportation Equipment Mfg.	Wood Product Manufacturing	Wastewater	Water	Mining	Agriculture
Emerging Technology - Advanced Motor - Motors Other	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-55 shows several characteristics for the measure: the percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, and measure life. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-55. Percentage Energy Savings over the Baseline Technology

Measure Name	Unit	Energy Savings	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost	Measure Life
Emerging Technology - Advanced Motor - Motors Other	Per site	5% [a]	0 – 11,684,177	0 - 1,689.289	$0 - 3,791,917 [b]	20 Years

[a] The Cadmus team assumed future advancement through either existing technology (just reconfigured) or emerging technology improvements on process end uses. The team added existing technology measures for transformational potential. Based on DNV GL conversations, process improvements will continually evolve and are unlikely to decline. These existing technology bundles include both existing and new technologies that will advance process improvements. DNV GL indicated that process improvements combined will account for 50% of the Consumers Energy program savings.
[b] The team assumed incremental cost would be twice the average current costs.

Path to Commercialization

The one measure in the industrial emerging motors category is expected to be commercially available by 2026. However, it faces barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Incremental cost
- Lack of established distribution channels to serve affected customers

Table C-56 shows the path to commercialization for the industrial motor measure.

Table C-56. Development Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Advanced Motor - Motors Other	Mid-Term (2026-2030)	X		X	

Bibliography

Minnesota Department of Commerce. January 1, 2020. “C/I Motors.” *Minnesota Technical Reference Manual, Version 3.0.* https://mn.gov/commerce/industries/energy/utilities/cip/technical-reference-manual/

Industrial Emerging Technology: Process

Industrial emerging process technologies make up 20% of the 20-year industrial portfolio achievable potential.

Bundle Measure Names and Industrial Sector Applicability

Table C-57 shows the five measures within the industrial emerging process bundle, as well as the industrial sectors in which the measures can be installed.

Table C-57. Industrial Emerging Process Measure Names and Applicable Segments

Measure Name	Apparel	Beverage and Tobacco	Chemical	Computer and Electronics	Electrical Equipment	Fabricated Metal Products	Food Manufacturing	Furniture Manufacturing	Industrial Machinery	Leather	Misc.	Nonmetallic Mineral	Paper Manufacturing	Petroleum Coal Products	Plastics Rubber Products	Primary Metal Manufacturing	Printing Related Support	Textile Mills	Textile Product Mills	Transportation Equipment Mfg.	Wood Product Manufacturing	Wastewater	Water	Mining	Agriculture
Emerging Technology - Process Improvement - Air Compressor	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Emerging Technology - Process Improvement - Electro Chemical	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Emerging Technology - Process Improvement - Heat	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Emerging Technology - Process Improvement - Other	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Emerging Technology - Process Improvement - Refrigeration and Cooling	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-58 shows several characteristics for each measure: the percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, and measure life. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-58. Percentage Energy Savings over the Baseline Technology

Measure Name	Unit	Energy Savings [a]	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost [b]	Measure Life [c]
Emerging Technology - Process Improvement - Air Compressor	Per site	5%	0 – 6,832,217	0 - 987.756	$0 – 3,460,278	15 Years
Emerging Technology - Process Improvement - Electro Chemical	Per site	10%	0 – 23,349,499	0 – 3,375.712	$0 – 2,434,273	10 Years
Emerging Technology - Process Improvement - Heat	Per site	5%	0 – 18,770,930	0 – 2,713.773	$0 – 1,717,727	15 Years
Emerging Technology - Process Improvement - Other	Per site	5% - 15%	0 – 7,739,592	0 – 1,118.938	$0 – 1,691,864	10 Years
Emerging Technology - Process Improvement - Refrigeration and Cooling	Per site	13%	0 – 49,699,005	0 – 7,185.144	$0 – 13,422,194	10 Years

[a] For these savings, the Cadmus team assumed future advancement through either existing technology (just reconfigured) or emerging technology improvements on process end uses. The team added emerging technology measures for transformational potential. Based on DNV GL conversations, process improvements will continually evolve and are unlikely to decline. These emerging technology bundles include both existing and new technologies that will advance process improvements. DNV GL indicated that process improvements combined will account for 50% of the Consumers Energy program savings.
[b] For the incremental costs, the team assumed maximum costs for existing technology.
[c] To determine measure life, the Cadmus team assumed similar EULs to existing technology.

Path to Commercialization

All five measures in the industrial emerging process category are expected to be commercially available by 2021; however, they face barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Lack of contractor and distributor trust in and understanding of the technology
- Incremental cost

Table C-59 shows the path to commercialization for each industrial process measure.

Table C-59. Development Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Process Improvement - Air Compressor	Near-Term (2021-2025)			X	
Emerging Technology - Process Improvement - Electro Chemical	Near-Term (2021-2025)			X	
Emerging Technology - Process Improvement - Heat	Near-Term (2021-2025)			X	
Emerging Technology - Process Improvement - Other	Near-Term (2021-2025)			X	
Emerging Technology - Process Improvement - Refrigeration and Cooling	Near-Term (2021-2025)			X	

Bibliography

N/A

Industrial Emerging Technology: Pumps

Industrial emerging pump technologies make up 4% of the 20-year industrial portfolio achievable potential.

Bundle Measure Names and Industrial Sector Applicability

Table C-60 shows the one measure within the emerging pumps bundle, as well as the industrial sectors in which the measure can be installed.

Table C-60. Industrial Emerging Pumps Measure Names and Applicable Segments

Measure Name	Apparel	Beverage and Tobacco	Chemical	Computer and Electronics	Electrical Equipment	Fabricated Metal Products	Food Manufacturing	Furniture Manufacturing	Industrial Machinery	Leather	Misc.	Nonmetallic Mineral	Paper Manufacturing	Petroleum Coal Products	Plastics Rubber Products	Primary Metal Manufacturing	Printing Related Support	Textile Mills	Textile Product Mills	Transportation Equipment Mfg.	Wood Product Manufacturing	Wastewater	Water	Mining	Agriculture
Emerging Technology - Advanced Motor - Pumps	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

Measure Characteristics Energy Savings, Demand Reduction, and Incremental Cost

Table C-61 shows several characteristics for each measure: the percentage of energy savings over the baseline technology, annual energy savings and demand reduction, incremental cost, and measure life. The team assumed the same measure cost and incremental cost over the 20-year planning horizon.

Table C-61. Percentage Energy Savings over the Baseline Technology

Measure Name	Unit	Energy Savings	Annual Energy Savings (kWh)	Annual Demand Reduction (kW)	Incremental Cost	Measure Life
Emerging Technology - Advanced Motor - Pumps	Per site	5%	0 - 8,193,352	0-1,184.539	$0-2,659,025	20 Years

Path to Commercialization

The one measure in the industrial emerging pumps category is expected to be commercially available by 2026; however, it faces barriers to adoption that are common to many new energy-efficient technologies:

- Lack of customer and contractor awareness of the technology
- Lack of contractor and distributor trust in and understanding of the technology
- Incremental cost

Table C-62 shows the path to commercialization for the industrial pumps measure.

Table C-62. Development Path to Commercialization

Measure Name	Development Timeline	Development Path			
		Technology Development and Demonstration	Delivery Strategy Optimization	Customer and Trade Ally Outreach	Regulatory Review and Acceptance
Emerging Technology - Advanced Motor - Pumps	Mid-Term (2026-2030)	X	X	X	

Bibliography

Minnesota Department of Commerce. January 1, 2020. "C/I Motors." *Minnesota Technical Reference Manual, Version 3.0.* https://mn.gov/commerce/industries/energy/utilities/cip/technical-reference-manual/