CPS ENERGY TECHNICAL GUIDEBOOK FOR ENERGY EFFICIENCY AND DEMAND RESPONSE

January 2022, Applies to FY 2023

CONTENTS

TABLES

FIGURES

ACRONYMS

4CP – The four monthly ERCOT system-wide peaks occurring in June, July, August, and September

ACCA – Air Conditioning Contractors of America

AHRI – Air-Conditioning, Heating, & Refrigeration Institute

ANSI – American National Standards Institute

ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers

CEE – Consortium for Energy Efficiency

COP – Coefficient of Performance

CP – Coincident Peak

EER – Energy Efficiency Ratio

EFLH – Effective Full Load Hours

ER – Early Retirement

EUL – Estimated Useful Life

IPLV – Integrated Part Load Value

NC – New Construction

NCP – Non-coincident Peak

PTAC – Packaged Terminal Air Conditioners

PTHP – Packaged Terminal Heat Pumps

RAC – Room Air Conditioner

ROB – Replace-on-Burnout

RUL – Remaining Useful Life

SEER – Seasonal Energy Efficiency Ratio

1. INTRODUCTION

CPS Energy offers numerous energy efficiency programs to its customers as part of its Save for Tomorrow Energy Plan (STEP). These programs reduce annual electric energy use and peak demand and reduce CPS Energy customers' electricity bills. CPS Energy and third parties administer these residential and commercial/industrial programs. Program effectiveness undergoes independent reviews annually.

1.1 OBJECTIVE OF THIS GUIDEBOOK

The purpose of the CPS Energy Technical Guidebook for Energy Efficiency and Demand Response (Guidebook) is to provide a single common reference document for estimating energy and peak demand savings resulting from the installation or implementation of energy efficiency and demand response measures provided through CPS Energy's programs. The Guidebook contains a compilation of deemed savings values for use in savings estimation.

The data and methodologies in this document are to be used by program planners, administrators, implementers, and evaluators for forecasting, reporting, and evaluating energy and demand savings from measures installed through CPS Energy's energy efficiency and demand response programs. The scope of the Guidebook is measure savings; therefore, other resources should be consulted for health and safety considerations related to implementation of measures (i.e., residential air sealing measures).

1.2 HOW TO USE THIS GUIDEBOOK

The Guidebook provides a means for the uniform application of savings methods and the assumptions behind them. This uniformity facilitates consistency among CPS Energy and other Texas utilities in estimating savings across programs and estimating program-level cost-effectiveness. By establishing clear qualification criteria for the development of projected and claimed savings estimates, the Guidebook provides transparency of savings calculations for all interested stakeholders.

The data and algorithms housed in the Guidebook are to be used by program administrators for the following purposes:

- Projecting program savings for the next year
- Reporting program savings from the previous year

2. EVALUATION OVERVIEW

2.1 CPS ENERGY STEP PROGRAM PORTFOLIO STRUCTURE

CPS Energy's portfolio of energy efficiency and demand response programs addresses all residential and most commercial markets and major end uses for both sectors. For more information on CPS Energy program offerings, please see https://www.cpsenergy.com/en/my-home/savenow.html.

CPS Energy evaluates the contribution of each residential and commercial program to the portfolio's energy, peak demand, and non-coincident peak savings, including avoided transmission charges. Except where noted, coincident peak savings values were calculated by using the weighted-average 20-hour probability method, as described below in Section 2.3.1.

2.2 IMPACT EVALUATION PROCESS

The Guidebook leverages existing evaluation, measurement, and verification (EM&V) work previously conducted for CPS Energy and other electric utilities in Texas. For the past fifteen years, investor-owned utilities, EM&V consultants, and stakeholder groups have collaborated to develop accurate and comprehensive "deemed" savings for hundreds of residential and commercial energy efficiency measures, under the auspices of the Public Utility Commission of Texas (PUCT). This extended effort has culminated in the publication of the Texas Technical Reference Manual (Texas TRM),[1] a compendium of algorithms, baseline efficiency data, efficiency standards, energy savings calculations and data tables. By utilizing the TRM, the Guidebook can provide CPS Energy with energy and demand impact estimates that have been vetted numerous times by independent third parties and are consistent with impact estimates being used by all the investor-owned utilities in Texas. For this Guidebook, the methodologies used are from Texas TRM version 7.0 except where noted.

Because the Texas TRM does not include expected energy impacts that are specific to San Antonio, additional building energy use model simulations were performed to derive energy savings estimates for weather-sensitive energy efficiency measures. These new estimates are consistent with the TRM but better reflect equipment usage in San Antonio's climate.

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[1] Public Utility Commission of Texas (PUCT) Technical Reference Manual (TRM). Available for download at: http://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

2.3 DEFINITION OF NON-COINCIDENT, COINCIDENT, AND 4CP PEAK DEMAND

2.3.1 Non-Coincident Peak (NCP)

For each measure and building type, annual kWh savings are allocated to each of the 8,760 hours in a year for the appropriate load shape. Non-coincident peak demand savings are the maximum difference between the pre- and post-retrofit demand, regardless of when that maximum value, or “peak,” occurs. Conceptually, “demand” is instantaneous; in practice, demand savings are frequently estimated using the difference in energy use between pre-and post-retrofit conditions over the course of a one-hour interval.

For measures for which the Guidebook deemed savings estimates are prepared using load shapes and/or engineering algorithms, the maximum estimated reduction in demand over any given hour of the year is reported as the non-coincident peak. In some cases, when deemed savings are estimated using building simulation models, the 99.9th percentile hourly savings estimate is used in lieu of the absolute maximum value.[2]

2.3.2 Coincident Peak (CP)

The calculation of coincident peak demand savings relies upon a probabilistic analysis of a San Antonio typical meteorological year (TMY), which contains hourly values of solar radiation and meteorological elements for a 1-year period. This analysis used the most recent version of these data, the TMY3 data set, which used data collected from Kelly Field Air Force Base (Kelly AFB) weather station.[3] This approach relates the TMY3 data set’s actual hourly weather, time-of-day, and day-of-week data to historical CPS Energy peak conditions and calculates a probability-weighted estimate of the average kW savings during the twenty hours with the highest probability of occurring during CPS Energy’s system peak. This approach enjoys broad acceptance in Texas because all investor-owned electric utilities began using it in 2016. A full description of the methodology to calculate the coincident peak demand appears in CPS Energy’s most recent evaluation report of its energy efficiency programs.[4]

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[2] This approach is taken with the residential envelope measures, developed with residential building simulation models, to account for some apparent time-displacement in when loads are met in the models. Given that single hour savings in some cases exceed the theoretical maximum hourly savings the measure could deliver according to engineering calculations, it appears that loads occasionally accumulate across hours giving hourly differences that may not realistically reflect the impacts of a measure.

[3] Data collected at the Kelly Field Air Force Base (Kelly AFB) station were generally used, because the temperature data series collected at the San Antonio International Airport is inexplicably higher than the readings collected at other local weather stations. (See Itron, CPS June 2014 Electricity Forecast, Sept. 2014, pp. 8-9.).

[4] Evaluation, Measurement & Verification of CPS Energy’s FY 2019 DSM Programs, Frontier Energy, July 18, 2019.

Fundamentally, this approach requires several key steps:

1. Establish the predicted peak hours in summer for CPS Energy.

This estimation approach involves identifying a set of hours during which CPS Energy peaks are likely to happen. Given the variability in when peaks occur, using a wider range of potential peak hours within a logistic model is optimal for estimating the actual, expected impact for a single utility peak hour per year. In other words, a probabilistic approach using 20 hours provides a better chance of estimating the actual peak rather than an approach that relies on a single hour. The 20 most probable hours for this estimate are based on a regression of 2010-2019 June to September 2:00pm-6:00pm historical load data plus CPS Energy estimated hourly demand response load and provide a sufficient range of hours to assign the highest probability of being within the set of actual peak hours.

2. Correlate weather and load data.

A logistic regression model and CPS Energy historical load data are used to estimate a relationship between CPS Energy peak hours and a set of explanatory variables, including a temperature variable and dummy variables representing the time-of-day and month-of-year.

3. Select Peak Hours in TMY Weather Files.

This step applies regression results to San Antonio TMY3 weather data by calculating the probability of an hour coinciding with CPS Energy peak by using marginal probabilities assigned to the explanatory variables. The twenty hours selected are those with the highest probability of occurring during CPS Energy’s peak.

Table 2.3-1 shows the selected top 20 hours in order of decreasing relative probability). Additional hours are shown because some hours, such as those occurring on weekends or holidays, are eliminated for some measures.

Kilowatt values for each of the top 20 hours were extracted from the 8,760 hourly load shapes for each specific measure. The coincident peak demand was then calculated as the probability-weighted average kW for the top 20 hours.

Table 2.3-1: [Evaluation Overview] Top Hours in Order of Relative Probability

Month	Day	Hour (start)	Temp (°F)	Peak Probability (with DR addback)
6	19	15	104.00	0.868682
6	19	16	102.92	0.846070
6	20	16	102.92	0.846070
6	20	15	101.84	0.488014
6	19	14	102.92	0.354302
6	20	14	102.92	0.354302
6	19	17	100.94	0.327983
6	10	15	100.94	0.298350
6	18	15	100.94	0.298350
7	31	15	102.02	0.292170
8	20	15	99.86	0.271695
8	19	16	98.96	0.267009
8	20	16	98.96	0.267009
6	10	16	99.86	0.261069
8	17	15	98.96	0.142675
7	31	16	100.04	0.132695
8	18	16	97.88	0.121478
6	20	17	98.96	0.076337
6	17	15	98.96	0.067168
8	18	15	97.88	0.059418
8	19	15	97.88	0.059418
8	17	16	96.98	0.058101
8	23	16	96.98	0.058101
6	12	16	97.88	0.056450
6	16	16	97.88	0.056450
6	17	16	97.88	0.056450
6	18	16	97.88	0.056450
7	30	16	98.96	0.054889
8	20	14	98.96	0.035089
8	23	14	98.96	0.035089
6	10	14	99.86	0.034069
6	18	14	99.86	0.034069
7	31	14	100.94	0.033105
8	18	17	96.98	0.031332
8	19	17	96.98	0.031332
8	20	17	96.98	0.031332
6	17	17	97.88	0.030418
6	18	17	97.88	0.030418
7	31	17	98.96	0.029554
6	13	15	97.88	0.026605
6	14	15	97.88	0.026605
6	21	15	97.88	0.026605
6	5	16	96.98	0.025995
6	11	16	96.98	0.025995
6	13	16	96.98	0.025995
6	21	16	96.98	0.025995
8	7	16	95.90	0.022879
8	28	16	95.90	0.022879
6	17	14	98.96	0.015490
7	30	14	100.04	0.015044

2.3.3 Avoided Transmission Charge (ERCOT 4CP TCOS)

CPS Energy is electrically interconnected to the other electric utilities in the Electric Reliability Council of Texas (ERCOT) region, which encompasses most of Texas. All the users of the ERCOT transmission system share the annual cost of operating the high-voltage transmission system, called the ERCOT transmission cost of service (TCOS). Each user's share of the TCOS is allocated based upon their individual electrical demand during the prior year's monthly ERCOT system peak for the months of June through September, known as the four coincident peaks (4CP).

To reduce their allocated share of the ERCOT 4CP TCOS charge, CPS Energy anticipates likely 4CP events and deploys demand response resources to reduce demand accordingly. Energy efficiency measures also contribute to demand reduction during 4CP events.

To estimate gross demand reduction within each demand response program/subprogram, the estimated load reduction per participant is multiplied by the number of active participants and a "deployment success rate," the rate at which CPS Energy correctly anticipated and deployed each resource during historical 4CP events.

For energy efficiency programs, hourly load shapes for each measure provide the estimate of the impacts during 4CP event hours for each weekday during the months of June through September. Based on historical CPS Energy interval data, the 4CP has occurred in the hour ending 17 for each 4CP month since 2011. Hourly kW values are extracted from measure load shapes for the hour ending 17 for each day during the 4CP months. Finally, the 90th percentile maximum monthly value is averaged across the 4CP months to estimate the 4CP impact for each program. The CPS Energy FY 2016 evaluation saw the addition of ERCOT 4CP demand savings resulting from energy efficiency programs. In previous CPS Energy evaluations, ERCOT 4CP demand savings were calculated only for demand response programs.

3. BENEFIT – COST ANALYSIS

3.1 BENEFIT – COST TESTS OVERVIEW

Five benefit-cost tests are commonly used to assess energy efficiency and demand response programs:

1. Participant Cost Test (PCT)
2. Program Administrator Cost Test (PACT)
3. Ratepayer Impact Measure Test (RIM)
4. Total Resource Cost Test (TRC)
5. Societal Cost Test (SCT)

The outcome of each test is expressed as the ratio of the net present value of program benefits divided by the net present value of program costs. A benefit-cost ratio greater than 1.00 indicates a program's net present value of benefits outweigh the net present value of costs, in accordance with how costs and benefits are tallied within each test. In general, ratios greater than 1.00 are preferred, though ratios must always be considered alongside other motivations and goals in comprehensive program evaluation. Analyzing all five tests together provides a comprehensive view of program performance. To understand how various energy efficiency programs performed collectively, benefit-cost ratios also may be evaluated at various levels of aggregation, including, for example:

- All residential programs
- All commercial programs
- All demand response programs
- Programs under development
- All programs (total portfolio)

3.1.1 Benefit-Cost Test Components

Different benefits and costs apply to each test, as summarized in the table below.

Table 3.1-1: [Benefit-Cost Analysis] Benefit-Cost Test Components

Test Component	PCT	PACT	RIM	TRC	SCT
Net Present Value of Benefits					
Customer Rebates Received	✓				
Customer Bill Savings	✓				
Avoided Energy Costs		✓	✓	✓	✓
Avoided Capacity Costs		✓	✓	✓	✓
Avoided Transmission Charges		✓	✓	✓	✓
Avoided Price Spikes		✓	✓	✓	✓
Net Present Value of Costs					
Incremental Costs	✓			✓	✓
Utility Administrative Costs		✓	✓	✓	✓
Utility Rebate Costs		✓	✓		
Lost Revenue because of Reduced Energy Bills			✓		
Other Externalities					✓

Evaluated benefits include the following:

Customer Rebates Received are the net present value of rebates received by customers who enrolled in the program each year. In most programs, these are one-time rebate payments made during the program year, and thus are equal to the amount spent by the utility on rebates during that year. However, some programs pay participants over several years. In these cases, the benefit reflects the net present value of the projected stream of customer rebates received and is different from the amount spent during the program year.

Customer Bill Savings are the net present value of participating customers' utility bill savings projected to result from installation of program-induced measures over their expected useful life.

Avoided Energy Costs are the net present value of utility energy cost reductions projected to result from installation of program-induced measures over their expected useful life.

Avoided Capacity Costs are the net present value of utility capacity cost reductions projected to result from installation of program-induced measures over their expected useful life.

Avoided Transmission Charges are the net present value of 4CP transmission cost reductions projected to result from installation of program-induced measures over their expected useful life. The process by which these transmission costs are allocated to CPS Energy is explained in Section 2.3.3.

Avoided Price Spikes are the net present value of wholesale energy price spikes avoided by deployment of demand response resources during wholesale price spike events. This value is only calculated for demand response programs and represents the price spike value less avoided energy costs to prevent double counting avoided energy value.

Other Externalities may include the net present value of avoided environmental impacts or national security costs, induced economic development impacts, and other benefits not directly measurable at the customer's site or on the utility's system.

Evaluated costs include the following:

Incremental Costs are the difference in the cost of a base case energy efficiency measure compared to the cost of a higher efficiency alternative. It represents the incremental cost that participating customers must pay to gain the energy savings benefits from the higher efficiency measure.

Utility Administrative Costs include the net present value of all non-incentive utility costs associated with the program (for example: program overhead costs, traditional administrative costs, marketing and outreach, and similar activities).

Utility Rebate Costs are the net present value of rebates paid to customers who enrolled in the program each year. In most programs, these are one-time payments made during the program year, and thus are equal to the amount spent by the utility on rebates during that year. However, some programs pay participants over several years. In these cases, the cost reflects the net present value of the projected stream of rebate payments and is different from the amount spent during the program year.

Lost Revenue because of Reduced Energy Bills is the net present value of reductions in utility revenue projected to result from installation of program-induced measures over their expected useful life.

3.1.2 Interpreting Benefit-Cost Test Results

3.1.2.1 Participant Cost Test (PCT)

The PCT represents a comparison of the costs and benefits of a utility customer installing or implementing an energy efficiency or demand response measure. Because this test reflects the participant's perspective, it helps inform the utility as to whether a participant will be well off because of their participation.

3.1.2.2 Program Administrator Cost Test (PACT)

The PACT measures each program's potential to reduce CPS Energy's revenue requirements in the form of reduced generation capacity investments, and reduced generation production cost and purchased power requirements. Established to reflect the utility's perspective, the PACT can help a utility evaluate a program's potential contribution to overall resource cost planning objectives.

3.1.2.3 Ratepayer Impact Measure Test (RIM)

The RIM provides an indication of the additional revenues required to keep the utility's rate of return at the same level it would have experienced had it not offered the program. This test attempts to assess the impact on customers who did not participate in the program. It is important to note that, except for certain program types, many standard energy efficiency programs commonly achieve a RIM test result of less than 1.00.

3.1.2.4 Total Resource Cost Test (TRC)

The TRC is a summation of all participant and utility reduced costs (benefits) and all participant and utility increased costs. Because the TRC only incorporates costs (either avoided or expended) in its calculation, customer inducements are excluded from its calculation. Customer inducements are also transfer payments, so if utility rebates were included, participant costs would be reduced by a corresponding amount. As the TRC combines both customers' and CPS Energy's costs and benefits, it gives an indication of how the program affects both participating and non-participating customers.

3.1.2.5 Societal Cost Test (SCT)

The SCT is a variant of the TRC, with the addition of "externalities" which may include environmental impacts, effects on national security, economic development impacts, and other impacts not directly measurable at the customer's site or on the utility's system. CPS Energy currently includes a projected cost of compliance with potential future carbon emissions regulations in its avoided cost of energy, and thus has already internalized at least a portion of the externalities that would be included in the SCT.

3.2 ADDITIONAL INPUTS & ASSUMPTIONS

3.2.1 Incremental Costs

Customer investment costs (used interchangeably with “incremental costs”) are key inputs in three of the five benefit-cost tests: (1) Participant Cost Test, (2) Total Resource Cost Test, and (3) Societal Cost Test. These estimates represent the difference in cost that must be paid between a baseline measure that could have been installed and a higher efficiency measure installed. Because of the nature of most energy efficiency and demand response programs, this type of information can be very hard to estimate precisely. Ideally, invoices showing the exact cost per installation compared to a “standard” cost for a baseline installation would determine the incremental costs. However, this level of detail is not available for all installed measures, so CPS Energy uses the best estimation method for each program. Please see the program sections for additional details.

3.2.2 Estimated Useful Life

The estimated useful life (EUL) of each measure is based on Texas standards used by the state’s investor-owned utilities or other knowledge or information specific to CPS Energy. Please see the program sections for more information.

3.2.3 CPS Energy Avoided Cost Periods

CPS Energy annually calculates and provides separate avoided energy cost values for each of five different avoided cost periods for use in benefit-cost modeling. These cost periods are listed in Table 3.2-1. Energy savings associated with each energy efficiency measure are allocated into these avoided cost periods based on the measure’s load shape to calculate the value of avoided energy costs.

Table 3.2-1: [Benefit-Cost Analysis] Avoided Cost Periods

Cost Period	Description	Number of Hours
Summer On-Peak	June-September, weekday hours 14-20	602
Summer Mid-Peak	June-September, weekday hours 8-13 and 21-22, weekend hours 8-22	1,228
Summer Off-Peak	June-September, hours 1-7 and 23-24	1,098
Non-Summer Mid-Peak	January-May and October-December, weekday hours 7-22	2,736
Non-Summer Off-Peak	January-May and October-December, weekday hours 1-6 and 23-24, all weekend hours	3,096

3.2.4 Net-to-Gross Ratios

The Net-to-Gross (NTG) ratio is a factor that represents the fraction of total purchases caused by the program. The ratio may be made up of a variety of factors that capture differences between gross and net savings, commonly considering the effects of free riders (savings that would have occurred without the program, such as those deriving from customers who would implement measures without rebates but accept them because they are offered) and spillover effects (additional savings induced in customers who implement measures but do not receive rebates as a direct or indirect result of the program). CPS Energy uses NTG ratios based on previous evaluations except for the residential weatherization program, which relies upon a 100% NTG ratio industry standard used in Texas for weatherization programs.

3.2.5 Other Inputs

CPS Energy provides Frontier Energy with current and projected residential and commercial rates, avoided energy costs for each avoided cost period, avoided capacity costs for energy efficiency and demand response measures, and avoided ERCOT Transmission Cost of Service costs, over a 25-year period. CPS Energy also provides Frontier Energy with separate energy and capacity loss factors, a corporate discount rate used in financial analysis, and an estimate of avoided carbon dioxide emissions per kWh.

Frontier estimates the incremental value, over avoided summer peak avoided costs, of avoided price spikes, for use in analyzing the cost-effectiveness of demand response programs. These data are updated annually. They are competitive in nature and are not published in this Guidebook. They do not affect the estimates of kWh, NCP, CP and 4CP savings achieved by each program, but do affect the cost-effectiveness analysis of these savings.

4. RESIDENTIAL: LIGHTING

4.1 ENERGY STAR® OMNI-DIRECTIONAL LED LAMPS

4.1.1 Measure Description

This measure provides a method for calculating savings for replacement of an incandescent lamp with an ENERGY STAR-qualified omni-directional LED lamp[5] in a residential application. Using ANSI C79.1-2002 nomenclature, the applicable omni-directional LED lamp types are A, BT, P, PS, S, and T.[6]

4.1.1.1 Eligibility Criteria

These savings values rely on usage patterns specific to both indoor and outdoor applications. In lieu of collecting lamp location, a default weighting of 90.5% indoor and 9.5% outdoor may be assumed.[7]

New homes must exceed the equipment requirements of the current state building city building code (IECC 2018) to be eligible for prescriptive lighting savings.

Fixtures with integrated LEDs may be eligible under this measure using a modified baseline.

4.1.1.2 Baseline Condition

The baseline is assumed to be the first tier EISA-mandated maximum wattage for a general service or standard incandescent or halogen lamp; see Table 4.1-1. Baseline wattages should be adjusted as EISA regulations dictate higher efficiency standards. A potential second tier EISA baseline adjustment was scheduled to go into effect beginning January 2020. At that time, general service lamps would need to comply with a 45 lumen-per-watt efficacy standard. However, the Department of Energy (DOE) issued a definition for general service lamps on September 5, 2019, concluding that "no backstop energy conservation has been imposed."[8] Therefore, no additional baseline adjustment will be imposed starting in 2020. However, standard practice must also be considered in determining an appropriate baseline for this measure. To account for a rapidly changing market, measure life assumptions have been reduced as described later in this measure.

New construction applications use the same baselines; however, savings can only be claimed for efficient lighting installed above the minimum amount required by code. Current code dictates 75% high-efficacy lighting. Therefore, if 100% of installed lighting is high-efficacy, savings can be claimed for the remaining 25% of installed lamps.

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[5] According to ENERGY STAR omni-directional LED products "…shall have an even distribution of luminous intensity (candelas) within the 0° to 135° zone (vertically axially symmetrical). Luminous intensity at any angle within this zone shall not differ from the mean luminous intensity for the entire 0° to 135° zone by more than 20%. At least 5% of total flux (lumens) must be emitted in the 135°-180° zone. Distribution shall be vertically symmetrical as measured in three vertical planes at 0°, 45°, and 90°." http://www.energystar.gov/ia/partners/product_specs/program_reqs/Integral_LED_Lamps_Program_Requirements.pdf.

[6] ENERGY STAR qualified product listing: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

[7] 2015 U.S. Lighting Market Characterization, Department of Energy. November 2017. Table 4.11. https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

[8] "Energy Conservation Program: Definition for General Service Lamps," Department of Energy. 9/5/2019. https://www.federalregister.gov/documents/2019/09/05/2019-18940/energy-conservation-program-definition-for-general-service-lamps.

Due to the variability among fixture types compared to screw-in lamps, qualified fixtures with integrated LEDs should use the rated installed wattage and equivalent wattage, or other approved custom methodology, in lieu of the deemed values outlined in the following table.

Table 4.1-1: [Omni-Directional LEDs] Baseline Wattage[9]

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Wattage Pre-EISA 2007	First Tier EISA 2007 (W_{base})[10]	Default W_{Post}[11] (if unknown)
250	309	25	Exempt	3.5
310	749	40	29	5.5
750	1,049	60	43	9.0
1,050	1,489	75	53	11.5
1,490	2,600	100	72	15.0
2,601	3,300	150	Exempt[12]	22.5

4.1.1.3 High-Efficiency Condition

LEDs must be ENERGY STAR-qualified[13] for the relevant lamp shape being installed as outlined in the latest ENERGY STAR specification.[14] Using ANSI C79.1-2002 nomenclature, the applicable omni-directional LED lamp types are A, BT, P, PS, S, and T.

The high-efficiency condition is the wattage of the replacement lamp.

4.1.2 Energy and Demand Savings Methodology

4.1.2.1 Savings Algorithms and Input Variables

Wattage reduction is defined as the difference between the wattage of a standard baseline lamp according to EISA 2007 (Table 4.1-1) and the wattage of a comparable omni-directional LED. An LED is considered comparable to the baseline lamp if they are aligned on the lumen output ranges set out in EISA 2007.

For new construction projects, programs should calculate savings using the methodology in this section for all efficient lamps installed in the home. The program should claim savings for the percentage of installed high-efficacy lamps that exceed the minimum required by code, which is currently 75% of lamps. For example, if a new home is built with high-efficacy lamps in 85% of the permanently installed

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[9] Federal standard for General Service Incandescent Lamps (GSILs): https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=20.

[10] If exempt, refer to incandescent equivalent wattage.

[11] Average rated wattage from ENERGY STAR qualified product listing rounded to nearest half-watt: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

[12] EISA 2007 specified that this lumen range was subject to a forthcoming efficiency standard that has not yet been finalized.

[13] ENERGY STAR qualified product listing: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

[14] http://www.energystar.gov/products/certified-products/detail/light-bulbs.

fixtures, the program would claim 10% of the total calculated savings.

Energy Savings

Annual energy (kWh) savings are calculated as follows.

$$\Delta kWh = \frac{(W_{base} - W_{post})}{1{,}000} \times HOU \times ISR \times IEF_E$$

Equation 4.1-1

Where:

W_{base} = *Baseline wattage corresponding with the lumen output of the purchased LED lamp for the year purchased/installed. Reduced baselines are provided for EISA-compliant lamps in Table 4.1-1.*

W_{post} = *Actual wattage of LED purchased/installed (if unknown, use default wattages from Table 4.1-1).*

HOU = *Average hours of use per year = 803 hours (for interior/exterior applications calculated based on an average daily usage of 2.2 hours per day[15]).*

IEF_E = *Interactive Effects Factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions; see*

Table 4.1-2.

ISR = *In-Service Rate, the percentage of incentivized units that are installed and in use (rather than removed, stored, or burnt out) to account for units incentivized but not operating = 0.97.[16]*

1,000 = *Constant to convert from watts to kilowatts.*

Table 4.1-2: [Omni-Directional LEDs] Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties[17]

Heating/Cooling Type[18]	IEF_E
Gas Heat with AC	1.17
Gas Heat with no AC	1.00
Heat Pump	1.05
Electric Resistance Heat with AC	0.90

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[15] The average daily usage of 2.2 hours per day is a blended value for indoor and outdoor lamps. Source: Evaluation of 2008 Texas 'Make Your Mark' Statewide CFL Program Report. Frontier Associates. June 2009.

[16] Dimetrosky, S., Parkinson, K. and Lieb, N. "Residential Lighting Evaluation Protocol – The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures." January 2015. ISR for upstream programs, including storage lamps installed within four years of purchase. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf.

[17] Extracted from BEopt energy models used to estimate savings for envelope measures. Referencing the EISA baseline table, the typical lumen output was determined by taking the midpoint for the 60-watt equivalent lamp (900 lm), which was assumed to be the most typical installation. The resulting lumens were divided by the default wattage for incandescents (43 W), CFLs (13 W), and LEDs (10 W) resulting in an assumed efficacy for incandescents (21 lm/W), CFLs (70 lm/W), and LEDs (90 lm/W). IEF values were calculated using the following formula: 1 + $HVAC_{savings}/Lighting_{savings}$.

[18] IEF values for homes with no AC are most appropriate for customers with evaporative cooling or room air conditioners.

Heading/Cooling Type[18]	IEF$_E$
Electric Resistance Heat with no AC	0.76
No heat with AC	1.17
Unconditioned Space	1.00
Heating/Cooling Unknown/Upstream[19]	1.04

Demand Savings

Demand savings are determined by applying a demand factor corresponding to the demand type.

$$\Delta kW_{summer} = \frac{(W_{base} - W_{post})}{1,000} \times DF_{summer} \times ISR \times IEF_D$$

Equation 4.1-2

Where:

DF = Demand Factor for NCP, CP, or 4CP peak demand; see

Table 4.1-3.

IEF$_D$ = Interactive Effects Factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions; see Table 4.1-4.

Table 4.1-3: [Omni-Directional LEDs] Demand Factors[20]

Factor Type	Demand Factor
NCP	0.399
CP	0.056
4CP	0.094

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[19] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% outdoor lighting except for upstream defaults. Cadmus report: Cadmus. Entergy Energy-Efficiency Portfolio Evaluation Report 2013 Program Year. Prepared for Entergy Arkansas, Inc. March 14, 2014. Docket No. 07-082-TF.

[20] Demand Factors were derived according to the method outlined in Section 2.3 using the load shape found in Section 22.2.

Table 4.1-4: [Omni-Directional LEDs] Interactive Effects Factor for Cooling Demand Savings and Heating Energy Penalties[21]

Heating/Cooling Type[22]	$IEF_{D,NCP}$	$IEF_{D,CP/4CP}$
Gas Heat with AC	1.17	1.68
Gas Heat with no AC	1.00	1.00
Heat Pump	1.05	1.68
Electric Resistance Heat with AC	0.90	1.68
Electric Resistance Heat with no AC	0.76	1.00
No heat with AC	1.17	1.68
Unconditioned Space	1.00	1.00
Heating/Cooling Unknown/Upstream[23]	1.04	1.58

Upstream/Midstream Program Assumptions

All general service lamps with an equivalent wattage of 100 W or lower distributed through upstream or midstream programs should utilize a 95/5% savings allocation between residential and non-residential sectors, with 95% allocated to the residential sector and the remaining 5% allocated to the commercial sector.[24] This can be accomplished by multiplying the residential savings by a 0.95 factor and the non-residential savings by a 0.05 factor.

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Building America House Simulation Protocols hourly and monthly profiles for residential lighting usage converted to a peak demand factor profile. The load shape can be found in Section 22.2 Load Shapes.

4.1.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

4.1.2.3 Deemed Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

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[21] Refer to
Table 4.1-2.

[22] IEF values for homes with no AC are most appropriate for customers with evaporative cooling or room air conditioners.

[23] Refer to
Table 4.1-2.

[24] Weighting assumptions based on evaluator review of LED purchasing behavior for similar program designs as referenced in the 2018 EM&V upstream lighting memo.

4.1.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

4.1.2.5 Measure Life and Lifetime Savings

Historically, the average measure life is based upon rated lamp life of the LED. The measure life assumes an average use of 2.2 hours per day based on blended usage for indoor/outdoor applications and applies a 0.85 degradation factor to indoor/outdoor LEDs.

$$\boldsymbol{EUL = \frac{Rated\ Life \times DF}{HOU \times 365.25}}$$

Equation 4.1-3

Where:

$Rated\ Life$ = *10,000 hours, 12,000 hours, 15,000 hours, or 20,000 hours, as specified by the manufacturer. If unknown, assume a 10,000-hour lifetime.*[25]

DF = *0.85 degradation factor.*[26]

HOU = *2.2 hours per day.*[27]

However, to account for a rapidly changing market, standard practice dictates that measure life assumptions be reduced to approximate the point at which the residential lighting market has been fully transformed to high-efficiency lamps. Due to market uncertainty in response to a recent rule issued by the Department of Energy, a simplified approach to claim half of the more conservative 16-year EUL will be implemented during fiscal year 2021, resulting in an 8-year EUL. This assumption will be reviewed annually to account for current market trends.

Based on an expected delay in market adoption among certain customer bases, the EUL is extended to 10 years for programs targeting low income and hard-to-reach customers.

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[25] Minimum lifetime requirement under ENERGY STAR Lamps Specification V1.1, effective September 30, 2014. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf.

[26] ENERGY STAR CFL Third Party Testing and Verification Off-the-Shelf CFL Performance: Batch 3. Figure 27, p. 47.

[27] The average daily usage of 2.2 hours per day is a blended value for indoor and outdoor lamps. Source: Evaluation of 2008 Texas 'Make Your Mark' Statewide CFL Program Report. Frontier Associates. June 2009.

Table 4.1-5: [Omni-Directional LEDs] Estimated Useful Life

Range of Rated Product Lifetime (Hours)	Assumed Rated Product Lifetime (Hours)	Rated Product Lifetime (Years)	Standard Baseline Measure Life (Years)	Low Income Baseline Measure Life (Years)
≤ 17,500	15,000	16	8	10
> 17,500	20,000	20[28]	8	10

4.1.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Number of LEDs installed
- Baseline and rated wattage for each replacement LED
- Lumen output of each replacement LED
- Manufacturer-rated lifetime of each replacement LED in hours
- Home cooling system type (refrigerated, evaporative, none)
- Home heating system type (gas, electric resistance, heat pump, none)
- Location of replacement lamp (conditioned, unconditioned, outdoor); only required when not assuming default weighting
- Proof of purchase with date of purchase and quantity
    - Alternative: representative photos of replacement lamps or another pre-approved method of installation verification
- ENERGY STAR certificate matching replacement model number
    - Alternative: another pre-approved method of certification (e.g., LM-79, LM-80, TM-21, and ISTMT lab reports)
- For new construction projects only, these data points must be gathered for all permanently installed lamps in the home to document the percentage that are high-efficacy

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[28] Measure life capped at 10 years. EUL may be deemed at 8 years in lieu of documenting customer baseline.

4.2 ENERGY STAR® SPECIALTY AND DIRECTIONAL LED LAMPS

4.2.1 Measure Description

This measure provides a method for calculating savings for replacement of an incandescent or halogen reflector or decorative lamp with an ENERGY STAR-qualified LED lamp in a residential application. These lamps include reflectors, G-shape lamps, T-shape lamps, B, BA, CA, F, G16-1/2, G25, G30, S or M14 lamps.[29]

4.2.1.1 Eligibility Criteria

These savings values rely on usage patterns specific to both indoor and outdoor applications. In lieu of collecting lamp location, a default weighting of 90.5% indoor and 9.5% outdoor may be assumed.[30]

New homes must exceed the equipment requirements of the current state building city building code (IECC 2018) to be eligible for prescriptive lighting savings.

Fixtures with integrated LEDs may be eligible under this measure using a modified baseline.

4.2.1.2 Baseline Condition

The baseline wattage will be determined based on the bulb shape of the installed lamp as outlined below. New construction applications use the same baselines; however, savings can only be claimed for efficient lighting installed above the minimum amount required by code. Current code dictates 75% high-efficacy lighting. Therefore, if 100% of installed lighting is high-efficacy, savings can be claimed for the remaining 25% of installed lamps.

Due to the variability among fixture types compared to screw-in lamps, qualified fixtures with integrated LEDs should use the rated installed wattage and equivalent wattage, or other approved custom methodology, in lieu of the deemed values outlined in the following table.

Some baseline conditions for specialty LEDs are affected by EISA and/or a DOE 2009 ruling on incandescent reflector lamps (IRLs). Based on the shape, lumen output, and/or wattage-equivalent of the installed lamp, the appropriate baseline shall be determined from one of the following categories. Appropriate baseline wattages are presented in Table 4.2-1 through Table 4.2-3. If a baseline cannot be determined using these tables, the following guidelines may be used to determine appropriate default baseline wattage:

- Non-Reflector Lamps, affected by EISA 2007: using the rated lumen output of the installed LED, determine the appropriate first tier EISA baseline default wattage from Table 4.2-1.
- Non-Reflector lamps, not affected by EISA 2007: nameplate wattage of removed product; if unknown, use ENERGY STAR rated equivalent wattage of installed LED.

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[29] ENERGY STAR qualified product listing: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

[30] 2015 U.S. Lighting Market Characterization, Department of Energy. November 2017. Table 4.11. https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

- Reflector lamps affected by the DOE ruling in 2009 on IRLs: using the rated lumen output of the installed LED, determine the appropriate first tier EISA baseline default wattage from Table 4.2-3.
- Reflector lamps not affected by the DOE ruling in 2009 on IRLs: nameplate wattage of removed product; if unknown, use ENERGY STAR rated equivalent wattage of installed LED.

EISA Standards: Baseline for Non-Reflector Lamps

EISA-affected[31]

EISA-affected bulbs are:

- G-shape lamps with a diameter less than 5 inches
- T-shape lamps greater than 40 watts or with a length of 10 inches or less
- B, BA, CA, F, G16-1/2, G25, G30, S or M14 lamps greater than 40 watts

Table 4.2-1: [Specialty LEDs] General Service Non-Reflector Baseline Wattage[32]

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Wattage	1st Tier EISA 2007 (W_{Base})	Default W_{Post}[33] (if unknown)
250	309	25	Exempt	3.5
310	749	40	29	5.5
750	1,049	60	43	9.0
1,050	1,489	75	53	11.5
1,490	2,600	100	72	15.0
2,601	3,300	150	Exempt[34]	22.5

EISA-exempt[35]

EISA-exempt bulbs are:

- Appliance lamps, black light lamps, bug lamps, colored lamps, infrared lamps, left-hand thread lamps, marine lamps, marine signal service lamps, mine service lamps, plant light lamps, reflector lamps, rough service lamps, shatter-resistant lamps, sign service lamps, silver bowl

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[31] Energy Independence and Security Act of 2007, Subtitle B – Lighting Energy Efficiency, Section 321 Efficient Light Bulbs. https://www.govinfo.gov/content/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf.

[32] Federal standard for General Service Incandescent Lamps (GSILs): https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=20.

[33] Average rated wattage from ENERGY STAR qualified product listing rounded to nearest half-watt: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

[34] EISA 2007 specified that this lumen range was subject to a forthcoming efficiency standard that has not yet been finalized.

[35] Energy Independence and Security act of 2007 (EISA 2007), https://www.govinfo.gov/content/pkg/PLAW-110publ140/pdf/PLAW-110publ140.pdf.

lamps, showcase lamps, 3-way incandescent lamps, and vibration service lamps

- G-shape lamp with a diameter of 5 inches or more
- T-shape lamp of 40 watts or less or a length of more than 10 inches
- B, BA, CA, F, G16-1/2, G25, G30, S or M14 lamp of 40 watts or less

Table 4.2-2: [Specialty LEDs] Decorative Non-Reflector Baseline Wattage[36]

Lamp Type	Minimum Lumens	Maximum Lumens	W_{Base}	Default W_{Post}[37] (if unknown)
3-Way	250	349	25	3.0
	350	499	40	5.0
	500	849	60[38]	8.0
	850	1,199	75[39]	10.5
	1,200	1,999	100	14.5
	2,000	--	150	22.0
G-shape w/ diameter > 5 inches[40]	--	--	--	--
Decorative (B, BA, CA, F, S, T)	120	159	15[41]	1.5
	160	299	25	2.5
	300	499	40	4.5
	500	--	60	5.5

DOE Standards for Incandescent Reflector Lamps (IRLs): Baseline for Reflector Lamps

DOE Ruling-affected[42]

Certain types of incandescent reflector bulbs are affected by a DOE 2009 ruling on reflector lamps. Products affected by the IRL ruling are:

- R, PAR, ER, BR, BPAR lamps

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[36] Federal standard for General Service Incandescent Lamps (GSILs): https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=20.

[37] Average rated wattage from ENERGY STAR qualified product listing rounded to nearest half-watt: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

[38] No products for this equivalent wattage are available on the ENERGY STAR qualified product listing. Lumen range for this row is split evenly and default wattage is interpolated between the available categories.

[39] Ibid.

[40] G-shape lamps are not included because there were very few ENERGY STAR qualified products with a diameter of 5 inches or more. For these products, use the equivalent and rated wattages from the ENERGY STAR certification.

[41] The 15-watt equivalent category only applies to lamps with a candelabra base.

[42] Federal standard for Incandescent Reflector Lamps (IRLs): https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=23.

- BR and ER lamps rated at more than 50 watts
- Reflector lamps between 2.25” (R18) and 2.75” (R22) in diameter
- 40–205-watt incandescent PAR lamps

Where available, the nameplate wattage of the removed lamp should be used as the baseline. Otherwise, the baseline wattage can be determined according to the lumen range of the installed lamp; see Table 4.2-3.

DOE Ruling-exempt[43]

The DOE 2009 ruling standards do not apply to the following types of IRLs:

- IRLs rated at 50 watts or less that are ER30, BR30, BR40, or ER40 lamps
- IRLs rated at 65 watts that are BR30, BR40, or ER40 lamps
- R20 IRLs rated 45 watts or less

Table 4.2-3: [Specialty LEDs] Reflector Baseline Wattage[44]

Lamp Type[45]	Minimum Lumens	Maximum Lumens	Incandescent Equivalent Wattage	1st Tier EISA 2007 (W_{Base})	Default W_{Post}[46] (if unknown)
BR30	500	649	50	50	7.5
	650	949	65	65	9.0
	950	1,099	75	75	12.5
	1,000	1,199	85	85	12.5
	1,200	1,399	90	90	16.5
	1,400	--	100	100	18.0
BR40	650	924	65	65	10.0
	925	1,099	75	75	12.5
	1,100	1,299	85	85	14.0
	1,300	1,399	90	90	15.5
	1,400	1,749	100	100	17.0
	1,750	2,174	120	120	22.0

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[43] Ibid.

[44] Federal standard for Incandescent Reflector Lamps (IRLs): https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=23.

[45] Lamp types excluded from this table were not included on the ENERGY STAR qualified product listing. For missing lamp types, refer to the equivalent and rated wattages from the ENERGY STAR certification.

[46] Average rated wattage from ENERGY STAR qualified product listing rounded to nearest half-watt: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

Lamp Type[45]	Minimum Lumens	Maximum Lumens	Incandescent Equivalent Wattage	1st Tier EISA 2007 (W_{Base})	Default W_{Post}[46] (if unknown)
	2,175	--	150	150	22.0
MR16/ MRX16	250	349	20	20	4.5
	350	449	35	35	6.0
	450	499	42	42	6.5
	500	574	50	50	7.0
	575	--	75	75	8.5
PAR16	250	349	20	20	3.5
	350	424	35	35	4.5
	425	499	40	40	5.5
	500	574	45	45	5.5
	575	649	50	50	6.5
	650	749	60	60	6.5
	750	--	75	75	7.5
PAR20	400	800	50	50	7.0
PAR30/ PAR30L/ PAR30S	500	899	50	50	11.5
	900	--	75	75	11.5
PAR38	500	649	45	45	7.0
	650	799	75	75	14.0
	800	999	90	90	14.0
	1,000	1,499	100	100	14.5
	1,500	1,999	120	120	16.0
	2,000	--	150	150	19.0
R14	250	299	25	25	4.0
R16	300	399	30	30	4.0
	400	474	40	40	5.5
	475	549	45	45	6.0

Lamp Type[45]	Minimum Lumens	Maximum Lumens	Incandescent Equivalent Wattage	1st Tier EISA 2007 (W_{Base})	Default W_{Post}[46] (if unknown)
	550	--	50	50	7.0
R20	300	399	30	30	4.5
	450	524	45	45	6.0
	525	649	50	50	7.0
	650	899	60	60	9.0
	900	1,399	75	75	12.5
	1,400	--	100	100	14.0

4.2.1.3 High-Efficiency Condition

LEDs must be ENERGY STAR-qualified[47] for the relevant lamp shape being removed as outlined in the latest ENERGY STAR specification.[48] These lamps include reflectors, G-shape lamps, T-shape lamps, B, BA, CA, F, G16-1/2, G25, G30, S or M14 lamps.

The high-efficiency condition is the wattage of the replacement lamp.

4.2.2 Energy and Demand Savings Methodology

4.2.2.1 Savings Algorithms and Input Variables

Wattage reduction is defined as the difference between the wattage of a specialty baseline lamp and the wattage of a directional or specialty LED.

For new construction projects, programs should calculate savings using the methodology in this section for all efficient lamps installed in the home. The program should claim savings for the percentage of installed high-efficacy lamps that exceed the minimum required by code, which is currently 75% of lamps. For example, if a new home is built with high-efficacy lamps in 85% of the permanently installed fixtures, the program would claim 10% of the total calculated savings.

Energy Savings

$$\Delta kWh = \frac{(W_{base} - W_{post})}{1,000} \times HOU \times ISR \times IEF_E$$

Equation 4.2-1

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[47] ENERGY STAR qualified product listing: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

[48] ENERGY STAR specification: http://www.energystar.gov/products/certified-products/detail/light-bulbs.

Where:

W_{base} = *Baseline wattage corresponding with the lumen output of the purchased LED lamp for the year purchased/installed. Reduced baselines are provided for EISA-compliant lamps in Table 4.2-1 through Table 4.2-3.*

W_{post} = *Actual wattage of LED purchased/installed (if unknown, use default wattages from Table 4.2-1 through Table 4.2-3).*

HOU = *Average hours of use per year = 803 hours (for interior/exterior applications calculated based on an average daily usage of 2.2 hours per day[49]).*

IEF_E = *Interactive Effects Factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions; see Table 4.2-4.*

ISR = *In-Service Rate, the percentage of incentivized units that are installed and in use (rather than removed, stored, or burnt out) to account for units incentivized but not operating = 0.97.[50]*

1,000 = *Constant to convert from watts to kilowatts.*

Table 4.2-4: [Specialty LEDs] Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties[51]

Heating/Cooling Type[52]	IEF_E
Gas Heat with AC	1.17
Gas Heat with no AC	1.00
Heat Pump	1.05
Electric Resistance Heat with AC	0.90
Electric Resistance Heat with no AC	0.76
No heat with AC	1.17
Unconditioned Space	1.00
Heating/Cooling Unknown/Upstream[53]	1.04

Demand Savings

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[49] The average daily usage of 2.2 hours per day is a blended value for indoor and outdoor lamps. Source: Evaluation of 2008 Texas 'Make Your Mark' Statewide CFL Program Report. Frontier Associates. June 2009.

[50] Dimetrosky, S., Parkinson, K. and Lieb, N., "Residential Lighting Evaluation Protocol – The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures." January 2015. ISR for upstream programs, including storage lamps installed within four years of purchase. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf.

[51] Extracted from BEopt energy models used to estimate savings for envelope measures. Referencing the EISA baseline table, the typical lumen output was determined by taking the midpoint for the 60-watt equivalent lamp (900 lm), which was assumed to be the most typical installation. The resulting lumens were divided by the default wattage for incandescents (43 W), CFLs (13 W), and LEDs (10 W) resulting in an assumed efficacy for incandescents (21 lm/W), CFLs (70 lm/W), and LEDs (90 lm/W). IEF values were calculated using the following formula: $1 + HVAC_{savings}/Lighting_{savings}$.

[52] IEF values for homes with no AC are most appropriate for customers with evaporative cooling or room air conditioners.

[53] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% outdoor lighting except for upstream defaults. Cadmus report: Cadmus. Entergy Energy-Efficiency Portfolio Evaluation Report 2013 Program Year. Prepared for Entergy Arkansas, Inc. March 14, 2014. Docket No. 07-082-TF.

Demand savings are determined by applying a demand factor corresponding to the demand type.

$$\Delta kW_{summer} = \frac{(W_{base} - W_{post})}{1{,}000} \times DF_{summer} \times ISR \times IEF_D$$

Equation 4.2-2

Where:

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 4.2-5.*

IEF_D = *Interactive Effects Factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions; see Table 4.2-6.*

Table 4.2-5: [Specialty LEDs] Demand Factors[54]

Factor Type	Demand Factor
NCP	0.399
CP	0.056
4CP	0.094

Table 4.2-6: [Specialty LEDs] Interactive Effects Factor for Cooling Demand Savings and Heating Energy Penalties[55]

Heating/Cooling Type[56]	$IEF_{D,NCP}$	$IEF_{D,CP/4CP}$
Gas Heat with AC	1.17	1.68
Gas Heat with no AC	1.00	1.00
Heat Pump	1.05	1.68
Electric Resistance Heat with AC	0.90	1.68
Electric Resistance Heat with no AC	0.76	1.00
No heat with AC	1.17	1.68
Unconditioned Space	1.00	1.00
Heating/Cooling Unknown/Upstream[57]	1.04	1.58

Upstream/Midstream Program Assumptions

All general service and reflector lamps with an equivalent wattage of 100 W or lower distributed through upstream or midstream programs should utilize a 95/5% savings allocation between residential

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[54] Demand Factors were derived according to the method outlined in Section 2.3 using the load shape found in Section 22.2.

[55] Refer to Table 4.2-4.

[56] IEF values for homes with no AC are most appropriate for customers with evaporative cooling or room air conditioners.

[57] Refer to Table 4.2-4.

and non-residential sectors, with 95% allocated to the residential sector and the remaining 5% allocated to the commercial sector.[58] This can be accomplished by multiplying the residential savings by a 0.95 factor and the non-residential savings by a 0.05 factor.

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Building America House Simulation Protocols hourly and monthly profiles for residential lighting usage converted to a peak demand factor profile. The load shape can be found in Section 22.2.

4.2.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

4.2.2.3 Deemed Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

4.2.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

4.2.2.5 Measure Life and Lifetime Savings

Historically, the average measure life is based upon rated lamp life of the LED. The measure life assumes an average use of 2.2 hours per day based on blended usage for indoor/outdoor applications and applies a 0.85 degradation factor to indoor/outdoor LEDs.

$$\boldsymbol{EUL = \frac{Rated\ Life \times DF}{HOU \times 365.25}}$$

Equation 4.2-3

Where:

$Rated\ Life$ = *10,000 hours, 12,000 hours, 15,000 hours, or 20,000 hours, as specified by the manufacturer. If unknown, assume a 10,000-hour lifetime.*[59]

DF = *0.85 degradation factor.*[60]

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[58] Weighting assumptions based on evaluator review of LED purchasing behavior for similar program designs as referenced in the 2018 EM&V upstream lighting memo.

[59] Minimum lifetime requirement under ENERGY STAR Lamps Specification V1.1, effective September 30, 2014. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf.

[60] ENERGY STAR CFL Third Party Testing and Verification Off-the-Shelf CFL Performance: Batch 3. Figure 27, p. 47.

$HOU = 2.2 \text{ hours per day.}$[61]

EISA Compliant Lamps

To account for a rapidly changing market, standard practice dictates that measure life assumptions be reduced to approximate the point at which the residential lighting market has been fully transformed to high-efficiency lamps. Due to market uncertainty in response to a recent rule issued by the Department of Energy, a simplified approach to claim half of the more conservative 16-year EUL will be implemented during fiscal year 2021, resulting in an 8-year EUL. This assumption will be reviewed annually to account for current market trends.

Based on an expected delay in market adoption among certain customer bases, the EUL is extended to 10 years for programs targeting low income and hard-to-reach customers.

These reductions do not apply to specialty lamps.

Table 4.2-7: [Specialty LEDs] Estimated Useful Life

Range of Rated Product Lifetime (Hours)	Assumed Rated Product Lifetime Assumed (Hours)	Rated Product Lifetime (Years)	Standard Baseline Measure Life (Years)	Low Income Baseline Measure Life (Years)
≤ 17,500	15,000	16	8	10
> 17,500	20,000	20[62]	8	10

4.2.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Number of LEDs installed
- ANSI C79.1-2002 nomenclature of CFL installed (G40, PAR, etc.)
- Baseline calculation methodology (replaced lamp nameplate wattage, EISA-affected non-reflector, EISA-exempt non-reflector, DOE ruling-affected reflector, DOE ruling-exempt reflector, manufacturer-rated equivalent incandescent wattage, or default wattage)
- Baseline and rated wattage of each replacement LED
- Lumen output of each replacement LED
- Manufacturer-rated lifetime of each replacement LED in hours
- Home cooling system type (refrigerated, evaporative, none)
- Home heating system type (gas, electric resistance, heat pump, none)
- Location of replacement lamp (conditioned, unconditioned, outdoor); only required when not

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[61] The average daily usage of 2.2 hours per day is a blended value for indoor and outdoor lamps. Source: Evaluation of 2008 Texas 'Make Your Mark' Statewide CFL Program Report. Frontier Associates. June 2009.

[62] Measure life capped at 20 or 10 years depending on the applicable baseline. EUL may be deemed at 16 or 8 years in lieu of collecting manufacturer rated life or documenting customer baseline for EISA compliant lamps

assuming default weighting

- Proof of purchase with date of purchase and quantity
  - Alternative: representative photos of replacement lamps or another pre-approved method of installation verification
- ENERGY STAR certificate matching replacement model number
  - Alternative: another pre-approved method of certification (e.g., LM-79, LM-80, TM-21, and ISTMT lab reports)
- For new construction projects only, these data points must be gathered for all permanently installed lamps in the home to document the percentage that are high-efficacy

5. RESIDENTIAL: HEATING, VENTILATION, AND AIR CONDITIONING

5.1 AIR CONDITIONER AND HEAT PUMP TUNE-UPS

5.1.1 Measure Description

This measure applies to central air conditioners (AC) and heat pumps (HP) of any configuration where all applicable actions from the checklist below are completed. An AC tune-up involves checking, cleaning, adjusting, and resetting the equipment to factory conditions to restore operating efficiencies, on average, closer to as-new performance. This measure applies to all residential applications.

For this measure, the service technician must complete the following tasks according to industry best practices. To properly assess and adjust the refrigerant charge level, the unit must be operating under significant (normal) cooling load conditions. Therefore, this measure may only be performed for energy savings reporting purposes when the outdoor ambient dry bulb temperature is above 75˚F, and the indoor return air dry bulb temperature is above 70˚F.

Air Conditioner Inspection and Tune-Up Checklist[63]

- Tighten all electrical connections; measure motor voltage and current.
- Lubricate all moving parts, including motor and fan bearings.
- Inspect and clean the condensate drain.
- Inspect controls of the system to ensure proper and safe operation. Check the startup/shutdown cycle of the equipment to ensure the system starts, operates, and shuts off properly.
- Clean evaporator and condenser coils.
- Clean indoor blower fan components.
- Inspect and clean or change air filters; replacement preferred best practice.
- Measure airflow via static pressure across the cooling coil and adjust to manufacturer specifications.
- Check refrigerant level and adjust to manufacturer specifications.
- Check capacitor functionality and capacitance; compare to original equipment manufacturer (OEM) specifications.

5.1.1.1 Eligibility Criteria

All residential customers are eligible for this measure if they have refrigerated air conditioning 65,000 Btu/hr or less in cooling capacity that has not been serviced in the last 5 years.

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[63] Based on ENERGY STAR HVAC Maintenance Checklist. https://www.energystar.gov/campaign/heating_cooling/maintenance_checklist.

5.1.1.2 Baseline Condition

The baseline is a system with some or all the following issues:

- Dirty condenser coil
- Dirty evaporator coil
- Dirty blower wheel
- Dirty filter
- Improper airflow
- Incorrect refrigerant charge

The baseline system efficiency should be calculated using the following formulas:

$$\boldsymbol{EER_{pre} = (1 - EL) \times EER_{post}}$$

Equation 5.1-1

$$\boldsymbol{HSPF_{pre} = (1 - EL) \times HSPF_{post}}$$

Equation 5.1-2

Where:

EER_{pre} = *Efficiency of the cooling equipment before tune-up.*

EL = *Efficiency loss because of dirty coils, blower, filter, improper airflow, and/or incorrect refrigerant charge = 0.05.*

EER_{post} = *Deemed cooling efficiency of the equipment after tune-up = 11.2 EER.*

$HSPF_{pre}$ = *Heating efficiency of the air source heat pump before tune-up.*

$HSPF_{post}$ = *Deemed heating efficiency of air source heat pumps after tune-up = 7.7 HSPF.*

Note: The efficiency loss factor specified above may be replaced with program specific values if an M&V plan and efficiency loss factor derivation are provided to the evaluation team. These factors will be subject to review at the end of each fiscal year and may be revised for the next fiscal year.

5.1.1.3 High-Efficiency Condition

After the tune-up, the equipment must be clean with airflows and refrigerant charges adjusted as appropriate and set forth above, with the added specification that refrigerant charge adjustments must be within +/- 3 degrees of target sub-cooling for units with thermal expansion valves (TXV) and +/- 5 degrees of target super heat for units with fixed orifices or capillary tubes.

The efficiency standard, or efficiency after the tune-up, is deemed to be the manufacturer specified energy efficiency ratio (EER) of the existing central air conditioner or heat pump, which has been determined using the following logic and standards. The useful life of an AC unit is 19 years. The useful life of a heat pump is 16 years. Therefore, it is conservatively thought that the majority of existing, functioning units were installed under the federal standard in place between January 23, 2006 and

January 1, 2015, which set a baseline of 13 SEER and 7.7 HSPF.[64] A 13 SEER is equivalent to approximately 11.2 EER[65] using the conversion developed by Lawrence Berkeley Lab and US DOE: EER = -0.02 x SEER^2 + 1.12 x SEER.

5.1.2 Energy and Demand Savings Methodology

5.1.2.1 Savings Algorithms and Input Variables

Savings are based on an assumed efficiency loss factor of 5% because of dirty coils, dirty filters, improper airflow, and/or incorrect refrigerant charge.[66]

Energy Savings

Heating energy savings are only applicable to heat pumps.

$$\boldsymbol{Energy\ Savings\ [kWh_{savings}] = kWh_{Savings,C} + kWh_{Savings,H}}$$

Equation 5.1-3

$$\boldsymbol{Energy\ (Cooling)\ [kWh_{Savings,C}] = Capacity_C \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right) \times \frac{EFLH_C}{1{,}000}}$$

Equation 5.1-4

$$\boldsymbol{Energy\ (Heating)\ [kWh_{Savings,H}] = Capacity_H \times \left(\frac{1}{HSPF_{pre}} - \frac{1}{HSPF_{post}}\right) \times \frac{EFLH_H}{1{,}000}}$$

Equation 5.1-5

Where:

$Capacity_C$ = *Rated cooling capacity of the equipment based on model number [Btuh] (1 ton = 12,000 Btuh).*

$Capacity_H$ = *Rated heating capacity of the equipment based on model number [Btuh] (1 ton = 12,000 Btuh).*

EER_{pre} = *Cooling efficiency of the equipment pre-tune-up using Equation 5.1-1 [Btuh/W].*

EER_{post} = *Cooling efficiency of the equipment after the tune-up [Btuh/W]. Assume 11.2.*

$HSPF_{pre}$ = *Heating efficiency of the equipment pre-tune-up using Equation 5.1-2 [Btuh/W].*

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[64] Code specified HSPF from federal standard effective January 23, 2006 through January 1, 2015.

[65] Code specified 13 SEER from federal standard effective January 23, 2006 through January 1, 2015, converted to EER using EER = -0.02 x SEER^2 + 1.12 x SEER. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

[66] Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research." https://focusonenergy.com/sites/default/files/centralairconditioning_report.pdf.

$HSPF_{post}$ = *Heating efficiency of the equipment after the tune-up [Btuh/W]. Assume 7.7.*

$EFLH_C$ = *Cooling equivalent full-load hours [hours] Use 2,237 hours in San Antonio.*

$EFLH_H$ = *Heating equivalent full-load hours [hours] Use 1,101 hours in San Antonio.*

1,000 = *Constant to convert from watts to kilowatts.*

Demand Savings

Summer savings are determined by applying a demand factor.

$$\boldsymbol{Summer\ Peak\ Demand\ [kW_{Savings,C}] = Capacity_C \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right) \times \frac{DF}{1,000}}$$

Equation 5.1-6

Where:

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 5.1-1.*

1,000 = *Constant to convert from watts to kilowatts.*

Table 5.1-1: [AC/HP Tune-up] Demand Factors

Peak Type	Demand Factors
NCP	1.000
CP	0.935
4CP	0.871

Load Shapes

The demand factors were derived according to the method outlined in Section 2.3 using a load shape extracted from NREL's BEopt energy simulation models developed for the residential envelope measures. The load shape can be found in Section 22.2.

5.1.2.2 Deemed Energy Savings Tables

Applying the above algorithms results in the deemed energy savings per ton in Table 5.1-2. Heating savings are only applicable for heat pumps.

Table 5.1-2: [AC/HP Tune-up] Deemed Energy Savings per ton

Climate Zone	Cooling kWh saved per ton	Heating kWh saved per ton
San Antonio	126.1	90.3

5.1.2.3 Deemed Summer Demand Savings Tables

Applying the above algorithms results in the deemed summer demand savings per ton in Table 5.1-3.

Table 5.1-3: [AC/HP Tune-up] Deemed Summer Demand Savings per ton

Climate Zone	NCP kW saved per ton	CP kW saved per ton	4CP kW saved per ton
San Antonio	0.056	0.053	0.049

5.1.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

5.1.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 5 years for AC or HP tune-ups.[67]

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[67] GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group; Page 1-3, Table 1. https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf.

5.1.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Manufacturer
- Model Number
- Cooling capacity of the serviced HVAC unit (tons)
- Heating capacity of the serviced HVAC unit (algorithm approach only)
- Type of unit (AC or HP)
- Recommended:
    - Serial number
    - Refrigerant type
    - Target superheat or subcooling
    - Post tune-up superheat or subcooling
    - Amount of refrigerant added or removed
    - Static pressures before and after tune-up
    - Return and supply dry bulb and wet bulb temperatures
    - Before and after tune-up pictures of components illustrating condition change because of cleanings
      Note: Pictures that include well-placed familiar objects like hand tools often provide a sense of scale and a reference for color/shading comparisons. Pictures of equipment name plates are useful.

5.2 DUCT SEALING

5.2.1 Measure Description

This measure involves sealing leaks in supply and return ducts of the HVAC distribution systems of homes or converted residences with central air conditioning. The standard approach for estimating savings in this measure is based on the results obtained via pre- and post-measure implementation leakage testing as defined in this measure (the "standard approach"). In lieu of leakage testing, savings for eligible duct sealing projects may be claimed using the deemed savings tables for implementations in which testing is not performed (subheadings "absent leakage testing").

5.2.1.1 Eligibility Criteria

All residential customers with ducted central refrigerated air cooling are eligible for this measure. Customers must have ducted central heating with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. The specified deemed savings are not applicable to residences with space (non-central or ducted) air conditioning or heating.

For the standard approach with leakage testing, duct leakage should be assessed following Building Performance Institute (BPI) standards. Duct leakage testing should not be conducted in homes where evidence of asbestos or mold is present or suspected.[68] Installers should be mindful of health and safety considerations related to implementation of duct efficiency measures and/or testing procedures.

Duct sealing is a residential retrofit measure and does not apply to new construction.

5.2.1.2 Baseline Condition

The savings calculation methods for this measure (when implemented with duct leakage testing) are valid up to a maximum pre-installation leakage rate of 35 percent of total fan flow.[69] For homes with an initial leakage rate greater than 35 percent of total fan flow, savings will be awarded with respect to this cap rather than the initial leakage. Data from nearly 28,000 single-family and mobile home duct blaster tests conducted for duct efficiency improvements in Texas between 2003 and 2006 show that more than 70 percent of all pre-retrofit leakage rates fall below 38 percent total leakage.[70]

Engineering calculations show that the interior temperature in those settings that exceed 38 percent total leakage would be above the thermally acceptable comfort levels published by ASHRAE in its 2009 Fundamentals publication. The proposed pre-installation leakage limits will help ensure that the deemed savings are an accurate reflection of the program's impacts, and that the program focuses its efforts on scenarios where leakage conditions are likely to persist if unaddressed for several years.

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[68] "Technical Standards for the Building Analyst Professional," Building Performance Institute (BPI), v1/4/12mda, Page 1 of 17, states: "Health and Safety: Where the presence of asbestos, lead, mold and/or other potentially hazardous material is known or suspected, all relevant state and federal (EPA) guidelines must be followed to ensure technician and occupant safety. Blower door depressurization tests may not be performed in homes where there is a risk of asbestos becoming airborne and being drawn into the dwelling." http://www.bpi.org/sites/default/files/Technical%20Standards%20for%20the%20Building%20Analyst%20Professional.pdf.

[69] $Total\ Fan\ Flow = Cooling\ Capacity\ (tons) \times 400\ cfm/ton.$

[70] Based on data collected by Frontier Energy for investor-owned utilities in Texas.

CPS Energy may waive the cap limiting the maximum pre-installation leakage rate to 35 percent of total fan flow for low-income qualified customers.

While these baseline criteria were applied in deriving the deemed savings for the alternate approach (absent leakage testing), it is not necessary to determine pre-installation leakage rate for projects in which implementers choose to apply those (absent leakage testing) savings.

5.2.1.3 High-Efficiency Condition

Materials used should be long-lasting materials, such as mastics, UL 181A or UL 181B approved foil tape, or aerosol-based sealants. Fabric-based duct tape is not allowed.

The selected methodology for estimating duct sealing deemed savings, according to the standard approach, requires duct leakage-to-outside testing using a combination duct pressurization and house pressurization.

5.2.1.4 Duct Leakage Testing (Standard Approach)

Measurements to determine pre-installation and post-installation leakage rates must be performed in accordance with CPS-approved procedures. For this measure, leakage-to-outside must be directly measured. The Project Sponsor shall use the Combination Duct Blaster™ (or equivalent) and Blower Door method. Prior to beginning any installations, the Project Sponsor must submit the intended method(s) and may be required to provide the utility with evidence of competency, such as Home Energy Rating System (HERS) or North American Technician Excellence (NATE) certification. Leakage rates must be measured and reported at the average air distribution system operating pressure (25 Pa).[71]

5.2.1.5 Categorizing Achieved Duct Leakage Reduction (absent leakage testing)

Participating project sponsors electing not to perform leakage testing should nevertheless provide an estimate of the expected outcome of the leakage reduction work performed: projects should be characterized according to the project sponsor’s estimation of whether the work required should result in ***low***, ***average***, or ***high*** reduction in duct system leakage. Sponsors should take the following considerations into account in assessing the likely leakage reduction achieved in each project:

- The number and size of repaired leaks
- Leak location: a leak in an attic joint will cause more energy loss than a joint that leaks to conditioned space
- Supply/Return: Supply-side leaks, particularly in the return air plenum and near the air handling unit can be especially problematic, as they tend to draw additional unconditioned air into the system

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[71] See RESNET Technical Committee, Proposed Amendment: Chapter 8 RESNET Standards, 800 RESNET Standard for Performance Testing and Work Scope: Enclosure and Air Distribution Leakage Testing; Section 803.2 and Table 803.1. https://www.resnet.us/wp-content/uploads/Chapter-Eight-22RESNET-Standard-for-Performance-Testing-and-Work-Scope-Enclosure-and-Air-Distribution-Leakage-Testing22.pdf.

Systems that were not initially very leaky and in which few joints and supply vents were sealed should be characterized as low reduction. Jobs with a typical number of supply vents and joints sealed, and in which the supply air return or the return air plenum were sealed, should be characterized as average reduction. Jobs requiring significant interventions to eliminate large or numerous leaks should be considered high reduction.

The following table provides a guideline for selecting an appropriate leakage category. How the category is determined may fluctuate on a per home basis.

Table 5.2-1: [Duct Sealing] Leakage Categorization Guide[72]

Category	Duct Location	Duct Insulation Value	Leakage Characteristics[73]
Low	> 90% Conditioned	> R7	Some observable leaks
			Substantial leaks
		R4 - R7	Some observable leaks
			Substantial leaks
		< R4	Some observable leaks
			Substantial leaks
	50-90% Conditioned	> R7	Some observable leaks
		R4 - R7	Some observable leaks
		< R4	Some observable leaks
Average	> 90% Conditioned	> R7	Catastrophic leaks
		R4 - R7	Catastrophic leaks
		< R4	Catastrophic leaks
	50-90% Conditioned	> R7	Substantial leaks
			Catastrophic leaks
		R4 - R7	Substantial leaks
		< R4	Substantial leaks
	< 50% Conditioned	> R7	Some observable leaks
		R4 - R7	Some observable leaks
		< R4	Some observable leaks
High	50-90% Conditioned	R4 - R7	Catastrophic leaks
		< R4	Catastrophic leaks
	< 50% Conditioned	R4 - R7	Substantial leaks
		> R7	Catastrophic leaks
		R4 - R7	Substantial leaks

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[72] Based on typical distribution efficiency assumptions from the Building Performance Institute (BPI) Technical Standards for the Heating Professional, November 20, 2007, page 7. http://www.bpi.org/sites/default/files/Technical%20Standards%20for%20the%20Heating%20Professional.pdf.

[73] Catastrophic leaks are defined by BPI as disconnected ducts, missing endcaps, and other catastrophic holes.

Category	Duct Location	Duct Insulation Value	Leakage Characteristics[73]
			Catastrophic leaks
		< R4	Substantial leaks
			Catastrophic leaks

5.2.2 Energy and Demand Savings Methodology

Savings may be claimed according to either the standard approach (with duct leakage testing) or the alternate approach, according to the following sections.

5.2.2.1 Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings, which are expressed as linear functions of the reduction in duct leakage achieved (in CFM_{25}). Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for San Antonio were modified as follows: the base case duct leakage rate was set to 8 CFM_{25} per 100 square feet. Results from running the base case model provide estimated hourly energy use for the prototypical home prior to treatment. Post-treatment conditions were simulated by setting the leakage rate to 6 CFM_{25} per 100 square feet. Results from running the change case model provide estimated hourly energy use for the prototypical home after treatment. Comparison of these two runs provides the deemed savings estimates.

Deemed savings are presented as a function of the CFM_{25} reduction achieved, as demonstrated by leakage to outside testing using the Combination Duct Blaster^{TM} (or equivalent) and Blower Door method. The kWh and kW per CFM_{25} values represented by the V_E, and V_D coefficients are derived by taking the difference between annual energy use and summer and winter peak demand as estimated by the two model runs and normalizing to the CFM_{25} reduction achieved.

5.2.2.2 Standard Approach (with leakage testing)

The annual energy and peak demand savings to be claimed for this measure, according to the standard approach, shall be calculated as a function of the reduction in duct leakage achieved, using the energy and demand savings coefficients from Table 5.2-2 through Table 5.2-3 for the type of heating equipment in the project home.

Energy Savings

In the standard approach, energy savings are estimated according to the differences in annual energy use in the pre-retrofit (base case) and post-retrofit (change case) models.

The following formula shall be used to calculate annual energy savings for duct leakage reduction:

$$\boldsymbol{Deemed\ Energy\ Savings\ (kWh) = \left(DL_{pre} - DL_{post}\right) \times V_E}$$

Equation 5.2-1

Where:

$\mathrm{DL_{pre}}$ = *Pre-improvement duct leakage at 25 Pa (cu. ft./min).*

$\mathrm{DL_{post}}$ = *Post-improvement duct leakage at 25 Pa (cu. ft./min).*

$V_{E,C}$ = *Cooling Energy Savings Coefficient in* Table 5.2-2*.*

$V_{E,H}$ = *Heating Energy Savings Coefficient in* Table 5.2-2*.*

Estimated savings per unit of leakage rate reduction (measured in CFM_{25}) are presented in the deemed energy savings tables below.

Demand Savings

Coincident Peak (CP), Non-coincident Peak (NCP) and ERCOT 4 Coincident Peak (4CP) demand savings are estimated in accordance with the definitions provided in Section 2.3 of this document. All are estimated according to the differences in energy use in specific hours of the simulations of the pre-retrofit (base case) and post-retrofit (change case) models. Estimated savings per unit of leakage rate reduction (measured in CFM_{50}) are presented in the deemed demand savings tables below.

The following formula shall be used to calculate deemed summer demand savings for duct leakage reduction:

$$\boldsymbol{Deemed\ Demand\ Savings\ (kW) = \left(DL_{pre} - DL_{post}\right) \times V_D}$$

Equation 5.2-2

Where:

$\mathrm{DL_{pre}}$ = *Pre-improvement duct leakage at 25 Pa (cu. ft./min).*

$\mathrm{DL_{post}}$ = *Post-improvement duct leakage at 25 Pa (cu. ft./min).*

V_D = *Demand Savings Coefficient in* Table 5.2-3*.*

Estimated savings per unit of leakage rate reduction (measured in CFM_{25}) are presented in the deemed demand savings tables below.

Load Shapes

The demand factors were derived according to the method outlined in Section 2.3 using a load shape extracted from the BEopt energy simulation models developed for the residential envelope measures. The load shape can be found in Section 22.2.

5.2.2.3 Deemed Energy Savings Tables (with leakage testing)

The following table presents the annual energy savings per CFM25 reduction for a residential duct sealing project.

Table 5.2-2: [Duct Sealing] V_E, Standard Approach Energy Savings per CFM_{50} Reduction

$V_{E,C}$: Cooling Savings	$V_{E,H}$: Heating Savings		
	Gas	Electric Resistance	Heat Pump
1.43	0.02	0.79	0.19

5.2.2.4 Deemed Summer Demand Savings Tables (with leakage testing)

Table 5.2-3: [Duct Sealing] Standard Approach Peak Summer Demand Savings V_D per CFM_{50} Reduction

V_D	Primary Heat Source	Demand Savings (kW/CFM_{50})
NCP	Gas Furnace	1.29×10^{-3}
	Electric Resistance	1.75×10^{-3}
	Heat Pump	2.60×10^{-3}
CP	All	9.43×10^{-4}
4CP	All	1.07×10^{-3}

5.2.2.5 Alternate Approach (absent leakage testing)

Savings tables are provided for projects implemented without performance of duct leakage testing, accounting for the application of pre-retrofit leakage caps to non-hard-to-reach (HTR) projects. The annual energy and peak demand savings to be claimed according to this alternate approach for this measure shall be taken from Table 5.2-4 and Table 5.2-5 according to the type of heating equipment in the project home.

While savings for multiple duct systems are additive for the standard approach, the following savings are specified per home when using the alternate approach and should not be multiplied by the number of treated duct systems.

NOTE: This approach is only available to programs with an incentive structure that does not vary by leakage category. Additionally, energy efficiency service providers (EESPs) should not alternate between the standard and alternate approaches during the same program year. The utility should either restrict all participants within an individual program to one approach or the other or they should restrict individual EESPs to one approach or the other across all program types.

5.2.2.6 Deemed Energy Savings Tables (absent leakage testing)

Table 5.2-4 presents the annual energy savings for a residential duct sealing project.

Table 5.2-4: [Duct Sealing] Alternate Approach Energy Savings

Assessed Leakiness	Cooling Savings	Heating Savings		
		Gas	Electric Resistance	Heat Pump
Low	327	4	180	44
Average	524	6	288	71
High	749	8	412	101

5.2.2.7 Deemed Summer Demand Savings Tables (absent leakage testing)

Table 5.2-5 presents the peak demand savings for a residential duct sealing project.

Table 5.2-5: [Duct Sealing] Alternate Approach Peak Demand Savings

V_D	Primary Heat Source	Low	Average	High
NCP	Gas Furnace	0.30	0.47	0.68
	Electric Resistance	0.40	0.64	0.91
	Heat Pump	0.59	0.95	1.36
CP	All	0.22	0.34	0.49
4CP	All	0.24	0.39	0.56

5.2.2.8 Additional Calculators and Tools

This section is not applicable for this measure.

5.2.2.9 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 18 years for duct sealing, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HV-DuctSeal-BW.[74]

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[74] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

5.2.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

All projects:

- Cooling type (central refrigerated cooling, none)
- Heating type (central gas furnace, central electric resistance furnace, heat pump, none)
    - Additional documentation is required to validate resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach)
- Cooling capacity of home HVAC unit(s) (tons)

Sponsors claiming savings according to duct leakage testing:

- Pre-improvement duct leakage at 25 Pa (cu. ft./min)
- Post-improvement duct leakage at 25 Pa (cu. ft./min)
- Pre and post photos of leakage test readings

Sponsors claiming savings without performing leakage testing should provide:

- Description of the leakage severity in the home (low, average, or high)
- Description and condition of ducts:
    - Duct location (> 90% conditioned, 50-90% conditioned, < 50% conditioned)
    - Existing duct insulation value (> R7, R4-R7, < R4)
- Leakage characteristics (some observable leaks, substantial leaks, catastrophic leaks)
- Other relevant details that may assist with validating claimed leakage category
- Description and photos of interventions taken (both pre and post condition), such as newly sealed joints, supply vents, and other relevant leaks sealed
- Incentive rate structure: incentive should be paid per home and should not vary by leakage category to protect against overstating existing leakage category

5.3 ENERGY STAR® GROUND SOURCE HEAT PUMPS

5.3.1 Measure Description

This measure requires the installation of a ground-source heat pump (GSHP) meeting the minimum requirements of ENERGY STAR geothermal heat pump key product criteria. The deemed savings are dependent upon the energy efficiency rating (EER) and coefficient of performance (COP) of the installed equipment. Savings calculations are presented for systems with and without desuperheaters.

5.3.1.1 Eligibility Criteria

The deemed savings apply to units with a capacity of ≤ 65,000 Btu/hour.

Energy savings for desuperheaters only apply if the desuperheater is attached to an electric storage water heater. The electric storage water heating cannot replace a gas water heater in a retrofit installation.

5.3.1.2 Baseline Condition

The baseline unit is assumed to be an air-source heat pump (ASHP) for new construction, and either an ASHP or an air conditioner with an electric resistance furnace for replace-on-burnout projects. New construction baseline efficiency values for ASHPs comply with the current federal minimum standard,[75] effective January 1, 2015.

For replace-on-burnout (ROB) projects, the cooling baseline is reduced to 13.08 SEER. This value incorporates an adjustment to the baseline SEER value to reflect the percentage of current replacements that do not include the installation of an AHRI-matched system.[76] The heating baseline for replace-on-burnout projects is dependent on the heating type of the baseline equipment.

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[75] DOE minimum efficiency standard for residential air conditioners/heat pumps. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=48&action=viewlive.

[76] Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Southwestern Electric Power Company, Texas-New Mexico Power Company, And Southwestern Public Service Company to Revise Existing Commission Approved Deemed Savings Values for Central Air Conditioning and Heat Pump Systems, Public Utility Commission of Texas, Docket No. 36780 (August 27, 2009). https://interchange.puc.texas.gov/. Adapted for new 14 SEER baseline.

Table 5.3-1: [GSHPs] Baseline Efficiencies

Project Type	Cooling Mode[77]	Heating Mode[78]
New Construction	11.8 EER 14.0 SEER	2.4 COP 8.2 HSPF
ROB – Air Source Heat Pump Baseline	11.2 EER 13.08 SEER	2.4 COP 8.2 HSPF
ROB – Air Conditioner with Electric Resistance Furnace Baseline		1.0 COP 3.412 HSPF

5.3.1.3 High-Efficiency Condition

Table 5.3-2 displays the ENERGY STAR requirements for eligible geothermal heat pumps as of January 1, 2012. Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

Table 5.3-2: [GSHPs] ENERGY STAR Efficiency Requirements

Project Type	Cooling Mode (EER)	Heating Mode (COP)
Closed Loop Water-to-Air	17.1	3.6
Open Loop Water-to-Air	21.1	4.1
Closed Loop Water-to-Water	16.1	3.1
Open Loop Water-to-Water	20.1	3.5
Direct Geoexchange (DGX)	16.0	3.6

The specifications in the charts above apply to single-stage models. Multi-stage models may be qualified based on:[79]

$$\boldsymbol{EER = (highest\ rated\ capacity\ EER + lowest\ rated\ capacity\ EER) \div 2}$$

Equation 5.3-1

$$\boldsymbol{COP = (highest\ rated\ capacity\ COP + lowest\ rated\ capacity\ COP) \div 2}$$

Equation 5.3-2

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[77] Code specified EER value converted to SEER using EER = -0.02 x SEER^2 + 1.12 x SEER. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

[78] Code specified HSPF value converted to COP using COP = HSPF x 1,055 J/Btu ÷ 3,600 J/W-h = HSPF ÷ 3.412.

[79] Geothermal Heat Pumps Key Product Criteria, https://www.energystar.gov/products/heating_cooling/heat_pumps_geothermal/key_product_criteria.

5.3.2 Energy and Demand Savings Methodology

5.3.2.1 Savings Algorithms and Input Variables

Peak demand and annual energy savings for GSHP systems should be calculated as shown below. Where a desuperheater is also installed, an additional factor is included in the calculations to account for estimated additional energy and demand savings.

Energy and demand savings for desuperheaters were adapted from a 2001 study conducted by Oak Ridge National Laboratory (ORNL) on ground source heat pumps in Texas.[80] Desuperheater savings were calculated by taking the difference in savings between GSHPs with and without desuperheaters and averaging the savings between low and high efficiency units. Savings for GSHP systems with desuperheaters should be calculated using the algorithms below with an additional energy credit based on the system capacity and efficiency.

The ORNL study draws from a 1998 analysis based on a study conducted at the Fort Polk Joint Readiness Training Center in Leesville, Louisiana. The Fort Polk study used calibrated simulations of 200 multifamily residences in the complex to estimate energy savings attributable to replacement of air source heat pumps with ground source heat pumps. These estimates were found to be within 5% of actual post-retrofit savings. Building models were developed using TRNSYS.[81]

Using the Fort Polk models, the ORNL study assumed a baseline of a 1.5-ton, 10 SEER air source heat pump. Simulations of low-, medium-, and high-efficiency ground source heat pumps with and without desuperheaters were compared against the baseline unit. The models were run using TMY-2 weather profiles for the San Antonio climate zone. Energy and demand differences between the pre- and post-retrofit models were used to estimate average savings per ton of cooling capacity.

In the 1998 analysis, low-efficiency GSHPs were assumed to be units with an EER of 12.4 and capacity of 19 kBtuh, while medium-efficiency units had an EER of 16.8 and capacity of 21 kBtuh. High-efficiency units had an EER of 18.3, with a capacity of 22 kBtuh.

These models were used to derive the energy and demand savings associated with installation of a desuperheater along with a ground source heat pump.

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[80] Shonder, J. A., Hughes, P., and Thornton, J. Development of Deemed Energy and Demand Savings for Residential Ground Source Heat Pump Retrofits in the State of Texas. Transactions-American Society of Heating, Refrigerating, and Air Conditioning Engineers. 108, no. 1: 953-961, 2001. http://web.ornl.gov/~webworks/cppr/y2001/pres/112677.pdf.

[81] Klein, S. A. TRNSYS Manual: A Transient Simulation Program. Solar Engineering Laboratory, University of Wisconsin-Madison, Version 14.2 for Windows, September 1996.

Energy Savings

$$kWh_{Savings} = kWh_{Savings,Summer} + kWh_{Savings,Winter} + kWh_{desuperheater}$$

Equation 5.3-3

$$kWh_{Savings,C} = CAP_C \times \frac{EFLH_C}{1,000} \times \left(\frac{1}{EER_{Base}} - \frac{1}{EER_{GSHP}}\right)$$

Equation 5.3-4

$$kWh_{Savings,H} = CAP_H \times \frac{1\ kWh}{3,412\ Btu} \times EFLH_H \times \left(\frac{1}{COP_{Base}} - \frac{1}{COP_{GSHP}}\right)$$

Equation 5.3-5

Where:

$kWh_{desuperheater}$ = *Annual energy savings [kWh] associated with installation of a desuperheater = 802 kWh. These savings should only be added if a desuperheater is installed.*

CAP_C = *Rated equipment cooling capacity of the installed GSHP [Btu/hr].*

CAP_H = *Rated equipment heating capacity of the installed GSHP [Btu/hr].*

$EFLH_C$ = *Equivalent full load hours for cooling. Use 2,237 hours for San Antonio.*[82]

$EFLH_H$ = *Equivalent full load hours for heating. Use 1,101 hours for San Antonio.*[83]

EER_{Base} = *Energy Efficiency Ratio of the baseline cooling equipment; see Table 5.3-1.*

EER_{GSHP} = *Energy Efficiency Ratio of the installed GSHP.*

COP_{Base} = *Coefficient of Performance of the baseline heating equipment; see Table 5.3-1.*

COP_{GSHP} = *Coefficient of Performance of the installed GSHP.*

1,000 = *Constant to convert from watts to kilowatts.*

3,412 = *Constant to convert from Btu to kWh.*

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[82] ENERGY STAR Central AC/HP Savings Calculator. April 2009 update. https://www.energystar.gov/sites/default/files/asset/document/ASHP_Sav_Calc.xls.

[83] Ibid.

Demand Savings

Cooling Demand Savings (Summer)

$$kW_{Savings} = \frac{CAP_C}{1,000} \times \left(\frac{1}{EER_{Base}} - \frac{1}{EER_{GSHP}}\right) \times DF + kW_{desuperheater}$$

Equation 5.3-6

Where:

CAP_C = *Rated equipment cooling capacity of the installed GSHP [Btu/hr].*

CAP_H = *Rated equipment heating capacity of the installed GSHP [Btu/hr].*

EER_{Base} = *Energy Efficiency Ratio of the baseline cooling equipment; see Table 5.3-1.*

EER_{GSHP} = *Energy Efficiency Ratio of the installed GSHP.*

COP_{Base} = *Coefficient of Performance of the baseline heating equipment; see Table 5.3-1.*

COP_{GSHP} = *Coefficient of Performance of the installed GSHP.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 5.3-3.*

$kW_{desuperheater}$ = *Summer demand savings [kW] associated with installation of a desuperheater = 0.405 kW. These savings should only be added if a desuperheater is installed.*

1,000 = *Constant to convert from watts to kilowatts.*

Table 5.3-3: [GSHPs] Demand Factors

Peak Type	Demand Factors
NCP	1.000
CP	0.668
4CP	0.589

Load Shapes

The demand factors were derived according to the method outlined in Section 2.3 using a load shape extracted from NREL's BEopt energy simulation models developed for the residential envelope measures. The load shape can be found in Section 22.2.

5.3.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

5.3.2.3 Deemed Summer Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

5.3.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

5.3.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 20 years for GSHPs. This value is consistent with the minimum life expectancy reported in the Department of Energy GSHP guide.[84]

5.3.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Decision/action type (Replace-on-Burnout, New Construction)
- Replaced unit heating type (heat pump, electric resistance furnace)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
- Manufacturer, model, and serial number of the new unit
    - AHRI certificate or reference number matching model number
- GSHP type of the new unit (closed loop water-to-air, open loop water-to-air, closed loop water-to-water, open loop water-to-water, direct geoexchange)
- Rated cooling and heating capacity of the new unit (Btu/hr)
- Energy Efficiency Ratio (EER) of the new unit
- Coefficient of Performance (COP) of the new unit
- Whether a desuperheater was installed or present
- Proof of purchase with date of purchase and quantity
    - Alternative: photo of replacement unit nameplate or other pre-approved method of installation verification

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[84] Department of Energy. "Guide to Geothermal Heat Pumps. February 2011. http://www.energy.gov/sites/prod/files/guide_to_geothermal_heat_pumps.pdf.

5.4 CENTRAL AIR CONDITIONERS AND HEAT PUMPS

5.4.1 Measure Description

Residential replacement of existing heating and cooling equipment with a new central air-source air conditioner (AC) or heat pump (HP) in an existing building, or the installation of a new central AC or HP in a new residential construction. Downsized systems that are rightsized per a heat load calculation are also eligible. A new central system includes an entire packaged unit, or a split system consisting of an indoor unit with a matching remote condensing unit. This measure also applies to the installation of dual-fuel HPs that meet all existing measure eligibility criteria.

5.4.1.1 Eligibility Criteria

Newly installed units must have a cooling capacity of less than 65,000 Btu/hour (5.4 tons) to be eligible for these deemed savings. Gas furnaces are not eligible to be awarded savings for replacement through this measure.

Equipment shall be properly sized to dwelling based on ASHRAE or ACCA Manual J standards. Manufacturer data sheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[85,86] Savings should be calculated using rated capacities whenever possible. Reported system capacities and efficiencies should always match those verified by AHRI or DOE as tested under AHRI operating conditions for a specific combination of equipment, including condenser, coil, and furnace (or condenser only for packaged units). Savings should never be calculated using efficiency ratings for individual system components.

Customers should be advised against using the emergency heat (EM HEAT) setting on heat pump thermostats. This setting is meant only for use in emergency situations when the heat pump is damaged or malfunctioning. Supplemental heating automatically kicks on below freezing conditions using the regular HEAT setting. Contractors installing a new thermostat with heat pump equipment shall advise customer of correct thermostat usage.

For early retirement or rightsizing projects, attempt to determine the rated capacity of the existing unit. The rated capacity may be found on the manufacturer specification sheet for the existing unit if the new system is not available on the AHRI or DOE CCMS directories. If the model number of the existing unit is unobtainable or if the manufacturer specification sheet cannot be found, use nominal tonnage for both the existing and new unit. Never use nominal tonnage for the existing unit in combination with rated tonnage for the new unit, which can lead to overstated savings. Additionally, never use nominal tonnage to determine savings for projects where no early retirement or rightsizing has occurred.

For early retirement to receive savings, the replaced unit must be functioning at the time of removal with a maximum age of 24 years for ACs and 20 years for HPs. To determine the remaining useful life of an existing unit; see Table 5.4-5 and Table 5.4-6. Otherwise claim savings for a replace-on-burnout project.

The replacement of a room AC with a central AC or HP is eligible and should be claimed against the new

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[85] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.

[86] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.

construction baseline. Refer to the Replace-on-Burnout or Early Retirement of an Electric Resistance section for guidance about the appropriate heating baseline for residences with electric resistance heat. Under this scenario, no savings should be awarded for rightsizing.

New construction projects are not eligible to receive deemed savings for system rightsizing. For system upsizing, savings should generally be claimed against the new construction baseline. However, when upsizing while going from a single larger capacity system to multiple smaller capacity systems, savings may be claimed against the applicable replace-on-burnout or early retirement baseline if the total pre and post tonnage are within ½ ton.[87] For this scenario, savings must be looked up using the lower pre tonnage. If the multiple installed units do not share the same efficiency value, savings should be looked up using the most conservative efficiency value.

Additionally, low income or hard-to-reach programs may use the electric resistance baseline for the following two scenarios. The electric resistance baseline may be used for systems upsized by no more than a half ton in lieu of the new construction baseline. Under this scenario, cooling savings should be claimed against the new construction baseline using the installed (higher) capacity. Heating savings should be claimed against the electric resistance baseline using the existing (lower) capacity. Documentation should be aligned with rightsizing and electric resistance baseline requirements outlined in this measure. The second scenario is for a major multifamily renovation when a centralized system, such as a boiler, is replaced with individual HPs. For this scenario, the electric resistance baseline may be claimed in lieu of new construction only if the building owner can document intent to install electric resistance furnaces without program intervention. The cooling savings should still be claimed against the new construction baseline. Documentation should follow early retirement and electric resistance baseline requirements.

When replacing a single unit with multiple units where the capacity is the same or has been downsized, savings should be looked up using the total system pre and post capacities. Again, if the multiple installed units do not share the same efficiency value, savings should be looked up using the most conservative efficiency value.

5.4.1.2 Baseline Condition

New Construction, Replace-on-Burnout, or Early Retirement of an Air-Source AC or HP

New construction baseline efficiency values for ACs or HPs are compliant with the current federal minimum standard,[88] effective January 1, 2015. The baseline is assumed to be a new system with an AHRI-listed SEER rating of 14.0. This baseline is also applicable to HP installations replacing ACs with central gas heat, or room/window ACs with central, space, or no heating.

For replace-on-burnout (ROB) projects, the cooling baseline is reduced to 13.08 SEER. This value incorporates an adjustment to the baseline SEER value to reflect the percentage of current

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[87] This exception is allowed to account for efficiency improvements due to zoning that are not reflected in the current savings methodology.

[88] DOE minimum efficiency standard for residential air conditioners/heat pumps. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=48&action=viewlive.

replacements that do not include the installation of an AHRI-matched system.[89]

For early retirement (ER) projects, the cooling baseline is reduced to 10 SEER for systems installed before January 23, 2006. For systems installed on or after January 23, 2006, the ER baseline increases to 12.44 SEER. Systems manufactured as of January 1, 2015 are not eligible for early retirement.

For ROB projects, heating baseline efficiency values for HPs comply with the current federal minimum standard, effective January 1, 2015. These standards specify an HSPF of 8.2 for split systems, or 8.0 for packaged systems. This baseline reflects updates to federal standards that take effect January 1, 2015, as defined in the Department of Energy (DOE) energy efficiency standards (10 CFR Part 430).[90]

For ER projects, the heating baseline efficiency is assumed to be 7.7 HSPF for units installed on or after January 23, 2006 based on the federal minimum standard in effect from January 23, 2006 through December 31, 2014.[91] Similarly, for ER projects installed before January 23, 2006, the heating baseline efficiency is assumed to be 6.8 HSPF based on the federal minimum standard in effect prior to January 23, 2006.

Replace-on-Burnout or Early Retirement of an Electric Resistance Furnace

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[92] Space heating refers primarily to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[93] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters should calculate savings using a heat pump baseline.

By the nature of the technology, all electric resistance furnaces have the same efficiency with HSPF = 3.41.[94] Projects in which an electric resistance furnace is replaced, whether in a replace-on-burnout or early retirement scenario, should use this baseline for heating-side savings.

For ROB projects, cooling savings are the same as for new construction and ROB of an air-source HP. For early retirement (ER) projects, the cooling baseline is reduced to 10 SEER for systems installed before January 23, 2006. For systems installed on or after January 23, 2006, the ER baseline increases to 12.44 SEER.

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[89] Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Southwestern Electric Power Company, Texas-New Mexico Power Company, And Southwestern Public Service Company to Revise Existing Commission Approved Deemed Savings Values for Central Air Conditioning and Heat Pump Systems, Public Utility Commission of Texas, Docket No. 36780 (August 27, 2009). https://interchange.puc.texas.gov/. Adapted for new 14 SEER baseline.

[90] 10 CFR Part 430.32(c)2. Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters; Final Rule. http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.

[91] Ibid.

[92] Electric resistance heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

[93] Portable heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

[94] COP = HSPF × 1,055 J/BTU / 3,600 J/W-hr. For Electric Resistance, heating efficiency is 1 COP. Therefore, HSPF = 1 × 3,600 / 1,055 = 3.41.

Table 5.4-1: [Central ACs & HPs] Baseline Efficiencies

Project Type	Cooling Mode	Heating Mode
New Construction	14.0 SEER	8.2 HSPF
Replace-on-Burnout, HP	13.08 SEER	8.2 HSPF
Replace-on-Burnout, Electric Resistance Furnace		3.41 HSPF
Early Retirement, HP (manufactured as of 1/23/2006 through 12/31/2014)	12.44 SEER	7.7 HSPF
Early Retirement, Electric Resistance Furnace (manufactured as of 1/23/2006 through 12/31/2014)		3.41 HSPF
Early Retirement, HP (manufactured before 1/23/2006)	10.0 SEER	6.8 HSPF
Early Retirement, Electric Resistance Furnace (manufactured before 1/23/2006)		3.41 HSPF

5.4.1.3 High-Efficiency Condition

Table 5.4-2 displays the Consortium for Energy Efficiency (CEE) requirements for eligible Tier 0 systems as of January 1, 2009. Energy efficiency service providers are expected to at least comply with the latest CEE Tier 0 requirements.

No full-load efficiency requirement is specified in the current federal standard. Therefore, systems with qualifying SEER and HSPF energy ratings are permitted to claim cooling and heating energy savings for systems where the EER does not comply with the below requirement. Claim zero demand savings rather than negative demand savings for systems with non-compliant EER ratings.

Table 5.4-2: [Central ACs & HPs] CEE Tier 0 Requirements[95]

SEER	EER	HSPF
14.5	12.0	8.5

Split system efficiencies are driven primarily by the efficiency of the condenser unit. If the paired outdoor and indoor units are not listed on the AHRI certification listing and only provide DOE CCMS testing results, then the capacity and efficiency of the high-efficiency condition shall not exceed the average of the AHRI certification listing pairing for the matching condenser. The DOE CCMS listing provides documentation of the results that are on the AHRI certification listing and can be downloaded and filtered based on listing using a similar condenser and various indoor units.

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[95] CEE Residential High Efficiency Central Air Conditioners Air Source Heat Pumps Specification, January 1, 2015. https://library.cee1.org/content/cee-residential-high-efficiency-central-air-conditioners-and-air-source-heat-pumps-specifica.

5.4.2 Energy and Demand Savings Methodology

5.4.2.1 Savings Algorithms and Input Variables

Replace-on-Burnout and New Construction

Energy, summer demand, and winter demand savings were estimated using AC and HP performance curves developed by the National Renewable Energy Laboratory[96] for typical units in each of the following SEER ranges:

- Baseline units
- 14.5 – 14.9
- 15.0 – 15.9
- 16.0 – 16.9
- 17.0 – 17.9
- 18.0 – 20.9
- 21.0 and above

This measure assumes 14.5 – 16.9 SEER units to be single stage and 17.0 and above SEER units to be multi-stage cooling units.

These performance curves provide the capacity and efficiency of the ACs and HPs operating in cooling mode across a wide range of outside air temperatures. Unit loading was estimated as a function of outside air temperature, and hours of cooling mode operation under different loadings were estimated using bin weather data for each weather zone. In heating mode, predicted HVAC operation was limited to meeting 77 percent of load, using a factor applied in Manual J to correlate design load hours to equivalent full load hours under actual operating conditions, considering that heating systems are not always operated even when outdoor conditions indicate they should.

Summer and winter demand savings are estimated according to expected unit performance under design conditions. For all weather zones, it is assumed that typical HVAC systems are sized to 115 percent of their design cooling load (oversized by 15 percent). Heating mode capacity was related to rated cooling capacity using the rated capacity in cooling and heating mode of the residential market HP products of four major manufacturers according to data exported from AHRI. Data were exported from the AHRI directory and the average ratio for each equipment size (1-ton, 1.5-ton, 2-ton, etc.) of heating capacity to cooling capacity was multiplied by the rated (cooling side) capacity to estimate the heat pump capacity. HP system output was then compared to its loading under design conditions.

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[96] D. Cutler et al. Improved Modeling of Residential Air Conditioners and Heat Pumps for Energy Calculations. National Renewable Energy Laboratory. NREL/TP-5500-56354. January 2013. Tables 12 and 13. http://www.nrel.gov/docs/fy13osti/56354.pdf.

The model uses the following set of normalized performance curves to scale the rated performance values as a function of outdoor dry-bulb temperature ranging from 65 to 115 degrees Fahrenheit. The total capacity and Energy Input Ratio (EIR = 1/COP) curves are a function of entering wet-bulb temperature (EWB) and outdoor dry-bulb temperature (ODB) and are both quadratic curve fits of the form:

$$y = a + b \times T_{EWB} + c \times T_{EWB}^2 + d \times T_{ODB} + e \times T_{ODB}^2 + f \times T_{EWB} \times T_{ODB}$$

Equation 5.4-1

Table 5.4-3: [Central ACs & HPs] Capacity Curve Coefficients

Coeff.	Cooling			Heating		
	Single Stage	Multi-Stage/Speed		Single Stage	Multi-Stage/Speed	
		Low	Low		Low	High
a	3.670270705	3.940185508	3.109456535	0.566333415	0.335690634	0.306358843
b	-0.098652414	-0.104723455	-0.085520461	-0.000744164	0.002405123	0.005376987
c	0.000955906	0.001019298	0.000863238	-0.0000103	-0.0000464	-0.0000579
d	0.006552414	0.006471171	0.00863049	0.009414634	0.013498735	0.011645092
e	-0.0000156	-0.00000953	-0.000021	0.0000506	0.0000499	0.0000591
f	-0.000131877	-0.000161658	-0.000140186	-0.00000675	-0.00000725	-0.0000203

Table 5.4-4: [Central ACs & HPs] EIR Curve Coefficients

Coeff.	Cooling			Heating		
	Single Stage	Multi-Stage/Speed		Single Stage	Multi-Stage/Speed	
		Low	Low		Low	High
a	-3.302695861	-3.87752688	-1.990708931	0.718398423	0.36338171	0.981100941
b	0.137871531	0.164566276	0.093969249	0.003498178	0.013523725	-0.005158493
c	-0.001056996	-0.001272755	-0.00073335	0.000142202	0.000258872	0.000243416
d	-0.012573945	-0.019956043	-0.009062553	-0.005724331	-0.009450269	-0.005274352
e	0.000214638	0.000256512	0.000165099	0.00014085	0.000439519	0.000230742
f	-0.000145054	-0.000133539	-0.0000997	-0.000215321	-0.000653723	-0.000336954

To estimate the baseline SEER value for retrofit installations, Texas A&M's Energy Systems Laboratory (ESL) surveyed dealers across the State to determine installation practices. The research found that in the event of a compressor failure out of warranty, dealers replaced the compressor 11.7% of the time, and replaced the condensing unit 88.3% of the time. Further, the condensing unit replacements consist of condensing unit-only replacements, replacements with mismatched evaporator coils, and replacements with matching evaporator coils.

The percentages for these installations are as follows:

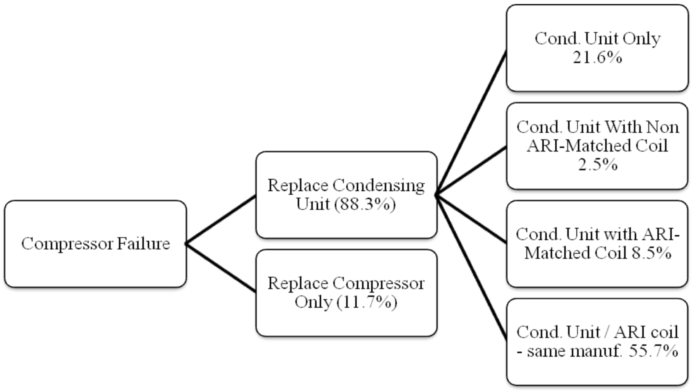

Figure 5.4-1: [Central ACs & HPs] Unit Replacement Percentages upon Compressor Failure[97]

To calculate a weighted average SEER for these installations, ESL assumed that a compressor-only replacement resulted in no increase in SEER, and that the SEER of a condensing unit installed without a matching coil would be 85% of the SEER value for a matched system. The ESL estimate of the baseline SEER for replacement AC units is given by the following equation:

$$\begin{aligned} \boldsymbol{SEER_{Base}} &= \left(\boldsymbol{SEER_{Compressor\ Replacement}}\right) \times (\boldsymbol{Actual}\ \%\ \boldsymbol{Compressor\ Replacement}) \\ &\quad + \left(\boldsymbol{SEER_{Condenser\ Replacement}}\right) \times (\boldsymbol{Actual}\ \%\ \boldsymbol{Condenser\ Replacement}) \\ &\quad + \left(\boldsymbol{SEER_{System\ Replacement}}\right) \times (\boldsymbol{Actual}\ \%\ \boldsymbol{System\ Replacement}) \end{aligned}$$

Equation 5.4-2

Substituting ESL SEER estimates and survey data provides the following baseline SEER estimate:

$$\boldsymbol{SEER_{Base}} = (\mathbf{9.5}) \times (\mathbf{11.7}\%) + (\mathbf{11.05}) \times (\mathbf{24.1}\%) + (\mathbf{13.5}) \times (\mathbf{64.2}\%) = \mathbf{12.44}$$

Adjusting for the increased 14 SEER baseline:

$$\boldsymbol{SEER_{Base}} = (\mathbf{10.5}) \times (\mathbf{11.7}\%) + (\mathbf{11.9}) \times (\mathbf{24.1}\%) + (\mathbf{14}) \times (\mathbf{64.2}\%) = \mathbf{13.08}$$

In new construction, there is no possibility of a partial system (e.g., condensing unit-only) changeout, so the 13.08 baseline would not be appropriate. Therefore, the baseline for new construction installations is set at the federal government's minimum efficiency standard of 14 SEER.

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[97] Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Southwestern Electric Power Company, Texas-New Mexico Power Company, And Southwestern Public Service Company to Revise Existing Commission Approved Deemed Savings Values for Central Air Conditioning and Heat Pump Systems, Public Utility Commission of Texas, Docket No. 36780 (August 27, 2009).

Early Retirement

Annual energy (kWh) and summer peak demand (kW) savings must be calculated separately for two time periods:

- The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
- The remaining time in the EUL period (EUL – RUL)

Annual energy and summer peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in Section 22.3.

Where:

RUL = *Remaining Useful Life (see Table 5.4-5 and Table 5.4-6); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 7.0 years (ACs) or 6.0 years (HPs). If individual system components were installed at separate times, use the condenser age as a proxy for the entire system. Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. For HPs replacing ACs with an electric resistance furnace, use the AC RUL table.*

EUL = *Estimated Useful Life = 18 years (AC); 15 years (HP).*

Table 5.4-5: [Central ACs & HPs] Remaining Useful Life of Replaced ACs[98]

Age of Replaced Unit (years)	RUL (years)	Age of Replaced Unit (years)	RUL (years)
1	16.8	14	8.6
2	15.8	15	8.2
3	14.9	16	7.9
4	14.1	17	7.6
5	13.3	18	7.0
6	12.6	19	6.0
7	11.9	20	5.0
8	11.3	21	4.0
9	10.8	22	3.0

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[98] Current federal standard effective date is 1/1/2015. Existing systems manufactured after this date are not eligible to use the early retirement baseline.

Age of Replaced Unit (years)	RUL (years)	Age of Replaced Unit (years)	RUL (years)
10	10.3	23	2.0
11	9.8	24	1.0
12	9.4	25[99,100]	0.0
13	9.0		

Table 5.4-6: [Central ACs & HPs] Remaining Useful Life of Replaced HPs[101]

Age of Replaced Unit (years)	RUL (years)	Age of Replaced Unit (years)	RUL (years)
1	13.7	12	7.9
2	12.7	13	7.6
3	12.0	14	7.0
4	11.3	15	6.0
5	10.7	16	5.0
6	10.2	17	4.0
7	9.7	18	3.0
8	9.3	19	2.0
9	8.9	20	1.0
10	8.5	21[102,103]	0.0
11	8.2		

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[99] RULs are capped at the 75th percentile of equipment age, 21 years, as determined based on DOE survival curves (Figure 5.4-3). Systems older than 21 years should use the ROB baseline. See the January 2015 memo, “Considerations for early replacement of residential equipment,” for further detail.

[100] Ward, B., Bodington, N., Farah, H., Reeves, S., and Lee, L. “Considerations for early replacement of residential equipment.” Prepared by the Evaluation, Measurement, and Verification (EM&V) team for the Electric Utility Marketing Managers of Texas (EUMMOT). January 2015. This document has been made available to Texas investor-owned utilities through the EM&V team’s SharePoint and are available for review upon request.

[101] Current federal standard effective date is 1/1/2015. Existing systems manufactured after this date are not eligible to use the early retirement baseline.

[102] RULs are capped at the 75th percentile of equipment age, 21 years, as determined based on DOE survival curves (Figure 5.4-3). Systems older than 21 years should use the ROB baseline. See the January 2015 memo, “Considerations for early replacement of residential equipment,” for further detail.

[103] Ward, B., Bodington, N., Farah, H., Reeves, S., and Lee, L. “Considerations for early replacement of residential equipment.” Prepared by the Evaluation, Measurement, and Verification (EM&V) team for the Electric Utility Marketing Managers of Texas (EUMMOT). January 2015. This document has been made available to Texas investor-owned utilities through the EM&V team’s SharePoint and are available for review upon request.

Derivation of RUL

ACs have an estimated useful life of 18 years, and HPs have an estimated useful life of 15 years. This estimate is consistent with the age at which approximately 50 percent of ACs and HPs installed in a given year will no longer be in service, as described by the survival functions in Figure 5.4-2 and Figure 5.4-3.

The method for estimating the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival functions shown in Figure 5.4-2 and Figure 5.4-3. The age of the system being replaced is found on the horizontal axis, and the corresponding percentage of surviving systems is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. The age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

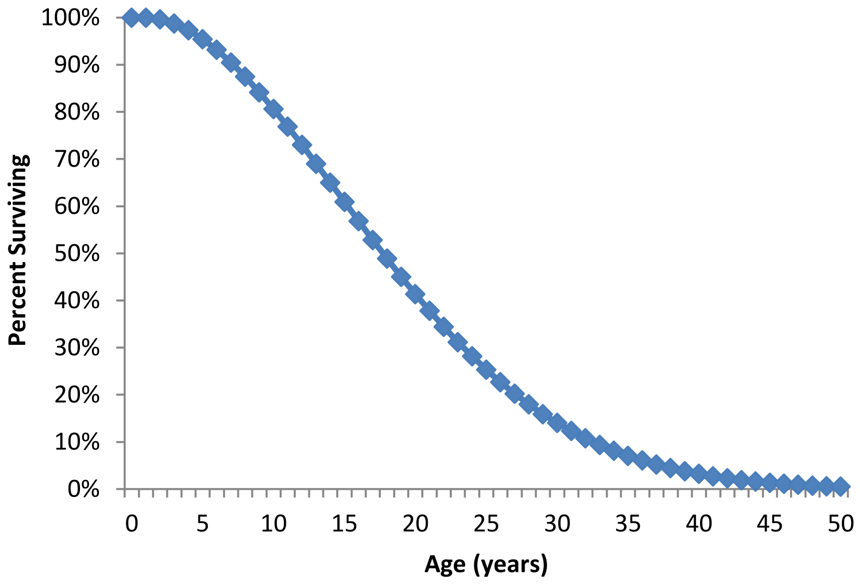

Figure 5.4-2: [Central ACs & HPs] Survival Function for ACs[104]

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[104] Department of Energy, Federal Register, 76 FR 37408, Technical Support Document: 8.2.3.5 Lifetime. June 2011. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=48&action=viewlive. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012.

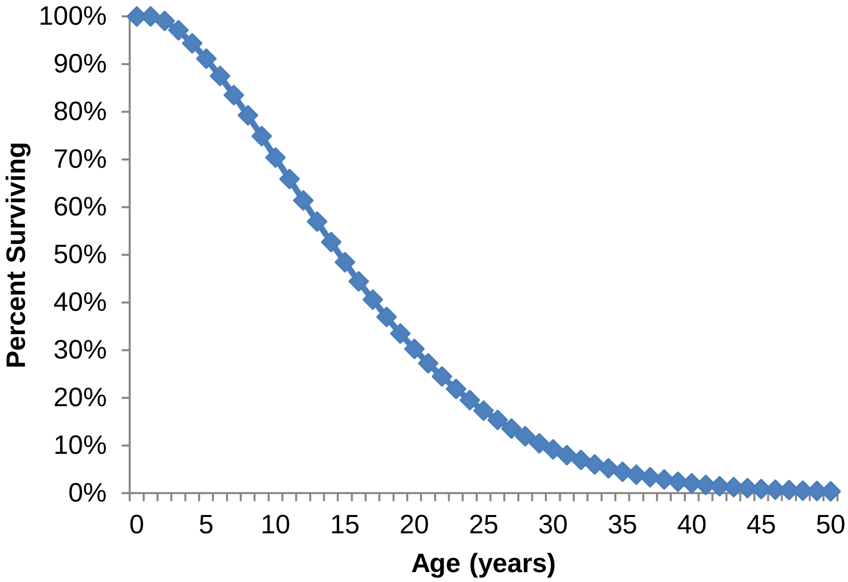

Figure 5.4-3: [Central ACs & HPs] Survival Function for HPs[105]

Load Shapes

The demand savings for this measure were derived using an approach adapted from the method outlined in Section 2.3. First, the Top 20 peak hours were mapped to the corresponding ambient temperature from the TMY3 weather file for San Antonio – Kelly AFB. Next, the kW savings at the resulting temperatures were weighted using the probabilities assigned to each of the top 20 peak hours and 4CP hours. NCP savings are derived based on the maximum temperature from the San Antonio weather file.

5.4.2.1 Deemed Energy Savings Tables

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume. Both cooling and heating savings are specified according to AHRI rated cooling capacity.

5.4.2.2 Deemed Summer Demand Savings Tables

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume. Both cooling and heating savings are specified according to AHRI rated cooling capacity.

5.4.2.3 Additional Calculators and Tools

This section is not applicable for this measure.

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[105] Ibid.

5.4.2.4 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 18 years for ACs and 15 years for HPs based on the current DOE Final Rule standards for ACs and HPs.[106] These values are consistent with the EUL reported in the Department of Energy 76 Final Rule 37408 Technical Support Document for Energy Conservation Standards for ACs and HPs.[107]

5.4.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Decision/action type (early retirement, replace-on-burnout, new construction)
- Manufacturer, model, and serial number of new unit
    - AHRI/DOE CCMS certificate or reference number matching model number
- Cooling capacity of the new unit (btuh)
- Seasonal Energy Efficiency Ratio (SEER) of the new unit
- Heating Seasonal Performance Factor (HSPF) of the new unit (HPs only)
- Type of unit replaced (AC with gas furnace, AC with electric resistance furnace, air source HP)
    - Baseline equipment used for savings (if different from unit replaced)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
- New unit type (central AC, central HP, dual-fuel HP)
- Age of the replaced unit (early retirement or rightsizing)
- Retired cooling unit model number, serial number, manufacturer, and cooling capacity (early retirement or rightsizing)
- Retired or replaced heating unit model number, serial number, manufacturer, and heating capacity (electric resistance only)
- Photograph of retired unit nameplate (early retirement, rightsizing, or electric resistance baseline)
    - If a photograph of the retired unit nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (early retirement and electric resistance baseline only)
    - If a photograph of the retired unit nameplate is unavailable or not legible, provide the estimated square footage of conditioned area served by the retired unit (rightsizing only)

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[106] Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=48&action=viewlive. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012.

[107] Department of Energy, Federal Register, 76 FR 37408, Technical Support Document: 8.2.3.5 Lifetime. June 2011.

- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)
- Proof of purchase with date of purchase and quantity
    - Alternative: photo of replacement unit nameplate or other pre-approved method of installation verification

5.5 MINI-SPLIT AIR CONDITIONERS AND HEAT PUMPS

5.5.1 Measure Description

Residential replacement of existing heating and cooling equipment with a new mini-split air-source air conditioner (AC) or heat pump (HP) in an existing building, or the installation of a new mini-split AC or HP in a new residential construction. Downsized systems that are right sized per a heat load calculation are also eligible. This measure also applies to the installation of DC inverter systems that meet all existing measure eligibility criteria.

5.5.1.1 Eligibility Criteria

Newly installed units must have a cooling capacity of less than 65,000 Btu/hour (5.4 tons) to be eligible for these deemed savings. Gas furnaces are not eligible to be awarded savings for replacement through this measure.

Equipment shall be properly sized to dwelling based on ASHRAE or ACCA Manual J standards. Manufacturer data sheets for new equipment or documentation of AHRI or DOE CCMS certification must be provided.[108,109] Savings should be calculated using rated capacities whenever possible. Reported system capacities and efficiencies should always match those verified by AHRI or DOE as tested under AHRI operating conditions for a specific combination of equipment, including condenser, coil, and furnace (or condenser only for packaged units). Savings should never be calculated using efficiency ratings for individual system components.

Customers should be advised against using the emergency heat (EM HEAT) setting on heat pump thermostats. This setting is meant only for use in emergency situations when the heat pump is damaged or malfunctioning. Supplemental heating automatically kicks on below freezing conditions using the regular HEAT setting. Contractors installing a new thermostat with heat pump equipment shall advise customer of correct thermostat usage.

For early retirement or rightsizing projects, attempt to determine the rated capacity of the existing unit. The rated capacity may be found on the manufacturer specification sheet for the existing unit if the new system is not available on the AHRI or DOE CCMS directories. If the model number of the existing unit is unobtainable or if the manufacturer specification sheet cannot be found, use nominal tonnage for both the existing and new unit. Never use nominal tonnage for the existing unit in combination with rated tonnage for the new unit, which can lead to overstated savings. Additionally, never use nominal tonnage to determine savings for projects where no early retirement or rightsizing has occurred.

For early retirement savings to receive savings, the replaced unit must be functioning at the time of removal with a maximum age of 24 years for ACs and 20 years for HPs. To determine the remaining useful life of an existing unit; see Table 5.4-5 and Table 5.4-6. Otherwise claim saving for a replace-on-burnout project.

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[108] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.

[109] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.

The replacement of a room AC with a mini-split AC or HP is eligible and should be claimed against the new construction baseline. Refer to the Replace-on-Burnout or Early Retirement of an Electric Resistance section for guidance about the appropriate heating baseline for residences with electric resistance heat. Under this scenario, no savings should be awarded for rightsizing.

New construction projects are not eligible to receive deemed savings for system rightsizing. For system upsizing, savings should generally be claimed against the new construction baseline. However, when upsizing while going from a single larger capacity system to multiple smaller capacity systems, savings may be claimed against the applicable replace-on-burnout or early retirement baseline if the total pre and post tonnage are within ½ ton.[110] For this scenario, savings must be looked up using the lower pre tonnage. If the multiple installed units do not share the same efficiency value, savings should be looked up using the most conservative efficiency value.

Additionally, low income or hard-to-reach programs may use the electric resistance baseline for the following two scenarios. The electric resistance baseline may be used for systems upsized by no more than a half ton in lieu of the new construction baseline. Under this scenario, cooling savings should be claimed against the new construction baseline using the installed (higher) capacity. Heating savings should be claimed against the electric resistance baseline using the existing (lower) capacity. Documentation should be aligned with rightsizing and electric resistance baseline requirements outlined in this measure. The second scenario is for a major multifamily renovation when a centralized system, such as a boiler, is replaced with individual HPs. For this scenario, the electric resistance baseline may be claimed in lieu of new construction only if the building owner can document intent to install electric resistance furnaces without program intervention. The cooling savings should still be claimed against the new construction baseline. Documentation should follow early retirement and electric resistance baseline requirements.

When replacing a single unit with multiple units where the capacity is the same or has been downsized, savings should be looked up using the total system pre and post capacities. Again, if the multiple installed units do not share the same efficiency value, savings should be looked up using the most conservative efficiency value.

5.5.1.2 Baseline Condition

New Construction, Replace-on-Burnout, or Early Retirement of an Air-Source AC or HP

New construction baseline efficiency values for ACs or HPs are compliant with the current federal minimum standard[111], effective January 1, 2015. The baseline is assumed to be a new system with an AHRI-listed SEER rating of 14.0. This baseline is also applicable to mini-split HP installations replacing ACs with central gas heat, or room/window ACs with central, space, or no heating.

For replace-on-burnout (ROB) projects, the cooling baseline is reduced to 13.08 SEER. This value

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[110] This exception is allowed to account for efficiency improvements due to zoning that are not reflected in the current savings methodology.

[111] DOE minimum efficiency standard for residential air conditioners/heat pumps. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=48&action=viewlive.

incorporates an adjustment to the baseline SEER value to reflect the percentage of current replacements that do not include the installation of an AHRI-matched system.[112]

For early retirement (ER) projects, the cooling baseline is reduced to 10 SEER for systems installed before January 23, 2006. For systems installed on or after January 23, 2006, the ER baseline increases to 12.44 SEER. Systems manufactured as of January 1, 2015 are not eligible for early retirement.

For ROB projects, heating baseline efficiency values for HPs comply with the current federal minimum standard, effective January 1, 2015. These standards specify an HSPF of 8.2 for split systems, or 8.0 for packaged systems. This baseline reflects updates to federal standards that take effect January 1, 2015, as defined in the Department of Energy (DOE) energy efficiency standards (10 CFR Part 430).[113]

For ER projects, the heating baseline efficiency is assumed to be 7.7 HSPF for units installed on or after January 23, 2006 based on the federal minimum standard in effect from January 23, 2006 through December 31, 2014.[114] Similarly, for ER projects installed before January 23, 2006, the heating baseline efficiency is assumed to be 6.8 HSPF based on the federal minimum standard in effect prior to January 23, 2006.

Replace-on-Burnout or Early Retirement of an Electric Resistance Furnace

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[115] Space heating refers primarily to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[116] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters should calculate savings using a heat pump baseline.

By the nature of the technology, all electric resistance furnaces have the same efficiency with HSPF = 3.41.[117] Projects in which an electric resistance furnace is replaced, whether in a replace-on-burnout or early retirement scenario, should use this baseline for heating-side savings.

For ROB projects, cooling savings are the same as for new construction and ROB of an air-source HP. For early retirement (ER) projects, the cooling baseline is reduced to 10 SEER for systems installed before January 23, 2006. For systems installed on or after January 23, 2006, the ER baseline increases to 12.44 SEER.

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[112] Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Southwestern Electric Power Company, Texas-New Mexico Power Company, And Southwestern Public Service Company to Revise Existing Commission Approved Deemed Savings Values for Central Air Conditioning and Heat Pump Systems, Public Utility Commission of Texas, Docket No. 36780 (August 27, 2009). https://interchange.puc.texas.gov/. Adapted for new 14 SEER baseline.

[113] 10 CFR Part 430.32(c)2. Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters; Final Rule. http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.

[114] Ibid.

[115] Electric resistance heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

[116] Portable heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

[117] COP = HSPF × 1,055 J/BTU / 3,600 J/W-hr. For Electric Resistance, heating efficiency is 1 COP. Therefore, HSPF = 1 × 3,600 / 1,055 = 3.41.

Table 5.5-1: [Mini-Split ACs & HPs] Baseline Efficiencies

Project Type	Cooling Mode	Heating Mode
New Construction	14.0 SEER	8.2 HSPF
Replace-on-Burnout, HP	13.08 SEER	8.2 HSPF
Replace-on-Burnout, Electric Resistance Furnace		3.41 HSPF
Early Retirement, HP (manufactured as of 1/23/2006 through 12/31/2014)	12.44 SEER	7.7 HSPF
Early Retirement, Electric Resistance Furnace (manufactured as of 1/23/2006 through 12/31/2014)		3.41 HSPF
Early Retirement, HP (manufactured before 1/23/2006)	10.0 SEER	6.8 HSPF
Early Retirement, Electric Resistance Furnace (manufactured before 1/23/2006)		3.41 HSPF

5.5.1.3 High-Efficiency Condition

Table 5.4-2 displays the Consortium for Energy Efficiency (CEE) requirements for eligible Tier 0 systems as of January 1, 2009. Energy efficiency service providers are expected to at least comply with the latest CEE Tier 0 requirements.

No full-load efficiency requirement is specified in the current federal standard. Therefore, systems with qualifying SEER and HSPF energy ratings are permitted to claim cooling and heating energy savings for systems where the EER does not comply with the below requirement. Claim zero demand savings rather than negative demand savings for systems with non-compliant EER ratings.

Table 5.5-2: [Mini-Split ACs & HPs] CEE Tier 0 Requirements[118]

SEER	EER	HSPF
14.5	12.0	8.5

Split system efficiencies are driven primarily by the efficiency of the condenser unit. If the paired outdoor and indoor units are not listed on the AHRI certification listing and only provide DOE CCMS testing results, then the capacity and efficiency of the high-efficiency condition shall not exceed the average of the AHRI certification listing pairing for the matching condenser. The DOE CCMS listing provides documentation of the results that are on the AHRI certification listing and can be downloaded and filtered based on listing using a similar condenser and various indoor units.

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[118] CEE Residential High Efficiency Central Air Conditioners Air Source Heat Pumps Specification, January 1, 2015. https://library.cee1.org/content/cee-residential-high-efficiency-central-air-conditioners-and-air-source-heat-pumps-specifica.

5.5.2 Energy and Demand Savings Methodology

5.5.2.1 Savings Algorithms and Input Variables

Replace-on-Burnout and New Construction

Energy, summer demand, and winter demand savings were estimated using AC and HP performance curves developed by the National Renewable Energy Laboratory[119] for typical units in each of the following SEER ranges:

- Baseline units
- 14.5 – 14.9
- 15.0 – 15.9
- 16.0 – 16.9
- 17.0 – 17.9
- 18.0 – 20.9
- 21.0 and above

This measure assumes 14.5 – 16.9 SEER units to be single stage and 17.0 and above SEER units to be multi-stage cooling units.

These performance curves provide the capacity and efficiency of the ACs and HPs operating in cooling mode across a wide range of outside air temperatures. Unit loading was estimated as a function of outside air temperature, and hours of cooling mode operation under different loadings were estimated using bin weather data for each weather zone. In heating mode, predicted HVAC operation was limited to meeting 77 percent of load, using a factor applied in Manual J to correlate design load hours to equivalent full load hours under actual operating conditions, considering that heating systems are not always operated even when outdoor conditions indicate they should.

Summer and winter demand savings are estimated according to expected unit performance under design conditions. For all weather zones, it is assumed that typical HVAC systems are sized to 115 percent of their design cooling load (oversized by 15 percent). Heating mode capacity was related to rated cooling capacity using the rated capacity in cooling and heating mode of the residential market HP products of four major manufacturers according to data exported from AHRI. Data were exported from the AHRI directory and the average ratio for each equipment size (1-ton, 1.5-ton, 2-ton, etc.) of heating capacity to cooling capacity was multiplied by the rated (cooling side) capacity to estimate the HP capacity. Heat pump system output was then compared to its loading under design conditions.

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[119] D. Cutler et al. Improved Modeling of Residential Air Conditioners and Heat Pumps for Energy Calculations. National Renewable Energy Laboratory. NREL/TP-5500-56354. January 2013. Tables 12 and 13. http://www.nrel.gov/docs/fy13osti/56354.pdf.

The model uses the following set of normalized performance curves to scale the rated performance values as a function of outdoor dry-bulb temperature ranging from 65 to 115 degrees Fahrenheit. The total capacity and Energy Input Ratio (EIR = 1/COP) curves are a function of entering wet-bulb temperature (EWB) and outdoor dry-bulb temperature (ODB) and are both quadratic curve fits of the form:

$$y = a + b \times T_{EWB} + c \times T_{EWB}^2 + d \times T_{ODB} + e \times T_{ODB}^2 + f \times T_{EWB} \times T_{ODB}$$

Equation 5.5-1

Table 5.5-3: [Mini-Split ACs & HPs] Capacity Curve Coefficients

Coeff.	Cooling			Heating		
	Single Stage	Multi-Stage/Speed		Single Stage	Multi-Stage/Speed	
		Low	Low		Low	High
a	3.670270705	3.940185508	3.109456535	0.566333415	0.335690634	0.306358843
b	-0.098652414	-0.104723455	-0.085520461	-0.000744164	0.002405123	0.005376987
c	0.000955906	0.001019298	0.000863238	-0.0000103	-0.0000464	-0.0000579
d	0.006552414	0.006471171	0.00863049	0.009414634	0.013498735	0.011645092
e	-0.0000156	-0.00000953	-0.000021	0.0000506	0.0000499	0.0000591
f	-0.000131877	-0.000161658	-0.000140186	-0.00000675	-0.00000725	-0.0000203

Table 5.5-4: [Mini-Split ACs & HPs] EIR Curve Coefficients

Coeff.	Cooling			Heating		
	Single Stage	Multi-Stage/Speed		Single Stage	Multi-Stage/Speed	
		Low	Low		Low	High
a	-3.302695861	-3.87752688	-1.990708931	0.718398423	0.36338171	0.981100941
b	0.137871531	0.164566276	0.093969249	0.003498178	0.013523725	-0.005158493
c	-0.001056996	-0.001272755	-0.00073335	0.000142202	0.000258872	0.000243416
d	-0.012573945	-0.019956043	-0.009062553	-0.005724331	-0.009450269	-0.005274352
e	0.000214638	0.000256512	0.000165099	0.00014085	0.000439519	0.000230742
f	-0.000145054	-0.000133539	-0.0000997	-0.000215321	-0.000653723	-0.000336954

To estimate the baseline SEER value for retrofit installations, Texas A&M's Energy Systems Laboratory (ESL) surveyed dealers across the State to determine installation practices. The research found that in the event of a compressor failure out of warranty, dealers replaced the compressor 11.7% of the time, and replaced the condensing unit 88.3% of the time. Further, the condensing unit replacements consist of condensing unit-only replacements, replacements with mismatched evaporator coils, and replacements with matching evaporator coils.

The percentages for these installations are as follows:

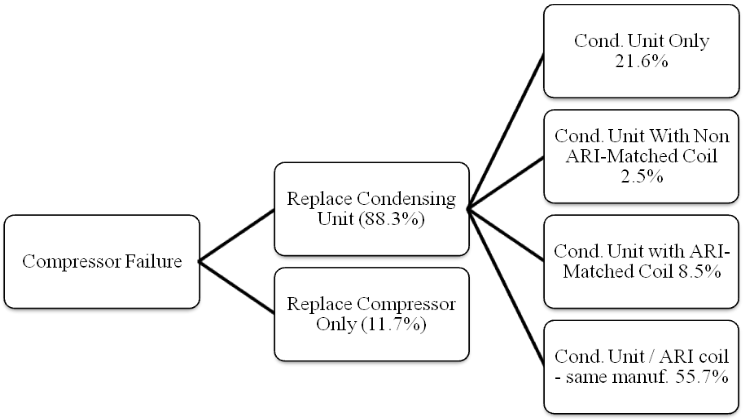

Figure 5.5-1: [Mini-Split ACs & HPs] Unit Replacement Percentages upon Compressor Failure[120]

To calculate a weighted average SEER for these installations, ESL assumed that a compressor-only replacement resulted in no increase in SEER, and that the SEER of a condensing unit installed without a matching coil would be 85% of the SEER value for a matched system. The ESL estimate of the baseline SEER for replacement AC units is given by the following equation:

$$\begin{aligned} \boldsymbol{SEER_{Base}} = {} & \left(\boldsymbol{SEER_{Compressor\ Replacement}}\right) \times (\boldsymbol{Actual}\ \%\ \boldsymbol{Compressor\ Replacement}) \\ & + \left(\boldsymbol{SEER_{Condenser\ Replacement}}\right) \times (\boldsymbol{Actual}\ \%\ \boldsymbol{Condenser\ Replacement}) \\ & + \left(\boldsymbol{SEER_{System\ Replacement}}\right) \times (\boldsymbol{Actual}\ \%\ \boldsymbol{System\ Replacement}) \end{aligned}$$

Equation 5.5-2

Substituting ESL SEER estimates and survey data provides the following baseline SEER estimate:

$$\boldsymbol{SEER_{Base}} = (\mathbf{9.5}) \times (\mathbf{11.7}\%) + (\mathbf{11.05}) \times (\mathbf{24.1}\%) + (\mathbf{13.5}) \times (\mathbf{64.2}\%) = \mathbf{12.44}$$

Adjusting for the increased 14 SEER baseline:

$$\boldsymbol{SEER_{Base}} = (\mathbf{10.5}) \times (\mathbf{11.7}\%) + (\mathbf{11.9}) \times (\mathbf{24.1}\%) + (\mathbf{14}) \times (\mathbf{64.2}\%) = \mathbf{13.08}$$

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[120] Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Southwestern Electric Power Company, Texas-New Mexico Power Company, And Southwestern Public Service Company to Revise Existing Commission Approved Deemed Savings Values for Central Air Conditioning and Heat Pump Systems, Public Utility Commission of Texas, Docket No. 36780 (August 27, 2009).

In new construction, there is no possibility of a partial system (e.g., condensing unit-only) changeout, so the 13.08 baseline would not be appropriate. Therefore, the baseline for new construction installations is set at the federal government's minimum efficiency standard of 14 SEER.

Early Retirement

Annual energy (kWh) and summer peak demand (kW) savings must be calculated separately for two time periods:

- The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
- The remaining time in the EUL period (EUL – RUL)

Annual energy and summer peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in Section 22.3.

Where:

RUL = *Remaining Useful Life (see Table 5.4-5 and Table 5.4-6); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 7.0 years (ACs) or 6.0 years (HPs). If individual system components were installed at separate times, use the condenser age as a proxy for the entire system. Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. For HPs replacing ACs with an electric resistance furnace, use the AC RUL table.*

EUL = *Estimated Useful Life = 18 years (AC); 15 years (HP).*

Table 5.5-5: [Mini-Split ACs & HPs] Remaining Useful Life of Replaced ACs[121]

Age of Replaced Unit (years)	RUL (years)	Age of Replaced Unit (years)	RUL (years)
1	16.8	14	8.6
2	15.8	15	8.2
3	14.9	16	7.9
4	14.1	17	7.6
5	13.3	18	7.0
6	12.6	19	6.0
7	11.9	20	5.0
8	11.3	21	4.0
9	10.8	22	3.0
10	10.3	23	2.0
11	9.8	24	1.0
12	9.4	25[122,123]	0.0
13	9.0		

Table 5.5-6: [Mini-Split ACs & HPs] Remaining Useful Life of Replaced HPs[124]

Age of Replaced Unit (years)	RUL (years)	Age of Replaced Unit (years)	RUL (years)
1	13.7	12	7.9
2	12.7	13	7.6
3	12.0	14	7.0
4	11.3	15	6.0
5	10.7	16	5.0
6	10.2	17	4.0
7	9.7	18	3.0
8	9.3	19	2.0
9	8.9	20	1.0
10	8.5	21[125,126]	0.0
11	8.2		

Derivation of RUL

ACs have an estimated useful life of 18 years, and HPs have an estimated useful life of 15 years. This estimate is consistent with the age at which approximately 50 percent of ACs and HPs installed in a given year will no longer be in service, as described by the survival functions in Figure 5.5-2 and Figure 5.5-3.

The method for estimating the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival functions shown Figure 5.5-2 and Figure 5.5-3. The age of the system being replaced is found on the horizontal axis, and the corresponding percentage of surviving systems is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. The age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

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[121] Current federal standard effective date is 1/1/2015. Existing systems manufactured after this date are not eligible to use the early retirement baseline.

[122] RULs are capped at the 75th percentile of equipment age, 21 years, as determined based on DOE survival curves (Figure 5.4-3). Systems older than 21 years should use the ROB baseline. See the January 2015 memo, “Considerations for early replacement of residential equipment,” for further detail.

[123] Ward, B., Bodington, N., Farah, H., Reeves, S., and Lee, L. “Considerations for early replacement of residential equipment.” Prepared by the Evaluation, Measurement, and Verification (EM&V) team for the Electric Utility Marketing Managers of Texas (EUMMOT). January 2015. This document has been made available to Texas investor-owned utilities through the EM&V team’s SharePoint and are available for review upon request.

[124] Current federal standard effective date is 1/1/2015. Existing systems manufactured after this date are not eligible to use the early retirement baseline.

[125] RULs are capped at the 75th percentile of equipment age, 21 years, as determined based on DOE survival curves (Figure 5.4-3). Systems older than 21 years should use the ROB baseline. See the January 2015 memo, “Considerations for early replacement of residential equipment,” for further detail.

[126] Ward, B., Bodington, N., Farah, H., Reeves, S., and Lee, L. “Considerations for early replacement of residential equipment.” Prepared by the Evaluation, Measurement, and Verification (EM&V) team for the Electric Utility Marketing Managers of Texas (EUMMOT). January 2015. This document has been made available to Texas investor-owned utilities through the EM&V team’s SharePoint and are available for review upon request.

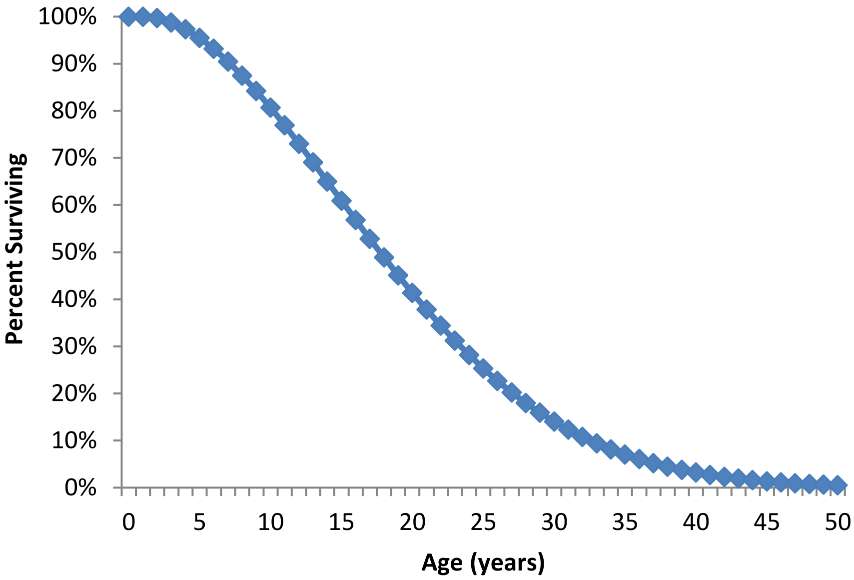

Figure 5.5-2: [Mini-Split ACs & HPs] Survival Function for ACs[127]

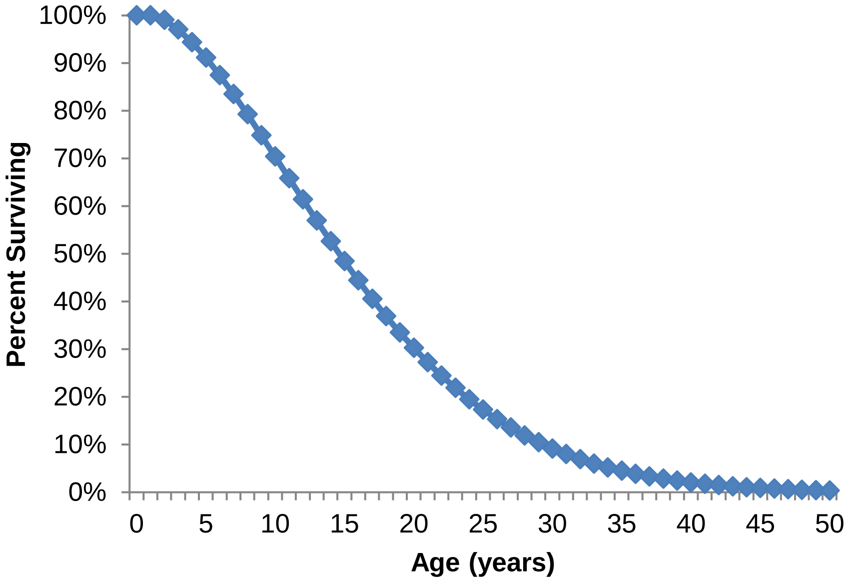

Figure 5.5-3: [Mini-Split ACs & HPs] Survival Function for HPs[128]

Load Shapes

The demand savings for this measure were derived using an approach adapted from the method

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[127] Department of Energy, Federal Register, 76 FR 37408, Technical Support Document: 8.2.3.5 Lifetime. June 2011. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=48&action=viewlive. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012.

[128] Ibid.

outlined in Section 2.3. First, the Top 20 peak hours were mapped to the corresponding ambient temperature from the TMY3 weather file for San Antonio – Kelly AFB. Next, the kW savings at the resulting temperatures were weighted using the probabilities assigned to each of the top 20 peak hours and 4CP hours. NCP savings are derived based on the maximum temperature from the San Antonio weather file.

5.5.2.2 Deemed Energy Savings Tables

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume. Both cooling and heating savings are specified according to AHRI rated cooling capacity.

5.5.2.3 Deemed Summer Demand Savings Tables

Due to the high volume of tables associated with this measure, deemed savings tables are provided in an appendix at the end of this volume. Both cooling and heating savings are specified according to AHRI rated cooling capacity.

5.5.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

5.5.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 18 years for ACs and 15 years for HPs based on the current DOE Final Rule standards for central ACs and HPs.[129] These values are consistent with the EUL reported in the Department of Energy 76 Final Rule 37408 Technical Support Document for Energy Conservation Standards for ACs and HPs.[130]

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[129] Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=48&action=viewlive. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012.

[130] Department of Energy, Federal Register, 76 FR 37408, Technical Support Document: 8.2.3.5 Lifetime. June 2011.

5.5.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Decision/action type (early retirement, replace-on-burnout, new construction)
- Manufacturer, model, and serial number of new unit
    - AHRI/DOE CCMS certificate or reference number matching model number
- Cooling capacity of the new unit (btuh)
- Seasonal Energy Efficiency Ratio (SEER) of the new unit
- Heating Seasonal Performance Factor (HSPF) of the new unit (HPs only)
- Type of unit replaced (air conditioner with gas furnace, air conditioner with electric resistance furnace, air source heat pump)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
- New unit type (mini-split AC, mini-split HP, DC inverter AC, DC inverter HP)
- Age of the replaced unit (early retirement or rightsizing)
- Retired cooling unit model number, serial number, manufacturer, and cooling capacity (early retirement or rightsizing)
- Retired or replaced heating unit model number, serial number, manufacturer, and heating capacity (electric resistance only)
- Photograph of retired unit nameplate (early retirement, rightsizing, or electric resistance baseline)
    - If a photograph of the retired unit nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (early retirement and electric resistance baseline only)
    - If a photograph of the retired unit nameplate is unavailable or not legible, provide the estimated square footage of conditioned area served by the retired unit (rightsizing only)
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)
- Proof of purchase with date of purchase and quantity
    - Alternative: photo of replacement unit nameplate or other pre-approved method of installation verification

5.6 LARGE CAPACITY SPLIT AND PACKAGED AIR CONDITIONERS AND HEAT PUMPS

5.6.1 Measure Description

This measure applies to the installation of a split/packaged air conditioner (AC) or heat pump (HP) with a capacity exceeding that of a typical residential system (greater than or equal to 65,000 Btu/hr) in a retrofit or new construction application. This measure also applies to the installation of ground-source heat pumps (GSHP) with a capacity exceeding 65,000 Btu/hr.

5.6.1.1 Eligibility Criteria

The deemed savings apply to central AC/HPs with a capacity of 65,000-240,000 Btu/hr (5.4-20 tons) and GSHPs with a capacity of 65,000-135,000 Btu/hr (5.4-11.3 tons).

Equipment shall be properly sized to dwelling based on ASHRAE or ACCA Manual J standards.

Manufacturer datasheets for new equipment or documentation of AHRI or DOE CCMS certification must be provided.[131,132]

5.6.1.2 Baseline Condition

New construction and replace-on-burnout baseline efficiency levels are provided in Table 5.6-1 and Table 5.6-2. These baseline efficiency levels reflect the latest minimum efficiency requirements from the current federal manufacturing standard, IECC 2015, and ASHRAE 90.1-2013.

Table 5.6-1: [Large Capacity AC/HPs] Baseline Efficiencies for AC/HPs[133]

System Type	Capacity (tons)	Heating Section Type	Baseline Efficiencies
Air conditioners	> 5.4 to 11.3	None or electric resistance	11.2 EER 12.8 IEER
		All other	11.0 EER 12.6 IEER
	≥ 11.3 to ≤ 20	None or electric resistance	11.0 EER 12.4 IEER
		All other	10.8 EER 12.2 IEER

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[131] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.

[132] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.

[133] IECC 2018 Table C403.3.2(1) and C403.3.2(2).

System Type	Capacity (tons)	Heating Section Type	Baseline Efficiencies
Heat Pumps (cooling)	> 5.4 to < 11.3	Heat pump	11.0 EER 12.0 IEER
	≥ 11.3 to ≤ 20		10.6 EER 11.6 IEER
Heat Pumps (heating)	> 5.4 to < 11.3		3.3 COP
	≥ 11.3 to ≤ 20		3.2 COP

Table 5.6-2: [Large Capacity AC/HPs] Baseline Efficiencies for GSHPs[134]

System Type	Capacity (tons)	Cooling EWT Rating Condition	Minimum Cooling EER	Heating EWT Rating Condition	Minimum Heating EER
Water to air (water loop)	> 5.4 to < 11.3	86°F	13.0	68°F	4.3
Water to air (groundwater)		59°F	18.0	50°F	3.7
Brine to air (ground loop)		77°F	14.1	32°F	3.2
Water to water (water loop)		86°F	10.6	68°F	3.7
Water to water (groundwater)		59°F	16.3	50°F	3.1
Brine to water (ground loop)		77°F	12.1	32°F	2.5

5.6.1.3 High-Efficiency Condition

Split and packaged systems must exceed the minimum efficiencies specified in Table 5.6-1 and Table 5.6-2.

For reference, both ENERGY STAR and the Consortium for Energy Efficiency (CEE) offer suggested guidelines for high-efficiency equipment.

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[134] IECC 2018 Table C403.3.2(2).

5.6.2 Energy and Demand Savings Methodology

5.6.2.1 Savings Algorithms and Input Variables

Energy Savings

$$kWh_{Savings} = kWh_{Savings,C} + kWh_{Savings,H}$$

Equation 5.6-1

$$kWh_{Savings,C} = CAP_C \times \left(\frac{1}{\eta_{baseline,C}} - \frac{1}{\eta_{installed,C}}\right) \times EFLH_C \times \frac{1\ kW}{1,000\ W}$$

Equation 5.6-2

$$kWh_{Savings,H} = CAP_H \times \left(\frac{1}{\eta_{baseline,H}} - \frac{1}{\eta_{installed,H}}\right) \times EFLH_H \times \frac{1\ kWh}{3,412\ Btu}$$

Equation 5.6-3

Where:

$CAP_{C/H}$ = *Rated equipment cooling/heating capacity of the installed equipment at AHRI standard conditions [Btu/hr]; 1 ton = 12,000 Btu/hr.*

$\eta_{baseline,C}$ = *Cooling efficiency of standard equipment (Btuh/W).*

$\eta_{installed,C}$ = *Rated cooling efficiency of the newly installed equipment (Btuh/W).*

$\eta_{baseline,H}$ = *Heating efficiency of standard equipment (Btuh/W or COP).*

$\eta_{installed,H}$ = *Rated heating efficiency of the newly installed equipment (Btuh/W or COP).*

Note: Use EER for cooling kW and COP for heating kW and kWh savings calculations. SEER/IEER should be used to calculate cooling kWh for central ACs and HPs. EER should be used to calculate cooling kWh for GSHPs. Heating efficiencies expressed as HSPF will be approximated as a seasonal COP and should be converted using the following equation:

$$COP = \frac{HSPF}{3.412}$$

Equation 5.6-4

$EFLH_C$ = *Equivalent full load hours for cooling. Use 2,237 hours for San Antonio.*[135]

$EFLH_H$ = *Equivalent full load hours for heating. Use 1,101 hours for San Antonio.*[136]

1,000 = *Constant to convert from watts to kilowatts.*

3,412 = *Constant to convert from Btu to kWh.*

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[135] ENERGY STAR Central AC/HP Savings Calculator. April 2009 update. https://www.energystar.gov/sites/default/files/asset/document/ASHP_Sav_Calc.xls.

[136] Ibid.

Demand Savings

$$kW_{Savings} = CAP_C \times \left(\frac{1}{\eta_{baseline,C}} - \frac{1}{\eta_{installed,C}}\right) \times DF_C \times \frac{1\ kW}{1,000\ W}$$

Equation 5.6-5

Where:

DF = Demand Factor for NCP, CP, or 4CP peak demand; see

Table 5.8-4.

Table 5.6-3: [Large Capacity AC/HPs] Demand Factors for AC/HPs

Peak Type	Demand Factors
NCP	1.000
CP	0.935
4CP	0.871

Table 5.6-4: [Large Capacity AC/HPs] Demand Factors for GSHPs

Peak Type	Demand Factors
NCP	1.000
CP	0.668
4CP	0.589

Load Shapes

The demand factors were derived according to the method outlined in Section 2.3 using a load shape extracted from the BEopt energy simulation models developed for the residential envelope measures. The load shape can be found in Section 22.2.

5.6.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

5.6.2.3 Deemed Summer Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

5.6.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

5.6.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 18 years for large-capacity ACs and 15 years for large capacity HPs based on the current DOE Final Rule standards for central HPs.[137] The EUL 20 years for GSHPs, consistent with the EUL reported in the DOE GSHP guide.[138] These values are consistent with the EULs reported in the Department of Energy 76 Final Rule 37408 Technical Support Document for Energy Conservation Standards for ACs and HPs.[139]

5.6.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Decision/action type (replace-on-burnout, new construction)
- Manufacturer, model, and serial number of new unit
    - AHRI/DOE CCMS certificate or reference number matching model number
- Cooling and heating capacities of the installed unit (Btu/hr)
- Full-load efficiency rating (EER) of the new unit
- Part-load efficiency rating (SEER/IEER) of the new unit (if applicable)
- Coefficient of performance (COP) of the new unit (heat pumps and GSHPs only)
- Proof of purchase with date of purchase and quantity
    - Alternative: photo of replacement unit nameplate or other pre-approved method of installation verification

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[137] Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=75.

[138] Department of Energy. "Guide to Geothermal Heat Pumps. February 2011. http://www.energy.gov/sites/prod/files/guide_to_geothermal_heat_pumps.pdf.

[139] Department of Energy, Federal Register, 76 FR 37408, Technical Support Document: 8.2.3.5 Lifetime. June 2011.

5.7 PACKAGED TERMINAL HEAT PUMPS

5.7.1 Measure Description

This section presents the deemed savings methodology for the installation of packaged terminal heat pumps (PTHP) replacing packaged terminal air conditioners (PTAC) with electric resistance heat. This measure covers assumptions made for baseline equipment efficiencies for early retirement (ER) and replace-on-burnout (ROB), based current and previous on efficiency standards. For ER, the actual age of the baseline system should be determined from the equipment nameplate or other physical documentation whenever possible. Default values are provided for when the actual age of the unit is unknown.

Applicable efficient measure types are restricted to packaged terminal heat pumps. Both standard and non-standard size equipment types are covered. Standard size refers to equipment with wall sleeve dimensions having an external wall opening greater than, equal to 16 inches high or greater than, or equal to 42 inches wide and a cross-sectional area greater than 670 in^2. Non-standard size refers to equipment with existing wall sleeve dimensions having an external wall opening of fewer than 16 inches high or fewer than 42 inches wide and a cross-sectional area less than 670 in^2.

5.7.1.1 Eligibility Criteria

Existing PTAC and installed PTHP must be the primary cooling source in the residence. Installed PTHPs must be compliant with the current commercial code.

ER projects must involve the replacement of a working system before natural burnout. Additionally, the ER approach cannot be used for projects involving a simultaneous renovation where a major structural change or internal space remodel has occurred. A ROB approach should be used for these scenarios.

Manufacturer datasheets for new equipment or documentation of AHRI or DOE CCMS certification must be provided.[140,141]

5.7.1.2 Baseline Condition

Early Retirement

Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL-RUL) period. For the ROB period, the baseline efficiency is the same as for a ROB scenario. For the ER period, the baseline efficiency should be estimated according to the capacity, system type (PTAC), and age (based on year of manufacture) of the replaced system.[142] When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 5.7-1, reflecting ASHRAE Standard 90.1-2001 through 90.1-

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[140] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.

[141] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.

[142] The actual age should be determined from the nameplate, building prints, equipment inventory list, etc. and whenever possible the actual source used should be identified in the project documentation.

2007, should be used. PTHPs replacing PTACs with built-in electric resistance heat should use a baseline heating efficiency of 1.0 COP.

When the system age is unknown, assume 15 years.[143] A default RUL may be used exclusively if applied consistently for all eligible early retirement projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

Existing systems manufactured as of February 2013 are not eligible for early retirement.

Table 5.7-1: [PTHPs] ER Baseline Efficiency Levels for Standard Size PTACs[144,145]

Equipment	Cooling Capacity (Btu/hr)	Baseline Cooling Efficiency (EER)	Baseline Heating Efficiency (COP) – without Built-in Resistance Heat	Baseline Heating Efficiency (COP) – with Built-in Resistance Heat
PTAC	< 7,000	11.0	--	1.0
	7,000-15,000	12.5 – (0.213 x Cap/1,000)		
	> 15,000	9.3		

Replace-on-Burnout

Table 5.7-2 provides minimum efficiency standards for PTAC/PTHP units and reflects the IECC 2018 efficiencies for Packaged Terminal Air Conditioners and Heat Pumps. These values are closely aligned with the federal standards for packaged terminal air-conditioners and heat pumps effective February 2013 and reflected in 10 CFR 431.

Table 5.7-2: [PTHPs] ROB Baseline Efficiency Levels for PTHPs[146,147]

Equipment	Category	Cooling Capacity (Btu/hr)	Baseline Cooling Efficiency (EER)	Baseline Heating Efficiency (COP)
PTHP	Standard	All	14.0 – (0.300 x Cap/1,000)	3.7 – (0.026 x Cap/1,000)
	Non-Standard	All	10.8 – (0.213 x Cap/1,000)	2.9 – (0.026 x Cap/1,000)

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[143] As noted in Docket 40885, page 14-15: Failure probability weights are established by assuming that systems for which age information will be unavailable are likely to be older, setting a minimum age threshold, and using the survival functions for the relevant system type to estimate the likelihood that an operational system is of a given age beyond that threshold. Baseline efficiency for each year of system age is established relative to program year. Baseline efficiency levels can be estimated for the next ten program years, considering increments in efficiency standards that took place in the historical period.

[144] ER only applies to standard size units because the minimum efficiency requirements for non-standard systems have never changed, making the ER baseline efficiency the same as for ROB.

[145] Cap refers to the rated cooling capacity in Btuh. If the capacity is less than 7,000 Btuh, use 7,000 Btuh in the calculation. If the capacity is greater than 15,000 Btuh, use 15,000 Btuh in the calculation.

[146] IECC 2018 Table C403.3.2(3).

[147] Cap refers to the rated cooling capacity in Btuh.

5.7.1.3 High-Efficiency Condition

The high-efficiency retrofits must exceed the minimum federal standards found in Table 5.7-2.

The high-efficiency retrofits must also meet the following criteria:[148]

- For ER projects only, the installed equipment cooling capacity must be within 80 percent to 120 percent of the replaced electric cooling capacity.
- No additional measures are being installed that directly affect the operation of the cooling equipment (i.e., control sequences).

5.7.2 Energy and Demand Savings Methodology

5.7.2.1 Savings Algorithms and Input Variables

Energy Savings

$$\boldsymbol{Total\ Energy\ [kWh_{Savings}] = kWh_{Savings,C} + kWh_{Savings,H}}$$

Equation 5.7-1

$$\boldsymbol{Energy\ (Cooling)\ [kWh_{Savings,C}] = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}}\right) \times \frac{EFLH_C}{1,000}}$$

Equation 5.7-2

$$\boldsymbol{Energy\ (Heating)\ [kWh_{Savings,H}] = \left(\frac{Cap_{H,pre}}{\eta_{baseline,H}} - \frac{Cap_{H,post}}{\eta_{installed,H}}\right) \times \frac{EFLH_H}{3,412}}$$

Equation 5.7-3

Where:

$Cap_{C/H,pre}$ = *For ER, rated equipment cooling/heating capacity of the existing equipment at AHRI standard conditions; for ROB & NC, rated equipment cooling/heating capacity of the new equipment at AHRI standard conditions [Btuh]; 1 ton = 12,000 Btuh.*

$Cap_{C/H,post}$ = *Rated equipment cooling/heating capacity of the newly installed equipment at AHRI standard conditions [Btuh]; 1 ton = 12,000 Btuh.*

$\eta_{baseline,C}$ = *Cooling efficiency of existing (ER) or standard (ROB/NC) equipment [EER, Btu/W-h]; see Table 5.7-1 and Table 5.7-2.*

$\eta_{baseline,H}$ = *Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP]; see Table 5.7-1 and Table 5.7-2.*

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[148] Modified from PUCT Docket #41070 for TRMv3 to limit replacement of only smaller-sized units and extend early retirement to cover PTAC/PTHP.

$\eta_{installed,C}$ = *Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h]. Rated cooling efficiency must exceed minimum federal standards found in Table 5.7-2.*[149]

$\eta_{installed,H}$ = *Rated heating efficiency of the newly installed equipment [COP]. Rated heating efficiency must exceed minimum federal standards found in Table 5.7-2.*[150]

$EFLH_C$ = *Equivalent full load hours for cooling. Use 2,237 hours for San Antonio.*[151]

$EFLH_H$ = *Equivalent full load hours for heating. Use 1,101 hours for San Antonio.*[152]

1,000 = *Constant to convert from watts to kilowatts.*

3,412 = *Constant to convert from Btu to kWh.*

Demand Savings

$$\textbf{Demand Savings } [kW_{Savings}] = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}}\right) \times \frac{DF}{1,000}$$

Equation 5.7-4

Where:

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 5.7-3.*

Table 5.7-3: [PTHPs] Demand Factors

Peak Type	Demand Factors
NCP	1.000
CP	0.935
4CP	0.871

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 by using a load shape developed through adapting NREL's Commercial Reference Building Models[153] for San Antonio. The load shape can be found in Section 22.2.

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[149] Rated efficiency is commonly reported at both 230V and 208V. Savings calculations should reference efficiency at 230V, as AHRI rating conditions specify that voltage.

[150] Ibid.

[151] ENERGY STAR Central AC/HP Savings Calculator. April 2009 update. https://www.energystar.gov/sites/default/files/asset/document/ASHP_Sav_Calc.xls.

[152] Ibid.

[153] NREL Commercial Reference Buildings, http://energy.gov/eere/buildings/commercial-reference-buildings.

5.7.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

5.7.2.3 Deemed Summer Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

5.7.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

5.7.2.5 Measure Life and Lifetime Savings

Estimated Useful Life (EUL)

The EUL is 15 years for PTHPs, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HVAC-PTHP.[154]

Remaining Useful Life (RUL) for PTAC/PTHP Systems

The RUL of ER replaced systems is provided according to system age in Table 13.4-8.

For ER units of unknown age, assume a default value of 15 years, equal to the measure EUL. Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. Both the RUL and EUL are needed to estimate savings for ER projects for two distinct periods: the ER period (RUL) and the ROB period (EUL - RUL). The calculations for ER projects are extensive, and as such are provided in Section 22.3.

Table 5.7-4: [PTHPs] Remaining Useful Life or Replaced Unit[155]

Age of Replaced System (Years)	RUL (Years)
1	14.0
2	13.0
3	12.0
4	11.0
5	10.0
6	9.1

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[154] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

[155] Current NC baseline matches the baseline for existing systems manufactured in 2018. Existing systems manufactured after 1/1/2018 are not eligible to use the early retirement baseline.

Age of Replaced System (Years)	RUL (Years)
7	8.2
8	7.3
9	6.5
10	5.7
11	5.0
12	4.4
13	3.8
14	3.3
15	2.8
16	2.0
17	1.0
18[156]	0.0

5.7.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Decision/action type: ROB or ER
- Baseline unit equipment type (PTAC with electric resistance heat)
- Baseline unit quantity
- Baseline rated cooling and heating capacities
- For ER ONLY: baseline Age and Method of Determination (e.g., nameplate, blueprints, customer reported, not available)
- For ER ONLY: photograph of retired unit nameplate demonstrating model number, serial number, and manufacturer; if photograph of nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (alternate forms of documentation can be approved at the evaluator's discretion)
- Manufacturer, model, and serial number of new unit
    - AHRI/DOE CCMS certificate or reference number matching model number
- New unit equipment type (PTHP)
- New unit equipment configuration category: standard/non-standard (PTAC/PTHP only)

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[156] RULs are capped at the 75th percentile of equipment age, 18 years, as determined based on DOE survival curves. Systems older than 18 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

- New unit quantity
- New unit rated cooling and heating capacities
- New unit cooling and heating efficiency ratings
- Proof of purchase with date of purchase and quantity
    - Alternative: photo of replacement unit nameplate or other pre-approved method of installation verification

5.8 ENERGY STAR® ROOM AIR CONDITIONERS

5.8.1 Measure Description

The following deemed savings values are applicable to the installation of a high-efficiency room air conditioner (RAC).

5.8.1.1 Eligibility Criteria

Installed RACs must comply with the current ENERGY STAR specification for RACs.

To claim early retirement savings, the replaced unit must be functioning at the time of removal with a maximum age of 12 years.

5.8.1.2 Baseline Condition

For new construction (NC) and replace-on-burnout (ROB), the baseline is assumed to be a new room air conditioning unit that is compliant with the current federal standard, effective June 1, 2014. [157] The standard refers to a revised efficiency rating, Combined Energy Efficiency Ratio (CEER), which accounts for standby/off-mode energy usage.

For early retirement (ER), the baseline efficiency is assumed to match the minimum federal standard efficiencies in place prior to June 1, 2014. Since the effective date occurred mid-year, existing systems manufactured as of 2015 are not eligible for early retirement.

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[157] DOE minimum efficiency standard for residential room air conditioners. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41.

Table 5.8-1: [Room ACs] Baseline Efficiencies

Reverse Cycle (Yes/No)	Louvered Sides (Yes/No)	Capacity (Btu/hr)	Federal Standard prior to June 1, 2014	Federal Standard as of June 1, 2014
			ER Baseline EER	NC/ROB Baseline CEER
No	Yes	< 8,000	9.7	11.0
		> 8,000 and < 14,000	9.8	10.9
		> 14,000 and < 20,000	9.7	10.7
		> 20,000 and < 28,000	8.5	9.4
		> 28,000	8.5	9.0
No	No	< 8,000	9.0	10.0
		> 8,000 and < 11,000	8.5	9.6
		> 11,000 and < 14,000	8.5	9.5
		> 14,000 and < 20,000	8.5	9.3
		> 20,000	8.5	9.4
Yes	Yes	< 20,000	9.0	9.8
		> 20,000	8.5	9.3
Yes	No	< 14,000	8.5	9.3
		> 14,000	8.0	8.7
Casement-only		All capacities	8.7	9.5
Casement-slider		All capacities	9.5	10.4

5.8.1.3 High-Efficiency Condition

ENERGY STAR specifications effective October 26, 2015 are provided in Table 5.8-2 as the efficient condition.[158] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

Table 5.8-2: [Room ACs] Efficient Condition Specification

Reverse Cycle (Yes/No)	Louvered Sides (Yes/No)	Capacity (Btu/hr)	Units with Connected Functionality[159]	Units without Connected Functionality
No	Yes	< 8,000	11.6	12.1
		> 8,000 and < 14,000	11.5	12.0
		> 14,000 and < 20,000	11.3	11.8
		> 20,000 and < 28,000	9.9	10.3
		> 28,000	9.5	9.9
No	No	< 8,000	10.5	11.0
		> 8,000 and < 11,000	10.1	10.6
		> 11,000 and < 14,000	10.0	10.5
		> 14,000 and < 20,000	9.8	10.2
		> 20,000	9.9	10.3
Yes	Yes	< 20,000	10.3	10.8
		> 20,000	9.8	10.2
Yes	No	< 14,000	9.8	10.2
		> 14,000	9.2	9.6
Casement-only		All capacities	10.0	10.5
Casement-slider		All capacities	11.0	11.4

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[158] ENERGY STAR Program Requirements Product Specification for Room Air Conditioners: Eligibility Criteria Version 4.0. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%204.0%20Room%20Air%20Conditioners%20Specification.pdf. February 20, 2015.

[159] Connected functionality refers to units that have been tested for demand response capabilities. These units receive a 5% credit toward ENERGY STAR certification. This means they must only achieve a 5% improvement over the federal standard compared to 10% for standard units.

5.8.2 Energy and Demand Savings Methodology

5.8.2.1 Savings Algorithms and Input Variables

Energy Savings

New Construction or Replace-on-Burnout

$$kWh_{Savings,C} = \frac{CAP}{1,000} \times AOH_C \times \left(\frac{1}{CEER_{Base}} - \frac{1}{CEER_{RAC}}\right)$$

Equation 5.8-1

Where:

CAP = *Rated equipment cooling capacity of the installed RAC [Btu/hr].*

AOH_C = *Annual operating hours for cooling = 1,351 hours.*[160]

$CEER_{Base}$ = *Combined Energy Efficiency Ratio of the baseline cooling equipment; see Table 5.8-1.*

$CEER_{RAC}$ = *Combined Energy Efficiency Ratio of the installed RAC.*

1,000 = *Constant to convert from watts to kilowatts.*

Early Retirement

Annual energy (kWh) and summer peak demand (kW) savings must be calculated separately for two time periods:

- The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
- The remaining time in the EUL period (EUL – RUL)

Annual energy (kWh) savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in Section 22.3.

Where:

RUL = *Remaining Useful Life (see Table 5.8-3); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 5 years.*

EUL = *Estimated Useful Life = 10 years.*

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[160] Association of Home Appliance Manufacturers (AHAM) Room Air Conditioner Cooling Calculator.

Table 5.8-3: [Room ACs] Remaining Useful Life (RUL)

Age of Replaced Unit (years)	RUL (years)	Age of Replaced Unit (years)	RUL (years)
1	8.0[161]	8	5.0
2	7.2	9	4.0
3	6.2	10	3.0
4	5.2	11	2.0
5	5.2	12	1.0
6	5.2	13[162,163]	0.0
7	5.2		

For the RUL period:

$$\boldsymbol{kWh_{savings,ER} = \frac{CAP}{1,000} \times AOH_C \times \left(\frac{1}{EER_{ER}} - \frac{1}{CEER_{RAC}}\right)}$$

Equation 5.8-2

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project:

$$\boldsymbol{kWh_{savings,ROB} = \frac{CAP}{1,000} \times AOH_C \times \left(\frac{1}{CEER_{ROB}} - \frac{1}{CEER_{RAC}}\right)}$$

Equation 5.8-3

Where:

CAP = *Rated equipment cooling capacity of the installed RAC [Btu/hr].*

AOH_C = *Annual operating hours for cooling = 1,351 hours.*[164]

$CEER_{ROB}$ = *Combined Energy Efficiency Ratio of the replace-on-burnout baseline cooling equipment; see Table 5.8-1.*

EER_{ER} = *Energy Efficiency Ratio of the early retirement baseline cooling equipment; see Table 5.8-1.*

$CEER_{RAC}$ = *Combined Energy Efficiency Ratio of the installed RAC.*

1,000 = *Constant to convert from watts to kilowatts.*

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[161] Capped at EUL because RUL cannot exceed EUL.

[162] RULs are capped at the 75th percentile of equipment age, 13 years, based on DOE survival curves. Systems older than 13 years should use the ROB baseline. See the January 2015 memo, “Considerations for early replacement of residential equipment,” for further detail.

[163] Ward, B., Bodington, N., Farah, H., Reeves, S., and Lee, L. “Considerations for early replacement of residential equipment.” Prepared by the Evaluation, Measurement, and Verification (EM&V) team for the Electric Utility Marketing Managers of Texas (EUMMOT). January 2015.

[164] Association of Home Appliance Manufacturers (AHAM) Room Air Conditioner Cooling Calculator. http://www.cooloff.org/sub_cool.html.

Demand Savings

Cooling Demand Savings (Summer)

To calculate demand savings for the early retirement of a RAC, a similar methodology is used as for replace-on-burnout installations, with separate savings calculated for the remaining useful life of the unit, and the remainder of the EUL as outlined in the section above.

For the RUL period:

$$kW_{Savings,ER} = \frac{CAP}{1,000} \times \left(\frac{1}{EER_{ER}} - \frac{1}{EER_{RAC}}\right) \times DF$$

Equation 5.8-4

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project:

$$kW_{Savings,ROB} = \frac{CAP}{1,000} \times \left(\frac{1}{EER_{ROB}} - \frac{1}{EER_{RAC}}\right) \times DF$$

Equation 5.8-5

Where:

DF = Demand Factor for NCP, CP, or 4CP peak demand; see

Table 5.8-4.

1,000 = *Constant to convert from watts to kilowatts.*

Table 5.8-4: [Room ACs] Demand Factors

Peak Type	Demand Factors
NCP	1.000
CP	0.935
4CP	0.871

Derivation of RULs

RACs have an estimated useful life of 10 years. This estimate is consistent with the age at which approximately 50 percent of the RACs installed in a given year will no longer be in service, as described by the survival function in Figure 5.8-1.

The method for estimating the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the survival function shown in Figure 5.8-1.

The age of the RAC being replaced is found on the horizontal axis, and the corresponding percentage of surviving RACs is determined from the chart. The surviving percentage value is then divided in half, creating a new percentage. Then, the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

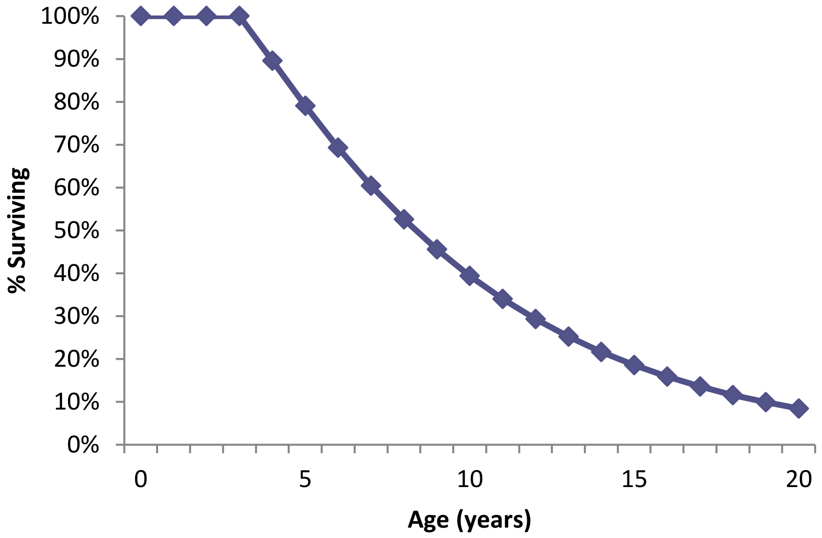

Figure 5.8-1: [Room ACs] Survival Function[165]

Load Shapes

The demand factors were derived according to the method outlined in Section 2.3 using a load shape extracted from the BEopt energy simulation models developed for the residential envelope measures. The load shape can be found in Section 22.2.

5.8.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous

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[165] Department of Energy, Federal Register, 76 FR 22454, Technical Support Document: 8.2.2.6 Product Lifetime. April 2011. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0053.

section for calculating energy and demand savings.

5.8.2.3 Deemed Summer Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

5.8.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

5.8.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 8 years for RACs based on the Technical Support Document for the current DOE Final Rule standards for RACs. This value is consistent with the EUL reported in the Department of Energy 76 Final Rule 52852 Technical Support Document for RACs.[166]

5.8.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Decision/action type (early retirement, replace-on-burnout, new construction)
- Manufacturer, model, and serial number of new unit
  - ENERGY STAR certificate matching model number
  - Connected functionality status
- Cooling capacity of the installed unit (Btu/hr)
- Combined Energy Efficiency Ratio (CEER) of the new unit
- Age of the replaced unit (early retirement only)
- Photograph of the retired unit nameplate (early retirement only)
  - If a photograph of the retired unit nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (early retirement only)
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)
- Proof of purchase with date of purchase and quantity
  - Alternative: photo of replacement unit nameplate or other pre-approved method of installation verification

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[166] Technical Support Document: Room Air Conditioners, June 2020, p. ES-14. https://beta.regulations.gov/document/EERE-2014-BT-STD-0059-0013.

5.9 ENERGY STAR® CONNECTED THERMOSTATS

5.9.1 Measure Description

Deemed savings are provided for the replacement of a standard or programmable thermostat with an ENERGY STAR Connected Thermostat.

5.9.1.1 Eligibility Criteria

All residential customers with refrigerated air conditioning are eligible to claim cooling savings for this measure. Customers must have electric central heating (either an electric resistance furnace or a heat pump) to claim heating savings.

The Connected Thermostats measure is primarily a residential retrofit measure, savings are presented for the average efficiency ratings of installed HVAC systems. Deemed savings are also presented for application to new construction for efficiency ratings of the units being installed (min. efficiency set by federal standards).

Customers should be advised against using the emergency heat (EM HEAT) setting on heat pump thermostats. This setting is meant only for use in emergency situations when the heat pump is damaged or malfunctioning. Supplemental heating automatically kicks on below freezing conditions using the regular HEAT setting. Contractors installing a new heat pump thermostat with equipment install shall advise customer of correct thermostat usage.

Customers that receive incentives for purchasing a thermostat device through an energy efficiency program, may be able to enroll in the load management program offered by the utility at the point of purchase. Deemed demand savings can only be claimed for those customers if they participate in the peak demand events. Otherwise, these devices are only eligible for the deemed energy efficiency savings.

5.9.1.2 Baseline Condition

The baseline condition is a residential central HVAC system controlled by a thermostat that does not meet the criteria for a connected thermostat (see High Efficiency Condition). For connected thermostats installed in conjunction with an existing HVAC unit, the baseline condition is an HVAC unit controlled by a manual or programmable thermostat with an average efficiency for existing HVAC units in Texas estimated as shown in Table 5.9-1.

Table 5.9-1: [Smart Thermostats] Baseline Efficiency of Existing HVAC Systems

Application	Efficiency Rating	Efficiency
Air Conditioner/Heat Pump Cooling Mode	SEER	12.2
Heat Pump Heating Mode	HSPF	7.6

Application	Efficiency Rating	Efficiency
Electric Resistance Heat	COP	3.41

For connected thermostats installed in conjunction with a new HVAC unit (for both retrofit and new construction applications), the baseline condition is an HVAC unit controlled by a manual or programmable thermostat with the baseline HVAC unit efficiency being equal to the efficiency of the installed system. The efficiency ratings of newly installed HVAC units should meet or exceed minimum values set by the federal manufacturing standards in effect at the time of the installation.

5.9.1.3 High-Efficiency Condition

The high efficiency condition is an HVAC unit being controlled by an ENERGY STAR Connected Thermostat. Details about the ENERGY STAR Connected Thermostats Specification are available on the program website,[167] as is a list of program-certified thermostats.[168]

5.9.2 Energy and Demand Savings Methodology

Energy savings are estimated according to the program requirements established by the ENERGY STAR program for thermostat service providers seeking certification. In addition to a series of other technical and programmatic requirements, providers must demonstrate that their thermostat services result in significant run-time reductions for the controlled cooling and heating equipment. Specifically, ENERGY STAR provides the runtime reduction criteria reproduced in Table 5.9-2.

The ENERGY STAR runtime reductions are translated to energy savings estimates using the following information:

- Capacity and efficiency curves for HVAC performance under different temperature conditions
- Outdoor dry bulb temperature data (binned TMY3 data) for San Antonio
- Annual HVAC consumption extracted from Central Air Conditioners and Heat Pumps measure savings spreadsheets

Energy use under the range of temperature conditions is estimated for San Antonio. Base case total energy use for a system of given nominal capacity (and efficiency) is estimated by multiplying each bin's energy use estimate by the number of hours of estimated operation in that bin. Energy savings are estimated by applying the runtime reductions in Table 5.9-2 uniformly to each bin's energy use.

Demand savings are not estimated for the Connected Thermostats measure.

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[167] ENERGY STAR Certified Products: Connected Thermostats Specification V1.0. https://www.energystar.gov/products/spec/connected_thermostats_specification_v1_0_pd.

[168] ENERGY STAR Certified Products: ENERGY STAR Certified Smart Thermostats. https://www.energysar.gov/productfinder/product/certified-connected-thermostats/results.

Table 5.9-2: [Smart Thermostats] Connected Thermostat Runtime Reduction Criteria for ENERGY STAR Certification

Metric	Statistical Measure	Performance Requirement
Annual % Run Time Reduction, Heating (HS)	Lower 95% Confidence Limit of Weighted National Average	≥ 8%
	Weighted National Average of 20th Percentiles	≥ 4%
Annual % Run Time Reduction, Cooling (CS)	Lower 95% Confidence Limit of Weighted National Average	≥ 10%
	Weighted National Average of 20th Percentiles	≥ 5%
Average Resistance Heat Utilization for Heat Pump Installations (RU)	National Mean in 5°F Outdoor Temperature Bins from 0 to 60°F	Reporting Requirement

5.9.2.1 Savings Algorithms and Input Variables

This section is not applicable.

5.9.2.2 Deemed Energy Savings Tables

Savings are presented in kWh per ton of HVAC system capacity. For projects where tonnage is unknown, assume a default of 3.7 tons.[169]

Table 5.9-3 presents the annual energy savings for installations in which the connected thermostat is not installed in conjunction with the installation of a new HVAC unit.

Table 5.9-3: [Smart Thermostats] Energy Savings for Installations with Existing HVAC Unit (kWh/ton)

Cooling Savings	Heating Savings	
	ER Heat	Heat Pump
246	187	68

When a connected thermostat is installed in conjunction with the installation of a new HVAC unit, the deemed savings are a function of the efficiency of the installed system. The deemed savings for connected thermostats installed on new HVAC units are provided in Table 5.9-4 and Table 5.9-5. The following savings are eligible to be claimed in both new construction programs and retrofit programs where a new HVAC system is installed.

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[169] Based on review of average reported cooling capacity for central air conditioners and heat pumps installed in Texas utility programs in previous program years.

Table 5.9-4: [Smart Thermostats] Cooling Energy Savings for Installations with New HVAC Unit (kWh/ton)

SEER						
14	14.5	15	16	17	18	21
220	211	203	188	166	157	136

Table 5.9-5: [Smart Thermostats] Heating Energy Savings (HP ONLY) for Installations with New HVAC Unit (kWh/ton)

Heat Pump HSPF							
8.2	8.5	8.6	8.7	9.0	9.3	9.5	9.7
63	61	59	59	56	53	52	51

The following table describes various equipment replacement scenarios that may be encountered and specifies which baseline should be used in each case. “Existing” corresponds to the savings from Table 5.9-6. “New” corresponds to the savings from Table 5.9-4 for cooling equipment and Table 5.9-5 for heating equipment.

Table 5.9-6: [Smart Thermostats] Baseline for Various Equipment Replacement Scenarios

Equipment Replacement Scenario	Baseline	
	Cooling	Heating
No HVAC equipment replacement	Existing	Existing
Non-condenser replacements (e.g., coil or furnace ONLY)	Existing	Existing
Air conditioner condenser replacement w/ gas furnace	New	No savings
Air conditioner condenser replacement w/ electric heat	New	Existing
Heat pump condenser replacement	New	New

For upstream programs, assume a heating type weighting of 41.8% gas, 49.3% electric resistance, and 9.0% heat pump heat.[170]

Table 5.9-7: [Smart Thermostats] Upstream and Midstream Program Energy Savings[171] (kWh/thermostat)

Total Energy Savings
1,274

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[170] Residential Energy Consumption Survey (RECS) 2015: Space heating in homes in the South and West Regions (HC6.8), February 27, 2017. https://www.eia.gov/consumption/residential/data/2015/.

[171] Assuming smart thermostat is installed in conjunction with an existing 3.7-ton HVAC unit.

5.9.2.3 Deemed Summer Demand Savings Tables

Summer demand savings shall not be claimed for the connected thermostats measure.

5.9.2.4 Additional Calculators and Tools

This section is not applicable.

5.9.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 11 years for connected thermostats, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HV-ProgTstat.[172]

5.9.3 Program Tracking Data and Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

All program types:

- Number of smart thermostats purchased/installed
- Smart thermostat manufacturer and model number

Additional requirements for all program types other than upstream/midstream:

- HVAC system type (AC/HP)
- Determine whether HVAC condenser was replaced in conjunction with thermostat
- HVAC capacity (tons)
- HVAC cooling efficiency (SEER) – ONLY if installed with new HVAC system
- HVAC heating efficiency (HSPF) – ONLY if installed with new heat pump
- Heating type (gas, electric resistance, heat pump, none)
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of replacement unit nameplate or other pre-approved method of installation verification

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[172] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

6. RESIDENTIAL: BUILDING ENVELOPE

6.1 AIR INFILTRATION

6.1.1 Measure Description

This measure involves application of techniques to reduce the amount of air infiltration into residences and the use of pre- and post-treatment blower door air pressure readings to confirm air leakage reduction.

Contractors must be trained on and consider health and safety considerations related to implementation of air sealing measures in residences. Homes without mechanical ventilation must not be sealed so tightly as to violate minimum ventilation requirements (detailed in High Efficiency Condition, below).

6.1.1.1 Eligibility Criteria

Cooling savings in this measure apply to all residential customers with central or mini-split electric refrigerated air HVAC systems in their residences. Residences must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. Customers are eligible to claim reduced heating savings for homes heated with gas or electric resistance space heaters by applying an adjustment to deemed savings specified by heating type. Customers are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that are specified for homes with refrigerated air.

While all homes are eligible for treatment, the savings that can be claimed for any individual home are limited by a maximum pre-retrofit infiltration rate of 5.2 CFM_{50} per square foot of house floor area.

Air leakage should be assessed through testing that follows Building Performance Institute (BPI) standards. In some limited cases, where testing is not possible or unsafe (e.g., because of potential presence of asbestos), visual assessment may be satisfactory. The air leakage testing should not be conducted in homes where evidence of asbestos or mold is present or suspected because of the age of the home.[173] CPS Energy may require certification or competency testing of personnel who will perform the blower door tests.

6.1.1.2 Baseline Condition

The baseline for this measure is defined by the leakage rate of the participating residence prior to treatment, capped at 5.2 CFM_{50}/ft^2 to account for the fact that the linear relationship described by the deemed savings values per CFM_{50} leakage reduction are only applicable up to the point where the

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[173] "Technical Standards for the Building Analyst Professional," Building Performance Institute (BPI), v1/4/125mda, Page 1 of 17, states: "Health and Safety: Where the presence of asbestos, lead, mold and/or other potentially hazardous material is known or suspected, all relevant state and federal (EPA) guidelines must be followed to ensure technician and occupant safety. Blower door depressurization tests may not be performed in homes where there is a risk of asbestos becoming airborne and being drawn into the dwelling." http://www.bpi.org/sites/default/files/Technical%20Standards%20for%20the%20Building%20Analyst%20Professional.pdf.

existing HVAC equipment would run continuously. Beyond that point, energy use will no longer increase linearly with an increase in leakage.[174,175]

Baseline assumptions used in the development of these deemed savings are based on a conversion from ACH$_{Natural}$. ASHRAE Handbook: Fundamentals specifies that more than 80% of sampled low-income housing had a pre-leakage rate at or below 1.75 ACH$_{Natural}$.[176] ACH$_{Natural}$ was converted to CFM$_{50}$/sqft using the following equation.

$$\boldsymbol{NL = 1{,}000 \times \frac{ELA_4}{A \times 0.3048^2} \times \left(\frac{H \times 0.3048}{2.5\ m}\right)^{0.3}}$$

Equation 6.1-1

$$\boldsymbol{Q_{50} = {ELA_4} \Big/ \left(\sqrt{\frac{\rho}{2(4\ Pa)}} \times \left(\frac{4\ Pa}{50\ Pa}\right)^{0.65}\right)}$$

Equation 6.1-2

$$\boldsymbol{CFM_{50,pre}/ft^2 = \frac{Q_{50} \times 60 \times 35.3147}{A}}$$

Equation 6.1-3

Where:

NL = *Normalized Leakage = 2.0 from LBNL study.*

ELA_4 = *Area of an orifice that would result in the same airflow through the building envelope at a pressure difference of 4 Pa [m^2].*

A = *Average area of a home in Texas from RECS 2009 [ft^2] = 1,757 ft^2.*

H = *Ceiling height [ft] = 8.5 (default).*[177]

0.3048 = *Constant to convert from feet to meters.*

Q_{50} = *Leakage rate at 50 Pa [m^3/s].*

ρ = *1.2 kg/m^3 from LBNL study.*

$CFM_{50,pre}/ft^2$ = *Maximum per-square-foot pre-installation infiltration rate.*

60 = *Constant to convert from minutes to seconds.*

35.3147 = *Constant to convert from cubic meters to cubic feet.*

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[174] Baseline assumptions used in the development of these deemed savings are based on a 2013 Lawrence Berkeley National Laboratory (LBNL) analysis of air leakage measurements of US houses. The LBNL study showed that approximately 95 percent of the home infiltration rates were below a normalized leakage rate of 2.0. Conversion of a normalized leakage rate of 2.0 to CFM$_{50}$/ft^2 through a series of equations results in the provided 5.2 CF M$_{50}$/ft^2 cap. TX TRM 8.0 updated this value to 4.6 based on 2017 ASHRAE Handbook: Fundamentals, Chapter 16, p. 16.19, Fig. 12. However, the reduction to the pre-leakage cap was not applied here based on a review of CPS Energy consumption data.

[175] Chan, W.R., Joh, J., and Sherman, M. H. Analysis of air leakage measurements of US houses. Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory (LBNL), p. 616-625.

[176] 2017 ASHRAE Handbook: Fundamentals, Chapter 16, p. 16.19, Fig. 12.

Using the above approach, the maximum per-square-foot pre-installation infiltration rate is 5.2. Therefore, to avoid incentivizing homes with envelope problems not easily remedied through typical weatherization procedures, or where blower door tests were improperly conducted, these savings should only be applied starting at a baseline CFM_{50}/ft^2 of 5.2 or lower.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[178] Space heating refers primarily to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[179] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer Demand Savings Tables sections.

6.1.1.3 High-Efficiency Condition

Blower door air pressure measurements shall be used to ensure that post-treatment air infiltration rates are not less than those set forth by the standard in Equation 6.1-4, based on floor area and number of bedrooms.[180] These calculated minimum CFM_{50} values assume two occupants for a one-bedroom dwelling unit and an additional person for each additional bedroom. At the utility's discretion, this minimum CFM_{50} requirement may be enforced as an eligibility requirement. Otherwise, savings may be claimed for projects where the measured final infiltration rate is less than the minimum allowable ventilation rate if the following conditions are met:

- Mechanical ventilation is present or introduced in compliance with ASHRAE 62.2-2013
- Post-treatment infiltration rate is reported as the actual measured CFM50 result
- Savings are calculated using the minimum allowable ventilation rate with no additional savings claimed for CFM reduction below this amount

Consistent with Equation 6.1-4, where higher occupant densities are known, the minimum rate shall be increased by 7.5 CFM_{Nat} for each additional person. A CFM_{Nat} value can be converted to CFM_{50} by multiplying by the appropriate N factor provided in Table 6.1-1.

$$\boldsymbol{Min\ CFM_{50}} = [\mathbf{0.03} \times \boldsymbol{A_{Floor}} + \mathbf{7.5} \times \boldsymbol{OCC}] \times \boldsymbol{N}$$

Equation 6.1-4

Where:

$Min\ CFM_{50}$ = *Minimum final ventilation rate [CFM_{50}].*

A_{Floor} = *Floor area [ft^2].*

OCC = *the number of home occupants, or 1+ the number of bedrooms (1 + BR), whichever is greater.*

N = *N factor; see Table 6.1-1.*

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[178] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

[179] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

[180] ASHRAE 62.2-2013. CFM_{Nat} values converted to CFM_{50} values by multiplying by appropriate N factor.

Table 6.1-1: [Air Infiltration] N Factors[181]

Shielding	Number of Stories		
	Single Story	Two Story	3 or More Stories
Well shielded	22.2	17.8	15.5
Normal	18.5	14.8	13.0
Exposed	16.7	13.3	11.7

The maximum CFM reduction percentage[182] is capped at 30 percent. It is important to note that the minimum ventilation rate specified earlier in this measure still applies for cases where the maximum 30 percent CFM reduction cannot be achieved due to the post CFM value being limited by the minimum allowable post CFM value provisioned for safety reasons.

An upper limit of 5.2 CFM_{50} per square foot of conditioned floor area is applied to the pre-retrofit infiltration rate. For homes where the pre-retrofit leakage exceeds this limit, energy and demand savings must be calculated using the pre-measure installation leakage cap. Therefore, when the pre-retrofit leakage is capped, energy and demand savings can only be claimed for a 30 percent reduction in CFM compared to the capped pre-CFM value. When the pre-retrofit leakage is not capped, energy and demand savings can only be claimed for a 30 percent reduction compared to the tested, actual pre-retrofit infiltration rate of the home.

Contractors shall provide documentary evidence—such as pictures capturing the scope/type of retrofit implemented and blower door test readings—for all projects claiming savings for achieving infiltration rate reductions greater than or equal to 30 percent.

6.1.2 Energy and Demand Savings Methodology

Calibrated simulation modeling was used to develop these deemed savings, which are expressed as linear functions of the leakage reduction achieved (in CFM_{50}).[183] Specifically, these deemed savings estimates were developed using NREL's BEopt 2.6 software, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home model was modified as follows: the base case air infiltration rate was set to 20 ACH_{50}. Post-treatment conditions were simulated by setting the leakage rate to 3 ACH_{50}. These modifications are shown in Table 6.1-2.

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[181] Krigger, J. and Dorsi, C., "Residential Energy: Cost Savings and Comfort for Existing Buildings." A-11 Building Tightness Limits, p. 284. Use Zone 2 for Texas climate.

[182] CFM reduction percentage is calculated as: (pre-CFM value – post-CFM value) / pre-CFM value.

[183] Model testing indicates a straight-line relationship between demand and energy savings achieved and CFM_{50} reductions is appropriate with beginning and ending leakage rates within the ranges permitted by the measure.

Table 6.1-2: [Air Infiltration] Modifications to Prototype Home

Shell Characteristic	Value
Base Case Ceiling Infiltration	20 ACH_{50}
Change Case Ceiling Insulation	3 ACH_{50}

6.1.2.1 Savings Algorithms and Input Variables

Deemed savings are presented as a function of the CFM_{50} reduction achieved, as demonstrated by blower door testing. The kWh and kW per CFM_{50} values represented by the V_E, V_S, and V_W coefficients are derived by taking the difference between annual energy use and summer and winter peak demand as estimated by the two model runs and normalizing to the CFM_{50} reduction achieved. The pre- and post-treatment ACH_{50} values (20 and 3, respectively) are converted to CFM_{50} by multiplying the pressurized air-change rate by the volume of the model home and dividing by 60 (minutes/hour).

Energy and demand savings claimed through this measure are not to exceed the savings that would be produced by achieving a 30 percent reduction in the home's air infiltration rate.

Energy Savings

Energy savings are estimated according to the differences in annual energy use in the pre-retrofit (base case) and post-retrofit (change case) models. Estimated savings per unit of leakage rate reduction (measured in CFM_{50}) are presented in the deemed energy savings tables below.

Demand Savings

Coincident Peak (CP), Non-coincident Peak (NCP) and ERCOT 4 Coincident Peak (4CP) demand savings are estimated in accordance with the definitions provided in Section 2.3 of this document. All are estimated according to the differences in energy use in specific hours of the simulations of the pre-retrofit (base case) and post-retrofit (change case) models. Estimated savings per unit of leakage rate reduction (measured in CFM_{50}) are presented in the deemed demand savings tables below.

Load Shapes

The building energy use simulation models used to estimate the savings for this measure are run on hourly time steps, producing 8,760 hourly estimates of energy use for the model year. The load shape used to estimate demand savings for the air infiltration measure is therefore the "delta load shape" developed by subtracting the whole house energy use in each hour of the post-retrofit model from the energy use in each hour of the pre-retrofit model.

6.1.2.2 Deemed Energy Savings Tables

Table 6.1-3 presents the energy savings per CFM_{50} reduction for a residential air sealing project. The following formula shall be used to calculate deemed energy savings for infiltration efficiency improvements. For customers who participate in Hard-to-Reach (HTR) or Low Income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying cooling savings in Table 6.1-3 by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying heating savings in Table 6.1-3 by a factor of 0.24.[184]

$$\boldsymbol{Deemed\ Energy\ Savings} = \Delta \boldsymbol{CFM_{50}} \times \left(\boldsymbol{V_{E,C}} \times \boldsymbol{CAF} + \boldsymbol{V_{E,H}} \times \boldsymbol{HAF}\right)$$

Equation 6.1-5

Where:

ΔCFM_{50} = *Air infiltration reduction in cubic feet per minute at 50 Pascal.*

$V_{E,C}$ = *Corresponding cooling savings value in Table 6.1-3.*

CAF = *Cooling adjustment factor in Table 6.1-4.*

$V_{E,H}$ = *Corresponding heating savings value in Table 6.1-3.*

HAF = *Heating adjustment factor in Table 6.1-4.*

Table 6.1-3: [Air Infiltration] V_E, Energy Savings per CFM_{50} Reduction

$V_{E,C}$: Cooling Savings	$V_{E,H}$: Heating Savings		
	Gas	Electric Resistance	Heat Pump
0.27	0.02	0.67	0.28

Table 6.1-4: [Air Infiltration] CAF/HAF, Cooling & Heating Adjustment Factors

HVAC System Type	CAF	HAF
Central AC	1.00	--
Window or Room AC	0.60	--
Central Furnace or HP	--	1.00
Electric Resistance Space Heater	--	0.24
None	0.00	0.00

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[184] This factor was derived based on expected capacity reduction assuming 1,200 sqft (historical analysis of HTR participants) x 0.35 BTU/sqft = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

6.1.2.3 Deemed Demand Savings Tables

Table 6.1-5 presents the peak demand savings per CFM_{50} reduction for a residential air sealing project. The following formula shall be used to calculate deemed demand savings for air infiltration improvements. For customers who participate in Hard-to-Reach (HTR) or Low Income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying V_D in Table 6.1-5 by a factor of 0.6.

$$\boldsymbol{Deemed\ Demand\ Savings} = \Delta \boldsymbol{CFM_{50}} \times \boldsymbol{V_D} \times \boldsymbol{AF}$$

Equation 6.1-6

Where:

V_D = *Corresponding demand savings value in Table 6.1-5.*

AF = *Adjustment factor based on HVAC system type in Table 6.1-6.*

Table 6.1-5: [Air Infiltration] Peak Summer Demand Savings V_D per CFM_{50} Reduction

V_D	Primary Heat Source	Demand Savings (kW/CFM_{50})
NCP	Gas Furnace	4.91×10^{-4}
	Electric Resistance	1.68×10^{-3}
	Heat Pump	6.46×10^{-4}
CP	All	2.18×10^{-4}
4CP	All	1.96×10^{-4}

Table 6.1-6: [Air Infiltration] AF, Adjustment Factors

Cooling System Type	NCP Adjustment Factor by Primary Heat Source				CP and 4CP Adjustment Factor by Primary Heat Source			
	Gas	Electric Resistance	Heat Pump	None	Gas	Electric Resistance	Heat Pump	None
Central AC	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Window or Room AC	0.6	1.0	0.6	0.6	0.6	0.6	0.6	0.6
None	0.0	1.0	NA	0.0	0.0	0.0	NA	0.0

6.1.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

6.1.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) for is 11 years for air infiltration reduction, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID BS-Wthr.[185]

6.1.3 Program Tracking Data & Evaluation Requirements

To inform the evaluation and ensure proper application of these deemed savings values, the following primary inputs and contextual data should be specified and tracked (e.g., in a program database) for each treated home:

- Pre-retrofit air infiltration in cubic feet per minute at 50 Pascal
- Post-retrofit air infiltration in cubic feet per minute at 50 Pascal
- Cooling type (central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
- Square footage
- Shielding level (well shielded, normal, exposed)
- Number of bedrooms
- Number of stories
- Number of occupants
- For homes in which a CFM reduction of greater than 30 percent is achieved, description of the scope/type of retrofit implemented and pictures capturing:
    - pre- and post-retrofit condition of the treated spot(s) such as newly added door strip, caulking around window frame and recessed lighting fixtures, and
    - blower door test readings.

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[185] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

6.2 CEILING INSULATION

6.2.1 Measure Description

Savings are estimated for insulation improvements made to the ceiling area above a conditioned space.

6.2.1.1 Eligibility Criteria

Residences must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. Customers are eligible to claim reduced heating savings for homes heated with gas or electric resistance space heaters by applying an adjustment to deemed savings specified by heating type. Cooling savings in this measure apply to all residential customers with central or mini-split electric refrigerated-air cooling systems in their residences. Certain customers are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that are specified for homes with refrigerated air.

6.2.1.2 Baseline Condition

Ceiling insulation levels encountered in existing homes can vary significantly, depending on factors such as the age of the home, type of insulation installed, and level of attic use (equipment, storage, etc.). Deemed savings have been developed based on different levels of encountered (existing) ceiling insulation in participating homes, ranging from no insulation material (R-0) to the equivalent of about 6 inches of fiberglass batt insulation (R-22). The insulation installer shall determine and document the existing average ceiling insulation level and account for any degradation of the existing insulation attributable to age and density at participating homes.

If existing insulation is to be or has been removed during measure implementation, the existing R-value shall be reported based upon the R-value of the existing insulation prior to removal.

For any reported pre-retrofit R-value that falls below R-5, contractors shall document the found condition as follows: 1) one or more pictures showing the entire attic floor, and 2) a close-up picture of a ruler that shows the measurement of the depth of the insulation. These pictures shall be provided to CPS Energy for quality assurance purposes. In the absence of evidence demonstrating pre-retrofit ceiling insulation to be below R-5, the lowest pre-retrofit baseline ceiling insulation R range that can be claimed is (R5 - R8).

In the event there are varying levels of existing insulation, an area-weighted U-factor should be used to find the effective R-value across the treated area. The U-factor should be taken from the existing insulation only. This approach should be used in single attic spaces and savings should be estimated separately for independent spaces where there is a separate heating or cooling method (i.e., additions).

Area-weighted U-factor Calculation Method:

$$U_A = [U_1 \times Area_1 + \mathrm{U}_2 \times \mathrm{Area}_2 + \ldots]/\ [\mathrm{Area}_1 + \mathrm{Area}_2 + \ldots]$$

$$Effective\ Rvalue = \frac{1}{U_A}$$

Equation 6.2-1

Alternatively, utilities may record varying R-values across separate defined areas to estimate savings for separate areas.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[186] Space heating refers primarily to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[187] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer Demand Savings Tables sections.

6.2.1.3 High-Efficiency Condition

A minimum ceiling insulation level of R-30 is recommended throughout Texas as prescribed by the Department of Energy.[188] Accordingly, deemed savings are provided for insulating to R-30. Contractors should estimate achieved post-retrofit R-value according to the average insulation depth across the treated area and the R-per-inch of the insulation material installed. Factors are provided to allow contractors to estimate savings for installation of post-retrofit insulation to levels higher or lower than R-30.

6.2.2 Energy and Demand Savings Methodology

6.2.2.1 Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed by using NREL's BEopt 2.6 software, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models were modified as follows: the default R-value of ceiling insulation (R-15) was set at different levels, ranging from R-0 (no ceiling insulation) to R-22. These modifications are shown in Table 6.2-1.

The model runs produced estimated peak demand and energy use for the modeled home at each of the base case ceiling insulation levels. The change-case models were run with the ceiling insulated to R-30. Scale-down and Scale-up factors were developed by modeling homes with R-24 and R-38 post-retrofit ceiling insulation levels.

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[186] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

[187] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

[188] Department of Energy Insulation R-value recommendations for zone 2/3, https://www.energy.gov/energysaver/weatherize/insulation.

Table 6.2-1: [Ceiling Insulation] Prototypical Home Characteristics

Shell Characteristic	Value	Source
Base Ceiling Insulation	R0-R4 R5-R8 R9-R14 R15-R22	Existing insulation level
Change Ceiling Insulation	R-30	R-30 retrofit insulation level

Energy Savings

Energy savings are estimated according to the differences in annual energy use in the pre-retrofit (base case) and post-retrofit (change case) models. Estimated savings per square foot of ceiling insulation installed (ceiling area net of framing materials) are presented in the deemed energy savings tables below.

Demand Savings

Coincident Peak (CP), Non-coincident Peak (NCP) and ERCOT 4 Coincident Peak (4CP) demand savings are estimated in accordance with the definitions provided in Section 2.3 of this document. All are estimated according to the differences in energy use in specific hours of the simulations of the pre-retrofit (base case) and post-retrofit (change case) models. Estimated savings per square foot of ceiling insulation installed are presented in the deemed demand savings tables below.

Load Shapes

The building energy simulation models used to estimate the savings for this measure are run on hourly time steps, producing 8,760 hourly estimates of energy use for the model year. The load shapes used to estimate demand savings for the ceiling insulation measure are therefore the “delta load shapes” developed by subtracting the whole house energy use in each hour of the post-retrofit models from the energy use in each hour of the pre-retrofit models.

6.2.2.2 Deemed Energy Savings Tables

Table 6.2-2 presents the cooling and heating energy savings (kWh) achieved for every square foot of R-30 ceiling insulation installed in attics in CPS Energy’s service territory. Annual energy savings are the sum of the cooling savings and the heating savings for the appropriate heating equipment type.

For customers who participate in Hard-to-Reach (HTR) or Low Income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying cooling savings in Table 6.2-2 by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying heating savings in Table 6.2-2 by a factor of 0.24.[189]

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[189] This factor was derived based on expected capacity reduction assuming 1200 sqft (historical analysis of HTR participants) x 0.35 BTU/sqft = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

$$\boldsymbol{Deemed\ Energy\ Savings\ (kWh) = \left(R30\ Savings/ft^2{}_C \times CAF + R30\ Savings/ft^2{}_H \times HAF\right) \times A}$$

Equation 6.2-2

Where:

R30 Savings/ft² = *Deemed cooling/heating energy savings per square foot taken from Table 6.2-2.*

A = *Treated area [ft²].*

CAF = *Cooling adjustment factor in Table 6.2-3.*

HAF = *Heating adjustment factor in Table 6.2-3.*

Table 6.2-2: [Ceiling Insulation] Energy Savings for Insulating to R-30 (kWh/sq. ft.)

Ceiling Insulation Base R Value	Cooling Savings	Heating Savings		
		Gas	Electric Resistance	Heat Pump
R-0 to R-4	1.29	0.07	1.86	0.78
R-5 to R-8	0.58	0.03	0.87	0.37
R-9 to R-14	0.30	0.02	0.47	0.20
R-15 to R-22	0.13	0.01	0.20	0.09

Table 6.2-3: [Ceiling Insulation] CAF/HAF, Cooling & Heating Adjustment Factors

HVAC System Type	CAF	HAF
Central AC	1.00	--
Window or Room AC	0.60	--
Central Furnace or HP	--	1.00
Electric Resistance Space Heater	--	0.24
None	0.00	0.00

Scale Down/Up Factors: Insulation to above or below R-30

The factors presented in this section are to be used when the average post-retrofit insulation depth provides less or more than R-30 insulation. Scale down factors are provided for the case when average post-retrofit insulation depth is not sufficient to achieve R-30; scale up factors are provided for the case when a contractor chooses to insulate to a level greater than R-30. In either case, the following equation should be applied to scale down or scale up the energy savings.

$$\begin{aligned}\boldsymbol{Deemed\ Energy\ Savings}\ (\boldsymbol{kWh}) \\ &= \{\boldsymbol{R30\ Savings/ft^2}_{\boldsymbol{C}} \times \boldsymbol{CAF} + [\boldsymbol{S}_{\boldsymbol{D/U,C}} \times (\boldsymbol{R}_{\boldsymbol{Achieved}} - \boldsymbol{30})] \\ &+ \boldsymbol{R30\ Savings/ft^2}_{\boldsymbol{H}} \times \boldsymbol{HAF} + [\boldsymbol{S}_{\boldsymbol{D/U,H}} \times (\boldsymbol{R}_{\boldsymbol{Achieved}} - \boldsymbol{30})]\} \times \boldsymbol{A}\end{aligned}$$

Equation 6.2-3

Where:

$S_{D/U,C}$ = *Project-appropriate Scale-down or Scale-up Cooling Factor from either of Table 6.2-4 or Table 6.2-5.*

$S_{D/U,H}$ = *Project-appropriate Scale-down or Scale-up Heating Factor from either of Table 6.2-4 or Table 6.2-5.*

$R_{Achieved}$ = *Achieved R-value of installed insulation (e.g., for R-28, $R_{Achieved} = 28$).*

If the ceiling is insulated to a level less than R-30, the following factors shall be applied to scale down the achieved energy savings per square foot of treated ceiling area.

Table 6.2-4: [Ceiling Insulation] Energy Savings Scale Down Factors for Insulating to Less than R-30 (kWh/sq. ft./ΔR)

Cooling Factor	Heating Factors by Primary Heat Source		
	Gas	Electric Resistance	Heat Pump
8.20×10^{-3}	4.88×10^{-4}	1.29×10^{-2}	5.44×10^{-3}

If the ceiling is insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved energy savings per square foot of treated ceiling area.

Table 6.2-5: [Ceiling Insulation] Energy Savings Scale Up Factors for Insulating to Greater than R-30 (kWh/sq. ft./ΔR)

Cooling Factor	Heating Factors by Primary Heat Source		
	Gas	Electric Resistance	Heat Pump
5.44×10^{-3}	3.11×10^{-4}	8.58×10^{-3}	3.63×10^{-3}

6.2.2.3 Deemed Summer Demand Savings Tables

Table 6.2-6 presents the non-coincident peak (NCP), coincident peak (CP), and ERCOT 4CP summer demand savings (kW) per sq. ft. associated with ceiling insulation for San Antonio.

For customers who participate in Hard-to-Reach (HTR) or Low Income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying cooling savings in Table 6.2-6 by a factor of 0.6.

$$\boldsymbol{Deemed\ Demand\ Savings_{NCP,CP,or\ 4CP}}\ (\boldsymbol{kW}) = \boldsymbol{R30\ Savings/ft^2}_{\boldsymbol{NCP,CP,or\ 4CP}} \times \boldsymbol{AF} \times \boldsymbol{A}$$

Equation 6.2-4

Where:

R30 Savings/ft² = *Deemed NCP, CP, or 4CP demand savings per square foot taken from Table 6.2-6.*

AF = *Adjustment factor based on HVAC system type in Table 6.2-7.*

Table 6.2-6: [Ceiling Insulation] Deemed Demand Savings for Insulating to R-30 (kW/sq. ft.)

Ceiling Insulation Base R-value	NCP by Primary Heat Source			CP	4CP
	Gas	Electric Resistance	Heat Pump		
R-0 to R-4	1.81×10^{-3}	2.00×10^{-3}	1.14×10^{-3}	1.23×10^{-3}	1.08×10^{-3}
R-5 to R-8	8.32×10^{-4}	9.37×10^{-4}	5.73×10^{-4}	5.49×10^{-4}	5.05×10^{-4}
R-9 to R-14	4.94×10^{-4}	5.20×10^{-4}	3.24×10^{-4}	2.90×10^{-4}	2.71×10^{-4}
R-15 to R-22	2.50×10^{-4}	2.58×10^{-4}	2.36×10^{-4}	1.28×10^{-4}	1.19×10^{-4}

Table 6.2-7: [Ceiling Insulation] AF, Adjustment Factors

Cooling System Type	NCP Adjustment Factor by Primary Heat Source				CP and 4CP Adjustment Factor by Primary Heat Source			
	Gas	Electric Resistance	Heat Pump	None	Gas	Electric Resistance	Heat Pump	None
Central AC	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Window or Room AC	0.6	1.0	0.6	0.6	0.6	0.6	0.6	0.6
None	0.0	1.0	NA	0.0	0.0	0.0	NA	0.0

Scale Down/Up Factors: Insulation to Above or Below R-30

The factors presented in this section are to be used when the average post-retrofit insulation depth is providing more or less than R-30 insulation. Scale down factors are provided for the case when average post-retrofit insulation depth is not sufficient to achieve R-30; scale up factors are provided for the case when a contractor chooses to insulate to a level greater than R-30. In either case, the following equation should be applied to scale down or scale up the NCP, CP, or 4CP deemed demand savings.

$$\boldsymbol{Deemed\ Demand\ Savings\ (kW) = \{R30\ Savings/ft^2 \times AF + [S_{D/U} * (R_{Achieved} - 30)]\} \times A}$$

Equation 6.2-5

Where:

$S_{D/U}$ = *Project-appropriate Scale-down or Scale-up factor from Table 6.2-8.*

If the ceiling is insulated to a level less than or greater than R-30, use the appropriate factor from Table 6.2-8 to scale down or scale up the achieved demand savings per square foot of treated ceiling area.

Table 6.2-8: [Ceiling Insulation] Demand Savings Scale Down/Up Factors for Insulating to Less or More than R-30 (kW/sq. ft./ΔR)

$S_{D/U}$	Demand Savings Scale Factor (kWh/sq. ft./ΔR)
Scale Down Factor, S_D, if final insulation is less than R-30	8.04×10^{-6}
Scale Up Factor, S_U if final insulation is greater than R-30	5.44×10^{-6}

Example Deemed Savings Calculation

Example 1 (Scale Up). A contractor installs 550 square feet of R-38 insulation in the attic of a home with central air conditioning and an electric resistance furnace that had existing insulation estimated at R-5.

$$\boldsymbol{Cooling\ energy\ savings\ per\ sq.ft. = 0.58 + 5.44 \times 10^{-3}\ \times\ (38 - 30) = 0.62\ kWh/sq.ft.}$$

$$\boldsymbol{Heating\ energy\ savings\ per\ sq.ft. = 0.87 + 8.58 \times 10^{-3}\ \times\ (38 - 30) = 0.94\ kWh/sq.ft.}$$

$$\boldsymbol{Energy\ savings = (0.62 + 0.94) \times 550 = 858\ kWh}$$

$$\boldsymbol{NCP\ demand\ savings\ per\ sq.ft. = 9.37 \times 10^{-4} + 5.44 \times 10^{-6}\ \times\ (38 - 30) = 9.81 \times 10^{-4}\ kW/sq.ft.}$$

$$\boldsymbol{NCP\ demand\ savings = 9.81 \times 10^{-4} \times 550 = 0.54\ kW}$$

$$\boldsymbol{CP\ demand\ savings\ per\ sq.ft. = 5.49 \times 10^{-4} + 5.44 \times 10^{-6}\ \times\ (38 - 30) = 5.93 \times 10^{-4}\ kW/sq.ft.}$$

$$\boldsymbol{CP\ demand\ savings = 5.93 \times 10^{-4} \times 550 = 0.33\ kW}$$

$$\boldsymbol{4CP\ demand\ savings\ per\ sq.ft. = 5.05 \times 10^{-4} + 5.44 \times 10^{-6}\ \times\ (38 - 30) = 5.49 \times 10^{-4}\ kW/sq.ft.}$$

$$\boldsymbol{4CP\ demand\ savings = 5.49 \times 10^{-4} \times 550 = 0.30\ kW}$$

Example 2 (Scale Down). A contractor installs 550 square feet of R-26 insulation in the attic of a home with central air conditioning and a gas furnace that had no existing ceiling insulation.

$$\boldsymbol{Cooling\ energy\ savings\ per\ sq.ft. = 1.58 + 8.20 \times 10^{-3}\ \times\ (26 - 30) = 1.55\ kWh/sq.ft.}$$

$$\boldsymbol{Heating\ energy\ savings\ per\ sq.ft. = 0.09 + 4.88 \times 10^{-4}\ \times\ (26 - 30) = 0.09\ kWh/sq.ft.}$$

$$\boldsymbol{energy\ savings = (1.55 + 0.09) \times 550 = 902\ kWh}$$

$$\boldsymbol{NCP\ demand\ savings\ per\ sq.ft. = 2.09 \times 10^{-3} + 8.04 \times 10^{-6}\ \times\ (26 - 30) = 2.06 \times 10^{-3}\ kW/sq.ft.}$$

$$\boldsymbol{NCP\ demand\ savings = (2.06 \times 10^{-3}) \times 550 = 1.13\ kW}$$

$$\boldsymbol{CP\ demand\ savings\ per\ sq.ft. = 1.45 \times 10^{-3} + 8.04 \times 10^{-6}\ \times\ (26 - 30) = 1.42 \times 10^{-3}\ kW/sq.ft.}$$

$$\boldsymbol{CP\ demand\ savings = (1.42 \times 10^{-3}) \times 550 = 0.78\ kW}$$

$$\boldsymbol{4CP\ demand\ savings\ per\ sq.ft. = 1.30 \times 10^{-3} + 8.04 \times 10^{-6}\ \times\ (26 - 30) = 1.27 \times 10^{-3}\ kW/sq.ft.}$$

$$\boldsymbol{4CP\ demand\ savings = (1.27 \times 10^{-3}) \times 550 = 0.70\ kW}$$

6.2.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

6.2.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 25 years for ceiling insulation.[190]

6.2.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Base R-value of original insulation
- R-value of installed insulation
- Cooling system type (evaporative cooling, central refrigerated cooling, room air conditioner, none)
- Heating system type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
- Square footage of ceiling insulation installed above a conditioned space
- For homes with a reported baseline R-value that is less than R-5, the following documentation:
    - Picture(s) showing the entire attic floor, and
    - A close-up picture of a ruler that shows the measurement of the depth of the insulation

Note: The second photo type is required for each area of insulation where there are varying R-values less than R-5. Additionally, both photo types are required for all separate attic/ceiling areas, even when the installed R-value is the same.

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[190] "Measure Life Report: Residential and Commercial Industrial Lighting and HVAC Measures," The New England State Program Working Group (SPWG). June 2007. https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf.

6.3 ATTIC ENCAPSULATION

6.3.1 Measure Description

Savings are presented for attic encapsulation, which is conceived as the combination of the following activities:

- Sealing of all penetrations in a ventilated attic so that it no longer vents to the outside
- Installation of insulation on the underside of the roof deck to at least R-19
- Removal of existing ceiling insulation to facilitate air exchange between the attic and finished space

6.3.1.1 Eligibility Criteria

Cooling savings in this measure apply to all residential customers with central or mini-split electric refrigerated-air cooling systems in their residences. Residences must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. Customers participating in hard-to-reach (HTR) or low income (LI) programs are eligible to claim heating savings for homes heated with gas or electric resistance space heaters. Customers participating in HTR or LI programs are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that are specified for homes with refrigerated air.

6.3.1.2 Baseline Condition

The baseline condition is a vented, unfinished attic with some level of ceiling insulation. Ceiling insulation levels in existing construction can vary significantly, depending on the age of the home, type of insulation installed, and activity in the attic (such as using the attic for storage and HVAC equipment). Deemed savings have been developed based on different levels of encountered (existing) ceiling insulation in participating homes, ranging from no insulation material (R-0) to the equivalent of about 6 inches of fiberglass batt insulation (R-22). The average ceiling insulation level prior to the retrofit at participating homes is to be determined and documented by the contractor. Degradation due to age and density of the existing insulation should be considered.

Because existing ceiling insulation must be removed during measure implementation, the existing R-value will be based upon the R-value of the existing insulation prior to removal.

For any reported pre-retrofit R-value that falls below R-5, it is required that all contractors provide sufficient evidence including two pictures: 1) a picture showing the entire attic floor, and 2) a close-up picture of a ruler that shows the measurement of the depth of the insulation. These pictures shall be provided to CPS Energy for quality assurance purposes. In the absence of evidence demonstrating pre-retrofit ceiling insulation below R-5, the lowest level of pre-retrofit ceiling insulation that can be claimed is the R-5 to R-8 range.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[191] Space heating refers primarily to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[192] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer Demand Savings Tables sections.

6.3.1.3 High-Efficiency Condition

A minimum ceiling insulation level of R-30 is recommended throughout Texas as prescribed by the Department of Energy.[193] Accordingly, deemed savings are provided for insulating to R-30. Adjustment factors are provided to allow contractors to estimate savings for installation of higher or lower levels of post-retrofit insulation: contractors should estimate post-retrofit R-value according to the average insulation depth achieved across the area treated and the R-per-inch of the insulation material installed.

Vents are sealed, as are obvious leaks. Ceiling insulation between the attic and the conditioned space is removed.

6.3.2 Energy and Demand Savings Methodology

The energy and demand savings produced by the attic encapsulation measures have two components: 1) reduced heat transfer into the attic from the insulation improvement; and 2) reduced leakage of conditioned air to outside by closing off vents and sealing of leaks. Accordingly, deemed energy and demand savings are presented by their insulation and air infiltration components. Both Insulation Improvement component and Infiltration Reduction component savings should be claimed for all projects. Insulation Improvement component savings shall be claimed using deemed savings derived for the ceiling insulation measure, as explained below. There are two paths for claiming Infiltration Reduction component savings depending on whether pre- and post-retrofit blower door testing is undertaken when implementing the attic encapsulation measure. If blower door testing is performed, savings for the Infiltration Reduction component can be estimated according to the Residential Air Infiltration Measure. If blower door testing is not undertaken, savings for the Infiltration Reduction component shall be claimed as presented in the Air Infiltration Reduction Component savings presented in this measure (below).

In previous versions of the Guidebook, energy and demand savings for the attic encapsulation measure have been presented according to the results achieved by directly modeling the attic encapsulation measure according to a best interpretation of how the measure should be represented. The expectation is that this measure should, at minimum, provide savings commensurate with those obtained from the installation of ceiling insulation. In general, the measure is expected to out-perform ceiling insulation. However, the modeling results have not reflected this expectation due to complications with sufficiently accounting for infiltration reduction, resulting in lower deemed savings for the attic encapsulation

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[191] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.
[192] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.
[193] Department of Energy Insulation R-value recommendations for zone 2/3, https://www.energy.gov/energysaver/weatherize/insulation.

measure than those estimated for ceiling insulation. To encourage implementation of the measure and begin to develop information about the outcomes, the savings presented in this measure for the Insulation Improvement component of the Attic Encapsulation Measure are equivalent to the ceiling insulation measure savings. After adding Air Infiltration Reduction component savings to the Insulation Improvement component savings, attic encapsulation measure savings will exceed those of the ceiling insulation measure.

6.3.2.1 Savings Algorithms and Input Variables (Insulation Component)

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed by modeling *the **ceiling insulation** measure* using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. For details on the derivation of these savings, refer to the Residential Ceiling Insulation Measure.

Energy Savings (Insulation Component)

Energy savings are estimated according to the differences in annual energy use in the pre-retrofit (base case) and post-retrofit (change case) models. Estimated savings per square foot of ceiling insulation installed (ceiling area net of framing materials) are presented in the deemed energy savings tables below.

Demand Savings (Insulation Component)

Coincident Peak (CP), Non-coincident Peak (NCP) and ERCOT 4 Coincident Peak (4CP) demand savings are estimated in accordance with the definitions provided in Section 2.3 of this document. All are estimated according to the differences in energy use in specific hours of the simulations of the pre-retrofit (base case) and post-retrofit (change case) models. Estimated savings per square foot of ceiling insulation installed are presented in the deemed demand savings tables below.

Load Shapes

The building energy simulation models used to estimate the savings for this measure are run on hourly time steps, producing 8,760 hourly estimates of energy use for the model year. The load shapes used to estimate demand savings for the ceiling insulation measure are therefore the “delta load shapes” developed by subtracting the whole house energy use in each hour of the post-retrofit models from the energy use in each hour of the pre-retrofit models.

6.3.2.2 Deemed Energy Savings Tables (Insulation Component)

Table 6.3-1 presents the cooling and heating energy savings (kWh) achieved for every square foot of R-30 ceiling insulation installed in attics in CPS Energy’s service territory. Annual energy savings are the sum of the cooling savings and the heating savings for the appropriate heating equipment type.

For customers who participate in Hard-to-Reach (HTR) or Low Income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying cooling savings in

Table 6.3-1 by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying heating savings in Table 6.3-1 by a factor of 0.24.[194]

$$\boldsymbol{Deemed\ Energy\ Savings\ (kWh) = \left(R30\ Savings/ft^2{}_C \times CAF + R30\ Savings/ft^2{}_H \times HAF\right) \times A}$$

Equation 6.3-1

Where:

$R30\ Savings/ft^2$ = *Deemed cooling/heating energy savings per square foot taken from Table 6.3-1.*

A = *Treated area [ft²].*

CAF = *Cooling adjustment factor in Table 6.3-2.*

HAF = *Heating adjustment factor in Table 6.3-2.*

Table 6.3-1: [Attic Encapsulation] Energy Savings for Insulating to R-30 (kWh/sq. ft.)

Ceiling Insulation Base R Value	Cooling Savings	Heating Savings		
		Gas	Electric Resistance	Heat Pump
R-0 to R-4	1.29	0.07	1.86	0.78
R-5 to R-8	0.58	0.03	0.87	0.37
R-9 to R-14	0.30	0.02	0.47	0.20
R-15 to R-22	0.13	0.01	0.20	0.09

Table 6.3-2: [Attic Encapsulation] CAF/HAF, Cooling & Heating Adjustment Factors

HVAC System Type	CAF	HAF
Central AC	1.00	--
Window or Room AC	0.60	--
Central Furnace or HP	--	1.00
Electric Resistance Space Heater	--	0.24
None	0.00	0.00

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[194] This factor was derived based on expected capacity reduction assuming 1200 sqft (historical analysis of HTR participants) x 0.35 BTU/sqft = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

Scale Down/Up Factors: Insulation to above or below R-30

The factors presented in this section are to be used when the average post-retrofit insulation depth provides less or more than R-30 insulation. Scale down factors are provided for the case when average post-retrofit insulation depth is not sufficient to achieve R-30; scale up factors are provided for the case when a contractor chooses to insulate to a level greater than R-30. In either case, the following equation should be applied to scale down or scale up the energy savings.

$$\begin{aligned}&\boldsymbol{Deemed\ Energy\ Savings}\ (\boldsymbol{kWh})\\&\quad= \left\{\boldsymbol{R30\ Savings/ft^2}_{\boldsymbol{C}} \times \boldsymbol{CAF} + \left[\boldsymbol{S}_{\boldsymbol{D/U,C}} \times (\boldsymbol{R}_{\boldsymbol{Achieved}} - \boldsymbol{30})\right]\right.\\&\qquad\left. + \boldsymbol{R30\ Savings/ft^2}_{\boldsymbol{H}} \times \boldsymbol{HAF} + \left[\boldsymbol{S}_{\boldsymbol{D/U,H}} \times (\boldsymbol{R}_{\boldsymbol{Achieved}} - \boldsymbol{30})\right]\right\} \times \boldsymbol{A}\end{aligned}$$

Equation 6.3-2

Where:

$S_{D/U,C}$ = *Project-appropriate Scale-down or Scale-up Cooling Factor from either of Table 6.3-3 or Table 6.3-4.*

$S_{D/U,H}$ = *Project-appropriate Scale-down or Scale-up Heating Factor from either of Table 6.3-3 or Table 6.3-4.*

$R_{Achieved}$ = *Achieved R-value of installed insulation (e.g., for R-28,* $R_{Achieved} = 28$*).*

If the ceiling is insulated to a level less than R-30, the following factors shall be applied to scale down the achieved energy savings per square foot of treated ceiling area.

Table 6.3-3: [Attic Encapsulation] Energy Savings Scale Down Factors for Insulating to Less than R-30 (kWh/sq. ft./ΔR)

Cooling Factor	Heating Factors by Primary Heat Source		
	Gas	Electric Resistance	Heat Pump
8.20×10^{-3}	4.88×10^{-4}	1.29×10^{-2}	5.44×10^{-3}

If the ceiling is insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved energy savings per square foot of treated ceiling area.

Table 6.3-4: [Attic Encapsulation] Energy Savings Scale Up Factors for Insulating to Greater than R-30 (kWh/sq. ft./ΔR)

Cooling Factor	Heating Factors by Primary Heat Source		
	Gas	Electric Resistance	Heat Pump
5.44×10^{-3}	3.11×10^{-4}	8.58×10^{-3}	3.63×10^{-3}

6.3.2.3 Deemed Summer Demand Savings Tables (Insulation Component)

Table 6.3-5 presents the non-coincident peak (NCP), coincident peak (CP), and ERCOT 4CP summer demand savings (kW) per sq. ft. associated with ceiling insulation for San Antonio.

For customers who participate in Hard-to-Reach (HTR) or Low Income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying cooling savings in

Table 6.3-5 by a factor of 0.6.

$$\boldsymbol{Deemed\ Demand\ Savings_{NCP,CP,or\ 4CP}\ (kW) = R30\ Savings/ft^2{}_{NCP,CP,or\ 4CP} \times AF \times A}$$

Equation 6.3-3

Where:

R30 Savings/ft^2 = Deemed NCP, CP, or 4CP demand savings per square foot taken from

Table 6.3-5.

AF = *Adjustment factor based on HVAC system type in Table 6.3-6.*

Table 6.3-5: [Attic Encapsulation] Deemed Demand Savings for Insulating to R-30 (kW/sq. ft.)

Ceiling Insulation Base R-value	NCP by Primary Heat Source			CP	4CP
	Gas	Electric Resistance	Heat Pump		
R-0 to R-4	1.81 x 10^{-3}	2.00 x 10^{-3}	1.14 x 10^{-3}	1.23 x 10^{-3}	1.08 x 10^{-3}
R-5 to R-8	8.32 x 10^{-4}	9.37 x 10^{-4}	5.73 x 10^{-4}	5.49 x 10^{-4}	5.05 x 10^{-4}
R-9 to R-14	4.94 x 10^{-4}	5.20 x 10^{-4}	3.24 x 10^{-4}	2.90 x 10^{-4}	2.71 x 10^{-4}
R-15 to R-22	2.50 x 10^{-4}	2.58 x 10^{-4}	2.36 x 10^{-4}	1.28 x 10^{-4}	1.19 x 10^{-4}

Table 6.3-6: [Attic Encapsulation] AF, Adjustment Factors

Cooling System Type	NCP Adjustment Factor by Primary Heat Source				CP and 4CP Adjustment Factor by Primary Heat Source			
	Gas	Electric Resistance	Heat Pump	None	Gas	Electric Resistance	Heat Pump	None
Central AC	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Window or Room AC	0.6	1.0	0.6	0.6	0.6	0.6	0.6	0.6
None	0.0	1.0	NA	0.0	0.0	0.0	NA	0.0

Scale Down/Up Factors: Insulation to Above or Below R-30

The factors presented in this section are to be used when the average post-retrofit insulation depth is providing more or less than R-30 insulation. Scale down factors are provided for the case when average post-retrofit insulation depth is not sufficient to achieve R-30; scale up factors are provided for the case when a contractor chooses to insulate to a level greater than R-30. In either case, the following equation should be applied to scale down or scale up the NCP, CP, or 4CP deemed demand savings.

$$\boldsymbol{Deemed\ Demand\ Savings\ (kW) = \{R30\ Savings/ft^2 \times AF + [S_{D/U} * (R_{Achieved} - 30)]\} \times A}$$

Equation 6.3-4

Where:

$S_{D/U}$ = *Project-appropriate Scale-down or Scale-up factor from Table 6.3-7.*

If the ceiling is insulated to a level less than or greater than R-30, use the appropriate factor from Table 6.3-7 to scale down or scale up the achieved demand savings per square foot of treated ceiling area.

Table 6.3-7: [Attic Encapsulation] Demand Savings Scale Down/Up Factors for Insulating to Less than or Greater than R-30 (kWh/sq. ft./ΔR)

$S_{D/U}$	Demand Savings Scale Factor (kWh/sq. ft./ΔR)
Scale Down Factor, S_D, if final insulation is less than R-30	8.04×10^{-6}
Scale Up Factor, S_U if final insulation is greater than R-30	5.44×10^{-6}

6.3.2.4 Savings Algorithms and Input Variables (Infiltration Component)

Energy and Demand savings for the Air Infiltration Reduction component of the attic encapsulation measure are calculated either using the results of pre- and post-retrofit blower door testing or using an average percent infiltration reduction. Regardless of how Air Infiltration Reduction component savings are calculated, they should be added to the Insulation Improvement component savings to arrive at the total energy and demand savings for implementing the Attic Encapsulation Measure.

Homes without refrigerated cooling should not claim Air Infiltration Reduction component savings for attic encapsulation.

With Blower Door Testing

Implementers choosing to perform pre- and post-measure blower door testing should claim Air Infiltration Reduction component deemed energy and demand savings for the Attic Encapsulation Measure using the estimated CFM_{50} reduction from the blower door tests with the equations and coefficients in the Residential Infiltration Measure (Section 6.1 Air Infiltration).

Without Blower Door Testing

Implementers electing not to perform blower door testing when performing this measure shall claim Air Infiltration Reduction component deemed energy and demand savings for the Attic Encapsulation Measure using this section, which presents the annual energy (kWh) and summer and winter demand savings (kW) associated with attic encapsulation in San Antonio**,** considering a mean leakage reduction of 18 percent.[195] Savings are presented per home.

Calibrated simulation modeling was used to develop air infiltration reduction deemed savings, which are expressed in the Residential Air Infiltration measure as linear functions of the leakage reduction achieved (in CFM_{50}).[196] For details on the derivation of the air infiltration measure savings, refer to the Residential Air Infiltration measure.

ACCA Manual J provides an average leakage reduction attributable to attic encapsulation projects of 18 percent.[197] Accordingly, deemed savings attributable to the Air Infiltration Reduction component of an attic encapsulation project implemented without pre- and post-implementation blower door testing are estimated by applying an 18 percent leakage reduction to the infiltration rates embedded in the deemed savings prototype model homes used in the derivation of residential envelope measure deemed savings for the Guidebook. This 18 percent leakage reduction provides the CFM_{50} reduction input required to estimate air infiltration measure deemed savings with the equations in the Residential Air Infiltration measure.

Table 6.3-8: [Attic Encapsulation] Prototypical Home Characteristics

Shell Characteristics	CFM_{50} Reduction	Source
Air Infiltration Reduction from Attic Encapsulation (without Blower Door Testing)	18% reduction	Mean reduction achieved via attic encapsulation according to ACCA Manual J, 8th Edition, Section 21-14[198]

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[195] Section 21-14 of ACCA Manual J states that, "…a foam encapsulated attic eliminates ceiling leakage to the outdoors (i.e., to a vented attic), which means that the reduction in infiltration CFM may range from 3 to 30 percent, with an 18 percent mean, as noted above." See Air Conditioning Contractors of America. Manual J, 8th Edition Version 2.10. Nov. 2011, p. 188.

[196] Model testing indicates a straight-line relationship between demand and energy savings achieved and CFM_{50} reductions is appropriate with beginning and ending leakage rates within the ranges permitted by the measure.

[197] Air Conditioning Contractors of America. Manual J, 8th Edition Version 2.10. Nov. 2011, p. 188.

[198] Section 21-14 of ACCA Manual J states that, "…a foam encapsulated attic eliminates ceiling leakage to the outdoors (i.e., to a vented attic), which means that the reduction in infiltration Cfm may range from 3 to 30 percent, with an 18 percent mean, as noted above." See Air Conditioning Contractors of America. Manual J, 8th Edition Version 2.10. Nov. 2011, p. 188.

6.3.2.5 Deemed Energy Savings Tables (Infiltration Component)

Annual energy savings are provided by space heating equipment type combined with refrigerated cooling. Savings are specified per home based on a deemed 18 percent infiltration reduction. Homes without refrigerated cooling are not eligible to claim these savings.

Table 6.3-9: [Attic Encapsulation] Deemed Energy Savings for Infiltration Component – 18% Air Infiltration Reduction (kWh/home)

Climate Zone	Heating Type			
	Gas	Electric Resistance	Heat Pump	None
San Antonio	177.9	576.7	337.4	177.9

6.3.2.6 Deemed Summer Demand Savings Tables (Infiltration Component)

Summer demand savings are specified per home based on a deemed 18 percent infiltration reduction. Homes without refrigerated cooling are not eligible to claim these savings.

Table 6.3-10: [Attic Encapsulation] Deemed Summer Demand Savings for Infiltration Component – 18% Air Infiltration Reduction (kW/home)

Climate Zone	Peak Type	Heating Type	Refrigerated Air kW/home
San Antonio	NCP	Gas	0.301
		Electric Resistance	1.031
		Heat Pump	0.396
	CP	All	0.134
	4CP	All	0.120

Example Deemed Savings Calculation

A contractor seals the attic and adds R-38 insulation to the underside of the roof to a home with 900 square feet of conditioned space below the treated attic with refrigerated air and a gas furnace, which has existing ceiling insulation estimated at R-7. No blower door testing is performed.

Insulation Component Savings:

$$\boldsymbol{Energy\ Savings/ft^2, Insulation\ to\ R-30 = 0.58 + 0.03 = 0.61\ kWh/ft^2}$$

$$\boldsymbol{Energy\ Savings, Insulation\ to\ R-38 =}$$

$$\boldsymbol{\{0.61 + [(5.44 \times 10^{-3} + 3.11 \times 10^{-4}) \times (38-30)]\} \times 900 = 590.4\ kWh}$$

$$\boldsymbol{NCP\ Summer\ Demand\ Savings, Insulation\ to\ R-38 =}$$

$$\boldsymbol{\{8.32 \times 10^{-4} + [5.44 \times 10^{-6} \times (38-30)]\} \times 900 = 0.788\ kW}$$

$$\boldsymbol{CP\ Summer\ Demand\ Savings, Insulation\ to\ R-38 =}$$

$$\boldsymbol{\{5.49 \times 10^{-4} + [5.44 \times 10^{-6} \times (38-30)]\} \times 900 = 0.533\ kW}$$

$$\boldsymbol{4CP\ Summer\ Demand\ Savings, Insulation\ to\ R-38 =}$$

$$\boldsymbol{\{5.05 \times 10^{-4} + [5.44 \times 10^{-6} \times (38-30)]\} \times 900 = 0.494\ kW}$$

Infiltration Reduction Component Savings:

$$\boldsymbol{Energy\ Savings, 18\%\ Infiltration\ Reduction = 177.9\ kWh}$$

$$\boldsymbol{NCP\ Summer\ Demand\ Savings, 18\%\ Infiltration\ Reduction = 0.301\ kW}$$

$$\boldsymbol{CP\ Summer\ Demand\ Savings, 18\%\ Infiltration\ Reduction = 0.134\ kW}$$

$$\boldsymbol{4CP\ Summer\ Demand\ Savings, 18\%\ Infiltration\ Reduction = 0.120\ kW}$$

Measure Savings:

$$\boldsymbol{Energy\ Savings = 590.4 + 177.9 = 768.3\ kWh}$$

$$\boldsymbol{NCP\ Summer\ Demand\ Savings = 0.788 + 0.301 = 1.089\ kW}$$

$$\boldsymbol{CP\ Summer\ Demand\ Savings = 0.533 + 0.134 = 0.667\ kW}$$

$$\boldsymbol{4CP\ Summer\ Demand\ Savings = 0.494 + 0.120 = 0.614kW}$$

6.3.2.7 Additional Calculators and Tools

This section is not applicable for this measure.

6.3.2.8 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 25 years for ceiling insulation.[199] The measure life specified for ceiling insulation is also appropriate for attic encapsulation.

6.3.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Base R-value of original ceiling insulation
- R-value of installed roof deck insulation
- Cooling system type (evaporative cooling, central refrigerated cooling, room air conditioner, none)
- Heating system type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
- Square footage of ceiling area below encapsulated attic
- For homes with a reported baseline R-value that is less than R-5, the following documentation:
    - Picture(s) showing the entire attic floor, and
    - A close-up picture of a ruler that shows the measurement of the depth of the insulation
- Indicate whether blower door testing was performed and whether air infiltration reduction component savings are claimed in this measure or separately using the Residential Air Infiltration measure

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[199] "Measure Life Report: Residential and Commercial Industrial Lighting and HVAC Measures," The New England State Program Working Group (SPWG). June 2007. https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf.

6.4 WALL INSULATION

6.4.1 Measure Description

Wall insulation is added to the walls surrounding conditioned space in existing homes by removing wall enclosures and applying batt or spray insulation into the cavity space between studs in the walls. Walls may be of either 2x4 or 2x6 construction. Savings are estimated for filling the wall cavities of 2x4 or 2x6 walls with fiberglass batts, cellulose, or closed-cell spray foam, and are presented per square foot of treated wall area (gross wall area less window and door area).

6.4.1.1 Eligibility Criteria

Residences must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. Customers are eligible to claim reduced heating savings for homes heated with gas or electric resistance space heaters by applying an adjustment to deemed savings specified by heating type. Cooling savings in this measure apply to all residential customers with central or mini-split electric refrigerated-air HVAC systems in their residences. Customers are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that are specified for homes with refrigerated air.

Residences with existing wall insulation more than the below-described baseline condition wall insulation level are not eligible for the measure.

6.4.1.2 Baseline Condition

The baseline is considered a house with little or no wall insulation in the wall cavity. For those homes for which a minimal level of insulation is encountered, the baseline is R-4. This baseline should be used to represent homes for which installed insulation covers a very limited amount of the wall area to be treated, is significantly degraded, and/or is less than an inch thick.

Baseline homes may have either 2x4 or 2x6 construction.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[200] Space heating refers primarily to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[201] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer Demand Savings Tables sections.

6.4.1.3 High-Efficiency Condition

The standard throughout Texas for adding wall insulation to an existing wall cavity is R-13, as prescribed by United States Department of Energy (DOE) and Texas Department of Housing & Community Affairs

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[200] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

[201] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

(TDHCA) programs. The standard is achieved by filling a 2x4 wall cavity with fiberglass batt or cellulose insulation, which typically provides an R-value per inch (thickness) of between 3 and 4 hr·ft2·°F/BTU. Other wall insulation materials may be used, such as closed-cell spray foam, which approximately provides an R-value of 6 per inch.

As such, deemed savings are provided for insulating 2x4 and 2x6 walls to the levels presented in Table 6.4-3 through Table 6.4-9.

Table 6.4-1: [Wall Insulation] High-Efficiency Condition R-Values for 2x4 and 2x6 Walls

Insulation Material	2x4 Wall	2x6 Wall
Fiberglass Batt or Cellulose	R-13	R-21
Closed-cell Spray Foam	R-17	R-33

Wall insulation reduces a home's ventilation rate; as such, a post-installation blower door test must be conducted to demonstrate adequate ventilation. Equations for determining the Minimum Ventilation Rate for residential buildings is discussed in the High-Efficiency Condition section of the Air Infiltration measure (Section 6.1 of this document).

6.4.2 Energy and Demand Savings Methodology

6.4.2.1 Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home model for San Antonio was modified as follows: the default R-11 insulation was reduced to either R-0 or R-4.

The model runs calculated energy use for the prototypical home prior to the installation of the wall insulation measure. Change-case models were run with different insulation materials and R-values achieved as shown in Table 6.4-2 to calculate energy use with the wall insulation measure in place.

Table 6.4-2: [Wall Insulation] Prototypical Home Characteristics

Shell Characteristic	Value	Source
Base Wall Insulation	R-0 R-4	BEopt estimates wall assembly R-value for uninsulated walls to be 3.6 for 2x4 construction and 3.7 for 2x6 construction. Assembly R-values for R-4 walls are 6.7 and 7.1 for 2x4 and 2x6 construction, respectively. Listed base levels are for the insulation material only.
Change Wall Insulation 2x4 wall	R-13 R-21	For retrofit with fiberglass batt/cellulose and closed-cell spray foam, respectively.
Change Wall Insulation 2x6 wall	R-17 R-33	For retrofit with fiberglass batt/cellulose and closed-cell spray foam, respectively.

Energy Savings

Energy savings are estimated according to the differences in annual energy use in the pre-retrofit (base case) and post-retrofit (change case) models. Estimated savings per square foot of insulation installed are presented in the deemed energy savings tables below.

Demand Savings

Coincident Peak (CP), Non-coincident Peak (NCP) and ERCOT 4 Coincident Peak (4CP) demand savings are estimated in accordance with the definitions provided in Section 2.4 of this document. All are estimated according to the differences in energy use in specific hours of the simulations of the pre-retrofit (base case) and post-retrofit (change case) models. Estimated savings per square foot of insulation installed are presented in the deemed demand savings tables below.

Load Shapes

The building energy simulation models used to estimate the savings for this measure are run on hourly time steps, producing 8,760 hourly estimates of energy use for the model year. The load shapes used to estimate demand savings for the wall insulation measure are therefore the "delta load shapes" developed by subtracting the whole house energy use in each hour of the post-retrofit models from the energy use in each hour of the pre-retrofit models.

6.4.2.2 Deemed Energy Savings Tables

Savings are presented separately for insulating 2x4 wall construction and homes with 2x6 walls. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

Table 6.4-3 through Table 6.4-6 presents the cooling and heating energy savings (kWh) achieved per square foot of ceiling area beneath the encapsulated attic in CPS Energy's service territory. Annual energy savings are the sum of the cooling savings and the heating savings for the appropriate heating equipment type.

For customers who participate in Hard-to-Reach (HTR) or Low Income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying cooling savings in Table 6.2-2 through Table 6.4-6 by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying heating savings in Table 6.2-2 through Table 6.4-6 by a factor of 0.24.[202]

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[202] This factor was derived based on expected capacity reduction assuming 1200 sqft (historical analysis of HTR participants) x 0.35 BTU/sqft = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

$$\boldsymbol{Deemed\ Energy\ Savings\ (kWh) = \left(Savings/ft^2{}_C \times CAF + Savings/ft^2{}_H \times HAF\right) \times A}$$

Equation 6.4-1

Where:

Savings/ft² = *Deemed cooling/heating energy savings per square feet taken from Table 6.2-2 through Table 6.4-6.*

A = *Area of the wall [ft²].*

CAF = *Cooling adjustment factor in Table 6.4-7.*

HAF = *Heating adjustment factor in Table 6.4-7.*

2x4 Walls

Table 6.4-3 presents the deemed energy savings values for insulating 2x4 walls to R-13 for San Antonio.

Table 6.4-3: [Wall Insulation] Deemed Annual Energy Savings, Insulation of 2x4 Walls to R- 13 (kWh/sq. ft.)

Base Case Wall Insulation	Cooling Savings	Heating Savings by Primary Heat Source		
		Gas	Electric Resistance	Heat Pump
Uninsulated (R-0)	1.13	0.07	1.62	0.68
R-4	0.41	0.03	0.62	0.26

Table 6.4-4 presents the deemed energy savings values for insulating 2x4 walls to R-21 for San Antonio.

Table 6.4-4: [Wall Insulation] Deemed Annual Energy Savings, Insulation of 2x4 Walls to R- 21 (kWh/sq. ft.)

Base Case Wall Insulation	Cooling Savings	Heating Savings by Primary Heat Source		
		Gas	Electric Resistance	Heat Pump
Uninsulated (R-0)	1.26	0.08	1.81	0.76
R-4	0.54	0.03	0.81	0.34

2x6 Walls

Table 6.4-5 presents the deemed energy savings values for insulating 2x6 walls to R-17 for San Antonio.

Table 6.4-5: [Wall Insulation] Deemed Annual Energy Savings, Insulation of 2x6 Walls to R-17 (kWh/sq. ft.)

Base Case Wall Insulation	Cooling Savings	Heating Savings by Primary Heat Source		
		Gas	Electric Resistance	Heat Pump
Uninsulated (R-0)	1.21	0.08	1.74	0.73
R-4	0.49	0.03	0.73	0.31

Table 6.4-6 presents the deemed energy savings values for insulating 2x6 walls to R-33 for San Antonio.

Table 6.4-6: [Wall Insulation] Deemed Annual Energy Savings, Insulation of 2x6 Walls to R-33 (kWh/sq. ft.)

Base Case Wall Insulation	Cooling Savings	Heating Savings by Primary Heat Source		
		Gas	Electric Resistance	Heat Pump
Uninsulated (R-0)	1.34	0.09	1.94	0.81
R-4	0.62	0.04	0.93	0.39

Table 6.4-7: [Wall Insulation] CAF/HAF, Cooling & Heating Adjustment Factors

HVAC System Type	CAF	HAF
Central AC	1.00	--
Window or Room AC	0.60	--
Central Furnace or HP	--	1.00
Electric Resistance Space Heater	--	0.24
None	0.00	0.00

6.4.2.3 Deemed Demand Savings Tables

For customers who participate in Hard-to-Reach (HTR) or Low Income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying cooling savings in Table 6.4-8 through Table 6.4-9 by a factor of 0.6.

$$\boldsymbol{Deemed\ Demand\ Savings_{NCP,CP,or\ 4CP}}\ (\boldsymbol{kW}) = \boldsymbol{Savings/ft^2}_{\boldsymbol{NCP,CP,or\ 4CP}} \times \boldsymbol{AF} \times \boldsymbol{A}$$

Equation 6.4-2

Where:

Savings/ft² = *Deemed NCP, CP, or 4CP demand savings per square feet taken from Table 6.4-8 through Table 6.4-9.*

AF = *Adjustment factor based on HVAC system type in Table 6.4-10.*

2x4 Walls

Table 6.4-8 presents the deemed demand savings values for insulating 2x4 walls to R-13 and R-21.

Table 6.4-8: [Wall Insulation] Deemed Demand Savings, Insulation of 2x4 Walls (kW/sq. ft.)

Base Case Wall Insulation	Peak Demand Definition	Primary Heat Source	R-13 Installed	R-21 Installed
Uninsulated (R-0)	NCP	Gas Furnace	1.64×10^{-3}	1.73×10^{-3}
		Elec. Res.	1.98×10^{-3}	2.22×10^{-3}
		Heat Pump	9.48×10^{-4}	1.04×10^{-3}
	CP	All	8.64×10^{-4}	9.69×10^{-4}
	4CP	All	8.13×10^{-4}	9.05×10^{-4}
R-4	NCP	Gas Furnace	8.42×10^{-4}	9.56×10^{-4}
		Elec. Res.	7.62×10^{-4}	1.01×10^{-3}
		Heat Pump	4.82×10^{-4}	5.72×10^{-4}
	CP	All	3.11×10^{-4}	4.17×10^{-4}
	4CP	All	2.89×10^{-4}	3.81×10^{-4}

2x6 Walls

Table 6.4-9 presents deemed summer demand savings values for insulating 2x6 walls to R-13 and R-21.

Table 6.4-9: [Wall Insulation] Deemed Demand Savings, Insulation of 2x6 Walls (kW/sq. ft.)

Base Case Wall Insulation	Peak Demand Definition	Primary Heat Source	R-17 Installed	R-33 Installed
Uninsulated (R-0)	NCP	Gas Furnace	1.69×10^{-3}	1.81×10^{-3}
		Elec. Res.	2.14×10^{-3}	2.40×10^{-3}
		Heat Pump	1.01×10^{-3}	1.11×10^{-3}
	CP	All	9.43×10^{-4}	1.04×10^{-3}
	4CP	All	8.78×10^{-4}	9.72×10^{-4}
R-4	NCP	Gas Furnace	9.92×10^{-4}	1.06×10^{-3}
		Elec. Res.	9.21×10^{-4}	1.19×10^{-3}
		Heat Pump	5.72×10^{-4}	6.39×10^{-4}
	CP	All	3.83×10^{-4}	4.82×10^{-4}
	4CP	All	3.44×10^{-4}	4.38×10^{-4}

Table 6.4-10: [Wall Insulation] AF, Adjustment Factors

Cooling System Type	NCP Adjustment Factor by Primary Heat Source				CP and 4CP Adjustment Factor by Primary Heat Source			
	Gas	Electric Resistance	Heat Pump	None	Gas	Electric Resistance	Heat Pump	None
Central AC	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Window or Room AC	0.6	1.0	0.6	0.6	0.6	0.6	0.6	0.6
None	0.0	1.0	NA	0.0	0.0	0.0	NA	0.0

6.4.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

6.4.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 25 years for wall insulation.[203]

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[203] "Measure Life Report: Residential and Commercial Industrial Lighting and HVAC Measures," The New England State Program Working Group (SPWG). June 2007. https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf.

6.4.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Cooling type (evaporative cooling, central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
- Square footage of retrofitted wall area (gross wall area less window and door area)

6.5 FLOOR INSULATION

6.5.1 Measure Description

Floor insulation is installed on the underside of floor areas that sit below conditioned space. Typically, it is installed in ventilated crawlspaces. Savings are presented per square foot of treated floor area.

6.5.1.1 Eligibility Criteria

Cooling savings in this measure apply to all residential customers with central or mini-split electric refrigerated-air HVAC systems in their residences. Residences must be centrally heated with either an electric resistance furnace or a heat pump to claim heating savings. Homes with gas heating are disqualified for adding floor insulation, as this may result in an energy penalty due to floors not being cooled by the ground during the summer. Customers are eligible to claim reduced heating savings for homes heated with electric resistance space heaters by applying an adjustment to deemed savings specified by heating type. Customers are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that are specified for homes with refrigerated air.

6.5.1.2 Baseline Condition

The baseline is a house with pier and beam construction and with uninsulated floors beneath the conditioned space.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[204] Space heating refers primarily to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[205] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer Demand Savings Tables sections.

6.5.1.3 High-Efficiency Condition

A floor insulation level of R-19 is recommended for site-built homes throughout Texas as prescribed by DOE and Texas Department of Housing & Community Affairs (TDHCA) programs. For site-built homes, various approaches to installation of floor insulation may be considered. Given typical ambient humidity levels in the San Antonio area, moisture management is a major concern in floor insulation jobs for ventilated crawlspaces. Poorly conceived floor insulation jobs can introduce significant moisture management problems. Impermeable floor covers inside the home – such as vinyl – can greatly exacerbate these problems. Implementers should consider the absence/presence of impermeable floor coverings in determining approach to floor insulation.

If the crawlspace is open (no skirt) and the home is well above ground, insulation (closed-cell spray foam

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[204] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

[205] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

or fiberglass batt) may be installed between the joists. However, if the crawlspace is enclosed (e.g., has an apron or skirt, though ventilated), then the floor insulation system should also include a vapor barrier that eliminates exposure of subfloor and joists to moisture from the crawlspace. This can be accomplished when using fiberglass batts by adding an impermeable rigid air barrier installed below the floor joists, or by insulating with closed-cell spray foam that completely encases the floor joists.[206] Where batt insulation is used, it must have the vapor barrier installed facing up and against the floor or conditioned area. Insulation should be attached or secured so that it can reasonably be expected to remain in place the entirety of the expected useful life (25 years).

It is highly recommended that the underfloor is completely sealed to air leaks prior to installation of floor insulation material. These deemed savings do not include an allowance for leakage reduction: if sealing activities are undertaken, it is recommended that pre- and post-retrofit blower door tests are run to document the achieved leakage reduction and claim the savings available for leakage reduction according to the Air Infiltration Measure (measure 6.1).

Typical floor construction depth of manufactured homes usually does not allow R-19 batt to be installed within the floor joists, so R-15 loose-fill insulation is recommended by TDHCA.

A minimum of 24-inch clearance from bottom of the insulation to the ground is required by Occupational Safety and Health Association (OSHA).

6.5.2 Energy and Demand Savings Methodology

6.5.2.1 Savings Algorithms and Input Variables

Energy Savings

Energy savings are estimated according to the differences in annual energy use in the pre-retrofit (base case) and post-retrofit (change case) models. Estimated savings per square foot of treated floor area are presented in the deemed energy savings tables below.

Demand Savings

Coincident Peak (CP), Non-coincident Peak (NCP) and ERCOT 4 Coincident Peak (4 CP) demand savings are estimated in accordance with the definitions provided in Section 2.4 of this document. All are estimated according to the differences in energy use in specific hours of the simulations of the pre-retrofit (base case) and post-retrofit (change case) models. Estimated savings per square foot of insulation installed are presented in the deemed demand savings tables below.

Load Shapes

The building energy simulation models used to estimate the savings for this measure are run on hourly

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[206] Note that at typical floor joist depths of 8 or 10 inches, application of closed-cell spray foam (~R-6/inch) that encases floor joists would result in floors insulated to R- 48 or R-60, which are significantly beyond the recommended levels for the region. Deemed savings are not presented for insulating to these levels.

time steps, producing 8,760 hourly estimates of energy use for the model year. The load shapes used to estimate demand savings for the floor insulation measure are therefore the "delta load shapes" developed by subtracting the whole house energy use in each hour of the post-retrofit models from the energy use in each hour of the pre-retrofit models.

6.5.2.2 Deemed Energy Savings Tables

Table 6.5-1 presents the cooling and heating energy savings (kWh) achieved per square foot of ceiling area beneath the encapsulated attic in CPS Energy's service territory. Annual energy savings are the sum of the cooling savings and the heating savings for the appropriate heating equipment type.

For customers who participate in Hard-to-Reach (HTR) or Low Income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying cooling savings in

Table 6.5-1 by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying heating savings in

Table 6.5-1 by a factor of 0.24.[207]

$$\boldsymbol{Deemed\ Energy\ Savings\ (kWh)} = \left(\boldsymbol{Savings/ft^2}_{\boldsymbol{C}} \times \boldsymbol{CAF} + \boldsymbol{Savings/ft^2}_{\boldsymbol{H}} \times \boldsymbol{HAF}\right) \times \boldsymbol{A}$$

Equation 6.5-1

Where:

Savings/ft² = *Deemed cooling/heating energy savings per square feet taken from Table 6.5-1.*

A = *Area of the ceiling beneath the encapsulated attic [ft²].*

CAF = *Cooling adjustment factor in Table 6.5-2.*

HAF = *Heating adjustment factor in Table 6.5-2.*

Table 6.5-1: [Floor Insulation] Deemed Annual Energy Savings (kWh/sq. ft.)

Home Type	Cooling Savings	Heating Savings		
		Gas	Electric Resistance	Heat Pump
Site-Built	0.09	0.042	1.153	0.46
Mfd. Home	0.085	0.038	1.048	0.417

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[207] This factor was derived based on expected capacity reduction assuming 1200 sqft (historical analysis of HTR participants) x 0.35 BTU/sqft = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

Table 6.5-2: [Floor Insulation] CAF/HAF, Cooling & Heating Adjustment Factors

HVAC System Type	CAF	HAF
Central AC	1.00	--
Window or Room AC	0.60	--
Central Furnace or HP	--	1.00
Electric Resistance Space Heater	--	0.24
None	0.00	0.00

6.5.2.3 Deemed Demand Savings Tables

For customers who participate in Hard-to-Reach (HTR) or Low Income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying cooling savings in Table 6.5-3 by a factor of 0.6.

$$\boldsymbol{Deemed\ Demand\ Savings}_{NCP,CP,or\ 4CP}\ (\boldsymbol{kWh}) = \boldsymbol{Savings/ft^2}_{NCP,CP,or\ 4CP} \times \boldsymbol{AF} \times \boldsymbol{A}$$

Equation 6.5-2

Where:

Savings/ft² = *Deemed NCP, CP, or 4CP demand savings per square feet taken from Table 6.5-3.*

AF = *Adjustment factor based on HVAC system type in Table 6.5-4*

Table 6.5-3: [Floor Insulation] Deemed Annual Demand Savings (kW/sq. ft.)

Peak Demand Definition	Primary Heat Source	Site-Built Home	Manufactured Home
NCP	Gas	1.74×10^{-3}	1.57×10^{-4}
	Elec. Res	1.06×10^{-3}	9.69×10^{-4}
	Heat Pump	4.75×10^{-4}	4.37×10^{-4}
CP	Elec. Res./ Heat Pump	1.74×10^{-4}	1.57×10^{-4}
4CP	Elec. Res./ Heat Pump	1.43×10^{-4}	1.27×10^{-4}

Table 6.5-4: [Floor Insulation] AF, Adjustment Factors

Cooling System Type	NCP Adjustment Factor by Primary Heat Source				CP and 4CP Adjustment Factor by Primary Heat Source			
	Gas	Electric Resistance	Heat Pump	None	Gas	Electric Resistance	Heat Pump	None
Central AC	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Window or Room AC	0.6	1.0	0.6	0.6	0.6	0.6	0.6	0.6
None	0.0	1.0	NA	0.0	0.0	0.0	NA	0.0

6.5.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

6.5.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 25 years for floor insulation.[208]

6.5.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Cooling type (evaporative cooling, central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
- Home type (site-built or manufactured)
- Square footage of installed insulation

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[208] "Measure Life Report: Residential and Commercial Industrial Lighting and HVAC Measures," The New England State Program Working Group (SPWG). June 2007. https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf.

6.6 SOLAR SCREENS

6.6.1 Measure Description

Savings are presented for the installation of solar screens on west, south, and east-facing windows or glass doors. Deemed savings are calculated per square foot of treated window or door opening. Energy savings are additive by treated window orientation: demand savings are specified for combinations of treated window orientations.

6.6.1.1 Eligibility Criteria

Cooling savings in this measure apply to all residential customers with central or mini-split electric refrigerated-air HVAC systems in their residences. Residences must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. Customers are eligible to claim reduced heating savings for homes heated with gas or electric resistance space heaters by applying an adjustment to deemed savings specified by heating type. Customers are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that are specified for homes with refrigerated air. Solar screens are not recommended for homes with no electric air conditioning and may only be marginally beneficial in homes with electric resistance heat unless the screens are taken down each winter and re-installed in the spring.

Solar screens must be installed on windows or glass doors that face east, west, or south and receive significant direct sun exposure. Solar screens must block at least 65 percent of the solar heat gain to qualify for deemed savings.

6.6.1.2 Baseline Condition

The baseline is a single pane, clear glass, unshaded, east, west-, or south-facing window with a solar heat gain coefficient of 0.76.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[209] Space heating refers primarily to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[210] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer Demand Savings Tables sections.

6.6.1.3 High-Efficiency Condition

Solar screens are installed on the east, west, or south -facing windows (or other fenestration). Solar screen material must reduce solar heat gain by at least 65 percent.

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[209] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

[210] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

6.6.2 Energy and Demand Savings Methodology

6.6.2.1 Savings Algorithms and Input Variables

Deemed savings values have been estimated using calibrated simulation models. Specifically, these deemed savings estimates were developed by using NREL's BEopt 2.6 software, running EnergyPlus 8.4 as the underlying simulation engine. A single modification was made to the prototype models for the different HVAC types to create the base case models for estimating savings for the solar screens measure. Windows facing all directions are assumed to be single-pane windows with U-Values of 1.16 BTU/h-ft^2-R and Solar Heat Gain Coefficients (SHGC) of 0.76.

For the change case models, an 80 percent reduction was applied to the solar heat gain coefficient and a 10 percent reduction was applied to the U-value for the treated windows.

Coincident peak demand savings are estimated by taking the difference in demand for the 20 hours identified from the TMY3 datasets in which the summer peak is most likely to occur. Non-coincident peak demand savings (NCP) are set by the single hour in which the base case model energy use most exceeds that of the change case model. ERCOT 4 CP demand savings are estimated by extracting the modeled demand difference in the hour ending 5 PM for all weekdays in each month and taking the 90th percentile of the differences in each month.

The model assumes the average solar screen installed blocks 80% of the solar heat gain attributed to the treated windows based on performance data from solar screens analyzed at sun angles of 30, 45 and 75 degrees to the window.[211]

While it is strongly recommended that solar screens be removed during winter to allow the advantage of free heat from the sun, often they are not removed seasonally. This practice may be because of solar screens serving as an insect screen in addition to blocking the sun or simply that they're installed in difficult-to-reach areas such as second floor windows. The savings estimates presented herein assume that the installed solar screens remain in place year-round.

Thermal Performance Improvement

A study by the University of Texas Center for Energy Studies modeled prototypical Austin homes and reported at least a 15 percent reduction in the thermal transmittance of a single pane, ¼" clear glass window with a solar screen.[212] The deemed savings models assume an average 10 percent improvement in thermal performance with the addition of a solar screen.

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[211] Performance data from Matrix, Inc., Mesa, Arizona testing facility for Phifer Wire Products' SunTex screen, blocks 80% of solar heat gain. https://www.phifer.com/product/suntex-80-90/.

[212] Energy Savings Resulting from Shading Devices on Single-Family Residences in Austin, Texas, R.K. Pletzer, J.W. Jones, and B.D. Hunn, Center for Energy Studies, Proceedings of the Fourth Symposium on Improving Building Systems in Hot and Humid Climates, Houston, TX, September 15-16, 1987.

Window Frame

The window frame accounts for 10-30 percent of the window area[213] and because it is opaque and blocks sunlight from entering the home, it is factored into the model. An average of 15 percent frame area was incorporated into the performance of the window.

Energy Savings

Energy savings are estimated according to the differences in annual energy use in the pre-retrofit (base case) and post-retrofit (change case) models. Estimated savings per square foot of solar screen installed are presented by window orientation in the deemed energy savings tables below. The energy savings are additive: if windows are installed on multiple orientations, the sum of the cooling savings and appropriate heating savings values for each orientation in Table 6.6-1 should be multiplied by the square feet of treated window area in that orientation. The resulting values should be summed to estimate total energy savings.

Demand Savings

Coincident Peak (CP), Non-coincident Peak (NCP) and ERCOT 4 Coincident Peak (4 CP) demand savings are estimated in accordance with the definitions provided in Section 2.3of this document. All are estimated according to the differences in energy use in specific hours of the simulations of the pre-retrofit (base case) and post-retrofit (change case) models.

Non-coincident Peak (NCP) savings for installations with individual orientations are calculated exactly as in Section 2.3, by taking the 99.9th percentile value from the 8,760 hourly savings values in the delta load shape. NCP savings for projects with multiple treated fenestration orientations are estimated differently. First, the absolute maximum NCP interval is identified by analyzing the delta load shape from a simulation model run representing the completed project with two or three treated orientations. For each treated orientation, the hourly savings value is extracted and normalized to the model treated window area for that orientation. These normalized values are then summed to obtain the NCP demand savings.

Similarly, CP and 4 CP demand savings for installations on multiple orientations are estimated by summing the normalized CP and 4 CP demand savings estimated for each orientation.

Estimated savings per square foot of solar screen installed are presented in the deemed demand savings tables below. Demand savings are presented for installations on individual window orientations and for installations on combinations of window orientations. The demand savings presented in Table 6.6-3 are not additive.

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[213] Residential Windows – A Guide to New Technologies and Energy Performance, 2000.

Load Shapes

The building energy simulation models used to estimate the savings for this measure are run on hourly time steps, producing 8,760 hourly estimates of energy use for the model year. The load shapes used to estimate demand savings for the solar screen measure are therefore the “delta load shapes” developed by subtracting the whole house energy use in each hour of the post-retrofit models from the energy use in each hour of the pre-retrofit models.

6.6.2.2 Deemed Energy Savings Tables

Table 6.6-1 presents the cooling and heating energy savings (kWh) achieved per square foot of ceiling area beneath the encapsulated attic in CPS Energy’s service territory. Annual energy savings are the sum of the cooling savings and the heating savings for the appropriate heating equipment type.

For customers who participate in Hard-to-Reach (HTR) or Low Income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying cooling savings in Table 6.6-1 by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying heating savings in Table 6.6-1 by a factor of 0.24.[214]

$$\boldsymbol{Deemed\ Energy\ Savings\ (kWh) = \left(Savings/ft^2{}_C \times CAF + Savings/ft^2{}_H \times HAF\right) \times A}$$

Equation 6.6-1

Where:

Savings/ft² = *Deemed cooling and heating energy savings per square feet taken from Table 6.6-1.*

A = *Area of the ceiling beneath the encapsulated attic [ft²].*

CAF = *Cooling adjustment factor in Table 6.6-2.*

HAF = *Heating adjustment factor in Table 6.6-2.*

Table 6.6-1: [Solar Screens] Deemed Energy Savings per Installed Square Foot (kWh/sq. ft.)

Window Orientation Treated	Cooling Savings	Heating Savings by Primary Heat Source		
		Gas	Electric Resistance	Heat Pump
East	10.72	-0.20	-5.90	-2.10
South	7.67	-0.25	-8.04	-3.07
West	12.48	-0.17	-4.95	-1.77

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[214] This factor was derived based on expected capacity reduction assuming 1200 sqft (historical analysis of HTR participants) x 0.35 BTU/sqft = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

Table 6.6-2: [Solar Screens] CAF/HAF, Cooling & Heating Adjustment Factors

HVAC System Type	CAF	HAF
Central AC	1.00	--
Window or Room AC	0.60	--
Central Furnace or HP	--	1.00
Electric Resistance Space Heater	--	0.24
None	0.00	0.00

6.6.2.3 Deemed Summer Demand Savings Tables

For customers who participate in Hard-to-Reach (HTR) or Low Income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying cooling savings in Table 6.6-3 by a factor of 0.6.

$$\boldsymbol{Deemed\ Demand\ Savings_{NCP,CP,or\ 4CP}\ (kWh) = Savings/ft^2{}_{NCP,CP,or\ 4CP} \times AF \times A}$$

Equation 6.6-2

Where:

Savings/ft² = *Deemed NCP, CP, or 4CP demand savings per square feet taken from Table 6.6-3.*

AF = *Adjustment factor based on HVAC system type in Table 6.6-4.*

Table 6.6-3: [Solar Screens] Deemed Demand Savings per Installed Square Foot (kW/sq. ft.)

Window Orientation Treated	NCP by Primary Heat Source			CP	4CP
	Gas	Electric Resistance	Heat Pump		
East	8.92 x 10^{-03}	7.17 x 10^{-03}	7.17 x 10^{-03}	2.49 x 10^{-03}	1.93 x 10^{-03}
South	9.74 x 10^{-03}	8.41 x 10^{-03}	8.40 x 10^{-03}	1.73 x 10^{-03}	1.78 x 10^{-03}
West	1.39 x 10^{-02}	7.15 x 10^{-03}	7.25 x 10^{-03}	6.29 x 10^{-03}	6.96 x 10^{-03}
East and West	1.91 x 10^{-02}	9.98 x 10^{-03}	9.80 x 10^{-03}	8.78 x 10^{-03}	9.41 x 10^{-03}
South and West	1.80 x 10^{-02}	9.12 x 10^{-03}	9.60 x 10^{-03}	8.02 x 10^{-03}	9.22 x 10^{-03}
West, South and East	2.89 x 10^{-02}	1.46 x 10^{-02}	1.54 x 10^{-02}	1.05 x 10^{-02}	1.07 x 10^{-02}

Table 6.6-4: [Solar Screens] AF, Adjustment Factors

Cooling System Type	NCP Adjustment Factor by Primary Heat Source				CP and 4CP Adjustment Factor by Primary Heat Source			
	Gas	Electric Resistance	Heat Pump	None	Gas	Electric Resistance	Heat Pump	None
Central AC	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Window or Room AC	0.6	1.0	0.6	0.6	0.6	0.6	0.6	0.6
None	0.0	1.0	NA	0.0	0.0	0.0	NA	0.0

6.6.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

6.6.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years for solar screens, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID BS-WinFilm.[215]

6.6.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Cooling type (evaporative cooling, central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
- Square footage of windows or door openings treated
- Proof of purchase with date of purchase, quantity, and model number

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[215] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

6.7 ENERGY STAR® COOL ROOFS

6.7.1 Measure Description

Reflective roofing materials reduce the overall heat load on a home by reducing the total heat energy absorbed into the building system from incident solar radiation. This reduction in total load provides space cooling energy savings during cooling season but reduces free heat during heating season, so the measure saves energy in the summer but uses more energy in winter. As such, cool roofs are most beneficial in warmer climates, and furthermore may not be recommendable for homes in which the primary heat source is electric resistance. The measure is for retrofit of existing homes.

6.7.1.1 Eligibility Criteria

Cooling savings in this measure apply to customers with central or mini-split electric refrigerated air conditioning in their homes. Homes must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. Customers who participate in Hard-to-Reach (HTR) or Low Income (LI) programs are eligible to claim heating savings for homes heated with gas or electric resistance space heaters. Customers participating in HTR or LI programs are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that are specified for homes with refrigerated air.

6.7.1.2 Baseline Condition

The baseline condition is an existing home with a standard medium- or dark-colored roof.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[216] Space heating refers primarily to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[217] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer Demand Savings Tables sections.

6.7.1.3 High-Efficiency Condition

The measure requires installation of roof products that have been rated by the Cool Roof Rating Council (CRRC) and demonstrate compliance with ENERGY STAR certified roof product performance specifications for the relevant roof application. ENERGY STAR test criteria[218] allows for products already participating in the CRRC Product Rating Program[219] to submit solar reflectance and thermal emittance product information derived from CRRC certification.

The ENERGY STAR program classifies roofs with slope greater than 2/12 as having a steep slope and

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[216] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.
[217] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.
[218] ENERGY STAR Program Requirements for Roof Products v2.1.
https://www.energystar.gov/ia/partners/product_specs/program_reqs/roofs_prog_req.pdf.
[219] CRRC Rated Products Directory: https://coolroofs.org/directory.

roofs with slope less than or equal to 2/12 as low slope roofs. ENERGY STAR performance specifications for cool roof products for use on roofs with steep slopes and low slopes are provided in Table 6.7-1.

The ENERGY STAR specification for roof products will sunset effective June 1, 2022.[220] No new roof products will be certified as of June 1, 2021. At this point, ENERGY STAR legacy or CRRC product certification will be required to demonstrate compliance with the previous ENERGY STAR specification.

If a cool roof is installed concurrent with changes to attic insulation levels, savings should be claimed for the reflective roof according to the post-retrofit (ceiling or roof deck) insulation levels. Savings for changes in insulation levels should be claimed separately according to the attic floor insulation or attic encapsulation measures, assuming the retrofit performed meets the requirements of those measures.

Table 6.7-1: [Cool Roofs] ENERGY STAR Specification

Roof Slope	Characteristic	Performance Specification
Low Slope ≤ 2/12	Initial Solar Reflectance	≥ 0.65
	3-Year Solar Reflectance	≥ 0.50
High Slope > 2/12	Initial Solar Reflectance	≥ 0.25
	3-Year Solar Reflectance	≥ 0.15

6.7.2 Energy and Demand Savings Methodology

Energy and demand savings are presented for cool roofs according to the rated 3-year reflectance of the installed cool roof product and the type of roof (low-slope, high-slope) on which it is installed.

6.7.2.1 Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for San Antonio were modified as follows. Roof slopes were modified to reflect representative levels for the low slope and steep slope roofs. A 1/12 slope was selected for modeling low slope roofs (defined as having slope ≤ 2/12), and a 4/12 slope was selected for modeling steep slope roofs (slope > 2/12). Based on the performance criteria and review of the rated 3-year reflectance of rated products listed in the CRRC database, four reflectance levels were selected for modeling: 0.2, 0.4, 0.6 and 0.8, representing 20 to 80 percent reflectance.

Because of the interplay between the performance of insulation and attic/roof deck temperatures, which are directly affected by the installation of a cool roof, savings were estimated for a range of different attic insulation scenarios: a range of attic floor insulation levels from no insulation (R-0) to R-30, and two roof deck insulation levels, R-19 and R-38, were modeled. Savings for a roof deck insulation level of R-30 are

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[220] ENERGY STAR Roof Products Sunset Decision Memo. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Roof%20Products%20Sunset%20Decision%20Memo.pdf.

provided by interpolating between the R-19 and R-38 scenarios.

These modifications are shown in Table 6.7-2.

The model runs calculated energy use for the prototypical home prior to encapsulating the attic. Next, change-case models were run to calculate energy use with the floor insulation measure in place with either R-30 or R-38 insulation.

Table 6.7-2: [Cool Roofs] Prototypical Home Characteristics

Shell Characteristic	Value	Source
Base Case Roof Material	Medium Asphalt Shingle, Reflectance = 0.15	Prototype home default
Change Case Roof Material	Medium Asphalt Shingle, Reflectance = 0.2 Reflectance = 0.4 Reflectance = 0.6 Reflectance = 0.8	Lower reflectance levels only relevant for steep slope roofs. Modeled reflectance levels reflect midpoints of ranges: 0.15 ≤ R < 0.3 Reflectance 0.3 ≤ R < 0.5 Reflectance 0.5 ≤ R < 0.7 Reflectance > 0.7
Roof Slope: Low-Slope Roof	1/12	Not modified between base and change cases
Roof Slope: Steep Slope Roof	4/12	Not modified between base and change cases
Ceiling (attic floor) Insulation Levels	R0-R4 R5-R8 R9-R14 R15-R22 R-30	Not modified between base and change cases
Roof Deck (underside) Insulation Levels	R-19 R-30 R-38	Not modified between base and change cases

6.7.2.2 Deemed Energy Savings Tables

Savings are presented first for homes with attic floor insulation, and subsequently for those with roof deck insulation. For customers who participate in Hard-to-Reach (HTR) or Low Income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying cooling savings in Table 6.7-3 through Table 6.7-6 by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying heating savings in Table 6.7-3 through Table 6.7-6 by a factor of 0.24.[221]

Homes with Attic Floor Insulation

Table 6.7-3 presents the energy savings (kWh) for installation of a reflective roof on homes with varying levels of ceiling (attic floor) insulation. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types. Savings are per square foot of treated roof area.

Table 6.7-3: [Cool Roofs] Home with AFI - Deemed Annual Energy Savings (kWh/sq. ft.)

Attic Floor Insulation R-value	Installed Roof Material 3-Year Reflectance	Cooling Savings (Refrigerated Air)	Heating Savings		
			Gas	Electric Resistance	Heat Pump
Steep Slope					
R-0 to R-4	0.15 - 0.29	0.09	0.00	-0.03	-0.01
R-0 to R-4	0.3 – 0.49	0.47	-0.01	-0.17	-0.07
R-0 to R-4	0.5 – 0.69	0.86	-0.01	-0.32	-0.13
R-0 to R-4	≥ 0.7	1.26	-0.02	-0.49	-0.20
R-5 to R-8	0.15 - 0.29	0.06	0.00	-0.02	-0.01
R-5 to R-8	0.3 – 0.49	0.30	0.00	-0.09	-0.04
R-5 to R-8	0.5 – 0.69	0.54	-0.01	-0.18	-0.08
R-5 to R-8	≥ 0.7	0.80	-0.01	-0.27	-0.12
R-9 to R-14	0.15 - 0.29	0.04	0.00	-0.01	-0.01
R-9 to R-14	0.3 – 0.49	0.22	0.00	-0.07	-0.03
R-9 to R-14	0.5 – 0.69	0.41	0.00	-0.13	-0.06
R-9 to R-14	≥ 0.7	0.61	-0.01	-0.19	-0.09
R-15 to R-22	0.15 - 0.29	0.03	0.00	-0.01	0.00
R-15 to R-22	0.3 – 0.49	0.17	0.00	-0.05	-0.02
R-15 to R-22	0.5 – 0.69	0.32	0.00	-0.09	-0.04
R-15 to R-22	≥ 0.7	0.47	0.00	-0.13	-0.06
R-30	0.15 - 0.29	0.03	0.00	-0.01	0.00

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[221] This factor was derived based on expected capacity reduction assuming 1200 sqft (historical analysis of HTR participants) x 0.35 BTU/sqft = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

Attic Floor Insulation R-value	Installed Roof Material 3-Year Reflectance	Cooling Savings (Refrigerated Air)	Heating Savings		
			Gas	Electric Resistance	Heat Pump
R-30	0.3 – 0.49	0.14	0.00	-0.03	-0.02
R-30	0.5 – 0.69	0.25	0.00	-0.06	-0.03
R-30	≥ 0.7	0.37	0.00	-0.09	-0.04
Low Slope					
R-0 to R-4	0.5 – 0.69	0.93	-0.01	-0.35	-0.14
R-0 to R-4	≥ 0.7	1.36	-0.02	-0.54	-0.22
R-5 to R-8	0.5 – 0.69	0.61	-0.01	-0.20	-0.09
R-5 to R-8	≥ 0.7	0.88	-0.01	-0.31	-0.13
R-9 to R-14	0.5 – 0.69	0.47	0.00	-0.15	-0.06
R-9 to R-14	≥ 0.7	0.68	-0.01	-0.22	-0.10
R-15 to R-22	0.5 – 0.69	0.37	0.00	-0.10	-0.05
R-15 to R-22	≥ 0.7	0.54	0.00	-0.15	-0.07
R-30	0.5 – 0.69	0.20	0.00	0.00	-0.03
R-30	≥ 0.7	0.29	0.00	0.00	-0.05

Homes with Roof Deck Insulation

Table 6.7-4 presents the energy savings (kWh) for installation of a reflective roof on homes with varying levels of roof deck insulation. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types. Savings are per square foot of treated roof area.

Table 6.7-4: [Cool Roofs] Home with RDI - Deemed Annual Energy Savings (kWh/sq. ft.)

Roof Deck Insulation R-value	Installed Roof Material 3-Year Reflectance	Cooling Savings (Refrigerated Air)	Heating Savings		
			Gas	Electric Resistance	Heat Pump
Steep Slope					
R-19	0.15 - 0.29	0.03	0.00	-0.02	-0.01
R-19	0.3 – 0.49	0.18	0.00	-0.09	-0.04
R-19	0.5 – 0.69	0.33	-0.01	-0.16	-0.07
R-19	≥ 0.7	0.49	-0.01	-0.24	-0.10
R-30	0.15 - 0.29	0.02	0.00	-0.01	-0.06
R-30	0.3 – 0.49	0.15	0.00	-0.07	-0.04
R-30	0.5 – 0.69	0.27	0.00	-0.13	-0.07
R-30	≥ 0.7	0.40	-0.01	-0.19	-0.10
R-38	0.15 - 0.29	0.02	0.00	-0.01	-0.10
R-38	0.3 – 0.49	0.13	0.00	-0.06	-0.04
R-38	0.5 – 0.69	0.23	0.00	-0.11	-0.07
R-38	≥ 0.7	0.34	-0.01	-0.16	-0.10
Low Slope					
R-19	0.5 – 0.69	0.32	0.00	-0.14	-0.06
R-19	≥ 0.7	0.47	-0.01	-0.21	-0.09
R-30	0.5 – 0.69	0.27	0.00	-0.11	-0.07
R-30	≥ 0.7	0.39	0.00	-0.16	-0.10
R-38	0.5 – 0.69	0.23	0.00	-0.09	-0.07
R-38	≥ 0.7	0.34	0.00	-0.13	-0.10

6.7.2.3 Deemed Summer Demand Savings Tables

Savings are presented first for homes with attic floor insulation, and subsequently for those with roof deck insulation. For customers who participate in Hard-to-Reach (HTR) or Low Income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying appropriate cooling values in Table 6.7-5 through Table 6.7-6 by a factor of 0.6.

Homes with Attic Floor Insulation

Table 6.7-5 presents the summer demand savings (kW) associated with installation of a reflective roof in homes with varying levels of attic floor insulation. Savings are per square foot of treated roof area.

Table 6.7-5: [Cool Roofs] Home with AFI - Deemed Demand Savings (kW/sq. ft.)

HVAC Type	Attic Floor Insulation R-value	Installed Roof Material 3-Year Reflectance	NCP	CP	4CP
Steep Slope					
AC + Gas	R-0 to R-4	0.15 - 0.29	1.26E-04	6.91E-05	8.41E-05
	R-0 to R-4	0.3 – 0.49	6.39E-04	3.51E-04	4.27E-04
	R-0 to R-4	0.5 – 0.69	1.17E-03	6.42E-04	7.82E-04
	R-0 to R-4	≥ 0.7	1.71E-03	9.36E-04	1.14E-03
	R-5 to R-8	0.15 - 0.29	8.62E-05	4.34E-05	5.20E-05
	R-5 to R-8	0.3 – 0.49	4.38E-04	2.21E-04	2.65E-04
	R-5 to R-8	0.5 – 0.69	8.04E-04	4.05E-04	4.85E-04
	R-5 to R-8	≥ 0.7	1.18E-03	5.96E-04	7.14E-04
	R-9 to R-14	0.15 - 0.29	6.82E-05	3.17E-05	4.33E-05
	R-9 to R-14	0.3 – 0.49	3.47E-04	1.61E-04	2.20E-04
	R-9 to R-14	0.5 – 0.69	6.37E-04	2.96E-04	4.04E-04
	R-9 to R-14	≥ 0.7	9.37E-04	4.36E-04	5.95E-04
	R-15 to R-22	0.15 - 0.29	6.21E-05	2.44E-05	3.63E-05
	R-15 to R-22	0.3 – 0.49	3.15E-04	1.24E-04	1.84E-04
	R-15 to R-22	0.5 – 0.69	5.77E-04	2.27E-04	3.37E-04
	R-15 to R-22	≥ 0.7	8.51E-04	3.34E-04	4.98E-04
	R-30	0.15 - 0.29	5.69E-05	2.04E-05	3.22E-05
	R-30	0.3 – 0.49	2.86E-04	1.02E-04	1.62E-04

HVAC Type	Attic Floor Insulation R-value	Installed Roof Material 3-Year Reflectance	NCP	CP	4CP
	R-30	0.5 – 0.69	5.29E-04	1.89E-04	3.00E-04
	R-30	≥ 0.7	7.81E-04	2.80E-04	4.43E-04
Low Slope					
AC + Gas	R-0 to R-4	0.5 – 0.69	1.28E-03	6.88E-04	7.94E-04
	R-0 to R-4	≥ 0.7	1.86E-03	1.00E-03	1.16E-03
	R-5 to R-8	0.5 – 0.69	8.02E-04	4.63E-04	5.07E-04
	R-5 to R-8	≥ 0.7	1.17E-03	6.74E-04	7.38E-04
	R-9 to R-14	0.5 – 0.69	6.17E-04	3.45E-04	4.42E-04
	R-9 to R-14	≥ 0.7	9.02E-04	5.05E-04	6.46E-04
	R-15 to R-22	0.5 – 0.69	5.89E-04	2.74E-04	3.58E-04
	R-15 to R-22	≥ 0.7	8.57E-04	4.00E-04	5.22E-04
	R-30	0.5 – 0.69	5.24E-04	2.28E-04	3.11E-04
	R-30	≥ 0.7	7.63E-04	3.31E-04	4.53E-04
Steep Slope					
AC + ER	R-0 to R-4	0.15 - 0.29	1.32E-04	7.53E-05	8.67E-05
	R-0 to R-4	0.3 – 0.49	6.59E-04	3.76E-04	4.32E-04
	R-0 to R-4	0.5 – 0.69	1.18E-03	6.71E-04	7.72E-04
	R-0 to R-4	≥ 0.7	1.66E-03	9.48E-04	1.09E-03
	R-5 to R-8	0.15 - 0.29	8.49E-05	4.54E-05	5.35E-05
	R-5 to R-8	0.3 – 0.49	4.27E-04	2.28E-04	2.69E-04
	R-5 to R-8	0.5 – 0.69	7.71E-04	4.12E-04	4.86E-04
	R-5 to R-8	≥ 0.7	1.12E-03	5.98E-04	7.05E-04
	R-9 to R-14	0.15 - 0.29	6.92E-05	3.32E-05	4.45E-05
	R-9 to R-14	0.3 – 0.49	3.47E-04	1.67E-04	2.23E-04
	R-9 to R-14	0.5 – 0.69	6.34E-04	3.04E-04	4.08E-04
	R-9 to R-14	≥ 0.7	9.25E-04	4.43E-04	5.94E-04

HVAC Type	Attic Floor Insulation R-value	Installed Roof Material 3-Year Reflectance	NCP	CP	4CP
	R-15 to R-22	0.15 - 0.29	6.22E-05	2.52E-05	3.78E-05
	R-15 to R-22	0.3 – 0.49	3.12E-04	1.27E-04	1.90E-04
	R-15 to R-22	0.5 – 0.69	5.70E-04	2.31E-04	3.46E-04
	R-15 to R-22	≥ 0.7	8.35E-04	3.38E-04	5.08E-04
	R-30	0.15 - 0.29	6.10E-05	1.97E-05	3.17E-05
	R-30	0.3 – 0.49	3.06E-04	9.88E-05	1.59E-04
	R-30	0.5 – 0.69	5.65E-04	1.82E-04	2.94E-04
	R-30	≥ 0.7	8.31E-04	2.68E-04	4.32E-04
Low Slope					
AC + ER	R-0 to R-4	0.5 – 0.69	1.31E-03	7.14E-04	8.21E-04
	R-0 to R-4	≥ 0.7	1.85E-03	1.01E-03	1.16E-03
	R-5 to R-8	0.5 – 0.69	8.18E-04	4.65E-04	5.33E-04
	R-5 to R-8	≥ 0.7	1.17E-03	6.63E-04	7.60E-04
	R-9 to R-14	0.5 – 0.69	6.21E-04	3.42E-04	4.45E-04
	R-9 to R-14	≥ 0.7	8.98E-04	4.95E-04	6.43E-04
	R-15 to R-22	0.5 – 0.69	5.88E-04	2.77E-04	3.60E-04
	R-15 to R-22	≥ 0.7	8.48E-04	3.99E-04	5.19E-04
	R-30	0.5 – 0.69	5.24E-04	2.28E-04	3.21E-04
	R-30	≥ 0.7	7.57E-04	3.30E-04	4.64E-04
Steep Slope					
HP	R-0 to R-4	0.15 - 0.29	7.43E-05	5.71E-05	5.73E-05
	R-0 to R-4	0.3 – 0.49	3.76E-04	2.89E-04	2.90E-04
	R-0 to R-4	0.5 – 0.69	6.84E-04	5.25E-04	5.27E-04
	R-0 to R-4	≥ 0.7	9.89E-04	7.59E-04	7.63E-04
	R-5 to R-8	0.15 - 0.29	8.16E-05	4.30E-05	5.00E-05
	R-5 to R-8	0.3 – 0.49	4.12E-04	2.17E-04	2.53E-04

HVAC Type	Attic Floor Insulation R-value	Installed Roof Material 3-Year Reflectance	NCP	CP	4CP
	R-5 to R-8	0.5 – 0.69	7.52E-04	3.96E-04	4.61E-04
	R-5 to R-8	≥ 0.7	1.10E-03	5.81E-04	6.76E-04
	R-9 to R-14	0.15 - 0.29	6.48E-05	3.18E-05	4.22E-05
	R-9 to R-14	0.3 – 0.49	3.28E-04	1.61E-04	2.14E-04
	R-9 to R-14	0.5 – 0.69	6.02E-04	2.96E-04	3.92E-04
	R-9 to R-14	≥ 0.7	8.83E-04	4.34E-04	5.75E-04
	R-15 to R-22	0.15 - 0.29	2.73E-05	1.84E-05	1.86E-05
	R-15 to R-22	0.3 – 0.49	1.37E-04	9.27E-05	9.36E-05
	R-15 to R-22	0.5 – 0.69	2.51E-04	1.70E-04	1.71E-04
	R-15 to R-22	≥ 0.7	3.70E-04	2.50E-04	2.52E-04
	R-30	0.15 - 0.29	2.23E-05	1.40E-05	1.43E-05
	R-30	0.3 – 0.49	1.12E-04	7.03E-05	7.17E-05
	R-30	0.5 – 0.69	2.06E-04	1.30E-04	1.32E-04
	R-30	≥ 0.7	3.04E-04	1.92E-04	1.95E-04
Low Slope					
HP	R-0 to R-4	0.5 – 0.69	1.23E-03	6.80E-04	7.78E-04
	R-0 to R-4	≥ 0.7	1.78E-03	9.82E-04	1.12E-03
	R-5 to R-8	0.5 – 0.69	7.76E-04	4.56E-04	5.06E-04
	R-5 to R-8	≥ 0.7	1.12E-03	6.59E-04	7.31E-04
	R-9 to R-14	0.5 – 0.69	5.85E-04	3.32E-04	4.24E-04
	R-9 to R-14	≥ 0.7	8.52E-04	4.84E-04	6.18E-04
	R-15 to R-22	0.5 – 0.69	5.60E-04	2.69E-04	3.45E-04
	R-15 to R-22	≥ 0.7	8.13E-04	3.90E-04	5.01E-04
	R-30	0.5 – 0.69	4.97E-04	2.22E-04	3.01E-04
	R-30	≥ 0.7	7.20E-04	3.23E-04	4.36E-04

HVAC Type	Attic Floor Insulation R-value	Installed Roof Material 3-Year Reflectance	NCP	CP	4CP
Steep Slope					
AC, no heat	R-0 to R-4	0.15 - 0.29	7.48E-05	5.40E-05	5.07E-05
	R-0 to R-4	0.3 – 0.49	3.80E-04	2.74E-04	2.58E-04
	R-0 to R-4	0.5 – 0.69	6.96E-04	5.02E-04	4.72E-04
	R-0 to R-4	≥ 0.7	1.02E-03	7.33E-04	6.89E-04
	R-5 to R-8	0.15 - 0.29	4.69E-05	3.29E-05	3.10E-05
	R-5 to R-8	0.3 – 0.49	2.34E-04	1.64E-04	1.55E-04
	R-5 to R-8	0.5 – 0.69	4.22E-04	2.96E-04	2.79E-04
	R-5 to R-8	≥ 0.7	6.25E-04	4.38E-04	4.13E-04
	R-9 to R-14	0.15 - 0.29	2.96E-05	2.12E-05	1.99E-05
	R-9 to R-14	0.3 – 0.49	1.63E-04	1.17E-04	1.09E-04
	R-9 to R-14	0.5 – 0.69	3.03E-04	2.18E-04	2.04E-04
	R-9 to R-14	≥ 0.7	4.51E-04	3.24E-04	3.03E-04
	R-15 to R-22	0.15 - 0.29	6.21E-05	2.44E-05	3.63E-05
	R-15 to R-22	0.3 – 0.49	3.14E-04	1.23E-04	1.84E-04
	R-15 to R-22	0.5 – 0.69	5.77E-04	2.27E-04	3.37E-04
	R-15 to R-22	≥ 0.7	8.51E-04	3.34E-04	4.97E-04
	R-30	0.15 - 0.29	1.94E-05	1.37E-05	1.28E-05
	R-30	0.3 – 0.49	9.75E-05	6.89E-05	6.47E-05
	R-30	0.5 – 0.69	1.80E-04	1.27E-04	1.19E-04
	R-30	≥ 0.7	2.66E-04	1.88E-04	1.77E-04
Low Slope					
AC no heat	R-0 to R-4	0.5 – 0.69	6.97E-04	5.49E-04	5.24E-04
	R-0 to R-4	≥ 0.7	1.02E-03	8.01E-04	7.64E-04
	R-5 to R-8	0.5 – 0.69	4.38E-04	3.36E-04	3.17E-04
	R-5 to R-8	≥ 0.7	6.32E-04	4.84E-04	4.57E-04

HVAC Type	Attic Floor Insulation R-value	Installed Roof Material 3-Year Reflectance	NCP	CP	4CP
	R-9 to R-14	0.5 – 0.69	3.29E-04	2.47E-04	2.37E-04
	R-9 to R-14	≥ 0.7	4.76E-04	3.58E-04	3.42E-04
	R-15 to R-22	0.5 – 0.69	5.88E-04	2.74E-04	3.58E-04
	R-15 to R-22	≥ 0.7	8.57E-04	3.99E-04	5.22E-04
	R-30	0.5 – 0.69	2.01E-04	1.49E-04	1.39E-04
	R-30	≥ 0.7	2.92E-04	2.17E-04	2.02E-04

Homes with Roof Deck Insulation

Table 6.7-6 presents the summer demand savings (kW) associated with installation of a reflective roof in homes with varying levels of roof deck insulation. Savings are per square foot of treated roof area.

Table 6.7-6: [Cool Roofs] Home with RDI - Deemed Summer Demand Savings (kW/sq. ft.)

HVAC Type	Roof Deck Insulation R-value	Installed Roof Material 3-Year Reflectance	NCP	CP	4CP
Steep Slope					
AC + Gas	R-19	0.15 - 0.29	4.43E-05	9.70E-06	1.63E-05
	R-19	0.3 – 0.49	2.26E-04	4.96E-05	8.31E-05
	R-19	0.5 – 0.69	4.17E-04	9.14E-05	1.53E-04
	R-19	≥ 0.7	6.18E-04	1.35E-04	2.27E-04
	R-30	0.15 - 0.29	2.52E-05	6.32E-06	9.77E-06
	R-30	0.3 – 0.49	1.29E-04	3.23E-05	5.00E-05
	R-30	0.5 – 0.69	2.37E-04	5.95E-05	9.21E-05
	R-30	≥ 0.7	3.51E-04	8.82E-05	1.36E-04
	R-38	0.15 - 0.29	1.13E-05	3.85E-06	5.04E-06
	R-38	0.3 – 0.49	5.78E-05	1.97E-05	2.58E-05
	R-38	0.5 – 0.69	1.06E-04	3.63E-05	4.75E-05
	R-38	≥ 0.7	1.57E-04	5.38E-05	7.04E-05

HVAC Type	Roof Deck Insulation R-value	Installed Roof Material 3-Year Reflectance	NCP	CP	4CP
Low Slope					
AC + Gas	R-19	0.5 – 0.69	7.71E-04	8.74E-05	1.44E-04
	R-19	≥ 0.7	1.14E-03	1.30E-04	2.14E-04
	R-30	0.5 – 0.69	5.55E-04	7.58E-05	8.80E-05
	R-30	≥ 0.7	8.22E-04	1.12E-04	1.30E-04
	R-38	0.5 – 0.69	3.98E-04	6.74E-05	4.72E-05
	R-38	≥ 0.7	5.89E-04	9.98E-05	6.98E-05
Steep Slope					
AC + ER	R-19	0.15 - 0.29	5.05E-05	1.12E-05	1.69E-05
	R-19	0.3 – 0.49	2.60E-04	5.74E-05	8.71E-05
	R-19	0.5 – 0.69	4.73E-04	1.05E-04	1.59E-04
	R-19	≥ 0.7	6.98E-04	1.54E-04	2.34E-04
	R-30	0.15 - 0.29	4.67E-05	9.17E-06	1.12E-05
	R-30	0.3 – 0.49	2.44E-04	4.77E-05	5.81E-05
	R-30	0.5 – 0.69	4.45E-04	8.72E-05	1.06E-04
	R-30	≥ 0.7	6.57E-04	1.29E-04	1.56E-04
	R-38	0.15 - 0.29	4.39E-05	7.72E-06	7.00E-06
	R-38	0.3 – 0.49	2.32E-04	4.07E-05	3.70E-05
	R-38	0.5 – 0.69	4.24E-04	7.45E-05	6.76E-05
	R-38	≥ 0.7	6.28E-04	1.10E-04	1.00E-04
Low Slope					
AC + ER	R-19	0.5 – 0.69	4.34E-04	8.79E-05	1.46E-04
	R-19	≥= 0.7	6.39E-04	1.29E-04	2.15E-04
	R-30	0.5 – 0.69	3.39E-04	6.50E-05	9.74E-05
	R-30	≥ 0.7	5.01E-04	9.59E-05	1.44E-04
	R-38	0.5 – 0.69	2.70E-04	4.84E-05	6.18E-05
	R-38	≥ 0.7	4.00E-04	7.16E-05	9.14E-05

HVAC Type	Roof Deck Insulation R-value	Installed Roof Material 3-Year Reflectance	NCP	CP	4CP
Steep Slope					
HP	R-19	0.15 - 0.29	2.04E-05	1.40E-05	1.64E-05
	R-19	0.3 – 0.49	1.05E-04	7.18E-05	8.39E-05
	R-19	0.5 – 0.69	1.92E-04	1.32E-04	1.54E-04
	R-19	≥ 0.7	2.85E-04	1.96E-04	2.28E-04
	R-30	0.15 - 0.29	1.67E-05	8.15E-06	9.60E-06
	R-30	0.3 – 0.49	8.56E-05	4.18E-05	4.93E-05
	R-30	0.5 – 0.69	1.57E-04	7.68E-05	9.05E-05
	R-30	≥ 0.7	2.33E-04	1.14E-04	1.34E-04
	R-38	0.15 - 0.29	1.40E-05	3.88E-06	4.68E-06
	R-38	0.3 – 0.49	7.19E-05	2.00E-05	2.41E-05
	R-38	0.5 – 0.69	1.32E-04	3.66E-05	4.41E-05
	R-38	≥ 0.7	1.95E-04	5.41E-05	6.52E-05
Low Slope					
HP	R-19	0.5 – 0.69	1.77E-04	1.24E-04	1.44E-04
	R-19	≥ 0.7	2.63E-04	1.84E-04	2.12E-04
	R-30	0.5 – 0.69	1.77E-04	7.30E-05	8.46E-05
	R-30	≥ 0.7	2.61E-04	1.08E-04	1.25E-04
	R-38	0.5 – 0.69	1.76E-04	3.57E-05	4.18E-05
	R-38	≥ 0.7	2.60E-04	5.28E-05	6.18E-05
Steep Slope					
AC no heat	R-19	0.15 - 0.29	2.28E-05	1.89E-05	1.72E-05
	R-19	0.3 – 0.49	1.16E-04	9.64E-05	8.77E-05
	R-19	0.5 – 0.69	2.15E-04	1.78E-04	1.62E-04
	R-19	≥ 0.7	3.18E-04	2.63E-04	2.40E-04
	R-30	0.15 - 0.29	1.85E-05	1.53E-05	1.40E-05
	R-30	0.3 – 0.49	9.48E-05	7.84E-05	7.15E-05
	R-30	0.5 – 0.69	1.75E-04	1.44E-04	1.32E-04
	R-30	≥ 0.7	2.59E-04	2.14E-04	1.95E-04
	R-38	0.15 - 0.29	1.54E-05	1.27E-05	1.17E-05
	R-38	0.3 – 0.49	7.91E-05	6.53E-05	5.97E-05
	R-38	0.5 – 0.69	1.46E-04	1.20E-04	1.10E-04
	R-38	≥ 0.7	2.15E-04	1.78E-04	1.63E-04

HVAC Type	Roof Deck Insulation R-value	Installed Roof Material 3-Year Reflectance	NCP	CP	4CP
Low Slope					
AC no heat	R-19	0.5 – 0.69	1.80E-04	1.54E-04	1.45E-04
	R-19	≥ 0.7	2.67E-04	2.29E-04	2.14E-04
	R-30	0.5 – 0.69	1.47E-04	1.26E-04	1.17E-04
	R-30	≥ 0.7	2.18E-04	1.86E-04	1.74E-04
	R-38	0.5 – 0.69	1.23E-04	1.05E-04	9.73E-05
	R-38	≥ 0.7	1.83E-04	1.55E-04	1.44E-04

6.7.2.4 Additional Calculators and Tools

This section is not applicable.

6.7.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years for cool roofs, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID BS-LtRoof.[222]

6.7.3 Program Tracking Data & Evaluation Requirements

It is required that the following list of primary inputs and contextual data be specified and tracked by the program database to inform the evaluation and apply the savings properly:

- R-value of insulation (as is, post measure installation of ceiling/roof insulation)
- Cooling type (evaporative cooling, central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
- Square footage of reflective roofing material installed
- Slope of the roof (low or high)
- Three-year solar reflectance as rated by Cool Roof Rating Certification of the reflective material installed
- Proof of purchase with date of purchase, quantity, model number, and treated square feet

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[222] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

7. RESIDENTIAL: WATER HEATING

7.1 FAUCET AERATORS

7.1.1 Measure Description

This measure involves installing aerators on kitchen and bathroom water faucets as a retrofit measure.

7.1.1.1 Eligibility Criteria

The savings values are per faucet aerator installed. It is not a requirement that all faucets in a home be treated for the deemed savings to be applicable.

These deemed savings are for residential, retrofit-only installation of kitchen and bathroom faucet aerators. To be awarded these deemed savings, the fuel type of the water heater must be electricity.

Aerators that have been defaced to make the flow rating illegible are not eligible for replacement. For direct install programs, all aerators removed shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

7.1.1.2 Baseline Condition

The 2.2 gallon per minute (GPM) baseline faucet flow rate is based on the Department of Energy (DOE) maximum flow rate standard.[223] The deemed savings assume that the existing faucet aerators have a flow rate of 2.2 GPM.

7.1.1.3 High-Efficiency Condition

Flow rates of installed faucet aerators must meet or exceed the requirements list in the US EPA WaterSense specification for faucet aerators: 1.5 GPM.[224]

7.1.2 Energy and Demand Savings Methodology

7.1.2.1 Savings Algorithms and Input Variables

Energy Savings

The deemed savings for any faucet aerator change case using aerators with flow rates of 1.5 GPM or lower are calculated as follows:

$$\textit{Energy Savings (per aerator)} = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times 365 \times \left(T_{FaucetAvg} - T_{SupplyAvg}\right)}{FPH \times RE \times 3{,}412}$$

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[223] DOE maximum flow rate for faucet aerators. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=40.

[224] "High Efficiency Lavatory Faucet Specification," WaterSense, U.S. Environmental Protection Agency, Office of Wastewater Management. http://www.epa.gov/watersense/partners/faucets_final.html.

Equation 7.1-1

Where:

ρ = *Water density, 8.33 lbs./gallon.*

C_P = *Specific heat of water, 1 Btu/lb°F.*

GPM_{Base} = *Average baseline flow rate of aerator = 2.2 gallons per minute.*

GPM_{Low} = *Post-installation flow rate of aerator, typically 1.5, 1.0, or 0.5 gallons per minute; if unknown, assume 1.5 gallons per minute.*

N = *Average number of persons per household = 2.86 persons.*[225]

t = *Average time in minutes of hot water usage per person per day; default = 2.34 min/person/day.*[226]

$T_{FaucetAvg}$ = *Average faucet temperature = 88°F.*[227]

$T_{SupplyAvg}$ = *Average supply water temperature, 75.9°F.*[228]

RE = *Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters.*[229]

FPH = *Average number of faucets per household = 3.87 faucets.*[230]

3,412 = *Constant to convert from Btu to kWh.*

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[225] Occupants per home for San Antonio from US Census Bureau, "Persons per household, 2010-2014." https://www.census.gov/quickfacts/TX.

[226] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study." Prepared for Michigan Evaluation Working Group. Derived by taking weighted average of average minutes per person per day specified for kitchens (4.5) and bathrooms (1.6) assuming 1 kitchen aerator and 2.93 bathrooms.

[227] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study." Prepared for Michigan Evaluation Working Group. Derived by taking weighted average of average temperature for kitchens (93°F) and bathrooms (86°F) assuming 1 kitchen aerator and 2.93 bathrooms.

[228] Based on typical meteorological year (TMY) dataset for TMY3, available through the National Solar Radiation Database (NSRDB) Data Viewer, https://nsrdb.nrel.gov/data-sets/archives.html.

[229] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database. https://www.ahridirectory.org/.

[230] Faucets per home assumed to be equal to one per kitchen and each half-bath plus 1.5 per each full bathroom per home. Bathroom counts extracted from the 2015 Residential Energy Consumption Survey (RECS), Table HC2.8. Structural and geographic characteristics of homes in West South-Central region.

Demand Savings

Demand savings are calculated by substituting the average supply temperature for the average seasonal temperature, multiplying by a demand factor equivalent to the daily fraction hot water use during the weighted peak hour, and dividing by 365 days/year, with 365 canceling from the savings algorithm numerator and denominator.

$$\boldsymbol{Demand\ Savings}\ (\boldsymbol{per\ aerator}) = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times \left(T_{FaucetAvg} - T_{Supply}\right)}{FPH \times RE \times Conversion\ Factor} \times DF$$

Equation 7.1-2

Where:

T_{Supply} = *For NCP, use average supply water temperature, 75.9°F.*[231]*; for CP and 4CP, use Seasonal supply water temperature 85.41°F.*[232]

DF = *Demand factor for NCP, CP. or 4CP peak demand; see Table 7.1-1.*

Table 7.1-1: [Low-Flow Faucet Aerators] Peak Demand Factors[233]

Ratio Type	Demand Ratio
NCP	0.105
CP	0.038
4CP	0.040

Load Shapes

This measure uses the load profile for sink usage from the Department of Energy's Building America Analysis spreadsheet.[234] The peak demand factors listed in Table 7.1-1 were derived from that load profile according to the methodologies described in Section 2.3. Those ratios represent the ratio of the NCP, CP, or 4CP peak demand savings (kW) to the annual energy savings (kWh).

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[231] Calculated according to the method in the Burch and Christensen 2007 paper "Towards Development of an Algorithm for Mains Water Temperature" and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base.

[232] Based on typical meteorological year (TMY) dataset for TMY3, available through the National Solar Radiation Database (NSRDB) Data Viewer, https://nsrdb.nrel.gov/data-sets/archives.html.

[233] Building America Performance Analysis Procedures for Existing Homes, page 18, figure 4: combined domestic hot water use profile. https://www.nrel.gov/docs/fy06osti/38238.pdf.

[234] Building America Analysis Spreadsheet, "B10 Analysis – Existing Homes 2011.01.26.xlsm." Available at http://energy.gov/eere/buildings/building-america-analysis-spreadsheets.

7.1.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

7.1.2.3 Deemed Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

7.1.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

7.1.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years for faucet aerators, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Aertr.[235]

7.1.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Recovery Efficiency (RE) or COP, if available
- Flow rate in gallons per minute (GPM) of faucet installed
- Water heater type (e.g., heat pump, electric resistance)
- Proof of purchase with date of purchase and quantity
    - Alternative: photo of replacement unit nameplate or other pre-approved method of installation verification

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[235] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

7.2 LOW-FLOW SHOWERHEADS

7.2.1 Measure Description

This measure consists of removing existing showerheads and installing low-flow showerheads in residences.

7.2.1.1 Eligibility Criteria

The incentive is for replacement of an existing showerhead with a new showerhead rated at or below 2.0 gallons per minute (GPM). The only showerheads eligible for installation are those that are not easily modified to increase the flow rate.

These deemed savings are for showerheads installed as a retrofit measure in existing homes. To be awarded these deemed savings, the fuel type of the water heater must be electricity.

In addition to meeting the baseline requirements above, existing showerheads that have been defaced to make the flow rating illegible are not eligible for replacement. All showerheads removed shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

7.2.1.2 Baseline Condition

The baseline flow rate is assumed to meet federal standards set at a maximum flow rate of 2.5 GPM.[236]

7.2.1.3 High-Efficiency Condition

Flow rates of installed showerheads must meet or exceed the US Environmental Protection Agency (EPA) WaterSense Program efficiency standards for showerheads of 2.0 GPM.[237]

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[236] Federal energy conservation standards specified in the Code of Federal Regulations at 10 CFR 430.32(p). http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/37.

[237] WaterSense, U.S. Environmental Protection Agency, Office of Wastewater Management http://www.epa.gov/watersense/products/showerheads.html.

7.2.2 Energy and Demand Savings Methodology

7.2.2.1 Savings Algorithms and Input Variables

Energy Savings

Energy savings for this measure are calculated as follows:

$$\boldsymbol{Energy\ Savings}\ (\boldsymbol{per\ showerhead}) = \frac{\boldsymbol{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times 365 \times (T_{ShowerAvg} - T_{SupplyAverage})}}{\boldsymbol{SPH \times RE \times 3,412}}$$

Equation 7.2-1

Where:

ρ = *Water density, 8.33 lbs/gallon.*

C_P = *Specific heat of water, 1 Btu/lb°F.*

GPM_{Base} = *Average baseline flow rate of aerator = 2.5 gallons per minute.*

GPM_{Low} = *Post-installation flow rate of aerator; if unknown, assume 2.0 gallons per minute.*

N = *Average number of persons per household = 2.86 persons.*[238]

t = *Average time in minutes of hot water usage per person per day; default = 7.8 min/person/day.*[239]

$T_{ShowerAvg}$ = *Average shower temperature = 101°F .*[240]

$T_{SupplyAverage}$ = *Average supply water temperature: 75.9°F.*[241]

SPH = *Average number of showerheads per household = 1.74 showerheads.*[242]

RE = *Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters.*[243]

3,412 = *Constant to convert from Btu to kWh.*

Demand Savings

Demand savings are calculated by substituting the average supply temperature for the average seasonal

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[238] Occupants per home for San Antonio from US Census Bureau, "Persons per household, 2010-2014." https://www.census.gov/quickfacts/TX.

[239] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study." Prepared for Michigan Evaluation Working Group.

[240] Ibid.

[241] Based on typical meteorological year (TMY) dataset for TMY3, available through the National Solar Radiation Database (NSRDB) Data Viewer, https://nsrdb.nrel.gov/data-sets/archives.html.

[242] Showerheads per home assumed to be equal to the number of full bathrooms per home. Bathroom counts extracted from the 2015 Residential Energy Consumption Survey (RECS), Table HC2.8. Structural and geographic characteristics of homes in the West South-Central region.

[243] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database. https://www.ahridirectory.org/.

temperature, multiplying by a demand factor equivalent to the daily fraction hot water use during the weighted peak hour, and dividing by 365 days/year, with 365 canceling from the savings algorithm numerator and denominator.

$$\boldsymbol{Demand\ Savings}\ (\boldsymbol{per\ showerhead}) = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times (T_{ShowerAvg} - T_{Supply})}{SPH \times RE \times Conversion\ Factor} \times DF$$

Equation 7.2-2

Where:

T_{Supply} = *For NCP, use average supply water temperature, 75.9°F.*[244]*; for CP and 4CP, use Seasonal supply water temperature 85.41°F.*[245]

DF = *Demand factor for NCP, CP, or 4CP peak demand; see Table 7.2-1.*

Table 7.2-1: [Low-Flow Showerheads] Peak Demand Factors[246]

Ratio Type	Demand Ratio
NCP	0.105
CP	0.038
4CP	0.040

Load Shapes

This measure uses the load profile for shower usage taken from the Department of Energy's Building America Analysis spreadsheet. The peak demand factors listed in Table 7.2-1 were derived from that load profile according to the methodologies described in Section 2.3. Those ratios represent the ratio of the NCP, CP, or 4CP peak demand savings (kW) to the annual energy savings (kWh).

7.2.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

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[244] Calculated according to the method in the Burch and Christensen 2007 paper "Towards Development of an Algorithm for Mains Water Temperature" and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base.

[245] Based on typical meteorological year (TMY) dataset for TMY3, available through the National Solar Radiation Database (NSRDB) Data Viewer, https://nsrdb.nrel.gov/data-sets/archives.html.

[246] Building America Performance Analysis Procedures for Existing Homes, page 18, figure 4: combined domestic hot water use profile. https://www.nrel.gov/docs/fy06osti/38238.pdf.

7.2.2.3 Deemed Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

7.2.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

7.2.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years for low-flow showerheads, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Shrhd.[247]

7.2.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Recovery Efficiency (RE) or COP, if available
- Flow rate in gallons per minute (GPM) of showerhead installed
- Water heater type (e.g., heat pump, electric resistance)
- Proof of purchase with date of purchase and quantity
    - Alternative: photo of replacement unit nameplate or other pre-approved method of installation verification

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[247] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

7.3 SHOWERHEAD TEMPERATURE SENSITIVE RESTRICTOR VALVES

7.3.1 Measure Description

This measure consists of installing a temperature sensitive restrictor valve (TSRV) between the existing shower arm and showerhead. The valve restricts hot water flow through the showerhead once the water reaches a set temperature (generally 95˚F) to prevent water from going down the drain prior to the user entering the shower, thereby eliminating behavioral waste.

7.3.1.1 Eligibility Criteria

These deemed savings are for temperature sensitive restrictor valves installed in new construction or as a retrofit measure in residential applications. Residences must have electrically fueled how water to be eligible for this measure.

7.3.1.2 Baseline Condition

The baseline condition is the residential shower arm and standard (2.5 gpm) showerhead without a temperature sensitive restrictor valve installed.

7.3.1.3 High-Efficiency Condition

The high-efficiency condition is a temperature sensitive restrictor valve installed on a residential showerarm and showerhead with either a standard (2.5 gpm) or low-flow (2.0, 1.75, or 1.5 gpm) showerhead. If this measure is installed in conjunction with a low-flow showerhead, refer to the Low-Flow Showerheads measure and claim additional savings as outlined in that measure.

7.3.2 Energy and Demand Savings Methodology

7.3.2.1 Savings Algorithms and Input Variables

To determine gallons of behavioral waste (defined as hot water that goes down the drain before the user enters the shower) per year, the following formula was used:

$$\boldsymbol{Annual\ Showerhead\ Behavioral\ Waste = SHFR \times BW \times n_S \times 365 \times \frac{n_O}{n_{SH}}}$$

Equation 7.3-1

Where:

$SHFR$ = *Showerhead flow rate, gallons per minute [gpm]; see* Table 7.3-1.

BW = *Behavioral waste, minutes per shower; see* Table 7.3-1.

n_S = *Number of showers per person per day; see* Table 7.3-1.

365 = *Constant to convert days to years.*

n_O = *Number of occupants per home; see* Table 7.3-1.

n_{SH} = *Number of showerheads per home; see* Table 7.3-1*.*

Applying the formula to the values returns the following values for baseline behavioral waste in gallons per showerhead per year:

$$\boldsymbol{Showerhead\ (2.5\ GPM): 2.5 \times\ 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72} = 713\ gal}$$

$$\boldsymbol{Showerhead\ (2.0\ GPM): 2.0 \times 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72} = 570\ gal}$$

$$\boldsymbol{Showerhead\ (1.75\ GPM): 1.75 \times 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72} = 499\ gal}$$

$$\boldsymbol{Showerhead\ (1.5\ GPM): 1.5 \times 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72} = 428\ gal}$$

Gallons of hot water saved per year can be found by multiplying the baseline behavioral waste gallons per year by the percent of hot water from Table 7.3-1.

$$\boldsymbol{Gallons\ of\ hot\ water\ saved\ per\ year =\ Annual\ Behavioral\ Waste \times HW\%}$$

Equation 7.3-2

Where:

HW% = *Hot water percentage; see* Table 7.3-1*.*

$$\boldsymbol{Gallons\ of\ hot\ water\ saved\ per\ year\ (2.5\ GPM): 713 \times\ 0.825 = 588\ gal}$$

$$\boldsymbol{Gallons\ of\ hot\ water\ saved\ per\ year\ (2.0\ GPM): 570 \times\ 0.825 = 470\ gal}$$

$$\boldsymbol{Gallons\ of\ hot\ water\ saved\ per\ year\ (1.75\ GPM): 490 \times\ 0.825 = 412\ gal}$$

$$\boldsymbol{Gallons\ of\ hot\ water\ saved\ per\ year\ (1.5\ GPM): 428 \times\ 0.825 = 353\ gal}$$

Table 7.3-1: [Showerhead TSRVs] Hot Water Usage Reduction

Description	2.5 gpm	2.0 gpm	1.75 gpm	1.5 gpm
Average behavioral waste (minutes per shower)[248]	0.783			
Showers/person/day[249]	0.6			
Occupants per home[250]	2.86			
Showerheads/home[251]	1.72			

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[248] "Disaggregating Residential Shower Warm-Up Waste," Sherman, Troy. August 2014. Derived by dividing average behavioral waste time (47 seconds) by 60 seconds.

[249] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study." Prepared for Michigan Evaluation Working Group. June 2013.

[250] Occupants per home for Texas from US Census Bureau, "Persons per household, 2014-2018." https://www.census.gov/quickfacts/TX.

[251] Showerheads per home assumed to be equal to the number of full bathrooms per home. Bathroom counts extracted from the 2015 Residential Energy Consumption Survey (RECS) Table HC2.8 Structural and geographic characteristics of homes in the West South Central region. https://www.eia.gov/consumption/residential/data/2015/#structural.

Description	2.5 gpm	2.0 gpm	1.75 gpm	1.5 gpm
Gallons behavioral waste per showerhead per year	713	570	499	428
Percent hot water[252]	80-85%, or 82.5% on average			
Gallons hot water saved per year	588	470	412	353

Energy Savings

Energy savings for this measure are calculated as follows:

$$\boldsymbol{Energy\ Savings\ per\ TRV} = \frac{\boldsymbol{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplyAverage})}}{\boldsymbol{RE \times 3,412}}$$

Equation 7.3-3

Where:

ρ = *Water density, 8.33 lbs/gallon.*

C_P = *Specific heat of water, 1 Btu/lb°F.*

V = *Gallons of hot water saved per year per showerhead; see Table 7.3-1.*

$T_{SetPoint}$ = *Average shower temperature = 120°F.*[253]

$T_{SupplyAverage}$ = *Average supply water temperature: 75.9°F.*[254]

RE = *Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters, or 0.8 for gas hot water heaters.*[255]

3,412 = *Constant to convert from Btu to kWh.*

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[252] "Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV," Sherman, Troy. Evolve Technologies. December 15, 2015.

[253] Data collection discussed in Appendix D of the Texas EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F. http://interchange.puc.texas.gov/Search/Documents?controlNumber=40891&itemNumber=19.

[254] Calculated according to the method in the Burch and Christensen 2007 paper "Towards Development of an Algorithm for Mains Water Temperature" and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base.

[255] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://cafs.ahrinet.org/gama_cafs/sdpsearch/search.jsp?table=CWH.

Demand Savings

Demand savings are calculated by substituting the average supply temperature for the average seasonal temperature, multiplying by a demand factor equivalent to the daily fraction hot water use during the weighted peak hour, and dividing by 365 days/year, with 365 canceling from the savings algorithm numerator and denominator.

$$\boldsymbol{Demand\ Savings\ per\ TRV} = \frac{\boldsymbol{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplySeasonal})}}{\boldsymbol{RE \times 3{,}412 \times 365}} \times \boldsymbol{DF}$$

Equation 7.3-4

Where:

$T_{SupplySeasonal}$ = *For NCP, use average supply water temperature, 75.9°F.*[256]*; for CP and 4CP, use Seasonal supply water temperature 85.41°F.*[257]

DF = *Demand factor for NCP, CP, or 4CP peak demand; see Table 7.3-2.*

Table 7.3-2: [Showerhead TSRVs] Peak Demand Factors[258]

Ratio Type	Demand Ratio
NCP	0.105
CP	0.038
4CP	0.040

Load Shapes

This measure uses the load profile for shower usage taken from the Department of Energy's Building America Analysis spreadsheet. The peak demand factors listed in Table 7.3-2 were derived from that load profile according to the methodologies described in Section 2.3. Those ratios represent the ratio of the NCP, CP, or 4CP peak demand savings (kW) to the annual energy savings (kWh).

7.3.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

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[256] Calculated according to the method in the Burch and Christensen 2007 paper "Towards Development of an Algorithm for Mains Water Temperature" and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base.

[257] Calculated according to the method in the Burch and Christensen 2007 paper "Towards Development of an Algorithm for Mains Water Temperature" and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base, taking the average mains temperature for June, July, August, and September.

[258] Building America Performance Analysis Procedures for Existing Homes, page 18, figure 4: combined domestic hot water use profile. https://www.nrel.gov/docs/fy06osti/38238.pdf.

7.3.2.3 Deemed Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

7.3.2.4 Additional Calculators and Tools

This section is not applicable.

7.3.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years for showerhead TSRVs, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Shrhd.[259]

7.3.3 Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- Flow rate in gallons per minute (gpm) of showerhead installed
- Water heater type (e.g., heat pump, electric resistance)
- DHW recovery efficiency (RE) or COP, if available
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of replacement unit nameplate or other pre-approved method of installation verification

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[259] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

7.4 TUB SPOUT AND SHOWERHEAD TEMPERATURE SENSITIVE RESTRICTOR VALVES

7.4.1 Measure Description

This measure consists of replacing existing tub spouts and shower heads with an automatically diverting tub spout and showerhead system with a temperature sensitive restrictor valve (TSRV) between the existing shower arm and showerhead. The tub spout will contain temperature sensitive restrictor technology that will cause the tub spout to automatically engage the anti-leak diverter once the water reaches a set temperature (generally 95˚F). The water will divert to a showerhead with a normally closed valve that will prevent the hot water from going down the drain prior to the user entering the shower, thereby eliminating behavioral waste and tub spout leakage waste.

7.4.1.1 Eligibility Criteria

These deemed savings are for tub spout and showerhead systems with temperature sensitive restrictor technology installed in new construction or as a retrofit measure in existing homes. Residences must have electrically fueled how water to be eligible for this measure.

7.4.1.2 Baseline Condition

The baseline condition is the residential tub spout with a standard diverter, and a standard (2.5 gpm) showerhead.

7.4.1.3 High-Efficiency Condition

The high-efficiency condition is an anti-leak, automatically diverting tub spout system with temperature sensitive restrictor technology installed on a residential showerarm and showerhead with a standard (2.5 gpm) or low-flow (2.0, 1.75, or 1.5 gpm) showerhead. If this measure is installed in conjunction with a low-flow showerhead, refer to the Low-Flow Showerheads measure and claim additional savings as outlined in that measure.

7.4.2 Energy and Demand Savings Methodology

7.4.2.1 Savings Algorithms and Input Variables

This system provides savings in two parts: elimination of behavioral waste (hot water that goes down the drain prior to the user entering the shower) and elimination of tub spout diverter leakage.

Part 1: To determine baseline gallons of behavioral waste per year, the following formula was used:

$$\boldsymbol{Annual\ Showerhead\ Behavioral\ Waste} = \%\boldsymbol{WUE_{SH}} \times \boldsymbol{SHFR} \times \boldsymbol{BW} \times \boldsymbol{n_S} \times \boldsymbol{365\ \frac{days}{year}} \times \boldsymbol{\frac{n_O}{n_{SH}}}$$

Equation 7.4-1

$$\boldsymbol{Annual\ Tub\ Spout\ Behavioral\ Waste} = \%\boldsymbol{WUE_{TS}} \times \boldsymbol{TSFR} \times \boldsymbol{BW} \times \boldsymbol{n_S} \times \boldsymbol{365\ \frac{days}{year}} \times \boldsymbol{\frac{n_O}{n_{SH}}}$$

Equation 7.4-2

Where:

$\%WUE_{SH}$ = *Showerhead percentage of warm-up events; see Table 7.4-1.*

$\%WUE_{TS}$ = *Tub spout percentage of warm-up events; see Table 7.4-1.*

$SHFR$ = *Showerhead flow rate, gallons per minute [gpm]; see Table 7.4-1.*

$TSFR$ = *Tub spout flow rate, gallons per minute [gpm]; see Table 7.4-1.*

BW = *Behavioral waste, minutes per shower; see Table 7.4-1.*

n_S = *Number of showers per person per day; see Table 7.4-1.*

365 = *Constant to convert days to years.*

n_O = *Number of occupants per home; see Table 7.4-1.*

n_{SH} = *Number of showerheads per home; see Table 7.4-1.*

Applying the formula to the values returns the following values:

$$\boldsymbol{Showerhead\ (1.5\ GPM): 0.6 \times \left(1.5 \times 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72}\right) = 257}$$

$$\boldsymbol{Showerhead\ (1.75\ GPM): 0.6 \times \left(1.75 \times 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72}\right) = 299}$$

$$\boldsymbol{Showerhead\ (2.0\ GPM): 0.6 \times \left(2.0 \times 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72}\right) = 342}$$

$$\boldsymbol{Showerhead\ (2.5\ GPM): 0.6 \times \left(2.5 \times 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72}\right) = 428}$$

$$\boldsymbol{Tub\ Spout\ (5.0\ GPM): 0.4 \times \left(5.0 \times 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72}\right) = 570}$$

Part 2: To determine baseline gallons of diverter leakage per year, the following formula was used:

$$\boldsymbol{Annual\ Diverter\ Waste = DLR \times t_S \times n_S \times 365\ \frac{days}{year} \times \frac{n_O}{n_{SH}}}$$

Equation 7.4-3

Where:

DLR = *Diverter leakage rate [gpm]; see* Table 7.4-1.

t_S = *Shower time [min/shower]; see* Table 7.4-1.

Applying the formula to the values returns the following values:

$$\boldsymbol{Diverter\ (0.8\ GPM)\text{: } 0.8 \times 7.8 \times 0.6 \times 365 \times \frac{2.86}{1.72} = 2,272}$$

Part 3: To determine gallons of water saved per year can be found by multiplying the total waste by the percent of hot water from Table 7.4-1.

$$\boldsymbol{Gallons\ of\ hot\ water\ saved = (SHBW + TSBW) \times HW\%_{SH,TS} + DW \times HW\%_{D}}$$

Equation 7.4-4

Where:

SHBW = *Showerhead behavioral waste [gal].*

$TSBW$ = *Tub spout behavioral waste [gal].*

DW = *Diverter waste [gal].*

$HW\%_{SH,TS}$ = *Showerheads and tub spout hot water percentage; see Table 7.4-1.*

$HW\%_{D}$ = *Diverter hot water percentage; see Table 7.4-1.*

Applying the formula to the values returns the following values:

$$\boldsymbol{Total\ Annual\ Waste\ (1.5\ gpm)\text{: } (257 + 570) \times 0.825 + 2,272 \times 0.737 = 2,357}$$

$$\boldsymbol{Total\ Annual\ Waste\ (1.75\ gpm)\text{: } (299 + 570) \times 0.825 + 2,272 \times 0.737 = 2,392}$$

$$\boldsymbol{Total\ Annual\ Waste\ (2.0\ gpm)\text{: } (342 + 570) \times 0.825 + 2,272 \times 0.737 = 2,427}$$

$$\boldsymbol{Total\ Annual\ Waste\ (2.5\ gpm)\text{: } (428 + 570) \times 0.825 + 2,272 \times 0.737 = 2,498}$$

Table 7.4-1: [Showerhead + Tub Spout TSRVs] Hot Water Usage Reduction

Description	Part 1 – Behavioral Waste		Part 2 – Diverter Leakage	Part 3 – Total
	Showerhead Warm-up	Tub spout Warm-up		
Baseline showerhead flow rate (gpm)	1.5, 1.75, 2.0, or 2.5	N/A		
Tub spout flow rate (gpm)[260]	N/A	5.0	N/A	
Percent of warm up events[261]	60%	40%	N/A	

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[260] Assumption from (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

[261] Percent of warm up events from (Sherman 2014) Disaggregating Residential Shower Warm-Up Waste (Appendix B, Question 8).

Description	Part 1 – Behavioral Waste		Part 2 – Diverter Leakage	Part 3 – Total
	Showerhead Warm-up	Tub spout Warm-up		
Average behavioral waste (minutes per shower)[262]	0.783		N/A	
Average diverter leakage rate (gpm)[263]	N/A		0.80	N/A
Average shower time (minutes)[264]	N/A		7.8	N/A
Showers/person/day[265]	0.6			
Occupants per home[266]	2.86			
Showerheads per home[267]	1.72			
Gallons behavioral waste per tub spout/showerhead per year (1.5 gpm)	257	570	2,272	3,099
Gallons behavioral waste per tub spout/showerhead per year (1.75 gpm)	299			3,142
Gallons behavioral waste per tub spout/showerhead per year (2.0 gpm)	342			3,185
Gallons behavioral waste per tub spout/showerhead per year (2.5 gpm)	428			3,270
Percent hot water[268]	80-85%, or 82.5% average		73.7%	N/A
Gallons hot water saved per year (1.5 gpm)	N/A			2,357
Gallons hot water saved per year (1.75 gpm)	N/A			2,392
Gallons hot water saved per year (2.0 gpm)	N/A			2,427
Gallons hot water saved per year (2.5 gpm)	N/A			2,498

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[262] "Disaggregating Residential Shower Warm-Up Waste," Sherman, Troy. August 2014. Derived by dividing average behavioral waste time (47 seconds) by 60 seconds.

[263] Average diverter leak rate from (Taitem 2011) Taitem Tech Tip – Leaking Shower Diverters.

[264] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study." Prepared for Michigan Evaluation Working Group.

[265] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study." Prepared for Michigan Evaluation Working Group. June 2013.

[266] Occupants per home for Texas from US Census Bureau, "Persons per household, 2014-2018." https://www.census.gov/quickfacts/TX.

[267] Showerheads per home assumed to be equal to the number of full bathrooms per home. Bathroom counts extracted from the 2015 Residential Energy Consumption Survey (RECS) Table HC2.8 Structural and geographic characteristics of homes in the West South-Central region. https://www.eia.gov/consumption/residential/data/2015/#structural.

[268] "Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV." Sherman, Troy. Evolve Technologies. December 15, 2015.

Energy Savings

Energy savings for this measure are calculated as follows:

$$\boldsymbol{Energy\ Savings\ per\ TS\ System} = \frac{\boldsymbol{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplyAverage})}}{\boldsymbol{RE \times 3,412}}$$

Equation 7.4-5

Where:

ρ = *Water density, 8.33 lbs/gallon.*

C_P = *Specific heat of water, 1 Btu/lb°F.*

V = *Gallons of hot water saved per year per showerhead; see Table 7.4-1.*

$T_{SetPoint}$ = *Average shower temperature = 101°F .*[269]

T_{Supply} = *Average supply water temperature: 75.9°F.*[270]

RE = *Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters, or 0.8 for gas hot water heaters.* [271]

3,412 = *Constant to convert from Btu to kWh.*

Demand Savings

Demand savings are calculated by substituting the average supply temperature for the average seasonal temperature, multiplying by a demand factor equivalent to the daily fraction hot water use during the weighted peak hour, and dividing by 365 days/year, with 365 canceling from the savings algorithm numerator and denominator.

$$\boldsymbol{Demand\ Savings\ per\ TS\ System} = \frac{\boldsymbol{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplySeasonal})}}{\boldsymbol{RE \times 3,412 \times 365}} \times \boldsymbol{DF}$$

Equation 7.4-6

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[269] Data collection discussed in Appendix D of the Texas EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F. http://interchange.puc.texas.gov/Search/Documents?controlNumber=40891&itemNumber=19.

[270] Calculated according to the method in the Burch and Christensen 2007 paper "Towards Development of an Algorithm for Mains Water Temperature" and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base.

[271] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://cafs.ahrinet.org/gama_cafs/sdpsearch/search.jsp?table=CWH.

Where:

$T_{SupplySeasonal}$ = *For NCP, use average supply water temperature, 75.9°F.*[272]*; for CP and 4CP, use Seasonal supply water temperature 85.41°F.*[273]

DF = Demand factor for NCP, CP, or 4CP peak demand; see

Table 7.4-2.

Table 7.4-2: [Showerhead + Tub Spout TSRVs] Peak Demand Factors[274]

Ratio Type	Demand Ratio
NCP	0.105
CP	0.038
4CP	0.040

Load Shapes

This measure uses the load profile for shower usage taken from the Department of Energy's Building America Analysis spreadsheet. The peak demand factors listed in

Table 7.4-2 were derived from that load profile according to the methodologies described in Section 2.3. Those ratios represent the ratio of the NCP, CP, or 4CP peak demand savings (kW) to the annual energy savings (kWh).

7.4.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

7.4.2.3 Deemed Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

7.4.2.4 Additional Calculators and Tools

This section is not applicable.

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[272] Calculated according to the method in the Burch and Christensen 2007 paper "Towards Development of an Algorithm for Mains Water Temperature" and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base.

[273] Calculated according to the method in the Burch and Christensen 2007 paper "Towards Development of an Algorithm for Mains Water Temperature" and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base, taking the average mains temperature for June, July, August, and September.

[274] Building America Performance Analysis Procedures for Existing Homes, page 18, figure 4: combined domestic hot water use profile. https://www.nrel.gov/docs/fy06osti/38238.pdf.

7.4.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years for tub spout and showerhead TSRVs, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Shrhd.[275]

7.4.3 Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- Flow rate in gallons per minute (GPM) of showerhead installed
- Water heater type (e.g., heat pump, electric resistance)
- DHW recovery efficiency (RE) or COP, if available
- Proof of purchase with date of purchase and quantity
    - Alternative: photo of replacement unit nameplate or other pre-approved method of installation verification

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[275] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

7.5 PIPE INSULATION

7.5.1 Measure Description

This measure requires the installation of pipe insulation on un-insulated water heater pipes that are served by an electric water heater.

7.5.1.1 Eligibility Criteria

Water heaters plumbed with functioning heat traps are not eligible to receive incentives for this measure. It is recommended that the installer (or contractor) checks to see if the water heater heat trap works properly before declaring the water heater ineligible.

Water heater pipe insulation is a residential retrofit measure. New construction and retrofits involving the installation of new water heaters are not eligible for this measure, because they must meet current code requirements. To be awarded these deemed savings, the fuel type of the water heater must be electricity.

7.5.1.2 Baseline Condition

The baseline is assumed to be a typical electric water heater with no functioning heat traps and no insulation on water heater pipes.

Table 7.5-1: [Pipe Insulation] Baseline Standard

Baseline
Un-insulated hot water pipes

7.5.1.3 High-Efficiency Condition

The efficiency standard requires an insulation thickness R-3.[276]

Table 7.5-2: [Pipe Insulation] Efficiency Standard

Efficiency Standard
Minimum insulation of R-3

All visible hot water piping must be insulated. Savings are based on a maximum allowable insulation length of 6 feet of piping.

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[276] According to the International Residential Code (IRC) 2018 section N1103.4: Mechanical system piping requires R-3 insulation.

7.5.2 Energy and Demand Savings Methodology

7.5.2.1 Savings Algorithms and Input Variables

Energy Savings

Hot water pipe insulation energy savings are calculated using the following formula:

$$\boldsymbol{Energy\ savings\ per\ year} = \left(\boldsymbol{U_{pre}} - \boldsymbol{U_{post}}\right) \times \boldsymbol{A} \times \left(\boldsymbol{T_{pipe}} - \boldsymbol{T_{ambient\ annual}}\right) \times \left(\frac{\mathbf{1}}{\boldsymbol{RE}}\right) \times \frac{\mathbf{8,760}}{\mathbf{3,412}}$$

Equation 7.5-1

Where:

U_{pre} = $\frac{1}{2.03} = 0.49 Btu/hr\ sq.ft.°F.$[277]

U_{post} = $\frac{1}{2.03+R_{Insulation}} Btu/hr\ sq.ft.°F.$

$R_{insulation}$ = *R-value of installed insulation.*

A = *Pipe surface area insulated in square feet* (πDL) *with L (length) and D (pipe diameter) in feet. The maximum length allowable for insulation is 6 feet. If the pipe area is unknown, use the following table.*

Table 7.5-3: [Pipe Insulation] Estimated Pipe Surface Area

Nominal Pipe Diameter (inches)	Outside Diameter (inches)	Pipe Surface Area (square feet)[278]
0.5	0.625	0.16 x required input "Pipe Length insulated (feet)"
0.75	0.875	0.23 x required input "Pipe Length insulated (feet)"
1.0	1.125	0.29 x required input "Pipe Length insulated (feet)"

T_{pipe} = *Water temperature in pipe [°F]. Use 120°F.*[279]

$T_{ambient\ annual}$ = *Ambient annual temperature [°F]. Use 78.3°F*[280] *for water heaters located in unconditioned space; 72.7°F*[281] *for water heaters located in conditioned space.*

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[277] 2.03 is the R-value representing the film coefficients between water and the inside of the pipe, and between the surface and air. Mark's Standard Handbook for Mechanical Engineers, 8th edition.

[278] Factors used in the calculation for pipe area were determined by using the outside diameter of the pipe in inches, converting it to feet, and multiplying by π.

[279] Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), supports a default value of 120°F. http://interchange.puc.texas.gov/Search/Documents?controlNumber=40891&itemNumber=19.

[280] Average ambient temperatures were taken from TMY3 data, with a 7°F increase in winter and an 11°F increase in summer based on ASHRAE 152 Heating System & Cooling System Location Temperatures (Garage).

[281] Weighted average reported thermostat setpoints from RECS. Times associated with these setpoints are assumed to be the same as those assumed by ENERGY STAR: http://www.energystar.gov/index.cfm?c=thermostats.pr_thermostats_guidelines.

RE = *Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters.*[282]

8,760 = *Total hours per year.*

3,412 = *Constant to convert from Btu to kWh.*

Demand Savings

$$\textbf{\textit{Pipe Insulation Demand Savings}}\ (\boldsymbol{kW}) = \left(\boldsymbol{U_{pre}} - \boldsymbol{U_{post}}\right) \times \boldsymbol{A} \times (\boldsymbol{T_{Pipe}} - \boldsymbol{T_{ambient}}) \times \left(\frac{\mathbf{1}}{\boldsymbol{RE}}\right) \times \frac{\boldsymbol{DF}}{\mathbf{3,412}}$$

Equation 7.5-2

Where:

$T_{ambient}$ = *For NCP, use annual ambient temperature, 78.3°F*[283] *for water heaters located in unconditioned space and 72.7°F*[284] *for water heaters located in conditioned space; for CP and 4CP, use seasonal ambient temperature, 86.04°F.*[285]

DF = *Demand factor for NCP, CP, or 4CP peak demand = 1.*[286]

Load Shapes

The load shape for this measure is assumed to be distributed evenly across all hours of the year.

7.5.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

7.5.2.3 Deemed Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

7.5.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

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[282] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database. https://www.ahridirectory.org/.

[283] Average ambient temperatures were taken from TMY3 data, with a 7°F increase in winter and an 11°F increase in summer based on ASHRAE 152 Heating System & Cooling System Location Temperatures (Garage).

[284] Weighted average reported thermostat setpoints from RECS. Times associated with these setpoints are assumed to be the same as those assumed by ENERGY STAR: http://www.energystar.gov/index.cfm?c=thermostats.pr_thermostats_guidelines.

[285] Calculated according to the method in the Burch and Christensen 2007 paper “Towards Development of an Algorithm for Mains Water Temperature” and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base, taking the average mains temperature for June, July, and August.

[286] Demand factor of 1 assumes a constant tank and near tank piping temperature is maintained across all hours of the year.

7.5.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 13 years for water heater pipe insulation, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-PipeIns-Elec.[287]

7.5.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- R-value of the installed insulation
- Recovery Efficiency (RE) or COP, if available
- Pipe length insulated (feet)
- Pipe surface area insulated in square feet (at least the pipe diameter in inches)

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[287] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

7.6 WATER HEATER TANK INSULATION

7.6.1 Measure Description

This measure requires the installation of tank insulation on un-insulated water heater tanks that are served by an electric water heater.

7.6.1.1 Eligibility Criteria

Water heaters meeting the National Appliance Energy Conservation Act standards with respect to insulation and standby loss requirements are not eligible for this measure. To ensure compliance, the contractor shall inspect the build date listed on the existing water heater label and verify that the listed build date is before 1991.

Water heater tank insulation is a residential retrofit measure. New construction and water heater replacements are not eligible for this measure, because they must meet current code requirements. To be awarded these deemed savings, the fuel type of the water heater must be electricity.

7.6.1.2 Baseline Condition

The baseline is assumed to be a typical electric water heater with no insulation.

7.6.1.3 High-Efficiency Condition

There is no minimum insulation requirement. Manufacturer's instructions on the water heater jacket and the water heater itself should be followed. Thermostat and heating element access panels must be left uncovered.

7.6.2 Energy and Demand Savings Methodology

7.6.2.1 Savings Algorithms and Input Variables

Energy Savings

Hot water tank insulation energy savings are calculated by using the following formula:

$$\boldsymbol{Energy\ savings\ per\ year = (U_{pre} - U_{post}) \times A \times (T_{tank} - T_{ambient\ annual}) \times \left(\frac{1}{RE}\right) \times \frac{8,760}{3,412}}$$

Equation 7.6-1

Where:

U_{pre} = 1/5 Btu/hr sq.ft. °F.[288]

U_{post} = $1/(5+R_{insulation})$ Btu/hr sq.ft. °F.

$R_{insulation}$ = R-value of installed insulation.

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[288] Baseline storage tank assembly is assumed to have thermal performance of R5.

A = *Tank surface area insulated in square feet* (πDL) *with L (length) and D (tank diameter) in feet. If the tank area is not known, use Table 7.6-1.*

Table 7.6-1: [DHW Insulation] Estimated Tank Area[289]

Volume (gal)	A (sf.)
30	17.45
40	21.81
50	22.63
60	26.94
80	30.36
120	38.73

T_{tank} = *Average temperature of the tank, default use 120°F.*[290]

$T_{ambient\ annual}$ = *Ambient annual temperature [°F]. Use 78.3°F*[291] *for water heaters located in unconditioned space; 72.7°F*[292] *for water heaters located in conditioned space.*

RE = *Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters.*[293]

8,760 = *Total hours per year.*

3,412 = *Constant to convert from kilo-watt hours to Btu.*

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[289] Tank area was obtained from a survey of electric water heater manufacturer data from A.O. Smith and Whirlpool conducted in 2013. Dimensions for each tank size were collected and averaged to determine typical square footage of each size water heater.

[290] Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Texas PUC Project Number 40891 (August 2015), supports a default value of 120°F. http://interchange.puc.texas.gov/Search/Documents?controlNumber=40891&itemNumber=19.

[291] Average ambient temperatures were taken from TMY3 data for Kelly AFB, with a 7°F increase in winter and an 11°F increase in summer based on ASHRAE 152 Heating System & Cooling System Location Temperatures (Garage).

[292] Weighted average reported thermostat setpoints from RECS. Times associated with these setpoints are assumed to be the same as those assumed by ENERGY STAR: http://www.energystar.gov/index.cfm?c=thermostats.pr_thermostats_guidelines.

[293] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database. https://www.ahridirectory.org/.

Demand Savings

$$Tank\ Insulation\ Demand\ Savings\ (kW) = (U_{pre} - U_{post}) \times A \times (T_{Tank} - T_{ambient\ seasonal}) \times \frac{1}{RE} \times \frac{DF}{3,412}$$

Equation 7.6-2

Where:

$T_{ambient\ seasonal}$ = *For NCP, use annual ambient temperature, 78.3°F[294] for water heaters located in unconditioned space and 72.7°F[295] for water heaters located in conditioned space; for CP and 4CP, use seasonal ambient temperature 86.04°F.[296]*

DF = *Demand factor for NCP, CP, or 4CP peak demand = 1.[297]*

Load Shapes

The load shape for this measure is assumed to be distributed evenly across all hours of the year.

7.6.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

7.6.2.3 Deemed Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

7.6.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

7.6.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 7 years for water heater tank insulation, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-TankIns-Elec.[298]

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[294] Average ambient temperatures were taken from TMY3 data, with a 7°F increase in winter and an 11°F increase in summer based on ASHRAE 152 Heating System & Cooling System Location Temperatures (Garage).

[295] Weighted average reported thermostat setpoints from RECS. Times associated with these setpoints are assumed to be the same as those assumed by ENERGY STAR: http://www.energystar.gov/index.cfm?c=thermostats.pr_thermostats_guidelines.

[296] Calculated according to the method in the Burch and Christensen 2007 paper "Towards Development of an Algorithm for Mains Water Temperature" and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base, taking the average mains temperature for June, July, and August.

[297] Demand factor of 1 assumes a constant tank and near tank piping temperature is maintained across all hours of the year.

[298] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

7.6.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Recovery Efficiency (RE) or COP, if available
- R-value of the installed insulation
- Tank surface area insulated in square feet (πDL) with L (length) and D (tank diameter) in feet; if unable to determine tank area, tank volume must be recorded
- Water heater manufacture date

7.7 ELECTRIC TANKLESS WATER HEATER REPLACEMENTS

7.7.1 Measure Description

This measure involves installing a new electric tankless water heater in place of an electric storage water heater.

7.7.1.1 Eligibility Criteria

This measure involves installing an electric tankless water heater in place of an electric storage water heater which meets all the additional requirements described below. Heat Pump Water Heaters (HPWHs) are not eligible for installation through this measure (see separate ENERGY STAR® Heat Pump Water Heaters measure). Electric tankless water heaters may only replace systems with tanks less than 55 gallons. For the installation of an electric water heater with a tank size greater than 55 gallons, please refer to the ENERGY STAR® Heat Pump Water Heaters measure.

These deemed savings are for water heater replacements installed as a replace-on-burnout, new construction, or early retirement measure. However, savings are calculated under the assumption of replace-on-burnout or new construction. Savings may be awarded for installations in newly constructed homes where customer and utility representatives provide written indication that an electric storage water heater would otherwise have been installed, along with relevant design documentation showing an electric storage water heater.

7.7.1.2 Baseline Condition

This measure applies to replace-on-burnout, early retirement, and new construction.

The baseline condition is an electric storage water heater with baseline efficiency determined by tank size according to the federal energy efficiency standards for residential water heaters as published in 10 CFR Part 430.32 of the Federal Register.[299]

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[299] 10 CFR Part 430.32 Energy and water conservation standards and their effective dates. Available online: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32.

Table 7.7-1: [Electric Tankless DHW Replacements] Federal Standard for Residential Electric Storage Water Heaters

Rated Storage Volume	Draw Pattern	First Hour Rating (FHR)[300,301]	Uniform Energy Factor (UEF)[302]
≥ 20 gal and ≤ 55 gal	Very small	0 ≤ FHR < 18	0.8808 – (0.0008 × Vr)
	Low	18 ≤ FHR < 51	0.9254 – (0.0003 × Vr)
	Medium	51 ≤ FHR < 75	0.9307 – (0.0002 × Vr)
	High	75 ≤ FHR	0.9349 – (0.0001 × Vr)
> 55 gal and ≤ 120 gal	Very small	0 ≤ FHR < 18	1.9236 – (0.0011 × Vr)
	Low	18 ≤ FHR < 51	2.0440 – (0.0011 × Vr)
	Medium	51 ≤ FHR < 75	2.1171 – (0.0011 × V_r)
	High	75 ≤ FHR	2.2418 – (0.0011 × V_r)

The new DOE efficiency standard effectively requires HPWHs (assuming electric water heating) for electric storage water heaters with tank size greater than 55 gallons. As such, electric water heaters with tanks greater than 55 gallons are not eligible for this measure. Instead, see the Heat Pump Water Heater measure. For smaller systems, the baseline technology remains an electric storage water heater with electric resistance as the primary heat source.

7.7.1.3 High-Efficiency Condition

The new unit must meet or exceed the following federal minimum energy factor from Table 7.7-2. Water heaters must be installed in accordance with local code requirements.

Table 7.7-2: [Electric Tankless DHW Replacements] Efficiency Standards for Electric Tankless DHW[303]

Rated Storage Volume	Draw Pattern	First Hour Rating (FHR)	Uniform Energy Factor (UEF)
< 2 gal	Very small	0 ≤ FHR < 18	0.91
	Low	18 ≤ FHR < 51	0.91
	Medium	51 ≤ FHR < 75	0.91
	High	75 ≤ FHR	0.92

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[300] "The Revised Method of Test for Residential Water Heating and Its Impact on Incentive Programs" presentation, Glanville, Paul. ACEEE Hot Water Forum. February 24, 2015. https://aceee.org/sites/default/files/pdf/conferences/hwf/2015/6B-Glanville.pdf.

[301] Assume FHR equal to that of installed water heater.

[302] V_r is the Rated Storage Volume (in gallons), as determined pursuant to 10 CFR 429.17.

[303] 10 CFR Part 430.32 Energy and water conservation standards. Available online: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32.

7.7.2 Energy and Demand Savings Methodology

7.7.2.1 Savings Algorithms and Input Variables

All deemed savings values are calculated using the following standard algorithms for water heating. These algorithms assume a replace-on-burnout or new construction scenario but may be used to award savings for early retirement projects.

Energy Savings

$$kWh_{savings} = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,annual}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}}\right)}{3,412}$$

Equation 7.7-1

Where:

ρ = *Water density = 8.33 lbs/gallons.*

C_p = *Specific heat of water = 1 Btu/lb·°F.*

GPY = *Estimated annual hot water use in gallons/year, specified by number of bedrooms in the home; see Table 7.7-3.*

Table 7.7-3: [Electric Tankless DHW Replacements] Water Heater Consumption (gal/year)[304]

Number of Bedrooms			
1	2	3	4
13,924	17,018	20,112	23,206

$T_{SetPoint}$ = *Water heater set point = 120°F.*[305]

$T_{Supply,ann}$ = *Average supply water temperature = 75.9°F.*[306]

UEF_{pre} = *Baseline uniform energy factor Table 7.7-1.*[307]

UEF_{post} = *Uniform energy factor of new water heater (must exceed values from Table 7.7-2).*

3,412 = *Constant to convert from Btu to kWh.*

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[304] Building America Research Benchmark Definition. December 2009. Available online: http://www.nrel.gov/docs/fy10osti/47246.pdf.

[305] The data collection discussed in Appendix D of the Texas EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015) supports a default value of 120°F. http://interchange.puc.texas.gov/Search/Documents?controlNumber=40891&itemNumber=19.

[306] Calculated according to the method in the Burch and Christensen 2007 paper "Towards Development of an Algorithm for Mains Water Temperature" and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base.

[307] Note that for efficient water heater installations in residential new construction, the baseline energy factor is the efficiency of the electric storage water heater that would otherwise have been installed, according to appropriate design documentation.

Demand Savings

$$kW_{savings,summer} = DF \times \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,summer}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}}\right)}{365 \times 3{,}412}$$

Equation 7.7-2

Where:

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 7.7-4.*

$T_{Supply,sum}$ = *For NCP, use average supply water temperature, 75.9°F*[308]*; for CP and 4CP, use Seasonal supply water temperature 85.41°F.*[309]

Table 7.7-4: [Electric Tankless DHW Replacements] Peak Demand Factors[310]

Ratio Type	Demand Ratio
NCP	0.105
CP	0.038
4CP	0.040

Load Shapes

This measure uses the load profile for shower usage taken from the Department of Energy's Building America Analysis spreadsheet. The peak demand factors were derived from that load profile according to the methodologies described in Section 2.3. Those ratios represent the ratio of the NCP, CP, or 4CP peak demand savings (kW) to the annual energy savings (kWh).

7.7.2.2 Deemed Energy Savings Tables

There are no deemed energy savings tables for this measure. Please see the algorithms above.

7.7.2.3 Deemed Demand Savings Tables

There are no deemed demand savings tables for this measure. Please see the algorithms above.

7.7.2.4 Additional Calculators and Tools

There are no additional calculators or tools for this measure.

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[308] Calculated according to the method in the Burch and Christensen 2007 paper "Towards Development of an Algorithm for Mains Water Temperature" and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base.

[309] Calculated according to the method in the Burch and Christensen 2007 paper "Towards Development of an Algorithm for Mains Water Temperature" and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base, taking the average mains temperature for June, July, August, and September.

[310] Building America Performance Analysis Procedures for Existing Homes, page 18, figure 4: combined domestic hot water use profile. https://www.nrel.gov/docs/fy06osti/38238.pdf.

7.7.2.5 Measure Life and Lifetime Savings

The EUL is 20 years for tankless water heaters, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-Instant-Res.[311]

7.7.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Volume of the existing water heater (gallons)
- Uniform energy factor of the replacement water heater
- First Hour Rating of the replacement water heater (gal/hr)
- Number of bedrooms
- Form signed by customer and utility representative indicating planned electric storage water heater installation (new construction only)
- Design documents indicating planned electric storage water heater installation (new construction only)
- Proof of purchase with date of purchase and quantity
    - Alternative: photo of replacement unit nameplate or other pre-approved method of installation verification

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[311] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

7.8 ENERGY STAR® HEAT PUMP WATER HEATERS

7.8.1 Measure Description

The residential heat pump water heater (HPWH) measure involves the installation of an integrated or "drop-in" ENERGY STAR HPWH. Deemed savings values are presented on a per-unit basis. Deemed savings variables include storage tank volume, first hour rating, and HPWH installation location (in conditioned or unconditioned space). In addition, this measure accounts for the interactive air conditioning energy savings and heating penalty associated with the HPWH when installed inside conditioned space.[312]

7.8.1.1 Eligibility Criteria

This measure applies to residential, electric, storage-type heat pump water heaters. Heat pump add-ons to existing storage water heaters are ineligible. The measure does not apply to the replacement of gas water heaters.

7.8.1.2 Baseline Condition

The baseline condition is an electric storage water heater (EWH) with baseline efficiency (Uniform Energy Factor – UEF) determined by tank size and draw pattern – a proxy for first hour rating – based on the amended federal energy efficiency standards for residential water heaters with tank sizes 20–120 gallons, as published in 10 CFR Part 430.32 of the Federal Register.[313]

This baseline applies to replace-on-burnout and new construction applications. No additional savings are awarded for early retirement at this time. Early retirement projects should calculate savings using an assumed replace-on-burnout baseline.

Table 7.8-1: [HPWHs] Federal Standard for Residential Water Heaters

Rated Storage Volume	Draw Pattern	First Hour Rating (FHR)	Uniform Energy Factor[314]
≥ 20 gal and ≤ 55 gal	Very Small Usage	$0 \le FHR < 18$	$0.8808 - (0.0008 \times Vr)$
	Low Usage	$18 \le FHR < 51$	$0.9254 - (0.0003 \times Vr)$
	Medium Usage	$51 \le FHR < 75$	$0.9307 - (0.0002 \times Vr)$
	High Usage	$75 \le FHR$	$0.9349 - (0.0001 \times Vr)$

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[312] Interaction with space heating equipment only affects deemed savings for units below 55 gallons. This is because the measure assumes replace-on-burnout and because the latest manufacturer standards effectively require heat pump water heaters (assuming electric water heating) for residential units with storage tank size greater than 55 gallons. For these units any interaction with the space conditioning systems is essentially the same for base and change case systems, so they cancel each other out.

[313] 10 CFR Part 430.32 Energy and water conservation standards and their effective dates. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32.

[314] Vr is the Rated Storage Volume (in gallons), as determined pursuant to 10 CFR 429.17.

Rated Storage Volume	Draw Pattern	First Hour Rating (FHR)	Uniform Energy Factor[314]
> 55 gal and ≤ 120 gal	Very Small Usage	0 ≤ FHR < 18	1.9236 – (0.0011 × Vr)
	Low Usage	18 ≤ FHR < 51	2.0440 – (0.0011 × Vr)
	Medium Usage	51 ≤ FHR < 75	2.1171 – (0.0011 × Vr)
	High Usage	75 ≤ FHR	2.2418 – (0.0011 × Vr)

Because 98% of all certified ENERGY STAR water heaters are in the medium and high usage categories, the *very small usage* and *low usage* draw pattern categories are not included in this measure. Discarding these draw patterns and applying average tank volumes within four strata of storage tank sizes, application of this equation provides the following baseline efficiency levels for residential electric storage water heaters.

Table 7.8-2: [HPWHs] Minimum Required Uniform Energy Factors

Usage Rate	Tank Size (Gallons)			
	45	65	75	82
Medium Usage	0.922	2.046	2.035	N/A
High Usage	N/A	2.170	2.159	2.152

The new DOE efficiency standard effectively requires heat pump water heaters (assuming electric water heating) for storage water heaters with tank size greater than 55 gallons. As such, the baseline technology for water heaters with tanks greater than 55 gallons is a heat pump water heater. For smaller systems, the baseline technology remains an electric storage water heater with electric resistance as the primary heat source.

7.8.1.3 High-Efficiency Condition

The efficient condition is a heat pump water heater certified by ENERGY STAR with Uniform Energy Factor (UEF) greater than 2.3.[315] A complete list of certified ENERGY STAR heat pump water heaters can be accessed via the ENERGY STAR program website.[316]

Heat pump water heaters depend on adequate ventilation for proper functioning, including adequate space for both inlet and outlet air flow, and should be installed in spaces in which temperature does not

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[315] ENERGY STAR Requirements (as of April 2015): HPWH must have nominal input of 75,000 BTU/h or less, a maximum current rating of 24 amperes, voltage no greater than 250 volts, and a transfer of thermal energy from one temperature to a higher temperature level for the purpose of heating water. Unit must have "integrated" or "drop-in" configuration. EF ≥ 2.0 for units ≤ 55 gal, EF ≥ 2.20 for units > 55 gal, first-hour rating (FHR) ≥ 50 gallons/hour, Warranty ≥ 6 years on sealed systems, Safety UL 174 and UL 1995. https://www.energystar.gov/products/water_heaters/residential_water_heaters_key_product_criteria.

[316] ENERGY STAR Certified Water Heaters qualified product listing. https://www.energystar.gov/productfinder/product/certified-water-heaters/results.

drop below a certain level. The Department of Energy recommends installation in locations that remain above 40°F year-round and provide a minimum of 1,000 cubic feet of air space around the water heater.[317]

7.8.2 Energy and Demand Savings Methodology

7.8.2.1 Savings Algorithms and Input Variables

The following variables specify the appropriate deemed demand and energy savings values for a given project:

- HPWH tank size
- HPWH first hour rating
- HPWH installed location (Conditioned vs. Unconditioned Space)
- For HPWH installations in conditioned space, the building heating type (electric resistance, air-source heat pump, or gas furnace)

Deemed savings are estimated using a model that applies a similar algorithm to that used in the Water Heater Installations measure, based on gallons per year, temperature difference, and average efficiency (UEF) of ENERGY STAR certified systems with UEF > 2.3 by storage tank size strata and first hour rating/usage draw pattern according to the list of certified products available in August 2018.[318] Consumption in gallons per year is estimated using data from Building America Performance Analysis Procedures for Existing Homes.[319] Temperature data are based on the TMY3 dataset.[320]

Energy Savings

There are no savings algorithms available for this measure. See deemed savings tables for calculating energy and demand savings.

Demand Savings

There are no savings algorithms available for this measure. See deemed savings tables for calculating energy and demand savings.

Load Shapes

This measure uses the load profile for shower usage taken from the Department of Energy's Building America Analysis spreadsheet. The peak demand savings were derived from that load profile according to the methodologies described in Section 2.3.Deemed Energy Savings Tables

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[317] Heat Pump Water Heaters. Department of Energy, May 2012. http://energy.gov/energysaver/articles/heat-pump-water-heaters.

[318] As of August 2021, the ENERGY STAR products list includes 233 residential heat pump water heaters with UEF > 2.3.

[319] Building America Performance Analysis Procedures for Existing Homes, page 18, figure 4: combined domestic hot water use profile. https://www.nrel.gov/docs/fy06osti/38238.pdf.

[320] TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, https://maps.nrel.gov/nsrdb-viewer/. https://nsrdb.nrel.gov/data-sets/archives.html.

Deemed savings are developed for heat pump water heaters in four size ranges: less than or equal to 55 gallons, 56-69 gallons, 70-79 gallons, and 80 gallons or more. These sizes correspond to the four basic sizes of HPWHs commercially available at the time these deemed savings were developed, according to review of manufacturer data provided on the ENERGY STAR and AHRI websites. Table 7.8-3 presents the deemed energy savings for HPWHs and assumes a replace-on-burnout scenario but may be used to award savings for early retirement and new construction projects.

Table 7.8-3: [HPWHs] Deemed Annual Energy Savings

Draw Pattern	Tank Size Range	Conditioned Space			Unconditioned Space
		Gas	Electric Resistance	Heat Pump	
Medium Usage	< 55	1,858	1,411	1,664	1,692
	55-69	451	451	451	442
	70-79	456	456	456	448
	80+	N/A			
High Usage	< 55	N/A			
	55-69	496	496	496	487
	70-79	585	585	585	574
	80+	364	364	364	357

7.8.2.2 Deemed Demand Savings Tables

Table 7.8-4: [HPWHs] Deemed NCP Demand Savings

Draw Pattern	Tank Size Range	Conditioned Space			Unconditioned Space
		Gas	Electric Resistance	Heat Pump	
Medium Usage	< 55	1.19	0.9	1.06	1.08
	55-69	0.29	0.29	0.29	0.28
	70-79	0.29	0.29	0.29	0.29
	80+	N/A			
High Usage	< 55	N/A			
	55-69	0.32	0.32	0.32	0.31
	70-79	0.37	0.37	0.37	0.37
	80+	0.23	0.23	0.23	0.23

Table 7.8-5: [HPWHs] Deemed CP Demand Savings

Draw Pattern	Tank Size Range	Conditioned Space			Unconditioned Space
		Gas	Electric Resistance	Heat Pump	
Medium Usage	< 55	0.26	0.2	0.23	0.23
	55-69	0.06	0.06	0.06	0.06
	70-79	0.06	0.06	0.06	0.06
	80+	N/A			
High Usage	< 55	N/A			
	55-69	0.07	0.07	0.07	0.07
	70-79	0.08	0.08	0.08	0.08
	80+	0.05	0.05	0.05	0.05

Table 7.8-6: [HPWHs] Deemed 4CP Demand Savings

Draw Pattern	Tank Size Range	Conditioned Space			Unconditioned Space
		Gas	Electric Resistance	Heat Pump	
Medium Usage	< 55	0.39	0.3	0.35	0.36
	55-69	0.09	0.09	0.09	0.09
	70-79	0.10	0.10	0.10	0.09
	80+	N/A			
High Usage	< 55	N/A			
	55-69	0.10	0.10	0.10	0.10
	70-79	0.12	0.12	0.12	0.12
	80+	0.08	0.08	0.08	0.08

7.8.2.3 Additional Calculators and Tools

There are no additional calculators or tools for this measure.

7.8.2.4 Measure Life and Lifetime Savings

The Estimated Useful Life is 13 years for HPWHs.[321]

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[321] 2010 ACEEE Summer Study on Energy Efficiency in Buildings, LBNL, “Heat Pump Water Heaters and American Homes: A Good Fit?” p 9-74. https://www.aceee.org/files/proceedings/2010/data/papers/2205.pdf.

7.8.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Approximate volume of the replacement heat pump water heater tank in gallons
- Baseline uniform energy factor (UEF)
- UEF of the replacement water heater
- First hour rating (FHR) of the replacement water heater
- Replaced water heater type (e.g., heat pump, electric resistance)
- Installed location (conditioned vs. unconditioned space)
- For heat pump water heater installations in conditioned space, the building heating type (electric resistance, air-source heat pump, or gas furnace)
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of replacement unit nameplate or other pre-approved method of installation verification

7.9 SOLAR WATER HEATERS

7.9.1 Measure Description

This measure involves installing a new solar water heater in place of an electric storage water heater. Solar water heating deemed savings values are calculated based on the Solar Rating and Certification Corporation's (SRCC) test for solar water heaters (test OG-300).

7.9.1.1 Eligibility Criteria

These deemed savings are for solar water heaters installed as a replace-on-burnout measure or as an early retirement measure in existing homes and in new construction homes. However, savings are calculated under the assumption of replace-on-burnout.

7.9.1.2 Baseline Condition

The baseline condition is an electric storage water heater with baseline efficiency determined by tank size according to the amended federal energy efficiency standards for residential water heaters with tank sizes from 20 to 120 gallons, which took effect April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register; see Table 7.9-1. This baseline applies to replace-on-burnout, early retirement, and new construction applications.

Table 7.9-1: [Solar Water Heaters] Federal Standard for Residential Electric Storage Water Heaters

Rated storage volume	Draw pattern	First hour rating (FHR)[322,323]	Uniform energy factor (UEF)[324]
≥ 20 gal and ≤ 55 gal	Very Small Usage	$0 \leq FHR < 18$	$0.8808 - (0.0008 \times V_r)$
	Low Usage	$18 \leq FHR < 51$	$0.9254 - (0.0003 \times V_r)$
	Medium Usage	$51 \leq FHR < 75$	$0.9307 - (0.0002 \times V_r)$
	High Usage	$75 \leq FHR$	$0.9349 - (0.0001 \times V_r)$
> 55 gal and ≤ 120 gal	Very Small Usage	$0 \leq FHR < 18$	$1.9236 - (0.0011 \times V_r)$
	Low Usage	$18 \leq FHR < 51$	$2.0440 - (0.0011 \times V_r)$
	Medium Usage	$51 \leq FHR < 75$	$2.1171 - (0.0011 \times V_r)$
	High Usage	$75 \leq FHR$	$2.2418 - (0.0011 \times V_r)$

7.9.1.3 High-Efficiency Condition

Only solar water heaters meeting the SRCC OG-300 standard (based on tank size and final Solar Energy Factor-SEF) qualify for these deemed savings estimates.

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[322] "The Revised Method of Test for Residential Water Heating and Its Impact on Incentive Programs" presentation, Glanville, Paul. ACEEE Hot Water Forum. February 24, 2015. https://aceee.org/sites/default/files/pdf/conferences/hwf/2015/6B-Glanville.pdf.

[323] Assume FHR equal to that of installed water heater.

[324] Vr is the Rated Storage Volume (in gallons), as determined pursuant to 10 CFR 429.17.

7.9.2 Energy and Demand Savings Methodology

Solar water heating savings values are on a per-unit basis. Deemed savings variables include tank volume and installed unit solar energy factor (SEF) as rated in the Solar Rating and Certification Corporation (SRCC) “Summary of SRCC Certified Solar Collector and Water Heating System Ratings.” The Solar Energy Factor (SEF) is determined under SRCC's Operating Guideline 300, "Operating Guidelines and Minimum Standards for Certifying Solar Water Heating Systems" and was developed to compare solar water heating systems with conventional water heating systems rated with an Energy Factor (EF) and listed in the Gas Appliance Manufacturers Association Directory of Certified Water Heating Products.

Both EF and SEF are based on the same environmental and hot water use conditions used in the DOE Test Procedures for Water Heaters. The only significant difference is that the DOE test does not specify solar radiation. So SRCC uses a 1500 Btu/sq.ft./day solar radiation profile—a value typical of Sunbelt states (note - the annual average solar radiation for Dallas is 1533 Btu/sq.ft./day. (Information on the SRCC can be found at http://www.solar-rating.org/.)

All deemed savings values are calculated using the following standard algorithms for water heating. These algorithms assume a replace-on-burnout or new construction scenario but may be used to award savings for early retirement projects.

7.9.2.1 Savings Algorithms and Input Variables

Energy Savings

$$kWh_{savings} = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,annual}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{SEF_{post}}\right)}{3,412}$$

Equation 7.9-1

Where:

ρ = *Water density (= 8.33 lbs/gallons).*

Cp = *Specific heat of water (= 1 Btu/lb·°F).*

GPY = *Estimated annual hot water use in gallons/year, specified by number of bedrooms in the home; see*

Table 7.9-2.

Table 7.9-2: [Solar Water Heaters] Water Heater Consumption (Gal/Year)[325]

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[325] Building America Research Benchmark Definition. December 2009, p 13. Available online: http://www.nrel.gov/docs/fy10osti/47246.pdf.

Number of Bedrooms			
1	2	3	4
13,924	17,018	20,112	23,206

$T_{setpoint}$ = *Water heater set point = 120°F.*[326]

$T_{supply,annual}$ = *Average supply water temperature = 75.9°F.*[327]

UEF_{pre} = *Baseline uniform energy factor Table 7.9-1.*

SEF_{post} = *Solar energy factor of new water heater.*

3,412 = *Constant to convert from Btu to kWh.*

Demand Savings

$$kW_{savings} = DF \times \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,seasonal}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{SEF_{post}}\right)}{365 \times 3{,}412}$$

Equation 7.9-2

DF = Demand Factor for NCP, CP, or 4CP peak demand; see

Table 7.9-3.

$T_{Supply,sum}$ = *For NCP, use average supply water temperature, 75.9°F*[328]*; for CP and 4CP, use Seasonal supply water temperature 85.41°F.*[329]

Table 7.9-3: [Solar Water Heaters] Peak Demand Factors[330]

Ratio Type	Demand Ratio
NCP	0.105
CP	0.038
4CP	0.040

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[326] The data collection discussed in Appendix D of the Texas EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015) supports a default value of 120°F. http://interchange.puc.texas.gov/Search/Documents?controlNumber=40891&itemNumber=19.

[327] Calculated according to the method in the Burch and Christensen 2007 paper "Towards Development of an Algorithm for Mains Water Temperature" and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base.

[328] Calculated according to the method in the Burch and Christensen 2007 paper "Towards Development of an Algorithm for Mains Water Temperature" and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base.

[329] Calculated according to the method in the Burch and Christensen 2007 paper "Towards Development of an Algorithm for Mains Water Temperature" and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base, taking the average mains temperature for June, July, August, and September.

[330] Building America Performance Analysis Procedures for Existing Homes, page 18, figure 4: combined domestic hot water use profile. https://www.nrel.gov/docs/fy06osti/38238.pdf.

Load Shapes

This measure uses the load profile for shower usage taken from the Department of Energy's Building America Analysis spreadsheet. The peak demand factors were derived from that load profile according to the methodologies described in Section 2.3. Those ratios represent the ratio of the NCP, CP, or 4CP peak demand savings (kW) to the annual energy savings (kWh).

7.9.2.2 Deemed Savings Tables

There are no deemed energy savings tables for this measure. Please see the algorithms above.

7.9.2.3 Additional Calculators and Tools

There are no additional calculators or tools for this measure.

7.9.2.4 Measure Life and Lifetime Savings

The estimated useful life (EUL) of a solar water heater is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-SWH.[331]

7.9.3 Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- Number of bedrooms
- The approximate volume of the replacement water heater in gallons
- First hour rating of baseline water heater
- SRCC OG-300 Solar Energy Factor of the replacement unit
- Proof of purchase – with date of purchase and quantity
- Alternative: photo of unit installed or another pre-approved method of installation verification.

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[331] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

8. RESIDENTIAL: APPLIANCES

8.1 ENERGY STAR® CLOTHES WASHERS

8.1.1 Measure Description

This measure involves the installation of an ENERGY STAR clothes washer.

8.1.1.1 Eligibility Criteria

This measure applies to ENERGY STAR-certified clothes washers.[332]

8.1.1.2 Baseline Condition

Effective January 1, 2018, the baseline condition is the Department of Energy (DOE) minimum efficiency standard[333] for Integrated Modified Energy Factor (IMEF) and Integrated Water Factor (IWF) of top-loading clothes washers. While the DOE provides criteria for both top and front-loading washers, only the standards for top-loading washers are listed below, as a top-loading unit is assumed to be the baseline equipment. This approach is based on customers having the option to install a top-loading clothes washer. Therefore, savings are calculated using the lower top-loading baseline condition.

Table 8.1-1: [Clothes Washers] Federal Standard

Product Type	Current Criteria As of Jan 1, 2018
Top-loading, Standard (≥ 1.6 ft^3 capacity)	IMEF ≥ 1.57 IWF ≤ 6.5
Top-loading, Compact (< 1.6 ft^3 capacity)	IMEF ≥ 1.15 IWF ≤ 12.0

8.1.1.3 High-Efficiency Condition

The high efficiency condition is the ENERGY STAR Final Version 8.1 requirements for eligible clothes washers, effective February 5, 2018.[334,335]

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[332] ENERGY STAR Clothes Washers qualified product listing: https://www.energystar.gov/productfinder/product/certified-clothes-washers/results.

[333] DOE minimum efficiency standard for residential clothes washers. https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39.

[334] ENERGY STAR specification for residential clothes washers. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%208.0%20Clothes%20Washer%20Partner%20Commitments%20and%20Eligibility%20Criteria.pdf.

[335] ENERGY STAR clothes washer key product criteria: https://www.energystar.gov/products/appliances/clothes_washers/key_product_criteria.

Table 8.1-2: [Clothes Washers] ENERGY STAR Specification

Product Type	Current Criteria As of Feb 5, 2018
Residential Front-loading (> 2.5 ft^3 capacity)	IMEF ≥ 2.76 IWF ≤ 3.2
Residential Top-loading (> 2.5 ft^3 capacity)	IMEF ≥ 2.06 IWF ≤ 4.3
Residential Small or Compact (< 2.5 ft^3 capacity)	IMEF ≥ 2.07 IWF ≤ 4.2

8.1.2 Energy and Demand Savings Methodology

Savings for this measure are based on methods and input assumptions from the ENERGY STAR Appliance Savings Calculator.[336]

8.1.2.1 Savings Algorithms and Input Variables

Energy Savings

Energy savings can be derived by using the following:

$$kWh_{savings} = kWh_{basline} - kWh_{ES}$$

Equation 8.1-1

$$kWh_{baseline} = kWh_{conv,machine} + kWh_{conv,WH} + kWh_{conv,dryer} + kWh_{conv,LPM}$$

Equation 8.1-2

$$kWh_{conv,machine} = MCF \times RUEC_{conv} \times \frac{LPY}{RLPY}$$

Equation 8.1-3

$$kWh_{conv,WH} = WHCF \times RUEC_{conv} \times \frac{LPY}{RLPY}$$

Equation 8.1-4

$$kWh_{savings} = \left[\left(\frac{CAP_{conv}}{IMEF_{FS}} \times LPY\right) - \left(RUEC_{conv} \times \frac{LPY}{RLPY}\right) - kWh_{conv,LPM}\right] \times \frac{DU_{DW}}{DUF}$$

Equation 8.1-5

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[336] ENERGY STAR Appliance Savings Calculator (updated October 2016). calculators@energystar.gov.

$$kWh_{conv,LPM} = kW_{conv,LPM} \times (8,760 - LPY)$$

Equation 8.1-6

$$kWh_{ES} = kWh_{ES,machine} + kWh_{ES,WH} + kWh_{ES,dryer} + kWh_{ES,LPM}$$

Equation 8.1-7

$$kWh_{ES,machine} = MCF \times RUEC_{ES} \times \frac{LPY}{RLPY}$$

Equation 8.1-8

$$kWh_{ES,WH} = WHCF \times RUEC_{ES} \times \frac{LPY}{RLPY}$$

Equation 8.1-9

$$kWh_{savings} = \left[\left(\frac{CAP_{ES}}{IMEF_{ES}} \times LPY\right) - \left(RUEC_{ES} \times \frac{LPY}{RLPY}\right) - kWh_{ES,LPM}\right] \times \frac{DU_{DW}}{DUF}$$

Equation 8.1-10

$$kWh_{ES,LPM} = kW_{ES,LPM} \times (8,760 - LPY)$$

Equation 8.1-11

Where:

$kWh_{baseline}$ = *Federal standard baseline energy usage.*

kWh_{ES} = *ENERGY STAR average energy usage.*

$kWh_{conv,machine}$ = *Conventional machine energy usage.*

$kWh_{ES,machine}$ = *ENERGY STAR machine energy usage.*

$kWh_{conv,WH}$ = *Conventional water heater energy usage.*

$kWh_{ES,WH}$ = *ENERGY STAR water heater energy usage.*

$kWh_{conv,LPM}$ = *Conventional combined low-power mode energy usage.*

$kWh_{ES,LPM}$ = *ENERGY STAR combined low-power mode energy usage.*

$kWh_{conv,dryer}$ = *Conventional dryer energy usage.*

$kWh_{ES,dryer}$ = *ENERGY STAR dryer energy usage.*

MCF = *Machine consumption factor = 20%.*

$WHCF$ = *Water heater consumption factor = 80%.*

LPY = *Loads per year = 295.*

$RLPY$ = *Reference loads per year = 392.*

$RUEC_{conv}$ = *Conventional rated unit electricity consumption = 381 kWh/year (top-loading, standard), 163 kWh/year (top-loading, compact).*

$RUEC_{ES}$ = *ENERGY STAR rated unit electricity consumption; see Table 8.1-3.*

CAP_{conv} = *Average conventional machine capacity = 4.5 ft³ (top-loading, standard), 2.1 ft³ (top-loading, compact).*

CAP_{ES} = *Average ENERGY STAR machine capacity; see Table 8.1-3.*

$IMEF_{FS}$ = *Federal standard integrated modified energy factor; see Table 8.1-1.*

$IMEF_{ES}$ = *ENERGY STAR integrated modified energy factor; see Table 8.1-2.*

$kW_{conv,LPM}$ = *Conventional combined low-power mode wattage = 0.00115 kW (top-loading, standard), 0.00144 kW (top-loading, compact).*

$kW_{ES,LPM}$ = *ENERGY STAR combined low-power mode wattage; see Table 8.1-3.*

DU_{DW} = *Dryer usage in households with both a washer and a dryer = 95%.*

DUF = *Dryer use factor (percentage of washer loads dried in machine) = 91%.*

8,760 = *Total hours per year.*

Table 8.1-3: [Clothes Washers] ENERGY STAR Clothes Washer Characteristics

Product Type	RUEC (kWh)	Average Capacity (ft^3)	LPM Wattage (kW)
Residential Front-loading (> 2.5 ft^3 capacity)	127	4.0	0.00160
Residential Top-loading (> 2.5 ft^3 capacity)	230	4.5	0.00155
Residential Small or Compact (< 2.5 ft^3 capacity)	108	2.1	0.00144

Demand Savings

Demand savings can be derived by using the following:

$$kW_{Savings} = \frac{kWh_{savings}}{AOH} \times DF$$

Equation 8.1-12

$$AOH = LPY \times d$$

Equation 8.1-13

Where:

AOH = *Annual operating hours.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 8.1-4.*

d = *Average wash cycle duration = 1 hour.*[337,338]

Table 8.1-4: [Clothes Washers] Demand Factors[339]

Factor Type	Demand Factor
NCP	0.076
CP	0.041
4CP	0.041

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Building America House Simulation Protocols hourly and monthly profiles for residential clothes washer usage converted to a peak demand factor profile. The load shape can be found in Section 22.2 Load Shapes.

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[337] Weighted average of Consumer Reports Cycle Times for Top and Front-Loading Clothes Washers.

[338] Consumer Reports. "Top-loading washers remain more popular with Americans." April 13, 2010. Weighted average of 75 percent Top-Loading Clothes Washers and 25 percent Front-Loading Clothes Washers.

[339] Demand Factors were derived according to the method outlined in Section 2.3 using the load shape found in Section 22.2 using data from the US Department of Energy's Building America B10 Benchmark load profiles for clothes washers.

8.1.2.2 Deemed Energy Savings Tables

Table 8.1-5: [Clothes Washers] Energy Savings

Washer Type	Water Heater Fuel Type	Dryer Fuel Type	kWh Savings
Front-loading > 2.5 ft^3	Electric	Electric	428
		Gas	187
	Gas	Electric	275
		Gas	34
Top-loading > 2.5 ft^3	Electric	Electric	205
		Gas	114
	Gas	Electric	114
		Gas	23
Compact ≤ 2.5 ft^3	Electric	Electric	248
		Gas	41
	Gas	Electric	215
		Gas	8

8.1.2.3 Deemed Demand Savings Tables

Table 8.1-6: [Clothes Washers] Demand Savings

Washer Type	Water Heater Fuel Type	Dryer Fuel Type	NCP kW Savings	CP kW Savings	4CP kW Savings
Front-loading > 2.5 ft^3	Electric	Electric	0.110	0.060	0.060
		Gas	0.048	0.026	0.026
	Gas	Electric	0.071	0.038	0.038
		Gas	0.009	0.005	0.005
Top-loading > 2.5 ft^3	Electric	Electric	0.053	0.028	0.028
		Gas	0.029	0.016	0.016
	Gas	Electric	0.029	0.016	0.016
		Gas	0.006	0.003	0.003
Compact ≤ 2.5 ft^3	Electric	Electric	0.064	0.340	0.340
		Gas	0.011	0.006	0.006
	Gas	Electric	0.055	0.030	0.030
		Gas	0.002	0.001	0.001

8.1.2.4 Additional Calculators and Tools

- The ENERGY STAR Appliance Savings Calculator, updated October 2016

8.1.2.1 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 11 years for clothes washers, which is consistent with the Technical Support Document for the current DOE Final Rule standards for residential clothes washers.[340]

8.1.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Unit quantity
- Manufacturer and model number
- Type of unit (top-loading, front-loading, compact)
- DHW fuel type (gas, electric)
- Dryer fuel type (gas, electric)
- Proof of purchase with date of purchase, quantity, and model
    - Alternative: photo of unit installed or other pre-approved method of installation verification
- ENERGY STAR certification

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[340] The median lifetime was calculated using the survival function outlined in the DOE Technical Support Document. Final Rule: Standards, Federal Register, 77 FR 32308 (May 31, 2012) and associated Technical Support Document. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=68&action=viewlive. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0019-0047.

8.2 ENERGY STAR® DISHWASHERS

8.2.1 Measure Description

This measure presents the accepted deemed savings awarded for the installation of an ENERGY STAR dishwasher. Savings are awarded at a flat per-unit rate, both for energy and demand savings. This measure will apply to existing homes and new construction.

8.2.1.1 Eligibility Criteria

This measure applies to both standard and compact dishwasher types.

8.2.1.2 Baseline Condition

Effective May 30, 2013, the baseline is the Department of Energy (DOE) minimum efficiency standard[341] for dishwashers.

Table 8.2-1: [ES Dishwashers] Federal Standards for Dishwashers

Product type	Estimated annual energy use (kWh/year)	Water consumption (gallons/cycle)
Standard (≥ 8 place settings)	≤ 307	≤ 5.0
Compact (< 8 place settings)	≤ 222	≤ 3.5

8.2.1.3 High-Efficiency Condition

The following table displays the ENERGY STAR Final Version 6.0 requirements for eligible dishwashers effective January 29, 2016.[342] These values are subject to updates in ENERGY STAR specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

Table 8.2-2: [ES Dishwashers] ENERGY STAR Specifications for Dishwashers

Product type	Estimated annual energy use (kWh/year)	Water consumption (gallons/cycle)
Standard (≥ 8 place settings + 6 serving pieces)	≤ 270	≤ 3.5
Compact (< 8 place settings + 6 serving pieces)	≤ 203	≤ 3.1

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[341] DOE minimum efficiency standard for residential dishwashers. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=38&action=viewlive..

[342] Available for download at: http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Dishwasher%20Version%206.0%20Final%20Program%20Requirements_0.pdf.

8.2.2 Energy and Demand Savings Methodology

8.2.2.1 Savings Algorithms and Input Variables

Energy Savings

Energy savings for this measure were derived using the ENERGY STAR Appliance Savings Calculator found on the ENERGY STAR website and the revised ENERGY STAR specification in Table 8.2-2.[343] Default values were taken directly from the ENERGY STAR calculator. This document will be updated regularly to apply the values provided in the latest available ENERGY STAR specification and appliance calculator. The most recent TRM version should be referenced to determine measure savings for this measure.

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Equation 8.2-1

$$kWh_{baseline} = kWh_{conv,machine} + kWh_{conv,WH}$$

Equation 8.2-2

$$kWh_{conv,machine} = RUEC_{conv} \times MCF$$

Equation 8.2-3

$$kWh_{conv,WH} = RUEC_{conv} \times WHCF$$

Equation 8.2-4

$$kWh_{ES} = kWh_{ES,machine} + kWh_{ES,WH}$$

Equation 8.2-5

$$kWh_{ES,machine} = RUEC_{ES} \times MCF$$

Equation 8.2-6

$$kWh_{ES,WH} = RUEC_{ES} \times WHCF$$

Equation 8.2-7

Where:

$kWh_{baseline}$ = *Federal standard baseline energy usage.*

kWh_{ES} = *ENERGY STAR average energy usage.*

$kWh_{conv,machine}$ = *Conventional machine energy.*

$kWh_{conv,WH}$ = *Conventional water heater energy.*

$kWh_{ES,machine}$ = *ENERGY STAR machine energy.*

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[343] ENERGY STAR Appliance Savings Calculator (updated October 2016). https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products.

$kWh_{ES,WH}$ = ENERGY STAR water heater energy.

$RUEC_{conv}$ = Conventional rated use electricity consumption = 307 kWh/year for standard and 222 kWh/year for compact; see Table 8.2-1.

$RUEC_{ES}$ = ENERGY STAR rated use electricity consumption = 270 kWh/year for standard and 203 kWh/year for compact; see Table 8.2-2.

MCF = Machine consumption factor = 44%.

$WHCF$ = Water heater consumption factor = 56%.

Demand Savings

$$kW_{savings} = \frac{kWh_{savings}}{AOH} \times DF$$

Equation 8.2-8

$$AOH = CPY \times d$$

Equation 8.2-9

Where:

AOH = Annual operating hours.

DF = Demand Factor for NCP, CP, or 4CP peak demand; see

Table 8.2-3.

CPY = Cycles per year = 215.

d = Average wash cycle duration = 2.1 hours.[344]

Table 8.2-3: [ES Dishwashers] Peak Demand Factors[345]

Season	NCP	CP	4CP
Summer	0.163	0.042	0.041

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Building America House Simulation Protocols hourly and monthly profiles for

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[344] Average of Consumer Reports Cycle Times for Dishwashers.

[345] See Section 2.3.

residential air purifier usage converted to a peak demand factor profile. The load shape can be found in Section 22.2 Load Shapes.

8.2.2.2 Deemed Energy Savings Tables

Table 8.2-4: [ES Dishwashers] Energy Savings

Product type	Electric water heating	Gas water heating
Standard	37	16
Compact	19	8

8.2.2.3 Deemed Demand Savings Tables

Table 8.2-5: [ES Dishwashers] Summer Peak Demand Savings

Dishwasher type	Water heating fuel	NCP	CP	4CP
Standard	Electric	0.013	0.003	0.003
	Gas	0.006	0.002	0.001
Compact	Electric	0.007	0.002	0.002
	Gas	0.003	0.001	0.001

8.2.2.4 Additional Calculators and Tools

This section is not applicable.

8.2.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years based on the Technical Support Document for the current DOE Final Rule standards for residential dishwashers.[346]

8.2.3 Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- Climate zone
- Number of units installed
- Type of dishwasher (standard or compact)

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[346] The median lifetime was calculated using the survival function outlined in the DOE Technical Support Document. Final Rule: Standards, Federal Register, 77 FR 31918 (May 30, 2012) and associated Technical Support Document. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=38&action=viewlive.

- Fuel type of water heater (gas or electric)
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

8.3 ENERGY STAR® REFRIGERATORS

8.3.1 Measure Description

This measure applies to all ENERGY STAR refrigerators that meet the criteria for the ENERGY STAR label specified below.

8.3.1.1 Eligibility Criteria

To qualify for early retirement, the ENERGY STAR unit must replace an existing, full-size unit with a maximum age of 20 years. To determine the remaining useful life of an existing unit; see

Table 8.3-4**Error! Reference source not found.**. All retired refrigerators must be dismantled in an environmentally safe manner in accordance with applicable federal, state, and local regulations. The installer will provide documentation of proper disposal of refrigerators. To receive early retirement savings, the unit to be replaced must be functioning at the time of removal.

Newly installed refrigerators must meet current ENERGY STAR efficiency levels.

8.3.1.2 Baseline Condition

For new construction or replace-on-burnout, the baseline is the Department of Energy (DOE) minimum efficiency standard[347] for refrigerators, effective September 15, 2014.

For early retirement, the baseline for refrigerators is the annual unit energy consumption of an assumed refrigerator's adjusted energy usage rating based on an average of values reported by the Midwest Energy Performance Analytics (MwEPA) Refrigerator and Freezer Energy Rating Database.[348] Since the federal standard effective date occurred in late 2014, existing units manufactured as of 2015 are not eligible for early retirement.

8.3.1.3 High-Efficiency Condition

Table 8.3-1 displays the ENERGY STAR requirements for eligible refrigerators, which went into effect on September 15, 2014. These values are subject to updates in ENERGY STAR specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

Table 8.3-1: [ES Refrigerators] ENERGY STAR Specifications for Refrigerators

Product type	Volume	Criteria as of September 15, 2014
Full-size Refrigerators and Refrigerator-Freezers	7.75 cubic feet or greater	Approximately 10 percent more energy efficient than the minimum federal standard (see Table 325)

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[347] DOE minimum efficiency standard for residential refrigerators and freezers. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43.

[348] Refrigerator and Freezer Energy Rating Database. Midwest Energy Performance Analytics, Inc. in combination with the State of Wisconsin and US Department of Energy's Weatherization Assistance Program. http://www.kouba-cavallo.com/refmods.htm.

Table 8.3-2: [ES Refrigerators] Formulas to Calculate the ENERGY STAR Criteria for each Refrigerator Product Category by Adjusted Volume[349]

Product number	Product class	Baseline energy usage federal standard as of September 15, 2014 (kWh/year)[350]	Average ENERGY STAR energy usage (kWh/year)[351]	Adjusted volume[352] (cubic feet)	Baseline energy usage (kWh/year)	ENERGY STAR energy usage (kWh/year)
3	Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker	8.07 × AV + 233.7	7.26 × AV + 210.3	16.9	370.1	333.0
5	Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	8.85 × AV + 317.0	7.97 × AV + 285.3	18.6	481.5	433.5
5A	Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	9.25 × AV + 475.4	8.33 × AV + 436.3	32.1	772.1	703.5
7	Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	8.54 × AV + 432.8	7.69 × AV + 397.9	30.4	692.1	631.4

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[349] Available for download at http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. Select product classes excluded.

[350] http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.

[351] Approximately 10 percent more efficient than baseline, as specified in the ENERGY STAR Appliance Savings Calculator (updated September 2015). http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.

[352] AV is calculated as a simple average across all refrigerators in the corresponding Product Class utilizing data provided by https://www.energystar.gov/productfinder/product/certified-residential-refrigerators/results.

8.3.2 Energy and Demand Savings Methodology

8.3.2.1 Savings Algorithms and Input Variables

New Construction or Replace-on-Burnout

Energy Savings

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Equation 8.3-1

Where:

$kWh_{baseline}$ = *Federal standard baseline energy usage; see Table 8.3-2.*

kWh_{ES} = *ENERGY STAR average energy usage; see Table 8.3-2.*

Demand Savings

$$kW_{savings} = \frac{kWh_{savings}}{8,760\ hrs} \times LSAF$$

Equation 8.3-2

Where:

$LSAF$ = *Load Shape Adjustment Factor; see*

Table 8.3-3.

Table 8.3-3: [ES Refrigerators] Load Shape Adjustment Factors[353]

Season	NCP	CP	4CP
Summer	1.325	1.134	1.155

Early Retirement

Annual energy (kWh) and peak demand (kW) savings must be calculated separately for two time periods:

1. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
2. The remaining time in the EUL period (EUL – RUL)

Annual energy and peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in Section

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[353] See Section 2.3.

22.3.

Where:

RUL = *Remaining useful life; see*

Table 8.3-4*; if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 5.0 years.*

EUL = *Estimated useful life = 16 years.*

Table 8.3-4: [ES Refrigerators] Remaining Useful Life (RUL) of Replaced Refrigerator[354]

Age of replaced refrigerator (years)	RUL (years)	Age of replaced refrigerator (years)	RUL (years)
1	15.2	12	7.0
2	14.2	13	6.6
3	13.2	14	6.3
4	12.2	15	6.0
5	11.2	16	5.0
6	10.3	17	4.0
7	9.6	18	3.0
8	8.9	19	2.0
9	8.3	20	1.0
10	7.8	21[355,356]	0.0
11	7.4		

Derivation of RULs

ENERGY STAR refrigerators have an estimated useful life of 16 years. This estimate is consistent with the age at which approximately 50 percent of the refrigerators installed in a given year will no longer be in

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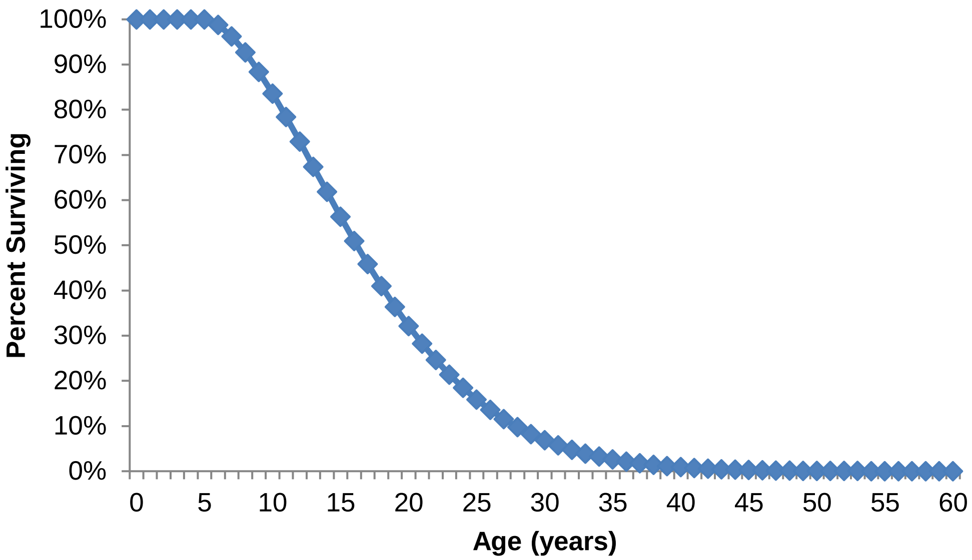
[354] Current federal standard effective date is 9/15/2014. Since the federal standard effective date occurred in late 2014, existing units manufactured as of 2015 are not eligible to use the early retirement baseline and should use the ROB baseline instead.

[355] RULs are capped at the 75th percentile of equipment age, 21 years, as determined based on DOE survival curves (see). Systems older than 21 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

[356] Ward, B., Bodington, N., Farah, H., Reeves, S., and Lee, L. "Considerations for early replacement of residential equipment." Prepared by the Evaluation, Measurement, and Verification (EM&V) team for the Electric Utility Marketing Managers of Texas (EUMMOT). January 2015. This document has been made available to all Texas investor-owned utilities through the EM&V team's SharePoint.

service, as described by the survival function in Figure 8.3-1.

Figure 8.3-1: [ES Refrigerators] Survival Function[357]



The method to estimate the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 8.3-1. The age of the refrigerator being replaced is found on the horizontal axis, and the corresponding percentage of surviving refrigerators is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. Then, the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For example, assume a refrigerator being replaced is 15 years old. The corresponding percent surviving value is 56 percent. Half of 56 percent is 28 percent. The age corresponding to 28 percent on the chart is 21 years. Therefore, the RUL of the refrigerator being replaced is (21–15) = 6 years.

Energy Savings

For the RUL period:

$$kWh_{savings,ER} = kWh_{manf} - kWh_{ES}$$

Equation 8.3-3

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project:

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[357] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf.

$$\boldsymbol{kWh_{savings,ROB} = kWh_{baseline} - kWh_{ES}}$$

Equation 8.3-4

Where:

kWh_{manf} = $968\ kWh/Year.$[358]

Demand Savings

To calculate demand savings for the early retirement of a refrigerator, a similar methodology is used as for replace-on-burnout installations, with separate savings calculated for the remaining useful life of the unit, and the remainder of the EUL as outlined in the section above.

For the RUL period:

$$\boldsymbol{kW_{savings,ER} = \frac{kWh_{savings,ER}}{8,760\ hrs} \times LSAF}$$

Equation 8.3-5

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project:

$$\boldsymbol{kW_{savings,ROB} = \frac{kWh_{savings,ROB}}{8,760\ hrs} \times LSAF}$$

Equation 8.3-6

Where:

LSAF = *Load shape adjustment factor; see*

Table 8.3-3*.*

Annual deemed summer peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in Section 22.3.

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Building America House Simulation Protocols hourly and monthly profiles for residential air purifier usage converted to a peak demand factor profile. The load shape can be found in Section 22.2 Load Shapes.

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[358] This is the weighted average of Adjusted annual unit energy consumption, derived from the MwEPA Refrigerator and Freezer Energy Rating Database (or from metering). Weights are calculated from the millions-of-households measurements obtained from the Residential Energy Consumption Survey, or RECS, (https://www.eia.gov/consumption/residential/data/2015/hc/php/hc3.6.php) corresponding to the year range classifications of refrigerators greater than 15 years old (specifically, 15-to-19-years-old and 20-or-more-years-old). Data in which refrigerators' model years were older than 1975 were excluded.

8.3.2.2 Deemed Energy Savings Tables

Table 8.3-5: [ES Refrigerators] Energy Savings (kWh) by Refrigerator Type

Through-the-door ice?	Door type	Product class	ROB savings (kWh/year)	ER savings (kWh/year)
No	Top Freezer	3: Refrigerator freezers—automatic defrost with a top-mounted freezer without an automatic icemaker	37	224
	Bottom Freezer	5: Refrigerator-freezers—automatic defrost with a bottom-mounted freezer without an automatic icemaker	48	200
Yes	Bottom Freezer	5A: Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	69	147
	Side-by-Side	7: Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	61	130
Unknown or Average Refrigerator[359]			44	205

8.3.2.3 Deemed Demand Savings Tables

Table 8.3-6: [ES Refrigerators] Replace-on-Burnout Summer Demand Savings (kW) by Refrigerator Type

Through-the-door ice?	Door type	Product class	NCP	CP	4CP
No	Top Freezer	3: Refrigerator freezers—automatic defrost with a top-mounted freezer without an automatic icemaker	0.0056	0.0048	0.0049

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[359] An "Unknown or Average" refrigerator's savings are calculated as the difference between the weighted average of baseline energy usage ratings and the weighted average of ENERGY STAR energy usage ratings for the four selected refrigerator categories, with weights ascertained from averages of refrigerators in 10-14 year-old, 5-9 year-old, and 2-4 year-old age groups. The data used to calculate weights is hosted by Natural Resources Canada (NRCAN) at the following link which contains a table of the distribution of refrigerator types in households by year: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CM&sector=aaa&juris=ca&rn=3&page=1. Weights were similarly calculated utilizing data from RECS (data which is summarized, i.e. not yearly, and located here: https://www.eia.gov/consumption/residential/data/2015/hc/php/hc3.6.php). While the reported distribution of refrigerator types between the two sets of data varies, we prefer the year-level granularity of the data from NRCAN considering that the differences between both sets of weighted average baseline energy usage and weighted average ENERGY STAR energy usage were nearly identical. Hence, we elect to utilize the more detailed weightings derived from the data hosted by NRCAN.

Through-the-door ice?	Door type	Product class	NCP	CP	4CP
	Bottom Freezer	5: Refrigerator-freezers—automatic defrost with a bottom-mounted freezer without an automatic icemaker	0.0073	0.0062	0.0063
Yes	Bottom Freezer	5A: Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	0.0104	0.0089	0.0090
	Side-by-Side	7: Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	0.0092	0.0079	0.0080
Unknown or Average Refrigerator			0.0067	0.0057	0.0058

Table 8.3-7: [ES Refrigerators] Early Retirement Summer Demand Savings (kW) by Refrigerator Type

Through-the-door ice?	Door type	Product class	NCP	CP	4CP
No	Top Freezer	3: Refrigerator freezers—automatic defrost with a top-mounted freezer without an automatic icemaker	0.034	0.029	0.030
	Bottom Freezer	5: Refrigerator-freezers—automatic defrost with a bottom-mounted freezer without an automatic icemaker	0.030	0.026	0.026
Yes	Bottom Freezer	5A: Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	0.020	0.017	0.017
	Side-by-Side	7: Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	0.022	0.019	0.019
Unknown or Average Refrigerator			0.031	0.026	0.027

8.3.2.4 Additional Calculators and Tools

This section is not applicable.

8.3.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 16 years based on the current DOE Final Rule standards for residential refrigerators.[360]

8.3.3 Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- Climate zone
- Number of units installed
- The project type of the installation (new construction, replace-on-burnout, or early retirement)
- Installed refrigerator model number
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)
- Document proper disposal of the existing refrigerator (early retirement only)
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

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[360] Final Rule: Standards, Federal Register, 76 FR 57516 (Sept. 15, 2011) and associated Technical Support Document. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128.

8.4 ENERGY STAR® FREEZERS

8.4.1 Measure Description

This measure applies to all ENERGY STAR freezers that meet the criteria for the ENERGY STAR label specified below.

8.4.1.1 Eligibility Criteria

To qualify for early retirement, the ENERGY STAR unit must replace an existing, full-size unit with a maximum age of 27 years. To determine the remaining useful life of an existing unit; see **Error! Reference source not found.**. All retired freezers must be dismantled in an environmentally safe manner in accordance with applicable federal, state, and local regulations. The installer will provide documentation of proper disposal of freezers. To receive early retirement savings, the unit to be replaced must be functioning at the time of removal.

Newly installed freezers must meet current ENERGY STAR efficiency levels.

8.4.1.2 Baseline Condition

For new construction or replace-on-burnout, the baseline is the Department of Energy (DOE) minimum efficiency standard[361] for freezers, effective September 15, 2014.

For early retirement, the baseline for freezers is the annual unit energy consumption of a freezer's adjusted energy usage rating based on an average of values reported by the Midwest Energy Performance Analytics (MwEPA) Refrigerator and Freezer Energy Rating Database.[362] Since the federal standard effective date occurred in late 2014, existing units manufactured as of 2015 are not eligible for early retirement.

Alternatively, the baseline annual energy usage of the freezer being replaced may be estimated by metering for a period of at least two hours using the measurement protocol specified in the DOE report, "Incorporating Refrigerator Replacement into the Weatherization Assistance Program."[363]

To determine annual kWh of the freezer being replaced, use the following formula:

$$\boldsymbol{Annual\ kWh\ Usage = \frac{WH \times 8,760}{h \times 1,000}}$$

Equation 8.4-1

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[361] DOE minimum efficiency standard for residential refrigerators and freezers. https://www.ecfr.gov/cgi-bin/text-idx?SID=48f64e166fe3561666f871e521996e13&mc=true&node=se10.3.430_132&rgn=div8.

[362] Refrigerator and Freezer Energy Rating Database. Midwest Energy Performance Analytics, Inc. in combination with the State of Wisconsin and US Department of Energy's Weatherization Assistance Program. http://www.kouba-cavallo.com/refmods.htm.

[363] Alex Moore, DandR International, Ltd. "Incorporating Refrigerator Replacement into the Weatherization Assistance Program" Information Tool Kit." Department of Energy. November 19, 2001. https://aceee.org/files/proceedings/2002/data/papers/SS02_Panel2_Paper16.pdf.

Where:

WH = *Watt-hours metered during a period.*

h = *Measurement time (hours).*

8,760 = *Total hours per year.*

1,000 = *Constant to convert from watts to kilowatts.*

8.4.1.3 High-Efficiency Condition

Table 8.4-1 displays the ENERGY STAR requirements for eligible freezers, which went into effect on September 15, 2014. These values are subject to updates in ENERGY STAR specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

Table 8.4-1: [ES Freezers] ENERGY STAR Specifications for Freezers[364]

Product type	Volume	Criteria as of September 15, 2014
Freezers	7.75 cubic feet or greater	Approximately 10 percent more energy efficient than the minimum federal standard (see Table 8.4-2)
Compact Freezers	Less than 7.75 cubic feet	Approximately 10 percent more energy efficient than the minimum federal standard (see Table 8.4-2)

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[364] https://www.energystar.gov/products/appliances/refrigerators/key_product_criteria

Table 8.4-2: [ES Freezers] Formulas to Calculate the ENERGY STAR Criteria for Select Freezer Product Categories by Adjusted Volume[365]

Product number	Full product name[366]	Product class	Baseline energy usage federal standard (kWh/year)[367]	Average ENERGY STAR® energy usage (kWh/year)[368]	Adjusted volume[369] (cubic feet)	Baseline energy usage (kWh/year)	ENERGY STAR energy usage (kWh/year)
8	Upright freezers with manual defrost	Upright (Manual Defrost)	5.57 × AV + 193.7	5.01 × AV + 174.3	16.12	283.5	255.1
9	Upright freezers with automatic defrost without an automatic icemaker	Upright (Auto Defrost)	8.62 × AV + 228.3	7.76 × AV + 205.5	29.96	486.6	438.0
10	Chest freezers and all other freezers except compact freezers	Chest	7.29 × AV + 107.8	6.56 × AV + 97	25.25	291.8	262.6
16	Compact upright freezers with manual defrost	Compact Upright (Manual Defrost)	8.65 × AV + 225.7	7.79 × AV + 203.1	5.34	271.9	244.7
17	Compact upright freezers with automatic defrost	Compact Upright (Auto Defrost)	10.17 × AV + 351.9	9.15 × AV + 316.7	7.95	432.7	389.4
18	Compact chest freezers	Compact Chest	9.25 × AV + 136.8	8.33 × AV + 123.1	9.06	220.6	198.6

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[365] Available for download at http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. Select product classes excluded.

[366] Note that when calculating deemed savings for upright freezers, we calculated a weighted average of adjusted energy usage of manual versus automatic defrost upright freezers, with weights based on the number of millions-of-households which contain these types of freezers, obtained from the Residential Energy Consumption Survey, or RECS, (https://www.eia.gov/consumption/residential/data/2015/hc/php/hc3.6.php), thus eliminating this input from consideration.

[367] https://www.ecfr.gov/cgi-bin/text-idx?SID=48f64e166fe3561666f871e521996e13&mc=true&node=se10.3.430_132&rgn=div8

[368] Approximately 10 percent more efficient than baseline, as specified in the ENERGY STAR Appliance Savings Calculator (updated September 2015). http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.

[369] AV is calculated as a simple average per selected freezer product type in the corresponding Product Class utilizing data provided by https://www.energystar.gov/productfinder/product/certified-residential-freezers/results

8.4.2 Energy and Demand Savings Methodology

8.4.2.1 Savings Algorithms and Input Variables

New Construction or Replace-on-Burnout

Energy Savings

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Equation 8.4-2

Where:

$kWh_{baseline}$ = *Federal standard baseline energy usage; see Table 8.4-2.*

kWh_{ES} = *ENERGY STAR average energy usage; see Table 8.4-2.*

Demand Savings

$$kW_{savings} = \frac{kWh_{savings}}{8,760\ hrs} \times LSAF$$

Equation 8.4-3

Where:

$LSAF$ = *Load Shape Adjustment Factor; see Table 8.4-3.*

Table 8.4-3: [ES Freezers] Load Shape Adjustment Factors[370]

Season	NCP	CP	4CP
Summer	1.325	1.134	1.155

Early Retirement

Annual energy (kWh) and peak demand (kW) savings must be calculated separately for two time periods:

1. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
2. The remaining time in the EUL period (EUL – RUL)

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[370] See Volume 1, Section 4.

Annual energy and peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in Section 22.3.

Where:

RUL = *Remaining useful life (see Table 8.4-4); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 5.0 years.*

EUL = *Estimated useful life = 22 years.*

Table 8.4-4: [ES Freezers] Remaining Useful Life (RUL) of Replaced Freezer[371]

Age of replaced freezer (years)	RUL (years)	Age of replaced Freezer (years)	RUL (years)	Age of replaced Freezer (years)	RUL (years)
1	20.7	10	12.1	19	6.6
2	19.7	11	11.3	20	6.2
3	18.7	12	10.6	21	5.9
4	17.7	13	9.9	22	5.0
5	16.7	14	9.2	23	4.0
6	15.7	15	8.6	24	3.0
7	14.8	16	8.1	25	2.0
8	13.8	17	7.5	26	1.0
9	13.0	18	7.1	27[372,373]	0.0

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[371] Current federal standard effective date is 9/15/2014. Since the federal standard effective date occurred in late 2014, existing units manufactured as of 2015 are not eligible to use the early retirement baseline and should use the ROB baseline instead.

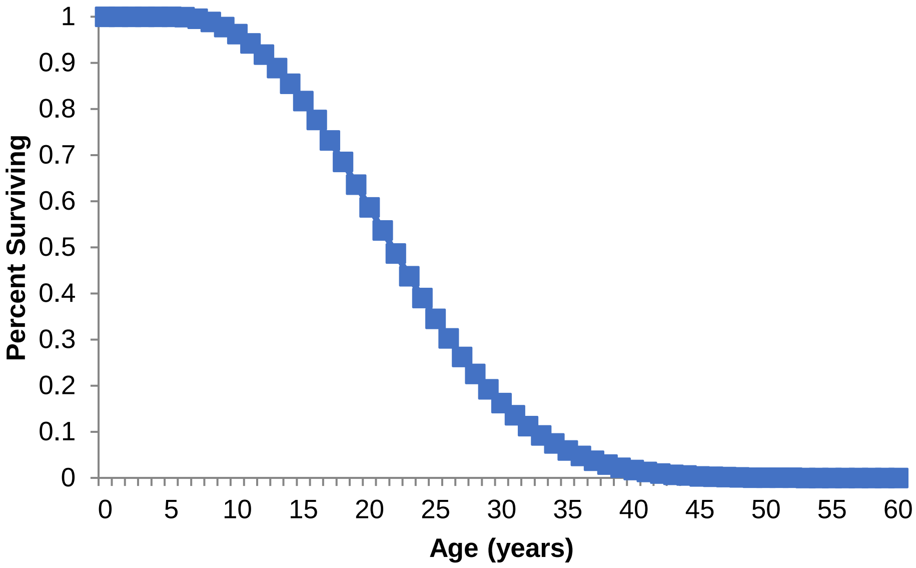
[372] RULs are capped at the 75th percentile of equipment age, 27 years, as determined based on DOE survival curves (see). Systems older than 27 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

[373] Ward, B., Bodington, N., Farah, H., Reeves, S., and Lee, L. "Considerations for early replacement of residential equipment." Prepared by the Evaluation, Measurement, and Verification (EM&V) team for the Electric Utility Marketing Managers of Texas (EUMMOT). January 2015. This document has been made available to all Texas investor-owned utilities through the EM&V team's SharePoint.

Derivation of RULs

ENERGY STAR freezers have an estimated useful life of 22 years. This estimate is consistent with the age at which approximately 50 percent of the freezers installed in a given year will no longer be in service, as described by the survival function in Figure 8.4-1.

Figure 8.4-1: [ES Freezers] Survival Function[374]



The method for estimating the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure . The age of the freezer being replaced is found on the horizontal axis, and the corresponding percentage of surviving freezers is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. Then, the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For example, assume a freezer being replaced is 22 years old (the estimated useful life). The corresponding percent surviving value is approximately 50 percent. Half of 50 percent is 25 percent. The age corresponding to 25 percent on the chart is approximately 27 years. Therefore, the RUL of the freezer being replaced is 27-22 = 5 years.

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[374] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf.

Energy Savings

For the RUL period:

$$\boldsymbol{kWh_{savings,ER} = kWh_{manf} - kWh_{ES}}$$

Equation 8.4-4

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project:

$$\boldsymbol{kWh_{savings,ROB} = kWh_{baseline} - kWh_{ES}}$$

Equation 8.4-5

Where:

kWh_{manf} = $841\ kWh/Year.$[375]

Demand Savings

To calculate demand savings for the early retirement of a freezer, a similar methodology is used as for replace-on-burnout installations, with separate savings calculated for the remaining useful life of the unit, and the remainder of the EUL as outlined in the section above.

For the RUL period:

$$\boldsymbol{kW_{savings,ER} = \frac{kWh_{savings,ER}}{8,760\ hrs} \times LSAF}$$

Equation 8.4-6

For The remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project:

$$\boldsymbol{kW_{savings,ROB} = \frac{kWh_{savings,ROB}}{8,760\ hrs} \times LSAF}$$

Equation 8.4-7

---

[375] This is the weighted average of adjusted annual unit energy consumption, a metric obtained from the MwEPA Refrigerator and Freezer Energy Rating Database (if from metering, substitute recorded value in lieu of this weighted average). Weights are calculated from the millions-of-households measurements obtained from RECS, (https://www.eia.gov/consumption/residential/data/2015/hc/php/hc3.6.php) corresponding to the year range classifications of freezers greater than 15 years old (specifically, 15-to-19 years old and 20+ years old). The oldest freezers for which we had data were from 1979.

Annual deemed summer peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in Section 22.3.

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Building America House Simulation Protocols hourly and monthly profiles for residential air purifier usage converted to a peak demand factor profile. The load shape can be found in Section 22.2 Load Shapes.

8.4.2.2 Deemed Energy Savings Tables

Table 8.4-5: [ES Freezers] Energy Savings (kWh) by Freezer Type

Freezer type	Product Class	ROB savings (kWh/year)	ER savings (kWh/year)
Chest	Standard (≥ 7.75 ft^3)	29	154
	Compact (< 7.75 ft^3)	22	163
Upright	Standard (≥ 7.75 ft^3)	48	130
	Compact (< 7.75 ft^3)	32	151

8.4.2.3 Deemed Demand Savings Tables

Table 8.4-6: [ES Freezers] Replace-on-Burnout Summer Demand Savings (kW) by Freezer Type

Freezer type	Product Class	NCP	4CP	CP
Chest	Standard (≥ 7.75 ft^3)	0.004	0.004	0.004
	Compact (< 7.75 ft^3)	0.003	0.003	0.003
Upright	Standard (≥ 7.75 ft^3)	0.007	0.006	0.006
	Compact (< 7.75 ft^3)	0.005	0.004	0.004

Table 8.4-7: [ES Freezers] Early Retirement Summer Demand Savings (kW) by Freezer Type

Freezer type	Product Class	NCP	4CP	CP
Chest	Standard (≥ 7.75 ft^3)	0.023	0.020	0.020
	Compact (< 7.75 ft^3)	0.025	0.021	0.021
Upright	Standard (≥ 7.75 ft^3)	0.020	0.017	0.017
	Compact (< 7.75 ft^3)	0.023	0.020	0.020

8.4.2.4 Additional Calculators and Tools

This section is not applicable.

8.4.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 22 years based on the current DOE Final Rule standards for residential freezers.[376]

8.4.3 Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- Climate zone
- Number of units installed
- The project type of the installation (new construction, replace-on-burnout, or early retirement)
- Installed freezer type (upright or chest)
- Installed freezer size (standard or compact)
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)
- The installer will provide documentation of proper disposal of freezers in accordance with applicable federal, state, and local regulations (early retirement only)

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[376] Final Rule: Standards, Federal Register, 76 FR 57516 (Sept. 15, 2011) and associated Technical Support Document. https://www.ecfr.gov/cgi-bin/text-idx?SID=48f64e166fe3561666f871e521996e13&mc=true&node=se10.3.430_132&rgn=div8. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128.

8.5 REFRIGERATOR/FREEZER RECYCLING

8.5.1 Measure Description

This measure involves the early retirement and recycling of an existing, full-size (7.75 ft^3 or greater) refrigerator and/or freezer in a residential application. Savings represent the estimated energy consumption of the existing unit over its remaining life.

8.5.1.1 Eligibility Criteria

This measure applies to operable primary and secondary retired refrigerators/freezers. Recycling savings for this measure are limited to the removal and recycling of a working refrigerator/freezer from the electrical grid and differ from the savings for a new ENERGY STAR refrigerator/freezer. To qualify, the customer must release the existing unit to the utility or utility representative to ensure proper disposal in accordance with applicable federal, state, and local regulations.

8.5.1.2 Baseline Condition

Without program intervention, the recycled refrigerator/freezer would have remained operable on the electrical grid. As a result, the baseline condition is continued operation of the existing refrigerator.

8.5.1.3 High-Efficiency Condition

There is no efficiency standard for a recycling measure because the energy efficient action is the removal of an operable appliance, not—as with most demand-side management programs—the installation of a higher efficiency model.

8.5.2 Energy and Demand Savings Methodology

Savings for this measure are based on the assumed annual energy consumption of the refrigerator/freezer being retired.

8.5.2.1 Savings Algorithms and Input Variables

Energy Savings

Demand savings can be derived by using the following:

$$\boldsymbol{kWh_{savings} = kWh_{existing} - ISAF \times PUF}$$

Equation 8.5-1

Where:

$kWh_{existing}$ = *Average annual energy consumption*[377]*; see Table 8.5-1.*

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[377] ENERGY STAR Flip Your Fridge Calculator. https://www.energystar.gov/index.cfm?fuseaction=refrig.calculator.

$ISAF$ = In Situ Adjustment Factor[378] $= 0.942$.

PUF = Part Use Factor[379] $= 0.915$.

Table 8.5-1: [Refrigerator/Freezer Recycling] Average Annual Energy Consumption

Total Capacity (ft³)	Year Manufactured	$kWh_{existing}$ by Freezer Configuration				
		Top	Bottom	Side	Upright	Chest
< 16.5	≤ 2000	861	962	1,139	937	532
	2001-2010	556	724	747	713	435
	≥ 2011	374	483	592	449	292
16.5-18.9	≤ 2000	962	1,051	1,266	1,058	621
	2001-2010	613	747	818	805	508
	≥ 2011	412	517	640	507	341
19.0-21.4	≤ 2000	1,031	1,110	1,329	1,138	680
	2001-2010	651	762	854	866	557
	≥ 2011	438	539	664	545	373
21.5-24.4	≤ 2000	1,090	1,172	1,368	1,194	721
	2001-2010	683	777	876	909	591
	≥ 2011	459	562	679	572	396
≥ 24.5	≤ 2000	1,223	1,347	1,528	1,355	840
	2001-2010	758	822	966	1,031	688
	≥ 2011	508	627	740	648	461

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[378] The Cadmus Group, Inc. "Residential Retrofit High Impact Measure Evaluation Report." Prepared for California Public Utilities Commission Energy Division. February 8, 2010. Factor to account for variation between site conditions and controlled DOE testing conditions (90°F test chamber, empty refrigerator and freezer cabinets, and no door openings). Appliances in warmer climate zones use more energy than those in cooler climate zones; utilized Southern California Edison data (highest percentage of warm climate projects) to best approximate Texas climate, p. 139-140.

[379] Ibid. Factor to account for the number of refrigerators that were running, running part time, or not running at the time of recycling, p. 142-143 (weighted by representative utility survey participation, p. 117).

Demand Savings

Demand savings can be derived by using the following:

$$kW_{Savings} = \frac{kWh_{savings}}{AOH} \times DF$$

Equation 8.5-2

Where:

AOH = *Annual operating hours = 8,760 hours.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 8.5-2.*

Table 8.5-2: [Refrigerator/Freezer Recycling] Demand Factors[380]

Factor Type	Demand Factor
NCP	1.325
CP	1.134
4CP	1.155

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Building America House Simulation Protocols hourly and monthly profiles for residential refrigerators usage converted to a peak demand factor profile. The load shape can be found in Section 22.2 Load Shapes.

8.5.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

8.5.2.3 Deemed Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

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[380] Demand Factors were derived according to the method outlined in Section 2.3 using the load shape found in Section 22.2 using data from the US Department of Energy's Building America B10 Benchmark load profiles for refrigerators.

8.5.2.4 Additional Calculators and Tools

This section is not applicable.

8.5.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 8 years for refrigerator and freezer recycling, representing the assumed remaining useful life of the retired unit.[381]

8.5.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Number of refrigerators/freezers removed
- Manufacture year for removed unit(s)
- Total unit capacity (ft^3)
- Freezer configuration (top, bottom, side-by-side, upright, chest)

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[381] KEMA, Inc. “Residential Refrigerator Recycling Ninth Year Retention Study.” Prepared for Southern California Edison. July 22, 2004.

8.6 ENERGY STAR® POOL PUMPS

8.6.1 Measure Description

This measure involves the replacement of a single-speed pool pump with an ENERGY STAR-certified variable speed pool pump.

8.6.1.1 Eligibility Criteria

This measure applies to all residential applications; however, pools that serve multiple tenants in a common area are not eligible for this measure. Ineligible pump products include waterfall, integral cartridge filter, integral sand filter, storable electric spa, and rigid electric spa.[382]

Multi-speed pool pumps are an alternative to variable speed pumps. The multi-speed pump uses an induction motor that functions as two motors in one, with full-speed and half-speed options. Multi-speed pumps may enable significant energy savings. However, if the half-speed motor is unable to complete the required water circulation task, the larger motor will operate exclusively. Having only two speed-choices limits the ability of the pump motor to fine-tune the flow rates required for maximum energy savings.[383] Therefore, multi-speed pumps must have a high-speed override capability to revert to low speed after a period not to exceed 24 hours.

8.6.1.2 Baseline Condition

The baseline condition is a 0.5-3 horsepower (hp) standard-efficiency single-speed[384] pool pump.

8.6.1.3 High-Efficiency Condition

The high efficiency condition is a 0.5-3 hp ENERGY STAR-certified variable-speed pool pump.

8.6.2 Energy and Demand Savings Methodology

Savings for this measure are based on methods and input assumptions from the ENERGY STAR Pool Pump Savings Calculator.

8.6.2.1 Savings Algorithms and Input Variables

Energy Savings

Energy savings for this measure were derived by using the ENERGY STAR Pool Pump Savings Calculator with Texas selected as the applicable location so Texas-specific assumptions were used.[385]

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[382] These product types are excluded by the ENERGY STAR specifications. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%203.0%20Pool%20Pumps%20Specification.pdf.

[383] Hunt, A. & Easley, S., 2012, "Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings." Building America Retrofit Alliance (BARA), U.S. U.S. DOE. May 2012. http://www.nrel.gov/docs/fy12osti/54242.pdf.

[384] The U.S. DOE passed minimum efficiency standards for pool pumps effective July 19, 2021. These new baseline standards will be incorporated into TRM 10.0 to allow for sell down of existing inventory.

[385] The ENERGY STAR Pool Pump Savings Calculator, updated February 2013, can be found on the ENERGY STAR website at: https://www.energystar.gov/products/certified-products/detail/pool-pumps.

$$kWh_{savings} = kWh_{conv} - kWh_{ES}$$

Equation 8.6-1

Where:

kWh_{conv} = *Conventional single-speed pool pump energy [kWh].*

kWh_{ES} = *ENERGY STAR variable speed pool pump energy [kWh].*

Algorithms to calculate the above parameters are defined as:

$$kWh_{conv} = \frac{PFR_{conv} \times 60 \times hours \times days}{EF_{conv} \times 1000}$$

Equation 8.6-2

$$kWh_{ES} = \frac{gal \times turn_{day} \times days}{EF_{ES} \times 1000}$$

Equation 8.6-3

Where:

hours = Pump daily operating hours; see

Table 8.6-1.

days = *Total days per year.*

PFR_{conv} = Conventional single-speed pump flow rate [gal/min]; see

Table 8.6-1.

EF_{conv} = Conventional single-speed pump energy factor [gal/W·hr]; see

Table 8.6-1.

EF_{ES} = ENERGY STAR pump energy factor [gal/W·hr]; see

Table 8.6-1.

gal = *Pool Volume = 22,000 gal (default).*

$turn_{day}$ = *Number of turnovers per day; see Table 8.6-2.*

60 = *Constant to convert between minutes and hours.*

1,000 = *Constant to convert from watts to kilowatts.*

Table 8.6-1: [Pool Pumps] Conventional Pool Pump Assumptions

Rated Pump (hp)	hours	PFR_{conv} (gal/min)	EF_{conv} (gal/W·h)
≤ 1.25	9.1062	75.5000	2.5131
1.25 < hp ≤ 1.75		78.1429	2.2677
1.75 < hp ≤ 2.25		88.6667	2.2990
2.25 < hp ≤ 2.75		93.0910	2.1812
2.75 < hp ≤ 3		101.6667	1.9987

Table 8.6-2: [Pool Pumps] ENERGY STAR Pool Pump Assumptions

Rated Pump (hp)	Gal	$Turn_{day}$	EF_{ES} (gal/W·h)
≤ 1.25	22,000	1.9	8.7
1.25 < hp ≤ 1.75		1.9	8.9
1.75 < hp ≤ 2.25		2.2	9.3
2.25 < hp ≤ 2.75		2.3	7.4
2.75 < hp ≤ 3		2.5	7.1

Demand Savings

Demand savings can be derived by using the following:

$$kW_{Savings} = \frac{kWh_{conv} - kWh_{ES}}{hours} \times \frac{DF}{days}$$

Equation 8.6-4

Where:

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 8.6-3.*

Table 8.6-3: [Pool Pumps] Demand Factors[386]

Factor Type	Demand Factor
NCP	1.000
CP	0.246
4CP	0.118

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a delta load shape developed from the Building America House Simulation Protocols summer and winter hourly profiles. The Building America load shape was used directly for steady state pool pumps and was adapted for variable speed pool pumps. The delta load shape was derived by taking the difference between the hourly values for each load shape. The resulting delta load shape can be found in Section 22.2.

8.6.2.2 Deemed Energy Savings Tables

Table 8.6-4: [Pool Pumps] Energy Savings[387]

Rated Pump (hp)	Energy Savings (kWh)
≤ 1.25	4,238
1.25 < hp ≤ 1.75	5,158
1.75 < hp ≤ 2.25	5,792
2.25 < hp ≤ 2.75	6,015
2.75 < hp ≤ 3	7,317

8.6.2.3 Deemed Demand Savings Tables

Table 8.6-5: [Pool Pumps] Demand Savings[388]

Rated Pump (hp)	NCP	CP	4CP
≤ 1.25	1.275	0.314	0.150
1.25 < hp ≤ 1.75	1.552	0.382	0.183
1.75 < hp ≤ 2.25	1.743	0.429	0.206
2.25 < hp ≤ 2.75	1.810	0.445	0.214

---

[386] Demand Factors were derived according to the method outlined in Section 2.3 using the load shape found in Section 22.2 using data from the US Department of Energy's Building America B10 Benchmark load profiles for pool pumps. The profile used to determine demand factors is calculated as the difference of single speed and variable speed profiles. Summer profiles include April through September.

[387] The results in this table may vary slightly from results produced by the ENERGY STAR calculator because of rounding of default savings coefficients throughout the measure.

[388] Ibid.

Rated Pump (hp)	NCP	CP	4CP
2.75 < hp ≤ 3	2.201	0.542	0.260

8.6.2.4 Additional Calculators and Tools

The ENERGY STAR Pool Pump Savings Calculator, updated May 2020, can be found on the ENERGY STAR website at https://www.energystar.gov/productfinder/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx.

8.6.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years for pool pumps, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID OutD-PoolPump.[389]

8.6.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

For all projects collect:

- Unit quantity
- Manufacturer and model number of new pool pump
- Rated pool pump horsepower
- Proof of purchase with date of purchase, quantity, and model
  - Alternative: photo of unit installed or other pre-approved method of installation verification
- ENERGY STAR certification

For a significant sample of projects where attainable (e.g., those projects that are selected for inspection, not midstream or retail programs):

- Decision/action type (early retirement, replace-on-burnout, or new construction)
- Rated horsepower of existing pool pump
- Existing and new pool pump operating hours

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[389] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

8.7 ENERGY STAR® AIR PURIFIERS

8.7.1 Measure Description

This measure involves the installation of an ENERGY STAR air purifier.

8.7.1.1 Eligibility Criteria

This measure applies to ENERGY STAR-certified floor, tabletop, and wall-mounted air purifiers/room air cleaners.[390]

8.7.1.2 Baseline Condition

The baseline condition is defined as 1.0 cfm/W representing the efficiency for a conventional air purifier. This value is taken from EPA research conducted in 2011, as cited in the ENERGY STAR Appliance Savings Calculator.[391]

8.7.1.3 High-Efficiency Condition

The high efficiency condition is the ENERGY STAR Final Version 1.2 specification for eligible air purifiers, effective July 1, 2004.[392,393]

Table 8.7-1: [Air Purifiers] ENERGY STAR Specification

Product Type	Clean Air Delivery Rate (CADR)	Minimum Performance Requirement	Standby Power Requirement	Ozone Production
Air Purifiers or Room Air Cleaners	≥ 50 ft^3/min	2.0 CFM/W	2.0 W	≤ 50 ppb

8.7.2 Energy and Demand Savings Methodology

Savings for this measure are based on methods and input assumptions from the ENERGY STAR Appliance Savings Calculator.

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[390] ENERGY STAR Air Purifiers qualified product listing: https://www.energystar.gov/productfinder/product/certified-room-air-cleaners/results.

[391] ENERGY STAR Appliance Savings Calculator (updated October 2016). calculators@energystar.gov.

[392] ENERGY STAR specification for air purifiers: https://www.energystar.gov/ia/partners/prod_development/revisions/downloads/room_aircleaners/Room_Air_Cleaners_Final_V1.2_Specification.pdf?6ec0-9f1a.

[393] ENERGY STAR air purifier key product criteria: https://www.energystar.gov/products/appliances/air_purifiers_cleaners/key_product_criteria.

8.7.2.1 Savings Algorithms and Input Variables

Energy Savings

Energy savings can be derived by using the following:

$$\boldsymbol{kWh_{savings} = (kWh_{conv,OP} + kWh_{conv,SB}) - (kWh_{ES,OP} + kWh_{ES,SB})}$$

Equation 8.7-1

$$\boldsymbol{kWh_{baseline,OP} = \frac{\left(\frac{CADR_{conv}}{Eff_{conv}}\right)}{1,000} \times hours \times days}$$

Equation 8.7-2

$$\boldsymbol{kWh_{baseline,SB} = (8,760 - hours \times days) \times W_{conv,SB}/1000}$$

Equation 8.7-3

$$\boldsymbol{kWh_{ES,OP} = \frac{\left(\frac{CADR_{ES}}{Eff_{ES}}\right)}{1,000} \times hours \times days}$$

Equation 8.7-4

$$\boldsymbol{kWh_{ES,SB} = \frac{8,760 - hours \times days \times W_{ES,SB}}{1,000}}$$

Equation 8.7-5

Where:

$kWh_{conv,OP}$ = *Conventional operating energy usage.*

$kWh_{conv,SB}$ = *Conventional standby energy usage.*

$kWh_{ES,OP}$ = *ENERGY STAR operating energy usage.*

kWh_{ESSB} = *ENERGY STAR standby energy usage.*

$CADR_{conv}$ = *Conventional unit clean air delivery rate [ft^3/min].*

$CADR_{ES}$ = *ENERGY STAR unit clean air delivery rate [ft^3/min].*

Eff_{conv} = *Conventional clean air delivery efficiency = 1.0 CFM/W.*

Eff_{ES} = *ENERGY STAR clean air delivery efficiency = 3.0 CFM/W.*

hours = *Operating hours per day = 16.*

days = *Total days per year.*

$W_{conv,SB}$ = *Conventional model standby power = 1.0 W.*

$W_{ES,SB}$ = *ENERGY STAR model standby power = 0.6 W.*

1,000 = *Constant to convert from watts to kilowatts.*

8,760 = *Total hours per year.*

Demand Savings

Demand savings can be derived by using the following:

$$kW_{Savings} = \frac{kWh_{savings}}{hours \times days} \times DF$$

Equation 8.7-6

Where:

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 8.7-2.*

Table 8.7-2: [Pool Pumps] Demand Factors[394]

Factor Type	Demand Factor
NCP	1.078
CP	0.644
4CP	0.702

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Building America House Simulation Protocols hourly and monthly profiles for residential air purifier usage converted to a peak demand factor profile. The load shape can be found in Section 22.2 Load Shapes.

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[394] Demand Factors were derived according to the method outlined in Section 2.3 using the load shape found in Section 22.2 using data from the US Department of Energy's Building America B10 Benchmark load profiles for pool pumps. The profile used to determine demand factors is calculated as the difference of single speed and variable speed profiles. Summer profiles include April through September.

8.7.2.2 Deemed Energy Savings Tables

Table 8.7-3: [Air Purifiers] Energy Savings

CADR Range (CFM)	Dust CADR Midpoint	Energy Savings (kWh)
51-100	75	293
101-150	125	488
151-200	175	683
201-250	225	877
> 250	275	1,072

8.7.2.3 Deemed Demand Savings Tables

Table 8.7-4: [Air Purifiers] Demand Savings

CADR Range (CFM)	NCP	CP	4CP
51-100	0.05	0.03	0.04
101-150	0.09	0.05	0.06
151-200	0.13	0.08	0.08
201-250	0.16	0.10	0.11
> 250	0.20	0.12	0.13

8.7.2.4 Additional Calculators and Tools

- The ENERGY STAR Appliance Savings Calculator, updated October 2016

8.7.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 9 years for air purifiers, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID RES-AirCleaner.[395]

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[395] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

8.7.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Unit quantity
- Manufacturer and model number
- Clean air delivery rate (CADR) in ft^3/min (CFM)
- Proof of purchase with date of purchase, quantity, and model
  - Alternative: photo of unit installed or other pre-approved method of installation verification
- ENERGY STAR certification

8.8 ADVANCED POWER STRIPS

8.8.1 Measure Description

This measure involves the installation of a multi-plug Advanced Power Strip (APS) that can automatically disconnect specific loads depending on the power draw of a specified or “master” load.

In the case of Tier 1 APS, a load sensor in the strip disconnects power from the control outlets when the master power draw is below a certain threshold. This feature allows for a reduction of power draw from peripheral consumer electronics, which usually maintain some load even when in the off or standby position. Thus, when the master device (e.g., television) is turned off, power supply is cut to other related equipment (e.g., set top boxes, speakers, video game consoles, etc.).

Tier 2 APS use an external sensor paired with a configurable countdown timer to manage both active and standby power loads for controlled devices in a complete system. Tier 2 APS may operate either with or without a master control socket. Those without a master control socket sense power of all devices connected to the controlled sockets; those with a master control socket sense power for the device connected to the control socket. The external sensor of a Tier 2 APS may utilize an infrared-only sensor, or it may utilize a “multi-sensor” which detects both infrared (IR) remote control signals and motion to determine device inactivity and deliver additional savings as compared to a Tier 1 APS device. Both versions of external sensor use IR filtering to prevent inappropriate switching events that may have otherwise resulted from natural interference such as sunlight or CFL light bulbs.

8.8.1.1 Eligibility Criteria

This measure applies to all residential applications. For Tier 2 applications, the APS must control at least two audiovisual devices.

8.8.1.2 Baseline Condition

For both Tier 1 and Tier 2 APS, the baseline case is the absence of an APS, where peripherals are plugged into a traditional surge protector or wall outlet.

8.8.1.3 High-Efficiency Condition

The high-efficiency condition is peripheral loads controlled by a Tier 1 or Tier 2 APS.

8.8.2 Energy and Demand Savings Methodology

8.8.2.1 Savings Algorithms and Input Variables

Savings were developed based on reported plug load electricity consumption and hourly use data. A set of home entertainment and home office peripheral equipment and related performance data are presented in the following table. “Daily Standby Hours” and “Daily Off Hours” represent the average number of hours the device is left in standby or off mode. For each device, a weighted watt per hour value is calculated based on projected watts consumed in either mode.

There are two savings paths available for Tier 1. Savings can be estimated by:

1. Complete system type (home entertainment or home office)

2. Per APS for an average complete system if the type is unknown

Tier 2 savings are determined using the average component uses for a complete system and an energy reduction percentage.

Table 8.8-1: [APS] Audio Equipment Watt Consumption Breakdown

System Type	Peripheral Device	Daily Standby Hours	Daily Off Hours	Standby Power (W)	Off Power (W)	Weighted W/hr	Annual APS Hours
Home Entertainment	Audio Equipment: AV Receiver	0.0	18.0	19.2	3.1	3.1	6,570
	Audio Equipment: Speakers	0.0	18.0	3.0	0.0	0.0	6,570
	Audio Equipment: Subwoofer	0.0	18.0	7.8	0.6	0.6	6,570
	Media Player: Blu-ray	2.5	20.8	7.0	0.1	0.8	8,505
	Media Player: DVD	2.5	20.8	5.0	2.0	2.3	8,505
	Media Player: DVD-R	2.5	20.8	7.0	3.0	3.4	8,505
	Media Player: DVD/VCR	2.5	20.4	8.0	4.0	4.4	8,359
	Media Player: VCR	2.2	21.4	6.0	3.0	3.3	8,614
	Set-Top Box: Cable	0.0	16.5	25.0	16.0	16.0	6,023
	Set-Top Box: Cable with DVR	0.0	16.5	45.0	43.0	43.0	6,023
	Set-Top Box: Satellite	0.0	15.1	10.0	15.0	15.0	5,512
	Set-Top Box: Satellite with DVR	0.0	15.1	27.0	28.0	28.0	5,512
	Set-Top Box: Stand Alone DVR	0.0	18.3	27.0	27.0	27.0	6,680
	Television: CRT	0.0	18.7	5.3	1.6	1.6	6,826
	Television: LCD	0.0	18.7	2.2	0.5	0.5	6,826
	Television: Plasma	0.0	18.7	0.9	0.6	0.6	6,826
	Television: Projection	0.0	18.7	4.4	7.0	7.0	6,826
	Video Game Console: Nintendo Wii	1.5	21.4	10.5	1.9	2.5	8,359

System Type	Peripheral Device	Daily Standby Hours	Daily Off Hours	Standby Power (W)	Off Power (W)	Weighted W/hr	Annual APS Hours
	Video Game Console: Wii U	1.5	21.4	34.0	0.4	2.6	8,359
	Video Game Console: PlayStation 2	1.5	21.4	17.0	0.2	1.3	8,359
	Video Game Console: PlayStation 3	1.5	21.4	152.9	1.1	11.0	8,359
	Video Game Console: PlayStation 4	1.5	21.4	137.0	6.4	14.9	8,359
	Video Game Console: XBOX	1.5	21.4	68.0	2.0	6.3	8,359
	Video Game Console: XBOX 360	1.5	21.4	117.5	3.1	10.6	8,359
	Video Game Console: XBOX One	1.5	21.4	112.0	11.9	18.4	8,359

Table 8.8-2: [APS] Home Office Peripheral Watt Consumption Breakdown

System Type	Peripheral Device	Daily Standby Hours	Daily Off Hours	Standby Power (W)	Off Power (W)	Weighted W/hr	Annual APS Hours
Home Office	Computer: Desktop	4.1	16.7	11.6	3.3	4.9	7,592.0
	Computer: Laptop	4.1	16.7	7.6	4.4	5.0	7,592.0
	Computer Monitor: CRT	2.4	16.5	7.6	1.5	2.3	6,898.5
	Computer Monitor: LCD	2.4	16.5	1.9	1.1	1.2	6,898.5
	Computer Speakers	0.0	18.7	3.7	2.3	2.3	6,825.5
	Copier	0.0	23.5	2.8	1.5	1.5	8,577.5
	Fax Machine: Inkjet	0.5	23.3	6.0	5.3	5.3	8,687.0
	Fax Machine: Laser	0.5	23.3	5.3	2.2	2.3	8,687.0
	Printer: Inkjet	4.4	19.5	2.5	1.3	1.5	8,723.5
	Printer: Laser	4.4	19.5	9.0	3.3	4.3	8,723.5
	Scanner	0.0	23.5	3.6	2.1	2.1	8,577.5

Energy Savings

Tier 1

Energy and demand savings for a Tier 1 APS in use in a home office or for a home entertainment system are calculated using the following algorithm, where kWh saved are calculated and summed for all peripheral devices:

$$\Delta kWh = \sum \frac{(W_{device} \times H_{device})}{1,000}$$

Equation 8.8-1

Where:

W = *Weighted watts per hour consumed in standby/off mode for each peripheral device; see Table 8.8-1.*

H = *Annual hours per year controlled by the APS; see Table 8.8-1.*

1,000 = *Constant to convert from watts to kilowatts.*

Tier 2

The energy and demand savings for Tier 2 APS are obtained using the average household entertainment center and home office component usages, multiplied by an energy reduction percentage.

$$\Delta kWh_{Entertainment\ Center} = kWh_{TV} \times ERP \times ISR$$

Equation 8.8-2

$$\Delta kWh_{Computer\ System} = kWh_{Comp} \times ERP \times ISR$$

Equation 8.8-3

$$\Delta kWh_{Unspecified\ Use} = \frac{kWh_{TV} + kWh_{Comp}}{2} \times ERP \times ISR$$

Equation 8.8-4

Where:

kWh_{TV} = *Average annualized energy consumption of Tier 2 qualifying TV systems, default value of 602.8.*[396]

kWh_{Comp} = *Average annualized energy consumption of Tier 2 qualifying computer systems, default value of 197.9.*[397]

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[396] New York State Energy Research and Development Authority (NYSERDA) 2011, Advanced Power Strip Research Report, p. 30. August.

[397] Ibid.

ERP = *Energy Reduction Percentage of qualifying Tier 2 APS product range, (default = 47.5%).*[398]

ISR = *In Service Rate, the percentage of units rebated that are installed, default value of 1.0.*

Demand Savings

Tier 1

Demand savings for a Tier 1 APS in use for a home entertainment system or home office are calculated using the following algorithm, where kWh saved is calculated and summed for all peripheral devices.

$$\Delta \boldsymbol{kW} = \sum \frac{\Delta \boldsymbol{kWh_{device}}}{\boldsymbol{H_{device}}} \times \boldsymbol{DF}$$

Equation 8.8-5

Where:

ΔkWh = *Annual energy savings (kWh) for each peripheral device; see Table 8.8-4.*

H = *Hours per year controlled by the Tier 1 APS; see Table 8.8-1.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 8.8-3.*

Tier 2

Demand savings for a Tier 2 APS are calculated using the average household home office and home entertainment center usages, multiplied by an assumed energy reduction percentage.

$$\Delta \boldsymbol{kW} = \sum \frac{\Delta \boldsymbol{kWh}}{\boldsymbol{H}} \times \boldsymbol{DF}$$

Equation 8.8-6

Where:

ΔkWh = *Annual energy savings (kWh) for each system, as calculated above; see Table 8.8-4 or Table 8.8-5.*

H = *Hours per year that the Tier 2 APS provides savings = 4,380 hours.*[399]

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 8.8-3.*

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[398] Average of ERP from Northeast Energy Efficiency Partnerships (NEEP), "Case Study: Tier 2 Advanced Power Strips and Efficiency Programs." April 2015.

[399] Estimate based on assumption that approximately half of savings are during active hours (assumed to be 5.3 hours/day, 1,936 hours per year (NYSERDA 2011. "Advanced Power Strip Research Report")) and half during standby hours (8,760-1,936 = 6,824 hours). The weighted average is 4,380 hours.

Table 8.8-3: [APS] Demand Factors

Factor Type	DF
NCP	1.000
CP	0.363
4CP	0.202

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Electric Power Research Institute IEPRI) end use load shapes for Residential TV and PC. The inverse of this load shape was used because savings for this measure are achieved when the equipment is in standby mode. The load shape can be found in Section 22.2.

8.8.2.2 Deemed Energy Savings Tables

Table 8.8-4: [APS] Tier 1 Deemed Energy Savings

System Type	kWh Savings
Home Entertainment[400]	269.9
Home Office[401]	87.1
Unspecified System[402]	178.5

Table 8.8-5: [APS] Tier 2 Deemed Energy Savings

System Type	kWh Savings
Home Entertainment	286.3
Home Office	94.0
Unspecified System	190.2

8.8.2.3 Deemed Demand Savings Tables

Table 8.8-6: [APS] Tier 1 Deemed Demand Home Entertainment Savings

System Type	NCP	CP	4CP
Home Entertainment[403]	0.040	0.015	0.008

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[400] Assuming Audio Equipment: AV Receiver, Media Player: Average, Set-Top Box: Average, and Video Game Console: Average.

[401] Assuming Computer: Desktop, Computer Monitor: LCD, Computer Speakers, Printer: Average.

[402] Average of Home Entertainment System and Home Office system averages.

[403] Assuming Audio Equipment: AV Receiver, Media Player: Average, Set-Top Box: Average, and Video Game Console: Average.

System Type	NCP	CP	4CP
Home Office[404]	0.011	0.004	0.002
Unspecified System[405]	0.026	0.009	0.005

Table 8.8-7: [APS] Tier 2 Deemed Demand Savings

System Type	NCP	CP	4CP
Entertainment Center	0.065	0.024	0.013
Computer System	0.021	0.008	0.004
Unspecified Usage	0.043	0.016	0.009

8.8.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

8.8.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years for advanced power strips according to the New York State Energy Research and Development Authority (NYSERDA) Advanced Power Strip Research Report from August 2011.[406]

8.8.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Number of APS installed
- APS type (Tier 1 or Tier 2)
- System Type
- Peripheral Devices
- Proof of purchase including date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification.

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[404] Assuming Computer: Desktop, Computer Monitor: LCD, Computer Speakers, Printer: Average.

[405] Average of Home Entertainment System and Home Office system averages.

[406] New York State Energy Research and Development Authority (NYSERDA) 2011, Advanced Power Strip Research Report, p. 30. August.

8.9 ENERGY STAR® ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE)

8.9.1 Measure Description

This measure applies to the installation of ENERGY STAR-certified Level 2 electric vehicle supply equipment (EVSE) at a residential site. EVSE is the infrastructure that enables plug-in electric vehicles (PEV) to charge onboard batteries. Level 2 EVSE require 240-volt electrical service.

8.9.1.1 Eligibility Criteria

Eligible equipment includes ENERGY STAR-certified Level 2 EVSE installed at a single-family residence.[407] The EVSE may be installed for use on either an all-battery electric vehicle (BEV) or a plug-in hybrid electric vehicle (PHEV). Multifamily buildings are not eligible to use the residential version of this measure.

8.9.1.2 Baseline Condition

The baseline condition is a standard or non-ENERGY STAR-certified Level 2 EVSE.

8.9.1.3 High-Efficiency Condition

The high efficiency condition is an ENERGY STAR-certified Level 2 EVSE.

8.9.2 Energy and Demand Savings Methodology

Savings for this measure are based on efficiency gains of the ENERGY STAR equipment during operating modes when the vehicle is plugged in but not charging and when not plugged in.

8.9.2.1 Savings Algorithms and Input Variables

Energy Savings

Energy savings can be derived by using the following:

$$IC_{ES} = \frac{\left(hr_{plug} \times W_{plug} + hr_{unplug,C} \times W_{unplug}\right) \times days_{C} + hr_{unplug,NC} \times W_{unplug} \times days_{NC}}{1,000}$$

Equation 8.9-1

$$IC_{baseline} = \frac{IC_{ES}}{0.6}$$

Equation 8.9-2

$$kWh_{savings} = IC_{baseline} - IC_{ES}$$

Equation 8.9-3

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[407] ENERGY STAR EVSE qualified product listing: https://www.energystar.gov/productfinder/product/certified-evse/results.

Where:

$IC_{baseline}$ = *Baseline idle consumption (kWh).*

IC_{ES} = *ENERGY STAR idle consumption (kWh).*

hr_{plug} = *Hours per day vehicle is plugged into the EVSE and not charging = 9.3 hours.*[408]

$hr_{unplug,C}$ = *Hours per day vehicle is not plugged into the EVSE on a charging day = 12.3 hours.*[409]

$hr_{unplug,NC}$ = *Hours per day vehicle is not plugged into the EVSE on a non-charging day = 24 hours.*

W_{plug} = *EVSE wattage when vehicle is plugged into EVSE and not charging = 6.9 W.*[410]

W_{unplug} = *EVSE wattage when vehicle is not plugged into EVSE on a non-charging day = 3.3 W.*[411]

$days_C$ = *Number of charging days per year = 321 days.*

$days_{NC}$ = *Number of non-charging days per year = 44 days.*

1,000 = *Constant to convert from watts to kilowatts.*

0.6 = *Efficiency adjustment factor.*[412]

Demand Savings

Demand savings can be derived by using the following:

$$kW_{savings} = \frac{kWh_{savings} \times DF}{365}$$

Equation 8.9-4

Where:

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 8.9-1.*

365 = *Constant to convert from days to years.*

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[408] Idaho National Lab (INL) EV Project, June 2015, "Characterize the Demand and Energy Characteristics of Residential Electric Vehicle Supply Equipment," page 5. A vehicle plugged in for 11.7 hours and charging for 2.4 hours leaves 9.3 hours when it is plugged in and not charging.

[409] INL; 24 hours per day minus 11.7 hours plugged in leaves 12.3 hours unplugged.

[410] Average Idle Mode Input Power from ENERGY STAR-certified EVSE product list as of July 13, 2020.

[411] Average No Vehicle Mode Input Power from ENERGY STAR-certified EVSE product list as of July 13, 2020.

[412] ENERGY STAR Electric Vehicle Chargers Buying Guidance: "ENERGY STAR-certified EV charger… on average use 40% less energy than a standard EV charger when the charger is in standby mode (i.e., not actively charging a vehicle)." https://www.energystar.gov/products/other/evse.

Table 8.9-1: [RES EVSE] Demand Factors[413]

Factor Type	Demand Factor
NCP	0.086
CP	0.043
4CP	0.048

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using hourly wattage load shapes from 3 studies.[414] These load shapes were converted to fractions of daily usage. The resulting delta load shape can be found in Section 22.2.

8.9.2.2 Deemed Energy Savings Tables

Table 8.9-2: [RES EVSE] Energy Savings

Energy Savings (kWh)
24.7

8.9.2.3 Deemed Demand Savings Tables

Table 8.9-3: [RES EVSE] Demand Savings

NCP	CP	4CP
0.00583	0.00291	0.00325

8.9.2.4 Additional Calculators and Tools

This section is not applicable.

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[413] Demand Factors were derived according to the method outlined in Section 2.3 using the load shape found in Section 22.2 using data from the US Department of Energy's Building America B10 Benchmark load profiles for pool pumps. The profile used to determine demand factors is calculated as the difference of single speed and variable speed profiles. Summer profiles include April through September.

[414] Referenced studies include: 1) CCET Wind Integration in ERCOT, 2) Avista Utilities Semi-Annual Report on Electric Vehicle Supply, and 3) Xcel CO EVCS Pilot.

8.9.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years for EVSE based on data from the U.S. Department of Energy Vehicle Technologies Office.[415]

8.9.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- EVSE quantity
- Manufacturer and model number
- Vehicle year, make, and model
- Estimated number of miles driven per day
- ENERGY STAR certification

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[415] "Costs Associated with Non-Residential Electric Vehicle Supply Equipment," U.S. DOE Vehicle Technologies Office, November 2015, p. 21. https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf.

9. RESIDENTIAL: RENEWABLE ENERGY

9.1 SOLAR PHOTOVOLTAIC

9.1.1 Measure Description

This measure involves the installation of a new or expanded residential grid-connected solar photovoltaic (PV) system.

9.1.1.1 Eligibility Criteria

Only PV systems that result in reductions of the customer's purchased energy and/or peak demand qualify for savings. Off-grid systems are not eligible. CPS Energy maintains additional eligibility criteria for participating in the incentive program.

9.1.1.2 Baseline Condition

PV system not currently installed (typical), or an existing system is present but additional generating capacity is added.

9.1.1.3 High-Efficiency Condition

PV system (or additional capacity on an existing system) is installed and operational.

9.1.2 Energy and Demand Savings Methodology

9.1.2.1 Savings Algorithms and Input Variables

Energy and demand savings are derived from meter-based savings validation of CPS Energy's fleet of residential solar energy systems conducted by Frontier Energy in 2021.

Energy Savings

Based on Frontier's 2021 analysis of CPS Energy's residential solar fleet, CPS Energy uses an average annual performance factor of 1,324 kWh per kW_{DC} per year for residential solar energy systems.[416] Thus,

$$\boldsymbol{Annual\ kWh\ savings\ =\ 1,324 \times kW_{DC}\ installed}$$

Equation 9.1-1

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[416] Evaluation, Measurement and Verification of CPS Energy's FY 2015 DSM Programs, June 11, 2015, Frontier Associates.

Where:

kW_{DC} = *Sum of the DC capacity at standard test conditions (STC) of all PV modules installed (or additional capacity installed on existing system). This factor may be reassessed periodically and updated if the composition of installed projects is determined to vary substantially from the assumed fleet-wide average.*

Load Shapes

The annual energy savings performance factor was derived from solar AMI data for commercial systems installed from 2017 through 2020.

The table below lists the percentage of annual kWh applied to each avoided cost period.

Table 9.1-1: [Solar PV] Residential Solar Initiative Allocation of Annual kWh Savings into CPS Energy Avoided Cost Periods

Load Shape Category	Summer On Peak	Summer Mid Peak	Summer Off Peak	Non-Summer Mid Peak	Non-Summer Off Peak
Residential Solar	12.21%	25.95%	0.23%	42.72%	18.89%

9.1.2.2 Deemed Energy Savings Tables

This section is not applicable for this measure.

9.1.2.3 Deemed Summer Demand Savings Tables

Frontier's 2021 analysis of CPS Energy's residential solar fleet produced estimated average performance factors for non-coincident peak (NCP), coincident peak (NCP), and ERCOT TCOS 4CP demand savings. These performance factors were determined by subjecting the residential fleet-wide 8,760 hourly load shape to methods for determining each demand metric:

- Non-Coincident Peak (NCP): CPS Energy uses a non-coincident peak factor of 104.6% (or 1.046) of the total array DC capacity at standard test conditions (STC). This factor represents the maximum hourly kW_{AC} value over the 8,760-hour TMY period, regardless of when it occurred.

$$\boldsymbol{Non\text{-}Coincident\ Peak\ (NCP) savings = 1.046 \times kW_{DC}}$$

Equation 9.1-2

- Coincident Peak (CP): CPS Energy uses a coincident peak factor of 43.3% (or 0.433) of the total array DC capacity at standard test conditions (STC). This factor is calculated as the probability-weighted average kW_{AC} output of a one (1) kW_{DC} "fleet average" residential array over the top 20 hours in a blended TMY weather file determined to be the most likely to coincide with CPS Energy's peak.

$$\boldsymbol{Coincident\ Peak\ (CP)\ savings = 0.433 \times kW_{DC}}$$

Equation 9.1-3

- ERCOT TCOS 4CP: CPS Energy uses an ERCOT TCOS 4CP factor of 36.4% (or 0.364) of the total array DC capacity at standard test conditions (STC). This factor is calculated as the average demand savings of a one (1) kW_{DC} “fleet average” residential array during 20 recent 4CP intervals.

$$\boldsymbol{ERCOT\ TCOS\ 4CP\ savings = 0.364 \times kW_{DC}}$$

Equation 9.1-4

9.1.2.4 Claimed Peak Demand Savings

This section is not applicable for this measure.

9.1.2.5 Additional Calculators and Tools

This section is not applicable for this measure.

9.1.2.6 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 30 years for solar PV. This value is consistent with engineering estimates based on manufacturers' warranties and historical data, and with the EUL reported in the Texas Technical Reference Manual (TRM).

9.1.3 Program Tracking Data & Evaluation Requirements

The following information will be required to be collected for each project.

- Project location (city) and zip code
- Module type: Standard, premium, or thin film
- Array Type: Fixed (open rack), fixed (roof mount), 1-axis tracking, 1-axis backtracking, 2-axis tracking, etc.
- Tilt, azimuth, and DC system size rating at standard test conditions for each array
- Date of PVWatts® run, and PVWatts® report (retained with project documentation) for each array

10. RESIDENTIAL: DEMAND RESPONSE/LOAD CONTROL

10.1 RESIDENTIAL DEMAND RESPONSE

10.1.1 Measure Description

Residential demand response (DR) measures include technologies or programs that enable CPS Energy to reduce aggregate residential customer demand to respond to an electric system need. Most commonly, these technologies include lowering voltage at the transformer level, or controlling thermostats, but may also include controllers for water heaters, pool pumps, room air conditioners, EVs, or other residential loads at the end-user level. There is also a behavioral demand response program covering residential houses that are not in direct load control residential programs. Instead of controlling thermostats or other devices, email and phone call notifications are sent to participants in advance of each event. Participants can also receive a utility bill credit for avoiding EV charging during on-peak time.

10.1.1.1 Eligibility Criteria

Any residential customer with an eligible control technology who is actively enrolled in one of CPS Energy's residential demand response programs. These programs and eligible control technologies/program included the following:

Table 10.1-1: [Demand Response] Programs and Eligible Control Technologies

Program	Eligible Control Technology/Program
Smart Thermostat	Any of several eligible Honeywell thermostats provided and installed by CPS Energy
Mail Me a Thermostat	Any of the eligible Nest thermostats provided (mailed) by CPS Energy in this program
Wi-Fi Thermostat Rewards (or: Bring Your Own Thermostat (BYOT))	Any of several eligible thermostats directly purchased by the customer and installed by the customer • Nest 1st, 2nd, 3rd generation or Nest Thermostat E • Honeywell D6 Pro, FocusPro® (WiFi 6000), VisionPro (WiFi 8000), WiFi 9000, Lyric Round, T5 or T6, Honeywell Home T9, Honeywell Home T10 • ecobee Smart, ecobee3, ecobee 3 lite, ecobee 4 • Emerson Sensi Wi-Fi Thermostat, Emerson Sensi Touch Wi-Fi Thermostat • Alarm.com Radio Thermostat CT-30, CT-80, CT-100, Trane ComfortLink Control, Alarm.com Smart Thermostat • Building36 Intelligent Thermostat • Radio Thermostat CT-30 (WiFi), CT-50 (WiFi), CT-80 (WiFi) • Filtrete™ 3M-50 (WiFi) • Lux Products GEO • Vivint Radio Thermostat CT100 with Vivint Go!Control Panel
Nest DI (direct install)	Nest Thermostat (CPS install)

Program	Eligible Control Technology/Program
Weatherization DR	Any of the eligible Nest Thermostats provided by CPS Energy in the weatherization program
Home Energy Assessment DR	Any of the eligible Nest Thermostats provided by CPS Energy in the Home Energy Assessment program
Reduce My Use/Behavioral Demand Response (BDR)	No device needed; an opt-out randomized control trial (RCT) for residential homes
FlexEV OffPeak Rewards	All participating level 2 EV chargers. Currently, eligible level 2 EV chargers only include Chargepoint and Enel X chargers.

10.1.1.2 Baseline Condition

Customer not enrolled in a residential demand response program.

10.1.1.3 High-Efficiency Condition

Customer enrolled in a residential demand response program.

10.1.2 Energy and Demand Savings Methodology

10.1.2.1 Savings Algorithms and Input Variables

Demand and Energy Savings

Energy (kWh) and demand (kW) savings for FY 2022 and FY 2023 residential DR programs will be estimated using actual AMI or device-level 15-minute interval consumption data. Specifically, for each residential DR program, savings will be estimated as described in the following sections.

Smart Thermostats Winter DR Program

In 2021, a severe winter storm hit Texas from February 13 to 17[417]. Due to surging electricity demand and supply shortage[418], CPS Energy temporarily deployed several winter DR events for both residential and C&I customers from February 14 to 19. Because of frequent power outages, there is no way to confirm whether any activity is due to DR or outages/closures for C&I customers. As a result, this measure will only quantify the savings contributed by residential customers.

Several challenges occurred when quantifying savings for winter DR events. First, residential DR programs were originally designed for load reduction during Texas summer. Therefore, little a priori information is available regarding the expected performance of the residential DR programs during winter events where space heating – not AC – is under control. Secondly, the impacts of the DR programs need to be isolated from the impacts of the outages of service to residential customers that

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[417] https://en.wikipedia.org/wiki/February_13%E2%80%9317,_2021_North_American_winter_storm.

[418] https://www.texastribune.org/2021/03/29/texas-power-outage-ERCOT/.

were due to outages implemented by CPS Energy in response to ERCOT's EEA-3 directives.

Several brands of thermostats participated in the winter DR events, including Honeywell, Emerson, ecobee and Nest. Not all thermostats participated, thus leaving room for identifying control groups. For each event and each device type, a control group was developed with the same thermostat device with power during the event.

To quantify per device kW savings for each thermostat type during each event, the level of energy consumption by participant group is compared to the adjusted control group per device. The adjustment factor applied to the control group is the ratio of energy consumption one hour before the start of each event[419] between participant group and control group. Multiplying per device kW savings by total number of targeted devices yields program level kW savings per event. Multiplying kW savings by event duration yields energy savings.

My Thermostat Rewards Bring Your Own Thermostat (BYOT) Program

Nest, Honeywell, ecobee, Emerson, and Other Thermostats on EnergyHub and Resideo Platforms
Actual aggregated 15-minute interval device-level data stratified by thermostat type from June to September will be used for quantifying thermostat device-level kW demand reduction for residential DR events.

Savings analyses are conducted in the following steps:

Step 1: convert CPS residential DR dashboard interval consumption data into average per device basis and convert AMI raw interval data into average per account basis by each category. Specifically, for each category on residential DR dashboard, divide aggregated interval kW by the corresponding device count, yielding average per device kW. Take the mean kWh of each interval and multiply by 4 for each category, yielding average per account kW for small commercial AMI data customers.

Step 2: for each event, utilize two methodologies - temperature-based regression and CPS "top 3 of 10" analysis, and select the methodology with the lowest RMSE during "test period".

Specifically, for each event, use the event day with the previous 10 eligible days, and use the 11 total days to conduct the following procedures:

(1) Regression: Average per device/account kW is modeled as a function of an event dummy variable indicating whether a time period is within the event period, a precool dummy variable indicating whether a time period is within the 1-hour precool period before each event[420], a snapback dummy variable indicating whether a time period is within the 2-hour snapback period right after each event, a cdh (cooling degree hours, with balance point set as 65 °F) variable, a cdh-squared (cooling degree hours squared, to account for non-linear relationship between temperature an load to some extent) variable, and three time-of-day dummy variables

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[419] Some events were called consecutively, in that case, the adjustment window was the hour before the first event.

[420] *Precool* dummy variable only existed in the regression model for Resideo platform WiFi thermostats. There was no obvious precooling consumption pattern for traditional cycling thermostats and this dummy variable was therefore not included.

indicating time of day – 0:00-6:00, 6:00-12:00, 12:00-18:00 or 18:00-24:00. The model equation can be expressed as follows:

$$kW_t = \beta_0 + \beta_1 \times event_t + \beta_2 \times precool_t + \beta_3 \times snapback_t + \beta_4 \times cdh_t + \beta_5 \times cdh_t^2 + \sum_{i=6}^{8} \beta_i \times time - of - day_t$$

$-\beta_1$ is the estimated kW load reduction per device/account during a certain event with regression method. Similarly, β_2 is the estimated kW precool, and β_3 is the estimated kW snapback per device during a certain event. Net energy savings (kWh) per device/account is calculated as $-\beta_1$ x event duration - $\beta_2 - \beta_3$ x 2 hours.

(2) CPS Energy's high 3-of-10 baseline analysis: This methodology ranks the last ten eligible days based on total kWh during the event period. The three days with the highest kWh during the event period are selected. These three days are then averaged for each interval to create a calculated baseline. An adjustment ratio to the calculated baseline is applied to factor in weather effects and customer operation levels on the event day. In this case, adjustment ratio is calculated as the ratio between the average kW of the event day and the three baseline days during the 1-hour adjustment window immediately preceding the precool period or event period (if there is no precool period). The average kW difference during the event period is the estimated kW savings. The kWh difference during the combination of 1-hour precool period, event period, and 2-hour snapback period is the estimated net kWh savings.

(3) Compare the RMSE (root mean square error) of these two analyses during test period, and select the results generated by the methodology with the lower RMSE. Here, "test period" consists of four separate periods. The first three periods are the event time periods during the "top previous 3 days" (i.e., the three baseline days illustrated in the "high 3-of-10 baseline analysis" section above); the last period is 10:00 am – 2:00 pm during event day. Multiplying per device kW savings by number of end-of-year (EOY) enrolled devices yields EOY kW savings.

Meanwhile, the previous time temperature matrix developed by Frontier will still be used for calculations, simply as a reference and for comparison.

To estimate year-round energy conservation savings attributable to the installation of Nest and ecobee thermostats, Frontier will refer to the deemed savings estimate in Guidebook section 5.9, since Nest thermostat is one of the ENERGY STAR-certified thermostat brands.

Smart Thermostat Program

In FY 2022, all thermostats in the Smart Thermostat program are categorized by dwelling type and cycling strategy as follows:

Table 10.1-2: [Demand Response] Smart Thermostat Dwelling Thermostat Type

Thermostat type	Dwelling type	Cycling strategy
Pager	Residential	33%
		50%
	Commercial	33%
		50%
Wi-Fi	Residential	Resideo
	Commercial	Resideo

Like the kW savings estimation process for BYOT thermostats, actual aggregated 15-minute interval device-level or AMI data stratified by dwelling type and cycling strategy from June to September will be used for quantifying per-device or per-AMI account level kW demand reduction for Smart Thermostat residential DR events. For each event day, the savings analysis is conducted in the same manner as those thermostats in the BYOT program. Multiplying per device kW savings by number of EOY enrollment devices yields EOY kW savings.

Multiplying kW savings by DR event duration (unit: hours) yields gross energy savings. Subtracting potential over-consumption during the pre-cooling or snapback period (if any) from gross energy savings yields net energy savings.

Like some of the thermostats in the BYOT program, previously developed temperature bins for the Smart Thermostat program will be used for reference or comparison calculation.

Nest DI Program, Mail Me a Thermostat Program, Home Energy Assessment Program, Weatherization DR Program

Because Nest thermostats operate in an equivalent manner to those Nest thermostats employed in the BYOT program, demand and energy savings attributable to Nest thermostats deployed within the Nest DI program, Mail Me a Thermostat Program, Home Energy Assessment Program and Weatherization DR program used the methodology described for the BYOT program.

Reduce My Use/Behavioral Demand Response (BDR)

CPS Energy partnered with Opower to implement a pilot behavioral demand response (BDR) program for residential customers beginning in summer 2017. This program was implemented as an opt-out randomized controlled trial (RCT). These participated households were all equipped with AMI meters and did not participate in other CPS Energy DR programs.

Every year, some residential customers are recruited into either treatment group or control group. Each year of new recruitment is called a “wave.” To this point, there are five waves – 2017, 2018, 2019, 2020, and 2021 waves. Treatment group participants receive a welcome letter in May before the program starts each summer. One day before each event day or on the same day before each event, participants receive a notification message through email and phone call. This notification also contains information explaining what a peak day is and personalized energy conservation tips. After each event, customers receive a follow up call. Two weeks later, personalized customer performance feedback is also provided to participants.

A simple difference method is employed for each of the four waves, i.e., savings are estimated as the simple difference between control group and treatment group for each event for this wave:

$$kW\ savings\ per\ participant = control\ group\ kW\ per\ participant - treatment\ group\ kW\ per\ participant$$

FlexEV Rewards Programs

CPS Energy launched two pilot EV charging demand response programs starting June 2021: the FlexEV Smart Rewards program and the FlexEV Off-Peak Rewards program. These two pilot programs will last two years. Customers with an eligible[421] level 2 EV charger can choose to sign up for either program.

FlexEV Smart Rewards Program

For the FlexEV Smart Rewards program, CPS Energy can make remote adjustments to participating EV chargers during the event period. EV chargers can either be turned off or reduced to level 1 charging (charging rate no higher than 1.8 kW). Events can be called from 2-9 pm during weekdays throughout the year. In return, customers receive a $250 utility bill credit and a $5 monthly credit while they remain enrolled in the program.[422] The FlexEV Smart Rewards program events can help soften snap-back from thermostat events (usually around 3-6 pm), as EV charging tends to begin coincidentally with the end of thermostat DR events (usually around 6-7 pm). Currently, there are 62 participants in the Flex EV Smart Rewards program.

Estimating average kW reduction can be a challenge, especially for a first-year pilot program since only limited customers have joined the programs to this point. As of June 2021, only 25 participants had joined the FlexEV Smart Rewards and FlexEV Off-Peak Rewards programs in total. As of October 2021, only 91 participants had joined. As a result, the following methodology is adopted for quantifying pilot program FlexEV Smart Rewards program kW savings per device/charger:

First, check if there is an overall trend for long term behavior change.[423] If there is an indication of long-term behavior change, use methodology #1. If not, adopt methodology #2. The two methodologies are described below:

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[421] Currently, eligible level 2 EV chargers only include Chargepoint and Enel X chargers. The full list of eligible model numbers can be found here: https://www.chargingrewards.com/faqs/cpsenergy/.

[422] https://www.cpsenergy.com/en/about-us/programs-services/electric-vehicles/ev-charging-solutions.html.

[423] It is possible for participants to shift the EV charging load to after 9pm or before 2pm by programming the EV charger, regardless of whether any event is called. In that case, non-event days after the first event might not serve as an optimal baseline because the load during these non-event days might have already been shifted after participants joined the program.

Method #1: Multiple baselining method using previous 10 eligible days[424] as baselines

When no obvious charging behavior change is detected, the eligible days after the initiation of the program can be chosen as potential candidates. Specifically, apply the following baselines:

(1) Average of previous 10 non-event weekdays
(2) Similar day: the non-event weekday with the closest all-day total EV charging amount of energy (kWh)

The baseline with the closest all-day total EV charging is chosen as final baseline. After baseline is determined, kW savings are the difference between baseline kW and event day kW during event period.

Method #2: Regression approach using AMI data

If customers have changed their charging behavior over time after 6/1/2021, data from other sources (in this case, whole house level AMI data) can be used to help quantify kW reduction due to EV charging.

Method #2 uses AMI data and runs the following panel data regression: kWh data as a function of time of day, temperature, day of week, other DR, and program time period (before joining the program, after joining the program on a non-event period, and after joining the program on an event period).

$$kWh_{i,t} = \alpha_i + \sum_{j=1}^{3} \beta_j \times TOD + \sum_{k=4}^{9} \beta_k \times DOW + \beta_{10} \times Other_{DR} + \beta_{11} \times Pre_{Post} \\ + \beta_{12} \times EV\_Event + \beta_{13} \times CDH + \beta_{14} \times HDH$$

Where:

kWh = *AMI household-level 15-minute interval consumption data*

i = *Each participant*

t = *Each 15-minute interval*

TOD = *Time of day; a set of dummy variables indicating time of day – morning (6 am – 12 pm), afternoon (12-6 pm), evening (6 pm – 12 am), and late night (12-6 am)*

DOW = *Day of week; a set of 6 dummy variables indicating day of week*

$Other\_DR$[425] = *Dummy variable; 1 indicates other DR occurring, otherwise 0*

Pre_Post = *Dummy variable; 1 indicates time period after the first EV event is called, 0 indicates time period before the first EV event is called*

EV_Event = *Dummy variable; 1 indicates EV event period, otherwise 0*

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[424] Eligible days are defined as non-event, non-holiday weekdays.

[425] Dummy variable "other-DR" may be a set of dummy variables instead of one single dummy variable, since different other DR programs may be identified and specified in the model, therefore each program may consist of a single dummy variable.

CDH = *Cooling degree hour variable with balance point of 65°F. When temperature is below 65°F, CDH = 0. When above 65°F, CDH is the difference between actual temperature and balance point (65°F). For example, if temperature is 80°F, CDH = 15; if temperature is 55°F, CDH = 0.*

HDH = *Heating degree hour variable with balance point of 65°F. When temperature is above 65°F, HDH = 0. When below 65°F, HDH is the difference between actual temperature and balance point (65°F). For example, if temperature is 80°F, HDH = 0; if temperature is 55°F, HDH = 10.*

The kW savings estimate for EV Smart Rewards program is $-(\beta_{11} + \beta_{12})$. Baseline situation: pre – post dummy = 0, ev – event = 0. EV event period: pre – post dummy = 1, ev – event dummy = 1. The difference between baseline situation and EV event period is $-(\beta_{11} + \beta_{12})$.

Program level achieved, EOY, and incremental CP kW, NCP kW, 4CP kW, and energy (kWh) savings will be estimated in the following manner:

Table 10.1-3: [Demand Response] FlexEV Smart Rewards Program Savings

Savings Type	NCP kW	CP kW	4CP kW	kWh[426]
Achieved savings	Maximum kW savings during any event throughout the year	Average kW savings for events coincided with "peak probability table"	Average kW savings during ERCOT 4CP events, multiplied by success rate	0
EOY savings	Maximum kW savings during any event throughout the year, scaled by EOY participation	Average kW savings for events coincided with "peak probability table", scaled by EOY participation	Average kW savings during ERCOT 4CP events, multiplied by success rate and scaled by EOY participation	0
Incremental savings	Same as EOY NCP kW savings due to first year pilot	Same as EOY CP kW savings due to first year pilot	Same as EOY 4CP kW savings due to first year pilot	0

<u>FlexEV Off-Peak Rewards Program</u>

For the FlexEV Off-peak Rewards program specifically, customers choose to only charge during off-peak hours (after 9pm and before 4pm during non-holiday weekdays), without any direct intervention from CPS Energy. In return, customers receive a $125 utility bill credit and can earn a $10 monthly credit if charging is limited to no more than twice monthly during peak hours. Currently, there are 19

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[426] The general assumption of EV programs is to shift load instead of saving energy.

participants in the Flex EV Off-Peak Rewards program.

Participants are expected to shift charging to off-peak hours after joining the program. Due to the limited pre-enrollment data, whole house level AMI data is used to help quantify kW reduction due to EV charging behavior change.

Specifically, AMI data during 4-9pm (peak period) non-holiday weekdays is used from either 3/1/2021 or the time point customers began the charging behavior in their homes (whichever comes later) until 1/31/2022. This is applied in combination with the following panel data regression: kWh data as a function of temperature, day of week, other DR, and program time period (before and after joining the program).

$$kWh_{i,t} = \alpha_i + \sum_{k=1}^{5} \beta_k \times DOW + \beta_6 \times Other\_DR + \beta_7 \times Pre\_Post + \beta_8 \times CDH + \beta_9 \times HDH$$

Where:

kWh = *AMI household-level 15-minute interval consumption data*

i = *Each participant*

t = *Each 15-minute interval*

DOW = *Day of week; a set of 6 dummy variables indicating day of week*

Other_DR[427] = *Dummy variable; 1 indicates other DR occurring, otherwise 0*

Pre_Post = *Dummy variable; 1 indicates time period after the first EV event is joined, 0 indicates time period before the first EV event is joined*

CDH = *Cooling degree hour variable with balance point of 65 °F. When temperature is below 65 °F, CDH = 0. When above 65 °F, CDH is the difference between actual temperature and balance point (65 °F). For example, if temperature is 80 °F, CDH = 15; if temperature is 55 °F, CDH = 0.*

HDH = *Heating degree hour variable with balance point of 65 °F. When temperature is above 65 °F, HDH = 0. When below 65 °F, HDH is the difference between actual temperature and balance point (65 °F). For example, if temperature is 80 °F, HDH = 0; if temperature is 55 °F, HDH = 10.*

The kW savings estimate for EV Smart Rewards program is $-\beta_7$.

Program level achieved, EOY and incremental CP kW, NCP kW, 4CP kW and energy (kWh) savings will be estimated in the following manner:

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[427] Similar to the FlexEV Smart Rewards Program, dummy variable “other-DR” may be a set of dummy variables indicating different DR programs instead of one single dummy variable.

Table 10.1-4: [Demand Response] FlexEV Off-Peak Rewards Program Savings

Savings Type	NCP kW	CP kW	4CP kW	kWh[428]
Achieved savings	Maximum kW savings during any peak period throughout the year	Average kW savings for days coincided with "peak probability table"	Average kW savings during ERCOT 4CP events	0
EOY savings	Maximum kW savings during any peak period throughout the year, scaled by EOY participation	Average kW savings for days coincided with "peak probability table", scaled by EOY participation	Average kW savings during ERCOT 4CP events, scaled by EOY participation	0
Incremental savings	Same as EOY NCP kW savings due to first year pilot	Same as EOY CP kW savings due to first year pilot	Same as EOY 4CP kW savings due to first year pilot	0

Load Shapes

This section is not applicable.

10.1.2.2 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 1 year for behavioral DR, and for all the other residential demand response measures the EUL is 10 years.

10.1.3 Program Tracking Data & Evaluation Requirements

Inputs and contextual data tracked by the program managers to inform the evaluation and apply the savings properly include:

- For each event, the starting and ending time, ambient temperature, and reason for deployment.
- Program enrollment at the beginning and end of the program year, and during each demand response event, by participant class.
- Aggregated fifteen-minute interval meter data by dwelling type or cycling strategy category.

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[428] The general assumption of EV programs is to shift load instead of saving energy.

11. RESIDENTIAL: NEW CONSTRUCTION

11.1 RESIDENTIAL NEW CONSTRUCTION

11.1.1 Measure Description

This measure involves the inclusion of energy efficient design features in new home construction.

11.1.1.1 Eligibility Criteria

New homes are eligible in the program year in which they are completed. Eligibility is established by building a home whose total source energy use is estimated to be less than that of a home built to IECC 2018 specifications by at least 15 percent.

Builders and homeowners can establish that participating homes meet this target by obtaining a Level 1 certification or higher from Build San Antonio Green. Alternatively, participating homes can document expected savings with simulation software that provides a code compliance report, such as REM/Rate or the International Code Compliance Calculator (IC3) developed and maintained by Texas A&M University's Energy Systems Lab.

11.1.1.2 Baseline Condition

For this program, the baseline is established as a home with the same footprint as the as built home but built to the current code in San Antonio (IECC 2018) according to the requirements of the standard's prescriptive approach to compliance. Efficiency of installed equipment in the baseline home meets the minimum requirements of the federal standards in place in a given program year.

For estimating program savings through building simulation modeling, a reference home model is specified according to the provisions for creating a standard reference design in Section R405 of IECC 2018. Where neither code nor federal manufacturing standards dictate settings for model parameters specified in the reference home, Building America House Simulation Protocols and general knowledge of typical residential sector construction practices are relied upon.

11.1.1.3 High-Efficiency Condition

The high-efficiency condition is the new home as built. CPS Energy's Residential New Construction program promotes a holistic approach to achieving energy efficient homes, including a combination of envelope and equipment-based improvements to reduce home energy use. The energy savings estimations process is designed to efficiently estimate electric energy and demand savings attributable to each participating home.

11.1.2 Energy and Demand Savings Methodology

Savings are achieved by introducing improvements in participating new homes in the following components:

- Building Envelope
- Space Conditioning Equipment
- Domestic Hot Water
- Lighting
- Appliances

Interactions between these various elements confound application of engineering algorithms: therefore, energy and demand savings for the residential new construction measure are estimated by using building simulation modeling.

11.1.2.1 Savings Algorithms and Input Variables

A set of representative models are used: individual participating homes are not modeled for evaluation purposes. These models are built to represent the population of participating homes based on what is known about the techniques being used by participating builders to achieve the program's goals. Builders earning Tier 1 incentives through Build San Antonio Green certification can follow a prescriptive path or a performance path to Level 1 or higher certification. Modeling the prescriptive path is straightforward: the specific requirements for achieving the tiers are specified in the model of the as built home. Builders taking advantage of the performance path also generally apply a standard set of measures. These measures can be simulated: for evaluation of homes submitted via the performance path, evaluation requires development of representative models for each builder.

In addition to variables that are exactly repeated across large numbers of homes, there are some variables for which multiple models will need to be developed to capture the range of possible outcomes:

- Layout: one-story and two-story homes are modeled separately.
- Square Footage: participant homes are binned in 500-square-foot blocks (1,500-2,000 sq. ft., 2,000-2,500, etc.). Achieved Leakage Rate: As this is an outcome, it cannot be pre-determined. Most participating builders are achieving leakage rates between 2 and 4 ACH_{50}. Multiple leakage rates will be applied to representative models to accurately capture the range of savings impacts from the different leakage rates.

Savings are estimated by using load shapes created by simulating the hourly savings for each representative model. Representative model savings are then aggregated to total program savings by multiplying each load shape's values by the number of homes represented by that model and summing these values across all representative models.

Energy Savings

Energy savings is the difference between the expected annual energy use of the as built participating homes and the simulated energy use of homes built with the same footprints as the participating homes but built strictly to the minimum requirements of current code (IECC 2018), modeled as specified above (see Baseline Condition).

Demand Savings

As with energy savings, demand savings is the difference between simulation results for the as built and the reference home models, except that difference is taken only for the specific hours necessary to identify demand savings according to the definitions of the different demand periods (non-coincident peak, coincident peak, and ERCOT 4CP).

Load Shapes

The building energy simulation models used to estimate the savings for this measure are run on hourly time steps, producing 8,760 estimates of hourly energy use for the model year. The load shapes used to estimate demand savings for the residential new construction program are the “delta load shapes” developed by subtracting the whole house energy use in each hour of the simulation of the as built models from the energy use in each corresponding hour of the respective reference home models.

11.1.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy savings.

11.1.2.3 Deemed Summer Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating demand savings.

11.1.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

11.1.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 23 years for residential new construction when reporting whole home savings. Prescriptive savings reported for individual energy efficiency measures should refer to the EUL for each respective measure.

11.1.3 Program Tracking Data & Evaluation Requirements

The evaluation approach requires several data points about participating homes for assigning homes to a given representative home model and for determining additional model permutations. The following data items should be collected and tracked in a program database:

- Builder
- Number of stories
- Conditioned floor area (square feet)
- Incentive achieved (Tier 1)
- Participation path
    - BSAG prescriptive path
    - BSAG performance path
    - Other
- Measured air infiltration rate
- Space conditioning equipment type (CAC with gas furnace or heat pump)
    - Capacity (tons)
    - Cooling efficiency (SEER)
    - Heating efficiency (AFUE/HSPF depending on type)
- Water heater:
    - Fuel type (gas/electric)
    - Storage volume (0 if tankless)
    - EF
- High efficacy lighting installed
    - High efficacy lighting as percent of total
        - CFL/LFL as percent of high efficacy lighting
        - LED as percent of high efficacy lighting
- ENERGY STAR appliances installed
- Additional/unusual features (e.g., solar water heater, rooftop solar PV system, etc.)

12. COMMERCIAL: LIGHTING

12.1 LIGHTING EFFICIENCY

12.1.1 Measure Description

This measure involves the installation of new energy-efficient lamps and/or ballasts because of new construction or the replacement of existing lamps and/or ballasts. The following lighting technologies are covered under this measure:

- Linear Fluorescent T5s, and High-Performance or Reduced Watt T8s. Linear fluorescent measures may also involve delamping[429] with or without the use of reflectors.
- Fluorescent Electrodeless Induction lamps and fixtures.
- Compact Fluorescent Lamp (CFL) screw-based lamps and hard-wired pin-based fixtures.
- Pulse-start Metal Halide (PSMH), Ceramic Metal Halide (CMH), and other High Intensity Discharge (HID) lamps.
- Light Emitting Diode (LED) screw-based lamps and hard-wired LED fixtures.

Energy and demand savings are based on operating hours, demand factors, and changes in pre-existing and post-installation lighting loads as determined by using an approved lighting Standard Fixture Wattage table, available for download from the Texas Efficiency website and in the Fixture Codes tab in the latest version of the Lighting Survey Form (LSF).[430] The LSF is one example of a calculator that is used to determine energy and demand savings. The LSF uses pre- and post-retrofit lighting inventories with the pre-loaded stipulated values and algorithms needed to calculate energy and demand savings. Components of the calculator include:

- Instructions and Project Information.
- Pre- and Post-retrofit lighting inventories. A tab for exempt fixtures, and a description of the exemptions, is also present in this calculator.
- Fixture wattages and descriptions are defined in a Standard Fixture Wattage table.
- Factor Tables that contain stipulated operating hours, peak demand factors, and interactive HVAC factors, control adjustment factors, and new construction lighting power density factors.
- A Summary tab that displays the final energy and demand calculations. The data from this tab also populates the utility program tracking data as the claimed savings values.

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[429] Delamping energy savings are eligible if done in conjunction with T-8 lamp and electronic ballast retrofits.

[430] Maintained by Frontier Energy on behalf of the Electric Utility Marketing Managers of Texas (EUMMOT): http://texasefficiency.com/index.php/regulatory-filings/lighting.

12.1.1.1 Eligibility Criteria

This section describes the system information and certified wattage values that must be used to estimate energy and peak savings from lighting systems installed as part of CPS Energy's energy efficiency programs. The Standard Fixture Wattage table lists the fixture codes and the demand values for use in calculating energy and demand savings for lighting efficiency projects.

Existing lighting fixtures must be removed or demolished in place after retrofit to count toward reduced pre-install wattage. Existing lighting fixtures that remain operable after retrofit should be listed in both the pre- and post-retrofit lighting inventory.

In addition, LED and linear fluorescent T8s need to be qualified as follows:

High-performance (HP) and reduced watt (RW) T8 linear fluorescent lamps need to be qualified by the *Consortium for Energy Efficiency* (CEE). Their respective ballasts need to be qualified by NEMA[431]. See High Efficiency Condition section for additional details.

To qualify, LED lamps and fixtures must have their input power (wattage) and an L^{70} rated life (hours) verified through some combination of the following references: *DesignLights Consortium™ (DLC)*, *ENERGY STAR*, or independent lab testing[432] (e.g., LM-79, LM-80, TM-21, ISTMT). Rated life for LED fixtures should be greater than or equal to 50,000 hours[433] and greater than or equal to 10,000 hours[434] for integrated-ballast LED lamps.

- DLC and ENERGY STAR certified model numbers should closely align with the installed model number. However, small variances are allowed for portions of the model number that may refer to aspects of the fixture that do not affect energy performance (e.g., color temperature, fixture housing). Reported model numbers should always default to the closest match available.
- DLC and ENERGY STAR specifications are periodically updated. Projects may report fixture wattage from older versions of product certifications according to the following certification date guidelines if a copy of the original certification is preserved.
    - New construction: permit date
    - Small business: date of customer acceptance or project proposal
    - All other: installation date
- If a product is available in various length increments but is DLC certified for a specific fixture length, the specified DLC power may be converted to a watts per square foot value to be multiplied against the installed fixture length instead of reporting as a non-qualified fixture.

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[431] While CEE stopped qualifying ballasts in January 2015, the NEMA Premium Electronic Ballast Program has continued to be maintained and is consistent with the prior CEE specifications for high performance lamps and ballasts, tested in accordance with ANSI C82 Standards.

[432] DLC test lab requirements: https://www.designlights.org/solid-state-lighting/qualification-requirements/testing-lab-requirements/.

[433] Equivalent to the L^{70} rated life requirement for all categories as specified in DesignLights Consortium™ (DLC) technical requirements v3.0, representing the point at which the minimum L^{70} was raised to 50,000 hours for all product categories. https://www.designlights.org/solid-state-lighting/qualification-requirements/past-technical-requirements/version-3-0-released-june-23-2015/.

[434] Equivalent to the rated life requirement for all lamps as specified in the ENERGY STAR lamps specification v2.1. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf.

Exempt Lighting for New Construction. Some types of new construction lighting fixtures are exempt from inclusion in the interior lighting demand savings calculation. Exempt fixtures are those that do not provide general/ambient/area lighting, have separate control devices, and are installed in one of the following applications[435]:

1. The connected power associated with the following lighting equipment is not included in calculating total connected lighting power.
    a. Television broadcast lighting for playing areas in sports arenas.
    b. Emergency lighting automatically off during normal building operation.
    c. Lighting in spaces specifically designed for use by occupants with special lighting needs including visual impairment and other medical and age-related issues.
    d. Casino gaming areas.
    e. Mirror lighting in dressing rooms.
2. Task lighting for medical and dental purposes that is in addition to general lighting and controlled by an independent control device.
3. Display lighting for exhibits in galleries, museums, and monuments that is in addition to general lighting and controlled by an independent control device.
4. Lighting for theatrical purposes, including performance, stage, film production, and video production.
5. Lighting for photographic processes.
6. Lighting integral to equipment or instrumentation and installed by the manufacturer.
7. Task lighting for plant growth or maintenance.
8. Advertising signage or directional signage.
9. Lighting for food warming.
10. Lighting equipment that is for sale.
11. Lighting demonstration equipment in lighting education facilities.
12. Lighting approved because of safety considerations.
13. Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions.
14. Furniture-mounted supplemental task lighting that is controlled by automatic shut off.
15. Exit signs.

Non-Qualifying LEDs

This section provides guidance on assessing and calculating nonresidential lighting project savings that include non-qualifying LEDs.

Savings Process

Figure 12.1-1: [Lighting Efficiency] Non-Qualifying LED Process for Lighting Projects summarizes the recommended protocol for lighting system projects with non-qualifying LEDs when square footage

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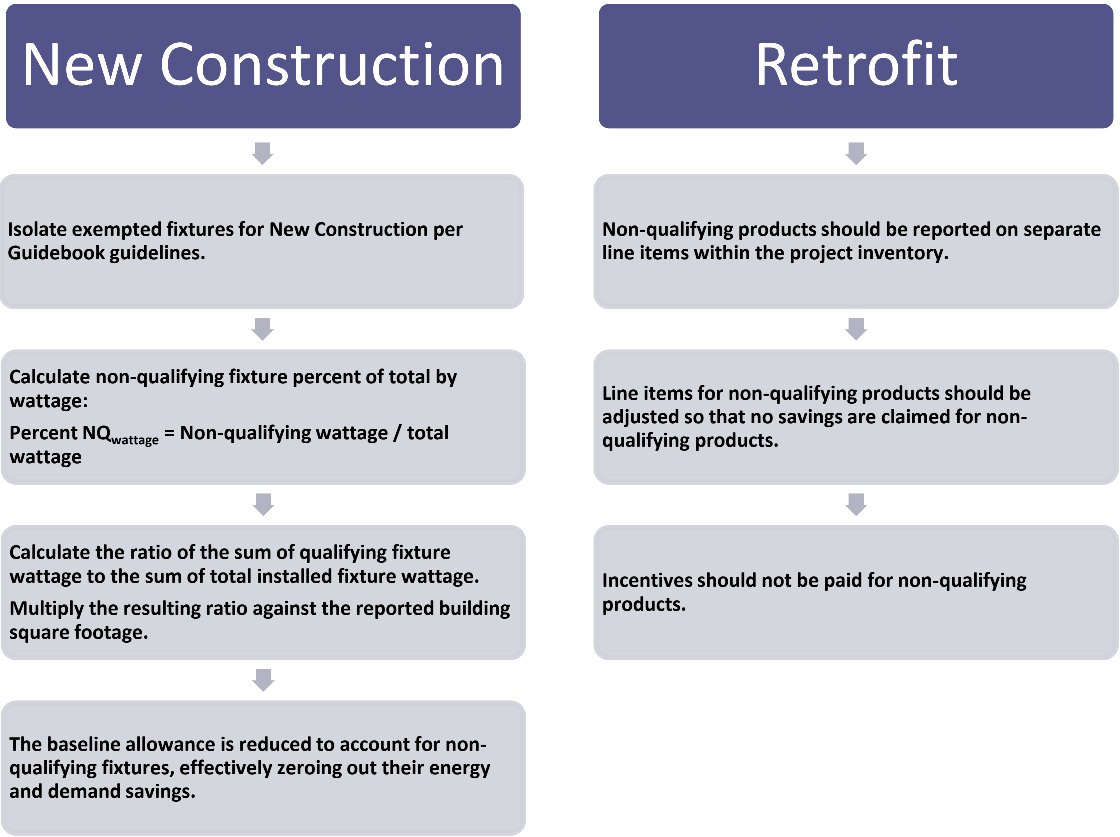
[435] IECC 2018, Section C405.3.1.

cannot be isolated. Additional explanation and criteria for use follows.



New Construction

Isolate exempted fixtures for New Construction per Guidebook guidelines.

Calculate non-qualifying fixture percent of total by wattage:

Percent $NQ_{wattage}$ = Non-qualifying wattage / total wattage

Calculate the ratio of the sum of qualifying fixture wattage to the sum of total installed fixture wattage.

Multiply the resulting ratio against the reported building square footage.

The baseline allowance is reduced to account for non-qualifying fixtures, effectively zeroing out their energy and demand savings.

Retrofit

Non-qualifying products should be reported on separate line items within the project inventory.

Line items for non-qualifying products should be adjusted so that no savings are claimed for non-qualifying products.

Incentives should not be paid for non-qualifying products.

Figure 12.1-1: [Lighting Efficiency] Non-Qualifying LED Process for Lighting Projects

Step 1: Qualify New Construction Projects

Calculate non-qualifying LED project percentage:

- Based as a percentage of demand (Percent $NQ_{wattage}$ = wattage of non-qualifying fixtures / wattage of total fixtures)

Step 2: New Construction Projects

Adjust baseline wattage to account for non-qualifying fixtures.

- List non-qualifying LEDs on separate lines (e.g., separate on lighting inventory worksheet of deemed savings tool). Non-qualifying fixtures are identified by a unique fixture code.
- Adjust code allowable baseline wattage so that non-qualifying fixture wattage is not included as part of the lighting power density (LPD) code limit requirements. To do so, calculate the sum of the qualifying fixture wattage and the sum of the total installed fixture wattage. Take the ratio of qualifying fixture wattage to total fixture wattage and multiply the resulting ratio against the total treated square footage for the space. The adjusted square footage is included as part of the overall LPD calculation and will decrease the total allowable baseline wattage

for the project.

- **Fixture Isolation Method**. If non-qualifying fixtures are isolated to a section of the building whose square footage can be easily segmented from the total building square footage, the non-qualifying fixtures and affected square footage can be excluded from the lighting inventory. Excluded fixtures must be documented when using the fixture isolation method.

Step 3: Retrofit Projects

List non-qualifying LEDs on separate lines (e.g., separate on lighting inventory worksheet of deemed savings tool).

- Include a unique identifier/marker for the non-qualifying LED within the inventory (e.g., fixture code, description, or another designator within deemed savings tool).
- Adjust non-qualifying LED wattage so their demand and energy savings are not included as part of the project savings. Demand and energy savings for non-qualifying LEDs shall result in zero project savings.
- Adjust non-qualifying LED quantities so they are not included as part of the project incentive. Incentives shall not be paid on non-qualifying LEDs.
- Provide clear visibility for all changes within the savings calculation (e.g., deemed savings tool), including changes to all input assumptions and calculation methodologies to implement the above procedure.
- All other savings procedures and requirements as specified within the Guidebook for lighting measures apply to all fixtures of a lighting project.

12.1.1.2 Baseline Condition

The baseline condition or assumed baseline efficiency used in the savings calculations depends on the decision type used for the measure. For new construction, the baseline will be based on a Lighting Power Density (LPD) in watts per square foot by building type, as specified by the relevant energy code/standard applied to a specific project. For retrofit applications, the baseline efficiency would typically reflect the in-situ, pre-existing equipment, except for linear fluorescent T12s and first generation T8s as explained below. Eligible baseline fixture types and wattages are specified in the Standard Fixture Wattages table.

Major renovation projects should use a new construction baseline (for the building type after the improvement) if either of the following conditions are met:

- Building type changes in combination with the renovation.
- Renovation scope includes removing drywall and gutting existing building to the studs.

Linear Fluorescent T12 Special Conditions

The U.S. Energy Policy Act of 1992 (EPACT) set energy efficiency standards that preclude certain lamps and ballasts from being manufactured in or imported into the U.S. The latest standards covering general service linear fluorescents went into full effect July 2014. Under this provision, almost all 4-foot and some 8-foot T12 lamps, as well as first-generation 4-foot, 700 series T8 lamps were prohibited from manufacture. Because all lighting equipment for CPS Energy's energy efficiency programs must be EPACT compliant, including existing or baseline equipment, adjustments were made to the T12 fixture values in the Standard Fixture Wattage table.

As such, 4-foot and 8-foot T12s are no longer an approved baseline technology for CPS Energy's efficiency programs. While 4-foot and 8-foot T12s are still eligible for lighting retrofit projects, an assumed electronic T8 baseline will be used for estimating the energy and demand savings instead of the actual baseline of the existing T12 equipment. T12 fixtures remain in the Standard Fixture Wattage table, but the label for these records now reads "T12 (T8 baseline)" and the fixture wattage for these records reflects the adjusted fixture wattages shown in Table 12.1-1.

Table 12.1-1: [Lighting Efficiency] Adjusted Baseline Wattages for T12 Equipment

T12 Length[436]	Lamp Count	Revised Lamp Wattage	Revised System Wattage
48 inch – Std, HO, and VHO (4-foot bulbs)	1	32	31
	2	32	58
	3	32	85
	4	32	112
	6	32	170
	8	32	224
96 inch – Std (8-foot bulbs) 60/75W	1	59	69
	2	59	110
	3	59	179
	4	59	219
	6	59	330
	8	59	438
96 inch - HO and VHO (8-foot bulbs) 95/110W	1	86	101
	2	86	160
	3	86	261
	4	86	319
	6	86	481
	8	86	638

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[436] Key: HO = high output; VHO = very high output.

T12 Length[436]	Lamp Count	Revised Lamp Wattage	Revised System Wattage
2-foot U-Tube	1	32	32
	2	32	60
	3	32	89

General Service Lamps

The baseline is assumed to be the first tier Energy Independence and Security Act of 2007 (EISA)-mandated maximum wattage for a general service or standard incandescent or halogen lamp; see Table 12.1-2. Baseline wattages should be adjusted as EISA regulations dictate higher efficiency standards. A potential second tier EISA baseline adjustment was scheduled to go into effect beginning January 2020. At that time, general service lamps would need to comply with a 45 lumen-per-watt efficacy standard. However, the Department of Energy (DOE) issued a definition for general service lamps on September 5, 2019, concluding that "no backstop energy conservation has been imposed."[437] Therefore, no additional baseline adjustment will be imposed starting in 2020. However, standard practice must also be considered in determining an appropriate baseline for this measure. To account for a rapidly changing market, measure life assumptions have been reduced as described later in this measure.

Table 12.1-2: [Lighting Efficiency] EISA 2007 Baseline Adjustment for GSILs[438]

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Wattage Pre-EISA 2007	1st Tier EISA 2007 Baseline Wattage
310	749	40	29
750	1,049	60	43
1,050	1,489	75	53
1,490	2,600	100	72

12.1.1.3 High-Efficiency Condition

Eligible efficient fixture types and wattages are specified in the Standard Fixture Wattages table. Some technologies, such as LEDs, must meet the additional requirements specified under Eligibility Criteria.

High-Efficiency/Performance Linear Fluorescent T8s

All 4-foot post-retrofit technologies and new construction projects must use electronic ballasts

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[437] "Energy Conservation Program: Definition for General Service Lamps," Department of Energy. 9/5/2019. https://www.federalregister.gov/documents/2019/09/05/2019-18940/energy-conservation-program-definition-for-general-service-lamps.

[438] Energy Independence and Security Act of 2007. https://www.govinfo.gov/content/pkg/PLAW-110publ140/pdf/PLAW-110publ140.pdf.

manufactured after November 2014,[439] and high performance T8 lamps that are on the T8 Replacement Lamp products list developed by the Consortium for Energy Efficiency (CEE) as published on its website.

If CEE does not have efficiency guidelines for a T8 system (such as for 8-foot, 3-foot, 2-foot, and U-bend T8 products), the product must have higher light output or reduced wattage than its standard equivalent product (minimum efficacy of 75 mean lumens per watt), a color rendering index (CRI) greater than 80, and an average rated life of 24,000 hours at 3 hours per start. In addition, 2-foot and 3-foot systems must also use electronic ballasts manufactured after November 2014.

12.1.2 Energy and Demand Savings Methodology

12.1.2.1 Savings Algorithms and Input Variables

This section describes the deemed savings methodology for both energy and demand savings for all lighting projects. Savings are calculated using separate methods for retrofit and new construction projects.

Retrofit[440,441]

$$\boldsymbol{Energy\ Savings = \left(EAF_{pre} \times kW_{pre} - kW_{installed}\right) \times Hours \times \left(HVAC_{energy}\right) \times ISR}$$

Equation 12.1-1

$$\boldsymbol{Peak\ Demand\ Savings = \left(PAF_{pre} \times kW_{pre} - kW_{installed}\right) \times CF \times (HVAC_{demand}) \times ISR}$$

Equation 12.1-2

New Construction

$$\boldsymbol{Energy\ Savings = \left(\frac{LPD \times FloorArea}{1,000} - kW_{installed}\right) \times Hours \times \left(HVAC_{energy}\right)}$$

Equation 12.1-3

$$\boldsymbol{Peak\ Demand\ Savings = \left(\frac{LPD \times FloorArea}{1,000} - kW_{installed}\right) \times DF \times (HVAC_{demand})}$$

Equation 12.1-4

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[439] Changes to the DOE Federal standards for electronic ballasts effective November 2014 met both the CEE performance specification and the NEMA Premium requirements, so CEE discontinued their specification and qualifying product lists. A legacy ballast list from January 2015 is still available.

[440] Inoperable fixtures are defined as fixtures that are not functional when the existing inventory is recorded or during utility inspection. However, fixtures with subsets of lamps that are both functional and inoperable should not be considered inoperable. The number of allowable inoperable fixtures will be limited to 10% of the total fixture count per facility. For projects where the number of inoperable fixtures exceeds 10%, multiply kW_{pre} by the amount above 10% (inoperable count ÷ total count – 10%).

[441] The energy and demand savings calculations should also account for lighting controls that are present on existing lighting systems. The EAF and PAF factors in the Lighting Controls measure section should be used for these calculations to adjust the deemed hours and peak demand factors on the pre side of the equations. Savings for controls installed on new fixtures are accounted for in the Lighting Controls measure.

Where:

kW_{pre} = *Total kW of existing measure(s) (Approved baseline fixture code wattage from deemed savings tool divided by 1,000 and multiplied by fixture/lamp quantity).*

$kW_{installed}$ = *Total kW of retrofit measure(s) (Verified installed fixture code wattage from deemed savings tool divided by 1,000 and multiplied by fixture/lamp quantity)*[442]*.*

Note: wattage for installed LED fixtures may be rounded up or down to the nearest half watt; all other wattages should be rounded to the nearest watt.

LPD = *Acceptable Lighting Power Density based on building type from efficiency codes from Table 12.1-3 [W/ft²].*

Floor Area = *Floor area of the treated space where the lights were installed.*

Hours = *Hours by building type; see Table 12.1-7.*

DF = *Demand factor by building type for NCP, CP, or 4CP; see Table 12.1-7.*

$HVAC_{energy}$ = *Energy Interactive HVAC factor by building type.*

$HVAC_{demand}$ = *Demand Interactive HVAC factor by building type.*

1,000 = *Constant to convert from watts to kilowatts.*

ISR = *In-Service Rate, the percentage of incentivized units that are installed and in use (rather than removed, stored, or burnt out) to account for units incentivized but not operating = 1.0 unless otherwise specified for upstream/midstream applications; see Table 12.1-9.*

Each of the parameters in these equations, and the approach or their stipulated values, is discussed in detail below.

Note: Using the savings coefficients defined below may result in NCP savings that are lower than CP or 4CP savings for some building types. In those cases, NCP savings should be set to the highest resulting demand savings when comparing NCP, CP, and 4CP demand savings.

Lamp and Fixture Wattages (kW_{pre}, $kW_{installed}$)

Existing Construction: Standard Fixture Wattage Table.[443] Another example of the Standard Fixture Wattages can be found in the Fixtures Codes tab of the latest version of the Lighting Survey Form. This table contains identification codes and demand values (watts) to common fixture types (fluorescent, incandescent, HID, LED, etc.) used in commercial applications. The table is subdivided into lamp types such as linear fluorescent, compact fluorescent, mercury vapor, etc., with each subdivision sorted by fixture code. Each record, or row, in the Table contains a fixture code, which serves as a unique

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[442] Installed fixture wattage for fixtures defined by DLC as having “field-adjustable light output capability under the product features tab should be reported at the “default,” or maximum lumen output, setting. These fixtures may also utilize the Institutional Tuning control type. Field adjustments should be tracked in project inventories and verified with lumen measurements conducted during field inspections.

[443] Maintained by Frontier Energy on behalf of EUMMOT: http://texasefficiency.com/index.php/regulatory-filings/lighting.

identifier. A legend explains the rules behind the fixture codes.

Each record also includes a description of the fixture, the number of lamps, the number of ballasts if applicable, and the fixture wattage. The table wattage values for each fixture type are averages of various manufacturers' laboratory tests performed to ANSI test standards. By using standardized demand values for each fixture type, the table simplifies the accounting procedures for lighting equipment retrofits. The table is updated periodically as new fixtures are added.

New Construction: Lighting Power Density Table. Installed lighting wattages for new construction are determined in the same way as for retrofit or replacement projects (by using the Standard Fixture Wattage table). However, the baseline wattage is determined from the treated floor area and the applicable lighting power density (LPD) value, the allowable watts per square foot of lit floor area as specified by the relevant energy code. The applicable baseline is the code that was in effect at the time of building permit issuance. The current commercial code for the city of San Antonio is IECC 2018. These values are presented in Table 12.1-3 for interior spaces and in Table 12.1-4 for exterior spaces.

In Table 12.1-4 , exterior space types are grouped into four zones:

- Zone 1: Developed areas of national parks, state parks, forest lands, and rural areas.
- Zone 2: Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited night-time use, and residential mixed-use areas.
- Zone 3: All other areas.
- Zone 4: High-activity commercial districts in major metropolitan areas as designated by the local land use planning authority.

Table 12.1-3: [Lighting Efficiency] New Construction LPDs for Interior Space Types by Building Type[444]

Facility Type	Lighting Power Density (W/ft^2)	Facility Type	Lighting Power Density (W/ft^2)
Automotive Facility	0.71	Multifamily	0.68
Convention Center	0.76	Museum	1.06
Courthouse	0.90	Office	0.79
Dining: Bar/Lounge/Leisure	0.90	Parking Garage	0.15
Dining: Cafeteria/Fast Food	0.79	Penitentiary	0.75
Dining: Family	0.78	Performing Arts Theater	1.18
Dormitory	0.61	Police Station	0.80
Exercise Center	0.65	Post Office	0.67
Fire Station	0.53	Religious Building	0.94
Gymnasium	0.68	Retail	1.06

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[444] IECC 2018 Table C405.3.2(1).

Facility Type	Lighting Power Density (W/ft^2)	Facility Type	Lighting Power Density (W/ft^2)
Health Care/Clinic	0.82	School/University	0.81
Hospital	1.05	Sports Arena	0.87
Hotel/Motel	0.75	Town Hall	0.80
Library	0.78	Transportation	0.61
Manufacturing Facility	0.90	Warehouse	0.48
Motion Picture Theater	0.83	Workshop	0.90

The total exterior lighting power allowance for all exterior building applications is the sum of the base site allowance plus the individual allowances for areas that are to be illuminated and are permitted in Table 12.1-4.

Table 12.1-4: [Lighting Efficiency] New Construction LPDs for Exterior Space Types by Building Type[445]

Facility Type	Lighting Power Density (W/ft^2)			
	Zone 1	Zone 2	Zone 3	Zone 4
Base Site Allowance	350 W	400 W	500 W	900 W
Uncovered Parking: Parking Areas and Drives	0.03	0.04	0.06	0.08
Building Grounds: Walkways ≥ 10 ft wide, Plaza Areas, and Special Feature Areas	0.10	0.10	0.11	0.14
Building Grounds: Stairways	0.60	0.70	0.70	0.70
Building Grounds: Pedestrian Tunnels	0.12	0.12	0.14	0.21
Building Grounds: Landscaping	0.03	0.04	0.04	0.04
Building Entrances and Exits: Entry Canopies	0.20	0.25	0.40	0.40
Building Entrances, Exits, and Loading Docks: Loading Docks	0.35	0.35	0.35	0.35
Sales Canopies: Free-standing and Attached	0.40	0.40	0.60	0.70
Outdoor Sales: Open Areas	0.20	0.20	0.35	0.50
Building Facades[446]	--	0.075	0.113	0.150
Entrances and Gatehouse Inspection Stations	0.50	0.50	0.50	0.50
Loading Areas for Emergency Vehicles	0.35	0.35	0.35	0.35

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[445] Ibid.

[446] ASHRAE 90.1-2013 reflects a higher baseline. The Guidebook specifies the higher, more conservative, baseline in order to allow the same LPD to apply to all buildings, regardless of whether they are state funded.

The following default metal halide baseline wattage assumptions have been approved for exterior athletic fields and courts, which are not included in the above LPD table. These baseline wattages were derived based on a review of reported lumen range for available LED products and their reported equivalent metal halide (MH) wattage.

Table 12.1-5: [Lighting Efficiency] New Construction Baseline Wattages for Athletic Field/Court LEDs[447]

Equivalent MH Wattage	# Lamps	LED Lumen Range
175	1	< 7,500
250	1	7,500-12,499
400	1	12,500-19,999
400	2	20,000-39,999
1,000	1	40,000-59,999
1,500	1	60,000-74,999
1,000	2	75,000-99,999
1,000	3	100,000-124,999
1,000	4	125,000-149,999
1,000	5	150,000-199,999
1,000	6 plus 1 additional lamp for every 50,000 lumens above 200,000 (rounded down)	≥ 200,000

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[447] Based on product review of LED replacement high-bay and corn lamp equivalent wattages.

Operating Hours (Hours) and Demand Factors (DFs)

Operating hours and demand factors vary by building type, as shown in Table 12.1-7. The building types used in this table are based on the Commercial Buildings Energy Consumption Survey (CBECS)[448] building types but have been modified for Texas.

The “Manufacturing” building type is specified with 1, 2, and 3 shift options:

- 1 Shift: typical operation of 9.5-11.5 hours per day and 4-6 days per week (< 70 hours per week)
- 2 Shift: typical operation of 18-20 hours per day and 5-6 days per week (70-120 hours per week)
- 3 Shift: typical operation of 24 hours per day and 5-6 days per week (> 120 hours per week)

“Outdoor Dusk-to-Dawn” applies to outdoor fixtures controlled by a photocell or timer with dusk-to-dawn operation throughout the entire year. Outdoor fixtures controlled by timers with less than dusk-to-dawn operation (excluding for athletic fields and courts) may be claimed separately using the “Outdoor Less than Dusk-to-Dawn” building type or using a custom timer schedule.

These tables also include an “Other” building type, which can be used for business types that are not explicitly listed. The Hours and CF values used for Other are the most conservative values from the explicitly listed building types (except for the CF values specified for “Education: K-12 without Summer Session” and “Lodging: Hotel/Motel/Dorm, Common Areas,” which are associated with a very specific operating schedules that experience low coincidence with the summer peak period). When the Other building type is used, a description of the actual building type, the primary business activity, the business hours, and the lighting schedule must be collected for the project site and stored in the utility tracking data system.

The operating hours and peak demand factors specified in this section have been calculated at the facility level and should be applied to the entire facility. Outdoor fixtures that are not associated with the typical building lighting schedule may be claimed separately. These can include parking lot, walkway, wallpack, or other lighting, while building-mounted lighting with an operating schedule that more closely approximates the interior lighting schedule typically should not be claimed separately.

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[448] DOE-EIA Commercial Building Energy Consumption Survey.

Table 12.1-6: [Lighting Efficiency] Building Type Descriptions and Examples

Building Type Code	Principal Building Activity	Definition	Operating Hours
Agriculture	Dairy Buildings	Buildings used to house dairy livestock and collect milk from dairy cows. Buildings used to grow herbs, fruits, or vegetables under artificial lighting.	1) Dairy Buildings
	Grow House		1) 24-Hour Grow House 2) Non 24-Hour Grow House
Data Center	Data Center	Buildings used to house computer systems and associated components.	1) Data Center
Education	College/University	Buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools, and classroom buildings on college or university campuses. Buildings on education campuses for which the main use is not classroom are included in the category relating to their use. For example, administration buildings are part of "Office," dormitories are "Lodging," and libraries are "Public Assembly."	1) College or University 2) Career or Vocational Training 3) Adult Education
	Primary School		1) Elementary or Middle School 2) Preschool or Daycare
	Secondary School		1) High School 2) Religious Education
Food Sales	Convenience	Buildings used for retail or wholesale of food.	1) Gas Station with a Convenience Store 2) Convenience Store
	Supermarket		1) Grocery Store or Food Market
Food Service	Full-Service Restaurant	Buildings used for preparation and sale of food and beverages for consumption.	1) Restaurant or Cafeteria
	Quick-Service Restaurant		1) Fast Food
Healthcare	Hospital	Buildings used as diagnostic and treatment facilities for inpatient care. Buildings used as diagnostic and treatment facilities for outpatient care. Medical offices are included here if they use any type of diagnostic medical equipment (if they do not, they are categorized as an office building).	1) Hospital 2) Inpatient Rehabilitation
	Outpatient Healthcare		1) Medical Office 2) Clinic or Outpatient Health Care 3) Veterinarian

Building Type Code	Principal Building Activity	Definition	Operating Hours
Multifamily	Common Area	Buildings containing Multifamily dwelling units, having multiple stories, and equipped with elevators.	1) Common Area
Lodging	Large Hotel	Buildings used to offer multiple accommodations for short-term or long-term residents.	1) Motel or Inn 2) Hotel 3) Dormitory, Fraternity, or Sorority 4) Retirement Home, Nursing Home, Assisted Living, or other Residential Care 5) Convent or Monastery
	Nursing Home		
	Small Hotel/Motel		
Manufacturing	1 Shift (<70 hr/week)	Buildings used for manufacturing/industrial applications.	1) Apparel 2) Beverage, Food, and Tobacco Products 3) Chemicals 4) Computer and Electronic Products 5) Appliances and Components 6) Fabricated Metal Products 7) Furniture 8) Leather and Allied Products 9) Machinery 10) Nonmetallic Mineral Products 11) Paper 12) Petroleum and Coal Products 13) Plastics and Rubber Products 14) Primary Metals 15) Printing and Related Support 16) Textile Mills 17) Transportation Equipment 18) Wood Products
	2 Shift (70-120 hr/week)		
	3 Shift (>120 hr/week)		

Building Type Code	Principal Building Activity	Definition	Operating Hours
Mercantile	Stand-Alone Retail	Buildings used for the sale and display of goods other than food. Shopping malls comprised of multiple connected establishments.	1) Retail Store 2) Beer, Wine, or Liquor Store 3) Rental Center 4) Dealership or Showroom for Vehicles or Boats 5) Studio or Gallery
	Strip Mall/Enclosed Mall		1) Strip Shopping Center 2) Enclosed Malls
Office	Large Office	Buildings used for general office space, professional office, or administrative offices. Medical offices are included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient health care building).	1) Administrative or Professional Office 2) Government Office 3) Mixed-Use Office 4) Bank or Other Financial Institution 5) Medical Office 6) Sales Office 7) Contractor's Office (e.g., Construction, Plumbing, HVAC) 8) Non-Profit or Social Services 9) Research and Development 10) City Hall or City Center 11) Religious Office 12) Call Center
	Medium Office		
	Small Office		
Parking	Parking Garage	Buildings used for parking applications.	No sub-categories collected.

Building Type Code	Principal Building Activity	Definition	Operating Hours
Public Assembly	Public Assembly	Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls.	1) Social or Meeting (e.g., Community Center, Lodge, Meeting Hall, Convention Center, Senior Center) 2) Recreation (e.g., Gymnasium, Health Club, Bowling Alley, Ice Rink, Field House, Indoor Racquet Sports) 3) Entertainment or Culture (e.g., Museum, Theater, Cinema, Sports Arena, Casino, Night Club) 4) Library 5) Funeral Home 6) Student Activities Center 7) Armory 8) Exhibition Hall 9) Broadcasting Studio 10) Transportation Terminal
Public Order and Safety	Jail and Prison	Government establishments engaged in justice, public order, and safety.	1) Correctional Institutions 2) Prison Administration and Operation
	Other		1) Police Protection 2) Legal Counsel and Prosecution 3) Fire Protection 4) Public Order and Safety, Not Elsewhere Classified
Religious Worship	Religious Worship	Buildings in which people gather for religious activities, (such as chapels, churches, mosques, synagogues, and temples).	No sub-categories collected.

Building Type Code	Principal Building Activity	Definition	Operating Hours
Service	Service	Buildings in which some type of service is provided, other than food service or retail sales of goods.	1) Vehicle Service or Vehicle Repair Shop 2) Vehicle Storage/Maintenance 3) Repair Shop 4) Dry Cleaner or Laundromat 5) Post Office or Postal Center 6) Car Wash 7) Gas Station with no Convenience Store 8) Photo Processing Shop 9) Beauty Parlor or Barber Shop 10) Tanning Salon 11) Copy Center or Printing Shop 12) Kennel
Warehouse	Warehouse	Buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage).	1) Refrigerated Warehouse 2) Non-refrigerated warehouse 3) Distribution or Shipping Center
Other	Other	For building types not explicitly listed.	Values used for Other are the most conservative values from the explicitly listed building types.

Table 12.1-7: [Lighting Efficiency] Operating Hours and Demand Factors by Building Type[449]

Building Type	Operating Hours	Demand Factors[450]		
		NCP	CP	4CP
Agriculture: Long-Day Lighting[451]	6,209	1.00	1.00	1.00
Agriculture: Non-24 Hour Grow Lighting[452]	5,479	1.00	1.00	1.00
Data Centers	4,008	0.85	0.85	0.85
Education: K-12 with Summer Session, College, University, Vocational, and Day Care	3,577	0.90	0.90	0.90
Education: K-12 with Partial Summer Session[453]	3,177	0.90	0.84	0.72
Education: K-12 without Summer Session	2,777	0.90	0.32	0.54
Food Sales: Non-24 Hour Supermarket or Convenience Store	4,706	0.90	0.90	0.90
Food Service: Full-Service Restaurant	4,368	0.90	0.90	0.90
Food Service: Quick-Service Restaurant	6,188	0.90	0.90	0.90
Food Service: 24 Hour Restaurant	7,311	0.90	0.90	0.90
Health Care: Inpatient	5,730	0.90	0.81	0.70
Health Care: Outpatient	3,386	0.90	0.71	0.50
Health Care: Resident Care and Nursing Home	4,271	0.90	0.71	0.50
Lodging: Hotel/Motel/Dorm, Common Area	6,630	0.90	0.90	0.90
Lodging: Hotel/Motel/Dorm, Room	3,055	0.90	0.30	0.30
Manufacturing: 1 Shift (<70 hr/week)	2,786	0.85	0.83	0.85
Manufacturing: 2 Shift (70-120 hr/week)	5,188	0.85	0.85	0.85
Manufacturing: 3 Shift (>120 hr/week)	6,414	0.85	0.85	0.85
Mercantile: Non-24 Hour Stand-Alone Retail	3,668	0.90	0.90	0.90
Mercantile: Enclosed Mall	4,813	0.90	0.90	0.90
Mercantile: Strip Center and Non-Enclosed Mall	3,965	0.90	0.90	0.90
Mercantile/Food Sales: 24 Hour Stand-Alone Retail, Supermarket, or Convenience Store	6,900	0.90	0.90	0.90
Multifamily: Common Area	4,772	0.90	0.90	0.90
Office	3,737	0.90	0.86	0.90
Outdoor: Athletic Field and Court[454]	767	1.00	0.00	0.00

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[449] The operating hours and peak demand factors listed in this table have been calculated at the facility level and should be applied to the entire facility. Outdoor fixtures that are not associated with the typical building schedule may be claimed separately.

[450] Building type operating schedules are adapted from COMNET Appendix C – Schedules (Rev. 3). https://comnet.org/appendix-c-schedules. Updated 7/25/2016.

[451] Daily operating hours are 17 hours/day, 365.25 days/year, for dairy cow housing that implements long daylighting practices. Deemed operating hours are based on assumptions from the MN and WI TRMs and market research indicating 16-18 hours of daily operation.

[452] Daily operating hours are 15 hours/day, 365.25 days/year. Deemed operating hours are based on market research indicating 14-16 hours of daily operation.

[453] Assuming a partial summer session in June with no summer session in July.

[454] "2015 U.S. Lighting Market Characterization," U.S. Department of Energy. November 2017. Value derived by multiplying average daily operating hours (2) by 365.25 hours/year.

Building Type	Operating Hours	Demand Factors[450]		
		NCP	CP	4CP
Outdoor: Billboard[455]	3,470	1.00	0.00	0.00
Outdoor: Dusk-to-Dawn[456]	4,161	1.00	0.00	0.00
Outdoor: Less than Dusk-to-Dawn[457]	1,998	1.00	0.00	0.00
Parking Garage	7,884	1.00	1.00	1.00
Public Assembly	2,638	0.65	0.65	0.65
Public Order and Safety: Jail and Prison	7,264	0.90	0.90	0.90
Public Order and Safety: Other	3,472	0.90	0.71	0.50
Religious Worship	1,824	0.65	0.65	0.65
Service: Excluding Food	3,406	0.90	0.90	0.90
Warehouse: Non-Refrigerated	3,501	0.85	0.79	0.75
Warehouse: Refrigerated	3,798	0.85	0.79	0.75
Other	2,638	0.65	0.65	0.50

Lighting Calculator Building Type

The deemed lighting hours of use (HOU) and peak summer demand factors (DF) for the utility to use in calculating savings associated with lighting are broken down by building type and use. If the building type changes in combination with the retrofit, the selected building type should be consistent with the space condition after improvement. These values are provided in Table 12.1-7. For most of the building types listed in this table, the HOU and CFs were created based on weighted averages of lighting usage across all activity areas of the building.[458] Therefore, the deemed HOU and CFs are representative of an entire building type, across all activity areas that are in a "typical" building for this type.

The following flow chart, Figure 12.1-2: [Lighting Efficiency] Building Type Decision Making, has been provided to assist the utility in understanding how to use the deemed methods for calculating lighting savings based on HOU and CF provided in the Guidebook. Additionally, it provides guidance on how to treat lodging facilities and outdoor lighting projects as well as unique building types.

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[455] Ibid.

[456] This space type refers to fixtures controlled either by photocells or by timers operating on a dusk-to-dawn schedule. Calculated based on average dark hours for Amarillo (northernmost) and Corpus Christi (southernmost) climate zones from sunrise to sunset excluding ½ of civil twilight period. https://www.timeanddate.com/sun/. Note: pending update to US Naval Observatory annual data once website maintenance has completed. http://aa.usno.navy.mil/data/docs/RS_OneYear.php.

[457] This space type refers to fixtures controlled by timers operating on a less than dusk-to-dawn schedule.

[458] More information on how these values were created can be found in PUCT Docket #39146.

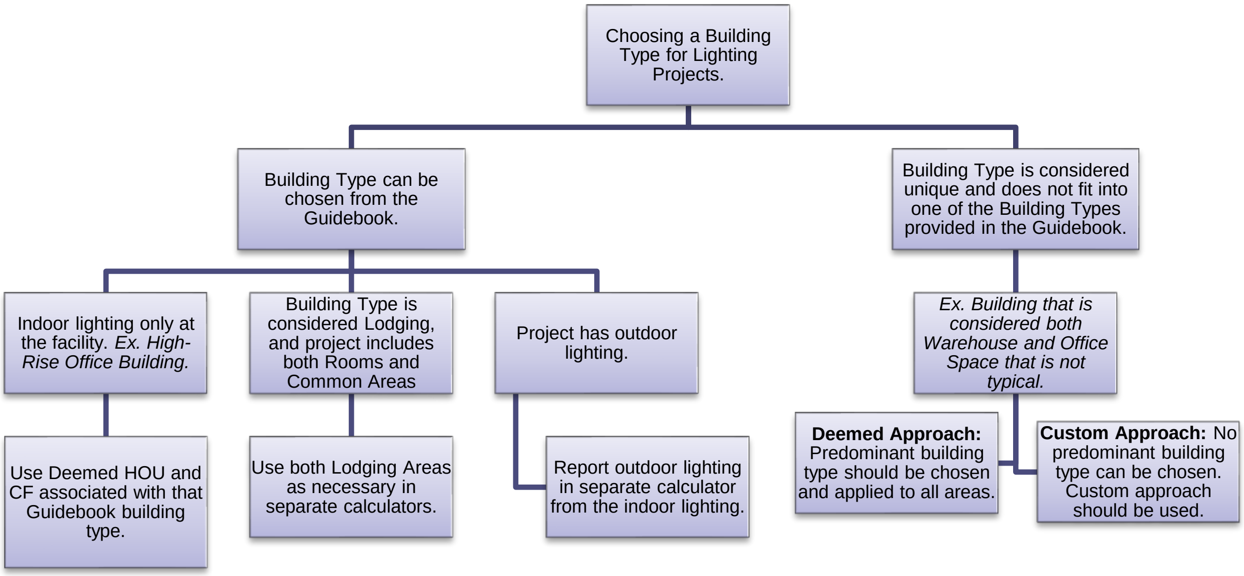

Figure 12.1-2: [Lighting Efficiency] Building Type Decision Making

Lodging sites. Lodging facilities (Hotel/Motel/Dormitories) have been identified in the Guidebook by *Common* and *Rooms*, both with different HOU and CF. As two different values have been provided for these areas, it is acceptable for the utility to use either or both building types for a single project.

Outdoor Lighting Projects that involve outdoor lighting should be claimed in a separate calculator. The exception to this is walkway lighting that is more consistent with building operation. In this application, the utility should use the primary building type as its HOU, and CFs have been rolled up into the overall building type calculations (e.g., walkway lighting between two buildings that operates during business hours).

In situations where multiple Guidebook building types seem plausible, or a predominant building type is unclear, the utility has two choices:

- **Deemed approach**. The deemed approach is a simplified method where the utility should choose a building type based on the “best fit” for the facility. This is determined by the largest interior area for the potential building areas. Although, if that is not the best fit, the utility will use its best judgment in making this decision and provide sufficient, defensible documentation for its decision-making process.
- **Custom approach**. In more unique situations where the deemed building types in the Guidebook may not be representative of the project’s facility type, or where the facility may represent multiple building types without a clear predominant building type (or the use of a predominant building type may be too conservative in the estimate of savings), the utility should consider these projects “custom.” The deemed methods are only applicable to specific scenarios and cannot be developed for all unique situations. The utility should provide sufficient, defensible documentation for its HOU and CF values used in its savings calculations that can be reviewed by the EM&V team.

Interactive HVAC Factors (HVAC energy, demand)

An adjustment to basic lighting savings captures the lighting system interaction with HVAC systems in conditioned or refrigerated spaces. A reduced lighting load reduces the internal heat gain to the building, which reduces the air conditioning/cooling load, but it also increases the heating load. This measure only considers the additional cooling savings, and the heating penalty or increase in usage is ignored.

As Table 12.1-8 shows, four conditioned space types are used. There is a single air-conditioned space type and two options for commercial refrigeration type spaces like walk-in coolers and refrigerated warehouses: medium and low temperature. If the temperature of the actual application falls between these values, then the higher temperature value should be used. The final space type is unconditioned (or more explicitly uncooled as the focus is on cooling). In the lighting calculators, these values are typically assigned at the line-item level based on the conditioning type for the space in which the fixtures are located.

Table 12.1-8: [Lighting Efficiency] Deemed Energy and Demand Interactive HVAC Factors[459]

Space Conditioning Type	Energy Interactive HVAC Factor	NCP Demand Interactive HVAC Factor	CP/4CP Demand Interactive HVAC Factor
Air Conditioned	1.05	1.05	1.10
Med. Temp. Refrigeration (33 to 41°F)	1.25	1.25	1.25
Low Temp. Refrigeration (-10 to 10°F)	1.30	1.30	1.30
None (Unconditioned/Uncooled)	1.00	1.00	1.00

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[459] Petition of Electric Utility Marketing Managers of Texas to Revise Existing M&V Guidelines for Lighting Measures, PUCT Docket No. 39146, from the Petition, Table 7 (page 17) and Table 12 (page 24).

Upstream/Midstream Programs

This section provides guidance on calculating and allocating savings at the sector-level for upstream/midstream lighting programs.

Upstream/Midstream Program Assumptions. For upstream/midstream program delivery, use the following AOH and CF assumptions specified by lamp type. Assumed AOH and CF values have been weighted based on building type survey data from 2012 CBECS[460] and 2014 MECS[461] as well as lamp density and lamp type distribution survey data from the DOE 2015 U.S. Lighting Market Characterization (LMC).[462]

All general service and reflector lamps with an equivalent wattage of 100 W or lower distributed through upstream or midstream programs should calculate savings using a combination of residential and non-residential savings methodologies with 95 percent of savings allocated to the residential sector and the remaining 5 percent of savings allocated to the commercial sector.[463]

Table 12.1-9: [Lighting Efficiency] Midstream Assumptions by Lamp Type[464]

Lamp Type	AOH	Demand Factors			ISR
		NCP	CP	4CP	
General Service Lamp	3,748	0.84	0.68	0.69	0.98
Directional/Reflector	3,774	0.85	0.78	0.76	1.00
LED Tube	3,522	0.86	0.73	0.76	1.00
High Bay Fixture	3,796	0.85	0.77	0.79	1.00
Garage	7,884	1.00	1.00	1.00	1.00
Outdoor	4,161	1.00	0.00	0.00	1.00

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[460] 2012 Commercial Building Energy Consumption Survey (CBECS). https://www.eia.gov/consumption/commercial/. 2018 version not available until mid-2020.

[461] 2014 Manufacturing Energy Consumption Survey (MECS). https://www.eia.gov/consumption/manufacturing/.

[462] 2015 U.S. Lighting Market Characterization, Department of Energy. November 2017. https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

[463] Weighting assumptions based on evaluator review of LED purchasing behavior for similar program designs.

[464] 2012 CBECS and 2014 MECS.

Additionally, baseline wattage for ENERGY STAR qualified products is assumed to be equal to the equivalent wattage from the ENERGY STAR certification. Baseline wattage assumptions for DLC and third-party qualified products should be determined based on product technical specifications and/or delivered light output (lumens) and detailed in the program qualified product listing.

Load Shapes

The demand factors for this measure were derived by using an approach adapted from the method outlined in Section 2.3. First, lighting schedules were extracted from the BEopt energy simulation models developed for the commercial HVAC measures based on Department of Energy (DOE) commercial reference buildings.[465] Next, hourly percentages of lighting in operation were extracted from the lighting schedules. The resulting lighting factors were weighted using the probabilities assigned to each of the top 20 peak hours and 4CP hours. NCP factors match the maximum lighting factor from the lighting schedule for each building type. The lighting load shape schedules can be found in Section 22.2.

12.1.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

12.1.2.3 Deemed Summer Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

12.1.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

12.1.2.5 Measure Life and Lifetime Savings

Estimated useful life (EUL) values are defined for the following lamp/fixture types.[466] A separate new construction EUL has been established to account for the whole-building baseline.

- Halogen Lamps: 1.5 years
- High Intensity Discharge Lamps: 15 years
- Integrated-ballast CCFL Lamps: 4.5 years
- Integrated-ballast CFL Lamps: 2.5 years
- Integral LED Lamps (general service): 9 years[467]
- LED Fixtures: 15 years
- LED Corn Cob Lamps: 15 years

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[465] DOE Commercial Reference Buildings: http://energy.gov/eere/buildings/commercial-reference-buildings.

[466] Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Southwestern Electric Power Company, Texas-New Mexico Power Company, and Southwestern Public Service Company to Revise Existing Estimated Useful Life Values, PUCT Docket No. 36779, (August 27, 2009).

[467] Petition of Electric Utility Marketing Managers of Texas to Establish Installation and Efficiency Standards for Non-Residential LED Technologies, PUCT Docket No. 38023, (June 14, 2010).

- LED Tubes: 15 years
- Modular CFL and CCFL Fixtures: 15 years
- T8 and T5 Linear Fluorescents: 15 years
- New Construction Interior Fixtures/Controls: 14 years[468]
- New Construction Exterior Fixtures: 15 years[469]

12.1.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Decision/action type: retrofit or new construction
- Building or space type
- For new construction projects ONLY:
    - Lighting power density factor
    - Interior and/or exterior space square footage
    - If applicable, verify if SECO compliance certification forms were filed[470]
    - Conditioned space type: cooling equipment type, refrigerated space temperature range, heating fuel type, and % heated/cooled
- Baseline fixture configuration
- Baseline lamp wattage
- Baseline ballast type
- Baseline lighting control type
- Baseline quantity of operating fixtures
- Baseline quantity of inoperable fixtures
- Post-retrofit manufacturer and model number[471]
- Post-retrofit fixture configuration
- Post-retrofit lamp wattage[472]
- Post-retrofit lamp specification sheets
- Post-retrofit ballast type
- Post-retrofit lighting control type
- Post-retrofit quantity of operating fixtures
- For field adjustable light output fixtures ONLY:
    - Isolate these fixtures by setting type and location within reported project inventories and track field adjustment settings
    - Post-retrofit lumen readings for inspection sample

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[468] Based on review of new construction EULs claimed by Texas investor-owned utilities during PY 2019 and 2020, weighted by energy savings.

[469] Ibid.

[470] State-funded buildings are required to submit SECO compliance forms as part of the NC/renovation process. Buildings that submit SECO compliance forms are considered state-funded and must meet the provisions of ASHRAE 90.1-2013 rather than IECC 2015. Previous tables in this section present the alternative compliance values where they are encountered in the codes.

[471] See Eligibility Criteria section for additional information and exceptions related to reporting post-retrofit model number.

[472] See Eligibility Criteria section for additional information and exceptions related to reporting post-retrofit fixture wattage.

- Equipment operating hours
- Lighting measure life category
- For upstream/midstream only: Qualified product list mapping efficient lighting products to baseline wattage assumptions.
- Proof of purchase
    - Retrofit: invoice showing model number, photo of the model number on product packaging and installed fixture, or evaluator pre-approved inspection approach
    - New construction: in addition to the options listed for retrofit projects, as built design drawings or lighting specifications package that provides detailed manufacturer and model number information are also accepted

12.2 LIGHTING CONTROLS

12.2.1 Measure Description

This measure promotes the installation of lighting controls in both new construction and retrofit applications. For retrofit applications, lighting controls would typically be installed where there is no control other than a manual switch (wall or circuit panel). For new construction lighting systems, they would be added where they are not already required by existing energy or building codes. Promoted technologies include occupancy sensors and daylight dimming controls. Energy and peak demand savings are calculated for these technologies via an energy adjustment factor (EAF) for kWh, and a power adjustment factor (PAF) for kW.

12.2.1.1 Eligibility Criteria

Measures installed through utility programs must be one of the occupancy sensor, daylighting, and tuning controls that are described in Table 12.2-1. Savings may be claimed for control types that exceed the minimum code required controls, mainly occupancy sensors for interior spaces.

For new construction applications, lighting systems are required to be installed with controls.[473] For the areas of a building where occupancy sensor control is required, time switch controls may be substituted for occupancy sensor controls.

Exceptions: Lighting controls are not required in the following.

- Areas designated as security or emergency areas that are required to be continuously lighted.
- Interior exit stairways, interior exit ramps, and exit passageways.
- Emergency egress lighting that is normally off.

Occupant sensor controls shall be installed to control lights in the following space types. Lighting controls savings are not allowed for these space types.

- Classrooms/lecture/training rooms
- Conference/meeting/multipurpose rooms
- Copy/print rooms
- Lounges/breakrooms
- Enclosed offices
- Open plan office areas
- Restrooms
- Storage rooms
- Janitorial closets
- Locker rooms
- Other spaces 30 square feet or less that are enclosed by floor-to-ceiling height partitions
- Warehouse storage areas

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[473] IECC 2018, Section C405.

12.2.1.2 Baseline Condition

The baseline condition assumes no existing or code-required (for new construction) automatic lighting controls are installed on the existing lighting fixtures (i.e., they are only manually switched).

For control types that exceed the minimum required control types (usually occupancy sensors or time switch controls), savings can be claimed with the minimum required controls as the baseline efficiency.

12.2.1.3 High-Efficiency Condition

The energy-efficient condition is properly installed (not bypassed or overridden) and calibrated lighting controls that control overhead lighting in a facility based on occupancy, day lighting, or tuning sensors.

12.2.2 Energy and Demand Savings Methodology

12.2.2.1 Savings Algorithms and Input Variables

The equations for lighting controls resemble those used in Section 12.1 for Lighting Efficiency, with the addition of the EAF and PAF multipliers, as shown below. Additionally, the pre/post kW difference is replaced by a single kW value (the total fixture wattage controlled by the device).

$$\boldsymbol{Energy\ Savings = kW_{controlled} \times EAF \times Hours \times HVAC_{energy}}$$

Equation 12.2-1

$$\boldsymbol{Peak\ Demand\ Savings = kW_{controlled} \times PAF \times DF \times HVAC_{demand}}$$

Equation 12.2-2

Where:

$kW_{controlled}$ = *Total kW of controlled fixtures (Fixture wattage from Standard wattage table multiplied by quantity of fixtures).*

$Hours$ = *Hours by building type from Table 12.1-7.*

EAF = *Lighting control Energy Adjustment Factor; see Table 12.2-2.*

PAF = *Lighting control Power Adjustment Factor; see Table 12.2-2.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand by building type; see Table 12.1-7.*

$HVAC_{energy}$ = *Energy Interactive HVAC factor by building type; see Table 12.1-8.*

$HVAC_{demand}$ = *Demand Interactive HVAC factor by building type; see Table 12.1-8.*

See Section 12.1, the Lighting Efficiency, for a full explanation of the non-control variables and their corresponding values. The lighting controls EAFs and PAFs for different building types are presented in Table 12.2-2. The EAF and PAF represent the reduction in energy and demand usage. For example, a factor of 0.24 would equate to 24% energy and demand savings. The same values from the referenced Lawrence Berkeley National Laboratory (LBNL) study are used for both EAF and PAF factors because of the lack of published data for demand factors.

Table 12.2-1: [Lighting Controls] Lighting Control Definitions

Control Type	Description
None	No control
Occupancy	Adjustment of light levels according to the presence of occupants -Wall or Ceiling-Mounted Occupancy Sensors -Integrated Fixture Occupancy Sensors -Time Clocks -Energy Management Systems
Daylighting (Indoor)	Adjustment of light levels automatically in response to the presence of natural light -Photosensors
Outdoor	Outdoor on/off photosensor/time clock controls; no savings attributed because already required by code
Personal Tuning	Adjustment of individual light levels by occupants according to their personal preference; applies to private offices, workstation-specific lighting in open-plan offices, and classrooms -Dimmers -Wireless ON/OFF switches -Personal computer-based controls -Pre-set scene selection
Institutional Tuning	Adjustment of light levels through commissioning or provision of switches or controls for areas or groups of occupants -Dimmable ballasts -On/Off or dimmer switches for non-personal tuning
Multiple Types	Any combination of the types described above

Table 12.2-2: [Lighting Controls] Energy and Power Adjustment Factors[474]

Control Type	Sub-Category	Control Codes	EAF	PAF
None	n/a	None	0.00	0.00
Occupancy	n/a	OS	0.24	0.24
Daylighting (Indoor)	Continuous dimming	DL-Cont	0.28	0.28
	Multiple step dimming	DL-Step		
	ON/OFF	DL-ON/OFF		
Outdoor[475]	n/a	Outdoor	0.00	0.00
Personal Tuning	n/a	PT	0.31	0.31
Institutional Tuning	n/a	IT	0.36	0.36
Multiple/Combined Types	Various combinations	Multiple[476]	0.47	0.47

Load Shapes

Refer to the Lighting Efficiency measure for a description of the load shapes used to estimate demand savings for this measure.

12.2.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

12.2.2.3 Deemed Summer Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

12.2.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

12.2.2.5 Measure Life and Lifetime Savings

Lighting controls savings for interior new construction projects should be claimed at the project level

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[474] Williams, A., Atkinson, B., Garbesi, K., & Rubinstein, F., "A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings." Lawrence Berkeley National Laboratory. September 2011. Table 6, p. 14. Weighted average by number of "reviewed" and "non reviewed" papers.

[475] No control savings are allowed for outdoor controls because they are already required by code. ASHRAE 90.1-1989, Section 6.4.2.8 specifies that exterior lighting not intended for 24-hour continuous use shall be automatically switched by timer, photocell, or a combination of timer and photocell. This is consistent with current specifications in ASHRAE 90.1-2010, Section 9.4.1.3, which specifies that lighting for all exterior applications shall have automatic controls capable of turning off exterior lighting when sufficient daylight is available or when the lighting is not required during nighttime hours.

[476] For multiple control types, specify the installed control types by combining the control codes for the individual control types. Savings factor based on: "Energy Savings from Networked Lighting Control (NLC) Systems," Prepared by Energy Solutions for DesignLights Consortium. September 21, 2017. https://www.designlights.org/lighting-controls/reports-tools-resources/nlc-energy-savings-report/.

(combined fixture and controls savings) using a 14-year estimated useful life (EUL).[477] Lighting controls savings are not eligible for exterior new construction applications.

The EUL is 10 years for retrofit lighting controls, which is consistent with the 2007 GDS Associates Report.[478]

- Occupancy Sensor: 10 years
- Daylighting Control: 10 years
- Time Clock: 10 years
- Tuning Control: 10 years

12.2.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Building type
- Decision/action type: retrofit or new construction
- Conditioned space type: cooling equipment type, refrigerated space temperature range (specified per control)
- Location of controlled lighting: interior or exterior (specified per control)
- Baseline & post-retrofit lighting control type code[479]
- Lighting control mount type: wall, ceiling, integrated fixture, etc.
- Lighting control specification sheets
- Quantity of controlled fixtures/lamps
- Controlled fixture/lamp type
- Controlled fixture/wattage
- Proof of purchase
    - Retrofit: invoice showing model number, photo of the model number on product packaging and installed fixture, or evaluator pre-approved inspection approach
    - New construction: in addition to the options listed for retrofit projects, as built design drawings or lighting specifications package that provides detailed manufacturer and model number information are also accepted

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[477] Based on review of new construction EULs claimed by Texas investor-owned utilities during PY 2019 and 2020, weighted by energy savings.

[478] GDS Associates. Measure Life Report – Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for the New England State Program Working Group (SPWG). June 2007. This report only specifies an EUL for Occupancy Sensors and Photocells, so it is assumed that the same EUL was applied to time clocks. http://library.cee1.org/content/measure-life-report-residential-and-commercialindustrial-lighting-and-hvac-measures.

[479] For a control type that combines multiple features (e.g., occupancy + daylighting), specify the installed control types by combining the control codes for the individual control types.

13. COMMERCIAL: HEATING, VENTILATION & AIR CONDITIONING

13.1 AIR CONDITIONER AND HEAT PUMP TUNE-UPS

13.1.1 Measure Description

This measure applies to direct expansion central air conditioners (AC) and heat pumps (HP) of any configuration where all applicable actions from the checklist below are completed. An AC tune-up involves checking, cleaning, adjusting, and resetting the equipment to factory conditions to restore operating efficiencies closer to as-new performance. This measure applies to all commercial applications.

For this measure, the service technician must complete the following tasks according to industry best practices. To properly assess and adjust the refrigerant charge level, the unit must be operating under significant (normal) cooling load conditions. Therefore, this measure may only be performed for energy savings reporting purposes when the outdoor ambient dry bulb temperature is above 75˚F, and the indoor return air dry bulb temperature is above 70˚F.

Air Conditioner Inspection and Tune-Up Checklist[480]

- Tighten all electrical connections and measure motor voltage and current.
- Lubricate all moving parts, including motor and fan bearings.
- Inspect and clean the condensate drain.
- Inspect controls of the system to ensure proper and safe operation. Check the startup/shutdown cycle of the equipment to ensure the system starts, operates, and shuts off properly.
- Clean evaporator and condenser coils.
- Clean indoor blower fan components.
- Inspect and clean or change air filters; replacement preferred best practice.
- Measure airflow via static pressure across the cooling coil and adjust to manufacturer specifications.
- Check refrigerant level and adjust to manufacturer specifications.
- Check capacitor functionality and capacitance and compare to original equipment manufacturer (OEM) specifications.

13.1.1.1 Eligibility Criteria

All commercial customers are eligible for this measure if they have direct expansion refrigerated air conditioning that has not been serviced in the last 5 years. This measure does not apply to chillers.

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[480] Based on ENERGY STAR HVAC Maintenance Checklist. www.energystar.gov/index.cfm?c=heat_cool.pr_maintenance.

13.1.1.2 Baseline Condition

The baseline is a system with some or all the following issues:

- Dirty condenser coil
- Dirty evaporator coil
- Dirty blower wheel
- Dirty filter
- Improper airflow
- Incorrect refrigerant charge

The baseline system efficiency should be calculated using the following formulas:

$$\boldsymbol{EER_{pre} = (1 - EL) \times EER_{post}}$$

Equation 13.1-1

$$\boldsymbol{HSPF_{pre} = (1 - EL) \times HSPF_{post}}$$

Equation 13.1-2

Where:

EER_{pre} = *Efficiency of the cooling equipment before tune-up.*

EL = *Efficiency loss because of dirty coils, blower, filter, improper airflow, and/or incorrect refrigerant charge = 0.05.*

EER_{post} = *Deemed cooling efficiency of the equipment after tune-up; see Table 13.1-1.*

$HSPF_{pre}$ = *Heating efficiency of the air source heat pump before tune-up.*

$HSPF_{post}$ = *Deemed heating efficiency of air source heat pumps after tune-up; see Table 13.1-1.*

Note: The efficiency loss factor specified above may be replaced with program specific values if an M&V plan and efficiency loss factor derivation are provided to the evaluation team. These factors will be subject to review at the end of each fiscal year and may be revised for the next fiscal year.

Table 13.1-1: [AC/HP Tune-up] Default EER and HSPF per Size Category[481]

Size Category (Btuh)	AC Only Default EER	Heat Pump Default EER	Default HSPF
< 65,000	11.2	11.2	7.7
≥ 65,000 and < 135,000	10.1	9.9	10.9
≥ 135,000 and < 240,000	9.5	9.1	10.6
≥ 240,000 and < 760,000	9.3	8.8	10.6
≥ 760,000	9.0	8.8	10.6

13.1.1.3 High-Efficiency Condition

After the tune-up, the equipment must be clean with airflows and refrigerant charges adjusted as appropriate and set forth above, with the added specification that refrigerant charge adjustments must be within +/- 3 degrees of target sub-cooling for units with thermal expansion valves (TXV) and +/- 5 degrees of target super heat for units with fixed orifices or capillary tubes.

The efficiency standard, or efficiency after the tune-up, is deemed to be the manufacturer specified energy efficiency ratio (EER) of the existing central air conditioner or heat pump, which has been determined by using the following logic and standards. The useful life of an AC unit is 19 years. The useful life of a heat pump is 16 years. Therefore, it is conservatively thought that the majority of existing, functioning units were installed under the federal standard in place between January 23, 2006 and January 1, 2015 for units less than 65,000 Btuh, which set a baseline of 13 SEER and 7.7 HSPF,[482] and prior to January 1, 2010 for units greater than 65,000 Btuh. A 13 SEER is equivalent to approximately 11.2 EER[483] using the conversion developed by Lawrence Berkeley Lab and US DOE: $EER = -0.02 \times SEER^2 + 1.12 \times SEER$. A 3.2 and 3.1 COP is equivalent to approximately 10.9 and 10.6 HSPF respectively using the conversion of $HSPF = 3.412 \times COP$.

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[481] Code specified EER and HSPF value from ASHRAE 90.1-2010 (efficiency value effective January 23, 2006 for units < 65,000 Btu/hr and prior to January 1, 2010 for units ≥ 65,000 Btu/hr). HSPF = COP x 3.412.

[482] Code specified HSPF from federal standard effective January 23, 2006 through January 1, 2015.

[483] Code specified 13 SEER from federal standard effective January 23, 2006 through January 1, 2015, converted to EER using $EER = -0.02 \times SEER^2 + 1.12 \times SEER$. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

13.1.2 Energy and Demand Savings Methodology

13.1.2.1 Savings Algorithms and Input Variables

Savings are based on an assumed efficiency loss factor of 5% because of dirty coils, dirty filters, improper airflow, and/or incorrect refrigerant charge.[484]

Energy Savings

Heating energy savings are only applicable to heat pumps.

$$\boldsymbol{Energy\ Savings\ [kWh_{savings}] = kWh_{Savings,C} + kWh_{Savings,H}}$$

Equation 13.1-3

$$\boldsymbol{Energy\ (Cooling)\ [kWh_{Savings,C}] = Capacity \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right) \times \frac{EFLH_C}{1,000}}$$

Equation 13.1-4

$$\boldsymbol{Energy\ (Heating)\ [kWh_{Savings,H}] = Capacity \times \left(\frac{1}{HSPF_{pre}} - \frac{1}{HSPF_{post}}\right) \times \frac{EFLH_H}{1,000}}$$

Equation 13.1-5

Where:

Capacity = *Rated cooling capacity of the equipment based on model number [Btuh] (1 ton = 12,000 Btuh).*

EER_{pre} = *Cooling efficiency of the equipment pre-tune-up using Equation 13.1-1 [Btuh/W].*

EER_{post} = *Cooling efficiency of the equipment after the tune-up [Btuh/W].*

$HSPF_{pre}$ = *Heating efficiency of the equipment pre-tune-up using Equation 2 [Btuh/W].*

$HSPF_{post}$ = *Heating efficiency of the equipment after the tune-up [Btuh/W].*

EFLHC/H = *Cooling/heating equivalent full-load hours [hours]; see Table 13.2-9 in Section 13.1, Split System/Single Packaged Air Conditioners and Heat Pumps Measure.*

1,000 = *Constant to convert from watts to kilowatts.*

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[484] Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

Demand Savings Algorithms

Summer demand savings are determined by applying a demand factor.

$$\boldsymbol{Summer\ Peak\ Demand}\left[\boldsymbol{kW_{Savings,C}}\right] = \boldsymbol{Capacity} \times \left(\frac{\mathbf{1}}{\boldsymbol{EER_{pre}}} - \frac{\mathbf{1}}{\boldsymbol{EER_{post}}}\right) \times \frac{\boldsymbol{DF}}{\mathbf{1,000}}$$

Equation 13.1-6

Where:

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 13.2-11 through Table 13.2-13 in Section13.2 Split and Packaged Air Conditioners and Heat Pumps.*

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed through adapting NREL's Commercial Reference Building Models[485] for San Antonio. The load shape can be found in Section 22.2.

13.1.2.2 Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

13.1.2.3 Deemed Summer Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

13.1.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

13.1.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 5 years for AC or HP tune-ups. [486]

13.1.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Manufacturer
- Model number
- Cooling capacity of the serviced HVAC unit (tons)

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[485] NREL Commercial Reference Buildings, http://energy.gov/eere/buildings/commercial-reference-buildings.

[486] GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group; Page 1-3, Table 1.

- Heating capacity of the serviced HVAC unit (HP only)
- Type of unit (AC or HP)
- Recommended:
  - Serial number
  - Refrigerant type
  - Target superheat or subcooling
  - Post tune-up superheat or subcooling
  - Amount of refrigerant added or removed
  - Static pressures before and after tune-up
  - Return and supply dry bulb and wet bulb temperatures
  - Before and after tune-up pictures of components illustrating condition change because of cleanings (Note: Pictures that include well-placed familiar objects like hand tools often provide a sense of scale and a reference for color/shading comparisons. Pictures of equipment name plates are useful.)

13.2 SPLIT AND PACKAGED AIR CONDITIONERS AND HEAT PUMPS

13.2.1 Measure Description

This measure involves the installation of air-cooled split system and single packaged air conditioning (AC) and heat pump (HP) systems.

Applicable efficient measure types include:

- Packaged and split air conditioners, direct expansion (DX) or air-cooled
- Packaged and split heat pumps, air-cooled

This document covers assumptions made for baseline equipment efficiencies based on the age of the replaced equipment for:

- Early retirement (ER)
    - Age of the baseline system should be determined from the equipment nameplate or other physical documentation whenever possible
- Replace-on-burnout (ROB)
- New construction (NC) based on efficiency standards.

If the actual age of the unit is unknown, default values are provided.

Savings calculations incorporate the use of both full-load and part-load efficiency values.

13.2.1.1 Eligibility Criteria

For a measure to be eligible to use this deemed savings approach, the following conditions must be met:

- The existing and proposed cooling equipment are electric.
- The building falls into one of the categories listed in Table 22.5-1. Building type descriptions and examples are provided in Table 22.4-1.
- ER projects involve the replacement of a working system. The ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. An ROB approach should be used for these scenarios.
- Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[487,488]

13.2.1.2 Baseline Condition

The baseline conditions related to efficiency and system capacity for ER and ROB/NC are as follows:

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[487] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.

[488] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.

Early Retirement

ER systems involve the replacement of a working system, prior to natural burnout. The ER baseline cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred.

Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL-RUL) period. For the ROB period, the baseline efficiency is the same as for an ROB/NC scenario. For the ER period, the baseline efficiency should be estimated according to the capacity, system type, and age (based on year manufactured) of the replaced system. When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), use the baseline efficiency levels provided in Table 13.2-1 through Table 13.2-5. If individual system components were installed at different times, use the condenser age as a proxy for the entire system. When the system age is unknown, assume a default value equal to the EUL. This corresponds to an age of 15 years. A default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

Baseline efficiency levels are specified based on assumptions of the predominant heating section types. For air conditioners, baseline cooling efficiencies are specified for a natural gas furnace heating section type. For heat pumps, baseline cooling efficiencies are specified for electric resistance supplemental heating section type.

Table 13.2-1: [Split/Packaged ACs & HPs] ER Baseline Full-Load Efficiency for ACs

Year Installed (Replaced System)	Split Systems < 5.4 tons [EER][489]	Package System < 5.4 tons [EER][490]	All Systems 5.4 to < 11.3 tons [EER]	All Systems 11.3 to < 20 tons [EER]	All Systems 20 to < 63.3 tons [EER]	All Systems ≥ 63.3 tons [EER]
≤ 2005	9.2	9.0	10.1	9.5	9.3	9.0
2006 – 2009	11.2	11.2	10.1	9.5	9.3	9.0
2010 – 2015	11.2	11.2	11.0	10.8	9.8	9.5
≥ 2016	11.2	11.8	11.0	10.8	9.8	9.5

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[489] The standards do not include an EER requirement for this size range, so the code specified SEER value was converted to EER using EER = -0.02 x $SEER^2$ + 1.12 x SEER. National Renewable Energy Laboratory (NREL). “Building America House Simulation Protocols.” U.S. Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

[490] Ibid.

Table 13.2-2: [Split/Packaged ACs & HPs] ER Baseline Part-Load Efficiency for ACs

Year Installed (Replaced System)	Split Systems < 5.4 tons [SEER]	Package System < 5.4 tons [SEER]	All Systems 5.4 to < 11.3 tons [IEER]	All Systems 11.3 to < 20 tons [IEER]	All Systems 20 to < 63.3 tons [IEER]	All Systems ≥ 63.3 tons [IEER]
≤ 2005	10.0	9.7	10.3	9.7	9.4	9.1
2006 – 2009	13.0	13.0	10.3	9.7	9.4	9.1
2010 – 2015	13.0	13.0	11.2	11.0	9.9	9.6
≥ 2016	13.0	14.0	12.6	12.2	11.4	11.0

Table 13.2-3: [Split/Packaged ACs & HPs] ER Baseline Full-Load Cooling Efficiency for HPs

Year Installed (Replaced System)	Split Systems < 5.4 tons [EER][491]	Package System < 5.4 tons [EER][492]	All Systems 5.4 to < 11.3 tons [EER]	All Systems 11.3 to < 20 tons [EER]	All Systems 20 to < 63.3 tons [EER]	All Systems ≥ 63.3 tons [EER]
≤ 2005	9.2	9.0	9.9	9.1	8.8	8.8
2006 – 2009	11.2	11.2	9.9	9.1	8.8	8.8
2010 – 2015	11.2	11.2	10.8	10.4	9.3	9.3
≥ 2016	11.8	11.8	11.0	10.6	9.5	9.5

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[491] The standards do not include an EER requirement for this size range, so the code specified SEER value was converted to EER using $EER = -0.02 \times SEER^2 + 1.12 \times SEER$. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

[492] Ibid.

Table 13.2-4: [Split/Packaged ACs & HPs] ER Baseline Part-Load Cooling Efficiency for HPs

Year Installed (Replaced System)	Split Systems < 5.4 tons [SEER]	Package System < 5.4 tons [SEER]	All Systems 5.4 to < 11.3 tons [IEER]	All Systems 11.3 to < 20 tons [IEER]	All Systems 20 to < 63.3 tons [IEER]	All Systems ≥ 63.3 tons [IEER]
≤ 2005	10.0	9.7	10.1	9.2	8.9	8.9
2006 – 2009	13.0	13.0	10.1	9.2	8.9	8.9
2010 – 2015	13.0	13.0	11.0	10.5	9.4	9.4
≥ 2016	14.0	14.0	12.0	11.6	10.6	10.6

Table 13.2-5: [Split/Packaged ACs & HPs] ER Baseline Heating Efficiency for HPs

Year Installed (Replaced System)	Split Systems < 5.4 tons [HSPF]	Package System < 5.4 tons [HSPF]	All Systems 5.4 to < 11.3 tons [COP]	All Systems ≥ 11.3 tons [COP]
≤ 2005	6.8	6.6	3.2	3.1
2006 – 2009	7.7	7.7	3.2	3.1
2010 – 2015	7.7	7.7	3.3	3.2
≥ 2016	8.2	8.0	3.3	3.2

Replace-on-Burnout and New Construction

These baseline efficiency levels reflect the latest minimum efficiency requirements from the current federal manufacturing standard and IECC 2018.

For air conditioners, baseline cooling efficiencies are specified for a natural gas furnace heating section type. For heat pumps, baseline cooling efficiencies are specified for electric resistance supplemental heating section type. For all other heating section types, or for no heating section type, the baseline efficiencies may need to be adjusted as specified by the footnotes in the tables.

Table 13.2-6: [Split/Packaged ACs & HPs] Baseline Efficiencies for ROB and NC Air Conditioners and Heat Pump[493]

System Type	Capacity [Tons]	Baseline Efficiencies
Air Conditioner	< 5.4	11.2 EER (split)[494] 13.0 SEER (split) 11.8 EER (packaged)[495] 14.0 SEER (packaged)
	5.4 to < 11.3	11.0 EER 12.6 IEER
	11.3 to < 20	10.8 EER 12.2 IEER
	20 to < 63.3	9.8 EER 11.4 IEER
	≥ 63.3	9.5 EER 11.0 IEER
Heat Pump (cooling)	< 5.4	11.8 EER[496] 14.0 SEER
	5.4 to < 11.3	11.0 EER 12.0 IEER
	11.3 to < 20	10.6 EER 11.6 IEER
	≥ 20	9.5 EER 10.6 IEER
Heat Pump (heating)	< 5.4	8.2 HSPF (split)
		8.0 HSPF (packaged)
	5.4 to < 11.25	3.3 COP
	≥ 11.3	3.2 COP

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[493] International Energy Conservation Code 2018.

[494] There is no code specified EER for this size category. The code specified SEER value was converted to EER using $EER = -0.02 \times SEER^2 + 1.12 \times SEER$ for systems < 5.4 tons. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

[495] IECC 2018 Table C403.2.3(1) and C403.2.3(2).

[496] Ibid.

For NC, ROB, and ER applications where a variable refrigerant flow (VRF) system is installed, use the corresponding baseline efficiency for a packaged system of the same tonnage range.

13.2.1.3 High-Efficiency Condition

Split and packaged systems must exceed the minimum efficiencies specified in Table 13.2-6. Split system efficiencies are driven primarily by the efficiency of the condenser unit. If the paired outdoor and indoor units are not listed on the AHRI certification listing and only provide DOE CCMS testing results, then the capacity and efficiency of the high-efficiency condition shall not exceed the average of the AHRI certification listing pairing for the matching condenser. The DOE CCMS listing provides documentation of the results that are on the AHRI certification listing and can be downloaded and filtered based on listing using a similar condenser and various indoor units.

For reference, both ENERGY STAR[497] and the Consortium for Energy Efficiency (CEE)[498] offer suggested guidelines for high-efficiency equipment. Additional conditions for ER, ROB, and NC are as follows:

New Construction and Replace-on-Burnout

This scenario includes equipment used for NC and retrofit/replacements that do not satisfy the ER criteria, such as units that are replaced after natural failure.

Early Retirement

The high-efficiency retrofits must meet the following criteria:

- For ER projects only, the installed equipment cooling capacity must be less than 120% of the replaced electric cooling capacity
- If the cooling capacity of the installed equipment decreases by more than 20% of the existing cooling capacity, the cooling capacity of the existing equipment used for calculating savings will be capped at 20% above the installed equipment cooling capacity
- For scenarios involving the replacement of a combination of systems by an alternate combination of systems of varying capacities, ER savings can still be claimed if the overall pre and post capacities for the total combination of systems are within +/- 20%. In these cases, a custom calculation should be performed to establish the following weighted savings factors to be applied over the ER portion of the savings calculation: manufacturer year, EUL, RUL, full and part-load baseline efficiency, demand factor, and EFLH. These factors should be weighted based on contribution to overall capacity.
- No additional measures may be installed that directly affect the operation of the cooling equipment (i.e., control sequences, cooling towers, and condensers).

The first-year savings algorithms in the above equations are used for all HVAC projects, across NC, ROB, and ER projects. However, ER projects require a weighted savings calculated over both the ER and ROB

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[497] ENERGY STAR Heating & Cooling, https://www.energystar.gov/products/heating_cooling.

[498] CEE Program Resources, http://www.cee1.org/content/cee-program-resources.

periods taking the EUL and RUL into account. The ER savings are applied over the remaining useful life (RUL) period, and the ROB savings are applied over the remaining period (EUL-RUL). The final reported savings for ER projects are not actually “first-year” savings, but “average annual savings over the lifetime (EUL) of the measure.” These savings calculations are explained in Appendix 22.3.

13.2.2 Energy and Demand Savings Methodology

13.2.2.1 Savings Algorithms and Input Variables

Energy Savings

$$\boldsymbol{Energy\ Savings\ \left[kWh_{savings}\right] = kWh_{Savings,C} + kWh_{Savings,H}}$$

Equation 13.2-1

$$\boldsymbol{Energy\ (Cooling)\ \left[kWh_{Savings,C}\right] = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}}\right) \times \frac{EFLH_C}{1,000}}$$

Equation 13.2-2

$$\boldsymbol{Energy\ (Heating)\ \left[kWh_{Savings,H}\right] = \left(\frac{Cap_{H,pre}}{\eta_{baseline,H}} - \frac{Cap_{H,post}}{\eta_{installed,H}}\right) \times \frac{EFLH_H}{3,412}}$$

Equation 13.2-3

Demand Savings

$$\boldsymbol{Demand\ [kW_{Savings,C}] = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}}\right) \times \frac{DF}{1,000}}$$

Equation 13.2-4

Where:

$Cap_{C/H,pre}$ = *For ER, rated equipment cooling/heating capacity of the existing equipment at AHRI standard conditions; for ROB & NC, rated equipment cooling/heating capacity of the new equipment at AHRI conditions [Btuh]; 1 ton = 12,000 Btuh.*

$Cap_{C/H,post}$ = *Rated equipment cooling/heating capacity of the newly installed equipment at AHRI standard conditions [Btuh]; 1 ton = 12,000 Btuh.*

$\eta_{baseline,C}$ = *Cooling efficiency of existing equipment (ER) or standard equipment (ROB/NC) [Btuh/W].*

$\eta_{installed,C}$ = *Rated cooling efficiency of the newly installed equipment [Btuh/W]. Efficiency rating must exceed ROB/NC baseline efficiency standards in Table 13.2-6.*

$\eta_{baseline,H}$ = *Heating efficiency of existing equipment (ER) or standard equipment (ROB/NC) [COP].*

$\eta_{installed,H}$ = *Rated heating efficiency of the newly installed equipment (Must exceed baseline efficiency standards in Table 13.2-6) [COP].*

Note: Use EER for kW savings calculations and SEER/IEER and COP for kWh savings calculations. The COP expressed for units > 5.4 tons is a full-load COP. Heating efficiencies expressed as HSPF will be approximated as a seasonal COP and should be converted by using the following equation:

$$COP = \frac{HSPF}{3.412}$$

Equation 13.2-5

DF = *Demand factor (NCP, CP, or 4CP) for appropriate building type and equipment type; see Table 13.2-11 through Table 13.2-13.*

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours for appropriate building type and equipment type [hours]; see Table 13.2-9.*

1,000 = *Constant to convert from watts to kilowatts.*

3,412 = *Constant to convert from Btu to kWh.*

System Type Conversion

Chiller to AC: Conversions from chiller-based systems to a split/packaged AC system are covered under this measure. The reference tables in the HVAC Chillers measure for the savings.

AC to Heat Pump: Conversions from AC to HP are acceptable in commercial applications. Use CAP_H, $\eta_{baseline,H}$, DF_H, and $EFLH_H$ values for the new HP as a proxy for the baseline AC heating savings coefficients.

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed through adapting NREL's Commercial Reference Building Models[499] for San Antonio. The load shape can be found in Section 22.2.

13.2.2.2 Deemed Energy Savings Tables

Table 13.2-9 contains the effective full load hours for commercial air conditioners and heat pumps for various building types in San Antonio. These building types are derived from the EIA CBECS study.[500]

The DF and EFLH values for packaged and split AC and HP units also include an "Other" building type, which can be used for business types that are not explicitly listed. The DF and EFLH values used for Other are the

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[499] NREL Commercial Reference Buildings, http://energy.gov/eere/buildings/commercial-reference-buildings.

[500] The Commercial Building Energy Consumption Survey (CBECS) implemented by the US Energy Information Administration includes a principal building activity categorization scheme that separates the commercial sector into 29 categories and 51 subcategories based on principal building activity (PBA). For its purposes, the CBECS defines commercial buildings as those buildings greater than 1,000 square feet that devote more than half of their floorspace to activity that is neither residential, manufacturing, industrial, nor agricultural. The high-level building types adopted for the Guidebook are adapted from this CBECS categorization, with select building types added/removed. https://www.eia.gov/consumption/commercial/.

most conservative values from the explicitly listed building types. When the Other building type is used, a description of the actual building type, the primary business activity, the business hours, and the HVAC schedule must be collected for the project site and stored in the utility tracking data system.

For those combinations of technology and building type where no values are present, a project with that specific combination should use the "Other" building type.

Table 13.2-7: [Split/Packaged ACs & HPs] Commercial HVAC Building Type Descriptions and Examples

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[501]
Data Center	Data Center	Buildings used to house computer systems and associated components.	• Data Center
Education	College	Buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools, and classroom buildings on college or university campuses. Buildings on education campuses for which the main use is not classroom are included in the category relating to their use. For example, administration buildings are part of "Office," dormitories are "Lodging," and libraries are "Public Assembly."	• College or University • Career or Vocational Training • Adult Education • Elementary or Middle School • Preschool or Daycare • High School • Religious Education
	Primary School		
	Secondary School		
Food Sales	Convenience	Buildings used for retail or wholesale of food.	• Gas Station with a Convenience Store • Convenience Store • Grocery Store or Food Market
	Supermarket		
Food Service	Full-Service Restaurant	Buildings used for preparation and sale of food and beverages for consumption.	• Restaurant or Cafeteria • Fast Food
	Quick-Service Restaurant		
Healthcare	Hospital	Buildings used as diagnostic and treatment facilities for inpatient care.	• Hospital • Inpatient Rehabilitation • Medical Office • Clinic or Outpatient Health Care • Veterinarian
	Outpatient Healthcare	Buildings used as diagnostic and treatment facilities for outpatient care. Medical offices are included here if they use any type of diagnostic medical equipment (if they do not, they are categorized as an office building).	
Large	Midrise	Buildings containing multifamily	No sub-categories collected.

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[501] Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[501]
Multifamily	Apartment	dwelling units, having multiple stories, and equipped with elevators.	
Lodging	Large Hotel	Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings.	• Motel or Inn • Hotel • Dormitory, Fraternity, or Sorority • Retirement Home, Nursing Home, Assisted Living, or other Residential Care • Convent or Monastery
	Nursing Home		
	Small Hotel/Motel		
Mercantile	Stand-Alone Retail	Buildings used for the sale and display of goods other than food. Shopping malls comprised of multiple connected establishments.	• Retail Store • Beer, Wine, or Liquor Store • Rental Center • Dealership or Showroom for Vehicles or Boats • Studio or Gallery • Strip Shopping Center • Enclosed Malls
	Strip Mall		
Office	Large Office	Buildings used for general office space, professional office, or administrative offices. Medical offices are included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient health care building).	• Administrative or Professional Office • Government Office • Mixed-Use Office • Bank or Other Financial Institution • Medical Office • Sales Office • Contractor's Office (e.g., Construction, Plumbing, HVAC) • Non-Profit or Social Services • Research and Development • City Hall or City Center • Religious Office • Call Center
	Medium Office		
	Small Office		

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[501]
Public Assembly	Public Assembly	Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls.	• Social or Meeting (e.g., Community Center, Lodge, Meeting Hall, Convention Center, Senior Center) • Recreation (e.g., Gymnasium, Health Club, Bowling Alley, Ice Rink, Field House, Indoor Racquet Sports) • Entertainment or Culture (e.g., Museum, Theater, Cinema, Sports Arena, Casino, Night Club) • Library • Funeral Home • Student Activities Center • Armory • Exhibition Hall • Broadcasting Studio • Transportation Terminal
Religious Worship	Religious Worship	Buildings in which people gather for religious activities, (such as chapels, churches, mosques, synagogues, and temples).	No sub-categories collected.
Service	Service	Buildings in which some type of service is provided, other than food service or retail sales of goods.	• Vehicle Service or Vehicle Repair Shop • Vehicle Storage/Maintenance • Repair Shop • Dry Cleaner or Laundromat • Post Office or Postal Center • Car Wash • Gas Station with no Convenience Store • Photo Processing Shop • Beauty Parlor or Barber Shop • Tanning Salon • Copy Center or Printing Shop • Kennel
Warehouse	Warehouse	Buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage).	• Refrigerated Warehouse • Non-refrigerated warehouse • Distribution or Shipping Center
Other	Other	Other	For building types not explicitly listed.

Table 13.2-8: [Split/Packaged ACs & HPs] Floor Area and Floor Assumptions by Building Type

Building Type	Principal Building Activity	Average Floor Area (ft^2)	Average # Floors
Data Center	Data Center	Not specified	Not specified
Education	College	Not specified	Not specified
	Primary School	73,960	1
	Secondary School	210,887	2
Food Sales	Convenience	Not specified	1
	Supermarket	45,000	1
Food Service	Full-Service Restaurant	5,500	1
	Quick-Service Restaurant	2,500	1
Healthcare	Hospital	241,351	5
	Outpatient Healthcare	40,946	3
Large Multifamily	Midrise Apartment	33,740	4
Lodging	Large Hotel	122,120	6
	Nursing Home	Not specified	Not specified
	Small Hotel/Motel	43,200	4
Mercantile	Stand-Alone Retail	24,962	1
	24 Hr Stand-Alone Retail	22,500	1
	Strip Mall	498,588	12
Office	Large Office	53,628	3
	Medium Office	5,500	1
	Small Office	Not specified	Not specified
Public Assembly	Public Assembly	Not specified	Not specified
Religious Worship	Religious Worship	Not specified	Not specified
Service	Service	52,045	1
Warehouse	Warehouse	Not specified	Not specified
Other	Other	Not specified	Not specified

Table 13.2-9: [Split/Packaged ACs & HPs] Equivalent Full-Load Hours

Building Type	Principal Building Activity	Package and Split DX		
		AC	Heat Pump	
		$EFLH_C$	$EFLH_C$	$EFLH_H$
Data Centers	Data Centers	4,022	4,022	-
Education	College	2,101	2,101	-
	Primary School	1,633	1,633	251
	Secondary School	1,429	1,429	281
Food Sales	Convenience	2,307	2,307	-
	Supermarket	829	829	-
Food Service	Full-Service Restaurant	2,249	2,249	542
	24 Hr Full-Service	2,548	2,548	680
	Quick-Service Restaurant	1,996	1,996	405
	24 Hr Quick-Service	2,311	2,311	599
Healthcare	Hospital	3,534	3,534	-
	Outpatient Healthcare	2,925	2,925	223
Large Multifamily	Midrise Apartment	2,429	2,429	-
Lodging	Large Hotel	2,600	2,600	307
	Nursing Home	2,467	2,467	-
	Small Hotel/Motel	2,421	2,421	147
Mercantile	Stand-Alone Retail	1,554	1,554	230
	24 Hr Stand-Alone Retail	2,059	2,059	276
	Strip Mall	1,467	1,467	247
Office	Large Office	2,866	2,866	175
	Medium Office	1,523	1,523	107
	Small Office	1,598	1,598	147
Public Assembly	Public Assembly	2,196	2,196	-
Religious Worship	Religious Worship	602	602	-
Service	Service	1,742	1,742	-
Warehouse	Warehouse	718	718	-
Other	Other	602	602	107

10

13.2.2.3 Deemed Summer Demand Savings Tables

Table 13.2-11 through Table 13.2-13 contain the NCP, CP, and 4CP demand factors.

Table 13.2-11: [Split/Packaged ACs & HPs] Non-Coincident Peak Demand Factors

Building Type	Principal Building Activity	DF_{NCP}	
		DX AC	DX HP
Data Centers	Data Centers	1.07	1.07
Education	College	1.12	1.12
	Primary School	1.10	1.10
	Secondary School	1.12	1.12
Food Sales	Convenience	1.13	1.13
	Supermarket	0.65	0.65
Food Service	Full-Service Restaurant	1.13	1.13
	24 Hr Full-Service	1.14	1.14
	Quick-Service Restaurant	1.13	1.13
	24 Hr Quick-Service	1.13	1.13
Healthcare	Hospital	0.98	0.98
	Outpatient Healthcare	0.90	0.90
Large Multifamily	Midrise Apartment	1.09	1.09
Lodging	Large Hotel	0.76	0.76
	Nursing Home	1.09	1.09
	Small Hotel/Motel	0.71	0.71
Mercantile	Stand-Alone Retail	1.04	1.04
	24 Hr Stand-Alone Retail	1.06	1.06
	Strip Mall	1.02	1.02
Office	Large Office	1.09	1.09
	Medium Office	0.90	0.90
	Small Office	1.05	1.05
Public Assembly	Public Assembly	1.10	1.10
Religious Worship	Religious Worship	0.71	0.71
Service	Service	1.13	1.13
Warehouse	Warehouse	1.05	1.05
Other	Other	0.65	0.65

Table 13.2-12: [Split/Packaged ACs & HPs] Coincident Peak Demand Factors

Building Type	Principal Building Activity	Package and Split DX	
		AC	Heat Pump
		DF_{CP}	DF_{CP}
Data Centers	Data Centers	1.05	1.05
Education	College	1.08	1.08
	Primary School	1.06	1.06
	Secondary School	1.08	1.08
Food Sales	Convenience	1.03	1.03
	Supermarket	0.61	0.61
Food Service	Full-Service Restaurant	1.06	1.06
	24 Hr Full-Service	1.07	1.07
	Quick-Service Restaurant	1.03	1.03
	24 Hr Quick-Service	1.06	1.06
Healthcare	Hospital	0.94	0.94
	Outpatient Healthcare	0.86	0.86
Large Multifamily	Midrise Apartment	1.05	1.05
Lodging	Large Hotel	0.72	0.72
	Nursing Home	1.05	1.05
	Small Hotel/Motel	0.68	0.68
Mercantile	Stand-Alone Retail	1.00	1.00
	24 Hr Stand-Alone Retail	1.03	1.03
	Strip Mall	0.97	0.97
Office	Large Office	1.07	1.07
	Medium Office	0.83	0.83
	Small Office	1.00	1.00
Public Assembly	Public Assembly	1.06	1.06
Religious Worship	Religious Worship	0.68	0.68
Service	Service	1.06	1.06
Warehouse	Warehouse	0.92	0.92
Other	Other	0.61	0.61

Table 13.2-13: [Split/Packaged ACs & HPs] 4CP Demand Factors

Building Type	Principal Building Activity	Package and Split DX	
		AC	Heat Pump
		DF_{4CP}	DF_{4CP}
Data Centers	Data Centers	0.89	0.89
Education	College	0.91	-
	Primary School	0.86	0.86
	Secondary School	0.91	0.91
Food Sales	Convenience	0.93	0.93
	Supermarket	0.83	0.83
Food Service	Full-Service Restaurant	0.94	0.94
	24 Hr Full-Service	0.98	0.98
	Quick-Service Restaurant	0.93	0.93
	24 Hr Quick-Service	0.97	0.97
Healthcare	Hospital	0.93	0.93
	Outpatient Healthcare	0.93	0.93
Large Multifamily	Midrise Apartment	0.91	0.91
Lodging	Large Hotel	0.89	0.89
	Nursing Home	0.91	0.91
	Small Hotel/Motel	0.87	0.87
Mercantile	Stand-Alone Retail	0.86	0.86
	24 Hr Stand-Alone Retail	0.88	0.88
	Strip Mall	0.86	0.86
Office	Large Office	0.91	0.91
	Medium Office	0.84	0.84
	Small Office	0.89	0.89
Public Assembly	Public Assembly	0.86	0.86
Religious Worship	Religious Worship	0.87	0.87
Service	Service	0.94	0.94
Warehouse	Warehouse	0.71	0.71
Other	Other	0.71	0.71

13.2.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

13.2.2.5 Measure Life and Lifetime Savings

The EUL and RULs for this HVAC equipment are provided below.

Estimated Useful Life (EUL)

The EUL is 15 years for split and packaged ACs and HPs, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HVAC-airAC and HVAC-airHP.[502]

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 13.2-14. If individual system components were installed at different times, use the condenser age as a proxy for the entire system. For ER units of unknown age, assume a default value equal to the EUL. This corresponds to a default RUL of 2.8 years. Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. Both the RUL and EUL are needed to estimate savings for ER projects for two distinct periods: The ER period (RUL) and the ROB period (EUL - RUL). The calculations for ER projects are extensive, and as such are provided in Section 22.3.

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[502] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

Table 13.2-14: [Split/Packaged ACs & HPs] Remaining Useful Life or Replaced Unit[503]

Age in Years of Replaced System	Split and Packaged A/C and HP Systems [years]
1	14.0
2	13.0
3	12.0
4	11.0
5	10.0
6	9.1
7	8.2
8	7.3
9	6.5
10	5.7
11	5.0
12	4.4
13	3.8
14	3.3
15	2.8
16	2.0
17	1.0
18[504]	0.0

13.2.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Building type
- For 'Other' building types ONLY: a description of the actual building type, the primary business activity, the business hours, and the HVAC schedule

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[503] Current NC baseline matches the baseline for existing systems manufactured in 2018. Existing systems manufactured after 1/1/2018 are not eligible to use the early retirement baseline.

[504] RULs are capped at the 75th percentile of equipment age, 18 years, as determined based on DOE survival curves. Systems older than 18 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

- Decision/action type; ER, ROB, NC, system type conversion
- Baseline equipment type
- Baseline unit quantity
- Baseline rated cooling and heating capacities
- For ER ONLY: baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available)
- For ER ONLY: photograph of retired unit nameplate demonstrating model number, serial number, and manufacturer if blueprints are not provided; if photograph of nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (alternate forms of documentation can be approved at the evaluator’s discretion)
- Manufacturer, model, and serial number of new unit
    - AHRI/DOE CCMS certificates or reference number matching model number
- New unit equipment type
- New unit quantity
- New unit rated cooling and heating capacities
- New unit cooling and heating efficiency ratings
- Proof of purchase: invoice showing model number; photo(s) of the model number on product packaging or installed unit(s); OR evaluator pre-approved approach
    - For NC ONLY, as built design drawings or HVAC specifications package that provides detailed manufacturer and model number information on installed unit(s) may also be accepted as the proof of purchase

13.3 CHILLERS

13.3.1 Measure Description

This measure involves the installation of chillers. Applicable efficient measure types include:

- Compressor Types: Centrifugal or Positive displacement (Screw, Scroll, or Reciprocating)
- Condenser/Heat Rejection Type: Air-cooled or Water-cooled System Type Conversions. Retrofits involving a change from a chiller-based system to a packaged/split system are also covered under this measure. In the event that this type of retrofit is performed, the tables from the Split/Single Packaged Air Conditioners and Heat Pumps measure will need to be referenced in Section 13.2 Split and Packaged Air Conditioners and Heat Pumps. Split and Packaged Air Conditioners and Heat Pumps.
- Chiller Type Conversions: Conversion from an air-cooled chiller system to a water-cooled chiller system is also addressed in this measure. An additional adjustment is made to the basic chiller savings to account for the auxiliary equipment associated with a water-cooled chiller.

This measure explains assumptions made for baseline equipment efficiencies based on the age of the replaced equipment for:

- Early retirement (ER)
    - Age of the baseline system should be determined from the equipment nameplate or other physical documentation whenever possible
- Replace-on-burnout (ROB)
- New construction (NC) based on efficiency standards.

Savings calculations incorporate the use of both full-load and part-load efficiency values.

13.3.1.1 Eligibility Criteria

For a measure to be eligible for this deemed savings approach the following conditions must be met:

- The existing and proposed cooling equipment are electric.
- The building falls into one of the categories listed in Table 22.5-1. Building type descriptions and examples are provided in Table 22.4-1.
- ER projects involve the replacement of a working system that is at least five years old and before natural burnout occurs. The ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. An ROB approach should be used for these scenarios.
- Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[505,506]

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[505] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.

[506] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.

13.3.1.2 Baseline Condition

The baseline conditions related to efficiency and system capacity for ER and ROB/NC are described in the following sections.

Early Retirement

ER systems involve the replacement of a working system prior to natural burnout. The ER baseline cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred.

Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL-RUL) period. For the ROB period, the baseline efficiency is the same as for an ROB/NC scenario. For the ER period, the baseline efficiency should be estimated according to the capacity, chiller type, and age (based on year manufactured) of the replaced system. When the chiller age can be determined (from a nameplate, building prints, equipment inventory list, etc.), use the baseline efficiency levels provided in Table 13.3-1 through Table 13.3-11. When the system age is unknown, assume a default value equal to the EUL. This corresponds to 20 years for non-centrifugal chillers and 25 years for centrifugal chillers. A default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

ER baseline efficiency values represent the code-specified efficiency in effect at the time the chiller was installed. Prior to 2002, code-specified efficiencies from ASHRAE 90.1-1989 were in effect. Code-specified efficiencies increased in 2002, approximating the effective date of ASHRAE 90.1-1999, which went into effect on October 29, 2001. Code-specified efficiencies increased again in 2010, coinciding with the state of Texas code increase to IECC 2009 (Path A).

Different code-specified efficiencies were in effect prior to 2010 (ASHRAE 90.1-2010). Those efficiencies were expressed as coefficients of performance (COP). Those COP values have been converted to EER (Energy Efficiency Ratio) and kW/ton in the tables below by using EER = COP x 3.412 and kW/ton = 3.516 ÷ COP. Values in the “< 2001” and “2002-2009” rows of Table 13.3-1, Table 13.3-5, and Table 13.3-9 are converted COP values.

ER Baseline – All Air-Cooled Chillers

Table 13.3-1: [Chillers] ER Baseline Full-Load Efficiency of Path A Air-Cooled Chillers

Year Installed (Replaced System)	< 150 tons [EER]	≥ 150 tons [EER]
≤ 2001	9.212	8.530
2002 - 2015	9.562	9.562
≥ 2016	10.100	10.100

Table 13.3-2: [Chillers] ER Baseline Full-Load Efficiency of Path B Air-Cooled Chillers

Year Installed (Replaced System)	< 150 tons [EER]	≥ 150 tons [EER]
≤ 2001	9.212	8.530
2002 - 2015	9.562	9.562
≥ 2016	9.700	9.700

Table 13.3-3: [Chillers] ER Baseline Part-Load Efficiency of Path A Air-Cooled Chillers

Year Installed (Replaced System)	< 150 tons [IPLV]	≥ 150 tons [IPLV]
≤ 2001	9.554	8.530
2002 - 2009	10.416	10.416
2010 - 2015	12.500	12.500
≥ 2016	13.700	14.000

Table 13.3-4: [Chillers] ER Baseline Part-Load Efficiency of Path B Air-Cooled Chillers

Year Installed (Replaced System)	< 150 tons [IPLV]	≥ 150 tons [IPLV]
≤ 2001	9.554	8.530
2002 - 2009	10.416	10.416
2010 - 2015	12.500	12.500
≥ 2016	15.800	16.100

ER Baseline - Centrifugal Water-Cooled Chillers

Table 13.3-5: [Chillers] ER Baseline Full-Load Efficiency of Path A Centrifugal Water-Cooled Chillers

Year Installed (Replaced System)	<150 tons [kW/ton]	≥ 150 to 300 tons [kW/ton]	≥ 300 to 600 tons [kW/ton]	≥ 600 tons [kW/ton]
≤ 2001	0.925	0.837	0.748	0.748
2002 - 2009	0.703	0.634	0.576	0.576
2010 - 2015	0.634	0.634	0.576	0.570
≥ 2016	0.610	0.610	0.560	0.560

Table 13.3-6: [Chillers] ER Baseline Full-Load Efficiency of Path B Centrifugal Water-Cooled Chillers

Year Installed (Replaced System)	<150 tons [kW/ton]	≥ 150 to 300 tons [kW/ton]	≥ 300 to 600 tons [kW/ton]	≥ 600 tons [kW/ton]
≤ 2001	0.925	0.837	0.748	0.748
2002 - 2009	0.703	0.634	0.576	0.576
2010 - 2015	0.639	0.639	0.600	0.590
≥ 2016	0.695	0.635	0.595	0.585

Table 13.3-7: [Chillers] ER Baseline Part-Load Efficiency of Path A Centrifugal Water-Cooled Chillers

Year Installed (Replaced System)	<150 tons [IPLV]	≥ 150 to 300 tons [IPLV]	≥ 300 to 600 tons [IPLV]	≥ 600 tons [IPLV]
≤ 2001	0.902	0.781	0.733	0.733
2002 - 2009	0.670	0.596	0.549	0.549
2010 - 2015	0.596	0.596	0.549	0.539
≥ 2016	0.550	0.550	0.520	0.500

Table 13.3-8: [Chillers] ER Baseline Part-Load Efficiency of Path B Centrifugal Water-Cooled Chillers

Year Installed (Replaced System)	<150 tons [IPLV]	≥ 150 to 300 tons [IPLV]	≥ 300 to 600 tons [IPLV]	≥ 600 tons [IPLV]
≤ 2001	0.902	0.781	0.733	0.733
2002 - 2009	0.670	0.596	0.549	0.549
2010 - 2015	0.450	0.450	0.400	0.400
≥ 2016	0.440	0.400	0.390	0.380

ER Baseline - Positive-Displacement Water-Cooled Chillers

Table 13.3-9: [Chillers] ER Baseline Full-Load Efficiency of Path A Screw/Scroll/Recip. Water-Cooled Chillers

Year Installed (Replaced System)	<75 tons [kW/ton]	≥75 to 150 tons [kW/ton]	≥ 150 to 300 tons [kW/ton]	≥ 300 to 600 tons [kW/ton]	≥ 600 tons [kW/ton]
≤ 2001	0.925	0.925	0.837	0.748	0.748
2002 - 2009	0.790	0.790	0.718	0.639	0.639
2010 - 2015	0.780	0.775	0.680	0.620	0.620
≥ 2016	0.750	0.720	0.660	0.610	0.560

Table 13.3-10: [Chillers] ER Baseline Full-Load Efficiency of Path B Screw/Scroll/Recip. Water-Cooled Chillers

Year Installed (Replaced System)	<75 tons [kW/ton]	≥75 to 150 tons [kW/ton]	≥ 150 to 300 tons [kW/ton]	≥ 300 to 600 tons [kW/ton]	≥ 600 tons [kW/ton]
≤ 2001	0.925	0.925	0.837	0.748	0.748
2002 - 2009	0.790	0.790	0.718	0.639	0.639
2010 - 2015	0.800	0.790	0.718	0.639	0.639
≥ 2016	0.780	0.750	0.680	0.625	0.585

Table 13.3-11: [Chillers] ER Baseline Part-Load Efficiency of Path A Screw/Scroll/Recip. Water-Cooled Chillers

Year Installed (Replaced System)	<75 tons [IPLV]	≥75 to 150 tons [IPLV]	≥ 150 to 300 tons [IPLV]	≥ 300 to 600 tons [IPLV]	≥ 600 tons [IPLV]
≤ 2001	0.902	0.902	0.781	0.733	0.733
2002 - 2009	0.676	0.676	0.628	0.572	0.572
2010 - 2015	0.630	0.615	0.580	0.540	0.540
≥ 2016	0.600	0.560	0.540	0.520	0.500

Table 13.3-12: [Chillers] ER Baseline Part-Load Efficiency of Path B Screw/Scroll/Recip. Water-Cooled Chillers

Year Installed (Replaced System)	<75 tons [IPLV]	≥75 to 150 tons [IPLV]	≥ 150 to 300 tons [IPLV]	≥ 300 to 600 tons [IPLV]	≥ 600 tons [IPLV]
≤ 2001	0.902	0.902	0.781	0.733	0.733
2002 - 2009	0.676	0.676	0.628	0.572	0.572
2010 - 2015	0.600	0.586	0.540	0.490	0.490
≥ 2016	0.500	0.490	0.440	0.410	0.380

Replace-on-Burnout and New Construction

New baseline efficiency levels for chillers are provided in Table 13.3-13, which includes both full load and Integrated Part Load Value (IPLV) ratings. The IPLV rating accounts for chiller efficiency at part-load operation for a given duty cycle. These baseline efficiency levels reference standard IECC 2018. This standard contains two paths for compliance, Path A or Path B. Path A is intended for applications where significant operating time is expected at full-load conditions, while Path B is an alternative set of efficiency levels for chillers intended for applications where considerable time is spent at part-load operation (such as with a VSD chiller). Both paths are eligible to claim demand savings using the applicable full-load baseline efficiencies for the selected path in combination with the demand coefficients defined in this measure. Similarly, both paths are eligible to claim energy savings using the applicable part-load baseline efficiencies for the selected path in combination with the energy coefficients defined in this measure.

For NC applications where a water-cooled chiller less than or equal to 500 tons is installed, the equivalent size air-cooled chiller baseline may be substituted for the water-cooled chiller baseline. IECC 2018 permits the installation of either air-cooled or water-cooled chillers. This substitution accounts for the situation that an air-cooled chiller may have been installed with a lower efficiency value than is required for a water-cooled chiller of the same tonnage.

Table 13.3-13: [Chillers] Baseline Efficiencies for ROB and NC Air-Cooled and Water-Cooled Chillers

System Type	Equipment Type	Efficiency Type	Capacity [Tons]	Path A		Path B	
				Full-Load	IPLV	Full-Load	IPLV
Air-Cooled	All	EER	< 150	≥ 10.100	≥ 13.700	≥ 9.700	≥ 15.800
			≥ 150	≥ 10.100	≥ 14.000	≥ 9.700	≥ 16.100
Water-Cooled	Electric, Positive Displacement (Screw/Scroll/ Reciprocating)	kW/ton	< 75	≤ 0.750	≤ 0.600	≤ 0.780	≤ 0.500
			≥ 75 and < 150	≤ 0.720	≤ 0.560	≤ 0.750	≤ 0.490
			≥ 150 and < 300	≤ 0.660	≤ 0.540	≤ 0.680	≤ 0.440
			≥ 300 and < 600	≤ 0.610	≤ 0.520	≤ 0.625	≤ 0.410
			≥ 600	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380
	Electric, Centrifugal	kW/ton	< 150	≤ 0.610	≤ 0.550	≤ 0.695	≤ 0.440
			≥ 150 and < 300	≤ 0.610	≤ 0.550	≤ 0.635	≤ 0.400
			≥ 300 and < 400	≤ 0.560	≤ 0.520	≤ 0.595	≤ 0.390
			≥ 400	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380

Path B Implementation

IECC 2018 specifies that Path B chiller compliance can be with either Path A or Path B for any application provided that both the full-load and IPLV requirements are met. Therefore, chillers with intensive operation at part-load may use either the Path A or Path B baseline provided that the AHRI-rated full-load and part-load efficiency ratings are both compliant with the selected path. EFLH and demand factors defined in this measure are eligible for use with either path.

13.3.1.3 High-Efficiency Condition

Chillers must exceed the minimum efficiencies specified in Table 13.3-13. Additional conditions for ER, ROB, and NC are described in the following sections.

New Construction and Replace-on-Burnout

This scenario includes equipment used for NC and retrofit/replacements that are not covered by ER, such as units that are replaced after natural failure.

Early Retirement

The high-efficiency retrofits must meet the following criteria:

- For ER projects only, the installed equipment cooling capacity must be less than 120% of the replaced electric cooling capacity. For scenarios involving the replacement of a combination of systems by an alternate combination of systems of varying capacities, ER savings can still be claimed if the overall pre and post capacities for the total combination of systems are within +/- 20%. In these cases, a custom calculation should be performed to establish the following weighted savings factors to be applied over the ER portion of the savings calculation: manufacturer year, EUL, RUL, path A/B full and part-load baseline efficiency, demand factor, and EFLH. These factors should be weighted based on contribution to overall capacity.
- If the cooling capacity of the installed equipment decreases by more than 20% of the existing cooling capacity, the cooling capacity of the existing equipment used for calculating savings will be capped at 20% above the installed equipment cooling capacity
- No additional measures are being installed that directly affect the operation of the cooling equipment (i.e., control sequences, cooling towers, and condensers).

The first-year savings algorithms in the above equations are used for all HVAC projects, across NC, ROB, and ER projects. However, ER projects require a weighted savings calculated over both the ER and ROB periods taking the EUL and RUL into account. The ER savings are applied over the remaining useful life (RUL) period, and the ROB savings are applied over the remaining period (EUL-RUL). The final reported savings for ER projects are not actually “first-year” savings, but “average annual savings over the lifetime (EUL) of the measure.” These savings calculations are explained in Appendix 22.3.

13.3.2 Energy and Demand Savings Methodology

13.3.2.1 Savings Algorithms and Input Variables

Energy Savings

$$\boldsymbol{Energy\ Savings\ [kWh_{Savings}] = \left(Cap_{C,pre} \times \eta_{baseline} - Cap_{C,post} \times \eta_{installed}\right) \times CAF \times EFLH_C}$$

Equation 13.3-1

Demand Savings

$$\boldsymbol{Demand\ Savings\ \left[kW_{Savings}\right] = \left(Cap_{C,pre} \times \eta_{baseline} - Cap_{C,post} \times \eta_{installed}\right) \times CAF \times DF}$$

Equation 13.3-2

Where:

$Cap_{C,pre}$ = *For ER, rated equipment cooling capacity of the existing equipment at AHRI standard conditions; for ROB & NC, rated equipment cooling capacity of the new equipment at AHRI standard conditions [Tons].*

$Cap_{C,post}$ = *Rated equipment cooling capacity of the newly installed equipment at AHRI standard conditions [Tons].*

$\eta_{baseline}$ = *Efficiency of existing equipment (ER) or standard equipment (ROB/NC) [kW/Ton] Use Table 13.3-1 through Table 13.3-11 or Equation 13.3-3.*

$\eta_{installed}$ = *Rated efficiency of the newly installed equipment [kW/Ton] Rated efficiency must exceed efficiency standards, shown in Table 13.3-13.*

CAF = *Capacity adjustment factor = 0.58 for chillers that are operating as part of a redundant chiller system where the backup chiller operates during peak load to allow chillers to operate at part-load efficiency[507]; for all other configurations, CAF = 1.00.*

Note: When CAF = 1.0, use full-load efficiency [kW/ton] for kW savings calculations and part-load efficiency [IPLV] for kWh savings calculations. When CAF = 0.58, kW savings calculations should use part-load efficiency [IPLV] instead of full-load efficiency [kW/ton].

$EFLH_C$ = *Cooling equivalent full-load hours for appropriate building type, and equipment type [hours]; see Table 13.3-14.*

DF = *Demand factor (NCP, CP, 4CP) for appropriate building type and equipment type; see Table 13.3-15 through Table 13.3-17.*

EER Efficiency Ratings – All Air-Cooled Chillers:

Table 13.3-1 through Table 13.3-11 provide efficiency ratings for baseline equipment where the efficiency ratings are given in terms of EER, kW/ton, or IPLV. In the cases where the full-load efficiency of the baseline or installed equipment is provided in terms of EER rather than kW/ton, a conversion to kW/ton needs to be performed using the following conversion:

$$\frac{kW}{Ton} = \frac{12}{EER}$$

Equation 13.3-3

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[507] AHRI's part-load efficiency calculation assumes 1% operation at 100% capacity, 42% operation at 75% capacity, 45% operation at 50% capacity, and 12% operation at 25% capacity. 0.01 x 1.00 + 0.42 x 0.75 + 0.45 x 0.50 + 0.12 x 0.25 = 0.58. http://www.ahrinet.org/App_Content/ahri/files/STANDARDS/AHRI/AHRI_Standard_550-590_I-P_2015_with_Errata.pdf.

Air-to Water-Cooled Replacement: Adjustments for Auxiliary Equipment:

The equipment efficiency for an air-cooled chiller includes condenser fans, but the equipment efficiency for a water-cooled chiller does not include the condenser water pump and cooling tower (auxiliary equipment). Therefore, when an air-cooled chiller is replaced with a water-cooled chiller, the savings must be reduced to account for the impact of the water-cooled system's additional equipment. This type of retrofit is only applicable for ER situations. The following equations are used:

$$kW_{adj} = \left(HP_{CW\ pump} + HP_{CT\ fan}\right) \times \frac{0.746}{0.86} \times 0.80$$

Equation 13.3-4

$$kWh_{adj} = kW \times 8,760$$

Equation 13.3-5

Where:

$HP_{CW\ pump}$ = *Horsepower of the condenser water pump.*

$HP_{CT\ fan}$ = *Horsepower of the cooling tower fan.*

0.746 = *Conversion from hp to kW [kW/hp].*

0.86 = *Assumed equipment efficiency.*

0.80 = *Assumed load factor.*

8,760 = *Total hours per year.*

The energy and demand of the condenser water pump and cooling tower fans are subtracted from the final savings, to reach the net savings.

$$kW_{savings,net} = kW_{Chiller} - kW_{adj}$$

Equation 13.3-6

$$kWh_{savings,net} = kWh_{Chiller} - kWh_{adj}$$

Equation 13.3-7

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed through adapting NREL's Commercial Reference Building Models[508] for San Antonio. The load shape can be found in Section 22.2.

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[508] NREL Commercial Reference Buildings, http://energy.gov/eere/buildings/commercial-reference-buildings.

13.3.2.2 Deemed Energy Savings Tables

Table 13.3-14 contains the effective full load hours for commercial chillers for various building types in San Antonio. These building types are derived from the EIA CBECS study.509

Table 13.3-14: [Chillers] Equivalent Full-Load Hours

Building Type	Principal Building Activity	EFLH	
		Air-Cooled	Water-Cooled
Education	College	2,173	3,894
	Primary School	915	1,716
	Secondary School	1,477	2,647
Healthcare	Hospital	3,115	4,015
Large Multifamily	Midrise Apartment	1,378	2,528
Lodging	Large Hotel	2,595	3,180
	Nursing Home	1,400	2,568
Mercantile	Stand-Alone Retail	1,184	1,652
	24 Hr Retail	1,642	2,488
Office	Large Office	2,009	2,401
Public Assembly	Public Assembly	1,231	2,307
Religious Worship	Religious Worship	713	994
Other	Other	713	994

13.3.2.3 Deemed Summer Demand Savings Tables

Table 13.3-15 through Table 13.3-17 contain the NCP, CP, and 4CP demand factors for commercial chillers for various building types in San Antonio.

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[509] The Commercial Building Energy Consumption Survey (CBECS) implemented by the US Energy Information Administration includes a principal building activity categorization scheme that separates the Commercial sector into 29 categories and 51 subcategories based on principal building activity (PBA). For its purposes, the CBECS defines Commercial buildings as those buildings greater than 1,000 square feet that devote more than half of their floorspace to activity that is neither residential, manufacturing, industrial, nor agricultural. The high-level building types adopted for the Guidebook are adapted from this CBECS categorization, with some building types left out and one additional building type—Large Multifamily—included. https://www.eia.gov/consumption/commercial/.

Table 13.3-15: [Chillers] Non-Coincident Peak Demand Factors

Building Type	Principal Building Activity	DF_{NCP}	
		Air-Cooled	Water-Cooled
Education	College	0.89	0.72
	Primary School	0.60	0.63
	Secondary School	0.89	0.72
Healthcare	Hospital	0.89	0.85
Large Multifamily	Midrise Apartment	0.66	0.69
Lodging	Large Hotel	0.98	1.00
	Nursing Home	0.66	0.69
Mercantile	Stand-Alone Retail	0.82	0.76
	24 Hr Retail	0.86	0.79
Office	Large Office	1.06	0.73
Public Assembly	Public Assembly	0.60	0.63
Religious Worship	Religious Worship	0.82	0.76
Other	Other	0.60	0.63

Table 13.3-16: [Chillers] Coincident Peak Demand Factors

Building Type	Principal Building Activity	DF_{CP}	
		Air-Cooled	Water-Cooled
Education	College	0.84	0.52
	Primary School	0.55	0.58
	Secondary School	0.84	0.52
Healthcare	Hospital	0.85	0.73
Large Multifamily	Midrise Apartment	0.63	0.61
Lodging	Large Hotel	0.61	0.68
	Nursing Home	0.63	0.61
Mercantile	Stand-Alone Retail	0.77	0.68
	24 Hr Retail	0.81	0.71
Office	Large Office	0.98	0.69
Public Assembly	Public Assembly	0.55	0.58
Religious Worship	Religious Worship	0.77	0.68
Other	Other	0.55	0.58

Table 13.3-17: [Chillers] 4CP Demand Factors

Building Type	Principal Building Activity	DF_{4CP}	
		Air-Cooled	Water-Cooled
Education	College	0.70	0.61
	Primary School	0.45	0.59
	Secondary School	0.70	0.61
Healthcare	Hospital	0.78	0.77
Large Multifamily	Midrise Apartment	0.58	0.63
Lodging	Large Hotel	0.90	0.90
	Nursing Home	0.58	0.63
Mercantile	Stand-Alone Retail	0.66	0.68
	24 Hr Retail	0.70	0.69
Office	Large Office	0.84	0.70
Public Assembly	Public Assembly	0.45	0.59
Religious Worship	Religious Worship	0.66	0.68
Other	Other	0.45	0.59

13.3.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

13.3.2.5 Measure Life and Lifetime Savings

Estimated Useful Life (EUL)

The EUL of HVAC equipment is provided below:

- Screw / Scroll / Reciprocating Chillers – 20 years[510]
- Centrifugal Chillers – 25 years[511]

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[510] DEER 2014 provides the value of 20 years for "High Efficiency Chillers." DEER does not differentiate between centrifugal and non-centrifugal chillers.

[511] Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, And Texas-New Mexico Power Company To Revise Deemed Saving Values For Commercial HVAC And Solar Photovoltaic Measures, PUCT Docket No. 40885, Review of multiple studies looking at the lifetime of Centrifugal Chillers as detailed in petition workpapers.

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 13.3-18. For ER units of unknown age, assume a default value equal to the EUL. This corresponds to a default RUL of 3.6 years for non-centrifugal chillers and 5.4 years for centrifugal chillers. Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. Both the RUL and EUL are needed to estimate savings for ER projects for two distinct periods: The ER period (RUL) and the ROB period (EUL - RUL). The calculations for ER projects are extensive, and as such are provided in Section 22.3.

Table 13.3-18: [Chillers] Remaining Useful Life or Replaced Unit[512]

Age in Years of Replaced System	Non-Centrifugal Chilled Water Systems	Centrifugal Chilled Water Systems
1	18.7	23.9
2	17.7	22.9
3	16.7	21.9
4	15.7	20.9
5	14.7	19.9
6	13.7	18.9
7	12.7	17.9
8	11.8	16.9
9	10.9	15.9
10	10.0	14.9
11	9.1	13.9
12	8.3	12.9
13	7.5	11.9
14	6.8	10.9
15	6.2	10.1
16	5.5	9.3
17	5.0	8.7
18	4.5	8.1
19	4.0	7.5
20	3.6	7.1
21	3.0	6.6

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[512] Current NC baseline matches the baseline for existing systems manufactured in 2018. Existing systems manufactured after 1/1/2018 are not eligible to use the early retirement baseline.

Age in Years of Replaced System	Non-Centrifugal Chilled Water Systems	Centrifugal Chilled Water Systems
22	2.0	6.3
23	1.0	5.9
24[513]	0.0	5.6
25	N/A	5.4
26	N/A	5.0
27	N/A	4.0
28	N/A	3.0
29	N/A	2.0
30	N/A	1.0
31[514]	N/A	0.0

13.3.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Building type
- For 'Other' building type ONLY: A description of the actual building type, the primary business activity, the business hours, and the HVAC schedule
- Decision/action type: ER, ROB, NC, system type conversion
- Baseline equipment type (compressor/condenser type)
- Baseline unit quantity
- Baseline rated cooling capacity
- For ER ONLY: baseline age of system and method of determination (e.g., nameplate, blueprints, customer reported, not available)
- For ER ONLY: photograph of retired unit nameplate demonstrating model number, serial number, and manufacturer if blueprints are not provided; if photograph of nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (alternate forms of documentation can be approved at the evaluator's discretion)
- Manufacturer, model, and serial number of new unit
    - AHRI/DOE CCMS certificates or reference number matching model number
- New unit equipment type (compressor/condenser type)

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[513] RULs are capped at the 75th percentile of non-centrifugal equipment age, 24 years, as determined based on DOE survival curves. Non-centrifugal systems older than 24 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

[514] Ibid.

- New unit quantity
- New unit rated cooling capacity
- New unit cooling efficiency ratings
- For chiller type conversion ONLY: condenser water pump horsepower and cooling tower fan horsepower
- Proof of purchase: invoice showing model number; photo(s) of the model number on product packaging or installed unit(s); OR evaluator pre-approved approach
  - For NC ONLY, as built design drawings or HVAC specifications package that provides detailed manufacturer and model number information on installed unit(s) may also be accepted as the proof of purchase

13.4 PACKAGED TERMINAL AIR CONDITIONERS, PACKAGED TERMINAL HEAT PUMPS, AND ROOM AIR CONDITIONERS

13.4.1 Measure Description

This measure involves the installation of Packaged Terminal Air Conditioners (PTAC), Packaged Terminal Heat Pumps (PTHP), and Room AC (RAC) systems.

Applicable efficient measure types include:

- Packaged Terminal Air Conditioners and Heat Pumps. Both Standard and Non-Standard size equipment types are covered. Standard Size refers to equipment with wall sleeve dimensions having an external wall opening greater than, or equal to 16 inches high or greater than, or equal to 42 inches wide and a cross sectional area greater than 670 in^2. Non-Standard Size refers to equipment with existing wall sleeve dimensions having an external wall opening of less than 16 inches high or less than 42 inches wide and a cross sectional area less than 670 in^2.
- Room Air Conditioners. Includes all equipment configurations covered by the federal appliance standards, including equipment with or without reverse cycle, louvered or non-louvered sides, casement-only, and casement-slide.

This measure explains assumptions made for baseline equipment efficiencies based on the age of the replaced equipment for:

- Early retirement (ER)
    - Age of the baseline system should be determined from the equipment nameplate or other physical documentation whenever possible
- Replace-on-burnout (ROB)
- New construction (NC) based on efficiency standards

13.4.1.1 Eligibility Criteria

For a measure to be eligible for this deemed savings approach the following conditions will be met:

- The existing and proposed cooling equipment are electric.
- The PTAC, PTHP, or RAC must be the primary cooling source for the space.
- ER projects involve the replacement of a working system that is at least five years old and before natural burnout occurs. The ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. An ROB approach should be used for these scenarios.
- Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[515,516]

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[515] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.

[516] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.

13.4.1.2 Baseline Condition

The baseline conditions related to efficiency and system capacity for ER and ROB/NC are described in the following sections.

Early Retirement

ER scenarios involve the replacement of a working system prior to natural burnout. The ER baseline cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred.

Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL-RUL) period. For the ROB period, the baseline efficiency is the same as for an ROB/NC scenario. For the ER period, the baseline efficiency should be estimated according to the capacity, system type (PTAC or PTHP), and age (based on year manufactured) of the replaced system. When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 13.4-1, reflecting ASHRAE Standard 90.1-2001 through 90.1-2007, should be used. PTHPs replacing PTACs with built-in electric resistance heat should use a baseline heating efficiency of 1.0 COP.

When the system age is unknown, assume a default value equal to the EUL. This corresponds to an age of 15 years. A default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

Existing systems manufactured as of February 2013 are not eligible for early retirement.

Table 13.4-1: [PTACs, PTHPs, & Room ACs] ER Baseline Efficiency for Standard Size PTAC/PTHPs[517,518]

Equipment	Cooling Capacity [Btuh]	Baseline Cooling Efficiency [EER]	Baseline Heating Efficiency [COP] (No Built-in Resistance Heat)	Baseline Heating Efficiency [COP] (With Built-in Resistance Heat)
PTAC	<7,000	11.0	--	1.0
	7,000-15,000	12.5 – (0.213 × Cap/1,000)		
	>15,000	9.3		
PTHP	<7,000	10.8	3.0	--
	7,000-15,000	12.3 – (0.213 × Cap/1,000)	3.2 – (0.026 × Cap/1,000)	
	>15,000	9.1	2.8	

Replace-on-Burnout and New Construction:

Table 13.4-2 provides minimum efficiency standards for PTAC/PTHP units and reflects the IECC 2018 efficiencies for Packaged Terminal Air Conditioners and Heat Pumps. These values are closely aligned with the federal standards for packaged terminal air-conditioners and heat pumps effective February 2013 and reflected in 10 CFR 431.

Table 13.4-2: [PTACs, PTHPs, & Room ACs] ROB/NC Baseline Efficiency for PTAC/PTHPs[519,520]

Equipment	Category	Cooling Capacity [Btuh]	Minimum Cooling Efficiency [EER]	Minimum Heating Efficiency [COP]
PTAC	Standard	All	14.0 – (0.300 x Cap/1,000)	--
	Non-Standard		10.9 – (0.213 x Cap/1,000)	
PTHP	Standard		14.0 – (0.300 x Cap/1,000)	3.7 – (0.026 x Cap/1,000)
	Non-Standard		10.8 – (0.213 x Cap/1,000)	2.9 – (0.026 x Cap/1,000)

Table 13.4-3 provides minimum efficiency standards for Room Air Conditioners and reflects the IECC 2018 efficiencies.

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[517] ER only applies to standard size units because the minimum efficiency requirements for non-standard systems have never changed, making the ER baseline efficiency the same as for ROB.

[518] Cap refers to the rated cooling capacity in Btuh. If the capacity is less than 7,000 Btuh, use 7,000 Btuh in the calculation. If the capacity is greater than 15,000 Btuh, use 15,000 Btuh in the calculation.

[519] IECC 2018 Table C403.3.2(3).

[520] Cap refers to the rated cooling capacity in Btuh.

Table 13.4-3: [PTACs, PTHPs, & Room ACs] Minimum Efficiency for ROB or NC Room Air Conditioners Units

Category	Cooling Capacity [Btuh]	Minimum Cooling Efficiency [CEER]
Without reverse cycle, with louvered sides	< 8,000	11.0
	≥ 8,000 and < 14,000	10.9
	≥ 14,000 and < 20,000	10.7
	≥ 20,000 and ≤ 25,000	9.4
	> 25,000	9.0
Without reverse cycle, without louvered sides	< 8,000	10.0
	≥ 8,000 and < 11,000	9.6
	≥ 11,000 and < 14,000	9.5
	≥ 14,000 and < 20,000	9.4
	≥ 20,000	9.4
With reverse cycle, with louvered sides	< 20,000	9.8
	≥ 20,000	9.3
With reverse cycle, without louvered sides	< 14,000	9.3
	≥ 14,000	8.7
Casement-only	All capacities	9.5
Casement-slider	All capacities	10.4

13.4.1.3 High-Efficiency Condition

The high-efficiency retrofits must exceed the minimum federal standards found in Table 13.4-2 and Table 13.4-3.

The high-efficiency retrofits must also meet the following criteria:

- For ER projects only, the installed equipment cooling capacity must be within 80% to 120% of the replaced electric cooling capacity. For scenarios involving the replacement of a combination of systems by an alternate combination of systems of varying capacities, ER savings can still be claimed if the overall pre and post capacities for the total combination of systems are within +/- 20%. In these cases, a custom calculation should be performed to establish the following weighted savings factors to be applied over the ER portion of the savings calculation: manufacturer year, EUL, RUL, path A/B full and part-load baseline, demand factor, and EFLH. These factors should be weighted based on contribution to overall capacity.

- Non-standard size PTAC/PTHPs cannot be used for NC.
- No additional measures are being installed that directly affect the operation of the cooling equipment (i.e., control sequences).

13.4.2 Energy and Demand Savings Methodology

13.4.2.1 Savings Algorithms and Input Variables

Energy Savings

$$Total\ Energy\ [kWh_{Savings}] = kWh_{Savings,C} + kWh_{Savings,H}$$

Equation 13.4-1

$$Energy\ (Cooling)\ [kWh_{Savings,C}] = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}}\right) \times \frac{EFLH_C}{1,000}$$

Equation 13.4-2

$$Energy\ (Heating)\ [kWh_{Savings,H}] = \left(\frac{Cap_{H,pre}}{\eta_{baseline,H}} - \frac{Cap_{H,post}}{\eta_{installed,H}}\right) \times \frac{EFLH_H}{3,412}$$

Equation 13.4-3

Demand Savings

$$Demand\ Savings\ [kW_{Savings}] = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}}\right) \times \frac{DF}{1,000}$$

Equation 13.4-4

Where:

$Cap_{C/H,pre}$ = *For ER, rated equipment cooling/heating capacity of the existing equipment at AHRI standard conditions; for ROB & NC, rated equipment cooling/heating capacity of the new equipment at AHRI standard conditions [Btuh]; 1 ton = 12,000 Btuh.*

$Cap_{C/H,post}$ = *Rated equipment cooling/heating capacity of the newly installed equipment at AHRI standard conditions [Btuh]; 1 ton = 12,000 Btuh.*

$\eta_{baseline,C}$ = *Cooling efficiency of existing (ER) or standard (ROB/NC) equipment [EER, Btu/W-h]; see Table 13.4-1 through Table 13.4-3.*

$\eta_{baseline,H}$ = *Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP]; see Table 13.4-1 and Table 13.4-2.*

$\eta_{installed,C}$ = *Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h]. Rated cooling efficiency must exceed minimum federal standards found in Table 13.4-2 and Table 13.4-3.*[521]

$\eta_{installed,H}$ = *Rated heating efficiency of the newly installed equipment [COP]. Rated heating efficiency must exceed minimum federal standards found in Table 13.4-2.*[522]

DF = *Demand factor (NCP, CP, or 4CP) for appropriate building and equipment type; see Table 13.4-5 through Table 13.4-7.*

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours for newly installed equipment based on appropriate building and equipment type [hours]. Table 13.4-4 contains the effective full load hours for commercial packaged terminal air conditioners, packaged terminal heat pumps, and room AC systems in San Antonio.*

1,000 = *Constant to convert from watts to kilowatts.*

3,412 = *Constant to convert from Btu to kWh.*

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 by using a load shape developed through adapting NREL's Commercial Reference Building Models[523] for San Antonio. The load shape can be found in Section 22.2.

13.4.2.2 Deemed Energy Savings Tables

Table 13.4-4 contains the effective full load hours for commercial PTACs, PTHPs, and RACs in San Antonio.

These tables also include an "Other" building type, which can be used for business types that are not explicitly listed. The DF and EFLH values used for Other are the most conservative values from the explicitly listed building types. When the Other building type is used, a description of the actual building type, the primary business activity, the business hours, and the HVAC schedule must be collected for the project site and stored in the utility tracking data system. For those combinations of technology, climate zone, and building type where no values are present, a project with that specific combination should use the "Other" building type.

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[521] Rated efficiency is commonly reported at both 230V and 208V. Savings calculations should reference efficiency at 230V, as AHRI rating conditions specify that voltage.
[522] Ibid.
[523] NREL Commercial Reference Buildings, http://energy.gov/eere/buildings/commercial-reference-buildings.

Table 13.4-4: [PTACs, PTHPs, & Room ACs] Equivalent Full-Load Hours

Building Type	Principal Building Activity	Package Terminal Unit		
		AC	Heat Pump	
		$EFLH_C$	$EFLH_C$	$EFLH_H$
Education	Primary School	1,330	1,330	86
	Secondary School	1,163	1,163	96
Food Sales	Convenience	1,878	1,878	120
Food Service	Full-Service Restaurant	1,831	1,831	185
	24 Hr Full-Service	2,075	2,075	232
	Quick-Service Restaurant	1,625	1,625	138
	24 Hr Quick Service	1,882	1,882	205
Lodging	Large Hotel	2,117	2,117	105
	Nursing Home	2,009	2,009	33
	Small Hotel	1,971	1,971	50
Mercantile	Strip Mall	1,194	1,194	84
Office	Small Office	1,301	1,301	50
Other	Other	1,163	1,163	33

13.4.2.3 Deemed Summer Demand Savings Tables

Table 13.4-5 through Table 13.4-7 contain the NCP, CP, and 4CP demand factors for commercial PTACs, PTHPs, and RACs in San Antonio.

Non-Coincident Peak Tables

Table 13.4-5: [PTACs, PTHPs, & Room ACs] Non-Coincident Peak Demand Factors

Building Type	Principal Building Activity	Package Terminal Unit	
		AC	Heat Pump
		NCP	NCP
Education	Primary School	0.88	0.88
	Secondary School	0.90	0.90
Food Sales	Convenience	0.90	0.90
Food Service	Full-Service Restaurant	0.90	0.90
	24 Hr Full-Service	0.91	0.91
	Quick-Service Restaurant	0.90	0.90
	24 Hr Quick Service	0.90	0.90
Lodging	Large Hotel	0.61	0.61
	Nursing Home	0.87	0.87
	Small Hotel	0.57	0.57
Mercantile	Strip Mall	0.82	0.82
Office	Small Office	0.84	0.84
Other	Other	0.57	0.57

Coincident Peak Tables

Table 13.4-6: [PTACs, PTHPs, & RACs] Coincident Peak Demand Factors

Building Type	Principal Building Activity	Package Terminal Unit	
		AC	Heat Pump
		CP	CP
Education	Primary School	0.85	0.85
	Secondary School	0.86	0.86
Food Sales	Convenience	0.82	0.82
Food Service	Full-Service Restaurant	0.85	0.85
	24 Hr Full-Service	0.86	0.86
	Quick-Service Restaurant	0.82	0.82
	24 Hr Quick Service	0.85	0.85
Lodging	Large Hotel	0.58	0.58
	Nursing Home	0.84	0.84
	Small Hotel	0.54	0.54
Mercantile	Strip Mall	0.78	0.78
Office	Small Office	0.80	0.80
Other	Other	0.54	0.54

4CP Tables

Table 13.4-7: [PTACs, PTHPs, & RACs] 4CP Demand Factors

Building Type	Principal Building Activity	Package Terminal Unit	
		AC	Heat Pump
		4CP	4CP
Education	Primary School	0.69	0.69
	Secondary School	0.73	0.73
Food Sales	Convenience	0.74	0.74
Food Service	Full-Service Restaurant	0.75	0.75
	24 Hr Full-Service	0.78	0.78
	Quick-Service Restaurant	0.74	0.74
	24 Hr Quick Service	0.78	0.78
Lodging	Large Hotel	0.71	0.71
	Nursing Home	0.73	0.73
	Small Hotel	0.70	0.70
Mercantile	Strip Mall	0.69	0.69
Office	Small Office	0.71	0.71
Other	Other	0.69	0.69

13.4.2.4 Additional Calculators and Tools

This section is not applicable for this measure.

13.4.2.5 Measure Life and Lifetime Savings

Estimated Useful Life (EUL)

The EUL is 15 years for PTAC/PTHPs, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HVAC-PTAC and HVAC-PTHP.[524] The EUL of RAC units is 10 years, which is consistent with the EUL reported in the Department of Energy Technical Support Document for RACs.[525]

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[524] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

[525] Technical Support Document: Room Air Conditioners, June 2020, p. ES-14. https://beta.regulations.gov/document/EERE-2014-BT-STD-0059-0013.

Remaining Useful Life (RUL) for PTAC/PTHP Systems

The RUL of ER replaced systems is provided according to system age in Table 13.4-8.

For ER units of unknown age, assume a default value equal to the EUL. This corresponds to a default RUL of 2.8 years. Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. Both the RUL and EUL are needed to estimate savings for ER projects for two distinct periods: the ER period (RUL) and the ROB period (EUL - RUL). The calculations for ER projects are extensive, and as such are provided in Section 22.3.

Table 13.4-8: [PTACs, PTHPs, & RACs] Remaining Useful Life or Replaced Unit[526]

Age of Replaced System (Years)	RUL (Years)
1	14.0
2	13.0
3	12.0
4	11.0
5	10.0
6	9.1
7	8.2
8	7.3
9	6.5
10	5.7
11	5.0
12	4.4
13	3.8
14	3.3
15	2.8
16	2.0
17	1.0
18[527]	0.0

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[526] Current NC baseline matches the baseline for existing systems manufactured in 2018. Existing systems manufactured after 1/1/2018 are not eligible to use the early retirement baseline.

[527] RULs are capped at the 75th percentile of equipment age, 18 years, as determined based on DOE survival curves. Systems older than 18 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

13.4.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Building type
- For ‘Other’ building type ONLY: a description of the actual building type, the primary business activity, the business hours, and the HVAC schedule
- Decision/action type: ROB, NC, or ER
- Baseline unit quantity
- Baseline rated cooling and heating capacities
- For ER ONLY: baseline Age and Method of Determination (e.g., nameplate, blueprints, customer reported, not available)
- For ER ONLY: photograph of retired unit nameplate demonstrating model number, serial number, and manufacturer if blueprints are not provided; if photograph of nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (alternate forms of documentation can be approved at the evaluator’s discretion)
- Manufacturer, model, and serial number of new unit
    - AHRI/DOE CCMS certificates or reference number matching model number
- New unit equipment type (PTAC, PTHP, RAC)
- New unit equipment configuration category: standard/non-standard (PTAC/PTHP only)
- New unit quantity
- New unit rated cooling and heating capacities
- New unit cooling and heating efficiency ratings
- Proof of purchase: invoice showing model number; photo(s) of the model number on product packaging or installed unit(s); OR evaluator pre-approved approach
    - For NC ONLY, as built design drawings or HVAC specifications package that provides detailed manufacturer and model number information on installed unit(s) may also be accepted as the proof of purchase

13.5 COMPUTER ROOM AIR CONDITIONERS

13.5.1 Measure Description

This section summarizes the deemed savings methodology for the installation of computer room air conditioning (CRAC) systems. A CRAC unit is a device that monitors and maintains the temperature, air distribution, and humidity in a network room or data center. This document covers assumptions made for baseline equipment efficiencies for early retirement (ER) based on the age of the replaced equipment and replace-on-burnout (ROB) and new construction (NC) situations based on efficiency standards. Savings calculations incorporate the use of only part-load efficiency values, as these types of units are only rated in units of seasonal COP (SCOP). For ER, the actual age of the baseline system should be determined from the equipment nameplate or other physical documentation whenever possible. If the actual age of the unit is unknown, default values are provided.

13.5.1.1 Eligibility Criteria

For a measure to be eligible for this deemed savings approach the following conditions will be met:

- The existing and proposed cooling equipment are electric.
- The building type is a network room or data center.
- ER projects involve the replacement of a working system. The ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. An ROB approach should be used for these scenarios.
- If these conditions are not met, the deemed savings approach cannot be used, and the M&V Methodology described in the commercial custom measure must be used.
- Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[528,529]

13.5.1.2 Baseline Condition

The baseline conditions related to efficiency and system capacity for ER and ROB/NC are described in the following sections.

Early Retirement

ER projects should claim savings using the ROB/NC baseline, as no additional savings are specified for ER projects. This section will not apply until the current baseline is updated, allowing the measure to refer to the existing baseline for ER projects.

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[528] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.

[529] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.

Replace-on-Burnout (ROB) and New Construction (NC)

Baseline efficiency levels for CRACs are provided in Table 13.4-2. These baseline efficiency levels reflect the minimum efficiency requirements from IECC 2018, which uses sensible coefficient of performance (SCOP) as the standard efficiency metric.

Table 13.5-1: [CRACs] Baseline Efficiency Levels for ROB or NC[530]

System Type	Capacity [Btu/hr]	Baseline Efficiencies for Downflow/Upflow Units [SCOP]
Air conditioners, air cooled	< 65,000	2.20 / 2.09
	≥ 65,000 and < 240,000	2.10 / 1.99
	≥ 240,000	1.90 / 1.79
Air conditioners, water cooled	< 65,000	2.60 / 2.49
	≥ 65,000 and < 240,000	2.50 / 2.39
	≥ 240,000	2.40 / 2.29
Air conditioners, water cooled with fluid economizer	< 65,000	2.55 / 2.44
	≥ 65,000 and < 240,000	2.45 / 2.34
	≥ 240,000	2.35 / 2.24
Air conditioners, glycol cooled (rated at 40% propylene glycol)	< 65,000	2.50 / 2.39
	≥ 65,000 and < 240,000	2.15 / 2.04
	≥ 240,000	2.10 / 1.99
Air conditioners, glycol cooled (rated at 40% propylene glycol) with fluid economizer	< 65,000	2.45 / 2.34
	≥ 65,000 and < 240,000	2.10 / 1.99
	≥ 240,000	2.05 / 1.94

13.5.1.3 High-Efficiency Condition

CRAC units must exceed the minimum efficiencies specified in Table 13.5-1. Additional conditions for ER, ROB, and NC are as follows:

New Construction and Replace-on-Burnout

This scenario includes equipment used for NC and retrofit/replacements that do not satisfy the ER criteria, such as units that are replaced after natural failure.

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[530] IECC 2018 Table C403.3.2(9).

Early Retirement

ER projects should claim savings using the ROB/NC baseline, as no additional savings are specified for ER projects. This section will not apply until the current baseline is updated, allowing the measure to refer to the existing baseline for ER projects.

13.5.1 Energy and Demand Savings Methodology

13.5.1.1 Savings Algorithms and Input Variables

Energy Savings

$$\boldsymbol{Energy\ (Cooling)\ [kWh_{Savings,C}] = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}}\right) \times EFLH_C \times \frac{1\ kWh}{3,412\ Btu}}$$

Equation 13.5-1

Demand Savings

$$\boldsymbol{Demand\ [kW_{Savings,C}] = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}}\right) \times DF \times \frac{1\ kW}{3,412\ Btuh}}$$

Equation 13.5-2

Where:

$Cap_{C,pre}$ = *Rated equipment cooling capacity of the newly installed equipment at AHRI standard conditions [Btuh]; 1 ton = 12,000 Btuh.*

$Cap_{C,post}$ = *Rated equipment cooling capacity of the newly installed equipment at AHRI standard conditions [Btuh]; 1 ton = 12,000 Btuh.*

Note: AHRI may rate cooling capacity in kW. In these cases, convert from kW to btu/hr by multiplying kW by 3,412.

$\eta_{baseline,C}$ = *Cooling efficiency of existing equipment (ER) or standard equipment (ROB/NC) [SCOP] in Table 13.5-1.*

$\eta_{installed,C}$ = *Rated cooling efficiency of the newly installed equipment [SCOP]. Efficiency rating must exceed ROB/NC baseline efficiency standards in Table 13.5-1.*

Note: Use SCOP for both kW and kWh savings calculations.

DF = *Demand factor (NCP, CP, or 4CP) for appropriate equipment type in Table 13.5-4.*

$EFLH_C$ = *Cooling equivalent full-load hours for appropriate equipment type [hours] in Table 13.5-3.*

1,000 = *Constant to convert from watts to kilowatts.*

3,412 = *Constant to convert from Btu to kWh.*

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed through adapting NREL's Commercial Reference Building Models[531] for San Antonio. The load shape can be found in Section 22.2.

13.5.1.2 Deemed Energy Savings Tables

Table 13.5-3 contains the effective full load hours for CRACs for data centers in San Antonio.

Table 13.5-2: [CRACs] Commercial HVAC Building Type Descriptions and Examples

Building Type	Definition	Detailed Business Type Examples
Data Center	Buildings used to house computer systems and associated components.	1) Data Center

Table 13.5-3: [CRACs] Equivalent Full-Load Hours

Building Type	$EFLH_C$	$EFLH_H$
Data Center	4,022	0

13.5.1.3 Deemed Summer Demand Savings Tables

Table 13.5-4 contains the NCP, CP, and 4CP demand factors for CRACs for data centers in San Antonio.

Table 13.5-4: [CRACs] Peak Demand Factors

Building Type	NCP	CP	4CP
Data Center	1.07	1.05	0.89

13.5.1.4 Additional Calculators and Tools

This section is not applicable for this measure.

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[531] NREL Commercial Reference Buildings, http://energy.gov/eere/buildings/commercial-reference-buildings.

13.5.1.5 Measure Life and Lifetime Savings

The EUL and RULs for this HVAC equipment are provided below.

Estimated Useful Life (EUL)

The EUL is 15 years for split and packaged ACs and HPs, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HVAC-airAC and HVAC-airHP.[532] This EUL is also applicable for CRACs.

Remaining Useful Life (RUL)

This section will not apply unless the current baseline is updated, allowing the measure to refer to the existing baseline for early retirement projects.

13.5.2 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Decision/action type; ER, ROB, NC, system type conversion
- Baseline equipment type
- Baseline unit quantity
- Baseline rated cooling and heating capacity
- Manufacturer, model, and serial number of new unit
  - AHRI/DOE CCMS certificates or reference number matching model number
- New unit equipment type
- New unit quantity
- New unit rated cooling capacity
- New unit cooling efficiency rating
- Proof of purchase: invoice showing model number; photo(s) of the model number on product packaging or installed unit(s); OR evaluator pre-approved approach
  - For NC ONLY, as built design drawings or HVAC specifications package that provides detailed manufacturer and model number information on installed unit(s) may also be accepted as the proof of purchase

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[532] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

13.6 HVAC VARIABLE FREQUENCY DRIVES

13.6.1 Measure Description

This measure involves the installation of a variable frequency drive (VFD) in a commercial HVAC application. Eligible applications include:

- AHU supply fan on a split or packaged HVAC system. The fan is in a variable air volume (VAV) system with terminal VAV boxes or constant air volume (CAV) unit with no control device.
- Hot water distribution pumps.
- Chilled water distribution pumps.

This measure does not apply to controls installed on the HVAC compressor. This measure accounts for the interactive air-conditioning demand savings during the utility-defined summer peak period. The savings are on a per-control basis and the lookup tables show the total savings for eligible scenarios.

13.6.1.1 Eligibility Criteria

Supply fans may not have variable pitch blades. Supply fan drives must be less than or equal to 100 horsepower (hp). New construction systems are ineligible. Equipment used for process loads are ineligible.

13.6.1.2 Baseline Condition

The AHU supply fan baseline is a centrifugal supply fan with a single-speed motor, a direct expansion (DX) air-conditioning (AC) unit, and VAV boxes. The motor is a standard efficiency motor based on ASHRAE Standard 90.1-2013 standards, which are provided by horsepower. The AC unit has standard cooling efficiency based on IECC 2018. The part-load fan control is an outlet damper, inlet damper, or inlet guide vane.

The HVAC pump baseline is a constant speed pump.

13.6.1.3 High-Efficiency Condition

The high efficiency condition is installation of a VFD on an AHU supply fan, hot water pump, or chilled water pump.

For AHU supply fans, when applicable, the existing damper or inlet guide vane will be removed or set completely open permanently after installation. The VFD will maintain a constant static pressure by adjusting fan speed and delivering the same amount of air as the baseline condition.

13.6.2 Energy and Demand Savings Methodology

13.6.2.1 Savings Algorithms and Input Variables

To calculate both Demand and Energy Savings, certain values (%CFM, %GPM, and %power) will initially need to be calculated for each hour.

Step 1 – Determine the percent flow rate for each hour of the year, *i.*

Flow Rate for AHUs:

$$\%\boldsymbol{CFM_i} = \boldsymbol{m} \times \boldsymbol{t_{db\,i}} + \boldsymbol{b}$$

Equation 13.6-1

Where:

$t_{db\,i}$ = *Dry bulb air temperature (DBT) at i^th^ hour taken from TMY3 hourly weather data.*[533]

m = *The slope of the relationship between DBT and CFM; see Table 13.6-1.*

b = *the intercept of the relationship between DBT and CFM; see Table 13.6-1.*

The minimum flow rate is set to 60%CFM based on common design practice.[534] Determination of the minimum dry bulb temperature assumes that cooling will only operate above the cooling reference temperature of 65°F dry bulb. The maximum DBT is the ASHRAE dry bulb design temperature for San Antonio.[535]

Table 13.6-1: [HVAC VFD] AHU VFD %CFM Inputs

Condition	Min	Max	Slope (m)	Intercept (b)
Flow Rate (%cfm)	60	100	1.17	-15.80
Dry Bulb T (°F)	65	99.3		

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[533] National Renewable Energy Laboratory's (NREL) National Solar Radiation Data Base: 1991- 2005 Update for Typical Meteorological Year 3 (TMY3). Available at https://sam.nrel.gov/weather-data.html.

[534] For AHU, a 60% minimum setpoint strategy is assumed, so any results below 60% are set to 60%. Similarly, any results greater than 100% are set to 100%.

[535] ASHRAE 2017 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

Flow Rate for Chilled Water Pumps:

$$\%GPM_i = m \times t_{db\_i} + b$$

Equation 13.6-2

Where:

t_{db_i} = *the hourly dry bulb temperature (DBT) based on TMY3 data.*[536]

m = *the slope of the relationship between DBT and GPM; see Table 13.6-2.*

b = *the intercept of the relationship between DBT and GPM; see Table 13.6-2.*

The minimum flow rate is set to 10%GPM based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.[537] Determination of the minimum dry bulb temperature assumes that cooling will only operate above the cooling reference temperature of 65°F dry bulb. The maximum DBT is the ASHRAE dry bulb design temperature for San Antonio.[538]

Table 13.6-2: [HVAC VFD] Chilled Water Pump VFD %GPM Inputs

Condition	Min	Max	Slope (m)	Intercept (b)
Flow Rate (%gpm)	10	100	2.62	-160.55
Dry Bulb T (°F)	65	99.3		

Flow Rate for Hot Water Pumps:

$$\%GPM_i = m \times t_{db\_i} + b$$

Equation 13.6-3

Where:

t_{db_i} = *the hourly dry bulb temperature (DBT) based on TMY3 data.*

m = *the slope of the relationship between DBT and GPM; see Table 13.6-3.*

b = *the intercept of the relationship between DBT and GPM; see Table 13.6-3.*

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[536] National Renewable Energy Laboratory's (NREL) National Solar Radiation Data Base: 1991- 2005 Update for Typical Meteorological Year 3 (TMY3). Available at https://sam.nrel.gov/weather-data.html.

[537] PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.249, pump minimum speed default.

[538] ASHRAE 2017 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

The minimum flow rate is set to 10%GPM based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.[539] Determination of the minimum dry bulb temperature assumes that heating will only operate below the reference temperature of 65°F dry bulb. The maximum DBT is the ASHRAE dry bulb design temperature for San Antonio.[540]

Table 13.6-3: [HVAC VFD] Hot Water Pump VFD %GPM Inputs

Condition	Min	Max	Slope (m)	Intercept (b)
Flow Rate (%gpm)	10	100	-2.56	176.67
Dry Bulb T (°F)	65	29.9		

Step 2 – Calculate the %power for each hour, i, of the applicable baseline technology (Outlet Damper, Inlet Damper, or Inlet Guide Vane) and the new VFD technology.

Power for Baseline Technologies

For AHU Supply Fans:[541]

$$\%\boldsymbol{power}_{i,OutletDamper} = \mathbf{0.00745} \times \%\boldsymbol{CFM}_i^{\,2} + \mathbf{0.10983} \times \%\boldsymbol{CFM}_i + \mathbf{20.41905}$$

Equation 13.6-4

$$\%\boldsymbol{power}_{i,InletDamper} = \mathbf{0.00013} \times \%\boldsymbol{CFM}_i^{\,3} - \mathbf{0.01452} \times \%\boldsymbol{CFM}_i^{\,2} + \mathbf{0.71648} \times \%\boldsymbol{CFM}_i + \mathbf{50.25833}$$

Equation 13.6-5

$$\%\boldsymbol{power}_{i,InletGuideVane} = \mathbf{0.00009} \times \%\boldsymbol{CFM}_i^{\,3} - \mathbf{0.00128} \times \%\boldsymbol{CFM}_i^{\,2} + \mathbf{0.06808} \times \%\boldsymbol{CFM}_i + \mathbf{20}$$

Equation 13.6-6

Note: %power for baseline technologies with no flow control should be set to 1 for each hour.

For Chilled and Hot Water Pumps[542]*:*

$$\%\boldsymbol{power}_{base} = \mathbf{2.5294} \times \%\boldsymbol{GPM}_i^{\,3} - \mathbf{4.7443} \times \%\boldsymbol{GPM}_i^{\,2} + \mathbf{3.2485} \times \%\boldsymbol{GPM}_i + \mathbf{0}$$

Equation 13.6-7

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[539] PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.249, pump minimum speed default.

[540] ASHRAE 2017 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 99.6% Heating DB.

[541] https://focusonenergy.com/sites/default/files/Focus%20on%20Energy_TRM_January2015.pdf, page 225. Please note, the CFM² coefficients in Equation 36 and Equation 37 have the wrong sign in the reference document.

[542] PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, Table 87 Default Part-Load CIRC-PUMP-FPLR Coefficients – Constant Speed, no VSD.

Power for VFD Technology

For AHU Supply Fans:

$$\%\boldsymbol{power}_{\boldsymbol{i,VFD}} = \mathbf{0.00004} \times \%\boldsymbol{CFM}_{\boldsymbol{i}}^{\mathbf{3}} + \mathbf{0.00766} \times \%\boldsymbol{CFM}_{\boldsymbol{i}}^{\mathbf{2}} - \mathbf{0.19567} \times \%\boldsymbol{CFM}_{\boldsymbol{i}} + \mathbf{5.9}$$

Equation 13.6-8

For Chilled and Hot Water Pumps[543]*:*

$$\%\boldsymbol{power}_{\boldsymbol{VFD}} = \mathbf{0.7347} \times \%\boldsymbol{GPM}_{\boldsymbol{i}}^{\mathbf{3}} - \mathbf{0.301} \times \%\boldsymbol{GPM}_{\boldsymbol{i}}^{\mathbf{2}} + \mathbf{0.5726} \times \%\boldsymbol{GPM}_{\boldsymbol{i}} + \mathbf{0}$$

Equation 13.6-9

Demand Savings

Demand Savings are calculated for each hour, i, over the course of the year:

Step 3 – Calculate kW_{full} by using the horsepower from the motor nameplate, load factor, and the applicable motor efficiency corresponding to the motor horsepower in use shown in Table 13.6-4. Use that result and the hourly %power results for both the baseline and VFD technology to determine power consumption at each hour.

$$\boldsymbol{kW}_{\boldsymbol{full}} = \mathbf{0.746} \times \boldsymbol{HP} \times \frac{\boldsymbol{LF}}{\boldsymbol{\eta}}$$

Equation 13.6-10

$$\boldsymbol{kW}_{\boldsymbol{i}} = \boldsymbol{kW}_{\boldsymbol{full}} \times \%\boldsymbol{power}_{\boldsymbol{i}}$$

Equation 13.6-11

Where:

$\%power_i$	=	*Percentage of full load power at the i^{th} hour calculated by an equation based on the technology and control type (outlet damper, inlet box damper, inlet guide vane-IGV, or VFD).*[544]
kW_{full}	=	*motor power demand operating at the design 100% flow[kW].*
kW_i	=	*real-time power at the i^{th} hour of a year [kW].*
HP	=	*Rated horsepower of the motor [hp].*
LF	=	*Load factor – ratio of the operating load to the nameplate rating of the motor – assumed to be 75%.*

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[543] PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, Table 87 Default Part-Load CIRC-PUMP-FPLR Coefficients – Default (VSD, No Reset).

[544] Fan curves by control type are provided in the BPA ASD Calculator, https://www.bpa.gov/EE/Sectors/Industrial/Documents/ASDCalculators.xls.

η = *[For Fans]: Motor efficiency of a standard efficiency Open Drip Proof (ODP) motor operating at 1800 RPM taken from ASHRAE Standard 90.1-2013, Reference Table 13.6-4. [For Pumps]: Assumed to be 0.9 for all motor sizes.*

0.746 = *Constant to convert from horsepower to kilowatts.*

Table 13.6-4: [HVAC VFDs] Motor Efficiencies for Open Drip Proof Motors at 1,800 RPM [545]

Motor Size (hp)	Nominal Efficiency
1	0.855
2	0.865
3	0.865
5	0.895
7.5	0.910
10	0.917
15	0.930
20	0.930
25	0.936
30	0.941
40	0.941
50	0.945
60	0.950
75	0.950
100	0.954

Step 4 – Calculate the kW savings for each hour across the year. The kW savings are equal to the hourly kW usage difference between the baseline and VFD, multiplied by the occupancy schedule for the specific hour of operation by using Equation 13.6-12.

Hourly Savings Calculations

$$(kW_i)_{Saved} = [(kW_i)_{Baseline} - (kW_i)_{VFD}] \times schedule_i$$

Equation 13.6-12

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[545] Table 10.8 Minimum Nominal Efficiency for General Purpose Design A and Design B Motors in ASHRAE Standard 90.1-2004, Standard Efficiency Open Drip Proof Motors at 1800 RPM.

Where:

$schedule_i$ = *Occupancy schedule. 1 when building is occupied, 0.2 when building is unoccupied; see Table 13.6-5.*

Table 13.6-5: [HVAC VFDs] Yearly Motor Operation Hours by Building Type[546]

Building Type	Weekday Schedule	Weekend Schedule	Annual Motor Operation Hours
Hospitals, Healthcare, Nursing Home, Hotel (common areas), Large Multifamily (Common Areas)	24 hr	24 hr	8,760
Office—Large, Medium	7am-11pm	7am-7pm (Saturday)	5,592
Office—Small	7am-8pm	closed	4,466
Education	8am-11pm	closed	4,884
Convenience Store, Service, Strip Mall	9am-10pm	9am-8pm (Saturday) 10am-7pm (Sunday)	5,298
Stand-alone Retail, Supermarket-	8am–10pm	8am-11pm (Saturday) 10am-7pm (Sunday)	5,674
Restaurants	6am-2am	6am-2am	7,592
Warehouse	7am-7pm	closed	4,258
Assembly, Worship	9am-11pm	9am-11pm	5,840
Other[547]	7am-7pm	closed	4,258

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[546] Hours for all building types except for Assembly come from the Department of Energy Commercial Building Prototype Models, Scorecards, HVAC Operation Schedule. Motor hours are set to equal 1 when the HVAC Operation Schedule is "on" and 0.2 when the HVAC Operation Schedule is "off." https://www.energycodes.gov/development/commercial/prototype_models. Assembly occupied hours come from COMNET Appendix C—Schedules (Rev 3) https://comnet.org/appendix-c-schedules updated 07/25/2016.

[547] The "other" building type may be used when none of the listed building types apply. The values used for other are the most conservative of the listed building types.

From these hourly kW savings, the methodologies in Section 2.3 provide the kW demand savings for the non-coincident peak, coincident peak, and ERCOT 4CP. The total NCP, CP, or 4CP demand saved can be calculated by multiplying the kW saved by the peak demand interactive effects factor, as shown in Equation 13.6-13.

Total Peak Demand Saved Calculation, including interactive effects, applies only to AHUs.

$$kW_{TotalSaved} = kW_{Saved} \times \left(1 + \frac{3.412}{Cooling_{SEER}}\right)$$

Equation 13.6-13

Where:

$Cooling_{SEER}$ = *Air conditioner cooling efficiency, assumed at 12.6, based on IECC 2018 minimum efficiency of a unitary AC system between 5 and 10 tons.*

Energy Savings

Step 5 – For the applicable baseline technology and VFD, multiply the hourly kW usage by the corresponding occupancy factor; sum these hourly results. Perform this calculation for both the applicable baseline and the VFD technologies.

$$Annual\ kWh_{baseline\ or\ VFD} = \sum_{i=1}^{8{,}760} (kW_i \times schedule_i)$$

Equation 13.6-14

Where:

8,760 = *Total hours per year.*

Step 6 – Subtract the Annual kWh_{VFD} from the Annual $kWh_{baseline}$ to get the Annual Energy Savings.

$$Annual\ Energy\ Savings: kWh_{Saved} = kWh_{baseline} - kWh_{VFD}$$

Equation 13.6-15

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 by using load shapes of %CFM and %power developed specifically for San Antonio through the calculation methods in Step 1 and Step 2 in the section above.

Table 13.6-5 contains the schedule used to determine operating hours per building type. These schedules are to be used in conjunction with the hourly values determined for %CFM and %power for each technology type. The load shape for %CFM, %power, and building occupancy schedules are included in Section 22.2.

13.6.2.2 Deemed Energy and Demand Savings Tables

The energy and demand savings tables listed are calculated based on San Antonio specific TMY3 weather data and are presented per motor hp.

Table 13.6-6: [HVAC VFDs] Deemed Savings for AHU Outlet Damper Part-Load Fan Control per Motor hp

Building Type	Savings per Motor HP			
	kWh	NCP kW	CP kW	4CP kW
Hospitals, Healthcare, Nursing Home, Hotel	1,044	0.143	0.083	0.092
Office—Large, Medium	632			
Office—Small	499			
Education	551			
Convenience Store, Service, Strip Mall	585			
Stand-alone Retail, Supermarket	633			
Restaurants	886			
Large Multifamily	1,044			
Warehouse	474			
Assembly, Worship	655			
Other	474			

Table 13.6-7: [HVAC VFDs] Deemed Savings for AHU Inlet Damper Part-Load Fan Control per Motor hp

Building Type	Savings per Motor HP			
	kWh	NCP kW	CP kW	4CP kW
Hospitals, Healthcare, Nursing Home, Hotel	1,546	0.235	0.097	0.110
Office—Large, Medium	917			
Office—Small	722			
Education	799			
Convenience Store, Service, Strip Mall	843			
Stand-alone Retail, Supermarket	914			
Restaurants	1,300			
Large Multifamily	1,546			
Warehouse	686			
Assembly, Worship	947			
Other	686			

Table 13.6-8: [HVAC VFDs] Deemed Savings for AHU Inlet Guide Vane Part-Load Fan Control per Motor hp

Building Type	Savings per Motor HP			
	kWh	NCP kW	CP kW	4CP kW
Hospitals, Healthcare, Nursing Home, Hotel	312	0.052	0.016	0.018
Office—Large, Medium	182			
Office—Small	143			
Education	159			
Convenience Store, Service, Strip Mall	167			
Stand-alone Retail, Supermarket	181			
Restaurants	261			
Large Multifamily	312			
Warehouse	136			
Assembly, Worship	188			
Other	136			

Table 13.6-9: [HVAC VFDs] Deemed Savings for AHU No Existing Fan Control per Motor hp

Building Type	Savings per Motor HP			
	kWh	NCP kW	CP kW	4CP kW
Hospitals, Healthcare, Nursing Home, Hotel	2,803	0.423	0.151	0.202
Office—Large, Medium	1,657			
Office—Small	1,302			
Education	1,443			
Convenience Store, Service, Strip Mall	1,519			
Stand-alone Retail, Supermarket	1,649			
Restaurants	2,356			
Large Multifamily	2,803			
Warehouse	1,237			
Assembly, Worship	1,710			
Other	1,237			

Table 13.6-10: [HVAC VFDs] Deemed Savings for Chilled Water Pumps per Motor hp

Building Type	Savings per Motor HP			
	kWh	NCP kW	CP kW	4CP kW
Hospitals, Healthcare, Nursing Home, Hotel	1,360	0.295	0.138	0.227
Office—Large, Medium	894			
Office—Small	704			
Education	777			
Convenience Store, Service, Strip Mall	847			
Stand-alone Retail, Supermarket	908			
Restaurants	1,195			
Large Multifamily	1,360			
Warehouse	668			
Assembly, Worship	933			
Other	668			

Table 13.6-11: [HVAC VFDs] Deemed Savings for Hot Water Pumps per Motor hp

Building Type	Savings per Motor HP			
	kWh	NCP kW	CP kW	4CP kW
Hospitals, Healthcare, Nursing Home, Hotel	624	0.295	-	-
Office—Large, Medium	342			
Office—Small	270			
Education	302			
Convenience Store, Service, Strip Mall	301			
Stand-alone Retail, Supermarket	331			
Restaurants	511			
Large Multifamily	624			
Warehouse	255			
Assembly, Worship	346			
Other	255			

13.6.2.3 Additional Calculators and Tools

This section is not applicable for this measure.

13.6.2.4 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years for HVAC VFDs, as specified in the California Database of

Energy Efficiency Resources (DEER) READI tool for EUL ID HVAC-VSD-fan.[548]

13.6.3 Program Tracking Data & Evaluation Requirements

A list follows of primary inputs and contextual data that should be specified and tracked in the program database to inform the evaluation and apply the savings properly.

- Building type
- Application type (AHU fan, hot water pump, chilled water pump)
- Motor horsepower
- For AHU supply fans, baseline part-load control type (outlet damper, inlet damper, inlet guide vane, constant volume/no control)

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[548] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

14. COMMERCIAL: BUILDING ENVELOPE

14.1 ENERGY STAR® COOL ROOFS

14.1.1 Measure Description

Reflective roofing materials reduce the overall heat load on a building by reducing the total heat energy absorbed into the building system from incident solar radiation. This reduction in total load provides space cooling energy savings during the cooling season but reduces free heat during the heating season, so the measure saves energy in the summer but uses more energy in winter. Cool roofs are most beneficial in warmer climates and may not be recommended for buildings where the primary heat source is electric resistance. The measure is for retrofit of existing buildings.

14.1.1.1 Eligibility Criteria

Measures installed through utility programs must be a roof that is compliant with the current ENERGY STAR specifications, effective July 2017.[549] For nonresidential facilities, these criteria for a high-efficiency roof include:

- An existing roof undergoing retrofit conditions as further defined under high-efficiency condition below; a roof installed in a new construction application is not eligible for applying these methodologies.
- A roof with a low slope of 2:12 inches or less.[550]
- An initial solar reflectance of greater than or equal to 65%.
- A maintenance of solar reflectance of greater than or equal to 50% three years after installation under normal conditions.
- 75 percent of the roof surface over conditioned space must be replaced.
- No significant obstruction of direct sunlight to roof.
- The facility must be conditioned with cooling, heating, or both.
- Be listed on the ENERGY STAR list of qualified products[551] or have a performance rating that is validated by the Cool Roof Rating Council (CRRC). ENERGY STAR test criteria[552] allows for products already participating in the CRRC Product Rating Program[553] to submit solar reflectance and thermal emittance product information derived from CRRC certification.
- The ENERGY STAR specification for roof products will sunset effective June 1, 2022.[554] No new roof products will be certified as of June 1, 2021. At this point, ENERGY STAR legacy or CRRC product certification will be required to demonstrate compliance with the previous ENERGY

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[549] ENERGY STAR Roof Products Specification. https://www.energystar.gov/products/building_products/roof_products/key_product_criteria.
[550] As defined in proposed ASTN Standard E 1918-97.
[551] ENERGY STAR Certified Roofs. http://www.energystar.gov/productfinder/product/certified-roof-products/.
[552] ENERGY STAR Program Requirements for Roof Products v2.1. https://www.energystar.gov/ia/partners/product_specs/program_reqs/roofs_prog_req.pdf.
[553] CRRC Rated Products Directory: https://coolroofs.org/directory.
[554] ENERGY STAR Roof Products Sunset Decision Memo. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Roof%20Products%20Sunset%20Decision%20Memo.pdf.

STAR specification.

If one of these conditions are not met, the deemed savings approach cannot be used, and the Simplified M&V Methodology or the Full M&V Methodology must be used.

14.1.1.2 Baseline Condition

The baseline is the thermal resistance (i.e., R-value) of the existing roof make-up, and the solar reflectance and emissivity of the surface layer. The R-value is estimated based on code envelope requirements applicable in the year of construction. Solar reflectance and emissivity of the surface layer are assumed to be 0.2 and 0.9 respectively, based on roof properties listed in the LBLN Roofing Materials Database.[555]

The cooling and heating efficiencies are assumed based on the space conditioning of the top floor of the building and are based on typical code requirements applicable in the year of construction.

Table 14.1-1: [Cool Roofs] Assumed Cooling and Heating Efficiencies

Year of Construction; Applicable Code	RTU	PTHP Cooling	PTHP Heating	Air Cooled Chiller	Water Cooled Chiller
Before 2011; 2000 IECC	2.9	2.9	2.9	2.5	4.2
Between 2011-2016; 2009 IECC	3.8	3.1	2.9	2.8	5.5
After 2016; 2015 & 2018 IECC[556]	3.8	3.1	2.9	2.8	5.5

14.1.1.3 High-Efficiency Condition

The high-efficiency condition depends on the project scope. The project scope is defined as one of:

- Adding surface layer only
- Adding insulation and surface layer
- Rebuilding entire roof assembly

If the project scope is only to add a new ENERGY STAR material as the new surface layer, then the R-value used for the baseline condition is used for the high-efficiency condition. If the project scope is to add insulation and an ENERGY STAR material as the new surface layer, then the R-value of the additional insulation is added to the R-value used for the baseline condition. If the entire roof assembly is rebuilt, then the R-value for each layer of the new roof construction is summed to get a total new R-value.

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[555] Lawrence Berkeley National Lab Cool Roofing Material Database. https://heatisland.lbl.gov/resources/cool-roofing-materials-database.

[556] There were no changes in the associated commercial HVAC efficiency requirements between IECC 2015 and 2018.

The measure requires installation of roof products that have been rated by the CRRC and demonstrate compliance with ENERGY STAR-certified roof product performance specifications for the relevant roof application. Initial and 3-year reflectance ratings must meet or exceed the minimum thresholds specified in Table 14.1-2.

Table 14.1-2: [Cool Roofs] ENERGY STAR Specification[557]

Roof Slope	Characteristic	Performance Specification
Low Slope ≤ 2/12	Initial Solar Reflectance	≥ 0.65
	3-Year Solar Reflectance	≥ 0.50

14.1.2 Energy and Demand Savings Methodology

14.1.2.1 Savings Algorithms and Input Variables

Energy savings are estimated using EnergyPlus v8.3.0 whole-building simulation. The prototype building characteristics match those used for developing Commercial HVAC demand factors and EFLH. The savings represent the difference of the modeled energy use of the baseline condition and the high efficiency condition divided by square foot of roof area. The demand savings are calculated following the method described in section 2.3.

The deemed energy and demand savings factors are used in the following formulas to calculate savings:

$$\boldsymbol{Energy\ Savings = Roof\ Area \times ESF}$$

Equation 14.1-1

$$\boldsymbol{Peak\ Summer\ Demand\ Savings = Roof\ Area \times PSDF \times 10^{-5}}$$

Equation 14.1-2

Where:

Roof Area = *Total area of ENERGY STAR roof [sq. ft.].*

ESF = *Energy Savings Factor from Table 14.1-4 by building type, pre/post insulation levels, and heating/cooling system.*

PSDF = *Peak Summer Demand Factor from Table 14.1-4 by building type, pre/post insulation levels, and heating/cooling system.*

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[557] ENERGY STAR Roof Products Specification. https://www.energystar.gov/products/building_products/roof_products/key_product_criteria.

If the insulation levels are unknown, use the mapping in Table 14.1-3 to estimate the R-value based on the year of construction.

Table 14.1-3: [Cool Roofs] Estimated R-value based on Year of Construction

Year of Construction	Estimated R-value[558]
Before 2011	R ≤ 13
Between 2011 - 2016	13 ≤ R ≤ 20
After 2016	20 < R

Table 14.1-4: [Cool Roofs] Savings Factors

Building Type	Pre R-Value	Post R-Value	ESF	PSDF
Retail	R ≤ 13	R ≤ 13	0.67	23.07
	R ≤ 13	13 ≤ R ≤ 20	1.08	39.91
	R ≤ 13	20 < R	1.10	42.66
	13 ≤ R ≤ 20	13 ≤ R ≤ 20	0.43	13.86
	13 ≤ R ≤ 20	20 < R	0.44	15.85
	20 < R	20 < R	0.15	6.11
Education - Chiller	R ≤ 13	R ≤ 13	0.66	14.25
	R ≤ 13	13 ≤ R ≤ 20	0.93	23.79
	R ≤ 13	20 < R	1.06	27.75
	13 ≤ R ≤ 20	13 ≤ R ≤ 20	0.35	7.90
	13 ≤ R ≤ 20	20 < R	0.42	11.03
	20 < R	20 < R	0.28	6.64
Education - RTU	R ≤ 13	R ≤ 13	0.32	11.93
	R ≤ 13	13 ≤ R ≤ 20	0.46	21.96
	R ≤ 13	20 < R	0.51	25.08
	13 ≤ R ≤ 20	13 ≤ R ≤ 20	0.20	8.44
	13 ≤ R ≤ 20	20 < R	0.25	11.44
	20 < R	20 < R	0.16	6.38
Office - Chiller	R ≤ 13	R ≤ 13	0.26	11.27

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[558] Estimated R-values are based on applicable code requirements in the year of construction.

Building Type	Pre R-Value	Post R-Value	ESF	PSDF
	R ≤ 13	13 ≤ R ≤ 20	0.33	22.19
	R ≤ 13	20 < R	0.37	24.96
	13 ≤ R ≤ 20	13 ≤ R ≤ 20	0.14	9.37
	13 ≤ R ≤ 20	20 < R	0.18	11.91
	20 < R	20 < R	0.16	4.97
Office - RTU	R ≤ 13	R ≤ 13	0.31	10.95
	R ≤ 13	13 ≤ R ≤ 20	0.51	19.30
	R ≤ 13	20 < R	0.60	22.92
	13 ≤ R ≤ 20	13 ≤ R ≤ 20	0.20	6.68
	13 ≤ R ≤ 20	20 < R	0.28	9.39
	20 < R	20 < R	0.16	5.49
Hotel	R ≤ 13	R ≤ 13	0.08	1.90
	R ≤ 13	13 ≤ R ≤ 20	0.08	2.51
	R ≤ 13	20 < R	0.08	2.78
	13 ≤ R ≤ 20	13 ≤ R ≤ 20	0.06	1.35
	13 ≤ R ≤ 20	20 < R	0.06	1.60
	20 < R	20 < R	0.05	1.16
Warehouse	R ≤ 13	R ≤ 13	0.06	4.15
	R ≤ 13	13 ≤ R ≤ 20	0.11	7.15
	R ≤ 13	20 < R	0.19	12.05
	13 ≤ R ≤ 20	13 ≤ R ≤ 20	0.03	1.96
	13 ≤ R ≤ 20	20 < R	0.09	5.93
	20 < R	20 < R	0.01	1.34
Other	R ≤ 13	R ≤ 13	0.06	1.90
	R ≤ 13	13 ≤ R ≤ 20	0.08	2.51
	R ≤ 13	20 < R	0.08	2.78
	13 ≤ R ≤ 20	13 ≤ R ≤ 20	0.03	1.35
	13 ≤ R ≤ 20	20 < R	0.06	1.60
	20 < R	20 < R	0.01	1.16

14.1.2.2 Deemed Energy and Demand Savings Tables

There are no deemed energy or demand savings tables for this measure. Please use algorithms and inputs as described above.

14.1.2.3 Additional Calculators and Tools

There are no tools for this measure.

14.1.2.4 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years for cool roofs, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID BldgEnv-CoolRoof.[559]

14.1.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Building type
- Total and treated roofing square footage (over conditioned space)
- Roof slope
- Existing roof insulation R-value, or year of building construction
- New roof insulation R-value, if adding insulation
- New roof initial solar reflectance
- New roof 3-year solar reflectance
- New roof rated life
- ENERGY STAR certification or alternative
- Proof of purchase, including date of purchase, manufacturer, and model

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[559] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

14.2 WINDOW TREATMENTS

14.2.1 Measure Description

This section presents the deemed savings methodology for the installation of window films and solar screens. The installation of window treatments decreases the window-shading coefficient and reduces the solar heat transmitted to the building space. During months when perimeter cooling is required in the building, this measure decreases cooling energy use and summer demand.

14.2.1.1 Eligibility Criteria

This measure is applicable for treatment of single or double-paned clear glass windows without reflective or low-E coatings in south or west facing orientations (as specified in Table 14.2-1). Existing windows must have no solar films/screens, interior shades, or exterior awnings or overhangs and must be installed in buildings that are mechanically cooled (DX or chilled water).

This methodology may be adapted for windows with existing shading devices on an individual project basis with prior evaluator approval of baseline solar heat gain coefficient (SHGC).

14.2.1.2 Baseline Condition

The baseline condition is single-pane clear glass, without existing window treatments.

14.2.1.3 High-Efficiency Condition

The high-efficiency condition is an eligible window treatment applied to eligible windows.

14.2.2 Energy and Demand Savings Methodology

14.2.2.1 Savings Algorithms and Input Variables

Energy and Demand Savings

The demand and energy savings equations in this section originated in calculations by the Electric Utility Marketing Managers of Texas (EUMMOT) utilities as presented in the EUMMOT program manual *Commercial Standard Offer Program: Measurement and Verification Guidelines for Retrofit and New Construction Projects.*[560] The method estimates reduction in solar heat gain/insolation attributable to a given window treatment using shading coefficients for the treated and untreated window and solar heat gain estimates by window orientation according to ASHRAE Fundamentals. The reduction in building energy use attributable to reduction in cooling system energy use is estimated based on the reduced heat removal requirement for a standard efficiency cooling system.

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[560] See, for example, section 5.4 of the Equipment Efficiency Standards Appendices to the AEP companies' 2013 Commercial & Industrial Standard Offer Program Manual. http://www.aepefficiency.com/cisop/downloads/2013_C&I_SOP_Appendices.pdf.

Energy and Demand Savings Algorithms

$$\boldsymbol{Demand\ Savings_o\ [kW]\ = \frac{A_{film,o}\ \times SHGF_o \times (SHGC_{pre,o} - SHGC_{post,o})}{3,412 \times COP}}$$

Equation 14.2-1

$$\boldsymbol{Peak\ Demand\ Savings\ [kW]\ = Demand\ Savings_{o,max}}$$

Equation 14.2-2

$$\boldsymbol{Energy\ Savings_o\ [kWh]\ = \frac{A_{film,o} \times SHG_o \times (SHGC_{pre,o} - SHGC_{post,o})}{3,412 \times COP}}$$

Equation 14.2-3

$$\boldsymbol{Energy\ Savings\ [kWh]\ = \sum Energy\ Savings_o}$$

Equation 14.2-4

Where:

Demand Savings$_o$ = *Peak demand savings per window orientation.*

Energy Savings$_o$ = *Energy savings per window orientation.*

$A_{film,o}$ = *Area of window film/screens applied to orientation [ft^2].*

$SHGF_o$ = *Peak solar heat gain factor for orientation of interest and demand type [Btu/hr-ft^2-year]; see Table 14.2-1.*

SHG_o = *Solar heat gain for orientation of interest [Btu/ ft2-year]; see Table 14.2-1.*

$SHGC_{pre}$ = *Solar heat gain coefficient for existing glass with no interior-shading device; see Table 14.2-2.*

$SHGC_{post}$ = *Solar heat gain coefficient for new film/interior-shading device, from manufacturer specifications.*

Note: Shading coefficients (SC) have been retired, but if a product specification lists SC instead of SHGC, you can convert to SHGC by multiplying SC by 0.87.[561]

COP = *Cooling equipment COP based on Table 14.2-3 or actual COP equipment, whichever is greater; if building construction year is unknown, assume IECC 2009 as applicable code.*

3,412 = *Constant to convert from Btu to kWh.*

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[561] 2001 ASHRAE Handbook: Fundamentals, p. 30.39.

Table 14.2-1: [Window Treatments] Solar Heat Gain Factors[562]

Orientation	Solar Heat Gain {SHG} [Btu/ft^2-year]	Peak Hour Solar Heat Gain (SHGF) [Btu/hr-ft^2-year]		
		NCP	CP	4CP
South-East	158,844	36	29	24
South-South-East	134,794	38	30	24
South	120,839	57	34	37
South-South-West	134,794	127	76	94
South-West	158,844	181	139	162
West-South-West	169,696	210	181	204
West	163,006	219	195	216
West-North-West	139,615	208	181	195
North-West	107,161	176	140	145

Table 14.2-2: [Window Treatments] Recommended Clear Glass SHGC$_{pre}$ by Window Type & Thickness[563]

Window Type/Thickness	SHGC
Single-pane 1/8-inch clear glass	0.86
Single-pane 1/4-inch clear glass	0.81
Double-pane 1/8-inch clear glass	0.76
Double-pane 1/4-inch clear glass	0.70

Table 14.2-3: [Window Treatments] Recommended COP by HVAC System Type[564]

Construction Year/ Applicable Code	AC/HP	PTAC/PTHP	Air Cooled Chiller	Water Cooled Chiller
Before 2011; 2000 IECC	2.9	2.9	2.5	4.2
Between 2011-2016; 2009 IECC	3.8	3.1	2.8	5.5
After 2016; 2015 & 2018 IECC[565]	3.8	3.1	2.8	5.5

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[562] Values are taken from the 1997 ASHRAE Fundamentals, Chapter 29 Table 17, based on the amount of solar radiation transmitted through single-pane clear glass for a cloudless day at 32°N Latitude for the 21st day of each month by hour of day and solar orientation. The SHG values listed above have been aggregated into daily totals for weekdays during the months of April through October.

[563] 2017 ASHRAE Handbook: Fundamentals, Chapter 15 Fenestration, Table 10 Solar Heat Gain Coefficient (SHGC).

[564] Based on review of applicable codes, including IECC 2000, 2009, and 2015.

[565] There were no changes in the associated commercial HVAC efficiency requirements between IECC 2015 and 2018.

Load Shapes

The load shape for this measure is represented through the peak solar heat gain factors developed using a modified approach of the method outlined in Section 2.3. ASHRAE solar heat gain factors were reported for monthly and hourly solar time values. Top 20 peak hours were mapped to the solar heat gain factor from the corresponding month and hour-end. The solar heat gain factors were weighted using the probabilities assigned to each of the top 20 peak hours and 4CP hours. NCP solar heat gain factors were derived based on the maximum factor for each directional orientation.

14.2.2.2 Additional Calculators and Tools

There are no calculators for this measure.

14.2.2.3 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years for window treatments (solar screens and films), as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GlazDaylt-WinFilm.[566]

14.2.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Existing window type, thickness, and SHGC
- Description of existing window presence of exterior shading from other buildings or obstacles
- Window film or solar screen SHGC
- Eligible window treatment application area by orientation (e.g., S, SSW, SW...)
- Year of construction, if available
- Cooling equipment type
- Cooling equipment rated efficiency

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[566] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

14.3 ENTRANCE AND EXIT DOOR AIR INFILTRATION

14.3.1 Measure Description

This measure applies to the installation of weather stripping or door sweeps on entrance and exit doors for a contained, pressurized space. Entrance and exit doors often leave clearance gaps to allow for proper operation. The gaps around the doors allow for the infiltration of unconditioned air into the building, adding to the cooling and heating load of the HVAC system. Weather stripping and door sweeps are designed to be installed along the bottom and jambs of exterior doors to prevent air infiltration to conditioned space.

14.3.1.1 Eligibility Criteria

Weather stripping or doors sweeps must be installed on doors of a conditioned and/or heated space. Treated doors must have visible gaps of at least 1/8 – 3/4 inches along the outside edge of the door. Spaces with interior vestibule doors are not eligible.

14.3.1.2 Baseline Condition

The baseline standard for this measure is a commercial building with exterior doors that are not sealed from unconditioned space.

14.3.1.3 High-Efficiency Condition

The high-efficiency condition for this measure is a commercial building with exterior doors that have been sealed from unconditioned space using weather stripping and/or brush style door sweeps.

14.3.2 Energy and Demand Savings Methodology

14.3.2.1 Savings Algorithms and Input Variables

Energy and Demand Savings

This savings methodology was derived by analyzing TMY3 weather data for San Antonio.

Derivation of Pre-Retrofit Air Infiltration Rate

The pre-retrofit air infiltration rate for each crack width is calculated by applying the methodologies presented in Chapter 5 of the ASHRAE Cooling and Heating Load Calculation Manual (CHLCM).[567] Building type characteristics for a typical commercial building were found in the DOE study PNNL-20026,[568] and an average building height of 20 feet is assumed for the deemed savings approach.

Because air infiltration is a function of the differential pressure due to stack effect, wind speed, velocity head, and the design conditions of the building, TMY3 for San Antonio was applied to account for the

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[567] ASHRAE Cooling and Heating Load Calculation Manual, p. 5.8. 1980. https://www.hud.gov/sites/documents/DOC_10603.PDF.

[568] Cho, H., K. Gowri, & B. Liu, “Energy Saving Impact of ASHRAE 90.1 Vestibule Requirements: Modeling of Air Infiltration through Door Openings.” November 2010. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20026.pdf.

varying weather conditions that are characteristic throughout an average year.

Figure 5.13 from the ASHRAE CHLCM provides the infiltration rate based on various crack width and the corresponding pressure difference across a door. Figures 5.1 and 5.2 (CHLCM) provide the differential pressure due to stack and wind pressure necessary to determine the total pressure difference across the door.

Applying a regression analysis to Figure 5.1 returns an equation which allows solving for the pressure difference due to stack effect, Δps. The aggregate curve fit for Figure 5.1 is shown below where x is based on the dry bulb temperature from the TMY3 data, and the design temperature is based on the appropriate seasonal condition.

$$\frac{\Delta \boldsymbol{p_s}}{\boldsymbol{C_d}} = \mathbf{0.0000334003}\boldsymbol{x} - \mathbf{0.00014468}$$

Equation 14.3-1

Where C_d is an assumed constant, 0.63, and the neutral pressure distance is 10 feet.

From Figure 5.2, $\Delta p_w/C_p$ is determined by applying a polynomial regression, which returns an equation for solving for the pressure difference due to wind, Δp_w. The curve fit for Figure 5.2 is shown below where *x* is the wind velocity based on TMY3 data.

$$\Delta \boldsymbol{p_w}/\boldsymbol{C_p} = \mathbf{0.00047749}\boldsymbol{x}^{2} - \mathbf{0.00013041}\boldsymbol{x}$$

Equation 14.3-2

Where C_p is an assumed constant, 0.13 (average wind pressure coefficient from Table 5.5 from CHLCM).

This yields the total pressure difference across the door, Δp_{Total}.

$$\Delta \boldsymbol{p_{Total}} = \Delta \boldsymbol{p_s} + \Delta \boldsymbol{p_w}$$

Equation 14.3-3

Solving for Δp_{Total} allows for the air infiltration rate per linear foot to be determined in Figure 5.13 (CHLCM). Applying a power regression analysis for each crack width (described in inches) represented in Figure 5.13 returns the equations listed below. In these equations, *Q* is the infiltration rate in cubic feet per minute through cracks around the door and *P* is the perimeter of the door in feet.

$$Q/P_{1/8"} = 41.572x^{0.5120}$$

Equation 14.3-4

$$Q/P_{1/4"} = 81.913x^{0.5063}$$

Equation 14.3-5

$$Q/P_{1/2"} = 164.26x^{0.5086}$$

Equation 14.3-6

$$Q/P_{3/4"} = 246.58x^{0.5086}$$

Equation 14.3-7

These infiltration rates were further disaggregated based on TMY3 average monthly day and night conditions.

Derivation of Design and Average Outside Ambient Temperatures

Taking average daytime and nighttime outdoor temperature values, standard set points and setbacks for daytime and nighttime design cooling and heating will yield the temperature difference needed for the sensible heat equation:

$$\Delta T = T_{design} - T_{avg\ outside\ ambient}$$

Equation 14.3-8

Where:

T_{design} = *Daytime and nighttime design temperature [°F]; see Table 14.3-2.*

$T_{avg\ outside\ ambient}$ = *Average outside ambient temperature, specified by month [°F]; see Table* 14.3-1.

Table 14.3-1: [Entrance/Exit Door Air Infiltration] Average Monthly Ambient Temperatures (°F)[569]

Month	Day[570]	Night[571]
Jan	53.4	45.4
Feb	63.6	52.8
Mar	63.6	53.0

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[569] TMY3 climate data.

[570] Day hours are defined as 7 AM-7PM.

[571] Night hours are defined as 8PM-6AM.

Month	Day[570]	Night[571]
April	76.6	63.4
May	86.1	75.2
June	89.7	78.3
July	87.5	77.7
Aug	88.1	77.2
Sept	86.3	74.0
Oct	76.0	63.9
Nov	72.5	60.0
Dec	61.8	50.1

Table 14.3-2: [Entrance/Exit Door Air Infiltration] Daytime and Nighttime Design Temperatures

Temperature Description	T_{design} (°F)
Daytime Cooling Design Temperature	74
Daytime Heating Design Temperature	72
Nighttime Cooling Design Temperature[572]	78
Nighttime Heating Design Temperature[573]	68
Daytime Cooling Design Temperature	74

Energy and Demand Savings Algorithms

To calculate HVAC load associated with air infiltration, the following sensible heat equations are used:

Electric Cooling Energy Savings

$$\boldsymbol{Cooling\ Energy\ Savings\ [kWh]_{Day} = \frac{CFM_{pre,day} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0 \times Hours_{day}}{12,000}}$$

Equation 14.3-9

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[572] Assuming 4-degree setback.

[573] Ibid.

$$\boldsymbol{Cooling\ Energy\ Savings\ [kWh]_{Night} = \frac{CFM_{pre,night} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0 \times Hours_{night}}{12,000}}$$

Equation 14.3-10

$$\boldsymbol{Cooling\ Energy\ Savings\ [kWh] = Cooling\ Energy\ Savings\ [kWh]_{Day} + Cooling\ Energy\ Savings\ [kWh]_{Night}}$$

Equation 14.3-11

Electric Heating Energy Savings

$$\boldsymbol{Heating\ Energy\ Savings\ [kWh]_{Day} = \frac{CFM_{pre,day} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0 \times Hours_{day}}{COP \times 3,412}}$$

Equation 14.3-12

$$\boldsymbol{Heating\ Energy\ Savings\ [kWh]_{Night} = \frac{CFM_{pre,night} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0 \times Hours_{night}}{COP \times 3,412}}$$

Equation 14.3-13

$$\boldsymbol{Heating\ Energy\ Savings\ [kWh] = Cooling\ Energy\ Savings\ [kWh]_{Day} + Cooling\ Energy\ Savings\ [kWh]_{Night}}$$

Equation 14.3-14

Electric Cooling Demand Savings[574]

$$\boldsymbol{Summer\ Demand\ Savings\ [kW]_{Day} = \frac{CFM_{pre,day} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0}{12,000}}$$

Equation 15.3-15

Where:

CFM_{pre} = *Calculated pre-retrofit air infiltration [cfm].*

$CFM_{reduction}$ = *59%*[575] *× TDF.*

TDF = *Technical degradation factor = 85%.*[576]

1.08 = *Sensible heat equation conversion.*[577]

ΔT = *Change in temperature across gap barrier [°F].*

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[574] CP demand savings are calculated by weighting demand savings for the top 20 peak hours. 4CP demand savings are calculated by averaging the demand savings calculated for the 4CP months. NCP demand savings are calculated by taking the maximum CP value from the top 20 hours.
[575] CLEAResult, "Commercial Door Air Infiltration Memo." March 18, 2015. Average reduction in Arkansas based on test results from the CLEAResult Brush Weather Stripping Testing Method & Results (59% infiltration reduction).
[576] This factor is applied to account for the difference between the laboratory test from the "Commercial Door Air Infiltration Memo" and the real-world ability to seal the openings around a door. In the absence of research regarding the actual difference, this factor was set to 0.85.
[577] 2013 ASHRAE Handbook of Fundamentals; Equation 33, p. 16.11.

$Hours_{day}$ = *12-hour cycles per day, per month = 4,380 hours.*

$Hours_{night}$ = *12-hour cycles per night, per month = 4,380 hours.*

COP = *Heating coefficient of performance; 1.0 for electric resistance and 3.3 for heat pumps.*

1.0 = *Constant to convert from kW to tons.*

12,000 = *Constant to convert from Btuh to tons.*

3,412 = *Constant to convert from Btu to kWh.*

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings per linear foot of installed weather stripping or door sweep are specified below based on existing door gap width (inches). The length measurement should be initially measured to the nearest ¼ inch and converted to linear feet rounded to hundredths (0.02), including any segments that are not sealed due to corners, hinges, handles, or other obstructions. The width of the door gap should be rounded to the nearest deemed gap width in inches. Heating savings are specified for both electric resistance (ER) and heat pump (HP) heating. Cooling savings are available for buildings with electric cooling and gas heat, but no heating savings should be claimed for buildings with gas heat.

Table 14.3-3: [Entrance/Exit Door Air Infiltration] Deemed Energy Savings per Linear Foot of Weather Stripping/Door Sweep

Savings Type	Gap Width (inches)			
	1/8	1/4	1/2	3/4
Cooling kWh	4.11	8.31	16.49	24.75
ER Heating kWh	27.17	54.95	109.03	163.68
HP Heating kWh	8.23	16.65	33.04	49.60

Table 14.3-4: [Entrance/Exit Door Air Infiltration] Deemed Demand Savings per Linear Foot of Weather Stripping/Door Sweep

Savings Type	Gap Width (inches)			
	1/8	1/4	1/2	3/4
NCP kW	0.0074	0.0149	0.0297	0.0445
CP kW	0.0051	0.0103	0.0204	0.0306
4CP kW	0.0033	0.0067	0.0133	0.0200

Load Shapes

Load shapes were not required for this measure because savings were calculated using the savings equations defined above.

14.3.2.2 Additional Calculators and Tools

There are no calculators for this measure.

14.3.2.3 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 11 years for entrance/exit door weatherization, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID BS-Wthr.[578] This measure life is consistent with residential air infiltration measure in the Guidebook.

14.3.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Existing gap width (1/8”, 1/4”, 1/2”, 3/4”)
- Installed measure (weather stripping or door sweep)
- Linear feet (to nearest 0.02 feet = 1/4”) of installed weather stripping or door sweep

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[578] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

15. COMMERCIAL: FOOD SERVICE EQUIPMENT

15.1 PRE-RINSE SPRAY VALVES

15.1.1 Measure Description

This document presents the deemed savings methodology for the installation of Pre-Rinse Sprayers to reduce hot water usage, which saves energy associated with heating the water. Water heating is assumed to be electric. The energy and demand savings are determined on a per-sprayer basis.

15.1.1.1 Eligibility Criteria

Units must be used for commercial food preparation only and have flow rates that are no greater than the baseline flow rates specified in Table 15.1-1 per product class ounce-force (ozf). These savings are applicable only to sites where water heating fuel type is electric.

15.1.1.2 Baseline Condition

Effective January 28, 2019, the reference baseline equipment is a pre-rinse spray valve with a flowrate that does not exceed the maximum flow rate per product class as specified in Table 15.1-1.

Table 15.1-1: [PRSVs] Flow Rate Limits[579]

Product Class (ozf)	Flow Rate (gpm)
≤ 5	1.00
> 5 and ≤ 8	1.20
> 8	1.28

15.1.1.3 High-Efficiency Condition

Following the passing of the Energy Policy Act of 2005, the EPA announced on September 21st, 2005 that it would no longer pursue an ENERGY STAR specification for Pre-rinse Spray Valves.[580] Rather than simply disallowing pre-rinse spray valves altogether, the savings resulting from this measure will be algorithm-based (as opposed to deemed using baseline and high-efficiency assumptions). If a standard flow rate for post-retrofit equipment can be identified, future updates will address the transformation of this measure from an algorithm-based approach to one which is deemed.

The high-efficiency equipment is a pre-rinse spray valve that has a flow rate no greater than the maximum flow rate per product class as specified in Table 15.1-1. The sprayer should be capable of the same cleaning ability as the old sprayer.[581]

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[579] Federal standards, 10 CFR 431.266. https://www.ecfr.gov/cgi-bin/text-idx?SID=2ab37ee5fbd56d810322f3adce2124c6&mc=true&node=sp10.3.431.o&rgn=div6#se10.3.431_1266.

[580] "Summary of ENERGY STAR Specification Development Process and Rationale for PreRinse Spray Valves." March 2006. https://www.energystar.gov/ia/partners/prod_development/downloads/PRSV_Decision_Memo_Final.pdf?1e37-d3b8.

[581] FEMP Performance Requirements for Federal Purchases of Pre-Rinse Spray Valves, Based on ASTM F2324-03: Standard Test Method for Pre-Rinse Spray Valves (FEMP).

15.1.2 Energy and Demand Savings Methodology

15.1.2.1 Savings Algorithms and Input Variables

Energy Savings

Deemed savings are calculated based on the following algorithms:

$$\boldsymbol{Energy\ Savings\ [kWh]} = \boldsymbol{U} \times (\boldsymbol{F_B} - \boldsymbol{F_P}) \times \frac{\boldsymbol{Days}}{\boldsymbol{Year}} \times (\boldsymbol{T_H} - \boldsymbol{T_C}) \times \boldsymbol{C_H} \times \frac{\boldsymbol{C_E}}{\boldsymbol{Eff_E}}$$

Equation 15.1-1

Where:

F_B = *Maximum baseline flow rate [GPM]; see Table 15.1-2.*

F_P = *Rated flow rate of new spray-valve [GPM], use actual value.*

U = *Water usage duration [minutes per day per unit]; see Table 15.1-2.*

T_H = *Average mixed hot water (after spray valve) temperature [°F], 120°F*[582]*.*

T_C = *Average supply (cold) water temperature [°F], 75.9°F*[583]*.*

$Days$ = *Annual facility operating days for the applications; see Table 15.1-2.*

C_H = *Unit conversion for water density: 8.33 lbs/gallon.*

C_E = *Unit conversion: 1 Btu = 0.00029308 kWh (1/3,412).*

Eff_E = *Recovery efficiency of electric water heater, 0.98*[584]*.*

Table 15.1-2: [PRSVs] Assumed Variables for Energy and Demand Savings Calculations

Variable	Assumption
U	Fast Food Restaurant: 45 min/day/unit[585] Casual Dining Restaurant: 105 min/day/unit[585] Institutional: 210 min/day/unit[585] Dormitory: 210 min/day/unit[585] K-12 School: 105 min/day/unit[586]

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[582] According to ASTM F2324-03 Cleanability Test, the optimal operating conditions are at 120°F. This test consists of cleaning a plate of dried tomato sauce in less than 21 seconds with 120 ± 4°F water at a specified distance from the plate. This test is performed at 60 ± 2 psi of flowing water pressure.

[583] FEMP Performance Requirements for Federal Purchases of Pre-Rinse Spray Valves, Based on ASTM F2324-03: Standard Test Method for Pre-Rinse Spray Valves. Average water temperature calculated according to the method in the Burch and Christensen 2007 paper “Towards Development of an Algorithm for Mains Water Temperature” and using typical meteorological year (TMY) dataset for TMY3 from Kelly Air Force Base.

[584] Recovery efficiency of electric water heaters as listed on the AHRI Directory of Certified Product Performance. https://www.ahridirectory.org.

[585] “CEE Commercial Kitchens Initiative Program Guidance on Pre-Rinse Valves,” p. 3. https://library.cee1.org/system/files/library/4252/PRSV%20Program%20Guidance.pdf.

[586] If institutions (e.g., prisons, university dining halls, hospitals, nursing homes) are serving three meals a day, prorate schools by 1.5 hours to 3 hours (assuming schools serve breakfast to half of the students and lunch to all), yielding 105 minutes per day.

Variable	Assumption
Days[587]	Fast Food Restaurant: 360 Casual Dining Restaurant: 360 Institutional: 360 Dormitory: 270 K-12 School: 193

Demand Savings

$$\boldsymbol{Peak\ Demand\ Savings\ [kW]} = \frac{\boldsymbol{Energy\ Savings\ [kWh] \times PLS}}{\boldsymbol{100,000}}$$

Equation 15.1-2

Where:

PLS = **Probability-weighted peak load share; see**

Table 15.1-3.

100,000 = *Adjustment factor to allow for better readability of PLS values tables.*

Table 15.1-3: [PRSVs] Peak Demand Factors[588]

Building Type	PLS Type	PLS
Full-service restaurant and cafeterias	NCP	11.416
	CP	3.612
	4CP	1.338
Fast-food	NCP	11.416
	CP	6.118
	4CP	5.854
Schools	NCP	11.416
	CP	2.321
	4CP	0

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[587] For facilities that operate year-round: assume operating days of 360 days/year; For schools open weekdays except summer: 360 x (5/7) x (9/12) = 193 days; For dormitories with few occupants in the summer: 360 x (9/12) = 270 days.

[588] Peak load share factors are developed in accordance with the definitions provided in Section 2.3 of this document, using load profiles derived from the American Society of Heating Refrigeration and Air-Conditioning Engineers, Inc., ASHRAE Handbook 2019. HVAC Applications. Chapter 50 51 - Service Water Heating, Section 9 – Hot Water Load and Equipment Sizing, Figure 24 – Hourly Flow Profiles for Various Building Types. PLS values are multiplied by 100,000 to allow for easier readability of the values.

Building Type	PLS Type	PLS

Load Shapes

Load shapes for this measure are taken from ASHRAE Handbook 2019, HVAC Applications for service water heating and can be found in Section 22.2.

15.1.2.2 Deemed Energy Savings Tables

There are no deemed savings tables for this measure.

15.1.2.3 Deemed Summer Demand Savings Tables

There are no deemed savings tables for this measure.

15.1.2.4 Additional Calculators and Tools

There are no calculators for this measure.

15.1.2.5 Measure Life and Lifetime Savings

The EUL is 5 years for PRSVs, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID Cook-LowPreRinse.[589]

15.1.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Spray force in ounce-force (ozf)
- Baseline equipment flowrate
- Retrofit equipment flowrate
- Building type

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[589] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

15.2 ENERGY STAR® COMBINATION OVENS

15.2.1 Measure Description

This section covers the deemed savings methodology for the installation of ENERGY STAR combination ovens. Combination ovens are convection ovens that include the added capability to inject steam into the oven cavity and typically offers at least three distinct cooking modes; combination mode to roast or bake with moist heat, convection mode to operate purely as a convection oven providing dry heat, or a straight pressureless steamer mode. The energy and demand savings are determined on a per-oven basis.

15.2.1.1 Eligibility Criteria

Eligible units must be compliant with the current ENERGY STAR qualifications, with half-size and full-size ovens as defined below and a pan capacity ≥ 5 and ≤ 20.[590] ,[591]

- Half-Size Combination Oven: A combination oven capable of accommodating a single 12 x 20 x 2½-inch steam table pan per rack position, loaded from front-to-back or lengthwise.
- Full-Size Combination Oven: A combination oven capable of accommodating two 12 x 20 x 2½-inch steam table pans per rack position, loaded from front-to-back or lengthwise.

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.[592]

The following products are excluded from the ENERGY STAR eligibility criteria:

- 2/3-sized combination ovens
- Dual-fuel heat source combination ovens
- Gas combination ovens
- Electric combination ovens with a pan capacity < 5 and > 20
- Hybrid ovens not defined as eligible above (e.g., those incorporating microwave settings)
- Electric rack ovens
- Conventional or standard ovens, conveyor, slow cook-and-hold, deck, range, rapid cook, and rotisserie

15.2.1.2 Baseline Condition

The baseline condition for retrofit situations is a half-size or full-size combination oven with a pan capacity ≥ 5 and ≤ 20 that does not meet ENERGY STAR key product criteria.

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[590] ENERGY STAR Program Requirements for Commercial Ovens. Eligibility Criteria Version 2.2. https://www.energystar.gov/sites/default/files/Commercial%20Ovens%20Final%20Version%202.2%20Specification.pdf.

[591] ENERGY STAR Qualified Product Listing: https://www.energystar.gov/productfinder/product/certified-commercial-ovens/results.

[592] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://library.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Mar2021.pdf.

15.2.1.3 High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v2.2 specification, effective October 7, 2015. Qualified products must meet the minimum energy efficiency and idle energy rate requirements from Table 15.2-1. Furthermore, Pan Capacity[593] must be ≥ 5 and ≤ 20 for both half and full-size combination ovens.

Table 15.2-1: [Combination Ovens] ENERGY STAR Specification[594]

Operation	Idle Rate (kW)[595]	Cooking Energy Efficiency (%)
Steam Mode	≤ 0.133P + 0.6400	≥ 55
Convection Mode	≤ 0.080P + 0.4989	≥ 76

15.2.2 Energy and Demand Savings Methodology

15.2.2.1 Savings Algorithms and Input Variables

Energy and Demand Savings

Deemed savings are calculated using the following algorithms:

$$Energy\ Savings\ [\Delta kWh] = kWh_{base} - kWh_{ES}$$

Equation 15.2-1

$$kWh_{base} = kWh_{ph,base} + kWh_{conv,base} + kWh_{st,base}$$

Equation 15.2-2

$$kWh_{ES} = kWh_{ph,ES} + kWh_{conv,ES} + kWh_{st,ES}$$

Equation 15.2-3

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[593] Pan Capacity is defined as the number of steam table pans the combination oven is designed to accommodate as per the ASTM F-1495-05 standard specification.

[594] ENERGY STAR Commercial Ovens Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria.

[595] P = Pan Capacity.

kWh_{ph}, kWh_{conv} and kWh_{st} are each calculated the same for both the baseline and ENERGY STAR cases, as shown below, except they require their respective input assumptions relative to convection and steam modes as seen in Table 15.2-2.

$$\boldsymbol{kWh} = \left(\boldsymbol{E_{ph}} + \left(\frac{\boldsymbol{W_{food}} \times \boldsymbol{E_{food}} \times \boldsymbol{50\%}}{\boldsymbol{\eta_{cook}}}\right) + \boldsymbol{E_{idle}} \times \left(\left(\boldsymbol{t_{on}} - \frac{\boldsymbol{W_{food}}}{\boldsymbol{PC}}\right) \times \boldsymbol{50\%}\right)\right) \times \frac{\boldsymbol{t_{days}}}{\boldsymbol{1,000}}$$

Equation 15.2-4

$$\boldsymbol{Peak\ Demand\ Savings}\ [\Delta \boldsymbol{kW}] = \frac{\boldsymbol{\Delta kWh} - \left(\frac{\boldsymbol{\Delta E_{ph}} \times \boldsymbol{t_{days}}}{\boldsymbol{1,000}}\right)}{\boldsymbol{t_{on}} \times \boldsymbol{t_{days}}} \times \boldsymbol{DF}$$

Equation 15.2-5

Where:

kWh_{base} = *Baseline annual energy consumption [kWh].*

kWh_{ES} = *ENERGY STAR annual energy consumption [kWh].*

E_{ph} = *Preheat energy [Wh/BTU].*

ΔE_{ph} = *Difference in baseline and ENERGY STAR preheat energy [Wh/BTU].*

E_{food} = *ASTM energy to food of energy absorbed by food product during cooking [Wh/lb].*

E_{Idle} = *Idle energy rate [W].*

W_{food} = *Pounds of food cooked per day [lb/day].*

η_{cook} = *Cooking energy efficiency [%].*

PC = *Production capacity per pan [lb/hr].*

t_{on} = *Equipment operating hours per day [hr/day].*

t_{days} = *Facility operating days per year [days/year].*

1,000 = *Constant to convert from watts to kilowatts.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 15.2-3.*

Table 15.2-2: [Combination Ovens] ENERGY STAR Commercial Food Service Calculator Inputs[596]

Variable		Convection-Mode		Steam-Mode	
		Baseline	ENERGY STAR	Baseline	ENERGY STAR
E_{ph}	P < 15	3,000		1,500	
	P ≧ 15	3,750		2,000	
W_{food}	P < 15	200			
	P ≧ 15	250			
E_{food}		73.2		30.8	
η_{cook}		72%	76%	49%	55%
E_{idle}	P < 15	1,320	(0.080P + 0.4989) x 1,000	5,260	(0.133P + 0.6400) x 1,000
	P ≧ 15	2,280		8,710	
PC	P < 15	79	119	126	177
	P ≧ 15	166	201	295	349
t_{on}		12			
t_{days}		365			

Table 15.2-3: [Combination Ovens] Demand Factors

Factor Type	Demand Factor
NCP	1.000
CP	0.926
4CP	0.978

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the California End Use Survey (CEUS)[597] usage data by building type and end use for the "restaurant" building type and the "cooking equipment" end use. The CEUS load data provided hourly data by fuel type for each day of the year for an 8,760 hourly load shape, which can be found in Section 22.2.

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[596] ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

[597] California End Use Survey (CEUS), Building workbooks with load shapes by end use. http://capabilities.itron.com/CeusWeb/Default.aspx.

15.2.2.2 Deemed Energy Savings Tables

The energy savings of High Efficiency Combination Ovens in Table 15.2-4 are calculated in the Savings Calculator for ENERGY STAR Qualified Commercial Kitchen Equipment using the default parameters shown above in Table 15.2-2.

Table 15.2-4: [Combination Ovens] Deemed Energy Savings[598]

Pan Capacity	Annual Energy Savings [kWh]	NCP Demand Savings [kW]	CP Demand Savings [kW]	4CP Demand Savings [kW]
5	4,015	0.803	0.744	0.786
6	4,677	0.952	0.882	0.931
7	5,356	1.104	1.023	1.080
8	6,051	1.260	1.167	1.233
9	6,761	1.420	1.315	1.389
10	7,488	1.583	1.466	1.548
11	8,231	1.750	1.621	1.712
12	8,990	1.921	1.779	1.879
13	9,765	2.095	1.940	2.049
14	10,556	2.273	2.105	2.223
15	11,363	2.455	2.273	2.401
16	12,187	2.640	2.445	2.582
17	13,026	2.829	2.620	2.767
18	13,881	3.022	2.798	2.956
19	14,753	3.218	2.980	3.148
20	15,640	3.419	3.166	3.343

15.2.2.3 Additional Calculators and Tools

There are no calculators for this measure.

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[598] ENERGY STAR Savings Calculator for ENERGY STAR Qualified Commercial Kitchen Equipment Calculator: http://www.energystar.gov/buildings/sites/default/uploads/files/Commercial_kitchen_equipment_calculator.xlsx.

15.2.2.4 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years for combination ovens, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID Cook-ElecCombOven.[599]

15.2.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Manufacturer and model number
- Pan capacity
- ENERGY STAR idle rate
- ENERGY STAR cooking efficiency
- ENERGY STAR certification or alternative
- Proof of purchase including date of purchase, manufacturer, and model number

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[599] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

15.3 ENERGY STAR® ELECTRIC CONVECTION OVENS

15.3.1 Measure Description

This section covers the savings from retrofit or new installation of full-size or half-size ENERGY STAR electric convection ovens. Convection ovens cook food by forcing hot dry air over the surface of the food product. The rapidly moving hot air strips away the layer of cooler air next to the food and enables the food to absorb the heat energy. The energy and demand savings are deemed, and based on oven energy rates, cooking efficiencies, operating hours, production capacities and building type. The energy and demand savings are determined on a per-oven basis.

15.3.1.1 Eligibility Criteria

Eligible units must be compliant with the current ENERGY STAR specification, with half-size and full-size electric ovens as defined below.[600,601]

- Full-Size Convection Oven: A combination oven capable of accommodating standard full-size sheet pans measuring 18 x 26 x 1-inch
- Half-Size Convection Oven: A convection oven capable of accommodating half-size sheet pans measuring 18 x 13 x 1-inch

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.[602]

Convection ovens eligible for rebate do not include ovens that can heat the cooking cavity with saturated or superheated steam. However, eligible convection ovens may have moisture injection capabilities (e.g., baking ovens and moisture-assist ovens). Ovens that include a "hold feature" are eligible under this specification if convection is the only method used to fully cook the food.

The following products are excluded from the ENERGY STAR eligibility criteria:

- Hybrid ovens not defined as eligible above (e.g., those incorporating microwave settings)
- Electric rack ovens
- Conventional or standard ovens, conveyor, slow cook-and-hold, deck, range, rapid cook, and rotisserie

15.3.1.2 Baseline Condition

The baseline condition for retrofit situations is an electric convection oven that does not meet ENERGY

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[600] ENERGY STAR Program Requirements for Commercial Ovens. Eligibility Criteria Version 2.2. https://www.energystar.gov/sites/default/files/Commercial%20Ovens%20Final%20Version%202.2%20Specification.pdf.

[601] ENERGY STAR Qualified Product Listing: https://www.energystar.gov/productfinder/product/certified-commercial-ovens/results.

[602] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://library.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Mar2021.pdf.

STAR key product criteria.

15.3.1.3 High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v2.2 specification, effective October 7, 2015. Qualified equipment must meet the minimum energy efficiency and idle energy rate requirements from Table 15.3-1:

Table 15.3-1: [Convection Ovens] ENERGY STAR Specification[603]

Oven Size	Idle Rate (W)	Cooking Energy Efficiency (%)
Full-Size	≤ 1,600	≥ 71
Half-Size	≤ 1,000	≥ 71

15.3.2 Energy and Demand Savings Methodology

15.3.2.1 Savings Algorithms and Input Variables

Energy and Demand Savings

$$\boldsymbol{Energy\ Savings}\ [\Delta \boldsymbol{kWh}] = \boldsymbol{kWh_{base}} - \boldsymbol{kWh_{ES}}$$

Equation 15.3-1

$$\boldsymbol{kWh}\ _{\boldsymbol{base}} = \boldsymbol{kWh_{ph,base}} + \boldsymbol{kWh_{conv,base}} + \boldsymbol{kWh_{st,base}}$$

Equation 15.3-2

$$\boldsymbol{kWh_{ES}} = \boldsymbol{kWh_{ph,ES}} + \boldsymbol{kWh_{conv,ES}} + \boldsymbol{kWh_{st,ES}}$$

Equation 15.3-3

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[603] ENERGY STAR Commercial Ovens Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria.

kWh_{ph}, kWh_{conv} and kWh_{st} are each calculated the same for both the baseline and ENERGY STAR cases, as shown below, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 15.3-2.

$$kWh = \left(E_{ph} + \left(\frac{W_{food} \times E_{food} \times 50\%}{\eta_{cook}} \right) + E_{idle} \times \left(\left(t_{on} - \frac{W_{food}}{PC} \right) \times 50\% \right) \right) \times \frac{t_{days}}{1,000}$$

Equation 15.3-4

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\Delta kWh - \left(\frac{\Delta E_{ph} \times t_{days}}{1,000} \right)}{t_{on} \times t_{days}} \times DF$$

Equation 15.3-5

Where:

kWh_{base} = *Baseline annual energy consumption [kWh].*

kWh_{ES} = *ENERGY STAR annual energy consumption [kWh].*

E_{ph} = *Preheat energy [Wh/BTU].*

ΔE_{ph} = *Difference in baseline and ENERGY STAR preheat energy [Wh/BTU].*

E_{food} = *ASTM energy to food of energy absorbed by food product during cooking [Wh/lb].*

E_{Idle} = *Idle energy rate [W].*

W_{food} = *Pounds of food cooked per day [lb/day].*

η_{cook} = *Cooking energy efficiency [%].*

PC = *Production capacity per pan [lb/hr].*

t_{on} = *Equipment operating hours per day [hr/day].*

t_{days} = *Facility operating days per year [days/year].*

1,000 = *Constant to convert from watts to kilowatts.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 15.3-3.*

Table 15.3-2: [Convection Ovens] ENERGY STAR Commercial Food Service Calculator Inputs[604]

Variable	Full-Size		Half-Size	
	Baseline	ENERGY STAR	Baseline	ENERGY STAR
E_{ph}	1,563	890	1,389	700

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[604] ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

Variable	Full-Size		Half-Size	
	Baseline	ENERGY STAR	Baseline	ENERGY STAR
W_{food}	100			
E_{food}	73.2			
η_{cook}	65%	71%	68%	70.67%
E_{idle}	2,000	1,600	1,030	1,000
PC	90	90	45	50
t_{on}	12			
t_{days}	365			

Table 15.3-3: [Convection Ovens] Demand Factors

Factor Type	Demand Factor
NCP	1.000
CP	0.926
4CP	0.978

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the California End Use Survey (CEUS)[605] usage data by building type and end use for the “restaurant” building type and the “cooking equipment” end use. The CEUS load data provided hourly data by fuel type for each day of the year for an 8,760 hourly load shape, which can be found in Section 22.2.

15.3.2.2 Deemed Energy and Demand Savings Tables

The following deemed energy and demand savings are based on the following input assumptions.

Table 15.3-4: [Convection Ovens] Deemed Energy and Demand Savings

Oven Size	Annual Energy Savings [kWh]	NCP Peak Demand Savings [kW]	CP Peak Demand Savings [kW]	4CP Peak Demand Savings [kW]
Full-Size	2,001	0.442	0.410	0.433
Half-Size	244	0.040	0.037	0.039

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[605] California End Use Survey (CEUS), Building workbooks with load shapes by end use. http://capabilities.itron.com/CeusWeb/Default.aspx.

15.3.2.3 Additional Calculators and Tools

There are no tools for this measure.

15.3.2.4 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years for electric convection ovens, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID Cook-ElecConvOven.[606]

15.3.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Manufacturer and model number
- Oven size
- ENERGY STAR idle rate
- ENERGY STAR cooking efficiency
- ENERGY STAR certification or alternative
- Proof of purchase including date of purchase, manufacturer, and model number

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[606] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

15.4 ENERGY STAR® DISHWASHERS

15.4.1 Measure Description

This section covers the deemed savings methodology for the installation of ENERGY STAR commercial dishwashers. On average, commercial dishwashers that have earned ENERGY STAR certification are 25% more energy-efficient and 25% more water-efficient than standard models. The energy savings associated with ENERGY STAR commercial dishwashers are primarily due to reduced water use and reduced need to heat water. A commercial kitchen may have external booster water heaters or booster water heaters may be internal to specific equipment. Both primary and booster water heaters may be either gas or electric; therefore, dishwasher programs need to ensure the savings calculations used are appropriate for the water heating equipment installed at the participating customer's facility. The energy and demand savings are determined on a per-dishwasher basis.

15.4.1.1 Eligibility Criteria

Eligible units must be compliant with the current ENERGY STAR specification and fall under one of the following categories.[607,608] These categories are described in Table 15.4-1:

- Under Counter Dishwasher
- Stationary Rack, Single Tank, Door Type Dishwasher
- Single Tank Conveyor Dishwasher
- Multiple Tank Conveyor Dishwasher
- Pot, Pan & Utensil

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.[609]

Dishwashers intended for use in residential or laboratory applications are not eligible for ENERGY STAR under this product specification. Steam, gas, and other non-electric models also do not qualify.

Additionally, though single and multiple tank flight type conveyor dishwashing machines (where the dishes are loaded directly on the conveyor rather than transported within a rack – also referred to as a rackless conveyor) are eligible per the ENERGY STAR version 2.0 specification, they are considered ineligible for this Guidebook measure, since default values are not available for flight type dishwashers in the ENERGY STAR Commercial Kitchen Equipment Calculator.

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[607] ENERGY STAR Program Requirements Product Specifications for Commercial Dishwashers. Eligibility Criteria Version 3.0. https://www.energystar.gov/sites/default/files/Commercial%20Dishwashers%20Final%20Version%203.0%20Specification_0.pdf.

[608] ENERGY STAR Qualified Product Listing: https://www.energystar.gov/productfinder/product/certified-commercial-dishwashers/results.

[609] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://library.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Mar2021.pdf.

Table 15.4-1: [Dishwashers] ENERGY STAR Equipment Type Descriptions

Equipment Type	Equipment Descriptions
Under Counter Dishwasher	A machine with overall height of 38" or less, in which a rack of dishes remains stationary within the machine while being subjected to sequential wash and rinse sprays and is designed to be installed under food preparation workspaces. Under counter dishwashers can be either chemical or hot water sanitizing, with an internal booster heater for the latter. For purposes of this specification, only those machines designed for wash cycles of 10 minutes or less can qualify for ENERGY STAR.
Stationary Rack, Single Tank, Door Type Dishwasher	A machine in which a rack of dishes remains stationary within the machine while subjected to sequential wash and rinse sprays. This definition also applies to machines in which the rack revolves on an axis during the wash and rinse cycles. Subcategories of stationary door type machines include single and multiple wash tank, double rack, pot, pan and utensil washers, chemical dump type and hooded wash compartment ("hood type"). Stationary rack, single tank, door type models are covered by this specification and can be either chemical or hot water sanitizing, with an internal or external booster heater for the latter.
Single Tank Conveyor Dishwasher	A washing machine that employs a conveyor or similar mechanism to carry dishes through a series of wash and rinse sprays within the machine. Specifically, a single tank conveyor machine has a tank for wash water followed by a final sanitizing rinse and does not have a pumped rinse tank. This type of machine may include a pre-washing section before the washing section. Single tank conveyor dishwashers can either be chemical or hot water sanitizing, with an internal or external booster heater for the latter.
Multiple Tank Conveyor Dishwasher	A conveyor type machine that has one or more tanks for wash water and one or more tanks for pumped rinse water, followed by a final sanitizing rinse. This type of machine may include one or more pre-washing sections before the washing section. Multiple tank conveyor dishwashers can be either chemical or hot water sanitizing, with an internal or external hot water booster heater for the latter.
Pot, Pan, and Utensil	A stationary rack, door type machine designed to clean and sanitize pots, pans, and kitchen utensils.

15.4.1.2 Baseline Condition

Baseline equipment is either a low temperature[610] or high temperature[611] machine as defined by Table 15.4-1, which is not used in a residential or laboratory setting. For low temperature units, the DHW is assumed to be electrically heated. For high temperature units, the DHW can either be heated by electric or natural gas methods. For units heated with natural gas, the unit shall have an electric booster heater attached to it.

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[610] Low temperature machines apply a chemical sanitizing solution to the surface of the dishes to achieve sanitation.

[611] High temperature machines apply only hot water to the surface of the dishes to achieve sanitation.

15.4.1.3 High-Efficiency Condition

Qualifying equipment must be compliant with the current ENERGY STAR v3.0 specification, effective July 27, 2021. High temperature equipment sanitizes using hot water and requires a booster heater. Low temperature equipment uses chemical sanitization and does not require a booster heater. Qualified products must be less than or equal to the maximum idle energy rate and water consumption requirements from Table 15.4-2.

Table 15.4-2: [Dishwashers] ENERGY STAR Specification[612]

Machine Type	Low Temperature Efficiency Requirements		High Temperature Efficiency Requirements	
	Idle Energy Rate [kW]	Water Consumption [gal/rack]	Idle Energy Rate [kW]	Water Consumption [gal/rack]
Under Counter	≤ 0.25	≤ 1.19	≤ 0.30	≤ 0.86
Stationary Single Tank Door	≤ 0.30	≤ 1.18	≤ 0.55	≤ 0.89
Single Tank Conveyor	≤ 0.85	≤ 0.79	≤ 1.20	≤ 0.70
Multiple Tank Conveyor	≤ 1.00	≤ 0.54	≤ 1.85	≤ 0.54
Pot, Pan and Utensil	--	--	≤ 0.90	≤ 0.58[613]

15.4.2 Energy and Demand Savings Methodology

15.4.2.1 Savings Algorithms and Input Variables

Energy and Demand Savings

Deemed savings are calculated using the following algorithms:

$$\boldsymbol{Energy\ Savings}\ [\Delta kWh] = (V_{base} - V_{ES}) \times \left(\frac{\Delta T_{DHW} + \Delta T_{boost}}{\eta_{DHW}}\right) \times \rho_{water} \times C_p \times \frac{1}{3,412} + (E_{idle,base} - E_{idle,ES}) \times \left(t_{hours} - n_{racks} \times \frac{t_{wash}}{60}\right) \times t_{days}$$

Equation 15.4-1

$$V_{base} = t_{days} \times n_{racks} \times V_{rack,base}$$

Equation 15.4-2

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[612] ENERGY STAR Commercial Dishwashers Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_dishwashers/key_product_criteria.

[613] Water Consumption for pot, pan and utensil is specified in gallons per square foot rather than gallons per rack.

$$V_{ES} = t_{days} \times n_{racks} \times V_{rack,ES}$$

Equation 15.4-3

$$\boldsymbol{Peak\ Demand\ Savings\ [\Delta kW]} = \frac{\Delta kWh}{t_{on} \times t_{days}} \times DF$$

Equation 15.4-4

Where:

ρ_{water} = *Density of water [lbs/gallon].*

C_p = *Specific heat of water [Btu/lb °F].*

ΔT_{DHW} = *Inlet water temperature increase for building water heater [°F].*

ΔT_{boost} = *Inlet water temperature for booster water heater [°F].*

η_{DHW} = *Building electric water heater and booster heater efficiency [%].*

n_{racks} = *Number of racks washed per day.*

V_{base} = *Baseline annual volume of water consumption [gal/year].*

V_{ES} = *ENERGY STAR annual volume of water consumption [gal/year].*

$V_{rack,base}$ = *Baseline per rack volume of water consumption [gal/rack].*

$V_{rack,ES}$ = *ENERGY STAR per rack volume of water consumption [gal/rack].*

$E_{idle,base}$ = *Baseline idle energy rate [kW].*

$E_{idle,ES}$ = *ENERGY STAR idle energy rate [kW].*

t_{wash} = *Wash time per rack [min].*

t_{on} = *Equipment operating hours per day [hr/day].*

t_{days} = *Facility operating days per year [days/year].*

3,412 = *Constant to convert from Btu to kWh.*

60 = *Constant to convert from minutes to hours.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 15.4-4.*

Table 15.4-3: [Dishwashers] ENERGY STAR Commercial Food Service Calculator Inputs[614]

Inputs	Under Counter	Single Door Type	Single Tank Conveyor	Multiple Tank Conveyor	Pot, Pan and Utensil
ρ_{water}	61.4 ÷ 7.48 = 8.2				
C_p	1.0				

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[614] ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

Inputs	Under Counter	Single Door Type	Single Tank Conveyor	Multiple Tank Conveyor	Pot, Pan and Utensil
ΔT_{DHW}	Gas Hot Water Heaters: 0°F Electric Hot Water Heaters: 70°F				
ΔT_{boost}	Gas Booster Heaters: 0°F Electric Booster Heaters: 40°F				
η_{DHW}	98%				
t_{hours}	18				
t_{days}	365				
Low Temperature Units					
n_{racks}	75	280	400	600	--
$V_{rack,base}$	1.73	2.10	1.31	1.04	--
$V_{rack,ES}$	1.19	1.18	0.79	0.54	--
$E_{idle,base}$	0.50	0.60	1.60	2.00	--
$E_{idle,ES}$	0.25	0.30	0.85	1.00	--
t_{wash}	2.0	1.5	0.3	0.3	--
High Temperature Units					
n_{racks}	75	280	400	600	280
$V_{rack,base}$	1.09	1.29	0.87	0.97	0.70
$V_{rack,ES}$	0.86	0.89	0.70	0.54	0.58
$E_{idle,base}$	0.76	0.87	1.93	2.59	1.20
$E_{idle,ES}$	0.30	0.55	1.20	1.85	0.90
t_{wash}	2.0	1.0	0.3	0.2	3.0

Table 15.4-4: [Dishwashers] Demand Factors

Factor Type	Demand Factor
NCP	1.000
CP	0.755
4CP	0.697

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the California End Use Survey (CEUS)[615] usage data by building type and end use for the “restaurant” building type and the “hot water” end use. The CEUS load data provided hourly data by fuel type for each day of the year for an 8,760 hourly load shape, which can be found in Section 22.2.

15.4.2.2 Deemed Energy Savings Tables

The following deemed energy savings are based on the input assumptions from Table 15.4-3.

Table 15.4-5: [Dishwashers] Deemed Energy Savings

Faculty Description	Under Counter	Single Door Type	Single Tank Conveyor	Multiple Tank Conveyor	Pot, Pan and Utensil
Low Temp./ Electric Hot Water Heater	3,955	17,362	17,426	24,292	--
High Temp./ Electric Hot Water Heater w/ Electric Booster Heater	4,303	12,596	10,966	29,751	3,750
High Temp./ Gas Hot Water Heater w/ Electric Booster Heater	3,221	5,572	6,700	13,569	1,642
High Temp./ Electric Hot Water Heater with Gas Booster Heater	3,684	8,582	8,528	20,504	2,545

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[615] California End Use Survey (CEUS), Building workbooks with load shapes by end use. http://capabilities.itron.com/CeusWeb/Default.aspx.

15.4.2.3 Deemed Demand Savings Tables

The following deemed demand savings are based on the input assumptions from Table 15.4-3.

Table 15.4-6: [Dishwashers] Deemed Demand Savings

Dishwasher Type	Demand Type	Low Temp./ Electric DHW	High Temp./ Electric DHW w/ Electric BH	High Temp./ Gas DHW w/ Electric BH	High Temp./ Electric DHW w/ Gas BH
Under Counter	NCP	0.602	0.655	0.490	0.561
	CP	0.454	0.494	0.370	0.423
	4CP	0.420	0.456	0.342	0.391
Door Type	NCP	2.643	1.917	0.848	1.306
	CP	1.995	1.448	0.640	0.986
	4CP	1.842	1.336	0.591	0.910
Single Tank Conveyor	NCP	2.652	1.669	1.020	1.298
	CP	2.003	1.260	0.770	0.980
	4CP	1.849	1.163	0.711	0.905
Multi Tank Conveyor	NCP	3.697	4.528	2.065	3.121
	CP	2.792	3.419	1.559	2.356
	4CP	2.577	3.156	1.439	2.175
Pot, Pan, Utensil	NCP	--	0.571	0.250	0.387
	CP	--	0.431	0.189	0.293
	4CP	--	0.398	0.174	0.270

15.4.2.4 Additional Calculators and Tools

There are no tools for this measure.

15.4.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) varies per eligible dishwasher type, as stated in the ENERGY STAR v2.0 Commercial Kitchen Equipment Savings Calculator.[616]

Table 15.4-7: [Dishwashers] Equipment Lifetime by Machine Type

Machine Type	EUL (years)
Under Counter	10
Stationary Single Tank Door	15
Single Tank Conveyor	20
Multiple Tank Conveyor	20
Pot, Pan, and Utensil	10

15.4.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Manufacturer and model number
- Energy source for primary water heater (gas, electric)
- Energy source for booster water heater (gas, electric)
- ENERGY STAR idle rate
- ENERGY STAR water consumption
- Verification of ENERGY STAR certification or alternative
- Proof of purchase including date of purchase, manufacturer, and model number

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[616] ENERGY STAR Savings Calculator for ENERGY STAR Qualified Commercial Kitchen Equipment.

15.5 ENERGY STAR® HOT FOOD HOLDING CABINETS

15.5.1 Measure Description

This section covers the deemed savings methodology for the installation of ENERGY STAR hot food holding cabinets (HFHCs). An HFHC is a heated, fully enclosed compartment with one or more solid or transparent doors designed to maintain the temperature of hot food that has been cooked using a separate appliance. HFHCs that have earned ENERGY STAR certification incorporate better insulation to reduce heat loss and may also offer additional energy saving devices such as magnetic door gaskets, auto-door closers, or Dutch doors. The insulation of the cabinet offers better temperature uniformity within the cabinet from top to bottom. The energy and demand savings are deemed and based on an interior volume range of the holding cabinets and the building type. An average wattage has been calculated for each volume range, half size, three quarter size, and full size. The energy and demand savings are determined on a per-cabinet basis.

15.5.1.1 Eligibility Criteria

HFHCs must be compliant with the current ENERGY STAR specification.[617,618] Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.[619]

The following products are excluded from the ENERGY STAR eligibility criteria:

- Dual function equipment (e.g., “cook-and-hold” and proofing units)
- Heater transparent merchandising cabinets
- Drawer warmers

15.5.1.2 Baseline Condition

The baseline condition is a half-size, three-quarter size, or full-size hot food holding cabinet that does not meet ENERGY STAR key product criteria.

15.5.1.3 High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v2.0 specification, effective October 1, 2011. Table 15.5-1 summarizes idle energy rate requirements based on cabinet interior volume.

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[617] ENERGY STAR Program Requirements Product Specifications for Commercial Hot Food Holding Cabinets. Eligibility Criteria Version 2.0. https://www.energystar.gov/sites/default/files/specs/private/Commercial_HFHC_Program_Requirements_2.0.pdf.

[618] ENERGY STAR Qualified Product Listing: https://www.energystar.gov/productfinder/product/certified-commercial-hot-food-holding-cabinets/results.

[619] CEE Commercial Kitchens Initiative’s overview of the Food Service Industry: https://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_January2015.pdf.

Table 15.5-1: [Hot Food Holding Cabinets] ENERGY STAR Specification[620]

Product Category	Product Interior Volume [ft³]	Idle Energy Rate [W]
Half Size	0 < V < 13	≤ 21.5 V
Three-Quarter Size	13 ≤ V ≤ 28	≤ 2.0 V + 254.0
Full Size	28 ≤ V	≤ 3.8 V + 203.5
* V = Interior Volume = Interior Height x Interior Width x Interior Depth		

15.5.2 Energy and Demand Savings Methodology

15.5.2.1 Savings Algorithms and Input Variables

Energy and Demand Savings

Deemed savings are calculated using the following algorithms:

$$\boldsymbol{Energy\ Savings}\ [\Delta \boldsymbol{kWh}] = \frac{(\boldsymbol{E_{Idle,base}} - \boldsymbol{E_{Idle,ES}})}{\boldsymbol{1,000}} \times \boldsymbol{t_{on}} \times \boldsymbol{t_{days}}$$

Equation 15.5-1

$$\boldsymbol{Peak\ Demand\ Savings}\ [\Delta \boldsymbol{kW}] = \frac{(\boldsymbol{E_{Idle,base}} - \boldsymbol{E_{Idle,ES}})}{\boldsymbol{1,000}} \times \boldsymbol{DF}$$

Equation 15.5-2

Where:

V = *Product Interior Volume [ft³].*

$E_{Idle,base}$ = *Baseline idle energy rate [W]; see Table 15.5-2.*

$E_{Idle,ES}$ = *ENERGY STAR idle energy rate [W]; see Table 15.5-2.*

t_{on} = *Equipment operating hours per day [hours/day].*

t_{days} = *Facility operating days per year [days/year].*

1,000 = *Constant to convert from watts to kilowatts.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 16.3-1.*

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[620] ENERGY STAR Commercial Fryers Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_hot_food_holding_cabinets/key_product_criteria.

Table 15.5-2: [Hot Food Holding Cabinets] ENERGY STAR Commercial Food Service Calculator Inputs[621]

Input Variable	Half-Size $0 < V < 13$	3/4-Size $13 \leq V < 28$	Full-Size $28 \leq V$
V[622]	8	22	53
$E_{Idle,base}$	30 x V		
$E_{Idle,ES}$	21.5 x V	2 x V + 254	3.8 x V + 203.5
t_{on}	9		
t_{days}	365		

Table 15.5-3: [Hot Food Holding Cabinets] Demand Factors

Factor Type	Demand Factor
NCP	1.000
CP	0.926
4CP	0.978

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the California End Use Survey (CEUS)[623] usage data by building type and end use for the "restaurant" building type and the "cooking equipment" end use. The CEUS load data provided hourly data by fuel type for each day of the year for an 8,760 hourly load shape, which can be found in Section 22.2.

15.5.2.2 Deemed Energy and Demand Savings Tables

The following deemed energy and demand savings are based on the input assumptions from Table 15.5-2.

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[621] ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

[622] Averages of product interior volume determined based on review of ENERGY STAR qualified product listing.

[623] California End Use Survey (CEUS), building workbooks with load shapes by end use. http://capabilities.itron.com/CeusWeb/Default.aspx.

Table 15.5-4: [Hot Food Holding Cabinets] Deemed Energy and Demand Savings

Size	Annual Energy Savings [kWh]	NCP Demand Savings [kW]	CP Demand Savings [kW]	4CP Demand Savings [kW]
Half	223	0.068	0.063	0.067
Three-Quarter	1,189	0.362	0.335	0.354
Full	3,893	1.185	1.097	1.159

15.5.2.3 Additional Calculators and Tools

There are no tools for this measure.

15.5.2.4 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years for HFHCs, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID Cook-HoldCab.[624]

15.5.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Manufacturer and model number
- Interior cabinet volume
- ENERGY STAR idle rate
- ENERGY STAR certification or alternative
- Proof of purchase including date of purchase, manufacturer, and model number

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[624] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

15.6 ENERGY STAR® ELECTRIC FRYERS

15.6.1 Measure Description

This section covers the deemed savings methodology for the installation of ENERGY STAR electric fryers. Fryers that have earned ENERGY STAR certification offer shorter cook times and higher production rates through advanced burner and heat exchanger designs. Fry pot insulation reduces standby losses resulting in a lower idle energy rate. The energy and demand savings are determined on a per-fryer basis.

15.6.1.1 Eligibility Criteria

Eligible units must be compliant with the current ENERGY STAR specification, either counter-top or floor type designs, with standard-size and large vat fryers as defined below.[625,626]

- Standard-Size Electric Fryer: A fryer with a vat that measures ≥ 12 inches and < 18 inches wide, and a shortening capacity ≥ 25 pounds and ≤ 65 pounds
- Large Vat Electric Fryer: A fryer with a vat that measures ≥ 18 inches and ≤ 24 inches wide, and a shortening capacity > 50 pounds

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.[627]

The following products are excluded from the ENERGY STAR eligibility criteria:

- Fryers with vats measuring < 12 inches wide, or > 24 inches wide

15.6.1.2 Baseline Condition

The baseline condition is an electric standard-size fryer ≥ 12 inches and < 18 inches wide or large vat fryer ≥ 18 inches and < 24 inches wide that do not meet ENERGY STAR key product criteria.

15.6.1.3 High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v3.0 specification, effective October 1, 2016. New electric standard fryers ≥ 12 inches and < 18 inches wide and large vat fryers ≥ 18 inches and < 24 inches wide that meet or exceed the requirements listed in Table 15.6-1.

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[625] ENERGY STAR Program Requirements Product Specifications for Commercial Fryers. Eligibility Criteria Version 3.0. https://www.energystar.gov/sites/default/files/Commercial%20Fryers%20Program%20Requirements.pdf.

[626] ENERGY STAR Qualified Product Listing: https://www.energystar.gov/productfinder/product/certified-commercial-fryers/results.

[627] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_January2015.pdf.

Table 15.6-1: [Electric Fryers] ENERGY STAR Specification[628]

Inputs	Standard	Large-Vat
Cooking energy efficiency	≥ 83%	≥ 80%
Idle energy rate [W]	≤ 800	≤ 1,100

15.6.2 Energy and Demand Savings Methodology

15.6.2.1 Savings Algorithms and Input Variables

Energy and Demand Savings

Deemed savings are calculated using the following algorithms:

$$\boldsymbol{Energy\ Savings}\ [\Delta \boldsymbol{kWh}] = \boldsymbol{kWh_{base}} - \boldsymbol{kWh_{ES}}$$

Equation 15.6-1

$$\boldsymbol{kWh_{base}} = \boldsymbol{kWh_{ph,base}} + \boldsymbol{kWh_{cook,base}} + \boldsymbol{kWh_{idle,base}}$$

Equation 15.6-2

$$\boldsymbol{kWh_{ES}} = \boldsymbol{kWh_{ph,ES}} + \boldsymbol{kWh_{cook,ES}} + \boldsymbol{kWh_{idle,ES}}$$

Equation 15.6-3

kWh_{ph}, kWh_{cook}, and kWh_{idle} are each calculated the same for both the baseline and ENERGY STAR cases, as shown below, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 15.6-2.

$$\boldsymbol{kWh} = \left(\boldsymbol{E_{ph}} + \left(\frac{\boldsymbol{W_{food}} \times \boldsymbol{E_{food}}}{\boldsymbol{\eta_{cook}}}\right) + \boldsymbol{E_{idle}} \times \left(\boldsymbol{t_{on}} - \frac{\boldsymbol{t_{ph}}}{\boldsymbol{60}} - \frac{\boldsymbol{W_{food}}}{\boldsymbol{PC}}\right)\right) \times \frac{\boldsymbol{t_{days}}}{\boldsymbol{1,000}}$$

Equation 15.6-4

$$\boldsymbol{Peak\ Demand\ Savings}\ [\boldsymbol{\Delta kW}] = \frac{\boldsymbol{\Delta kWh} - \left(\frac{\boldsymbol{\Delta E_{ph}} \times \boldsymbol{t_{days}}}{\boldsymbol{1,000}}\right)}{\boldsymbol{t_{on}} \times \boldsymbol{t_{days}}} \times \boldsymbol{DF}$$

Equation 15.6-5

Where:

kWh_{base} = *Baseline annual energy consumption [kWh].*

kWh_{ES} = *ENERGY STAR annual energy consumption [kWh].*

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[628] ENERGY STAR Commercial Fryers Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_fryers/key_product_criteria.

E_{ph} = *Preheat energy [Wh/BTU].*

ΔE_{ph} = *Difference in baseline and ENERGY STAR preheat energy [Wh/BTU].*

E_{food} = *ASTM energy to food of energy absorbed by food product during cooking [Wh/lb].*

E_{Idle} = *Idle energy rate [W].*

W_{food} = *Pounds of food cooked per day [lb/day].*

η_{cook} = *Cooking energy efficiency [%].*

PC = *Production capacity [lb/hr].*

t_{on} = *Equipment operating hours per day [hr/day].*

t_{days} = *Facility operating days per year [days/year].*

$1,000$ = *Constant to convert from watts to kilowatts.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 15.6-3.*

Table 15.6-2: [Electric Fryers] ENERGY STAR Commercial Food Service Calculator Inputs[629]

Parameter	Standard-Sized Vat		Large-Vat	
	Baseline	ENERGY STAR	Baseline	ENERGY STAR
E_{ph}	2,400	1,900	2,400	1,900
W_{food}	150			
E_{food}	167			
η_{cook}	75%	83%	70%	80%
E_{idle}	1,200	800	1,350	1,100
C_{Cap}	65	70	100	110
t_{on}	16		12	
t_{days}	365			

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[629] ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

Table 15.6-3: [Electric Fryers] Demand Factors

Factor Type	Demand Factor
NCP	1.000
CP	0.926
4CP	0.978

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the California End Use Survey (CEUS) [630] usage data by building type and end use for the "restaurant" building type and the "cooking equipment" end use. The CEUS load data provided hourly data by fuel type for each day of the year for an 8,760 hourly load shape, which can be found in Section 22.2.

15.6.2.2 Deemed Energy Savings Tables

The following deemed energy savings are based on the input assumptions from Table 15.6-2.

Table 15.6-4: [Electric Fryers] Deemed Energy Savings by Fryer Type

Fryer Type	Annual Energy Savings [kWh]
Standard	3,272
Large Vat	2,696

15.6.2.3 Deemed Demand Savings Tables

The following deemed demand savings are based on the input assumptions from Table 15.6-2.

Table 15.6-5: [Electric Fryers] Deemed Demand Savings by Fryer Type

Fryer Type	Demand Savings [kW]		
	NCP	CP	4CP
Standard	0.529	0.490	0.517
Large Vat	0.574	0.531	0.561

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[630] California End Use Survey (CEUS), Building workbooks with load shapes by end use.

15.6.2.4 Additional Calculators and Tools

There are no tools for this measure.

15.6.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years for electric fryers, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID Cook-ElecFryer.[631]

15.6.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Manufacturer and model number
- Fryer width
- ENERGY STAR idle rate
- ENERGY STAR cooking efficiency
- ENERGY STAR certification or alternative
- Proof of purchase including date of purchase, manufacturer, and model number

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[631] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

15.7 ENERGY STAR® ELECTRIC STEAM COOKERS

15.7.1 Measure Description

This section covers the deemed savings methodology for the installation of ENERGY STAR electric steam cookers. Steam cookers are available in 3, 4, 5, or ≥ 6 pan capacities. Steam cookers that have earned ENERGY STAR certification are up to 50% more efficient than standard models. They have higher production rates and reduced heat loss due to better insulation and a more efficient steam delivery system. The energy and demand savings are determined on a per-cooker basis.

15.7.1.1 Eligibility Criteria

Eligible units must be compliant with the current ENERGY STAR specification. [632,633] Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.[634]

Baseline and post-retrofit ENERGY STAR electric steam cookers must have equivalent pan capacities.

15.7.1.2 Baseline Condition

The baseline condition for retrofit situations is an electric steam cooker that does not meet ENERGY STAR key product criteria.

15.7.1.3 High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v1.2 specification, effective August 1, 2003. Qualified products must meet the requirements from Table 15.7-1.

Table 15.7-1: [Steam Cookers] ENERGY STAR Specification[635]

Pan Capacity	Cooking Energy Efficiency [%][636]	Idle Rate [W]
3-Pan	50%	400
4-Pan	50%	530
5-Pan	50%	670
6-Pan and Larger	50%	800

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[632] ENERGY STAR Program Requirements Product Specifications for Commercial Steam Cookers. Eligibility Criteria Version 1.2. https://www.energystar.gov/sites/default/files/specs/private/Commercial_Steam_Cookers_Program_Requirements%20v1_2.pdf.

[633] ENERGY STAR Qualified Product Listing: https://www.energystar.gov/productfinder/product/certified-commercial-steam-cookers/results.

[634] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_January2015.pdf.

[635] ENERGY STAR. Commercial Steam Cookers Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_steam_cookers/key_product_criteria.

[636] Cooking Energy Efficiency is based on "heavy load (potato) cooking capacity," i.e., 12 by 20 by 2½ inch (300 by 500 by 65 mm) perforated hotel pans each filled with 8.0 ± 0.2 lb (3.6 ± 0.1 kg) of fresh, whole, US No. 1, size B, red potatoes.

15.7.2 Energy and Demand Savings Methodology

15.7.2.1 Savings Algorithms and Input Variables

Energy and Demand Savings

$$\boldsymbol{Energy\ Savings}\ [\Delta \boldsymbol{kWh}] = \boldsymbol{kWh_{base}} - \boldsymbol{kWh_{ES}}$$

Equation 15.7-1

$$\boldsymbol{kWh_{base}} = \boldsymbol{kWh_{ph,base}} + \boldsymbol{kWh_{cook,base}} + \boldsymbol{kWh_{idle,base}}$$

Equation 15.7-2

$$\boldsymbol{kWh_{ES}} = \boldsymbol{kWh_{ph,ES}} + \boldsymbol{kWh_{cook,ES}} + \boldsymbol{kWh_{idle,ES}}$$

Equation 15.7-3

kWh_{ph}, *kWh_{cook}*, and *kWh_{idle}* are each calculated the same for both the baseline and ENERGY STAR cases, as shown below, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 15.7-2.

$$\boldsymbol{kWh} = \left(\boldsymbol{E_{ph}} + \left(\frac{\boldsymbol{W_{food}} \times \boldsymbol{E_{food}}}{\boldsymbol{\eta_{cook}}}\right) + \left[(\boldsymbol{1} - \boldsymbol{40\%}) \times \boldsymbol{E_{idle}} + \frac{\boldsymbol{40\%} \times \boldsymbol{PC} \times \boldsymbol{P}}{\boldsymbol{\eta_{cook}}}\right] \times \left(\boldsymbol{t_{on}} - \frac{\boldsymbol{W_{food}}}{\boldsymbol{PC} \times \boldsymbol{P}}\right)\right) \times \frac{\boldsymbol{t_{days}}}{\boldsymbol{1,000}}$$

Equation 15.7-4

$$\boldsymbol{Peak\ Demand\ Savings}\ [\boldsymbol{\Delta kW}] = \frac{\boldsymbol{\Delta kWh} - \left(\frac{\boldsymbol{\Delta E_{ph}} \times \boldsymbol{t_{days}}}{\boldsymbol{1,000}}\right)}{\boldsymbol{t_{on}} \times \boldsymbol{t_{days}}} \times \boldsymbol{DF}$$

Equation 15.7-5

Where:

kWh_{base} = *Baseline annual energy consumption [kWh].*

kWh_{ES} = *ENERGY STAR annual energy consumption [kWh].*

E_{ph} = *Preheat energy [Wh/BTU].*

ΔE_{ph} = *Difference in baseline and ENERGY STAR preheat energy [Wh/BTU].*

E_{food} = *ASTM energy to food of energy absorbed by food product during cooking [Wh/lb].*

E_{Idle} = *Idle energy rate [W] (Differs for boiler-based or steam-generator equipment).*

W_{food} = *Pounds of food cooked per day [lb/day].*

η_{cook} = *Cooking energy efficiency [%] (Differs for boiler-based or steam generator equipment).*

40% = *Percent of time in constant steam mode [%].*

PC = *Production capacity [lb/hr].*

P = *Pan capacity.*

t_{on} = *Average daily operating hours per day [hr/day].*

t_{days} = *Facility operating days per year [days/year].*

$1{,}000$ = *Constant to convert from watts to kilowatts.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; Table 15.7-3.*

Table 15.7-2: [Steam Cookers] ENERGY STAR Commercial Food Service Calculator Inputs[637]

Parameter	Baseline Value	Post-Retrofit Value
E_{ph}	1,776	1,671.7
W_{food}	100	
E_{food}	30.8	
η	Boiler Based: 26% Steam Generator: 30%	50%
E_{Idle}	Boiler Based: 1,000 Steam Generator: 1,200	3-Pan: 400 4-Pan: 530 5-Pan: 670 6-Pan: 800
PC	23.3	16.7
P	3, 4, 5, or 6	
t_{on}	9.25	
t_{days}	311	

Table 15.7-3: [Steam Cookers] Demand Factors

Factor Type	Demand Factor
NCP	1.000
CP	0.926
4CP	0.978

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[637] ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the California End Use Survey (CEUS)[638] usage data by building type and end use for the “restaurant” building type and the “cooking equipment” end use. The CEUS load data provided hourly data by fuel type for each day of the year for an 8,760 hourly load shape, which can be found in Section 22.2.

15.7.2.2 Deemed Energy Savings Tables

The following deemed energy savings are based on the input assumptions from Table 15.7-2.

Table 15.7-4: [Steam Cookers] Deemed Energy Savings

Steam Cooker Type	P	Annual Energy Savings [kWh]
Boiler Based	3-Pan	7,988
	4-Pan	9,822
	5-Pan	11,614
	6-Pan and larger	13,408
Steam Generator	3-Pan	6,715
	4-Pan	8,139
	5-Pan	9,515
	6-Pan and larger	10,891

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[638] California End Use Survey (CEUS), Building workbooks with load shapes by end use.

15.7.2.3 Deemed Demand Savings Tables

The following deemed demand savings are based on the input assumptions from Table 15.7-2.

Table 15.7-5: [Steam Cookers] Deemed Demand Savings

Steam Cooker Type	P	Demand Savings (kW)		
		NCP	CP	4CP
Boiler Based	3-Pan	2.766	2.561	2.705
	4-Pan	3.403	3.151	3.328
	5-Pan	4.026	3.728	3.937
	6-Pan and larger	4.650	4.306	4.547
Steam Generator	3-Pan	2.323	2.151	2.272
	4-Pan	2.818	2.609	2.756
	5-Pan	3.296	3.053	3.224
	6-Pan and larger	3.775	3.495	3.692

15.7.2.4 Additional Calculators and Tools

This section is not applicable.

15.7.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years for electric steam cookers, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID Cook-ElecStmCooker.[639]

15.7.3 Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- Manufacturer and model number
- Steam cooker type (boiler-based or steam generator)
- Pan capacity (3, 4, 5, or 6+)
- ENERGY STAR idle rate
- ENERGY STAR cooking efficiency
- ENERGY STAR certification or alternative
- Proof of purchase including date of purchase, manufacturer, and model number

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[639] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

16. COMMERCIAL: REFRIGERATION

16.1 DOOR HEATER CONTROLS

16.1.1 Measure Description

This measure involves the installation of Door Heater Controls for glass-door refrigerated cases with anti-sweat heaters (ASH).

16.1.1.1 Eligibility Criteria

The efficient equipment must be a standard-heat configuration door heater control utilized in an eligible commercial retail facility on glass-door refrigerated cases for the purpose of dynamically controlling humidity.

16.1.1.2 Baseline Condition

The baseline efficiency case is a cooler or a freezer door heater that operates 8,760 hours per year without any controls.

16.1.1.3 High-Efficiency Condition

Eligible high efficiency equipment is a cooler or a freezer door heater connected to a heater control system, which measures the ambient humidity and temperature of the store, calculates the dew point (DP) temperature, and uses pulse width modulation to control the anti-sweat door heater based on specific algorithms for freezer and cooler doors.

16.1.2 Energy and Demand Savings Methodology

A door heater controller senses dew point (DP) temperature in the store and modulates power supplied to the heaters accordingly. DP inside a building is primarily dependent on the moisture content of outdoor ambient air. The reduced door heating also results in a reduced cooling load in the cooler. The savings are on a per-horizontal-linear foot of display case basis.

16.1.2.1 Savings Algorithms and Input Variables

Energy Savings

The energy savings from the installation of anti-sweat heater controls result from the reduced time the heater runs (kWh_{ASH}) and the reduced load on the freezer or cooler refrigeration (kWh_{refrig}). These savings are calculated using the following procedures:

Indoor dew point ($T_{d\text{-}in}$) for every hour can be calculated from outdoor dew point ($T_{d\text{-}out}$) during that hour by using the following equation:

$$\boldsymbol{T_{d-in} = 0.005379 \times (T_{d-out})^2 + 0.171795 \times T_{d-out} + 19.87006}$$

Equation 16.1-1[640]

The pre-retrofit baseline assumes door heaters operate 8,760 hours annually. In the post-retrofit case, the duty for each hourly reading is calculated by assuming a linear relationship between indoor DP and duty cycle for each hour. It is assumed that the door heaters will be all off (duty cycle of 0%) at 42.89°F DP and all on (duty cycle of 100%) at 52.87°F DP for a typical supermarket[641]. Between these values, the door heaters' hourly duty cycle changes proportionally with DP, as modeled in Equation 16.1-2. For each hour of the year, the percent of time the door heater is on can be determined from that hour's DP.

$$\boldsymbol{Door\ Heater\ ON\% = \frac{T_{d-in} - All\ OFF\ setpt\ (42.89°F)}{All\ ON\ setpt\ (52.87°\mathrm{F}) - All\ OFF\ setpt\ (42.89°F)}}$$

Equation 16.1-2

The controller only changes the run-time of the heaters, not the kW demand. Therefore, the instantaneous door heater power (kW_{ASH}), as a resistive load, remains constant per linear foot of door heater[642], at:

<u>Medium temperature:</u>

kW_{Ash} = 0.109 per door or 0.0436 per horizontal linear foot of door.[643]

<u>Low temperature:</u>

kW_{Ash} = 0.191 per door or 0.0764 per horizontal linear foot of door.[644]

Door heater energy consumption for each hour of the year is a product of power and run-time:

$$\boldsymbol{kWh_{ASH-Hourly} = kW_{ASH} \times Door\ Heater\ ON\% \ \times 1\ hour}$$

Equation 16.1-3

$$\boldsymbol{kWh_{ASH} = \sum kWh_{ASH-Hourly}}$$

Equation 16.1-4

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[640] San Diego Gas & Electric, Work Paper WPSDGENRRN0009: Anti-Sweat Heat (ASH) Controls, "Energy Savings Estimation Methodologies". page 4, Figure 2. August 2012. https://www.sdge.com/sites/default/files/WPSDGENRRN0009%2520Rev%25200%2520Anti-Sweat%2520Heat%2520%2528ASH%2529%2520Controls%2520_0.doc.

[641] Ibid, "Direct ASH Power", page 6.
42.89°F DP and 52.87°F DP correspond to relative humidities of 35% and 50% respectively for a 72°F indoor space. These relative humidities are common practice setpoints for a typical supermarket of this temperature.

[642] Pennsylvania TRM, "3.5.6 Controls: Anti-Sweat Heater Controls". page 381, Table 3-101. June 2016. http://www.puc.pa.gov/pcdocs/1350348.docx. Additional reference from Pennsylvania TRM: State of Wisconsin, Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual. Table 4-75., March 22, 2010. https://focusonenergy.com/sites/default/files/bpdeemedsavingsmanuav10_evaluationreport.pdf.

[643] Ibid.

[644] Ibid.

Where:

$kWh_{ASH\text{-}Hourly}$ = *Hourly energy consumption of door heater.*

To calculate energy savings from the reduced refrigeration load using average system efficiency and assuming 35% of the anti-sweat heat becomes a load on the refrigeration system,[645] the cooling load contribution from door heaters for each hour of the year can be determined by:

$$Q_{ASH}(ton-hrs) = 0.35 \times kW_{ASH} \times \frac{3412\frac{Btu}{hr}}{12000\frac{Btu}{ton}} \times Door\ Heater\ ON\%$$

Equation 16.1-5

Where:

Q_{ASH} = *Hourly cooling load contribution by door heaters.*

$kWh_{ASH\text{-}Hourly}$ = *Hourly energy consumption of door heater.*

0.35 = *Portion of anti-sweat heat that becomes cooling load.*

3,412 = *Constant to convert kWh to Btu.*

12,000 = *Constant to convert tons to Btu/hr.*

The compressor power requirements are based on calculated cooling load and energy-efficiency ratios obtained from manufacturers' data. The compressor analysis is limited to the additional cooling load imposed by the door heaters, not the total cooling load of the refrigeration system.

For medium temperature refrigerated cases, the saturated condensing temperature (SCT) is calculated as the design dry-bulb temperature plus 15 degrees. For low temperature refrigerated cases (freezers), the SCT is the design dry-bulb temperature plus 10 degrees. The EER for both medium- and low-temperature applications is a function of SCT and part load ratio (PLR) of the compressor. PLR is the ratio of total cooling load to compressor capacity and is assumed to be a constant of 1/1.15, or approximately 0.87.[646]

For medium temperature compressors, the following equation is used to determine EER_{MT} [Btu/hr/watts] for each hour of the year.

$$EER_{MT} = a + (b \times SCT) + (c \times PLR) + (d \times SCT^2) + (e \times PLR^2) + (f \times SCT \times PLR) + (g \times SCT^3) + (h \times PLR^3) + (i \times SCT \times PLR^2) + (j \times SCT^2 \times PLR)$$

Equation 16.1-6[647]

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[645] A Study of Energy Efficient Solutions for Anti-Sweat Heaters. Southern California Edison RTTC. December 1999.

[646] Work Paper PGEREF108: Anti-Sweat Heat (ASH) Controls. Pacific Gas & Electric Company. May 29, 2009. Assumes 15% oversizing.

[647] San Diego Gas & Electric, Work Paper WPSDGENRRN0009: Anti-Sweat Heat (ASH) Controls, "Energy Savings Estimation Methodologies". page 4, Figure 2. August 2012. https://www.sdge.com/sites/default/files/WPSDGENRRN0009%2520Rev%25200%2520Anti-Sweat%2520Heat%2520%2528ASH%2529%2520Controls%2520_0.doc.

Where:

a = 3.75346018700468.

b = -0.049642253137389.

c = 29.4589834935596.

d = 0.000342066982768282.

e = -11.7705583766926.

f = -0.212941092717051.

g = $-1.46606221890819 \times 10^{-6}$.

h = 6.80170133906075.

i = -0.020187240339536.

j = 0.000657941213335828.

PLR = 1/1.15 = 0.87.

T_{DB} = Summer design dry-bulb temperature for San Antonio.

SCT = T_{DB}+15°F.

For low temperature compressors, the following equation is used to determine the EER_{LT} [Btu/hr/watts]:

$$\boldsymbol{EER_{LT}} = \boldsymbol{a} + (\boldsymbol{b} \times \boldsymbol{SCT}) + (\boldsymbol{c} \times \boldsymbol{PLR}) + (\boldsymbol{d} \times \boldsymbol{SCT^2}) + (\boldsymbol{e} \times \boldsymbol{PLR^2}) + (\boldsymbol{f} \times \boldsymbol{SCT} \times \boldsymbol{PLR}) + (\boldsymbol{g} \times \boldsymbol{SCT^3}) + (\boldsymbol{h} \times \boldsymbol{PLR^3}) + (\boldsymbol{i} \times \boldsymbol{SCT} \times \boldsymbol{PLR^2}) + (\boldsymbol{j} \times \boldsymbol{SCT^2} \times \boldsymbol{PLR})$$

Equation 16.1-7[648]

Where:

a = 9.86650982829017.

b = -0.230356886617629.

c = 22.905553824974.

d = 0.00218892905109218.

e = -2.48866737934442.

f = -0.248051519588758.

g = $-7.57495453950879 \times 10^{-6}$.

h = 2.03606248623924.

i = -0.0214774331896676.

j = 0.000938305518020252.

PLR = 1/1.15= 0.87.

T_{DB} = Summer design dry-bulb temperature for San Antonio.

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[648] Ibid.

$SCT = T_{DB}+10°F.$

The annual energy used by the compressor to remove heat imposed by the door heaters for each hour is determined by calculating the hourly energy used based on calculated cooling load and EER, Equation 16.1-8, then summing the hourly energy for the entire year, Equation 16.1-9.

$$kWh_{refrig-hourly} = Q_{ASH} \times \frac{12}{EER}$$

Equation 16.1-8

$$kWh_{refrig} = \sum kWh_{refrig-Hourly}$$

Equation 16.1-9

Total annual energy consumption (direct door heaters and indirect refrigeration) is the sum of both annual kWh consumption variables:

$$kWh_{total} = kWh_{refrig} + kWh_{ASH}$$

Equation 16.1-10

Total energy savings is the difference between the baseline and post-retrofit case:

$$Annual\ Energy\ Savings\ [kWh] = kWh_{total-baseline} + kWh_{total-post}$$

Equation 16.1-11

Demand Savings

Peak demand savings are calculated as the weighted average of the probability of winter or summer peak load's top twenty hours' coincidence with system peak and the hourly calculated kWh_{total} for said twenty hours per climate zone.

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using the calculated 8,760 load profile of kWh savings. These hourly kWh savings are calculated using TMY3 Hourly Weather Data for San Antonio which provides the Dry Bulb and Dew Point independent variables needed to proceed through the algorithms.

16.1.2.2 Deemed Energy and Demand Savings Tables

The energy and demand savings of Anti-Sweat Door Heater Controls are deemed values based on San Antonio weather and refrigeration temperature. Table 16.1-1 provides these deemed values.

Table 16.1-1: [Door Heater Controls] Deemed Savings

Case Type	Annual Energy Savings [kWh/ft]	NCP Peak Demand Savings [kW/ft]	CP Peak Demand Savings [kW/ft]	4CP Peak Demand Savings [kW/ft]
Medium Temperature Case	196	0.052	0.018	0.023
Low Temperature Case	351	0.096	0.034	0.042

16.1.2.3 Additional Calculators and Tools

There are no tools for this measure.

16.1.2.4 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years for door heater controls, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-ASH.[649]

16.1.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Refrigeration Temperature
- Linear Feet of Medium-Temperature Doors
- Linear Feet of Low-Temperature Doors

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[649] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

16.2 ECM EVAPORATOR FAN MOTORS

16.2.1 Measure Description

This measure involves the installation of an electronically commutated motor (ECM) replacing an existing evaporative fan motor in cooler and freezer display cases. ECMs can provide up to 65 percent reduction in fan energy use with higher efficiencies, automatic variable-speed drive, lower motor operating temperatures, and less maintenance.

16.2.1.1 Eligibility Criteria

All ECMs must constitute suitable, size-for-size replacements of existing evaporator fan motors.

16.2.1.2 Baseline Condition

Baseline efficiency case is an existing shaded pole evaporator fan motor in a refrigerated case.

16.2.1.3 High-Efficiency Condition

Eligible high efficiency equipment is an electronically commutated motor that replaces an existing evaporator fan motor.

16.2.2 Energy and Demand Savings Methodology

16.2.2.1 Savings Algorithms and Input Variables

ECMs can reduce fan energy use by as much as 65%, and can also provide higher efficiency, automatic variable-speed drive, lower motor operating temperatures, and less maintenance.

Energy Savings

The energy savings from the installation of ECMs result from increased efficiency of the fan, and reduced heat produced from the fan operation. The energy and demand savings are calculated using the following equations:

<u>Cooler and Freezer:</u>

$$\boldsymbol{Energy}\ [\boldsymbol{kWh}] = \boldsymbol{N} \times\ \boldsymbol{\Delta kWh_{per\ unit}}$$

Equation 16.2-1

$$\boldsymbol{\Delta kWh_{per\ unit}} = \boldsymbol{\Delta kW_{peak\ per\ unit}} \times \boldsymbol{Hours}\ \times \boldsymbol{DC_{evap}}\ \times (\boldsymbol{1} - \boldsymbol{\%OFF})$$

Equation 16.2-2

Where:

N = *Number of motors replaced.*

$\Delta kWh_{per\ unit}$ = *Energy savings attributable to increased efficiency of each evaporator fan.*

$\Delta kW_{peak\ per\ unit}$ = *Power demand reduction attributable to the increased efficiency of each evaporator fan.*

Hours = *Annual operating hours are assumed to be 8,760 for coolers and 8,273 for walk-in freezers.*[650]

$DC_{EvapCool}$ = *Duty cycle of evaporator fan motor for cooler, 100%.*[651]

$DC_{EvapFreeze}$ = *Duty cycle of evaporator fan motor for freezer, 94.4%.*[652]

%OFF = *The percentage of time that the evaporator fan motors are off. If the facility does not have evaporator fan controls %OFF = 0, if the facility has evaporator fan controls %OFF = 46%.*[653]

Demand Savings

Peak demand savings are calculated by the following equation:

Cooler

$$\boldsymbol{Peak\ Demand\ [kW] = N \times \Delta kW_{per\ unit}}$$

Equation 16.2-3

$$\boldsymbol{\Delta kW_{peak\ per\ unit} = (W_{base} - W_{ee})/1000 \times LF \times DC_{EvapCool} \times \left(1 + \frac{1}{COP_{cooler}}\right) \times DF}$$

Equation 16.2-4

Freezer

$$\boldsymbol{Peak\ Demand\ [kW] = N \times \Delta kW_{per\ unit}}$$

Equation 16.2-5

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[650] The Pennsylvania TRM, June 2016, utilizes the Efficiency Vermont source reproduced below this footnoted statement for an assumption of 8,273 hours for walk-in freezers. This is, furthermore, equivalent to stating the freezer's duty cycle is approximately 94.4% (8,273 / 8,760 ≈ 0.944), an assumed value which appears in Table 155 for the $DC_{EvapFreezer}$ variable. The Maine TRM, July 2019, details the derivation of 8,273 and thus approximately 94.4%: "A[n] evaporator fan in a cooler runs all the time, but a freezer runs only 8,273 hours per year due to defrost cycles (4 20-min defrost cycles per day)"

- Pennsylvania TRM, "3.5.3 High-Efficiency Fan Motors for Walk-In Refrigerated Cases." Page 369, Table 3-93. June 2016. http://www.puc.pa.gov/pcdocs/1350348.docx.
- Efficiency Vermont, Technical Reference Manual 2009-54, 12/08. Hours of operation accounts for defrosting periods where motor is not operating. http://www.greenmountainpower.com/upload/photos/371TRM_User_Manual_No_2013-82-5-protected.pdf.
- Efficiency Maine, Commercial/Industrial and Multifamily Technical Reference Manual 2020.1, July 1, 2019. Page 83, footnote 401.

[651] Efficiency Maine, Commercial/Industrial and Multifamily Technical Reference Manual 2020.1, July 1, 2019. Page 83, footnote 401.

[652] Ibid (two previous footnotes).

[653] The Massachusetts Technical Reference Manual, 2012 Program Year – Plan Version, "Refrigeration – Evaporator Fan Controls," October 2011. Page 216, footnote 414 cites the following as the source for this variable:
"The value is an estimate by National Resource Management (NRM) based on extensive analysis of hourly use data. These values are also supported by Select Energy (2004). Cooler Control Measure Impact Spreadsheet User's Manual. Prepared for NSTAR."

$$\Delta kW_{peak\ per\ unit} = (W_{base} - W_{ee})/1000 \times LF \times DC_{EvapFreeze} \times \left(1 + \frac{1}{COP_{freezer}}\right) \times DF$$

Equation 16.2-6

Where:

W_{base} = *Input wattage of existing/baseline evaporator fan motor; see Table 16.2-1.*

W_{ee} = *Input wattage of new energy efficient evaporator fan motor; see Table 16.2-1.*

LF = *Load factor of evaporator fan motor, 0.9.*[654]

$DC_{EvapCool}$ = *Duty cycle of evaporator fan motor for cooler, 100%.*[655]

$DC_{EvapFreeze}$ = *Duty cycle of evaporator fan motor for freezer, 94.4%.*[656]

COP_{cooler} = *Coefficient of performance of compressor in the cooler, 12/EERMT; see Table 16.2-2.*

$COP_{freezer}$ = *Coefficient of performance of compressor in the freezer, 12/EERLT; see Table 16.2-2.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 16.2-3.*

Table 16.2-1: [ECM Motors] Motor Sizes, Efficiencies, and Input Watts[657,658]

Nominal Motor Size	Motor Output (W)	Shaded Pole Eff	Shaded Pole Input (W)	PSC Eff	PSC Input (W)	ECM Eff.	ECM Input (W)
(1-14W)	9	30%	30	60%	15	70%	13
1/40 HP (16-23W)	19.5	30%	65	60%	33	70%	28
1/20 HP (37W)	37	30%	123	60%	62	70%	53
1/15 HP (49W)	49.0	30%	163	60%	82	70%	70
1/4 HP	186.5	30%	622	60%	311	70%	266

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[654] The Pennsylvania TRM, June 2016, cites the following as the source for determining the load factor of the evaporator fan motor: "ActOnEnergy; Business Program-Program Year 2, June 2009 through May 2010. Technical Reference Manual, No. 2009-01." Published 12/15/2009.
Pennsylvania TRM, "3.5.2 High-Efficiency Fan Motors for Reach-In Refrigerated Cases." page 365, Table 3-89. June 2016. http://www.puc.pa.gov/pcdocs/1350348.docx.

[655] "Efficiency Maine, Commercial/Industrial and Multifamily Technical Reference Manual 2020.1," July 1, 2019, p.83, footnote 401.

[656] Ibid.

[657] The first four rows are from the Pennsylvania TRM and the last two rows are estimated using logarithmic linear regression of smaller motor efficiencies.

[658] Motor efficiencies: "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment." Department of Energy. December 2013. Motor efficiencies for the baseline motors are from Table 2.1, which provides peak efficiency ranges for a variety of motors. ECM motor efficiencies are from discussion in section 2.4.3. https://www.energy.gov/sites/prod/files/2014/02/f8/Motor%20Energy%20Savings%20Potential%20Report%202013-12-4.pdf.

Nominal Motor Size	Motor Output (W)	Shaded Pole Eff	Shaded Pole Input (W)	PSC Eff	PSC Input (W)	ECM Eff.	ECM Input (W)
1/3 HP	248.7	30%	829	60%	415	70%	355

Table 16.2-2: Compressor Coefficient of Performance by Refrigeration Type (COP_{cooler} or $COP_{freezer}$) for San Antonio

Summer Design Dry Bulb Temperature	EER_{MT}[659]	EER_{LT}[660]	COP_{Cooler}	$COP_{Freezer}$
100.4	6.00	4.63	2.00	2.59

Table 16.2-3: [ECM Motors] Demand Factors

Factor Type	Demand Factor
NCP	1.000
CP	0.981
4CP	0.974

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Electric Power Research Institute (EPRI) average weekday and average weekend refrigeration end use load shape values. The EPRI load data provided representative hourly load shapes for the peak-season months of April through September and off-peak-season months of October through March. These shapes were used to create the 8,760 hourly load shape, which can be found in Section 22.2.

16.2.2.2 Deemed Energy and Demand Savings Tables

The energy and demand savings of ECMs are calculated using a deemed algorithm, based on dry bulb temperature, refrigeration temperature, and whether the motors have controls, and are therefore not associated with deemed energy nor demand tables.

16.2.2.3 Additional Calculators and Tools

There are no tools for this measure.

16.2.2.4 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years for ECM evaporator fan motors, as specified in the California

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[659] See Door Heater Controls measure.

[660] Ibid.

Database of Energy Efficiency Resources (DEER) READI tool for EUL IDs GrocDisp-FEEvapFanMtr and GrocWlkIn-WEvapFanMtr.[661]

16.2.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Building type
- Motor efficiency
- Motor power rating
- Evaporator fan control type
- Refrigeration temperature

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[661] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

16.3 ELECTRONIC DEFROST CONTROLS

16.3.1 Measure Description

This measure involves the installation of an electronic defrost control that senses whether a refrigerated case requires a defrost cycle in place of a time clock defrost control mechanism.

16.3.1.1 Eligibility Criteria

The refrigerated case must have a time clock mechanism that controls its defrost cycle.

16.3.1.2 Baseline Condition

The baseline efficiency case is a refrigerated case without defrost controls or with an evaporator fan defrost system that uses a time clock mechanism to initiate electronic resistance defrost.

16.3.1.3 High-Efficiency Condition

Eligible high efficiency equipment is an evaporator fan defrost system with electronic defrost controls.

16.3.2 Energy and Demand Savings Methodology

16.3.2.1 Savings Algorithms and Input Variables

Energy Savings

The energy savings from the installation of electronic defrost controls result from increased operating efficiency and reduced heat from fewer required defrosts. The energy and demand savings are calculated by using the following equations, with the coefficient of performance variable corresponding to low temperature or medium temperature applications:

$$\boldsymbol{Energy\ [kWh] = \Delta kWh_{defrost} + \Delta kWh_{heat}}$$

Equation 16.3-1

$$\boldsymbol{\Delta kWh_{defrost} = kW_{defrost} \times DRF \times Hours}$$

Equation 16.3-2

$$\boldsymbol{\Delta kWh_{heat} = \Delta kWh_{defrost} \times 0.28 \times Eff\ (kW/ton)}$$

Equation 16.3-3

Where:

$\Delta kWh_{defrost}$ = *Energy savings resulting from an increase in operating efficiency attributable to the addition of electronic defrost controls.*

ΔkWh_{heat} = *Energy savings attributable to the reduced heat from reduced number of defrosts.*

$kW_{defrost}$ = *Load of electric defrost (default = 0.9kW*[662]*).*

Hours = *Number of hours defrost occurs over a year without defrost controls, 487.*[663]

DRF = *Defrost reduction factor – percent reduction in defrosts required per year, 35%.*

0.28 = *Constant to convert from kW and tons; 3,412 Btuh/kW divided by 12,000 Btuh/ton.*

COP_{cooler} = *Coefficient of performance of compressor in the cooler, 12/*EER_{MT}*.*

$COP_{freezer}$ = *Coefficient of performance of compressor in the freezer, 12/*EER_{LT}*.*

EER_{MT} = *See calculations in Section 16.1.2.1.*

EERLT = *See calculations in Section 16.1.2.1.*

Demand Savings

Peak demand savings are calculated by the following equation:

$$\boldsymbol{Peak\ Demand}\ [\boldsymbol{kW}] = \frac{\boldsymbol{\Delta kWh}}{\boldsymbol{Hours}} \times \boldsymbol{DF}$$

Equation 16.3-4

Where:

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 16.3-1.*

Table 16.3-1: [Electronic Defrost Controls] Demand Factors

Factor Type	Demand Factor
NCP	1.000
CP	0.981
4CP	0.974

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Electric Power Research Institute (EPRI) average weekday and average weekend refrigeration end use load shape values. The EPRI load data provided representative hourly

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[662] Efficiency Vermont TRM, 3/16/2015, p. 170. The total defrost element kW is proportional to the number of evaporator fans blowing over the coil. The typical wattage of the defrost element is 900W per fan. https://www.puc.nh.gov/EESE%20Board/EERS_WG/vt_trm.pdf.

[663] Demand Defrost Strategies in Supermarket Refrigeration Systems, Oak Ridge National Laboratory, 2011. The refrigeration system is assumed to be in operation every day of the year, while savings from the evaporator coil defrost control will only occur during set defrost cycles. This is assumed to be (4) 20-minute cycles per day, for a total of 487 hours. https://info.ornl.gov/sites/publications/files/pub31296.pdf.

load shapes for the peak-season months of April through September and off-peak-season months of October through March. These shapes were used to create the 8,760 hourly load shape, which can be found in Section 22.2.

16.3.2.2 Deemed Energy and Demand Savings Tables

There are no deemed savings tables for this measure.

16.3.2.3 Additional Calculators and Tools

There are no tools for this measure.

16.3.2.4 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years for electronic defrost controls.[664]

16.3.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Hours that defrost occurs over a year without defrost controls
- Load of electric defrost
- Refrigeration temperature (low, medium)

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[664] GDS Associates, Inc. (June 2007). Measure Life Report. Prepared for The New England State Program Working Group (SPWG). https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf.
Additionally, the Pennsylvania TRM Volume 3 Page 162 cites the Vermont TRM, March 16, 2015. Pg. 171: "This is a conservative estimate is based on a discussion with Heatcraft based on the components expected life. https://www.puc.nh.gov/EESE%20Board/EERS_WG/vt_trm.pdf.

16.4 EVAPORATOR FAN CONTROLS

16.4.1 Measure Description

This measure involves the installation of an evaporator fan controller in a walk-in cooler or freezer so that the evaporator fan only operates when the compressor operates instead of continuously.

16.4.1.1 Eligibility Criteria

To be eligible under this measure, the existing walk-in cooler or freezer must not have an evaporator fan controller.

16.4.1.2 Baseline Condition

Baseline efficiency case is an existing shaded pole evaporator fan motor with no temperature controls, running 8,760 annual hours.

16.4.1.3 High-Efficiency Condition

Eligible high efficiency equipment will be regarded as an energy management system (EMS) or other electronic controls to modulate evaporator fan operation based on temperature of the refrigerated space.

16.4.2 Energy and Demand Savings Methodology

16.4.2.1 Savings Algorithms and Input Variables

Energy Savings

The energy savings from the installation of electronic defrost controls result from increased operating efficiency and reduced heat load produced by fewer numbers of defrosts (i.e., decreased fan operation). The energy and demand savings are calculated using the following equations:

$$\boldsymbol{Energy\ Savings}\ [\boldsymbol{kWh}] = \left((\boldsymbol{kW}_{\boldsymbol{evap}} \times \boldsymbol{n}_{\boldsymbol{fans}}) - \boldsymbol{kW}_{\boldsymbol{circ}}\right) \times (\mathbf{1} - \boldsymbol{DC}_{\boldsymbol{comp}}) \times \boldsymbol{DC}_{\boldsymbol{evap}} \times \boldsymbol{BF} \times \mathbf{8,760}$$

Equation 16.4-1

Demand Savings

Peak demand savings are calculated by the following equation:

$$\boldsymbol{Demand\ Savings\ [kW]} = \left(\left(\boldsymbol{kW_{evap}} \times \boldsymbol{n_{fans}} \right) - \boldsymbol{kW_{circ}} \right) \times \left(\boldsymbol{1} - \boldsymbol{DC_{comp}} \right) \times \boldsymbol{DC_{evap}} \times \boldsymbol{BF} \times \boldsymbol{DF}$$

Equation 16.4-2

Where:

kW_{evap} = *Connected load kW of each evaporator fan.*

kW_{circ} = *Connected load kW of the circulating fan.*

n_{fans} = *Number of evaporator fans.*

DC_{comp} = *Duty cycle of the compressor; see*

Table 16.4-1.

DC_{evap} = *Duty cycle of the evaporator fan; see*

Table 16.4-1.

BF = *Bonus factor for reducing cooling load from replacing the evaporator fan with a lower wattage circulating fan when the compressor is not running; see*

Table 16.4-1.

8,760 = *Total hours per year.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 16.4-2.*

Table 16.4-1: [Evaporator Fan Controls] Deemed Variables for Energy and Demand Savings Calculations[665]

Variable	Deemed Values
kW_{evap}	0.123 kW
kW_{circ}	0.035 kW
DC_{comp}	50%
DC_{evap}	Cooler: 100% Freezer: 94.4%
BF	Low Temp: 1.5 Medium Temp: 1.3 High Temp: 1.2

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[665] The Maine Technical Reference Manual was utilized to determine all assumed values.
Efficiency Maine, Commercial/Industrial and Multifamily Technical Reference Manual 2020.1, July 1, 2019.

Table 16.4-2: [Evaporator Fan Controls] Demand Factors

Factor Type	Demand Factor
NCP	1.000
CP	0.981
4CP	0.974

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Electric Power Research Institute (EPRI) average weekday and average weekend refrigeration end use load shape values. The EPRI load data provided representative hourly load shapes for the peak-season months of April through September and off-peak-season months of October through March. These shapes were used to create the 8,760 hourly load shape, which can be found in Section 22.2.

16.4.2.2 Deemed Energy and Demand Savings Tables

There are no deemed savings tables for this measure.

16.4.2.3 Additional Calculators and Tools

There are no tools for this measure.

16.4.2.4 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 16 years for evaporator fan controls, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocWlkIn-WEvapFMtrCtrl.[666]

16.4.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- kW_{evap}: Page 78, footnote 366 states this value is determined “based on a weighted average of 80% shaded-pole motors at 132 watts and 20% PSC motors at 88 watts. This weighted average is based on discussions with refrigeration contractors and is considered conservative (market penetration estimated at approximately 10%).”
- kW_{circ}: Page 78, footnote 367 states this value is the “wattage of fan used by Freeaire and Cooltrol”
- DC_{comp}: Page 78, footnote 368 states the reasoning for this value as follows: “A 50% duty cycle is assumed based on examination of duty cycle assumptions from Richard Traverse (35%-65%), Control (35%-65%), Natural Cool (70%), Pacific Gas and Electric (58%). Also, manufacturers typically size equipment with a built-in 67% duty factor and contractors typically add another 25% safety factor, which results in a 50% overall duty factor.”
- DC_{evap}: 94.4% is equivalent to 8,273 / 8,760 annual operating hours. The assumption of 8,273 is the annual total of the assumption that “a[n] evaporator fan in a cooler runs all the time, but a freezer only runs 8273 hours per year due to defrost cycles (4 20-min defrost cycles per day),” an explanation given on page 82, footnote 401.
- BF: Page 183, Table 45, footnote A summarizes the Bonus Factor (-1 + 1/COP) as “assum[ing] 2.0 COP for low temp, 3.5 COP for medium temp, and 5.4 COP for high temp, based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F, 20°F, and 45°F, respectively, and a condensing temperature of 90°F.”

[666] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

- Number of evaporator fans controlled
- Refrigeration type
- Refrigeration temperature

16.5 NIGHT COVERS FOR OPEN REFRIGERATED DISPLAY CASES

16.5.1 Measure Description

This measure involves the installation of Night Covers on open vertical (multi-deck) and horizontal (or coffin-type) low-temperature and medium-temperature display. Night Covers reduce the cooling load borne by the refrigerated display case's compressor due to a combination of factors: 1) a decrease in convective heat transfer from reduced air infiltration, 2) increased insulation reducing conductive heat transfer, and 3) decreased radiation through the blocking of radiated heat.

16.5.1.1 Eligibility Criteria

The existing low or medium temperature open display case must not have night covers.

16.5.1.2 Baseline Condition

Baseline efficiency case is an open low-temperature or medium-temperature refrigerated display case (vertical or horizontal) that is not equipped with a night cover.

16.5.1.3 High-Efficiency Condition

Eligible high efficiency equipment is considered any suitable low-emissivity material sold as a Night Cover. It is recommended that these film-type covers have small, perforated holes to decrease the build-up of moisture. The cover must be applied for a period of at least 6 hours[667] per day (i.e., continuous overnight use).

16.5.2 Energy and Demand Savings Methodology

16.5.2.1 Savings Algorithms and Input Variables

Energy Savings

This section outlines the assumptions and approach used to estimate demand and energy savings attributable to installation of Night Covers on open low and medium temperature, vertical and horizontal, refrigerated display cases. Heat transfer components of the display case include infiltration (convection), transmission (conduction), and radiation.

$$\Delta \boldsymbol{kWh} = \boldsymbol{L} \times \boldsymbol{kWh}_{\boldsymbol{baseline}} \times \mathbf{9}\%$$

Equation 16.5-1

Where:

L = *Horizontal linear feet of the low- or medium-temperature refrigerated display case.*

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[667] Faramarzi, R and Woodworth-Szepler, Michele L. "Modified Effects of Low-E Shields on the Performance and Power Use of a Refrigerated Display Case", Southern California Edison Refrigeration Technology and Test Center, Energy Efficiency Division, August 8, 1997. https://www.econofrost.com/acrobat/sce_report_long.pdf.

$kWh_{baseline}$ = *Average annual unit energy consumption in terms of kWh/horizontal linear foot/year.*

9% = *The reduction in compressor electricity consumption due to the night cover decreasing of convection, conduction, and radiation heat transfer.*[668]

Demand Savings

There are no NCP, CP or 4CP demand savings because this measure is implemented outside of the CP and 4CP demand periods.

Load Shapes

This section is not applicable.

16.5.2.2 Deemed Energy Savings Tables

The per-linear-foot energy savings of Night Covers are deemed as 9% (the compressor load reduction from Night Covers defined in the previous section) of the "base-case scenario" efficiency level's average annual unit energy consumption per horizontal linear foot per display case type from the U.S. Department of Energy's (DOE) Technical Support Document for Commercial Refrigeration Equipment. [669] Vertical and horizontal open equipment types were selected for inclusion given the nature of this measure.

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[668] Ibid. "Table 1 - Effects of utilizing Heat Reflecting Shields on Refrigeration System Parameters Non-24-hour Supermarket with Shields and Holiday Case versus Base Case"

[669] In 2013, the U.S. DOE conducted an extensive life-cycle cost (LCC) analysis of the commercial refrigeration equipment classes listed in the current federal standard 10 CFR 431.66 to determine average annual unit energy consumption per equipment class. In this analysis, 10,000 separate simulations yielded probability distributions for various parameters associated with each equipment class, among them: the efficiency level in kWh/yr. These efficiency levels were then subject to roll-up calculations to determine market shares of each efficiency level, which were then utilized to compute the average consumption for said efficiency level listed in **Error! Reference source not found.**.
Energy Conservation Standards for Commercial Refrigeration Equipment: Technical Support Document, U.S. Department of Energy, September 2013.
https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/cre2_nopr_tsd_2013_08_28.pdf.
LCC Summary Statistics: Section 8B2
Average Annual Unit Energy Consumption per Linear Foot by Efficiency Level: Table 10.2.4

Table 16.5-1: [Night Covers] Deemed Energy Savings

Temperature[670]	Condensing Unit Configuration	Equipment Family	Average Annual Energy Consumption per Horizontal Linear Foot	ΔkWh
Medium (≥32±2 °F)	Remote Condensing	Vertical Open	1,453	130.77
		Horizontal Open	439	39.51
	Self-Contained	Vertical Open	2,800	252.00
		Horizontal Open	1,350	121.50
Low (<32±2 °F)	Remote Condensing	Vertical Open	3,292	296.28
		Horizontal Open	1,007	90.63
	Self-Contained	Horizontal Open	2,748	247.32

16.5.2.3 Deemed Demand Savings Tables

There are no deemed demand savings tables for this measure.

16.5.2.4 Additional Calculators and Tools

This section is not applicable.

16.5.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 5 years for night covers, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-DispCvrs.[671]

16.5.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Display case equipment type
    - Condensing unit configuration (Remote Condensing or Self-Contained)
    - Equipment Family (Vertical or Horizontal)
    - Operating Temperature (Low or Medium as defined in Table 16.5-1)

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[670] Temperature ranges per commercial refrigeration equipment type are detailed in the current federal standard 10 CFR 431.66. https://www.ecfr.gov/cgi-bin/text-idx?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431_166&rgn=div8.

[671] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

- Horizontal linear feet of night covers

16.6 ENERGY STAR® SOLID AND GLASS DOOR REACH-IN COOLERS

16.6.1 Measure Description

This document presents the deemed savings methodology for the installation of ENERGY STAR certified solid and glass door reach-in refrigerators and freezers, which are significantly more efficient than units that are not certified ENERGY STAR units. The high-efficiency criteria, developed by ENERGY STAR, relate the volume of the appliance (in cubic feet) to its daily energy consumption.

16.6.1.1 Eligibility Criteria

Solid or glass door reach-in vertical refrigerators and freezers must meet ENERGY STAR minimum efficiency requirement; see Table 16.6-2.

The following products are excluded from the ENERGY STAR eligibility criteria:

- Residential refrigerators and freezers
- Chef base or griddle stands, prep tables, service over counter equipment, horizontal open equipment, vertical open equipment, semi-vertical open equipment, remote condensing equipment, convertible temperature equipment, and ice cream freezers

16.6.1.2 Baseline Condition

The baseline efficiency case is a regular vertical refrigerator or freezer with anti-sweat heaters on doors that meets federal standards. The baseline daily kWh for solid door and glass door commercial reach-in refrigerators and freezers are shown in Table 16.6-1.

Table 16.6-1: [Solid and Glass Door Reach-Ins] Baseline Energy Consumption[672],[673]

Baseline Standards	Refrigerator Daily Consumption (kWh)	Freezer Daily Consumption (kWh)
Solid Door	$0.10 \times V + 2.04$	$0.40 \times V + 1.38$
Glass Door	$0.12 \times V + 3.34$	$0.75 \times V + 4.10$

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[672] https://www.ecfr.gov/cgi-bin/text-idx?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431_166&rgn=div8.

[673] V = Interior volume [ft^3] of a refrigerator or freezer (as defined in the Association of Home Appliance Manufacturers Standard HRF1-1979).

16.6.1.3 High-Efficiency Condition

Eligible high efficiency equipment for solid or glass door reach-in refrigerators and freezers must meet ENERGY STAR minimum efficiency requirements, as shown in Table 16.6-2.

Table 16.6-2: [Solid and Glass Door Reach-Ins] Efficient Energy Consumption[674]

Door Type	Product Volume (ft^3)	Refrigerator Daily Consumption (kWh)	Freezer Daily Consumption (kWh)
Vertical solid door	$0 < V < 15$	0.022V + 0.97	0.210V + 0.900
	$15 \leq V < 30$	0.066V + 0.31	0.400V – 2.249
	$30 \leq V < 50$	0.040V + 1.09	0.163V + 2.703
	$V \geq 50$	0.024V + 1.89	0.158V + 4.455
Vertical glass door	$0 < V < 15$	0.095V + 0.445	0.232V + 2.360
	$15 \leq V < 30$	0.050V + 1.120	
	$30 \leq V < 50$	0.076V + 0.340	
	$V \geq 50$	0.105V + 1.111	

16.6.2 Energy and Demand Savings Methodology

16.6.2.1 Savings Algorithms and Input Variables

Energy Savings

The energy and demand savings of Solid and Glass Door Reach-In Refrigerators and Freezers are calculated using values in Table 16.6-1 and Table 16.6-2, based on the volume of the units.

The energy savings calculations are found below.

$$\boldsymbol{Energy[kWh] = (kWh_{base} - kWh_{ee}) \times 365}$$

Equation 16.6-1

Where:

kWh_{base} = *Baseline maximum daily energy consumption in kWh, based on volume (V) of the unit; see Table 16.6-1.*

kWh_{ee} = *Maximum daily energy consumption in kWh of an efficient door retrofit, based on volume (V) of the unit; see Table 16.6-2.*

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[674] ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers Partner Commitments Version 4.0, U.S. Environmental Protection Agency. https://www.energystar.gov/sites/default/files/Commercial%20Refrigerators%20and%20Freezers%20V4%20Spec%20Final%20Version_0.pdf.

V = *Chilled or frozen compartment volume [ft^3] (as defined in the Association of Home Appliance Manufacturers Standard HFR-1-1979).*

365 = *Total days per year.*

Demand Savings

The demand savings calculations are found below.

$$\boldsymbol{Peak\ Demand[kW] = \frac{\Delta kWh}{8,760} \times DF}$$

Equation 16.6-2

Where:

8,760 = *Total hours per year.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 16.6-3.*

Table 16.6-3: [Solid and Glass Door Reach-Ins] Demand Factors

Factor Type	Demand Factor
NCP	1.000
CP	0.981
4CP	0.974

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Electric Power Research Institute (EPRI) average weekday and average weekend refrigeration end use load shape values. The EPRI load data provided representative hourly load shapes for the peak-season months of April through September and off-peak-season months of October through March. These shapes were used to create the 8,760 hourly load shape, which can be found in Section 22.2.

16.6.2.2 Deemed Energy Savings Tables

Calculated for volume ranges specified in Table 16.6-1 and Table 16.6-2, yielding the following energy savings for each unit type:

Table 16.6-4: [Solid and Glass Door Reach-Ins] Demand Factors

Refrigerator or Freezer	Door type	Product volume range (cubic feet)	Average product volume[675]	Energy Savings (kWh)
Refrigerator	Vertical Solid Door	0 < V < 15	8.54	16
		15 ≤ V < 30	21.00	892
		30 ≤ V < 50	41.53	1,256
		V ≥ 50	67.19	1,919
	Vertical Glass Door	0 < V < 15	8.84	1,137
		15 ≤ V < 30	21.30	1,355
		30 ≤ V < 50	42.76	1,782
		V ≥ 50	68.93	2,002
Freezer	Vertical Solid Door	0 < V < 15	7.76	713
		15 ≤ V < 30	19.99	1,726
		30 ≤ V < 50	43.13	3,301
		V ≥ 50	66.86	5,177
	Vertical Glass Door	0 < V < 15	5.98	1,766
		15 ≤ V < 30	19.49	4,321
		30 ≤ V < 50	42.29	8,630
		V ≥ 50	65.89	13,093

16.6.2.3 Deemed Demand Savings Tables

Calculated for volume ranges specified in Table 16.6-1 and Table 16.6-2, yielding the following demand savings for each unit type:

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[675] Average volume ranges for Refrigerator and Freezer Door Types obtained from ENERGY STAR qualified product listing. https://www.energystar.gov/productfinder/product/certified-commercial-refrigerators-and-freezers/results.

Table 16.6-5: [Solid and Glass Door Reach-Ins] Demand Factors

Refrigerator or Freezer	Door type	Product volume range (cubic feet)	Average product volume	NCP Demand Savings	CP Demand Savings	4CP Demand Savings
Refrigerator	Vertical Solid Door	0 < V < 15	8.54	0.002	0.002	0.002
		15 ≤ V < 30	21.00	0.102	0.100	0.099
		30 ≤ V < 50	41.53	0.143	0.141	0.140
		V ≥ 50	67.19	0.219	0.215	0.213
	Vertical Glass Door	0 < V < 15	8.84	0.130	0.127	0.126
		15 ≤ V < 30	21.30	0.155	0.152	0.151
		30 ≤ V < 50	42.76	0.203	0.200	0.198
		V ≥ 50	68.93	0.229	0.224	0.223
Freezer	Vertical Solid Door	0 < V < 15	7.76	0.081	0.080	0.079
		15 ≤ V < 30	19.99	0.197	0.193	0.192
		30 ≤ V < 50	43.13	0.377	0.370	0.367
		V ≥ 50	66.86	0.591	0.580	0.576
	Vertical Glass Door	0 < V < 15	5.98	0.202	0.198	0.196
		15 ≤ V < 30	19.49	0.493	0.484	0.480
		30 ≤ V < 50	42.29	0.985	0.966	0.960
		V ≥ 50	65.89	1.495	1.466	1.456

16.6.2.4 Additional Calculators and Tools

This section is not applicable.

16.6.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years for solid and glass door reach-in coolers, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-FixtDoors.[676]

16.6.3 Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- Baseline unit volume
- Baseline unit door type (solid, glass)

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[676] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

- Baseline unit temperature (refrigerator, freezer)
- Post-retrofit unit volume
- Post-retrofit unit door type (solid, glass)
- Post-retrofit unit temperature (refrigerator, freezer)

16.7 STRIP CURTAINS FOR WALK-IN REFRIGERATED STORAGE

16.7.1 Measure Description

This measure refers to the installation of infiltration barriers (strip curtains or plastic swinging doors) on walk-in coolers or freezers. These units impede heat transfer from adjacent warm and humid spaces into walk-ins when there is an opening or a door is opened, reducing the cooling load. This measure results in a reduced compressor run-time and energy consumption. The measure assumes varying durations for time the walk-in door is open based on facility type and that the strip curtains cover the entire doorframe.

16.7.1.1 Eligibility Criteria

Strip curtains or plastic swinging doors installed on walk-in coolers or freezers.

16.7.1.2 Baseline Condition

The baseline efficiency case is a refrigerated walk-in space with nothing to impede air flow from the refrigerated space to adjacent warm and humid space when the door is opened.

16.7.1.3 High-Efficiency Condition

Eligible high efficiency equipment is a polyethylene strip curtain added to the walk-in cooler or freezer that is at least 0.06 inches thick, or equivalent. Low temperature strip curtains must be used on low temperature applications (e.g., freezers). The strip curtain must cover the entire area of opening and may not leave gaps between strips or along the doorframe.

16.7.2 Energy and Demand Savings Methodology

16.7.2.1 Savings Algorithms and Input Variables

Energy and Demand Savings

The algorithms and assumptions detailed in this section are based on the Regional Technical Forum's methodology[677], which utilizes calculations that determine refrigeration load due to infiltration by air exchange from ASHRAE's Refrigeration Handbook.

Saturation pressure over liquid water, for both the temperature of the refrigerated space which will be treated with strip curtains and the adjacent space, is calculated as follows:

$$\ln\left(P_{ws,Adj}\right) = \frac{C_1}{{}^{\circ}R_{Adj}} + C_2 + (C_3 * {}^{\circ}R_{Adj}) + (C_4 * {}^{\circ}R_{Adj}^2) + (C_5 * {}^{\circ}R_{Adj}^3) + (C_6 * {}^{\circ}R_{Adj}^4) + (C_7 * \ln\,({}^{\circ}R_{Adj}))$$

Equation 16.7-1

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[677] Regional Technical Forum Strip Curtains UES Measure Workbook (Commercial Grocery Strip Curtain v2.1.xlsx). September 10th, 2019. https://rtf.nwcouncil.org/measure/strip-curtains.

$$\ln\left(P_{ws,Refrig}\right) = \frac{C_1}{{}^{\circ}R_{Refrig}} + C_2 + \left(C_3 * {}^{\circ}R_{Refrig}\right) + \left(C_4 * {}^{\circ}R_{Refrig}^2\right) + \left(C_5 * {}^{\circ}R_{Refrig}^3\right) + \left(C_6 * {}^{\circ}R_{Refrig}^4\right) + (C_7 * \ln\left({}^{\circ}R_{Refrig}\right))$$

Equation 16.7-2

Where:

$P_{ws,Adj}$ = *Saturation pressure over liquid water for the adjacent space.*

$P_{ws,Refrig}$ = *Saturation pressure over liquid water for the refrigerated space.*

C_1 = *-1.0214165E+04.*

C_2 = *-4.8932428E+00.*

C_3 = *-5.3765794E-03.*

C_4 = *1.9202377E-07.*

C_5 = *3.5575832E-10.*

C_6 = *-9.0344688E-14.*

C_7 = *4.1635019E+00.*

C_8 = *-1.0440397E+04.*

C_9 = *-1.1294650E+01.*

C_{10} = *-2.7022355E-02.*

C_{11} = *1.2890360E-05.*

C_{12} = *-2.4780681E-09.*

C_{13} = *6.5459673E+00.*

${}^{\circ}R_{Adj}$ = *Adjacent absolute temperature,* $t_{DB,Adj} + 459.67$*; see Table 16.7-1.*

${}^{\circ}R_{Refrig}$ = *Refrigeration box absolute temperature,* $t_{DB,Refrig} + 459.67$*; see Table 16.7-1.*

Saturation pressure over liquid water is then utilized to calculate the humidity ratio of both the refrigerated and adjacent space:

$$W_{Adj} = 0.62198 * \frac{Rh_{Adj} * P_{ws,Adj}}{14.696 - \left(Rh_{Adj} * P_{ws,Adj}\right)}$$

Equation 16.7-3

$$W_{Refrig} = 0.62198 * \frac{Rh_{Refrig} * P_{ws,Refrig}}{14.696 - \left(Rh_{Refrig} * P_{ws,Refrig}\right)}$$

Equation 16.7-4

Where:

W_{Adj} = *Humidity ratio of the adjacent space.*

W_{Refrig} = *Humidity ratio of the refrigerated space.*

Rh_{Adj} = *Relative humidity of the adjacent space; see Table 16.7-1.*

Rh_{Refrig} = *Relative humidity of the refrigerated space; see Table 16.7-1.*

The humidity ratio is utilized to compute the air enthalpies for the adjacent and refrigerated space:

$$h_{Adj} = 0.24 * t_{DB,Adj} + \left(W_{Adj} * \left(1061 + \left(0.444 * t_{DB,Adj}\right)\right)\right)$$

Equation 16.7-5

$$h_{Refrig} = 0.24 * t_{DB,Refrig} + \left(W_{Refrig} * \left(1061 + \left(0.444 * t_{DB,Refrig}\right)\right)\right)$$

Equation 16.7-6

Where:

h_{Adj} = *Air enthalpy of the adjacent space.*

h_{Refrig} = *Air enthalpy of the refrigerated space.*

$t_{DB,Adj}$ = *Dry bulb temperature of the adjacent space; see Table 16.7-1.*

$t_{DB,Refrig}$ = *Dry bulb temperature of the refrigerated space; see Table 16.7-1.*

This pair of air enthalpies is then utilized alongside the density factor and the adjacent and refrigerated spaces' air temperature densities and specific volumes to compute the refrigeration load for the fully established flow:

$$v_{Adj} = 0.025210942 * {}^{\circ}R_{Adj} * \left(1 + \left(1.6078 * W_{Adj}\right)\right)$$

Equation 16.7-7

$$v_{Refrig} = 0.025210942 * {}^{\circ}R_{Refrig} * \left(1 + \left(1.6078 * W_{Refrig}\right)\right)$$

Equation 16.7-8

$$r_{Adj} = \frac{1}{v_{Adj}}$$

Equation 16.7-9

$$r_{Refrig} = \frac{1}{v_{Refrig}}$$

Equation 16.7-10

$$F_m = \frac{2}{1 + \frac{r_{Refrig}}{r_{Adj}}^{\frac{1}{3}}}^{\frac{3}{2}}$$

Equation 16.7-11

$$q = 795.6 * Height * Width * \left(h_{Adj} - h_{Refrig}\right) * r_{Refrig} * \left(1 - \frac{r_{Adj}}{r_{Refrig}}\right)^{\frac{1}{2}} * (32.174 * Height)^{\frac{1}{2}} * F_m$$

Equation 16.7-12

v_{Adj} = *Specific volume of the adjacent space.*

v_{Refrig} = *Specific volume of the refrigerated space.*

r_{Adj} = *Air temperature density of the adjacent space.*

r_{Refrig} = *Air temperature density of the refrigerated space.*

F_m = *Density factor.*

q = *Refrigeration load for fully established flow.*

$Height$ = *Doorway height; see Table 16.7-1.*

$Width$ = *Doorway width; see Table 16.7-1.*

The infiltration between the adjacent and refrigerated space before and after the installation of the strip curtains is a product of the refrigeration load between the two spaces, the time the doorway is assumed to be open per day, the assumed doorway flow factor, and the assumed effectiveness against infiltration post-retrofit:

$$Q_{baseline} = q * \frac{m}{60 * 24} * D_F * (1 - E_{baseline})$$

Equation 16.7-13

$$Q_{retrofit} = q * \frac{m}{60 * 24} * D_F * (1 - E_{retrofit})$$

Equation 16.7-14

Where:

$Q_{baseline}$ = *Baseline total infiltration load.*

$Q_{retrofit}$ = *Total infiltration load post-retrofit.*

m = *Time the door is open per day; see Table 16.7-1.*

D_F = *Doorway flow factor; see Table 16.7-1.*

$E_{baseline}$ = *Baseline assumed effectiveness against infiltration, 0.*

$E_{retrofit}$ = *Assumed effectiveness against infiltration post-retrofit; see Table 16.7-1.*

The demand and energy consumption of the compressor associated with each infiltration case are calculated as follows:

$$kW_{baseline} = \frac{Q_{baseline}}{EER * 1000}$$

Equation 16.7-15

$$kW_{retrofit} = \frac{Q_{retrofit}}{EER * 1000}$$

Equation 16.7-16

$$kWh_{baseline} = kW_{baseline} * EFLH$$

Equation 16.7-17

$$kWh_{retrofit} = kW_{retrofit} * EFLH$$

Equation 16.7-18

Where:

$kW_{baseline}$ = *Baseline demand consumption of the compressor.*

$kW_{retrofit}$ = *Demand consumption of the compressor post-retrofit.*

$kWh_{baseline}$ = *Baseline energy consumption of the compressor.*

$kWh_{retrofit}$ = *Energy consumption of the compressor post-retrofit.*

EER = *EER per facility type (see Table 16.7-1), which are averaged or weighted across suction group types; see Table 16.7-2.*

$EFLH$ = *Assumed full-load hours per facility type; see Table 16.7-1.*

The difference between the baseline and retrofit demand/energy calculations yields whole-door energy savings, which are divided by the area of the doorway to yield per-square foot savings:

$$\Delta kW = kW_{baseline} - kW_{retrofit}$$

Equation 16.7-19

$$\Delta kWh = kWh_{baseline} - kWh_{retrofit}$$

Equation 16.7-20

$$kW_{Savings} = \frac{\Delta kWh \times DF}{Height * Width}$$

Equation 16.7-21

$$kWh_{Savings} = \frac{\Delta kWh}{Height * Width}$$

Equation 16.7-22

Where:

ΔkW = *Whole-door demand savings*

ΔkWh = *Whole-door energy savings*

$kW_{Savings}$ = *Per-square foot demand savings*

$kWh_{Savings}$ = *Per-square foot energy savings*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see **Error! Reference*** *source not found.*.

Several assumptions for independent variables are utilized in the prior equations; these are tabulated in Table 16.7-1. EER variables are calculated as either the simple or weighted average of representative EERs for refrigeration suction groups that correspond to medium temperature (cooler) or low temperature (freezer) multiplex or standalone units; these are detailed in Table 16.7-2:

Table 16.7-1: [Strip Curtains] Assumed Independent Variables[678]

Variable	Notation	Restaurant		Convenience Store		Grocery		Refrigerated Warehouse	
		Cooler Main Door	Freezer Main Door	Cooler Main Door	Freezer Main Door	Cooler Main Door	Freezer Main Door	Cooler Main Door	Freezer Main Door
Adjacent temperature	t_{DB}	70	67	68	64	71	67	59	n/a
Refrigeration box temperature		39	8	39	5	37	5	28	n/a
Relative Humidity of Adjacent Surroundings	Rh	0.55	0.55	0.55	0.55	0.55	0.55	0.3	n/a
Relative Humidity of Refrigeration Box		0.65	0.4	0.4	0.6	0.5	0.45	0.86	n/a
Height	$Height$	7	7	7	7	7	7	12	n/a
Width	$Weight$	3	3	3	3	3	3	10	n/a
Doorway flow factor	D_F	0.51	0.51	0.51	0.51	0.625	0.625	0.8	n/a
Effectiveness against infiltration – Post-retrofit	$E_{retrofit}$	0.8	0.81	0.79	0.83	0.88	0.88	0.89	n/a
Time door open per day	m	45	38	38	9	132	102	494	n/a
Full-load-hours (FLH) of operation	FLH	5,509	5,509	6,887	6,887	6,482	6,482	2,525	n/a
EER[679]	EER	9.8	4.0	9.8	4.0	11	4.1	9.8	n/a

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[678] Regional Technical Forum Strip Curtains UES Measure Workbook - Assumptions (Commercial Grocery Strip Curtain v2.1.xlsx). September 10th, 2019. https://rtf.nwcouncil.org/measure/strip-curtains.

[679] EER is not an independent variable but is rather dependent on **Error! Reference source not found.**. It is appended here to specify which average corresponds to which facility/refrigeration type.

Table 16.7-2: [Strip Curtains] Default EER by System Configuration[680]

System Configurations	Representative Suction Group	Annual Average EER Value (Btu/hr-W)	Average EER of System Configuration (Btu/hr-W)	Straight Average EER of Temperature (Btu/hr-W)	Grocery Store Weighted Average EER for Temperature (Btu/hr-W)
Medium Temperature Multiplex	Suction Group 2075	12	11	9.8	11
	Suction Group 2014	12			
	Suction Group 2185	12			
	Suction Group 2668	9.2			
Medium Temperature Standalone	Suction Group 2754	7.8	8.4		
	Suction Group 894	8.7			
	Suction Group 512	8.8			
	Suction Group 2043	8.3			
Low Temperature Multiplex	Suction Group 1509	3.7	4.2	4.0	4.1
	Suction Group 898	4.1			
	Suction Group 2152	4.7			
	Suction Group 1753	4.4			
Low Temperature Standalone	Suction Group 996	3.3	3.7		
	Suction Group 2518	3.4			
	Suction Group 1950	4.6			
	Suction Group 2548	3.7			

Table 16.7-3: [Strip Curtains] Energy Consumption and Demand for Coolers and Freezers

Variable	Notation	Restaurant		Convenience Store		Grocery		Refrigerated Warehouse	
		Cooler Main Door	Freezer Main Door	Cooler Main Door	Freezer Main Door	Cooler Main Door	Freezer Main Door	Cooler Main Door	Freezer Main Door
Compressor power (kW)	$kW_{baseline}$	0.11	0.54	0.09	0.12	0.44	1.82	8.19	n/a
	$kW_{retrofit}$	0.02	0.10	0.02	0.02	0.05	0.22	0.90	n/a

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[680] Regional Technical Forum Strip Curtains UES Measure Workbook - Assumptions (Commercial Grocery Strip Curtain v2.1.xlsx). September 10th, 2019. https://rtf.nwcouncil.org/measure/strip-curtains.

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Electric Power Research Institute (EPRI) average weekday and average weekend refrigeration end use load shape values. The EPRI load data provided representative hourly load shapes for the peak-season months of April through September and off-peak-season months of October through March. These shapes were used to create the 8,760 hourly load shape, which can be found in Section 22.2.

The demand coefficients applied to the demand savings derived from the M&V study are as follows:

Table 16.7-4: [Strip Curtains] Demand Factors

Factor Type	Demand Factor
NCP	1.000
CP	0.981
4CP	0.974

16.7.2.2 Deemed Energy and Demand Savings Tables

The energy and demand savings for strip curtains are shown below in Table 16.7-5.

Table 16.7-5: [Strip Curtains] Deemed Energy and Demand Savings

Savings		Restaurant		Convenience Store		Grocery		Refrigerated Warehouse	
		Cooler Main Door	Freezer Main Door	Cooler Main Door	Freezer Main Door	Cooler Main Door	Freezer Main Door	Cooler Main Door	Freezer Main Door
$kWh_{Savings}$		22.50	114.01	23.58	33.15	119.88	494.32	153.36	n/a
$kW_{Savings}$	NCP	0.0041	0.0207	0.0034	0.0048	0.0185	0.0763	0.0607	n/a
	CP	0.0040	0.0203	0.0034	0.0047	0.0181	0.0748	0.0596	n/a
	4CP	0.0040	0.0202	0.0033	0.0047	0.0180	0.0743	0.0592	n/a

16.7.2.3 Additional Calculators and Tools

This section is not applicable.

16.7.2.4 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 4 years for strip curtains, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocWlkIn-StripCrtn.[681]

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[681] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

16.7.3 Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- Number of treated doors
- Unit temperature (refrigerator or freezer)

16.8 ZERO-ENERGY DOORS FOR REFRIGERATED CASES

16.8.1 Measure Description

This document presents the deemed savings methodology for the installation of zero-energy doors for refrigerated cases. These new zero-energy door designs eliminate the need for anti-sweat heaters to prevent the formation of condensation on the glass surface by incorporating heat reflective coatings on the glass, gas inserted between the panes, non-metallic spacers to separate glass panes, and/or non-metallic frames.

16.8.1.1 Eligibility Criteria

This measure cannot be used in conjunction with anti-sweat heat (ASH) controls. It is not eligible to be installed on cases above 0°F.

16.8.1.2 Baseline Condition

Baseline efficiency case is a standard vertical reach-in refrigerated case with anti-sweat heaters on the glass surface of the doors.

16.8.1.3 High-Efficiency Condition

Eligible high efficiency equipment is the installation of special doors that eliminate the need for anti-sweat heaters, for low-temperature cases only (below 0°F). Doors must have either heat reflective treated glass, be gas-filled, or both.

16.8.2 Energy and Demand Savings Methodology

16.8.2.1 Savings Algorithms and Input Variables

Energy Savings

The energy savings from the installation of zero-energy doors are a result of eliminating the heater (kWh_{ASH}) and the reduction in load on the refrigeration (kWh_{refrig}). These savings are calculated using the following procedures.

The baseline assumes door heaters are running on an 8,760-hour operation. In the post-retrofit case, it is assumed that the door heaters will all be off (duty cycle of 0%).

The instantaneous door heater power (kW_{ASH}) as a resistive load remains constant per horizontal linear foot of door heater at an assumed 2.5 linear horizontal feet of door:

Medium temperature:

kW_{ASH} = 0.109 per door[682]

Low temperature:

kW_{ASH} = 0.191 per door[683]

Door heater energy consumption for each hour of the year is a product of power and run-time:

$$\boldsymbol{kWh_{ASH-Hourly} = kW_{ASH} \times Door\ Heater\ ON\% \ \times 1\ hour}$$

Equation 16.8-1

$$\boldsymbol{kWh_{ASH} = \sum kWh_{ASH-Hourly}}$$

Equation 16.8-2

Where:

$kWh_{ASH\text{-}Hourly}$ = *Hourly energy consumption of door heater.*

To calculate energy savings from the reduced refrigeration load using average system efficiency and assuming 35% of the anti-sweat heat becomes a load on the refrigeration system,[684] the cooling load contribution from door heaters can be determined by:

$$\boldsymbol{Q_{ASH}(ton - hrs) = 0.35 \times kW_{ASH} \times \frac{3,412 \frac{Btu}{hr}}{12,000 \frac{Btu}{ton}} \times Door\ Heater\ ON\%}$$

Equation 16.8-3

Where:

Q_{ASH} = *Hourly cooling load contribution by door heaters.*

$kWh_{ASH\text{-}Hourly}$ = *Hourly energy consumption of door heater.*

0.35 = *Portion of anti-sweat heat that becomes cooling load.*

3,412 = *Constant to convert kWh to Btu.*

12,000 = *Constant to convert tons to Btu/hr.*

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[682] Here, "medium temperature" is equivalent to the categorization "coolers."
Pennsylvania TRM, "3.5.6 Controls: Anti-Sweat Heater Controls." page 383, June 2016. http://www.puc.pa.gov/pcdocs/1350348.docx.

[683] Ibid. Here, "low temperature" is equivalent to the categorization "freezers."

[684] A Study of Energy Efficient Solutions for Anti-Sweat Heaters. Southern California Edison RTTC. December 1999.

The annual energy used by the compressor to remove heat imposed by the door heaters for each hour is determined by calculating the hourly energy used based on calculated cooling load and EER, Equation 16.8-4 then summing the hourly energy for the entire year, Equation 16.8-5.

$$kWh_{refrig-hourly} = Q_{ASH} \times \frac{12}{EER}$$

Equation 16.8-4

$$kWh_{refrig} = \sum kWh_{refrig-Hourly}$$

Equation 16.8-5

Where:

EER_{MT} = *Section 16.1.2.1.*

EER_{LT} = *Section 16.1.2.1.*

Total annual energy consumption (direct door heaters and indirect refrigeration) is the sum of all hourly reading values:

$$kWh_{total} = kWh_{refrig} + kWh_{ASH}$$

Equation 16.8-6

Total energy savings is a result of the baseline and post-retrofit case:

$$Annual\ Energy\ Savings\ [kWh] = kWh_{total-baseline} + kWh_{total-post}$$

Equation 16.8-7

Demand Savings

While there might be instantaneous demand savings because of the cycling of the door heaters, peak demand savings will only be attributable to the reduced refrigeration load. NCP, CP, and 4CP peak demand savings are calculated by using Equation 16.8-8 and the appropriate demand factors in Table 16.8-1.

$$Peak\ Demand\ Savings\ [kW] = \frac{kWh_{refrig-baseline} - kWh_{refrig-post}}{8760} \times DF$$

Equation 16.8-8

Where:

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 16.8-1.*

Table 16.8-1: [Zero Energy Doors] Demand Factors

Factor Type	Demand Factor
NCP	1.000
CP	0.981
4CP	0.974

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Electric Power Research Institute (EPRI) average weekday and average weekend refrigeration end use load shape values. The EPRI load data provided representative hourly load shapes for the peak-season months of April through September and off-peak-season months of October through March. These shapes were used to create the 8,760 hourly load shape, which can be found in Section 22.2.

16.8.2.1 Deemed Energy and Demand Savings Tables

Table 16.8-2: [Zero Energy Doors] Deemed Energy and Demand Savings by Refrigeration Temperature in kWh per Linear Foot of Display Case[685]

Technology Type	Annual Energy Savings [kWh/door]	NCP Savings [kWh/door]	CP Savings [kWh/door]	4CP Savings [kWh/door]
Medium Temperature Case	1,141	0.130	0.128	0.127
Low Temperature Case	2,095	0.239	0.235	0.233

16.8.2.2 Additional Calculators and Tools

This section is not applicable.

16.8.2.3 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years for zero-energy doors, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-ZeroHtDrs.[686]

16.8.3 Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

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[685] Ibid.

[686] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

- Refrigerator Temperature Range

16.9 DOOR GASKETS FOR WALK-IN AND REACH-IN COOLERS AND FREEZERS

16.9.1 Measure Description

This measure applies to the installation of door gaskets on walk-in coolers and freezers to reduce the refrigeration load associated with the infiltration of non-refrigerated air into the refrigerated space. Additionally, the reduction in moisture entering the refrigerated space also helps prevent frost on the cooling coils. Frost build-up adversely impacts the coil's heat transfer effectiveness, reduces air passage (lowering heat transfer efficiency), and increases energy use during the defrost cycle. Therefore, replacing defective door gaskets reduces compressor run time and improves the overall effectiveness of heat removal from a refrigerated cabinet.

16.9.1.1 Eligibility Criteria

Door gaskets must be installed on walk-in and reach-in coolers and freezers. The most likely applications for this measure are supermarkets, convenience stores, restaurants, and refrigerated warehouses.

16.9.1.2 Baseline Condition

The baseline standard for this measure is a walk-in or reach-in cooler or freezer with worn-out, defective door gaskets. An average baseline gasket efficacy of 90 percent is assumed for this measure.[687]

16.9.1.3 High-Efficiency Condition

The efficiency standard for this measure is a new, better-fitting gasket. Tight fitting gaskets inhibit infiltration of warm, moist air into the cold refrigerated space, reducing the cooling load. A decrease in moisture entering the refrigerated space also prevents frost on cooling coils.

16.9.2 Energy and Demand Savings Methodology

16.9.2.1 Savings Algorithms and Input Variables

Savings for this measure are based on a DEER 2005 analysis performed by Southern California Edison (SCE) and an evaluation of Pacific Gas and Electric (PG&E) direct install refrigeration measures for program year 2006-2008.[688,689] The results from the PG&E evaluation were used as the foundation for establishing the energy savings for the refrigeration gasket measures. The energy savings achievable for new gaskets replacing baseline gaskets were found during this study to be dependent almost entirely on the leakage through the baseline gaskets. Therefore, the energy savings attributable to door gaskets were derived for various scenarios regarding baseline gasket efficacies and are shown in Table 16.9-1 below:

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[687] Gasket efficacy is defined as the ratio of the gasket length that was removed by the installers to the gasket length that was replaced. A 90% gasket efficacy equates to an average of 10% missing, badly damaged, or ineffective gasket by length replaced.

[688] Southern California Edison (SCE). WPSCNRRN0013—Door Gaskets for Glass Doors of Medium and Low Temperature Reach-in Display Cases and Solid Doors of Reach-in Coolers and Freezers. 2007.

[689] Commercial Facilities Contract Group (ComFac), 2006-2008 Direct Impact Evaluation Study ID: PUC0016.01. February 18, 2010. https://energy.mo.gov/sites/energy/files/comfac_evaluation_v1_final_report_02-18-2010.pdf.

Table 16.9-1: [Door Gaskets] Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies (per Linear Foot of Installed Door Gasket)[690]

Refrigerator type	Baseline 0% efficacy (kWh/ft)	Baseline 50% efficacy (kWh/ft)	Baseline 90% efficacy (kWh/ft)	Baseline 100% efficacy (kWh/ft)
Cooler	30	15	3	0
Freezer	228	114	23	0

As the PG&E analysis was performed in California with different climate zones than those in Texas, an analysis was conducted to develop an adjustment factor to associate the savings in Table 16.9-1 to Texas anticipated results. The PG&E study could not be used to determine these effects, as insufficient climate zones were researched. Therefore, the SCE study was utilized as savings in this study were determined for each of the 16 climate zones in California and were similar[691] to those assessed within the PG&E results at 90 percent efficacy. A comparison was completed between the SCE energy savings and the typical meteorological year 3 (TMY3) data[692] to establish a cooling degree day (CDD) correlation across the 16 California climate zones. Figure 16.9-1 provides a summary comparison for coolers and Figure 16.9-2 does the same for freezers. The resulting correlations are strong, with an R^2 of 0.85 for coolers and an R^2 of 0.88 for freezers, respectively.

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[690] Ibid., Table 5-3.

[691] The SCE ex-ante savings as reported in the PG&E report were 10.2 and 21.7 kWh/linear foot for coolers and freezers respectively. Commercial Facilities Contract Group (ComFac), 2006-2008 Direct Impact Evaluation Study ID: PUC0016.01. February 18, 2010. Table 5-3. http://www.calmac.org/publications/comfac_evaluation_v1_final_report_02-18-2010.pdf.
Modeled savings as reported in the SEC report for climate zone 4 were approximately 6 and 15 kWh/linear foot for coolers and freezers respectively.

[692] Available for download on the Texas Efficiency website: http://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

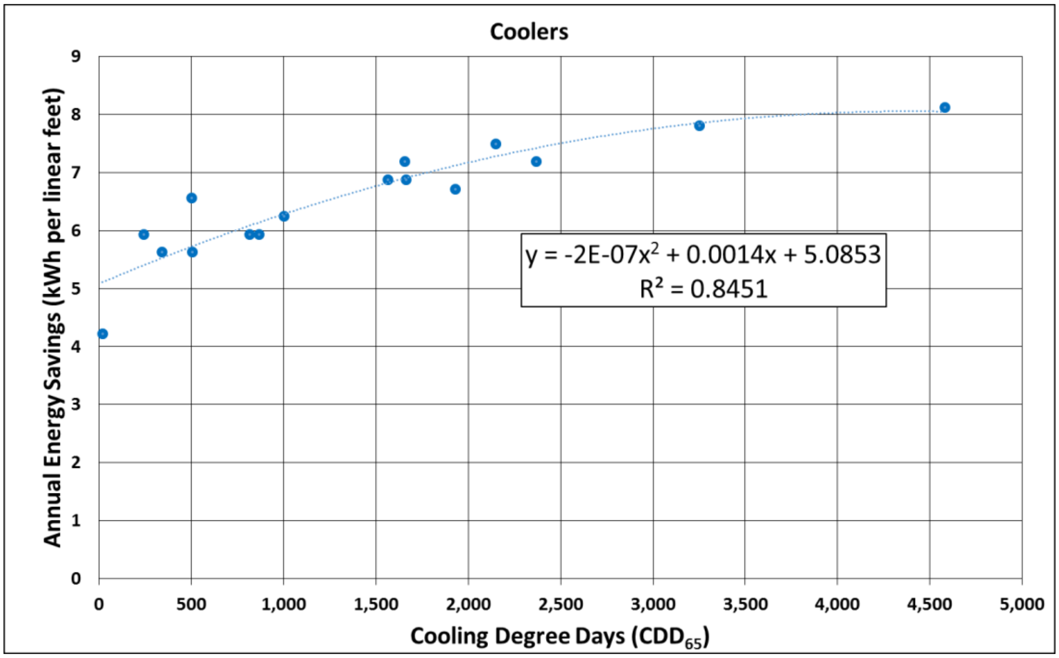

Figure 16.9-1: [Door Gaskets] Comparison of Projected Annual Energy Savings to Cooling Degree Days for All 16 California Climate Zones for Reach-In Display Cases (Coolers)

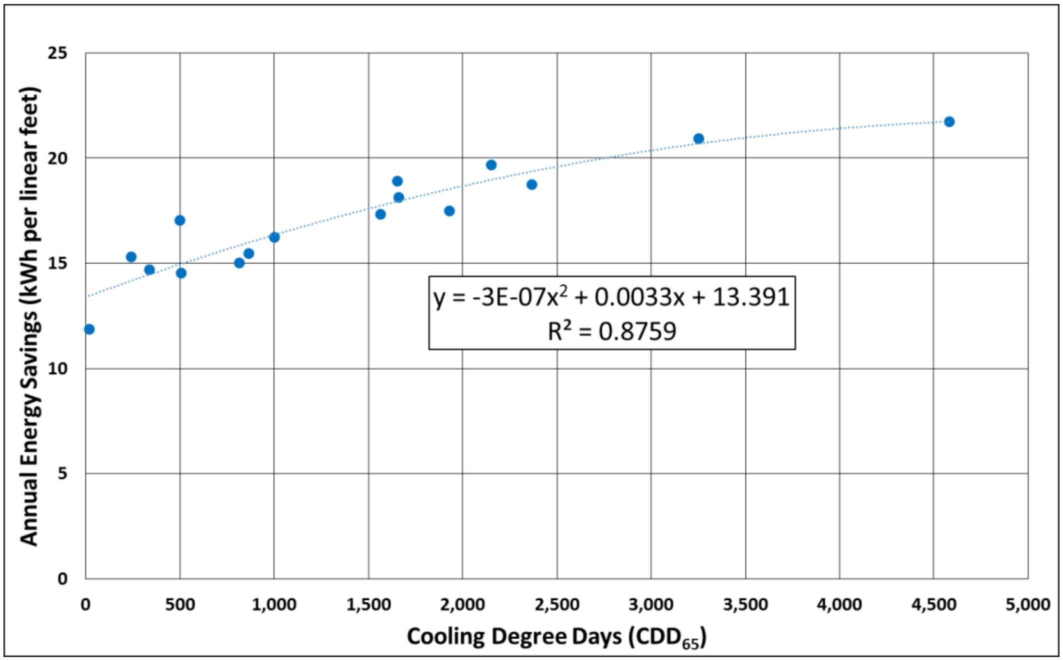

Figure 16.9-2: [Door Gaskets] Comparison of Projected Annual Energy Savings to Cooling Degree Days for All 16 California Climate Zones for Reach-In Display Cases (Freezers)

These correlations were used to adjust the energy savings and TMY3 CDDs in California to TMY3 CDDs in Texas to determine an average energy savings of 7.4 and 20.0 kWh/linear feet for coolers and freezers in Texas. Comparing the average energy savings between California and Texas, the CDD adjustment results in a 113 percent adjustment factor for coolers and a 117 percent adjustment factor for freezers. For simplicity, an average adjustment factor of 115 percent (the midpoint of 113% and 117% TX vs. CA Energy Savings values) was applied to the PG&E results at 90 percent efficacy (as shown in Table 16.9-1 above), resulting in Texas-based annual energy savings values for coolers of 3.5 kWh/linear feet and freezers of 26.5 kWh/linear feet. These results are summarized in Table 16.9-4 below:

Table 16.9-2: [Door Gaskets] Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies (per Linear Foot of Installed Door Gasket)

Refrigerator type	CA CZ1-CZ16 average savings (kWh/ft)	CA average savings normalized to TX by CDD (kWh/ft)	TX vs. CA energy savings	Average CDD adjustment factor	PG&E baseline 90% efficacy (kWh/ft)	TX baseline 90% efficacy (kWh/ft)
Cooler	6.5	7.4	113%	115%	3	3.5
Freezer	17.1	20.0	117%		23	26.5

Energy and Demand Savings

The energy and demand algorithms and associated input variables are listed below:

$$\boldsymbol{Energy}\ [\boldsymbol{kWh}] = \frac{\Delta \boldsymbol{kWh}}{\boldsymbol{ft}} \times \boldsymbol{L} \times \boldsymbol{CAF}$$

Equation 16.9-1

$$\boldsymbol{Peak\ Demand}\ [\boldsymbol{kW}] = \frac{\boldsymbol{kWh_{savings}}}{\boldsymbol{8760}} \times \boldsymbol{L} \times \boldsymbol{DF}$$

Equation 16.9-2

Where:

$\frac{\Delta kWh}{ft}$ = *Annual CA energy savings per linear foot of gasket [kWh/ft] = 3 for coolers and 23 for freezers.*

L = *Total gasket length as measured [ft].*

CAF = *California to Texas climate adjustment factor = 115%; see Table 16.6-2.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 16.9-3.*

Load Shapes

The peak demand factors were derived according to the method outlined in Section 2.3 using a load shape developed from the Electric Power Research Institute (EPRI) average weekday and average weekend refrigeration end use load shape values. The EPRI load data provided representative hourly load shapes for the peak-season months of April through September and off-peak-season months of October through March. These shapes were used to create the 8,760 hourly load shape, which can be found in Section 22.2.

Table 16.9-3: [Door Gaskets] Demand Factors

Factor Type	Demand Factor
NCP	1.000
CP	0.981
4CP	0.974

16.9.2.2 Deemed Energy Savings Tables

Table 16.9-4: [Door Gaskets] Deemed Energy Savings (per Linear Foot of Gasket)

Refrigerator Type	Walk-In or Reach-In Deemed Savings (ΔkWh/ft)
Cooler	3.5
Freezer	26.5

16.9.2.3 Deemed Demand Savings Tables

Because the walk-in or reach-in cooler or freezer is kept at a constant temperature, the demand savings are estimated as the total energy savings divided evenly over the full year (8,760 hours).

Table 16.9-5: [Door Gaskets] Deemed Demand Savings (per Linear Foot of Gasket)

Refrigerator Type	Walk-In or Reach-In Deemed Savings (ΔkW/ft)		
	NCP	CP	4CP
Cooler	0.000394	0.000386	0.000384
Freezer	0.003019	0.002962	0.002941

16.9.2.4 Additional Calculators and Tools

This section is not applicable.

16.9.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 4 years for refrigerated door gaskets, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GrocDisp-FixtDrGask.[693]

16.9.3 Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- Building type (convenience store, supermarket, restaurant, refrigerated warehouse)
- Refrigerator type (walk-in or reach-in cooler or freezer)
- Presence of existing gasket (yes, no)
- Optional (if applicable): length of ineffective baseline gasket (ft), general description of baseline gasket condition (e.g., good, moderate, poor, non-existent), and primary reason for baseline gasket ineffectiveness (partial tear, torn and dislocated, rotted/dry, poor fit/shrink, missing, or other)
- Total gasket length in cooler (ft)
- Total gasket length in freezer (ft)

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[693] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

16.10 HIGH SPEED DOORS FOR COLD STORAGE

16.10.1 Measure Description

This measure presents deemed savings for installation of high-speed doors for cold storage facilities. High speed automatic doors differ from regular automatic doors by increasing their closing speed. High speed doors can save energy over regular automatic and manual doors by shortening the duration that the door to the cold storage area is open.

16.10.1.1 Eligibility Criteria

Eligible equipment includes high speed doors with a minimum opening rate of 32 inches per second, a minimum closing rate of 24 inches per second, and a means to automatically reclose the door, as defined by the Door and Access Systems Manufacturers' Association, International (DASMA).[694] The high speed doors must be installed for access to a cold storage area either from exterior conditions, such as a loading dock, or from a conditioned area, such as a non-refrigerated warehouse.

16.10.1.2 Baseline Condition

The baseline condition is a manual or non-high speed automatic door installed for access to a cold storage area.

16.10.1.3 High-Efficiency Condition

The efficient condition is a high speed door installed for access to a cold storage area.

16.10.2 Energy and Demand Savings Methodology

16.10.2.1 Savings Algorithms and Input Variables

Energy and Demand Savings

Savings are calculated based on a reduction in heat gain from airflow across the door opening area. The algorithms below are modeled after equations 14 and 16 in Chapter 24: Refrigerated-Facility Loads of the 2018 ASHRAE Handbook—Refrigeration to calculate heat load associated with infiltration air exchange. This measure does not account for associated motor load or efficiencies; if the new high-speed door includes an efficient motor, reference the motor measure for savings.

$$kWh\ savings = \frac{w \times h^{1.5} \times EC}{COP\ \times 3{,}412}$$

Equation 16.10-1

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[694] DASMA Standard Specification for High Speed Doors and Grilles, definition 2.6 for High Speed Door. https://www.dasma.com/wp-content/uploads/pubs/Standards/DASMA403.pdf.

$$\boldsymbol{EC = hours \times 3{,}790 \times \frac{q_s}{A} \times \frac{1}{R_s} \times \Delta D_t \times D_f \times \Delta E}$$

Equation 16.10-2

$$\boldsymbol{kW\ savings = \frac{w \times h^{1.5} \times DC}{COP \times 3{,}412} \times DF}$$

Equation 16.10-3

$$\boldsymbol{DC = 3{,}790 \times \frac{q_s}{A} \times \frac{1}{R_s} \times \Delta D_t \times D_f \times \Delta E}$$

Equation 16.10-4

Where:

w = *Width of the door opening [ft].*

h = *Height of the door opening [ft].*

EC = *Energy coefficient, the outcome of Equation 16.10-2 based on climate zone and cold storage application; see Table 16.10-1.*

DC = *Demand coefficient, the outcome of Equation 16.10-4 based on climate zone and cold storage application; see Table 16.10-1.*

$hours$ = *Operating hours, 3,798.*[695]

3,790 = *Constant.*[696]

$\frac{q_s}{A}$ = *Sensible heat load of infiltration air per square foot of door opening [ton/ft²]; see Table 16.10-2.*

R_s = *Sensible heat ratio of the infiltration air heat gain; see Table 16.10-3.*

ΔD_t = *Change in percent of time the doorway is open, 0.33.*[697]

D_f = *Doorway flow factor, varies based on Temperature delta between cold room and infiltration air, 0.8 for delta T ≥ 20°F, 1.1 for delta T < 20°F.*[698]

ΔE = *Change in door effectiveness, 0.2.*[699]

COP = *Coefficient of performance, assume 2.8 COP.*[700]

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[695] Operating hours taken from the Texas TRM Volume 3, Table 8, hours for refrigerated warehouse.

[696] From ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, equation 16.

[697] From ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, simplification of equation 17 notes; assume baseline door open-close time is 15 seconds, and high speed door open-close time is 10 seconds, for a difference in percent of time the door is open of (15-10)/15 = 0.33.

[698] ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, equation 17 notes.

[699] ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, simplification of equation 17 notes. ASHRAE provides a range of doorway effectiveness, stating 0.95 for newly installed doors though that may quickly decrease to 0.8 or 0.85 depending on door use frequency and maintenance. Air curtain effectiveness ranges from very poor to more than 0.7. The input assumptions for this measure are conservatively estimated for baseline door effectiveness of 0.7 and high speed door effectiveness of 0.9.

[700] Air cooled chiller efficiency from IECC 2009.

3,412 = *Constant to convert from Btu to kWh.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 16.10-4*

Table 16.10-1: [High Speed Doors] Energy and Demand Coefficients for Doors to Unconditioned and Conditioned Areas

Door-to Space Type	Factor	Cold room temperature			
		-20°F	0°F	20°F	40°F
Unconditioned	Energy Factor	1,098,620	764,564	506,518	251,996
	Demand Factor	293.09	216.28	151.60	109.15
Conditioned	Energy Factor	783,056	518,199	322,435	230,311
	Demand Factor	1.0	1.0	1.0	1.0

Table 16.10-2: [High Speed Doors] Sensible Heat Load of Infiltration Air[701]

Cold Room Temperature	Conditioned	Annual	Summer Peak
	Infiltration Air Temperature		
	75°F	76°F	104°F
-20°F	1.02	1.03	1.45
0°F	0.68	0.68	1.07
20°F	0.42	0.43	0.75
40°F	0.3	0.22	0.54

Table 16.10-3: [High Speed Doors] Sensible Heat Ratio of Infiltration Air[702]

For energy factor, unconditioned space				For energy factor, conditioned space	For demand factor, conditioned and unconditioned space
Cold Room Temperature					
20°F	0°F	20°F	40°F	All temps	Summer, all temps
0.72	0.68	0.65	0.67	1.0	1.0

---

[701] From ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, figure 9. Values in table are summarized to reflect average annual and summer and winter peak infiltration air Temperatures. Where infiltration air Temperatures are not shown on ASHRAE figure 9, $\frac{q_s}{A}$ is estimated by extrapolation. Values for infiltration air temperature of 75°F are used to calculate energy and demand factors for doorways between cold room and conditioned space.

[702] Sensible heat ratio determined from psychrometric chart, using values for the air properties of dry bulb Temperature and relative humidity.

Load Shapes

The peak demand factors are specified for warehouse building types in 13.2 Split and Packaged Air Conditioners and Heat Pumps.

Table 16.10-4: [High Speed Doors] Demand Factors

Factor Type	Demand Factor
NCP	1.050
CP	0.920
4CP	0.710

16.10.2.2 Deemed Energy and Demand Savings Tables

There are no deemed savings tables for this measure. Please refer to the savings algorithms above.

16.10.2.3 Additional Calculators and Tools

This section is not applicable.

16.10.2.4 Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 5 years based on published manufacturer warranty duration.

16.10.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Climate zone
- Cold room temperature
- Doorway opening location – conditioned or unconditioned
- Width and height of door

Relative humidity of the cold room is estimated at 90% based on ASHRAE 2018 Refrigeration Handbook, Chapter 24-4, Table 9. Energy factor values for unconditioned space are the average annual values between the expected operating hours of 8am – 6pm using TMY3 data. Demand factor values for unconditioned space are taken using the highest probability Temperatures from TRM Volume 1 and their associated relative humidity from TMY3 data. Energy and demand factor values for conditioned space assume conditioned air temperature of 75°F and 45% RH.

17. COMMERCIAL: NEW CONSTRUCTION

17.1 COMMERCIAL NEW CONSTRUCTION

17.1.1 Measure Description

New construction projects are projects that take a whole-building approach to incorporating energy efficient technologies during the design and construction of new facilities.

17.1.1.1 Eligibility Criteria

New construction projects are required to submit a qualifying measurement and verification (M&V) plan prior to beginning work. The M&V plan should adhere to the International Performance Measurement & Verification Protocol (IPMVP) Option D: Calibrated Simulation method.[703]

Project implementers are required to conduct a simulation analysis using a method that is appropriate for the complexity of the project site. A whole-building simulation program that uses hourly calculation techniques may be required to estimate project savings on most sites, but simplified models may be accepted on a per-project basis. Evaluation of new construction projects requires review of simulation models and design documents by the Evaluation, Measurement & Verification (EM&V) contractor.

A visual site inspection will be conducted by the EM&V contractor post construction and before occupancy to confirm that as built conditions match design documents.

Model calibration is required to be conducted using metered site data over a reporting period long enough to capture a period of stable operation. The reporting period will be declared in the M&V plan. To implement this recommendation, it is necessary to ensure that whole-building energy models are obtained and retained at the time of application submittal.

17.1.1.2 Baseline Condition

The applicable baseline condition shall be based on the building code in effect for the City of San Antonio at the time of project permitting, which is IECC 2018 as of October 2018. For projects that were permitted outside of the City of San Antonio's jurisdiction, the applicable baseline will be the statewide code adopted for Texas, IECC 2015.

17.1.1.3 High-Efficiency Condition

The high efficiency condition is the facility as built.

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[703] International Performance Measurement & Verification Protocol (IPMVP). Available at: http://evo-world.org/en/.

17.1.2 Energy and Demand Savings Methodology

17.1.2.1 Energy Savings

Energy savings will be determined on a per-project basis according to the M&V plan.

17.1.2.2 Demand Savings

Demand savings will be determined on a per-project basis according to the M&V plan.

Load Shapes

To determine peak impacts, project-specific hourly simulation modeling outputs are the preferred source for determining the load profile for new construction projects.

17.1.2.3 Deemed Energy Savings Tables

There are no lookup tables available for this measure.

17.1.2.4 Deemed Summer Demand Savings Tables

There are no lookup tables available for this measure.

17.1.2.5 Additional Calculators and Tools

There are no calculators or tools available for this measure.

17.1.2.6 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 18 years for commercial new construction when reporting whole building savings based on a mix of energy efficient design features (envelope, mechanical/plumbing, lighting). Prescriptive savings reported for individual energy efficiency measures should refer to the EUL for each respective measure.

17.1.3 Program Tracking Data & Evaluation Requirements

The follow items are suggested for inclusion in project submittal to facilitate impact evaluation:

- Approved contractor product submittals for HVAC and lighting equipment, or product sheets from operations and maintenance (O&M) manual
- Simulation summary reports
- Hourly energy output files
- Demand and energy savings calculation file (spreadsheet)
- Commissioning Report and HVAC TAB (test, adjust & balance) Report - review of these reports will confirm initial building control settings are in accordance with design

18. COMMERCIAL: CUSTOM

18.1 COMMERCIAL CUSTOM

18.1.1 Measure Description

Measures that do not fit into existing prescriptive programs will require measure-specific energy and demand savings calculations to be done, sometimes requiring development of new and unique savings calculation methods. These measures are referred to as custom measures and the measurement and verification (M&V) procedures as outlined in this section should be followed to facilitate impact evaluation.

18.1.1.1 Eligibility Criteria

Projects whose measures fall into the custom category are required to submit a qualifying M&V plan prior to beginning work. The proposed M&V plan should adhere to industry best practices such as the options put forth in the International Performance Measurement & Verification Protocol (IMPVP). [704] M&V plan contents may include the following sections, as suggested by the IPMVP.

- Energy Conservation Measure (ECM) Intent
- Measurement Boundary
- Baseline & Reporting Period, Energy and Conditions
- Basis for Adjustment
- Analysis Procedures
- Energy Prices
- Meter Specifications
- Monitoring Responsibilities
- Expected Accuracy
- Justification of Estimates
- Quality Assurance

18.1.1.2 Baseline Condition

Baseline conditions will be determined on a per-project basis and should be declared in the M&V plan.

18.1.1.3 High-Efficiency Condition

High Efficiency conditions will be determined on a per-project basis and should be declared in the M&V plan.

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[704] International Performance Measurement & Verification Protocol (IPMVP). Available at: http://evo-world.org/en/.

18.1.2 Energy and Demand Savings Methodology

18.1.2.1 Savings Algorithms and Input Variables

The savings methodology will be determined on a per-project basis and declared in the M&V plan.

Load Shapes

To determine peak impacts, site-specific meter data and measurements are the preferred source for determining the load profile for specific custom measures. Where site-specific measurements are not available or not robust enough to determine peak impacts, an alternative load shape will be selected that best represents the site and project conditions.

18.1.2.2 Deemed Energy Savings Tables

There are no deemed savings tables for this measure.

18.1.2.3 Deemed Summer Demand Savings Tables

There are no lookup tables available for this measure.

18.1.2.4 Additional Calculators and Tools

There are no calculators available for this measure.

18.1.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) will be determined on a per-project basis.

18.1.3 Program Tracking Data & Evaluation Requirements

To facilitate impact evaluation, primary inputs and contextual data necessary for savings evaluation should be specified in the M&V plan and submitted with the project documentation.

19. COMMERCIAL: RENEWABLE ENERGY

19.1 COMMERCIAL AND SCHOOLS SOLAR PHOTOVOLTAIC

19.1.1 Measure Description

This measure involves the installation of a new or expanded commercial grid-connected solar photovoltaic (PV) system.

19.1.1.1 Eligibility Criteria

Only PV systems that result in reductions of the customer's purchased energy and/or peak demand qualify for savings. Off-grid systems are not eligible. CPS Energy maintains additional eligibility criteria for participating in the incentive program.

19.1.1.2 Baseline Condition

PV system not currently installed (typical), or an existing system is present but additional generating capacity is added.

19.1.1.3 High-Efficiency Condition

PV system (or additional capacity on an existing system) is installed and operational.

19.1.2 Energy and Demand Savings Methodology

19.1.2.1 Savings Algorithms and Input Variables

Energy and demand savings are derived from meter-based savings validation of CPS Energy's commercial fleet of solar energy systems conducted by Frontier Energy in 2021.

Energy Savings

Based on Frontier's 2021 analysis of CPS Energy's residential solar fleet, CPS Energy uses an average annual performance factor of 1,206 kWh per kW_{DC} per year for commercial and school solar energy systems. [705] Thus,

$$\boldsymbol{Annual\ kWh\ savings = 1,206\ \times kW_{DC}\ installed}$$

Equation 19.1-1

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[705] Evaluation, Measurement and Verification of CPS Energy's FY 2015 DSM Programs, June 11, 2015, Frontier Associates.

Where:

kW_{DC} = *Sum of the DC capacity at standard test conditions (STC) of all PV modules installed (or additional capacity installed on existing system). This factor may be reassessed periodically and updated if the composition of installed projects is determined to vary substantially from the assumed fleet-wide average.*

Load Shapes

The annual energy savings performance factor above results from the analysis of solar AMI data for commercial systems installed from 2017 through 2020.

The table below lists the percentage of annual kWh applied to each costing period.

Table 19.1-1 [Solar PV] Commercial/Schools Solar Initiative Allocation of Annual kWh Savings into CPS Energy Costing Periods

Load Shape Category	Summer On Peak	Summer Mid Peak	Summer Off Peak	Non-Summer Mid Peak	Non-Summer Off Peak
Commercial/ Schools Solar	12.60%	26.36%	0.25%	42.18%	18.61%

19.1.2.2 Deemed Energy Savings Tables

This section is not applicable for this measure.

19.1.2.3 Deemed Summer Demand Savings Tables

Frontier's 2021 analysis of CPS Energy's commercial and schools solar fleet estimated average performance factors for coincident peak (CP), non-coincident peak (NCP), and ERCOT TCOS 4CP demand savings. These performance factors were determined by subjecting the commercial fleet-wide 8,760 hourly load shape to methods for determining each demand metric:

- **Non-Coincident Peak (NCP):** CPS Energy uses a non-coincident peak factor of 91.5% (or 0.915) of the total array DC capacity at standard test conditions (STC). This factor represents the maximum hourly kW_{AC} value over the 8,760-hour period, regardless of when it occurred.

$$\boldsymbol{Non\text{-}Coincident\ Peak\ (NCP) savings = 0.915 \times kW_{DC}}$$

Equation 19.1-2

- **Coincident Peak (CP):** CPS Energy uses a coincident peak factor of 41.1% (or 0.411) of the total array DC capacity at standard test conditions (STC). This factor is calculated as the probability-weighted average kW_{AC} output of a one (1) kW_{DC} "fleet average" commercial/schools array over the top 20 hours in a blended TMY weather file determined to be the most likely to coincide with CPS Energy's peak.

$$\boldsymbol{Coincident\ Peak\ (CP)\ savings = 0.411 \times kW_{DC}}$$

Equation 19.1-3

- **ERCOT TCOS 4CP:** CPS Energy uses an ERCOT TCOS 4CP factor of 34.5% (or 0.345) of the total array DC capacity at standard test conditions (STC). This factor is calculated as the average demand savings of a one (1) kW_{DC} “fleet average” commercial and schools array during the most recent 20 historical 4CP intervals.

$$\boldsymbol{ERCOT\ TCOS\ 4CP\ savings = 0.345 \times kW_{DC}}$$

Equation 19.1-4

19.1.2.4 Deemed Winter Demand Savings Tables

This section is not applicable for this measure.

19.1.2.5 Claimed Peak Demand Savings

This section is not applicable for this measure.

19.1.2.6 Additional Calculators and Tools

This section is not applicable for this measure.

19.1.2.7 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 30 years for solar PV. This value is consistent with engineering estimates based on manufacturers' warranties and historical data, and with the EUL reported in the Texas Technical Reference Manual (TRM).

19.1.3 Program Tracking Data & Evaluation Requirements

The following information will be required to be collected for each project.

- Project location (city) and zip code
- Module type: Standard, premium, or thin film
- Array Type: Fixed (open rack), fixed (roof mount), 1-axis tracking, 1-axis backtracking, 2-axis tracking, etc.
- Tilt, azimuth, and DC system size rating at standard test conditions for each array
- Date of PVWatts® run, and PVWatts® report (retained with project documentation) for each array

20. COMMERCIAL: DEMAND RESPONSE/LOAD CONTROL

20.1 COMMERCIAL DEMAND RESPONSE

20.1.1 Measure Description

Commercial demand response (DR) measures include technologies that enable CPS Energy to reduce aggregate commercial customer demand to respond to an electric system need. These technologies include a variety of control mechanisms affecting production processes, large appliances, and other controllable loads.

CPS Energy plans to deploy commercial demand response through customers enrolled in one of the C&I DR program options (there are currently four), and the Automatic Demand Response (ADR) program.

20.1.1.1 Eligibility Criteria

Any commercial or industrial customer with an eligible control technology who is actively enrolled in one of CPS Energy's commercial and industrial demand response programs.

20.1.1.2 Baseline Condition

Customer did not participate in a demand response event.

20.1.1.3 High-Efficiency Condition

Customer participated in a commercial/industrial demand response event.

20.1.2 Energy and Demand Savings Methodology

20.1.2.1 Savings Algorithms and Input Variables

Demand and Energy Savings

CPS Energy estimates demand and energy savings from C&I DR events using a multiple baselining method. This approach calculates savings using 4 different methods first and then selects the savings generated by the most appropriate method by evaluating some statistical criteria. To be more specific, the general calculation process of "multiple-baselining method" is as follows:

Step 1: data selection. For each event and each customer, the previous 10 eligible days and the event day are selected. These 11 days of data will be used for the analysis in the following steps.

Step 2: calculation. For each customer on each event, kW savings are calculated using 4 different methods, described as follows.

- Regression: Load is modeled as a function of cdh (cooling degree hours), notifying-period dummy variable indicating whether a period is a notifying period, event dummy variable indicating whether a period is an event period, 10 day-dummy variables indicating date and 3 time-of-day dummy variables indicating time of day – 0:00-6:00, 6:00-12:00, 12:00-18:00 or 18:00-24:00. The model equation can be expressed as follows:

$$kW_t = \beta_0 + \beta_1 * cdh_t + \beta_2 * event_t + \beta_3 * notify\text{-}period_t + \sum_{i=4}^{6} \beta i * time\text{-}of\text{-}day_t + \sum_{j=7}^{16} \beta j * date_t$$

-β_2 is the estimated load reduction for a certain customer during a certain event.

- CPS "High 3 of 10 baseline" analysis
- Previous X hours: X = event duration + notifying period. For example, if an event duration is 2 hours, and CPS notify customers 2 hours in advance, then X = 4. So, if an event is 3:30-5:30pm, then the baseline would be the average of 11:30am – 1:30pm)
- Average everything: this method calculates the average of all the load for the previous 10 eligible days and serve as baseline and is designed for customers with rather amorphous and irregular load.

Step 3: evaluation. For the testing data period,[706] three measures including accuracy (RMSE), bias (difference) and variability (standard deviation) are calculated. This step measures how fit the model results are when compared with actual results for a similar period.

Step 4: final selection. For the three measures described in Step 3, a pairwise comparison is conducted using ranking method.[707] The method with top ranking is selected.

After kW savings are generated by the automatic ranking selection process, manual inspections and potential manual adjustments may be needed for certain events or account IDs with unusual load profiles.

Demand savings are converted to energy savings by multiplying by the event duration. Per-customer kW and kWh savings are summed to yield program-wide demand and energy savings.

Load Shapes

Under typical operations, for commercial demand response programs, 100 percent of energy and demand savings is allocated to the summer peak period, because the programs primarily reduce summer peaks. However, it is possible that some commercial DR programs could be deployed in response to other, off-peak emergencies; in these cases, savings would be allocated as appropriate.

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[706] Here "testing data period" refers to the same period as event period on top 3 of the previous 10 eligible days, plus 09:00am – 1:00pm on event day.

[707] General rule for "pairwise comparison using ranking": if the difference for a pair of baselines > 2% then the baseline with the higher one gets one point; otherwise, both baselines get 0.5 point. In the end, for each method respectively, RMSE, Error and standard deviation score are added together.

20.1.2.2 Measure Life and Lifetime Savings

Because commercial customers must re-enroll annually, the estimated useful life (EUL) is one year for commercial DR options 1, 2, 3, and 4. For the ADR program, in which CPS Energy makes significant investments in control technologies at the participating customers' premises, the EUL is assumed to be 10 years to better reflect the expected useful life of the installed equipment.

20.1.3 Program Tracking Data & Evaluation Requirements

Inputs and contextual data tracked by the program managers to inform the evaluation and apply the savings properly include:

- For each event, the starting and ending time, ambient temperature, and reason for deployment
- Program enrollment at the beginning and end of the program year, and during each demand response event, by participant class
- Fifteen-minute interval meter data should be available for all program participants

21. COMMERCIAL: OTHER

21.1 LODGING GUEST ROOM OCCUPANCY CONTROLS

21.1.1 Measure Description

This measure captures the potential energy and demand savings resulting from occupancy sensor control of HVAC and lighting in unoccupied hotel/motel guest rooms. Hotel and motel guest room occupancy schedules are highly variable, and guests often leave HVAC equipment and lighting on when they leave the room. Installation of occupancy controls can reduce the unnecessary energy consumption in unoccupied guest rooms. Savings have also been developed for use of this measure in college dormitories. This measure is also commonly referred to as a guest room energy management (GREM) system.

21.1.1.1 Eligibility Criteria

To be eligible for HVAC savings, controls must be capable of either a 5°F or 10°F temperature offset. To be eligible for lighting savings, at least 50% of all the lighting fixtures in a guest room – both hardwired and plug-load lighting – must be actively controlled.

21.1.1.2 Baseline Condition

The baseline condition is a guest room or dorm room without occupancy controls.

21.1.1.3 High-Efficiency Condition

The high-efficiency condition is a guest room or dorm room with occupancy controls. The occupancy sensors can control either the HVAC equipment only, or the HVAC equipment and the interior lighting (including plug-in lighting).

The occupancy-based control system must include, but not be limited to, infrared sensors, ultrasonic sensors, door magnetic strip sensors, and/or card-key sensors. The controls must be able to either completely shut-off the HVAC equipment serving the space and/or place it into an unoccupied temperature setback/setup mode.

21.1.2 Energy and Demand Savings Methodology

21.1.2.1 Savings Algorithms and Input Variables

Energy Savings

Energy and demand savings are deemed values based on energy simulation runs performed using EnergyPro Version 5. Building prototype models were developed for a hotel, motel, and dormitory building types. The base case for each prototype model assumed a uniform temperature setting and was calibrated to a baseline energy use. Occupancy patterns based on both documented field studies[708] and prototypical ASHRAE 90.1-1999 occupancy schedules were used in the energy simulation runs to create realistic vacancy schedules. The prototype models were then adjusted to simulate an occupancy control system, which was compared to the baseline models.

Energy and demand savings are provided for HVAC-Only and HVAC+Lighting control configurations, and for three facility types: Motel and Hotel guest rooms, and Dormitory rooms.

Load Shapes

A building simulation approach was used to produce savings estimates. No direct load shapes from these simulations are available currently.

21.1.2.2 Deemed Energy Savings Tables

Energy savings are provided for HVAC-Only and HVAC+Lighting control configurations, and for three facility types: Motel and Hotel guest rooms, and Dormitory rooms.

Table 21.1-1: [Guest Room Occupancy Sensors] Deemed Energy Savings for Motel per Guest Room

Heat Pump		Electric Resistance	
HVAC-Only	HVAC & Lighting	HVAC-Only	HVAC & Lighting
kWh	kWh	kWh	kWh
5-Degree Setup/Setback Offset			
324	461	351	484
10-Degree Setup/Setback Offset			
559	695	602	735

Table 21.1-2: [Guest Room Occupancy Sensors] Deemed Energy Savings for Hotel per Guest Room

Heat Pump		Electric Resistance	
HVAC-Only	HVAC & Lighting	HVAC-Only	HVAC & Lighting
kWh	kWh	kWh	kWh
5-Degree Setup/Setback Offset			
242	430	260	450
10-Degree Setup/Setback Offset			
423	599	446	621

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[708] HVAC occupancy rates appear to be based on a single HVAC study of three hotels, but not dorms or multifamily buildings. For the lighting study, a typical guest room layout was used as the basis for the savings analysis. Hotel guest rooms are quite different from either dorms or multifamily units.

Table 21.1-3: [Guest Room Occupancy Sensors] Deemed Energy Savings for Dormitories per Guest Room

Heat Pump		Electric Resistance	
HVAC-Only	HVAC & Lighting	HVAC-Only	HVAC & Lighting
kWh	kWh	kWh	kWh
5-Degree Setup/Setback Offset			
242	461	244	462
10-Degree Setup/Setback Offset			
326	543	328	545

21.1.2.3 Deemed Summer Demand Savings Tables

Demand savings are provided for HVAC-Only and HVAC+Lighting control configurations, and for three facility types: Motel and Hotel guest rooms, and Dormitory rooms.

Table 21.1-4: [Guest Room Occupancy Sensors] Deemed Demand Savings for Motel per Guest Room

Peak Demand	Heat Pump		Electric Resistance	
	HVAC-Only	HVAC & Lighting	HVAC-Only	HVAC & Lighting
	kW	kW	kW	kW
5-Degree Setup/Setback Offset				
CP	0.082	0.097	0.082	0.097
NCP	0.058	0.069	0.058	0.069
4CP	0.071	0.084	0.071	0.084
10-Degree Setup/Setback Offset				
CP	0.151	0.166	0.151	0.166
NCP	0.107	0.118	0.107	0.118
4CP	0.131	0.144	0.131	0.144

Table 21.1-5: [Guest Room Occupancy Sensors] Deemed Demand Savings for Hotel per Guest Room

Peak Demand	Heat Pump		Electric Resistance	
	HVAC-Only	HVAC & Lighting	HVAC-Only	HVAC & Lighting
	kW	kW	kW	kW
5-Degree Setup/Setback Offset				
CP	0.074	0.094	0.074	0.094
NCP	0.053	0.067	0.053	0.067
4CP	0.064	0.082	0.064	0.082
10-Degree Setup/Setback Offset				
CP	0.136	0.156	0.136	0.156
NCP	0.097	0.111	0.097	0.111
4CP	0.118	0.136	0.118	0.136

Table 21.1-6: [Guest Room Occupancy Sensors] Deemed Demand Savings for Dormitories per Guest Room

Peak Demand	Heat Pump		Electric Resistance	
	HVAC-Only	HVAC & Lighting	HVAC-Only	HVAC & Lighting
	kW	kW	kW	kW
5-Degree Setup/Setback Offset				
CP	0.051	0.078	0.051	0.078
NCP	0.036	0.055	0.036	0.055
4CP	0.044	0.068	0.044	0.068
10-Degree Setup/Setback Offset				
CP	0.081	0.108	0.081	0.108
NCP	0.058	0.077	0.058	0.077
4CP	0.070	0.094	0.070	0.094

21.1.2.4 Additional Calculators and Tools

There are no calculators for this measure.

21.1.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years for lodging guest room occupancy controls based on the value for retrofit energy management system (EMS) HVAC control from the Massachusetts Joint Utility Measure Life Study.[709]

21.1.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- HVAC system and equipment type
- Heating type (heat pump, electric resistance)
- Temperature offset category (5 or 10 °F)
- Control type (HVAC-only or HVAC and lighting)
- Building type (hotel, motel, dormitory)
- Number of rooms

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[709] Energy & Resource Solutions (2005). Measure Life Study. Prepared for the Massachusetts Joint Utilities; Table 1-1, Prescriptive Common Measure Life Recommendations, Large C&I Retrofit, HVAC Controls, EMS.

21.2 VENDING MACHINE CONTROLS

21.2.1 Measure Description

This measure is for the installation of Vending Machine Controls to reduce energy usage during periods of inactivity. These controls reduce energy usage by powering down the refrigeration and lighting systems when the control device signals that there is no human activity near the machine. If no activity or sale is detected over the manufacturer's programmed time duration, the device safely de-energizes the compressor, condenser fan, evaporator fan, and any lighting. For refrigerated machines, it will power up occasionally to maintain cooling to meet the machine's thermostat set point. When activity is detected, the system returns to full power. The energy and demand savings are determined on a per-vending machine basis.

21.2.1.1 Eligibility Criteria

This measure applies to refrigerated beverage vending machines manufactured and purchased prior to August 31, 2012. Refrigerated beverage vending machines manufactured after this date must already comply with federal standard maximum daily energy consumption requirements. The current federal standard further reduced these maximum consumption values, effective January 8, 2019.[710]

All non-refrigerated snack machines are eligible if controls are installed on equipment consistent with the Baseline Condition below. Display lighting must not have been permanently disabled.

21.2.1.2 Baseline Condition

The baseline condition is a 120-volt single phase refrigerated beverage or non-refrigerated snack vending machine without any controls.

21.2.1.3 High-Efficiency Condition

The high-efficiency condition is a 120-volt single phase refrigerated beverage or non-refrigerated snack vending machine with occupancy controls and compliant with the current federal standard, effective January 8, 2019. [711]

21.2.2 Energy and Demand Savings Methodology

21.2.2.1 Savings Algorithms and Input Variables

Energy Savings

Energy savings are deemed based on a metering study completed by Pacific Gas & Electric (PG&E). Delta load shapes for this measure are taken from a Sacramento Municipal Utility District (SMUD) metering

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[710] Appliance Standards for Refrigerated Beverage Vending Machines. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=29#current_standards.

[711] Appliance Standards for Refrigerated Beverage Vending Machines. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=29#current_standards.

study. Demand savings for refrigerated cold drink units are calculated based on a probability weighted analysis of hourly consumption impacts, and demand savings for other unit types are adjusted proportionally based on differences in rated product wattage.

Load Shapes

Load shapes for this measure are taken from a Sacramento Municipal Utility District (SMUD) study on vending machine controls and their verified savings performance.[712]

The load shapes for hourly savings are included in Section 22.2.

21.2.2.2 Deemed Energy Savings Tables

Table 21.2-1: [Vending Machine Controls] Deemed Energy Savings by Equipment Type

Vending Machine Controls	Annual Energy Savings [kWh]
Control for Refrigerated Cold Drink Unit cans or bottles[713]	1,612
Control for Refrigerated Reach-in Unit any sealed beverage[714]	1,086
Control for Non-Refrigerated Snack Unit with lighting (including warm beverage)[715]	387

21.2.2.3 Deemed Summer Demand Savings Tables

Table 21.2-2: [Vending Machine Controls] Deemed Demand Savings by Unit Type

Unit Type	Demand Type	Demand Savings [kW]
Refrigerated Cold Drink Unit	NCP	0.165
	CP	0.022
	4CP	0.030
Refrigerated Reach-in Unit	NCP	0.190
	CP	0.026
	4CP	0.035
Non-Refrigerated Snack Unit	NCP	0.035
	CP	0.005
	4CP	0.006

21.2.2.4 Additional Calculators and Tools

There are no calculators for this measure.

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[712] Chappell, C., Hanzawi, E., Bos, W., Brost, M., and Peet, R. (2002). "Does It Keep the Drinks Cold and Reduce Peak Demand? An Evaluation of a Vending Machine Control Program," 2002 ACEEE Summer Study on Energy Efficiency in Buildings Proceedings, pp. 10.47-10.56.

[713] Pacific Gas and Electric, Work Paper VMCold, Revision 3, August 2009, Measure Code R97.

[714] Pacific Gas and Electric, Work Paper VMReach, Revision 3, August 2009, Measure Code R143.

[715] Pacific Gas and Electric, Work Paper VMSnack, Revision 3, August 2009, Measure Code R98.

21.2.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 5 years for vending machine controls, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID Plug-VendCtrler.[716]

21.2.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Vending machine type (refrigerated cold drink unit, refrigerated reach-in unit, non-refrigerated snack unit with lighting)
- Vending machine manufacture date

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[716] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

21.3 PUMP-OFF CONTROLLERS

21.3.1 Measure Description

Pump-off Controllers (POC) are micro-processor-based devices that continuously monitor pump down conditions, which is the condition when the fluid in the well bore is insufficient to warrant continued pumping. These controllers are used to shut down the pump when the fluid falls below a certain level and "fluid pounding"[717] occurs. POCs save energy by optimizing the pump run-times to match the flow conditions of the well.

21.3.1.1 Eligibility Criteria

The POC measure is only available as a retrofit measure for existing wells (wells with an existing API number[718] prior to September 11th, 2014) with rod pumps using 15 hp or larger motors operating on time clock controls or less efficient devices. These cannot be integrated with a variable frequency drive, and only apply to POCs using load cells, which measure the weight on the rod string for greater precision. Additionally, the POC must control a conventional well (above ground, vertical, with a standard induction motor of 480V or less).

21.3.1.2 Baseline Condition

The baseline condition is an existing conventional well (with an API number prior to September 11th, 2014) with rod pumps operating on time clock controls or less efficient control devices.

21.3.1.3 High-Efficiency Condition

The efficient condition is the same well, retrofitted with a pump-off controller.

21.3.2 Energy and Demand Savings Methodology

21.3.2.1 Savings Algorithms and Input Variables

Two main sources were referenced to develop the savings methods for the POC measure: Electrical Savings in Oil Production (SPE 16363),[719] which identified a relationship between volumetric efficiency and pump run times, and the 2006-2008 Evaluation Report for PG&E Fabrication, Process, and Manufacturing Contract Group,[720] which showed a reduction in savings from the SPE 16363 paper. These two methods were the basis of the current savings calculations and deemed inputs listed below.

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[717] Fluid pounding occurs when the downhole pump rate exceeds the production rate of the formation. The pump strikes the top of the fluid column on the downstroke causing extreme shock loading of the components which can result in premature equipment failure.

[718] The API number is a unique, permanent identifier assigned by the American Petroleum Institute. The API number should correspond to a well that was in existence prior to the date of PUCT Docket 42551.

[719] Bullock, J.E. "SPE 16363 Electrical Savings in Oil Production," (paper presented at the Society of Petroleum Engineers California Regional Meeting held in Ventura, California, April 8-10, 1987).

[720] 2006-2008 Evaluation Report for PG&E Fabrication, Process and Manufacturing Contract Group. Calmac Study ID: CPU0017.01. Itron, Inc. Submitted to California Public Utilities Commission. February 3, 2010.

Energy Savings

Energy Savings Algorithm

Deemed savings are calculated based on the following algorithms:

$$\boldsymbol{Energy\ Savings\ [kWh] = kW_{avg} * (TimeClock\%On - POC\%On) * 8,760}$$

Equation 21.3-1

The inputs for the energy and peak coincident demand savings are listed below:

$$\boldsymbol{kW_{avg} = HP \times 0.746 \times \frac{\frac{LF}{ME}}{SME}}$$

Equation 21.3-2

$$\boldsymbol{POC\%On = \frac{Run_{Constant} + Run_{Coefficient} \times VolumetricEfficiency\% \times TimeClock\%On \times 100}{100}}$$

Equation 21.3-3 4[721]

Where:

kW_{avg} = *The demand used by each rod pump.*

HP = *Rated pump motor horsepower.*

0.746 = *Constant to convert from HP to kW.*

LF = *Motor load factor – ratio of average demand to maximum demand; see* Table 21.3-1.

ME = *Motor efficiency, based on NEMA Standard Efficiency Motor; see Table 21.3-2.*

SME = *Mechanical efficiency of sucker rod pump; see Table 21.3-1.*

TimeClock%On = *Stipulated baseline timeclock setting; see Table 21.3-1.*

$Run_{constant}$ = *8.336, derived from SPE 16363.*[722]

$Run_{coefficient}$ = *0.956, derived from SPE 16363.*[723]

VolumetricEfficiency% = *Average well gross production divided by theoretical production (provided on rebate application).*

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[721] This equation from the petition deviates from that in SPE 16363 but will provide conservative savings estimates. The equation will be updated and made consistent when this measure is updated with field data. The correct equation term is ($Run_{contstant}$ + $Run_{coefficient}$ * VolumetricEfficiency%) with the volumetric efficiency expressed as percent value not a fraction (i.e., 25 not 0.25 for 25%).

[722] Bullock, J.E. "SPE 16363 Electrical Savings in Oil Production," (paper presented at the Society of Petroleum Engineers California Regional Meeting held in Ventura, California, April 8-10, 1987).

[723] Ibid.

Table 21.3-1: [Pump-Off Controllers] Deemed Variables for Energy and Demand Savings Calculations

Variable	Deemed Values
LF (Load Factor)	25%[724]
ME (motor efficiency)	See Table 21.3-2
SME (pump mechanical efficiency)	95%[725]
Timeclock%On	65%[726]

Table 21.3-2: [Pump-Off Controllers] NEMA Premium Efficiency Motor Efficiencies[727]

Motor Horsepower	Nominal Full Load Efficiency					
	Open Motors (ODP)			Enclosed Motors (TEFC)		
	6 poles	4 poles	2 poles	6 poles	4 poles	2 poles
	1200 rpm	1800 rpm	3600 rpm	1200 rpm	1800 rpm	3600 rpm
15	91.7%	93.0%	90.2%	91.7%	92.4%	91.0%
20	92.4%	93.0%	91.0%	91.7%	93.0%	91.0%
25	93.0%	93.6%	91.7%	93.0%	93.6%	91.7%
30	93.6%	94.1%	91.7%	93.0%	93.6%	91.7%
40	94.1%	94.1%	92.4%	94.1%	94.1%	92.4%
50	94.1%	94.5%	93.0%	94.1%	94.5%	93.0%
60	94.5%	95.0%	93.6%	94.5%	95.0%	93.6%
75	94.5%	95.0%	93.6%	94.5%	95.4%	93.6%
100	95.0%	95.4%	93.6%	95.0%	95.4%	94.1%
125	95.0%	95.4%	94.1%	95.0%	95.4%	95.0%
150	95.4%	95.8%	94.1%	95.8%	95.8%	95.0%
200	95.4%	95.8%	95.0%	95.8%	96.2%	95.4%

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[724] Comprehensive Process and Impact Evaluation of the (Xcel Energy) Colorado Motor and Drive Efficiency Program, FINAL. TetraTech. March 28, 2011. Adjusted based on Field Measurements provided by ADM Associates, based on 2010 custom projects.

[725] Engineering estimate for standard gearbox efficiency.

[726] A TimeClock%On of 80% is typical from observations in other jurisdictions, but that was adjusted to 65% for a conservative estimate.

[727] DOE Final Rule regarding energy conservation standards for electric motors. 79 FR 30933. Full-Load Efficiencies for General Purpose Electric Motors [Subtype I] https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=6&action=viewlive.

Demand Savings Algorithm

$$\boldsymbol{Demand\ Savings\ [kW] = \frac{EnergySavings}{8,760}}$$

Equation 21.3-5[728]

Load Shapes

Because the operation of the POC coincident with the peak demand period is uncertain, a simple average of the total savings over the full year (8,760 hours) is used, as shown in Equation 21.3-5.

21.3.2.2 Deemed Energy Savings Tables

There are no deemed savings tables for this measure.

21.3.2.3 Deemed Summer Demand Savings Tables

There are no deemed savings tables for this measure.

21.3.2.4 Additional Calculators and Tools

There are no calculators for this measure.

21.3.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years for pump-off controllers.[729]

21.3.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Motor manufacturer
- Motor model number
- Rated motor horsepower
- Motor type (TEFC or ODP)
- Rated motor RPM
- Baseline control type and timeclock % on time (or actual on-time schedule)
- Volumetric efficiency
- Field data on actual energy use and post-run times if available

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[728] The equations in the petition for peak demand simplify to the equation shown.

[729] CPUC 2006-2008 Industrial Impact Evaluation "SCIA_06-08_Final_Report_Appendix_D-5": An EUL of 15 years was used for the ex-post savings, consistent with the SPC – Custom Measures and System Controls categories in the CPUC Energy Efficiency Policy Manual (Version 2) and with DEER values for an energy management control system.

21.4 ENERGY STAR® POOL PUMPS

21.4.1 Measure Description

This measure involves the replacement of a single-speed pool pump with an ENERGY STAR-certified variable speed pool pump.

21.4.1.1 Eligibility Criteria

This measure applies to all commercial applications, indoor or outdoor, with a pump size up to 3 hp; larger sizes should be implemented through a custom program. Motor-only retrofits are not eligible. Ineligible pump products include waterfall, integral cartridge filter, integral sand filter, storable electric spa, and rigid electric spa.[730]

Multi-speed pool pumps are not permitted. The multi-speed pump uses an induction motor that functions as two motors in one, with full-speed and half-speed options. Multi-speed pumps may enable significant energy savings. However, if the half-speed motor is unable to complete the required water circulation task, the larger motor will operate exclusively. Having only two speed-choices limits the ability of the pump motor to fine-tune the flow rates required for maximum energy savings.[731] The default pump curves provided in the ENERGY STAR Pool Pump Savings Calculator indicate that the motor operating at half-speed will be unable to meet the minimum turnover requirements for commercial pool operation as mandated by Texas Administrative Code.

21.4.1.2 Baseline Condition

The baseline condition is a [1]-3 horsepower (HP) standard efficiency single-speed pool pump.

21.4.1.3 High Efficiency Condition

The high efficiency condition is a 1-3 HP ENERGY STAR certified variable speed pool pump.

21.4.2 Energy and Demand Savings Methodology

Savings for this measure are based on methods and input assumptions from the ENERGY STAR Pool Pump Savings Calculator. ENERGY STAR has not published updates to the calculator for version 2.0 and therefore the deemed input assumptions that follow are based on certification version 1.0. This measure will be updated when the ENERGY STAR Pool Pump Savings Calculator is updated to version 2.0.

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[730] These pump products are ineligible for ENERGY STAR v3.0 certification: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%203.0%20Pool%20Pumps%20Specification.pdf.

[731] Hunt, A. & Easley, S., 2012, "Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings." Building America Retrofit Alliance (BARA), U.S. U.S. DOE. May/. http://www.nrel.gov/docs/fy12osti/54242.pdf.

21.4.2.1 Savings Algorithms and Input Variables

Energy Savings

Energy Savings Algorithm

Energy savings for this measure were derived using the ENERGY STAR Pool Pump Savings Calculator.[732]

$$\boldsymbol{kWh_{Savings} = kWh_{conv} - kWh_{ES}}$$

Equation 21.4-1

Where:

kWh_{conv} = *Conventional single-speed pool pump energy (kWh)*

kWh_{ES} = *ENERGY STAR variable speed pool pump energy (kWh)*

Algorithms to calculate the above parameters are defined as:

$$\boldsymbol{kWh_{conv} = \frac{PFR_{conv} \times 60 \times hours \times days}{EF_{conv} \times 1,000}}$$

Equation 21.4-2

$$\boldsymbol{kWh_{ES} = \frac{gal \times turn_{day} \times days}{EF_{ES} \times 1,000}}$$

Equation 21.4-3

Where:

$hours$ = *Pump daily operating hours; see Table 21.4-1.*

$days$ = *Operating days per year = Year-round operation: 365 days; Seasonal operation: 7 months x 30.4 days/month = 212.8 days (default).*

PFR_{conv} = *Conventional single-speed pump flow rate [gal/min]; see Table 21.4-1.*

EF_{conv} = *Conventional single-speed pump energy factor [gal/W·hr]; see Table 21.4-1.*

EF_{ES} = *ENERGY STAR weighted energy factor [gal/W·hr]; see Table 21.4-2.*

gal = *Pool volume; see Table 21.4-2.*

$turn_{day}$ = *Turnovers per day, or number of times the volume of the pool is run through the pump per day; see Table 21.4-2.*

60 = *Constant to convert between minutes and hours.*

1,000 = *Constant to convert from watts to kilowatts.*

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[732] The ENERGY STAR Pool Pump Savings Calculator, updated May 2020, can be found on the ENERGY STAR website at: https://www.energystar.gov/productfinder/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx.

Table 21.4-1: [Pool Pumps] Conventional Pool Pump Assumptions[733]

New Rated Pump HP	hour Limited[734]	hours 24/7	PFR_{conv} (gal/min)	EF_{conv} (gal/W·h)
≤ 1.25	12	24	75.5000	2.5131
1.25 < hp ≤ 1.75			78.1429	2.2677
1.75 < hp ≤ 2.25			88.6667	2.2990
2.25 < hp ≤ 2.75			93.0910	2.1812
2.75 < hp ≤ 3			101.6667	1.9987

Table 21.4-2: [Pool Pumps] ENERGY STAR Pool Pump Assumptions[735]

Rated Pump (hp)	Gal	$Turn_{day}$ Limited	$Turn_{day}$ 24/7	EF_{ES} (gal/W·h)
≤ 1.25	20,000	2.7	5.4	8.7
1.25 < hp ≤ 1.75	20,000	2.8	5.6	8.9
1.75 < hp ≤ 2.25	22,000	2.9	5.8	9.3
2.25 < hp ≤ 2.75	25,000	2.7	5.4	7.4
2.75 < hp ≤ 3	28,000	2.6	5.2	7.1

Demand Savings

Demand Savings Algorithm

$$kW_{Savings} = \frac{kWh_{conv} - kWh_{ES}}{hours} \times \frac{DF}{days}$$

Equation 21.4-4

Where:

DF = *Demand Factor from Table 21.4-3.*

---

[733] Conventional pump PFR and EF values are taken from pump curves found in the ENERGY STAR Pool Pump Savings Calculator.

[734] Limited Hours assumes that pump operating hours are 12 hours per day, based on 2016 commercial pool pump program data reviewed by the Texas Evaluation Contractor.

[735] ENERGY STAR PFR and EF values are taken from pump curves found in the ENERGY STAR Pool Pump Savings Calculator.

Table 21.4-3: [Pool Pumps] Demand Factors

Operation	Summer DF
24/7 Operation	1.0
Seasonal/Limited Hours	1.0

Load Shapes

21.4.2.2 Deemed Energy Savings Tables

Table 21.4-4: [Pool Pumps] Deemed Energy Savings[736]

New Rated Pump HP	Year-Round Operation		Seasonal Operation (7 months)
	24/7 Operation	Limited Hours	
	kWh Savings	kWh Savings	kWh Savings
≤ 1.25	11,259	5,630	3,282
1.25 < hp ≤ 1.75	13,518	6,759	3,941
1.75 < hp ≤ 2.25	15,263	7,632	4,449
2.25 < hp ≤ 2.75	15,773	7,887	4,598
2.75 < hp ≤ 3	19,250	9,625	5,612

21.4.2.3 Deemed Demand Savings Tables

Table 21.4-5: [Pool Pumps] Deemed Summer Demand Savings—For All Operating Profiles

New Rated Pump (HP)	Demand Savings (kW)
≤ 1.25	0.749
1.25 < hp ≤ 1.75	0.900
1.75 < hp ≤ 2.25	1.016
2.25 < hp ≤ 2.75	1.050
2.75 < hp ≤ 3	1.281

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[736] The results in this table may vary slightly from results produced by the ENERGY STAR calculator because of rounding of default savings coefficients throughout the measure and pool volume.

21.4.2.4 Additional Calculators and Tools

ENERGY STAR Pool Pump Savings Calculator, updated May 2020, can be found on the ENERGY STAR website at: https://www.energystar.gov/products/certified-products/detail/pool-pumps.

21.4.2.5 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years for pool pumps, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID OutD-PoolPump.[737]

21.4.2.6 Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- For all projects collect:
  - Manufacturer and model number of new pool pump
  - Rated pool pump horsepower
  - Proof of purchase – with date of purchase, quantity, and model
    - Alternative: photo of unit installed or other pre-approved method of installation verification
  - ENERGY STAR certification
  - Facility operation schedule (24/7, year-round limited hours, seasonal)
- For a significant sample of projects where attainable (e.g., those projects that are selected for inspection, not midstream or retail programs)
  - Decision/action type (early retirement, replace-on-burnout, or new construction)
  - Rated horsepower of existing pool pump
  - Existing and new pump operating hours

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[737] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

21.5 COMPUTER POWER MANAGEMENT

21.5.1 Measure Description

This measure presents deemed savings for implementation of computer power management strategies. Computer power management includes the use of operational settings that automate the power management features of computer equipment, including automatically placing equipment into a low power mode during periods of inactivity. This may be done either with built-in features integral to the computer operating system or through an add-on software program. Typically, this measure is implemented across an entire network of computers.

21.5.1.1 Eligibility Criteria

To be eligible for this measure, computers must not have any automatic sleep or other low power setting in place. Both conventional and ENERGY STAR computer equipment is eligible for this measure. Applicable building types include offices and schools.

21.5.1.2 Baseline Condition

The baseline conditions are the estimated number of hours that the computer spends in active, sleep, and off modes before the power settings are actively managed. Operating hours may be estimated from metering, or the default hours provided in the calculation of deemed savings may be used. The default baseline hours are taken from the ENERGY STAR modeling study assumptions contained in the Low Carbon IT Savings Calculator,[738] and assume baseline computer settings never enter sleep mode, and 60% of computers are turned off each night.[739]

21.5.1.3 High Efficiency Condition

The efficient conditions are the estimated number of hours that the computer spends in active, sleep, and off modes after the power settings are actively managed. Operating hours may be estimated from metering, or the default hours provided in the calculation of deemed savings may be used. The default efficient hours are taken from the ENERGY STAR modeling study assumptions contained in the Low Carbon IT Savings Calculator and assume managed computer settings enter sleep mode after 15 minutes of inactivity, and 80% of computers are turned off each night.[740]

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[738] ENERGY STAR Low Carbon IT Calculator available for download at: https://www.energystar.gov/products/low_carbon_it_campaign/put_your_computers_sleep.

[739] Based on 2015 custom project metering from El Paso Electric.

[740] Based on 2015 custom project metering from El Paso Electric.

21.5.2 Energy and Demand Savings Methodology

21.5.2.1 Savings Algorithms and Input Variables

Energy Savings Algorithm

$$kWh_{savings} = \frac{W_{active}\left(\mathrm{hrs}_{\mathrm{active,pre}} - \mathrm{hrs}_{\mathrm{active,post}}\right) + W_{sleep}\left(\mathrm{hrs}_{\mathrm{sleep,pre}} - \mathrm{hrs}_{\mathrm{sleep,post}}\right) + W_{off}\left(\mathrm{hrs}_{\mathrm{off,pre}} - \mathrm{hrs}_{\mathrm{off,post}}\right)}{1,000}$$

Equation 21.5-1

Demand Savings Algorithm

$$kW_{savings} = \frac{\left(W_{active} - W_{sleep}\right) \times DF_{inactive}}{1,000}$$

Equation 21.5-2

Where:

W_{active} = *total wattage of the equipment, including computer and monitor, in active/idle mode; see Table 21.5-1.*

$hrs_{active,pre}$ = *annual number of hours the computer is in active/idle mode before computer management software is installed; see Table 21.5-2.*

$hrs_{active,post}$ = *annual number of hours the computer is in active/idle mode after computer management software is installed; see Table 21.5-2.*

W_{sleep} = *total wattage of the equipment, including computer and monitor, in sleep mode; see Table 21.5-1.*

$hrs_{sleep,pre}$ = *annual number of hours the computer is in sleep mode before computer management software is installed; see Table 21.5-2.*

$hrs_{sleep,post}$ = *annual number of hours the computer is in sleep mode after computer management software is installed; see Table 21.5-2.*

W_{off} = *total wattage of the equipment, including computer and monitor, in off mode; see Table 21.5-1.*

$hrs_{off,pre}$ = *annual number of hours the computer is in off mode before computer management software is installed; see Table 21.5-2.*

$hrs_{off,post}$ = *annual number of hours the computer is in off mode after computer management software is installed; see Table 21.5-2.*

1,000 = *Constant to convert from watts to kilowatts.*

$DF_{inactive}$ = *Demand factor for inactive hours (sleep and off); see Table 21.5-3.*

Table 21.5-1: [Computer Power Management] Equipment Wattages[741]

Equipment	W_{active}	W_{sleep}	W_{off}
Conventional Monitor[742]	18.30	0.30	0.30
Conventional Computer	48.11	2.31	0.96
Conventional Notebook (including display)	14.82	1.21	0.61
ENERGY STAR Monitor	15.00	0.26	0.26
ENERGY STAR Computer	27.11	1.80	0.81
ENERGY STAR Notebook (including display)	8.61	0.89	0.46

Table 21.5-2: [Computer Power Management] Operating Hours[743]

Building Activity Type	$hrs_{active,pre}$	$hrs_{active,post}$	$hrs_{sleep,pre}$	$hrs_{sleep,post}$	$hrs_{off,pre}$	$hrs_{off,post}$
Typical office (8 hours/day, 5 days/week, 22 non-workdays/year)	4,650	1,175	-	2,105	4,110	5,480
Typical school (8 hours/day, 5 days/week, 113 non-school days/year)	4,213	727	-	1,970	4,547	6,063

Table 21.5-3: [Computer Power Management] Demand Factors[744]

Demand Factors	$DF_{inactive}$
NCP	1.00
CP	0.36
4CP	0.75

Load Shapes

The load shapes for this measure were taken from the ENERGY STAR Low Carbon IT calculator modeling profile,

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[741] Equipment wattages taken from the Low Carbon IT Savings Calculator. https://www.energystar.gov/sites/default/files/asset/document/LowCarbonITSavingsCalc.xlsx.

[742] Average of 17.0-24.9 inches monitor sizes taken from the ENERGY STAR Office Equipment Calculator.

[743] Hours taken from assumptions in the ENERGY STAR calculator. $Hours_{pre}$ assume baseline computer settings never enter sleep mode, and 60% of computers are turned off each night. $Hours_{post}$ assume managed computer settings enter sleep mode after 15 minutes of inactivity, and 80% of computers are turned off each night.

[744] Coincident Peak (CP), Non-coincident Peak (NCP) and ERCOT 4 Coincident Peak (4CP) demand factors are calculated in accordance with the definitions provided in Section 2.3 of this document. All are estimated according to specific hours of the load shape that correspond to the relevant peak period.

with computer settings to enter sleep mode after 15 minutes of inactivity. Office load shapes assume the same daily profile throughout the year.

21.5.2.2 Deemed Energy and Demand Savings Tables

Table 21.5-4: [Computer Power Management] Deemed Energy and Demand Savings: Office and School

Equipment	kWh	NCP kW	CP kW	4CP kW
Conventional Monitor	62.6	0.018	0.006	0.014
Conventional Computer	161.4	0.046	0.016	0.034
Conventional Notebook (including display)	48.2	0.014	0.005	0.010
ENERGY STAR Monitor	51.3	0.015	0.005	0.011
ENERGY STAR Computer	89.5	0.025	0.009	0.019
ENERGY STAR Notebook (including display)	27.5	0.008	0.003	0.006

21.5.2.3 Additional Calculators and Tools

This section is not applicable for this measure.

21.5.2.4 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 3 years for computer power management based on the useful life of the computer equipment being controlled.[745]

21.5.3 Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Equipment type:
    - Conventional or ENERGY STAR
    - Monitor, computer, or notebook
- Application type (office, school)

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[745] Internal Revenue Service, 1.35.6.4 (09-27-2019), Property and Equipment Capitalization, Useful life for Laptop and Desktop Equipment. https://www.irs.gov/irm/part1/irm_01-035-006.

21.6 PREMIUM EFFICIENCY MOTORS

21.6.1 Measure Description

Currently a wide variety of National Electrical Manufacturers Association (NEMA) premium efficiency motors from 1 to 500 horsepower (hp) are available. Deemed saving values for demand and energy savings associated with this measure must be for electric motors with an equivalent operating period (hours x load factor) over 1,000 hours.

21.6.1.1 Eligibility Criteria

To qualify for early retirement, the premium efficiency unit must replace an existing, full-size unit with a maximum age of 16 years. To determine the remaining useful life of an existing unit; see Table 21.6-5. To receive early retirement savings, the unit to be replaced must be functioning at the time of removal.

21.6.1.2 Baseline Condition and High Efficiency Conditions

New Construction or Replace-on-Burnout

The EISA 2007 Sec 313 adopted the new federal standard and required that electric motors that are manufactured and sold in the United States on or after December 19, 2010, to before June 1, 2016, shall have a nominal full-load efficiency that is not less than the values found in Table 21.6-4 with increased efficiency requirements for 250-500 hp motors as of June 1, 2016. These standards replace legislation commonly referred to as EPAct 1992 (the Federal Energy Policy Act of 1992). The standards can also be found in section 431.25 of the Code of Federal Regulations (10 CFR Part 431).[746]

With these changes, any 1-500 hp motor bearing the “NEMA Premium" trademark will align with national energy efficiency standards and legislation. The Federal Energy Management Program (FEMP) adopted NEMA MG 1-2006 Revision 1 2007 in its Designated Product List for federal customers.

Additionally, NEMA Premium standards include general purpose electric motors, subtype II (i.e., motors ranging from 1-200 hp and 200-500hp) including:

- U-Frame Motors
- Design C Motors
- Close-coupled pump motors
- Footless motors
- Vertical solid shaft normal thrust (tested in a horizontal configuration)
- 8-pole motors
- All poly-phase motors with voltages up to 600 volts other than 230/460 volts (230/460-volt motors are covered by EPAct-92)

Under these legislative changes, 200-500 hp and Subtype II motors baselines are to be based on the

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[746] Federal Standards for Electric Motors, Table 1: Nominal Full-Load Efficiencies of General Purpose Electric Motors (Subtype I), Except Fire Pump Electric Motors, https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#sp10.3.431.b.

minimum efficiency allowed under the EPAct[747] (Table 21.6-4) and are thus no longer equivalent to pre-1992/pre-EPAct defaults.

Early Retirement

The baseline for early retirement projects is the nameplate efficiency of the existing motor to be replaced, if known. If the nameplate is illegible and the in-situ efficiency cannot be determined, then the baseline should be based on the minimum efficiency allowed under the EPAct,[748] as listed in Table 21.6-6.

NEMA Premium Efficiency motor levels continue to be industry standard for minimum-efficiency levels. The savings calculations assume that the minimum motor efficiency for replacement motors for both replace-on-burnout and early retirement projects exceeds that listed in Table 21.6-4.

For early retirement, the maximum age of an eligible piece of equipment is capped at the point at which it is expected that 75 percent of the equipment has failed (17 years). In situations where the age of the unit exceeds the 75 percent failure age, ROB savings should be applied. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure. 1-200 hp motors manufactured as of December 19, 2020 and 250-500 hp motors manufactured as of June 1, 2016 are not eligible for early retirement.

21.6.2 Energy and Demand Savings Methodology

Actual motor operating hours are expected to be used to calculate savings. Every effort should be made to capture the estimated operating hours. Short and/or long-term metering can be used to verify estimates. If metering is not possible, interviews with facility operators and review of operations logs should be conducted to obtain an estimate of actual operating hours. If there is not sufficient information to accurately estimate operating hours, then the annual operating hours in Table 21.6-1 or Table 21.6-2 can be used.

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[747] Federal Standards for Electric Motors, Table 4: Nominal Full-Load Efficiencies of NEMA Design B General Purpose Electric Motors (Subtype I and II), Except Fire Pump Electric Motors, https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#sp10.3.431.b.

[748] Federal Standards for Electric Motors, Tables 3 (≤ 200 hp), and 4 (> 200hp), https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#sp10.3.431.b.

21.6.2.1 Savings Algorithms and Input Variables

New Construction or Replace-on-Burnout

Energy Savings Algorithms

$$kWh_{savings,ROB} = hp \times 0.746 \times LF \times \left(\frac{1}{\eta_{baseline,ROB}} - \frac{1}{\eta_{post}}\right) \times Hours$$

Equation 21.6-1

Demand Savings Algorithms

HVAC Applications:

$$kW_{savings,ROB} = \left(\frac{kWh_{savings,ROB}}{Hours}\right) \times DF$$

Equation 21.6-2

Industrial Applications[749]:

$$kW_{savings,ROB} = \left(\frac{kWh_{savings,ROB}}{8{,}760}\right)$$

Equation 21.6-3

Where:

hp = *Nameplate horsepower data of the motor.*

0.746 = *Constant to convert from hp to kWh.*[750]

LF = *Estimated load factor; if unknown, see Table 21.6-1 or Table 21.6-2.*

$\eta_{baseline,ROB}$ = *Assumed original motor efficiency [%]; see Table 21.6-4.*[751]

η_{post} = *Efficiency of the newly installed motor [%].*

$Hours$ = *Estimated annual operating hours; if unknown, see Table 21.6-1 or Table 21.6-2.*

DF = *Demand Factor for NCP, CP, or 4CP peak demand; see Table 21.6-1.*

$kWh_{savings,ROB}$ = *Total energy savings for a new construction or ROB project.*

$kW_{savings,ROB}$ = *Total demand savings for a new construction or ROB project.*

8,760 = *Total hours per year.*

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[749] Assumes 3-shift operating schedule.

[750] U.S. DOE, Technical Support Document, "Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors, 10.2.2.1 Motor Capacity." Download TSD at: https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf.

[751] In the case of rewound motors, in-situ efficiency may be reduced by a percentage as found in Table 21.6-3.

Table 21.6-1: [Premium Motors] HVAC Assumptions by Building Type

Building Type	Load Factor[752]	DF[753]	HVAC Fan Hours[754]
Hospital	0.75	1.00	8,760
Large Office (>30k SqFt)			4,424
Small Office (≤30k SqFt)			4,006
K-12 School			4,173
College			4,590
Retail			5,548
Restaurant (Fast Food)			6,716
Restaurant (Sit-Down)			5,256

Table 21.6-2: [Premium Motors] Industrial Assumptions by Building Type

Industrial Processing (hp)	Load Factor[755]	Hours[756]					
		Chem	Paper	Metals	Petroleum Refinery	Food Production	Other
1-5	0.54	4,082	3,997	4,377	1,582	3,829	2,283
6-20	0.51	4,910	4,634	4,140	1,944	3,949	3,043
21-50	0.60	4,873	5,481	4,854	3,025	4,927	3,530
51-100	0.54	5,853	6,741	6,698	3,763	5,524	4,732
101-200	0.75	5,868	6,669	7,362	4,170	5,055	4,174
201-500	0.58	5,474	6,975	7,114	5,311	3,711	5,396
501-1,000	0.58	7,495	7,255	7,750	5,934	5,260	8,157
> 1,000	0.58	7,693	8,294	7,198	6,859	6,240	2,601

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[752] Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25. http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf.

[753] Commercial Prototype Building Models HVAC operating schedules for hours ending 15-18. U.S. Department of Energy. https://www.energycodes.gov/development/commercial/prototype_models.

[754] Assumed equivalent to 13.6 HVAC Variable Frequency Drive Hours per Building Type

[755] United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-19. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf.

[756] United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-15. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf.

Table 21.6-3: [Premium Motors] Rewound Motor Efficiency Reduction Factors[757]

Motor Horsepower	Efficiency Reduction Factor
< 40	0.010
≥ 40	0.005

Table 21.6-4: [Premium Motors] New Construction and Replace-on-Burnout Baseline Efficiencies by Motor Size (%)[758,759]

hp	Open Motors: $\eta_{\text{baseline, ROB}}$			Closed Motors: $\eta_{\text{baseline, ROB}}$		
	6-Pole	4-Pole	2-Pole	6-Pole	4-Pole	2-Pole
1	82.5	85.5	77.0	82.5	85.5	77.0
1.5	86.5	86.5	84.0	87.5	86.5	84.0
2	87.5	86.5	85.5	88.5	86.5	85.5
3	88.5	89.5	85.5	89.5	89.5	86.5
5	89.5	89.5	86.5	89.5	89.5	88.5
7.5	90.2	91.0	88.5	91.0	91.7	89.5
10	91.7	91.7	89.5	91.0	91.7	90.2
15	91.7	93.0	90.2	91.7	92.4	91.0
20	92.4	93.0	91.0	91.7	93.0	91.0
25	93.0	93.6	91.7	93.0	93.6	91.7
30	93.6	94.1	91.7	93.0	93.6	91.7
40	94.1	94.1	92.4	94.1	94.1	92.4
50	94.1	94.5	93.0	94.1	94.5	93.0
60	94.5	95.0	93.6	94.5	95.0	93.6
75	94.5	95.0	93.6	94.5	95.4	93.6
100	95.0	95.4	93.6	95.0	95.4	94.1
125	95.0	95.4	94.1	95.0	95.4	95.0

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[757] U.S. DOE, Technical Support Document, "Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors, 8.2.2.1 Annual Energy Consumption." Download TSD at: https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf.

[758] Ibid.

[759] Federal Standards for Electric Motors, Tables 1 and 5, https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#sp10.3.431.b.

hp	Open Motors: $\eta_{baseline, ROB}$			Closed Motors: $\eta_{baseline, ROB}$		
	6-Pole	4-Pole	2-Pole	6-Pole	4-Pole	2-Pole
150	95.4	95.8	94.1	95.8	95.8	95.0
200	95.4	95.8	95.0	95.8	96.2	95.4
250	95.8	95.8	95.0	95.8	96.2	95.8
300	95.8	95.8	95.4	95.8	96.2	95.8
350	95.8	95.8	95.4	95.8	96.2	95.8
400	n/a	95.8	95.8	n/a	96.2	95.8
450	n/a	96.2	96.2	n/a	96.2	95.8
500	n/a	96.2	96.2	n/a	96.2	95.8

Early Retirement

Annual energy (kWh) and peak demand (kW) savings must be calculated separately for two time periods:

3. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
4. The remaining time in the EUL period (EUL—RUL)

Annual energy and peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in Section 22.3.

Where:

RUL = *Remaining Useful Life; see Table 21.6-5. If unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 2.0 years.*

EUL = *Estimated Useful Life = 15 years*

Table 21.6-5: [Premium Motors] Remaining Useful Life (RUL) of Replaced Motor[760]

Age of Replaced Motor (years)	RUL (years)	Age of Replaced Motor (years)	RUL (years)
1	13.9	10	5.0
2	12.9	11	4.2
3	11.9	12	3.6
4	10.9	13	3.0
5	9.9	14	2.5
6	8.9	15	2.0
7	7.9	16	1.0
8	6.9	17[761]	0.0
9	5.9		

Derivation of RULs

Premium Efficiency Motors have an estimated useful life of 15 years. This estimate is consistent with the age at which approximately 50 percent of the motors installed in a given year will no longer be in service, as described by the survival function for a general fan or air compressor application in Figure 21.6-1.

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[760] Current federal standard effective date is 12/19/2010. Existing systems manufactured after this date are not eligible to use the early retirement baseline.

[761] RULs are capped at the 75th percentile of equipment age, 17 years, as determined based on DOE survival curves (see Figure 21.6-1). Systems older than 17 years should use the ROB baseline. See the January 2015 memo, “Considerations for early replacement of residential equipment,” for further detail.

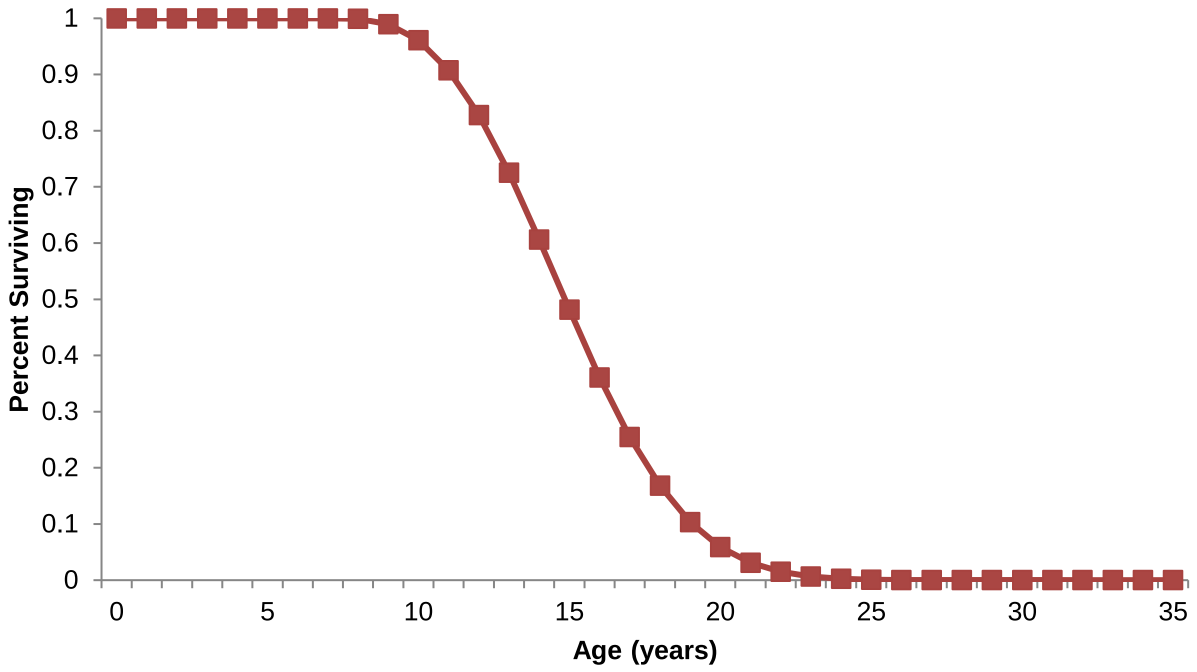

Figure 21.6-1: [Premium Motors] Survival Function[762]

The method for estimating the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 21.6-1. The age of the motor being replaced is found on the horizontal axis, and the corresponding percentage of surviving motors is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. Then, the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For example, assume a motor being replaced is 15 years old (the estimated useful life). The corresponding percent surviving value is approximately 50 percent. Half of 50 percent is 25 percent. The age corresponding to 25 percent on the chart is approximately 17 years. Therefore, the RUL of the motor being replaced is (17 – 15) = 2 years.

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[762] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf.

Energy Savings Algorithms

For the RUL period:

$$kWh_{savings,RUL} = hp \times 0.746 \times LF \times \left(\frac{1}{\eta_{baseline,ER}} - \frac{1}{\eta_{post}}\right) \times Hrs$$

Equation 21.6-4

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project.

$$kWh_{savings,EUL} = hp \times 0.746 \times LF \times \left(\frac{1}{\eta_{baseline,ROB}} - \frac{1}{\eta_{post}}\right) \times Hrs$$

Equation 21.6-5

It follows that total lifetime energy savings for early retirement projects are then determined by adding the savings calculated under the two preceding equations:

$$kWh_{savings,ER} = kWh_{savings,RUL} \times RUL + kWh_{savings,EUL} \times (EUL - RUL)$$

Equation 21.6-6

Demand Savings Algorithms

To calculate demand savings for the early retirement of a motor, a similar methodology is used as for replace-on-burnout installations, with separate savings calculated for the remaining useful life of the unit, and the remainder of the EUL as outlined in the section above.

For the RUL period:

HVAC Applications:

$$kW_{savings,RUL} = \frac{kWh_{savings,RUL}}{Hrs} \times CF$$

Equation 21.6-7

Industrial Applications:

$$kW_{savings,RUL} = \frac{kWh_{savings,RUL}}{8{,}760}$$

Equation 21.6-8

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project:

HVAC Applications:

$$kW_{savings,EUL} = \frac{kWh_{savings,EUL}}{Hrs} \times CF$$

Equation 21.6-9

Industrial Applications:

$$kW_{savings,EUL} = \frac{kWh_{savings,EUL}}{8{,}760}$$

Equation 21.6-10

Annual deemed peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in Section 22.3.

$$kW_{\ savings,ER} = \ kW_{savings,RUL} \ \times RUL + \ kW_{savings,EUL} \ \times (EUL - RUL)$$

Equation 21.6-11

Where:

$\eta_{baseline,ER}$ = *Assumed original motor efficiency for RUL period; if unknown, see Table 21.6-6 or Table 21.6-7.*[763]

$kWh_{savings,RUL}$ = *Energy savings for RUL period in an ER project.*

$kWh_{savings,EUL}$ = *Energy savings for remaining EUL period in an ER project.*

$kW_{savings,RUL}$ = *Demand savings for RUL period in an ER project.*

$kW_{savings,EUL}$ = *Demand savings for remaining EUL period in an ER project.*

$kWh_{savings,ER}$ = *Total energy savings for an ER project.*

$kW_{savings,ER}$ = *Total demand savings for an ER project.*

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[763] Ibid.

Table 21.6-6: [Premium Motors] Early Retirement Baseline Efficiencies by Motor Size for 1-200 hp Motors Manufactured Prior to December 19, 2010 (%)[764]

hp	Open Motors: $\eta_{baseline, ER}$			Closed Motors: $\eta_{baseline, ER}$		
	6-Pole	4-Pole	2-Pole	6-Pole	4-Pole	2-Pole
1	80.0	82.5	75.5	80.0	82.5	75.5
1.5	84.0	84.0	82.5	85.5	84.0	82.5
2	85.5	84.0	84.0	86.5	84.0	84.0
3	86.5	86.5	84.0	87.5	87.5	85.5
5	87.5	87.5	85.5	87.5	87.5	87.5
7.5	88.5	88.5	87.5	89.5	89.5	88.5
10	90.2	89.5	88.5	89.5	89.5	89.5
15	90.2	91.0	89.5	90.2	91.0	90.2
20	91.0	91.0	90.2	90.2	91.0	90.2
25	91.7	91.7	91.0	91.7	92.4	91.0
30	92.4	92.4	91.0	91.7	92.4	91.0
40	93.0	93.0	91.7	93.0	93.0	91.7
50	93.0	93.0	92.4	93.0	93.0	92.4
60	93.6	93.6	93.0	93.6	93.6	93.0
75	93.6	94.1	93.0	93.6	94.1	93.0
100	94.1	94.1	93.0	94.1	94.5	93.6
125	94.1	94.5	93.6	94.1	94.5	94.5
150	94.5	95.0	93.6	95.0	95.0	94.5
200	94.5	95.0	94.5	95.0	95.0	95.0

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[764] Federal Standards for Electric Motors, Table 3, https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#sp10.3.431.b.

Table 21.6-7: [Premium Motors] Early Retirement Baseline Efficiencies by Motor Size for 250-500 hp Motors Manufactured Prior to June 1, 2016 (%)[765]

hp	Open Motors: $\eta_{baseline, ER}$			Closed Motors: $\eta_{baseline, ER}$		
	6-Pole	4-Pole	2-Pole	6-Pole	4-Pole	2-Pole
250	95.4	95.4	94.5	95.0	95.0	95.4
300	95.4	95.4	95.0	95.0	95.4	95.4
350	95.4	95.4	95.0	95.0	95.4	95.4
400	n/a	95.4	95.4	n/a	95.4	95.4
450	n/a	95.8	95.8	n/a	95.4	95.4
500	n/a	95.8	95.8	n/a	95.8	95.4

21.6.2.2 Deemed Energy and Demand Savings Tables

There are no deemed savings tables for this measure.

21.6.2.3 Additional Calculators and Tools

This section is not applicable.

21.6.2.4 Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years for premium efficiency motors.[766]

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[765] Federal Standards for Electric Motors, Table 4, https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#sp10.3.431.b.

[766] U.S. DOE, Technical Support Document, "Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors," Median of "Table 8.2.23 Average Application Lifetime." Download TSD at: https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf.

21.6.3 Program Tracking Data & Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

-
- The project type of the installation (new construction, replace-on-burnout, or early retirement)
- Motor quantity
- Estimated annual operating hours
- Estimated load factor
- Number of poles in and horsepower of original motor
- Newly installed motor horsepower
- Newly installed motor efficiency (%)
- Description of motor service application
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)

22. APPENDICES

22.1 ESTIMATED USEFUL LIFE TABLE

Measure	Estimated Useful Life (years)
4. RESIDENTIAL: LIGHTING	
4.1 ENERGY STAR® Omni-Directional LED Lamps	8-10; see measure
4.2 ENERGY STAR® Specialty and Directional LED Lamps	8-20; see measure
5. RESIDENTIAL: HEATING, VENTILATION, AND AIR CONDITIONING	
5.1 Air Conditioner and Heat Pump Tune-ups	5
5.2 Duct Sealing	18
5.3 ENERGY STAR® Ground Source Heat Pumps	20
5.4 Central Air Conditioners and Heat Pumps	ACs: 18 HPs: 15
5.5 Mini-Split Air Conditioners and Heat Pumps	ACs: 18 HPs: 15
5.6 Large Capacity Split and Packaged Air Conditioners and Heat Pumps	ACs: 18 HPs: 15
5.9 Packaged Terminal Heat Pumps	15
5.8 ENERGY STAR® Room Air Conditioners	10
5.9 ENERGY STAR® Connected Thermostats	11
6. RESIDENTIAL: BUILDING ENVELOPE	
6.1 Air Infiltration	11
6.2 Ceiling Insulation	25
6.3 Attic Encapsulation	25
6.4 Wall Insulation	25
6.5 Floor Insulation	25
6.6 Solar Screens	10
6.7 ENERGY STAR® Cool Roofs	15
7. RESIDENTIAL: WATER HEATING	
7.1 Faucet Aerators	10
7.2 Low-Flow Showerheads	10
7.3 Showerhead Temperature Sensitive Restrictor Valves	10
7.4 Tub Spout and Showerhead Temperature Sensitive Restrictor Valves	10
7.5 Pipe Insulation	13
7.6 Water Heater Tank Insulation	7
7.7 Electric Tankless Water Heater Replacements	20
7.8 ENERGY STAR® Heat Pump Water Heaters	13

Measure	Estimated Useful Life (years)
8. RESIDENTIAL: APPLIANCES	
8.1 ENERGY STAR® Clothes Washers	11
8.2 ENERGY STAR® Dishwashers	15
8.3 ENERGY STAR® Refrigerators	16
8.4 ENERGY STAR® Freezers	22
8.5 Refrigerator/Freezer Recycling	8
8.6 ENERGY STAR® Pool Pumps	10
8.7 ENERGY STAR® Air Purifiers	9
8.8 Advanced Power Strips	10
8.9 ENERGY STAR® Electric Vehicle Supply Equipment (EVSE)	10
9. RESIDENTIAL: RENEWABLE ENERGY	
9.1 Solar Photovoltaic	30
10. RESIDENTIAL: DEMAND RESPONSE/LOAD CONTROL	
10.1 Residential Demand Response	Behavioral: 1 All other Res DR: 10
11. RESIDENTIAL: NEW CONSTRUCTION	
11.1 Residential New Construction	23
12. COMMERCIAL: LIGHTING	
12.1 Lighting Efficiency	1.5-15; see measure
12.2 Lighting Controls	10
13. COMMERCIAL: HEATING, VENTILATION & AIR CONDITIONING	
13.1 Air Conditioner and Heat Pump Tune-	5
13.2 Split and Packaged Air Conditioners and Heat PumpsSplit and Packaged Air Conditioners and Heat Pumps	15
13.3 Chillers	20-25; see measure
13.4 Packaged Terminal Air Conditioners, Packaged Terminal Heat Pumps, and Room Air Conditioners	10-15; see measure
13.5 Computer Room Air Conditioners	15
13.6 HVAC Variable Frequency Drives	15
14. COMMERCIAL: BUILDING ENVELOPE	
14.1 ENERGY STAR® Cool Roofs	15
14.2 Window Treatments	10
14.3 Entrance and Exit Door Air Infiltration	11
15. COMMERCIAL: FOOD SERVICE EQUIPMENT	
15.1 Pre-Rinse Spray Valves	5
15.2 ENERGY STAR® Combination Ovens	12
15.3 ENERGY STAR® Electric Convection Ovens	12
15.4 ENERGY STAR® Dishwashers	10-20; see measure
15.5 ENERGY STAR® Hot Food Holding Cabinets	12
15.6 ENERGY STAR® Electric Fryers	12

Measure	Estimated Useful Life (years)
15.7 ENERGY STAR® Electric Steam Cookers	12
16. COMMERCIAL: REFRIGERATION	
16.1 Door Heater Controls	12
16.2 ECM Evaporator Fan Motors	15
16.3 Electronic Defrost Controls	10
16.4 Evaporator Fan Controls	16
16.5 Night Covers for Open Refrigerated Display Cases	5
16.6 ENERGY STAR® Solid and Glass Door Reach-in Coolers	12
16.7 Strip Curtains for Walk-in Refrigerated Storage	4
16.8 Zero-Energy Doors for Refrigerated Cases	12
16.9 Door Gaskets for Walk-in and Reach-in Coolers and Freezers	3
16.10 High Speed Doors for Cold Storage	5
17. COMMERCIAL: NEW CONSTRUCTION	
17.1 Commercial New Construction	18
18. COMMERCIAL: CUSTOM	
18.1 Commercial Custom	Project specific
19. COMMERCIAL: RENEWABLE ENERGY	
19.1 Commercial and Schools Solar Photovoltaic	30
20. COMMERCIAL: DEMAND RESPONSE/LOAD CONTROL	
20.1 Commercial Demand Response	Options 1, 2, 3, 4: 1 year ADR: 10 years
21. COMMERCIAL: OTHER	
21.1 Lodging Guest Room Occupancy Controls	10
21.2 Vending Machine Controls	5
21.3 Pump-Off Controllers	15
21.4 ENERGY STAR® Pool Pumps	10
21.5 Computer Power Management	3
21.6 Premium Efficiency Motors	15

22.2 LOAD SHAPES

The embedded Microsoft Excel spreadsheet contains the load shapes used in the Guidebook measures.

CPS Load Shapes
02102021.xlsx

22.3 MEASURE LIFE CALCULATIONS FOR EARLY RETIREMENT PROGRAMS

This section describes the method of calculating savings for early retirement programs. While this methodology addresses early retirement installations, it is also applicable to scenarios in which the baseline changes over the lifetime of the measure. This methodology tracks the early retirement calculations approved by the Public Utility Commission of Texas for use by other utilities in Texas.[767]

Step 1: Determine the measure life for ER and ROB components of the calculated savings:

$$\boldsymbol{Early\ Retirement\ (ER)Period = ML_{ER} = RUL}$$

Equation 22.3-1

$$\boldsymbol{Replace\ on\ Burnout\ (ROB)Period = \ ML_{ROB} = EUL - RUL}$$

Equation 22.3-2

Where:

RUL = *Remaining useful life determined from lookup tables based on the age of the replaced unit (or default age when actual age is unknown).*

EUL = *Estimated useful life as specified in applicable energy efficiency measure.*

Step 2: Calculate the ER demand and energy savings and the ROB demand and energy savings:

$$\boldsymbol{\Delta kW_{ER} = kW_{replaced} - kW_{installed}}$$

Equation 22.3-3

$$\boldsymbol{\Delta kW_{RPB} = kW_{baseline} - kW_{installed}}$$

Equation 22.3-4

$$\boldsymbol{\Delta kWh_{ER} = kWh_{replaced} - kWh_{installed}}$$

Equation 22.3-5

$$\boldsymbol{\Delta kWh_{RPB} = kWh_{baseline} - kWh_{installed}}$$

Equation 22.3-6

Where:

ΔkW_{ER} = *Early retirement demand savings.*

ΔkW_{ROB} = *Replace-on-burnout demand savings.*

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[767] Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, And Texas-New Mexico Power Company to Approve Revisions to Residential and Nonresidential Deemed Savings Incorporated in Texas TRM 2.0 (February 18, 2015).

$kW_{replaced}$ = *Demand of the retired system.*[768]

$kW_{baseline}$ = *Demand of the baseline ROB system.*[769]

$kW_{installed}$ = *Demand of the replacement system.*[770]

ΔkWh_{ER} = *Early retirement energy savings.*

ΔkWh_{ROB} = *Replace-on-burnout energy savings.*

$kWh_{replaced}$ = *Energy Usage of the retired system.*[771]

$kWh_{baseline}$ = *Energy Usage of the baseline ROB system.* [772]

$kWh_{installed}$ = *Energy Usage of the replacement system.*[773]

Step 3: Calculate the avoided capacity and energy cost contributions of the total NPV for both the ER and ROB components:

$$NPV_{ER,kW} = AC_{kW} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{ML_{ER}}\right\} \times \Delta kW_{ER}$$

Equation 22.3-7

$$NPV_{ROB,kW} = AC_{kW} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{ML_{ROB}}\right\} \times \frac{(1+e)^{ML_{ER}}}{(1+d)^{ML_{ER}}} \times \Delta kW_{ROB}$$

Equation 22.3-8

$$NPV_{ER,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{ML_{ER}}\right\} \times \Delta kWh_{ER}$$

Equation 22.3-9

$$NPV_{ROB,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{ML_{ROB}}\right\} \times \frac{(1+e)^{ML_{ER}}}{(1+d)^{ML_{ER}}} \times \Delta kWh_{ROB}$$

Equation 22.3-10

Where:

$NPV_{ER,\,kW}$ = *Net Present Value (kW) of ER projects.*

$NPV_{ROB,\,kW}$ = *Net Present Value (kW) of ROB projects.*

$NPV_{ER,\,kWh}$ = *Net Present Value (kWh) of ER projects.*

---

[768] Retired system refers to the existing equipment that was in use before the retrofit has occurred.

[769] Baseline used for a replace-on-burnout project of the same type and capacity as the system being installed in the early retirement project (as specified in the applicable measure).

[770] Replacement system refers to the installed equipment that is in place after the retrofit has occurred.

[771] Retired system refers to the existing equipment that was in use before the retrofit has occurred.

[772] Baseline used for a replace-on-burnout project of the same type and capacity as the system being installed in the early retirement project (as specified in the applicable measure).

[773] Replacement system refers to the installed equipment that is in place after the retrofit has occurred.

$NPV_{ROB,\ kWh}$ = *Net Present Value (kWh) of ROB projects.*

e = *Escalation Rate, provided by CPS Energy.*

d = *Discount rate weighted average cost of capital, provided by CPS Energy.*

AC_{kW} = *Avoided cost per kW, provided by CPS Energy.*

AC_{kWh} = *Avoided cost per kWh, provided by CPS Energy.*

ML_{ER} = *ER Measure Life (calculated in Equation 22.3-1).*

ML_{ROB} = *ROB measure life (calculated in Equation 22.3-2).*

Note: (1) the Early Retirement savings, earned for the RUL of the replaced system, are estimated by using the difference between the efficiency of the replaced system and that of the installed system; (2) the replace-on-burnout savings, earned over the measure EUL minus the project's RUL, are estimated by using the difference between the replace-on-burnout baseline efficiency and the efficiency of the installed system.

Step 4: Calculate the total capacity and energy cost contributions to the total NPV:

$$\boldsymbol{NPV_{Total,kW} = NPV_{ER,kW} + NPV_{ROB,kW}}$$

Equation 22.3-11

$$\boldsymbol{NPV_{Total,kWh} = NPV_{ER,kWh} + NPV_{ROB,kWh}}$$

Equation 22.3-12

Where:

$NPV_{Total,\ kW}$ = *Total capacity contributions to NPV of both ER and ROB component.*

$NPV_{Total,\ kWh}$ = *Total energy contributions to NPV of both ER and ROB component.*

Step 5: Calculate the capacity and energy cost contributions to the NPV without weighting by demand and energy savings for a scenario using the original EUL:

$$\boldsymbol{NPV_{EUL,kW} = AC_{kW} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{EUL}\right\}}$$

Equation 22.3-13

$$\boldsymbol{NPV_{EUL,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{1 - \left[\frac{1+e}{1+d}\right]^{EUL}\right\}}$$

Equation 22.3-14

Where:

$NPV_{EUL,\ kW}$ = *Capacity contributions to NPV without weighting, using original EUL.*

$NPV_{EUL,\ kWh}$ = *Energy contributions to NPV without weighting, using original EUL.*

Step 6: Calculate the weighted demand and energy savings by dividing the combined capacity and energy cost contributions from the ER and ROB scenarios by the non-savings weighted capacity and energy cost contributions from the single EUL scenario. These weighted savings are claimed over the original measure EUL:

$$\boldsymbol{Weighted\ kW = \frac{NPV_{Total.kW}}{NPW_{EUL,kW}}}$$

Equation 22.3-15

$$\boldsymbol{Weighted\ kWh = \frac{NPV_{Total.kWh}}{NPW_{EUL,kWh}}}$$

Equation 22.3-16

Where:

Weighted kW = *Weighted lifetime demand savings.*

Weighted kWh = *Weighted lifetime energy savings.*

$NPV_{Total,\ kW}$ = *Total capacity contributions to NPV of both ER and ROB component, calculated in Equation 22.3-11.*

$NPV_{Total,\ kWh}$ = *Total energy contributions to NPV of both ER and ROB component, calculated in Equation 22.3-12.*

$NPV_{EUL,\ kW}$ = *Capacity contributions to NPV without weighting, using original EUL, calculated in Equation 22.3-13.*

$NPV_{EUL,\ kWh}$ = *Energy contributions to NPV without weighting, using original EUL, calculated in Equation 22.3-14.*

22.4 BUILDING TYPE DESCRIPTIONS

Table 22.4-1: Commercial HVAC Building Type Descriptions and Examples

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[774]
Education	College	Buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools, and classroom buildings on college or university campuses. Buildings on education campuses for which the main use is not classroom are included in the category relating to their use. For example, administration buildings are part of "Office," dormitories are "Lodging," and libraries are "Public Assembly."	- College or University - Career or Vocational Training - Adult Education
	Primary School		- Elementary or Middle School - Preschool or Daycare
	Secondary School		- High School - Religious Education
Food Sales	Convenience	Buildings used for retail or wholesale of food.	- Gas Station with a Convenience Store
	Supermarket		- Convenience Store
Food Service	Full-Service Restaurant	Buildings used for preparation and sale of food and beverages for consumption.	- Restaurant or Cafeteria
	Quick-Service Restaurant		- Fast Food
Healthcare	Hospital	Buildings used as diagnostic and treatment facilities for inpatient care.	- Hospital - Inpatient Rehabilitation
	Outpatient Healthcare	Buildings used as diagnostic and treatment facilities for outpatient care. Medical offices are included here if they use any type of diagnostic medical equipment (if they do not, they are categorized as an office building).	- Medical Office - Clinic or Outpatient Health Care - Veterinarian
Large Multifamily	Midrise Apartment	Buildings containing multifamily dwelling units, having multiple stories, and equipped with elevators.	No sub-categories collected.

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[774] Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[774]
Lodging	Large Hotel	Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings.	• Motel or Inn • Hotel • Dormitory, Fraternity, or Sorority • Retirement Home, Nursing Home, Assisted Living, or other Residential Care • Convent or Monastery
	Nursing Home		
	Small Hotel/Motel		
Mercantile	Stand-Alone Retail	Buildings used for the sale and display of goods other than food.	• Retail Store • Beer, Wine, or Liquor Store • Rental Center • Dealership or Showroom for Vehicles or Boats • Studio or Gallery
	Strip Mall	Shopping malls comprised of multiple connected establishments.	• Strip Shopping Center • Enclosed Malls
Office	Large Office	Buildings used for general office space, professional office, or administrative offices. Medical offices are included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient health care building).	• Administrative or Professional Office • Government Office • Mixed-Use Office • Bank or Other Financial Institution • Medical Office • Sales Office • Contractor's Office (e.g., Construction, Plumbing, HVAC) • Non-Profit or Social Services • Research and Development • City Hall or City Center • Religious Office • Call Center
	Medium Office		
	Small Office		
Public Assembly	Public Assembly	Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls.	• Social or Meeting (e.g., Community Center, Lodge, Meeting Hall, Convention Center, Senior Center) • Recreation (e.g., Gymnasium, Health Club, Bowling Alley, Ice Rink, Field House, Indoor Racquet Sports) • Entertainment or Culture (e.g., Museum, Theater, Cinema, Sports Arena, Casino, Night Club) • Library • Funeral Home • Student Activities Center • Armory • Exhibition Hall • Broadcasting Studio • Transportation Terminal

Building Type	Principal Building Activity	Definition	Detailed Business Type Examples[774]
Religious Worship	Religious Worship	Buildings in which people gather for religious activities, (such as chapels, churches, mosques, synagogues, and temples).	No sub-categories collected.
Other	Other	For building types not explicitly listed	Values used for Other are the most conservative values from the explicitly listed building types
Service	Service	Buildings in which some type of service is provided, other than food service or retail sales of goods.	• Vehicle Service or Vehicle Repair Shop • Vehicle Storage/Maintenance • Repair Shop • Dry Cleaner or Laundromat • Post Office or Postal Center • Car Wash • Gas Station with no Convenience Store • Photo Processing Shop • Beauty Parlor or Barber Shop • Tanning Salon • Copy Center or Printing Shop • Kennel
Warehouse	Warehouse	Buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage).	• Refrigerated Warehouse • Non-refrigerated warehouse • Distribution or Shipping Center

22.5 BUILDING CHARACTERISTICS

Table 22.5-1: Commercial HVAC Floor Area and Floor Assumptions by Building Type

Building Type	Principal Building Activity	Average Floor Area (ft^2)	Average # Floors
Education	College	Not specified	Not specified
	Primary School	73,960	1
	Secondary School	210,887	2
Food Sales	Convenience	Not specified	1
	Supermarket	45,000	1
Food Service	Full-Service Restaurant	5,500	1
	Quick-Service Restaurant	2,500	1
Healthcare	Hospital	241,351	5
	Outpatient Healthcare	40,946	3
Large Multifamily	Midrise Apartment	33,740	4
Lodging	Large Hotel	122,120	6
	Nursing Home	Not specified	Not specified
	Small Hotel/Motel	43,200	4
Mercantile	Stand-Alone Retail	24,962	1
	Strip Mall	22,500	1
Office	Large Office	498,588	12
	Medium Office	53,628	3
	Small Office	5,500	1
Public Assembly	Public Assembly	Not specified	Not specified
Religious Worship	Religious Worship	Not specified	Not specified
Service	Service	Not specified	Not specified
Warehouse	Warehouse	52,045	1

22.6 CENTRAL AIR CONDITIONER AND HEAT PUMP DEEMED SAVINGS TABLES

22.6.1 Deemed Energy Savings Tables[775]

Cooling Energy Savings

Table 22.6-1: [Central ACs & HPs] Cooling Energy kWh for 14.0 SEER New Construction Baseline

Size (tons)	SEER Range						
	14.5-14.9	15.0-15.9	16.0-16.9	17.0-17.9	18.0-20.9	21.0-23.9	24.0+
< 1.25	88	169	314	536	624	837	998
1.25-1.74	132	253	470	803	936	1,255	1,498
1.75-2.24	176	338	627	1,071	1,247	1,673	1,997
2.25-2.74	220	422	784	1,339	1,559	2,092	2,496
2.75-3.24	263	507	941	1,607	1,871	2,510	2,995
3.25-3.74	307	591	1,098	1,875	2,183	2,928	3,494
3.75-4.49	351	675	1,254	2,142	2,495	3,347	3,994
4.50+	439	844	1,568	2,678	3,119	4,183	4,992

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[775] Rated capacity ranges are specified based on normal rounding convention between capacity categories (values at and above the midpoint round up, while values below the midpoint round down).

Table 22.6-2: [Central ACs & HPs] Cooling Energy kWh for 13.08 SEER Replace-on-Burnout Baseline

14.5-14.9 SEER								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	242							
1.25-1.74	1,417	363						
1.75-2.24	2,592	1,538	484					
2.25-2.74	3,767	2,713	1,659	606				
2.75-3.24	4,941	3,888	2,834	1,780	727			
3.25-3.74	6,116	5,062	4,009	2,955	1,901	848		
3.75-4.49	7,291	6,237	5,184	4,130	3,076	2,023	969	
4.50+	9,641	8,587	7,533	6,479	5,426	4,372	3,318	1,211
15.0-15.9 SEER								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	323							
1.25-1.74	1,498	485						
1.75-2.24	2,673	1,660	647					
2.25-2.74	3,848	2,834	1,821	808				
2.75-3.24	5,022	4,009	2,996	1,983	970			
3.25-3.74	6,197	5,184	4,171	3,158	2,145	1,131		
3.75-4.49	7,372	6,359	5,346	4,333	3,319	2,306	1,293	
4.50+	9,722	8,708	7,695	6,682	5,669	4,656	3,643	1,616

14.5-14.9 SEER								
16.0-16.9 SEER								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	468							
1.25-1.74	1,643	702						
1.75-2.24	2,818	1,877	936					
2.25-2.74	3,992	3,052	2,111	1,170				
2.75-3.24	5,167	4,226	3,286	2,345	1,404			
3.25-3.74	6,342	5,401	4,460	3,520	2,579	1,638		
3.75-4.49	7,517	6,576	5,635	4,694	3,754	2,813	1,872	
4.50+	9,866	8,926	7,985	7,044	6,103	5,162	4,222	2,340
17.0-17.9 SEER								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	690							
1.25-1.74	1,865	1,035						
1.75-2.24	3,040	2,210	1,380					
2.25-2.74	4,214	3,385	2,555	1,725				
2.75-3.24	5,389	4,559	3,730	2,900	2,070			
3.25-3.74	6,564	5,734	4,904	4,075	3,245	2,415		
3.75-4.49	7,739	6,909	6,079	5,249	4,420	3,590	2,760	
4.50+	10,088	9,259	8,429	7,599	6,769	5,939	5,110	3,450

14.5-14.9 SEER

18.0-20.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**778**							
1.25-1.74	1,953	**1,167**						
1.75-2.24	3,128	2,342	**1,556**					
2.25-2.74	4,303	3,517	2,731	**1,945**				
2.75-3.24	5,477	4,692	3,906	3,120	**2,334**			
3.25-3.74	6,652	5,866	5,081	4,295	3,509	**2,723**		
3.75-4.49	7,827	7,041	6,255	5,470	4,684	3,898	**3,113**	
4.50+	10,176	9,391	8,605	7,819	7,034	6,248	5,462	**3,891**

21.0-23.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**991**							
1.25-1.74	2,166	**1,487**						
1.75-2.24	3,341	2,661	**1,982**					
2.25-2.74	4,515	3,836	3,157	**2,478**				
2.75-3.24	5,690	5,011	4,332	3,652	**2,973**			
3.25-3.74	6,865	6,186	5,506	4,827	4,148	**3,469**		
3.75-4.49	8,040	7,361	6,681	6,002	5,323	4,643	**3,964**	
4.50+	10,389	9,710	9,031	8,352	7,672	6,993	6,314	**4,955**

14.5-14.9 SEER								
24.0+ SEER								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	1,153							
1.25-1.74	2,328	1,729						
1.75-2.24	3,502	2,904	2,306					
2.25-2.74	4,677	4,079	3,480	2,882				
2.75-3.24	5,852	5,254	4,655	4,057	3,458			
3.25-3.74	7,027	6,428	5,830	5,232	4,633	4,035		
3.75-4.49	8,202	7,603	7,005	6,406	5,808	5,210	4,611	
4.50+	10,551	9,953	9,354	8,756	8,158	7,559	6,961	5,764

Table 22.6-3: [Central ACs & HPs] Cooling Energy kWh for 12.44 SEER Early Retirement Baseline

14.5-14.9 SEER								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	363							
1.25-1.74	1,598	545						
1.75-2.24	2,834	1,780	726					
2.25-2.74	4,069	3,015	1,961	908				
2.75-3.24	5,304	4,250	3,197	2,143	1,089			
3.25-3.74	6,539	5,486	4,432	3,378	2,324	1,271		
3.75-4.49	7,774	6,721	5,667	4,613	3,560	2,506	1,452	
4.50+	10,245	9,191	8,138	7,084	6,030	4,976	3,923	1,815

14.5-14.9 SEER

15.0-15.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**444**							
1.25-1.74	1,679	**666**						
1.75-2.24	2,915	1,901	**888**					
2.25-2.74	4,150	3,137	2,124	**1,110**				
2.75-3.24	5,385	4,372	3,359	2,346	**1,332**			
3.25-3.74	6,620	5,607	4,594	3,581	2,568	**1,554**		
3.75-4.49	7,856	6,842	5,829	4,816	3,803	2,790	**1,777**	
4.50+	10,326	9,313	8,300	7,286	6,273	5,260	4,247	**2,221**

16.0-16.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**589**							
1.25-1.74	1,824	**883**						
1.75-2.24	3,059	2,119	**1,178**					
2.25-2.74	4,295	3,354	2,413	**1,472**				
2.75-3.24	5,530	4,589	3,648	2,707	**1,767**			
3.25-3.74	6,765	5,824	4,883	3,943	3,002	**2,061**		
3.75-4.49	8,000	7,059	6,119	5,178	4,237	3,296	**2,356**	
4.50+	10,471	9,530	8,589	7,648	6,708	5,767	4,826	**2,944**

14.5-14.9 SEER

17.0-17.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**811**							
1.25-1.74	2,046	**1,216**						
1.75-2.24	3,281	2,452	**1,622**					
2.25-2.74	4,517	3,687	2,857	**2,027**				
2.75-3.24	5,752	4,922	4,092	3,262	**2,433**			
3.25-3.74	6,987	6,157	5,327	4,498	3,668	**2,838**		
3.75-4.49	8,222	7,392	6,563	5,733	4,903	4,073	**3,244**	
4.50+	10,693	9,863	9,033	8,203	7,374	6,544	5,714	**4,054**

18.0-20.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**899**							
1.25-1.74	2,134	**1,349**						
1.75-2.24	3,369	2,584	**1,798**					
2.25-2.74	4,605	3,819	3,033	**2,248**				
2.75-3.24	5,840	5,054	4,268	3,483	**2,697**			
3.25-3.74	7,075	6,289	5,504	4,718	3,932	**3,147**		
3.75-4.49	8,310	7,525	6,739	5,953	5,167	4,382	**3,596**	
4.50+	10,781	9,995	9,209	8,424	7,638	6,852	6,067	**4,495**

14.5-14.9 SEER

21.0-23.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,112**							
1.25-1.74	2,347	**1,668**						
1.75-2.24	3,582	2,903	**2,224**					
2.25-2.74	4,818	4,138	3,459	**2,780**				
2.75-3.24	6,053	5,374	4,694	4,015	**3,336**			
3.25-3.74	7,288	6,609	5,930	5,250	4,571	**3,892**		
3.75-4.49	8,523	7,844	7,165	6,485	5,806	5,127	**4,448**	
4.50+	10,994	10,314	9,635	8,956	8,277	7,597	6,918	**5,560**

24.0+ SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,274**							
1.25-1.74	2,509	**1,911**						
1.75-2.24	3,744	3,146	**2,547**					
2.25-2.74	4,979	4,381	3,783	**3,184**				
2.75-3.24	6,215	5,616	5,018	4,419	**3,821**			
3.25-3.74	7,450	6,851	6,253	5,655	5,056	**4,458**		
3.75-4.49	8,685	8,087	7,488	6,890	6,291	5,693	**5,095**	
4.50+	11,156	10,557	9,959	9,360	8,762	8,164	7,565	**6,368**

Table 22.6-4: [Central ACs & HPs] Cooling Energy kWh for 10.0 SEER Early Retirement Baseline

14.5-14.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**966**							
1.25-1.74	2,503	**1,449**						
1.75-2.24	4,039	2,985	**1,932**					
2.25-2.74	5,576	4,522	3,468	**2,415**				
2.75-3.24	7,112	6,059	5,005	3,951	**2,898**			
3.25-3.74	8,649	7,595	6,542	5,488	4,434	**3,381**		
3.75-4.49	10,186	9,132	8,078	7,025	5,971	4,917	**3,864**	
4.50+	13,259	12,205	11,152	10,098	9,044	7,990	6,937	**4,829**
15.0-15.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**1,047**							
1.25-1.74	2,584	**1,570**						
1.75-2.24	4,120	3,107	**2,094**					
2.25-2.74	5,657	4,644	3,630	**2,617**				
2.75-3.24	7,193	6,180	5,167	4,154	**3,141**			
3.25-3.74	8,730	7,717	6,704	5,691	4,677	**3,664**		
3.75-4.49	10,267	9,254	8,240	7,227	6,214	5,201	**4,188**	
4.50+	13,340	12,327	11,314	10,300	9,287	8,274	7,261	**5,235**

14.5-14.9 SEER

16.0-16.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,192**							
1.25-1.74	2,728	**1,788**						
1.75-2.24	4,265	3,324	**2,383**					
2.25-2.74	5,802	4,861	3,920	**2,979**				
2.75-3.24	7,338	6,397	5,457	4,516	**3,575**			
3.25-3.74	8,875	7,934	6,993	6,052	5,112	**4,171**		
3.75-4.49	10,411	9,471	8,530	7,589	6,648	5,707	**4,767**	
4.50+	13,485	12,544	11,603	10,662	9,722	8,781	7,840	**5,958**

17.0-17.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,414**							
1.25-1.74	2,950	**2,121**						
1.75-2.24	4,487	3,657	**2,827**					
2.25-2.74	6,024	5,194	4,364	**3,534**				
2.75-3.24	7,560	6,730	5,901	5,071	**4,241**			
3.25-3.74	9,097	8,267	7,437	6,607	5,778	**4,948**		
3.75-4.49	10,633	9,804	8,974	8,144	7,314	6,484	**5,655**	
4.50+	13,707	12,877	12,047	11,217	10,388	9,558	8,728	**7,068**

14.5-14.9 SEER

18.0-20.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,502**							
1.25-1.74	3,038	**2,253**						
1.75-2.24	4,575	3,789	**3,004**					
2.25-2.74	6,112	5,326	4,540	**3,755**				
2.75-3.24	7,648	6,863	6,077	5,291	**4,505**			
3.25-3.74	9,185	8,399	7,613	6,828	6,042	**5,256**		
3.75-4.49	10,722	9,936	9,150	8,364	7,579	6,793	**6,007**	
4.50+	13,795	13,009	12,223	11,438	10,652	9,866	9,080	**7,509**

21.0-23.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,715**							
1.25-1.74	3,251	**2,572**						
1.75-2.24	4,788	4,109	**3,429**					
2.25-2.74	6,325	5,645	4,966	**4,287**				
2.75-3.24	7,861	7,182	6,503	5,823	**5,144**			
3.25-3.74	9,398	8,719	8,039	7,360	6,681	**6,002**		
3.75-4.49	10,934	10,255	9,576	8,897	8,217	7,538	**6,859**	
4.50+	14,008	13,328	12,649	11,970	11,291	10,611	9,932	**8,574**

14.5-14.9 SEER								
24.0+ SEER								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	1,876							
1.25-1.74	3,413	2,815						
1.75-2.24	4,950	4,351	3,753					
2.25-2.74	6,486	5,888	5,290	4,691				
2.75-3.24	8,023	7,425	6,826	6,228	5,629			
3.25-3.74	9,560	8,961	8,363	7,764	7,166	6,568		
3.75-4.49	11,096	10,498	9,899	9,301	8,703	8,104	7,506	
4.50+	14,169	13,571	12,973	12,374	11,776	11,177	10,579	9,382

Heating Energy Savings

Table 22.6-5: [Central HPs] Heating kWh Savings for 8.2 HSPF Baselines (NC, ROB of HP)

8.5-8.9 HSPF								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	54							
1.25-1.74	443	81						
1.75-2.24	833	470	107					
2.25-2.74	1,223	860	497	134				
2.75-3.24	1,613	1,250	887	524	161			
3.25-3.74	2,003	1,640	1,277	914	551	188		
3.75-4.49	2,392	2,029	1,666	1,304	941	578	215	
4.50+	3,172	2,809	2,446	2,083	1,720	1,357	994	268

8.5-8.9 HSPF

9.0-9.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**115**							
1.25-1.74	504	**172**						
1.75-2.24	894	562	**229**					
2.25-2.74	1,284	952	619	**287**				
2.75-3.24	1,674	1,341	1,009	676	**344**			
3.25-3.74	2,064	1,731	1,399	1,066	734	**401**		
3.75-4.49	2,453	2,121	1,788	1,456	1,123	791	**459**	
4.50+	3,233	2,900	2,568	2,236	1,903	1,571	1,238	**573**

9.5-9.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**146**							
1.25-1.74	536	**219**						
1.75-2.24	926	609	**293**					
2.25-2.74	1,316	999	682	**366**				
2.75-3.24	1,705	1,389	1,072	755	**439**			
3.25-3.74	2,095	1,779	1,462	1,145	829	**512**		
3.75-4.49	2,485	2,168	1,852	1,535	1,218	902	**585**	
4.50+	3,265	2,948	2,631	2,315	1,998	1,681	1,365	**731**

8.5-8.9 HSPF

10.0-10.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**158**							
1.25-1.74	548	**237**						
1.75-2.24	938	627	**316**					
2.25-2.74	1,328	1,017	706	**395**				
2.75-3.24	1,717	1,407	1,096	785	**475**			
3.25-3.74	2,107	1,796	1,486	1,175	864	**554**		
3.75-4.49	2,497	2,186	1,876	1,565	1,254	943	**633**	
4.50+	3,276	2,966	2,655	2,344	2,034	1,723	1,412	**791**

10.5-10.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**170**							
1.25-1.74	559	**254**						
1.75-2.24	949	644	**339**					
2.25-2.74	1,339	1,034	729	**424**				
2.75-3.24	1,729	1,424	1,119	814	**509**			
3.25-3.74	2,119	1,814	1,509	1,204	899	**594**		
3.75-4.49	2,508	2,203	1,898	1,593	1,288	984	**679**	
4.50+	3,288	2,983	2,678	2,373	2,068	1,763	1,458	**848**

8.5-8.9 HSPF								
11.0-11.4 HSPF								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**181**							
1.25-1.74	570	**271**						
1.75-2.24	960	661	**361**					
2.25-2.74	1,350	1,051	751	**452**				
2.75-3.24	1,740	1,440	1,141	841	**542**			
3.25-3.74	2,130	1,830	1,531	1,231	932	**632**		
3.75-4.49	2,519	2,220	1,921	1,621	1,322	1,022	**723**	
4.50+	3,299	3,000	2,700	2,401	2,101	1,802	1,502	**903**
11.5-11.9 HSPF								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**191**							
1.25-1.74	581	**287**						
1.75-2.24	971	677	**383**					
2.25-2.74	1,361	1,067	772	**478**				
2.75-3.24	1,750	1,456	1,162	868	**574**			
3.25-3.74	2,140	1,846	1,552	1,258	964	**670**		
3.75-4.49	2,530	2,236	1,942	1,648	1,354	1,059	**765**	
4.50+	3,310	3,015	2,721	2,427	2,133	1,839	1,545	**957**

8.5-8.9 HSPF								
12.0+ HSPF								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	198							
1.25-1.74	587	296						
1.75-2.24	977	686	395					
2.25-2.74	1,367	1,076	785	494				
2.75-3.24	1,757	1,466	1,175	884	593			
3.25-3.74	2,146	1,855	1,564	1,273	982	691		
3.75-4.49	2,536	2,245	1,954	1,663	1,372	1,081	790	
4.50+	3,316	3,025	2,734	2,443	2,152	1,861	1,570	988

Table 22.6-6: [Central HPs] Heating kWh Savings for 7.7 HSPF Baseline (ER of HP)

8.5-8.9 HSPF								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	130							
1.25-1.74	558	195						
1.75-2.24	985	622	259					
2.25-2.74	1,413	1,050	687	324				
2.75-3.24	1,841	1,478	1,115	752	389			
3.25-3.74	2,269	1,906	1,543	1,180	817	454		
3.75-4.49	2,697	2,334	1,971	1,608	1,245	882	519	
4.50+	3,552	3,189	2,826	2,463	2,100	1,737	1,374	649

8.5-8.9 HSPF

9.0-9.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**191**							
1.25-1.74	618	**286**						
1.75-2.24	1,046	714	**381**					
2.25-2.74	1,474	1,142	809	**477**				
2.75-3.24	1,902	1,569	1,237	904	**572**			
3.25-3.74	2,330	1,997	1,665	1,332	1,000	**667**		
3.75-4.49	2,757	2,425	2,093	1,760	1,428	1,095	**763**	
4.50+	3,613	3,281	2,948	2,616	2,283	1,951	1,618	**953**

9.5-9.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**222**							
1.25-1.74	650	**333**						
1.75-2.24	1,078	761	**445**					
2.25-2.74	1,506	1,189	872	**556**				
2.75-3.24	1,934	1,617	1,300	984	**667**			
3.25-3.74	2,361	2,045	1,728	1,411	1,095	**778**		
3.75-4.49	2,789	2,472	2,156	1,839	1,523	1,206	**889**	
4.50+	3,645	3,328	3,011	2,695	2,378	2,061	1,745	**1,112**

8.5-8.9 HSPF

10.0-10.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**234**							
1.25-1.74	662	**351**						
1.75-2.24	1,090	779	**468**					
2.25-2.74	1,518	1,207	896	**586**				
2.75-3.24	1,945	1,635	1,324	1,013	**703**			
3.25-3.74	2,373	2,063	1,752	1,441	1,130	**820**		
3.75-4.49	2,801	2,490	2,180	1,869	1,558	1,248	**937**	
4.50+	3,657	3,346	3,035	2,725	2,414	2,103	1,792	**1,171**

10.5-10.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**246**							
1.25-1.74	673	**369**						
1.75-2.24	1,101	796	**491**					
2.25-2.74	1,529	1,224	919	**614**				
2.75-3.24	1,957	1,652	1,347	1,042	**737**			
3.25-3.74	2,385	2,080	1,775	1,470	1,165	**860**		
3.75-4.49	2,812	2,508	2,203	1,898	1,593	1,288	**983**	
4.50+	3,668	3,363	3,058	2,753	2,448	2,143	1,838	**1,228**

8.5-8.9 HSPF

11.0-11.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	257							
1.25-1.74	685	385						
1.75-2.24	1,112	813	513					
2.25-2.74	1,540	1,241	941	642				
2.75-3.24	1,968	1,668	1,369	1,070	770			
3.25-3.74	2,396	2,096	1,797	1,497	1,198	898		
3.75-4.49	2,824	2,524	2,225	1,925	1,626	1,326	1,027	
4.50+	3,679	3,380	3,080	2,781	2,481	2,182	1,882	1,284

11.5-11.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	267							
1.25-1.74	695	401						
1.75-2.24	1,123	829	535					
2.25-2.74	1,551	1,257	962	668				
2.75-3.24	1,979	1,684	1,390	1,096	802			
3.25-3.74	2,406	2,112	1,818	1,524	1,230	936		
3.75-4.49	2,834	2,540	2,246	1,952	1,658	1,364	1,069	
4.50+	3,690	3,396	3,101	2,807	2,513	2,219	1,925	1,337

8.5-8.9 HSPF								
12.0+ HSPF								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**274**							
1.25-1.74	701	**410**						
1.75-2.24	1,129	838	**547**					
2.25-2.74	1,557	1,266	975	**684**				
2.75-3.24	1,985	1,694	1,403	1,112	**821**			
3.25-3.74	2,413	2,122	1,831	1,539	1,248	**957**		
3.75-4.49	2,840	2,549	2,258	1,967	1,676	1,385	**1,094**	
4.50+	3,696	3,405	3,114	2,823	2,532	2,241	1,950	**1,368**

Table 22.6-7: [Central HPs] Heating kWh Savings for 6.8 HSPF Baseline (ER of HP)

8.5-8.9 HSPF								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**312**							
1.25-1.74	831	**469**						
1.75-2.24	1,351	988	**625**					
2.25-2.74	1,870	1,507	1,144	**781**				
2.75-3.24	2,389	2,026	1,663	1,300	**937**			
3.25-3.74	2,908	2,545	2,182	1,819	1,456	**1,093**		
3.75-4.49	3,427	3,064	2,701	2,338	1,975	1,612	**1,249**	
4.50+	4,465	4,102	3,739	3,376	3,014	2,651	2,288	**1,562**

8.5-8.9 HSPF

9.0-9.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**373**							
1.25-1.74	892	**560**						
1.75-2.24	1,412	1,079	**747**					
2.25-2.74	1,931	1,598	1,266	**933**				
2.75-3.24	2,450	2,117	1,785	1,452	**1,120**			
3.25-3.74	2,969	2,636	2,304	1,971	1,639	**1,307**		
3.75-4.49	3,488	3,156	2,823	2,491	2,158	1,826	**1,493**	
4.50+	4,526	4,194	3,861	3,529	3,196	2,864	2,531	**1,866**

9.5-9.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**405**							
1.25-1.74	924	**607**						
1.75-2.24	1,443	1,127	**810**					
2.25-2.74	1,962	1,646	1,329	**1,012**				
2.75-3.24	2,481	2,165	1,848	1,531	**1,215**			
3.25-3.74	3,001	2,684	2,367	2,051	1,734	**1,417**		
3.75-4.49	3,520	3,203	2,886	2,570	2,253	1,936	**1,620**	
4.50+	4,558	4,241	3,925	3,608	3,291	2,975	2,658	**2,025**

8.5-8.9 HSPF

10.0-10.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**417**							
1.25-1.74	936	**625**						
1.75-2.24	1,455	1,144	**834**					
2.25-2.74	1,974	1,664	1,353	**1,042**				
2.75-3.24	2,493	2,183	1,872	1,561	**1,251**			
3.25-3.74	3,012	2,702	2,391	2,080	1,770	**1,459**		
3.75-4.49	3,532	3,221	2,910	2,599	2,289	1,978	**1,667**	
4.50+	4,570	4,259	3,948	3,638	3,327	3,016	2,706	**2,084**

10.5-10.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**428**							
1.25-1.74	947	**642**						
1.75-2.24	1,467	1,162	**857**					
2.25-2.74	1,986	1,681	1,376	**1,071**				
2.75-3.24	2,505	2,200	1,895	1,590	**1,285**			
3.25-3.74	3,024	2,719	2,414	2,109	1,804	**1,499**		
3.75-4.49	3,543	3,238	2,933	2,628	2,323	2,018	**1,713**	
4.50+	4,581	4,276	3,971	3,666	3,361	3,056	2,751	**2,142**

8.5-8.9 HSPF

11.0-11.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	439							
1.25-1.74	958	659						
1.75-2.24	1,478	1,178	879					
2.25-2.74	1,997	1,697	1,398	1,098				
2.75-3.24	2,516	2,216	1,917	1,617	1,318			
3.25-3.74	3,035	2,736	2,436	2,137	1,837	1,538		
3.75-4.49	3,554	3,255	2,955	2,656	2,356	2,057	1,757	
4.50+	4,592	4,293	3,993	3,694	3,395	3,095	2,796	2,197

11.5-11.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	450							
1.25-1.74	969	675						
1.75-2.24	1,488	1,194	900					
2.25-2.74	2,007	1,713	1,419	1,125				
2.75-3.24	2,526	2,232	1,938	1,644	1,350			
3.25-3.74	3,046	2,751	2,457	2,163	1,869	1,575		
3.75-4.49	3,565	3,271	2,976	2,682	2,388	2,094	1,800	
4.50+	4,603	4,309	4,015	3,721	3,426	3,132	2,838	2,250

8.5-8.9 HSPF								
12.0+ HSPF								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**456**							
1.25-1.74	975	**684**						
1.75-2.24	1,494	1,203	**912**					
2.25-2.74	2,014	1,723	1,432	**1,140**				
2.75-3.24	2,533	2,242	1,951	1,660	**1,369**			
3.25-3.74	3,052	2,761	2,470	2,179	1,888	**1,597**		
3.75-4.49	3,571	3,280	2,989	2,698	2,407	2,116	**1,825**	
4.50+	4,609	4,318	4,027	3,736	3,445	3,154	2,863	**2,281**

Table 22.6-8: [Central HPs] Heating kWh Savings for 3.41 HSPF Baseline (ROB/ER of an Electric Resistance Furnace)

8.5-8.9 HSPF								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,684**							
1.25-1.74	2,889	**2,526**						
1.75-2.24	4,094	3,731	**3,368**					
2.25-2.74	5,299	4,936	4,573	**4,210**				
2.75-3.24	6,504	6,141	5,778	5,415	**5,052**			
3.25-3.74	7,709	7,346	6,983	6,620	6,257	**5,894**		
3.75-4.49	8,914	8,551	8,188	7,825	7,462	7,099	**6,736**	
4.50+	11,323	10,960	10,598	10,235	9,872	9,509	9,146	**8,420**

8.5-8.9 HSPF

9.0-9.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,745**							
1.25-1.74	2,950	**2,617**						
1.75-2.24	4,155	3,822	**3,490**					
2.25-2.74	5,360	5,027	4,695	**4,362**				
2.75-3.24	6,565	6,232	5,900	5,567	**5,235**			
3.25-3.74	7,770	7,437	7,105	6,772	6,440	**6,107**		
3.75-4.49	8,975	8,642	8,310	7,977	7,645	7,312	**6,980**	
4.50+	11,384	11,052	10,719	10,387	10,055	9,722	9,390	**8,725**

9.5-9.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,777**							
1.25-1.74	2,982	**2,665**						
1.75-2.24	4,186	3,870	**3,553**					
2.25-2.74	5,391	5,075	4,758	**4,441**				
2.75-3.24	6,596	6,280	5,963	5,646	**5,330**			
3.25-3.74	7,801	7,485	7,168	6,851	6,535	**6,218**		
3.75-4.49	9,006	8,690	8,373	8,056	7,740	7,423	**7,106**	
4.50+	11,416	11,099	10,783	10,466	10,149	9,833	9,516	**8,883**

8.5-8.9 HSPF

10.0-10.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,788**							
1.25-1.74	2,993	**2,683**						
1.75-2.24	4,198	3,888	**3,577**					
2.25-2.74	5,403	5,093	4,782	**4,471**				
2.75-3.24	6,608	6,298	5,987	5,676	**5,365**			
3.25-3.74	7,813	7,502	7,192	6,881	6,570	**6,260**		
3.75-4.49	9,018	8,707	8,397	8,086	7,775	7,465	**7,154**	
4.50+	11,428	11,117	10,807	10,496	10,185	9,874	9,564	**8,942**

10.5-10.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,800**							
1.25-1.74	3,005	**2,700**						
1.75-2.24	4,210	3,905	**3,600**					
2.25-2.74	5,415	5,110	4,805	**4,500**				
2.75-3.24	6,620	6,315	6,010	5,705	**5,400**			
3.25-3.74	7,825	7,520	7,215	6,910	6,605	**6,300**		
3.75-4.49	9,030	8,725	8,420	8,115	7,810	7,505	**7,200**	
4.50+	11,439	11,134	10,829	10,525	10,220	9,915	9,610	**9,000**

8.5-8.9 HSPF

11.0-11.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,811**							
1.25-1.74	3,016	**2,716**						
1.75-2.24	4,221	3,921	**3,622**					
2.25-2.74	5,426	5,126	4,827	**4,527**				
2.75-3.24	6,631	6,331	6,032	5,732	**5,433**			
3.25-3.74	7,836	7,536	7,237	6,937	6,638	**6,338**		
3.75-4.49	9,041	8,741	8,442	8,142	7,843	7,543	**7,244**	
4.50+	11,450	11,151	10,852	10,552	10,253	9,953	9,654	**9,055**

11.5-11.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,822**							
1.25-1.74	3,027	**2,732**						
1.75-2.24	4,231	3,937	**3,643**					
2.25-2.74	5,436	5,142	4,848	**4,554**				
2.75-3.24	6,641	6,347	6,053	5,759	**5,465**			
3.25-3.74	7,846	7,552	7,258	6,964	6,670	**6,376**		
3.75-4.49	9,051	8,757	8,463	8,169	7,875	7,581	**7,286**	
4.50+	11,461	11,167	10,873	10,579	10,285	9,990	9,696	**9,108**

8.5-8.9 HSPF								
12.0+ HSPF								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,828**							
1.25-1.74	3,033	**2,742**						
1.75-2.24	4,238	3,947	**3,656**					
2.25-2.74	5,443	5,152	4,861	**4,570**				
2.75-3.24	6,648	6,357	6,066	5,774	**5,483**			
3.25-3.74	7,852	7,561	7,270	6,979	6,688	**6,397**		
3.75-4.49	9,057	8,766	8,475	8,184	7,893	7,602	**7,311**	
4.50+	11,467	11,176	10,885	10,594	10,303	10,012	9,721	**9,139**

22.6.1 Deemed Summer Demand Savings Tables[776]

NCP Demand Savings

Table 22.6-9: [Central ACs & HPs] NCP kW Savings for 14.0 SEER New Construction Baseline

Size (tons)	SEER Range						
	14.5-14.9	15.0-15.9	16.0-16.9	17.0-17.9	18.0-20.9	21.0-23.9	24.0+
< 1.25	0.05	0.09	0.16	0.17	0.20	0.28	0.34
1.25-1.74	0.07	0.13	0.24	0.25	0.30	0.42	0.51
1.75-2.24	0.09	0.17	0.32	0.34	0.40	0.56	0.68
2.25-2.74	0.11	0.22	0.40	0.42	0.50	0.70	0.85
2.75-3.24	0.14	0.26	0.48	0.51	0.60	0.84	1.02
3.25-3.74	0.16	0.30	0.56	0.59	0.70	0.98	1.19
3.75-4.49	0.18	0.35	0.64	0.68	0.80	1.12	1.36
4.50+	0.23	0.43	0.80	0.85	1.01	1.40	1.70

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[776] Rated capacity ranges are specified based on normal rounding convention between capacity categories (values at and above the midpoint round up, while values below the midpoint round down).

Table 22.6-10: [Central ACs & HPs] NCP kW Savings for 13.08 SEER Replace-on-Burnout Baseline

14.5-14.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.12**							
1.25-1.74	0.73	**0.19**						
1.75-2.24	1.33	0.79	**0.25**					
2.25-2.74	1.93	1.39	0.85	**0.31**				
2.75-3.24	2.53	1.99	1.45	0.91	**0.37**			
3.25-3.74	3.14	2.60	2.06	1.52	0.98	**0.43**		
3.75-4.49	3.74	3.20	2.66	2.12	1.58	1.04	**0.50**	
4.50+	4.94	4.40	3.86	3.32	2.78	2.24	1.70	**0.62**
15.0-15.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.17**							
1.25-1.74	0.77	**0.25**						
1.75-2.24	1.37	0.85	**0.33**					
2.25-2.74	1.97	1.45	0.93	**0.41**				
2.75-3.24	2.58	2.06	1.54	1.02	**0.50**			
3.25-3.74	3.18	2.66	2.14	1.62	1.10	**0.58**		
3.75-4.49	3.78	3.26	2.74	2.22	1.70	1.18	**0.66**	
4.50+	4.99	4.47	3.95	3.43	2.91	2.39	1.87	**0.83**

14.5-14.9 SEER								
16.0-16.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.24**							
1.25-1.74	0.84	**0.36**						
1.75-2.24	1.45	0.96	**0.48**					
2.25-2.74	2.05	1.57	1.08	**0.60**				
2.75-3.24	2.65	2.17	1.69	1.20	**0.72**			
3.25-3.74	3.25	2.77	2.29	1.81	1.32	**0.84**		
3.75-4.49	3.86	3.37	2.89	2.41	1.93	1.44	**0.96**	
4.50+	5.06	4.58	4.10	3.61	3.13	2.65	2.17	**1.20**
17.0-17.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.23**							
1.25-1.74	0.63	**0.34**						
1.75-2.24	1.03	0.74	**0.45**					
2.25-2.74	1.43	1.14	0.86	**0.57**				
2.75-3.24	1.83	1.55	1.26	0.97	**0.68**			
3.25-3.74	2.24	1.95	1.66	1.37	1.08	**0.79**		
3.75-4.49	2.64	2.35	2.06	1.77	1.48	1.20	**0.91**	
4.50+	3.44	3.15	2.87	2.58	2.29	2.00	1.71	**1.14**

14.5-14.9 SEER

18.0-20.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	0.26							
1.25-1.74	0.66	0.39						
1.75-2.24	1.06	0.79	0.51					
2.25-2.74	1.46	1.19	0.92	0.64				
2.75-3.24	1.87	1.59	1.32	1.05	0.77			
3.25-3.74	2.27	1.99	1.72	1.45	1.17	0.90		
3.75-4.49	2.67	2.40	2.12	1.85	1.58	1.30	1.03	
4.50+	3.47	3.20	2.93	2.65	2.38	2.11	1.83	1.29

21.0-23.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	0.33							
1.25-1.74	0.74	0.50						
1.75-2.24	1.14	0.90	0.67					
2.25-2.74	1.54	1.31	1.07	0.84				
2.75-3.24	1.94	1.71	1.47	1.24	1.00			
3.25-3.74	2.34	2.11	1.88	1.64	1.41	1.17		
3.75-4.49	2.75	2.51	2.28	2.04	1.81	1.57	1.34	
4.50+	3.55	3.32	3.08	2.85	2.61	2.38	2.14	1.67

14.5-14.9 SEER								
24.0+ SEER								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	0.39							
1.25-1.74	0.80	0.59						
1.75-2.24	1.20	0.99	0.79					
2.25-2.74	1.60	1.39	1.19	0.98				
2.75-3.24	2.00	1.80	1.59	1.38	1.18			
3.25-3.74	2.40	2.20	1.99	1.79	1.58	1.38		
3.75-4.49	2.80	2.60	2.39	2.19	1.98	1.78	1.57	
4.50+	3.61	3.40	3.20	2.99	2.79	2.58	2.38	1.97

Table 22.6-11: [Central ACs & HPs] NCP kW Savings for 12.44 SEER Early Retirement Baseline

14.5-14.9 SEER								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	0.19							
1.25-1.74	0.82	0.28						
1.75-2.24	1.45	0.91	0.37					
2.25-2.74	2.09	1.55	1.01	0.47				
2.75-3.24	2.72	2.18	1.64	1.10	0.56			
3.25-3.74	3.35	2.81	2.27	1.73	1.19	0.65		
3.75-4.49	3.99	3.45	2.91	2.37	1.83	1.29	0.74	
4.50+	5.25	4.71	4.17	3.63	3.09	2.55	2.01	0.93

14.5-14.9 SEER								
15.0-15.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.23**							
1.25-1.74	0.86	**0.34**						
1.75-2.24	1.49	0.98	**0.46**					
2.25-2.74	2.13	1.61	1.09	**0.57**				
2.75-3.24	2.76	2.24	1.72	1.20	**0.68**			
3.25-3.74	3.40	2.88	2.36	1.84	1.32	**0.80**		
3.75-4.49	4.03	3.51	2.99	2.47	1.95	1.43	**0.91**	
4.50+	5.30	4.78	4.26	3.74	3.22	2.70	2.18	**1.14**
16.0-16.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.30**							
1.25-1.74	0.94	**0.45**						
1.75-2.24	1.57	1.09	**0.60**					
2.25-2.74	2.20	1.72	1.24	**0.76**				
2.75-3.24	2.84	2.35	1.87	1.39	**0.91**			
3.25-3.74	3.47	2.99	2.50	2.02	1.54	**1.06**		
3.75-4.49	4.10	3.62	3.14	2.66	2.17	1.69	**1.21**	
4.50+	5.37	4.89	4.41	3.92	3.44	2.96	2.48	**1.51**

14.5-14.9 SEER

17.0-17.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	0.27							
1.25-1.74	0.70	0.40						
1.75-2.24	1.13	0.83	0.53					
2.25-2.74	1.56	1.26	0.96	0.66				
2.75-3.24	2.00	1.70	1.40	1.10	0.80			
3.25-3.74	2.43	2.13	1.83	1.53	1.23	0.93		
3.75-4.49	2.86	2.56	2.26	1.96	1.66	1.36	1.06	
4.50+	3.73	3.43	3.13	2.83	2.53	2.23	1.93	1.33

18.0-20.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	0.30							
1.25-1.74	0.73	0.45						
1.75-2.24	1.16	0.88	0.59					
2.25-2.74	1.60	1.31	1.03	0.74				
2.75-3.24	2.03	1.74	1.46	1.18	0.89			
3.25-3.74	2.46	2.18	1.89	1.61	1.33	1.04		
3.75-4.49	2.89	2.61	2.33	2.04	1.76	1.47	1.19	
4.50+	3.76	3.47	3.19	2.91	2.62	2.34	2.06	1.49

14.5-14.9 SEER

21.0-23.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.38**							
1.25-1.74	0.81	**0.56**						
1.75-2.24	1.24	1.00	**0.75**					
2.25-2.74	1.67	1.43	1.19	**0.94**				
2.75-3.24	2.11	1.86	1.62	1.37	**1.13**			
3.25-3.74	2.54	2.30	2.05	1.81	1.56	**1.32**		
3.75-4.49	2.97	2.73	2.48	2.24	1.99	1.75	**1.51**	
4.50+	3.84	3.59	3.35	3.10	2.86	2.62	2.37	**1.88**

24.0+ SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.44**							
1.25-1.74	0.87	**0.65**						
1.75-2.24	1.30	1.09	**0.87**					
2.25-2.74	1.73	1.52	1.30	**1.09**				
2.75-3.24	2.17	1.95	1.74	1.52	**1.31**			
3.25-3.74	2.60	2.38	2.17	1.96	1.74	**1.53**		
3.75-4.49	3.03	2.82	2.60	2.39	2.17	1.96	**1.74**	
4.50+	3.90	3.68	3.47	3.25	3.04	2.82	2.61	**2.18**

Table 22.6-12: [Central ACs & HPs] NCP kW Savings for 10.0 SEER Early Retirement Baseline

14.5-14.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.50**							
1.25-1.74	1.28	**0.74**						
1.75-2.24	2.07	1.53	**0.99**					
2.25-2.74	2.86	2.32	1.78	**1.24**				
2.75-3.24	3.65	3.11	2.57	2.03	**1.49**			
3.25-3.74	4.44	3.90	3.36	2.81	2.27	**1.73**		
3.75-4.49	5.22	4.68	4.14	3.60	3.06	2.52	**1.98**	
4.50+	6.80	6.26	5.72	5.18	4.64	4.10	3.56	**2.48**
15.0-15.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.54**							
1.25-1.74	1.33	**0.81**						
1.75-2.24	2.11	1.59	**1.07**					
2.25-2.74	2.90	2.38	1.86	**1.34**				
2.75-3.24	3.69	3.17	2.65	2.13	**1.61**			
3.25-3.74	4.48	3.96	3.44	2.92	2.40	**1.88**		
3.75-4.49	5.27	4.75	4.23	3.71	3.19	2.67	**2.15**	
4.50+	6.84	6.32	5.80	5.28	4.76	4.24	3.72	**2.69**

14.5-14.9 SEER

16.0-16.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.61**							
1.25-1.74	1.40	**0.92**						
1.75-2.24	2.19	1.71	**1.22**					
2.25-2.74	2.98	2.49	2.01	**1.53**				
2.75-3.24	3.76	3.28	2.80	2.32	**1.83**			
3.25-3.74	4.55	4.07	3.59	3.10	2.62	**2.14**		
3.75-4.49	5.34	4.86	4.38	3.89	3.41	2.93	**2.44**	
4.50+	6.92	6.43	5.95	5.47	4.99	4.50	4.02	**3.06**

17.0-17.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.58**							
1.25-1.74	1.36	**0.86**						
1.75-2.24	2.15	1.65	**1.15**					
2.25-2.74	2.94	2.44	1.94	**1.44**				
2.75-3.24	3.73	3.23	2.73	2.23	**1.73**			
3.25-3.74	4.52	4.02	3.52	3.02	2.52	**2.02**		
3.75-4.49	5.31	4.80	4.30	3.80	3.30	2.80	**2.30**	
4.50+	6.88	6.38	5.88	5.38	4.88	4.38	3.88	**2.88**

14.5-14.9 SEER

18.0-20.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.63**							
1.25-1.74	1.42	**0.95**						
1.75-2.24	2.21	1.74	**1.27**					
2.25-2.74	3.00	2.53	2.05	**1.58**				
2.75-3.24	3.79	3.31	2.84	2.37	**1.90**			
3.25-3.74	4.57	4.10	3.63	3.16	2.69	**2.22**		
3.75-4.49	5.36	4.89	4.42	3.95	3.48	3.00	**2.53**	
4.50+	6.94	6.47	6.00	5.52	5.05	4.58	4.11	**3.17**

21.0-23.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.71**							
1.25-1.74	1.50	**1.07**						
1.75-2.24	2.29	1.86	**1.43**					
2.25-2.74	3.08	2.65	2.21	**1.78**				
2.75-3.24	3.87	3.43	3.00	2.57	**2.14**			
3.25-3.74	4.65	4.22	3.79	3.36	2.93	**2.50**		
3.75-4.49	5.44	5.01	4.58	4.15	3.72	3.28	**2.85**	
4.50+	7.02	6.59	6.16	5.72	5.29	4.86	4.43	**3.57**

14.5-14.9 SEER								
24.0+ SEER								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	0.78							
1.25-1.74	1.57	1.17						
1.75-2.24	2.36	1.96	1.56					
2.25-2.74	3.15	2.75	2.35	1.95				
2.75-3.24	3.93	3.54	3.14	2.74	2.34			
3.25-3.74	4.72	4.32	3.93	3.53	3.13	2.73		
3.75-4.49	5.51	5.11	4.71	4.32	3.92	3.52	3.12	
4.50+	7.09	6.69	6.29	5.89	5.50	5.10	4.70	3.90

CP Demand Savings

Table 22.6-13: [Central ACs & HPs] CP kW Savings for 14.0 SEER New Construction Baseline

Size (tons)	SEER Range						
	14.5-14.9	15.0-15.9	16.0-16.9	17.0-17.9	18.0-20.9	21.0-23.9	24.0+
< 1.25	0.04	0.08	0.16	0.12	0.17	0.25	0.32
1.25-1.74	0.07	0.13	0.23	0.18	0.26	0.38	0.48
1.75-2.24	0.09	0.17	0.31	0.23	0.35	0.50	0.63
2.25-2.74	0.11	0.21	0.39	0.29	0.43	0.63	0.79
2.75-3.24	0.13	0.25	0.47	0.35	0.52	0.75	0.98
3.25-3.74	0.15	0.29	0.55	0.41	0.61	0.88	1.11
3.75-4.49	0.18	0.34	0.63	0.47	0.69	1.01	1.27
4.50+	0.22	0.42	0.78	0.59	0.87	1.26	1.59

Table 22.6-14: [Central ACs & HPs] CP kW Savings for 13.08 SEER Replace-on-Burnout Baseline

14.5-14.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.12**							
1.25-1.74	0.71	**0.18**						
1.75-2.24	1.29	0.77	**0.24**					
2.25-2.74	1.88	1.35	0.83	**0.30**				
2.75-3.24	2.46	1.94	1.41	0.89	**0.36**			
3.25-3.74	3.05	2.53	2.00	1.47	0.95	**0.42**		
3.75-4.49	3.64	3.11	2.59	2.06	1.53	1.01	**0.48**	
4.50+	4.81	4.28	3.76	3.23	2.71	2.18	1.66	**0.60**
15.0-15.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.16**							
1.25-1.74	0.75	**0.24**						
1.75-2.24	1.33	0.83	**0.32**					
2.25-2.74	1.92	1.41	0.91	**0.40**				
2.75-3.24	2.51	2.00	1.49	0.99	**0.48**			
3.25-3.74	3.09	2.59	2.08	1.58	1.07	**0.56**		
3.75-4.49	3.68	3.17	2.67	2.16	1.66	1.15	**0.64**	
4.50+	4.85	4.34	3.84	3.33	2.83	2.32	1.82	**0.81**

14.5-14.9 SEER

16.0-16.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.23**							
1.25-1.74	0.82	**0.35**						
1.75-2.24	1.41	0.94	**0.47**					
2.25-2.74	1.99	1.52	1.05	**0.58**				
2.75-3.24	2.58	2.11	1.64	1.17	**0.70**			
3.25-3.74	3.16	2.69	2.22	1.76	1.29	**0.82**		
3.75-4.49	3.75	3.28	2.81	2.34	1.87	1.40	**0.93**	
4.50+	4.92	4.45	3.98	3.51	3.04	2.58	2.11	**1.17**

17.0-17.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.19**							
1.25-1.74	0.78	**0.29**						
1.75-2.24	1.37	0.88	**0.39**					
2.25-2.74	1.95	1.46	0.97	**0.49**				
2.75-3.24	2.54	2.05	1.56	1.07	**0.58**			
3.25-3.74	3.12	2.64	2.15	1.66	1.17	**0.68**		
3.75-4.49	3.71	3.22	2.73	2.24	1.75	1.27	**0.78**	
4.50+	4.88	4.39	3.90	3.42	2.93	2.44	1.95	**0.97**

14.5-14.9 SEER

18.0-20.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.25**							
1.25-1.74	0.84	**0.38**						
1.75-2.24	1.42	0.96	**0.50**					
2.25-2.74	2.01	1.55	1.09	**0.63**				
2.75-3.24	2.59	2.13	1.67	1.21	**0.75**			
3.25-3.74	3.18	2.72	2.26	1.80	1.34	**0.88**		
3.75-4.49	3.77	3.31	2.84	2.38	1.92	1.46	**1.00**	
4.50+	4.94	4.48	4.02	3.56	3.09	2.63	2.17	**1.25**

21.0-23.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.33**							
1.25-1.74	0.91	**0.49**						
1.75-2.24	1.50	1.08	**0.66**					
2.25-2.74	2.09	1.66	1.24	**0.82**				
2.75-3.24	2.67	2.25	1.83	1.41	**0.99**			
3.25-3.74	3.26	2.84	2.41	1.99	1.57	**1.15**		
3.75-4.49	3.84	3.42	3.00	2.58	2.16	1.74	**1.31**	
4.50+	5.02	4.59	4.17	3.75	3.33	2.91	2.49	**1.64**

14.5-14.9 SEER								
24.0+ SEER								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.39**							
1.25-1.74	0.98	0.59						
1.75-2.24	1.57	1.18	0.79					
2.25-2.74	2.15	1.76	1.37	0.99				
2.75-3.24	2.74	2.35	1.96	1.57	1.18			
3.25-3.74	3.32	2.94	2.55	2.16	1.77	1.38		
3.75-4.49	3.91	3.52	3.13	2.74	2.36	1.97	1.58	
4.50+	5.08	4.69	4.30	3.92	3.53	3.14	2.75	1.97

Table 22.6-15: [Central ACs & HPs] CP kW Savings for 12.44 SEER Early Retirement Baseline

14.5-14.9 SEER								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.18**							
1.25-1.74	0.80	**0.27**						
1.75-2.24	1.41	0.89	**0.36**					
2.25-2.74	2.03	1.50	0.98	**0.45**				
2.75-3.24	2.65	2.12	1.59	1.07	**0.54**			
3.25-3.74	3.26	2.74	2.21	1.69	1.16	**0.63**		
3.75-4.49	3.88	3.35	2.83	2.30	1.78	1.25	**0.72**	
4.50+	5.11	4.58	4.06	3.53	3.01	2.48	1.96	**0.91**

14.5-14.9 SEER								
15.0-15.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.22**							
1.25-1.74	0.84	**0.33**						
1.75-2.24	1.45	0.95	**0.44**					
2.25-2.74	2.07	1.56	1.06	**0.55**				
2.75-3.24	2.69	2.18	1.68	1.17	**0.66**			
3.25-3.74	3.30	2.80	2.29	1.79	1.28	**0.78**		
3.75-4.49	3.92	3.41	2.91	2.40	1.90	1.39	**0.89**	
4.50+	5.15	4.65	4.14	3.63	3.13	2.62	2.12	**1.11**
16.0-16.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.29**							
1.25-1.74	0.91	**0.44**						
1.75-2.24	1.53	1.06	**0.59**					
2.25-2.74	2.14	1.67	1.20	**0.73**				
2.75-3.24	2.76	2.29	1.82	1.35	**0.88**			
3.25-3.74	3.37	2.91	2.44	1.97	1.50	**1.03**		
3.75-4.49	3.99	3.52	3.05	2.58	2.11	1.64	**1.17**	
4.50+	5.22	4.75	4.28	3.82	3.35	2.88	2.41	**1.47**

14.5-14.9 SEER

17.0-17.9 SEER

Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.25**							
1.25-1.74	0.87	**0.38**						
1.75-2.24	1.49	1.00	**0.51**					
2.25-2.74	2.10	1.61	1.13	**0.64**				
2.75-3.24	2.72	2.23	1.74	1.25	**0.76**			
3.25-3.74	3.34	2.85	2.36	1.87	1.38	**0.89**		
3.75-4.49	3.95	3.46	2.97	2.48	2.00	1.51	**1.02**	
4.50+	5.18	4.69	4.21	3.72	3.23	2.74	2.25	**1.27**

18.0-20.9 SEER

Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.31**							
1.25-1.74	0.93	**0.47**						
1.75-2.24	1.54	1.08	**0.62**					
2.25-2.74	2.16	1.70	1.24	**0.78**				
2.75-3.24	2.77	2.31	1.85	1.39	**0.93**			
3.25-3.74	3.39	2.93	2.47	2.01	1.55	**1.09**		
3.75-4.49	4.01	3.55	3.09	2.62	2.16	1.70	**1.24**	
4.50+	5.24	4.78	4.32	3.86	3.40	2.93	2.47	**1.55**

14.5-14.9 SEER

21.0-23.9 SEER

Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.39**							
1.25-1.74	1.00	**0.58**						
1.75-2.24	1.62	1.20	**0.78**					
2.25-2.74	2.24	1.82	1.39	**0.97**				
2.75-3.24	2.85	2.43	2.01	1.59	**1.17**			
3.25-3.74	3.47	3.05	2.63	2.20	1.78	**1.36**		
3.75-4.49	4.09	3.66	3.24	2.82	2.40	1.98	**1.55**	
4.50+	5.32	4.90	4.47	4.05	3.63	3.21	2.79	**1.94**

24.0+ SEER

Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.45**							
1.25-1.74	1.07	0.68						
1.75-2.24	1.69	1.30	0.91					
2.25-2.74	2.30	1.91	1.53	1.14				
2.75-3.24	2.92	2.53	2.14	1.75	1.36			
3.25-3.74	3.54	3.15	2.76	2.37	1.98	1.59		
3.75-4.49	4.15	3.76	3.37	2.99	2.60	2.21	1.82	
4.50+	5.38	5.00	4.61	4.22	3.83	3.44	3.05	2.27

Table 22.6-16: [Central ACs & HPs] CP kW Savings for 10.0 SEER Early Retirement Baseline

14.5-14.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.48**							
1.25-1.74	1.25	**0.72**						
1.75-2.24	2.01	1.49	**0.96**					
2.25-2.74	2.78	2.26	1.73	**1.20**				
2.75-3.24	3.55	3.02	2.50	1.97	**1.45**			
3.25-3.74	4.31	3.79	3.26	2.74	2.21	**1.69**		
3.75-4.49	5.08	4.56	4.03	3.50	2.98	2.45	**1.93**	
4.50+	6.61	6.09	5.56	5.04	4.51	3.99	3.46	**2.41**
15.0-15.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.52**							
1.25-1.74	1.29	**0.78**						
1.75-2.24	2.06	1.55	**1.04**					
2.25-2.74	2.82	2.32	1.81	**1.31**				
2.75-3.24	3.59	3.08	2.58	2.07	**1.57**			
3.25-3.74	4.35	3.85	3.34	2.84	2.33	**1.83**		
3.75-4.49	5.12	4.62	4.11	3.60	3.10	2.59	**2.09**	
4.50+	6.65	6.15	5.64	5.14	4.63	4.13	3.62	**2.61**

14.5-14.9 SEER

16.0-16.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.59**							
1.25-1.74	1.36	**0.89**						
1.75-2.24	2.13	1.66	**1.19**					
2.25-2.74	2.89	2.42	1.96	**1.49**				
2.75-3.24	3.66	3.19	2.72	2.25	**1.78**			
3.25-3.74	4.43	3.96	3.49	3.02	2.55	**2.08**		
3.75-4.49	5.19	4.72	4.25	3.79	3.32	2.85	**2.38**	
4.50+	6.73	6.26	5.79	5.32	4.85	4.38	3.91	**2.97**

17.0-17.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.56**							
1.25-1.74	1.32	**0.83**						
1.75-2.24	2.09	1.60	**1.11**					
2.25-2.74	2.85	2.37	1.88	**1.39**				
2.75-3.24	3.62	3.13	2.64	2.15	**1.67**			
3.25-3.74	4.39	3.90	3.41	2.92	2.43	**1.94**		
3.75-4.49	5.15	4.67	4.18	3.69	3.20	2.71	**2.22**	
4.50+	6.69	6.20	5.71	5.22	4.73	4.24	3.75	**2.78**

14.5-14.9 SEER

18.0-20.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	0.61							
1.25-1.74	1.38	0.92						
1.75-2.24	2.14	1.68	1.22					
2.25-2.74	2.91	2.45	1.99	1.53				
2.75-3.24	3.68	3.22	2.75	2.29	1.83			
3.25-3.74	4.44	3.98	3.52	3.06	2.60	2.14		
3.75-4.49	5.21	4.75	4.29	3.83	3.37	2.91	2.44	
4.50+	6.74	6.28	5.82	5.36	4.90	4.44	3.98	3.06

21.0-23.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	0.69							
1.25-1.74	1.46	1.03						
1.75-2.24	2.22	1.80	1.38					
2.25-2.74	2.99	2.57	2.15	1.72				
2.75-3.24	3.76	3.33	2.91	2.49	2.07			
3.25-3.74	4.52	4.10	3.68	3.26	2.83	2.41		
3.75-4.49	5.29	4.87	4.44	4.02	3.60	3.18	2.76	
4.50+	6.82	6.40	5.98	5.56	5.13	4.71	4.29	3.45

14.5-14.9 SEER								
24.0+ SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.76**							
1.25-1.74	1.52	1.13						
1.75-2.24	2.29	1.90	1.51					
2.25-2.74	3.05	2.67	2.28	1.89				
2.75-3.24	3.82	3.43	3.04	2.66	2.27			
3.25-3.74	4.59	4.20	3.81	3.42	3.03	2.64		
3.75-4.49	5.35	4.97	4.58	4.19	3.80	3.41	3.02	
4.50+	6.89	6.50	6.11	5.72	5.33	4.94	4.55	3.78

4CP Demand Savings

Table 22.6-17: [Central ACs & HPs] 4CP kW Savings for 14.0 SEER New Construction Baseline

Size (tons)	SEER Range						
	14.5-14.9	**15.0-15.9**	**16.0-16.9**	**17.0-17.9**	**18.0-20.9**	**21.0-23.9**	**24.0+**
< 1.25	0.04	0.07	0.13	0.14	0.18	0.27	0.33
1.25-1.74	0.05	0.10	0.19	0.21	0.27	0.40	0.50
1.75-2.24	0.07	0.14	0.26	0.28	0.36	0.53	0.67
2.25-2.74	0.09	0.17	0.32	0.35	0.45	0.67	0.83
2.75-3.24	0.11	0.21	0.38	0.42	0.54	0.80	1.00
3.25-3.74	0.13	0.24	0.45	0.49	0.63	0.93	1.17
3.75-4.49	0.14	0.28	0.51	0.56	0.73	1.06	1.33
4.50+	0.18	0.35	0.64	0.70	0.91	1.33	1.67

Table 22.6-18: [Central ACs & HPs] 4CP kW Savings for 13.08 SEER Replace-on-Burnout Baseline

14.5-14.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.10**							
1.25-1.74	0.58	**0.15**						
1.75-2.24	1.06	0.63	**0.20**					
2.25-2.74	1.54	1.11	0.68	**0.25**				
2.75-3.24	2.02	1.59	1.16	0.73	**0.30**			
3.25-3.74	2.50	2.07	1.64	1.21	0.78	**0.35**		
3.75-4.49	2.98	2.55	2.12	1.69	1.26	0.83	**0.40**	
4.50+	3.94	3.51	3.08	2.65	2.22	1.79	1.36	**0.50**
15.0-15.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.13**							
1.25-1.74	0.61	**0.20**						
1.75-2.24	1.09	0.68	**0.26**					
2.25-2.74	1.57	1.16	0.75	**0.33**				
2.75-3.24	2.05	1.64	1.23	0.81	**0.40**			
3.25-3.74	2.54	2.12	1.71	1.29	0.88	**0.46**		
3.75-4.49	3.02	2.60	2.19	1.77	1.36	0.94	**0.53**	
4.50+	3.98	3.56	3.15	2.73	2.32	1.90	1.49	**0.66**

14.5-14.9 SEER

16.0-16.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.19**							
1.25-1.74	0.67	**0.29**						
1.75-2.24	1.15	0.77	**0.38**					
2.25-2.74	1.63	1.25	0.86	**0.48**				
2.75-3.24	2.11	1.73	1.34	0.96	**0.57**			
3.25-3.74	2.59	2.21	1.82	1.44	1.05	**0.67**		
3.75-4.49	3.07	2.69	2.31	1.92	1.54	1.15	**0.77**	
4.50+	4.04	3.65	3.27	2.88	2.50	2.11	1.73	**0.96**

17.0-17.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.20**							
1.25-1.74	0.68	**0.30**						
1.75-2.24	1.16	0.79	**0.41**					
2.25-2.74	1.64	1.27	0.89	**0.51**				
2.75-3.24	2.13	1.75	1.37	0.99	**0.61**			
3.25-3.74	2.61	2.23	1.85	1.47	1.09	**0.71**		
3.75-4.49	3.09	2.71	2.33	1.95	1.57	1.19	**0.81**	
4.50+	4.05	3.67	3.29	2.91	2.53	2.15	1.77	**1.02**

14.5-14.9 SEER								
18.0-20.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.24**							
1.25-1.74	0.73	**0.37**						
1.75-2.24	1.21	0.85	**0.49**					
2.25-2.74	1.69	1.33	0.97	**0.61**				
2.75-3.24	2.17	1.81	1.45	1.09	**0.73**			
3.25-3.74	2.65	2.29	1.93	1.57	1.21	**0.86**		
3.75-4.49	3.13	2.77	2.41	2.05	1.69	1.34	**0.98**	
4.50+	4.09	3.73	3.37	3.01	2.66	2.30	1.94	**1.22**
21.0-23.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.33**							
1.25-1.74	0.81	**0.49**						
1.75-2.24	1.29	0.97	**0.66**					
2.25-2.74	1.77	1.46	1.14	**0.82**				
2.75-3.24	2.25	1.94	1.62	1.30	**0.99**			
3.25-3.74	2.73	2.42	2.10	1.78	1.47	**1.15**		
3.75-4.49	3.21	2.90	2.58	2.26	1.95	1.63	**1.32**	
4.50+	4.17	3.86	3.54	3.23	2.91	2.59	2.28	**1.65**

14.5-14.9 SEER								
24.0+ SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.40**							
1.25-1.74	0.88	0.59						
1.75-2.24	1.36	1.07	0.79					
2.25-2.74	1.84	1.56	1.27	0.99				
2.75-3.24	2.32	2.04	1.75	1.47	1.19			
3.25-3.74	2.80	2.52	2.23	1.95	1.67	1.39		
3.75-4.49	3.28	3.00	2.71	2.43	2.15	1.87	1.58	
4.50+	4.24	3.96	3.68	3.39	3.11	2.83	2.55	1.98

Table 22.6-19: [Central ACs & HPs] 4CP kW Savings for 12.44 SEER Early Retirement Baseline

14.5-14.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.15**							
1.25-1.74	0.65	**0.22**						
1.75-2.24	1.16	0.73	**0.30**					
2.25-2.74	1.66	1.23	0.80	**0.37**				
2.75-3.24	2.17	1.74	1.31	0.88	**0.45**			
3.25-3.74	2.67	2.24	1.81	1.38	0.95	**0.52**		
3.75-4.49	3.18	2.75	2.32	1.89	1.46	1.03	**0.59**	
4.50+	4.19	3.76	3.33	2.90	2.47	2.04	1.60	**0.74**

14.5-14.9 SEER

15.0-15.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	0.18							
1.25-1.74	0.69	0.27						
1.75-2.24	1.19	0.78	0.36					
2.25-2.74	1.70	1.28	0.87	0.45				
2.75-3.24	2.20	1.79	1.37	0.96	0.55			
3.25-3.74	2.71	2.29	1.88	1.46	1.05	0.64		
3.75-4.49	3.21	2.80	2.38	1.97	1.56	1.14	0.73	
4.50+	4.22	3.81	3.40	2.98	2.57	2.15	1.74	0.91

16.0-16.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	0.24							
1.25-1.74	0.75	0.36						
1.75-2.24	1.25	0.87	0.48					
2.25-2.74	1.76	1.37	0.99	0.60				
2.75-3.24	2.26	1.88	1.49	1.11	0.72			
3.25-3.74	2.77	2.38	2.00	1.61	1.23	0.84		
3.75-4.49	3.27	2.89	2.50	2.12	1.73	1.35	0.96	
4.50+	4.28	3.90	3.51	3.13	2.74	2.36	1.97	1.20

14.5-14.9 SEER

17.0-17.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.25**							
1.25-1.74	0.76	**0.38**						
1.75-2.24	1.26	0.88	**0.51**					
2.25-2.74	1.77	1.39	1.01	**0.63**				
2.75-3.24	2.27	1.89	1.52	1.14	**0.76**			
3.25-3.74	2.78	2.40	2.02	1.64	1.26	**0.88**		
3.75-4.49	3.28	2.91	2.53	2.15	1.77	1.39	**1.01**	
4.50+	4.29	3.92	3.54	3.16	2.78	2.40	2.02	**1.26**

18.0-20.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**0.29**							
1.25-1.74	0.80	**0.44**						
1.75-2.24	1.30	0.95	**0.59**					
2.25-2.74	1.81	1.45	1.09	**0.73**				
2.75-3.24	2.32	1.96	1.60	1.24	**0.88**			
3.25-3.74	2.82	2.46	2.10	1.75	1.39	**1.03**		
3.75-4.49	3.33	2.97	2.61	2.25	1.89	1.53	**1.18**	
4.50+	4.34	3.98	3.62	3.26	2.90	2.54	2.19	**1.47**

14.5-14.9 SEER								
21.0-23.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.38**							
1.25-1.74	0.88	**0.57**						
1.75-2.24	1.39	1.07	**0.76**					
2.25-2.74	1.89	1.58	1.26	**0.95**				
2.75-3.24	2.40	2.08	1.77	1.45	**1.14**			
3.25-3.74	2.91	2.59	2.27	1.96	1.64	**1.33**		
3.75-4.49	3.41	3.09	2.78	2.46	2.15	1.83	**1.52**	
4.50+	4.42	4.11	3.79	3.47	3.16	2.84	2.53	**1.89**
24.0+ SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.45**							
1.25-1.74	0.95	0.67						
1.75-2.24	1.46	1.17	0.89					
2.25-2.74	1.96	1.68	1.40	1.11				
2.75-3.24	2.47	2.18	1.90	1.62	1.34			
3.25-3.74	2.97	2.69	2.41	2.12	1.84	1.56		
3.75-4.49	3.48	3.19	2.91	2.63	2.35	2.07	1.78	
4.50+	4.49	4.21	3.92	3.64	3.36	3.08	2.79	2.23

Table 22.6-20: [Central ACs & HPs] 4CP kW Savings for 10.0 SEER Early Retirement Baseline

14.5-14.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.40**							
1.25-1.74	1.02	**0.59**						
1.75-2.24	1.65	1.22	**0.79**					
2.25-2.74	2.28	1.85	1.42	**0.99**				
2.75-3.24	2.91	2.48	2.05	1.62	**1.19**			
3.25-3.74	3.54	3.11	2.68	2.24	1.81	**1.38**		
3.75-4.49	4.17	3.74	3.30	2.87	2.44	2.01	**1.58**	
4.50+	5.42	4.99	4.56	4.13	3.70	3.27	2.84	**1.98**
15.0-15.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.43**							
1.25-1.74	1.06	**0.64**						
1.75-2.24	1.69	1.27	**0.86**					
2.25-2.74	2.31	1.90	1.49	**1.07**				
2.75-3.24	2.94	2.53	2.11	1.70	**1.28**			
3.25-3.74	3.57	3.16	2.74	2.33	1.91	**1.50**		
3.75-4.49	4.20	3.79	3.37	2.96	2.54	2.13	**1.71**	
4.50+	5.46	5.04	4.63	4.21	3.80	3.38	2.97	**2.14**

14.5-14.9 SEER

16.0-16.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	0.49							
1.25-1.74	1.12	0.73						
1.75-2.24	1.74	1.36	0.97					
2.25-2.74	2.37	1.99	1.60	1.22				
2.75-3.24	3.00	2.62	2.23	1.85	1.46			
3.25-3.74	3.63	3.25	2.86	2.48	2.09	1.71		
3.75-4.49	4.26	3.87	3.49	3.10	2.72	2.33	1.95	
4.50+	5.52	5.13	4.75	4.36	3.98	3.59	3.21	2.44

17.0-17.9 SEER

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	0.50							
1.25-1.74	1.13	0.75						
1.75-2.24	1.76	1.38	1.00					
2.25-2.74	2.38	2.01	1.63	1.25				
2.75-3.24	3.01	2.63	2.26	1.88	1.50			
3.25-3.74	3.64	3.26	2.88	2.51	2.13	1.75		
3.75-4.49	4.27	3.89	3.51	3.13	2.75	2.38	2.00	
4.50+	5.53	5.15	4.77	4.39	4.01	3.63	3.25	2.50

14.5-14.9 SEER								
18.0-20.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.54**							
1.25-1.74	1.17	**0.81**						
1.75-2.24	1.80	1.44	**1.08**					
2.25-2.74	2.43	2.07	1.71	**1.35**				
2.75-3.24	3.05	2.70	2.34	1.98	**1.62**			
3.25-3.74	3.68	3.33	2.97	2.61	2.25	**1.89**		
3.75-4.49	4.31	3.95	3.60	3.24	2.88	2.52	**2.16**	
4.50+	5.57	5.21	4.85	4.49	4.14	3.78	3.42	**2.70**
21.0-23.9 SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.63**							
1.25-1.74	1.25	**0.94**						
1.75-2.24	1.88	1.57	**1.25**					
2.25-2.74	2.51	2.20	1.88	**1.56**				
2.75-3.24	3.14	2.82	2.51	2.19	**1.88**			
3.25-3.74	3.77	3.45	3.14	2.82	2.50	**2.19**		
3.75-4.49	4.40	4.08	3.77	3.45	3.13	2.82	**2.50**	
4.50+	5.65	5.34	5.02	4.71	4.39	4.07	3.76	**3.13**

14.5-14.9 SEER								
24.0+ SEER								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**0.69**							
1.25-1.74	1.32	1.04						
1.75-2.24	1.95	1.67	1.38					
2.25-2.74	2.58	2.30	2.01	1.73				
2.75-3.24	3.21	2.92	2.64	2.36	2.08			
3.25-3.74	3.84	3.55	3.27	2.99	2.71	2.42		
3.75-4.49	4.46	4.18	3.90	3.62	3.33	3.05	2.77	
4.50+	5.72	5.44	5.16	4.87	4.59	4.31	4.03	3.46

22.7 MINI-SPLIT AIR CONDITIONER AND HEAT PUMP DEEMED SAVINGS TABLES

22.7.1 Deemed Energy Savings Tables[777]

Cooling Energy Savings

Refer to Appendix 22.6 Table 22.6-1 through Table 22.6-4.

Heating Energy Savings

Table 22.7-1: [Mini-Split HPs] Heating kWh Savings for 8.2 HSPF Baselines (NC, ROB of HP)

8.5-8.9 HSPF								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**60**							
1.25-1.74	450	**90**						
1.75-2.24	840	480	**121**					
2.25-2.74	1,230	870	510	**151**				
2.75-3.24	1,619	1,260	900	541	**181**			
3.25-3.74	2,009	1,650	1,290	930	571	**211**		
3.75-4.49	2,399	2,039	1,680	1,320	961	601	**241**	
4.50+	3,179	2,819	2,459	2,100	1,740	1,380	1,021	**302**

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[777] Rated capacity ranges are specified based on normal rounding convention between capacity categories (values at and above the midpoint round up, while values below the midpoint round down).

8.5-8.9 HSPF

9.0-9.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**121**							
1.25-1.74	511	**182**						
1.75-2.24	901	572	**243**					
2.25-2.74	1,291	961	632	**303**				
2.75-3.24	1,680	1,351	1,022	693	**364**			
3.25-3.74	2,070	1,741	1,412	1,083	754	**424**		
3.75-4.49	2,460	2,131	1,802	1,473	1,143	814	**485**	
4.50+	3,240	2,910	2,581	2,252	1,923	1,594	1,265	**606**

9.5-9.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**153**							
1.25-1.74	543	**229**						
1.75-2.24	932	619	**306**					
2.25-2.74	1,322	1,009	696	**382**				
2.75-3.24	1,712	1,399	1,085	772	**459**			
3.25-3.74	2,102	1,789	1,475	1,162	849	**535**		
3.75-4.49	2,492	2,178	1,865	1,552	1,238	925	**612**	
4.50+	3,271	2,958	2,645	2,331	2,018	1,705	1,391	**765**

8.5-8.9 HSPF

10.0-10.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**165**							
1.25-1.74	555	**247**						
1.75-2.24	944	637	**330**					
2.25-2.74	1,334	1,027	719	**412**				
2.75-3.24	1,724	1,417	1,109	802	**494**			
3.25-3.74	2,114	1,806	1,499	1,192	884	**577**		
3.75-4.49	2,504	2,196	1,889	1,581	1,274	967	**659**	
4.50+	3,283	2,976	2,668	2,361	2,054	1,746	1,439	**824**

10.5-10.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**176**							
1.25-1.74	566	**264**						
1.75-2.24	956	654	**353**					
2.25-2.74	1,346	1,044	742	**441**				
2.75-3.24	1,735	1,434	1,132	831	**529**			
3.25-3.74	2,125	1,824	1,522	1,220	919	**617**		
3.75-4.49	2,515	2,213	1,912	1,610	1,308	1,007	**705**	
4.50+	3,295	2,993	2,691	2,390	2,088	1,786	1,485	**881**

8.5-8.9 HSPF								
11.0-11.4 HSPF								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**187**							
1.25-1.74	577	**281**						
1.75-2.24	967	671	**375**					
2.25-2.74	1,357	1,061	764	**468**				
2.75-3.24	1,746	1,450	1,154	858	**562**			
3.25-3.74	2,136	1,840	1,544	1,248	952	**656**		
3.75-4.49	2,526	2,230	1,934	1,638	1,342	1,045	**749**	
4.50+	3,306	3,009	2,713	2,417	2,121	1,825	1,529	**937**
11.5-11.9 HSPF								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**198**							
1.25-1.74	588	**297**						
1.75-2.24	978	687	**396**					
2.25-2.74	1,367	1,077	786	**495**				
2.75-3.24	1,757	1,466	1,176	885	**594**			
3.25-3.74	2,147	1,856	1,565	1,274	984	**693**		
3.75-4.49	2,537	2,246	1,955	1,664	1,373	1,083	**792**	
4.50+	3,316	3,025	2,735	2,444	2,153	1,862	1,571	**990**

8.5-8.9 HSPF								
12.0+ HSPF								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	204							
1.25-1.74	594	306						
1.75-2.24	984	696	408					
2.25-2.74	1,374	1,086	798	510				
2.75-3.24	1,763	1,476	1,188	900	613			
3.25-3.74	2,153	1,865	1,578	1,290	1,002	715		
3.75-4.49	2,543	2,255	1,967	1,680	1,392	1,104	817	
4.50+	3,322	3,035	2,747	2,459	2,172	1,884	1,596	1,021

Table 22.7-2: [Mini-Split HPs] Heating kWh Savings for 7.7 HSPF Baseline (ER of HP)

8.5-8.9 HSPF								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	136							
1.25-1.74	564	205						
1.75-2.24	992	632	273					
2.25-2.74	1,420	1,060	700	341				
2.75-3.24	1,848	1,488	1,128	769	409			
3.25-3.74	2,275	1,916	1,556	1,196	837	477		
3.75-4.49	2,703	2,344	1,984	1,624	1,265	905	545	
4.50+	3,559	3,199	2,839	2,480	2,120	1,761	1,401	682

8.5-8.9 HSPF

9.0-9.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**197**							
1.25-1.74	625	**296**						
1.75-2.24	1,053	724	**395**					
2.25-2.74	1,481	1,152	822	**493**				
2.75-3.24	1,909	1,579	1,250	921	**592**			
3.25-3.74	2,336	2,007	1,678	1,349	1,020	**691**		
3.75-4.49	2,764	2,435	2,106	1,777	1,448	1,118	**789**	
4.50+	3,620	3,291	2,961	2,632	2,303	1,974	1,645	**987**

9.5-9.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**229**							
1.25-1.74	657	**343**						
1.75-2.24	1,085	771	**458**					
2.25-2.74	1,512	1,199	886	**572**				
2.75-3.24	1,940	1,627	1,314	1,000	**687**			
3.25-3.74	2,368	2,055	1,741	1,428	1,115	**801**		
3.75-4.49	2,796	2,482	2,169	1,856	1,542	1,229	**916**	
4.50+	3,651	3,338	3,025	2,711	2,398	2,085	1,771	**1,145**

8.5-8.9 HSPF

10.0-10.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**241**							
1.25-1.74	669	**361**						
1.75-2.24	1,096	789	**482**					
2.25-2.74	1,524	1,217	910	**602**				
2.75-3.24	1,952	1,645	1,337	1,030	**723**			
3.25-3.74	2,380	2,072	1,765	1,458	1,150	**843**		
3.75-4.49	2,808	2,500	2,193	1,886	1,578	1,271	**963**	
4.50+	3,663	3,356	3,049	2,741	2,434	2,126	1,819	**1,204**

10.5-10.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**252**							
1.25-1.74	680	**378**						
1.75-2.24	1,108	806	**505**					
2.25-2.74	1,536	1,234	932	**631**				
2.75-3.24	1,964	1,662	1,360	1,059	**757**			
3.25-3.74	2,391	2,090	1,788	1,486	1,185	**883**		
3.75-4.49	2,819	2,517	2,216	1,914	1,613	1,311	**1,009**	
4.50+	3,675	3,373	3,071	2,770	2,468	2,166	1,865	**1,262**

8.5-8.9 HSPF

11.0-11.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**263**							
1.25-1.74	691	**395**						
1.75-2.24	1,119	823	**527**					
2.25-2.74	1,547	1,251	955	**658**				
2.75-3.24	1,975	1,678	1,382	1,086	**790**			
3.25-3.74	2,402	2,106	1,810	1,514	1,218	**922**		
3.75-4.49	2,830	2,534	2,238	1,942	1,646	1,350	**1,053**	
4.50+	3,686	3,390	3,094	2,797	2,501	2,205	1,909	**1,317**

11.5-11.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**274**							
1.25-1.74	702	**411**						
1.75-2.24	1,130	839	**548**					
2.25-2.74	1,557	1,267	976	**685**				
2.75-3.24	1,985	1,694	1,404	1,113	**822**			
3.25-3.74	2,413	2,122	1,831	1,541	1,250	**959**		
3.75-4.49	2,841	2,550	2,259	1,968	1,678	1,387	**1,096**	
4.50+	3,696	3,406	3,115	2,824	2,533	2,242	1,952	**1,370**

8.5-8.9 HSPF								
12.0+ HSPF								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	280							
1.25-1.74	708	420						
1.75-2.24	1,136	848	560					
2.25-2.74	1,564	1,276	988	700				
2.75-3.24	1,991	1,704	1,416	1,128	841			
3.25-3.74	2,419	2,131	1,844	1,556	1,268	981		
3.75-4.49	2,847	2,559	2,272	1,984	1,696	1,408	1,121	
4.50+	3,703	3,415	3,127	2,839	2,552	2,264	1,976	1,401

Table 22.7-3: [Mini-Split HPs] Heating kWh Savings for 6.8 HSPF Baseline (ER of HP)

8.5-8.9 HSPF								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	319							
1.25-1.74	838	478						
1.75-2.24	1,357	998	638					
2.25-2.74	1,876	1,517	1,157	797				
2.75-3.24	2,395	2,036	1,676	1,317	957			
3.25-3.74	2,915	2,555	2,195	1,836	1,476	1,116		
3.75-4.49	3,434	3,074	2,714	2,355	1,995	1,636	1,276	
4.50+	4,472	4,112	3,753	3,393	3,033	2,674	2,314	1,595

8.5-8.9 HSPF

9.0-9.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**380**							
1.25-1.74	899	**570**						
1.75-2.24	1,418	1,089	**760**					
2.25-2.74	1,937	1,608	1,279	**950**				
2.75-3.24	2,456	2,127	1,798	1,469	**1,140**			
3.25-3.74	2,976	2,646	2,317	1,988	1,659	**1,330**		
3.75-4.49	3,495	3,166	2,836	2,507	2,178	1,849	**1,520**	
4.50+	4,533	4,204	3,875	3,545	3,216	2,887	2,558	**1,900**

9.5-9.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**412**							
1.25-1.74	931	**617**						
1.75-2.24	1,450	1,137	**823**					
2.25-2.74	1,969	1,656	1,342	**1,029**				
2.75-3.24	2,488	2,175	1,861	1,548	**1,235**			
3.25-3.74	3,007	2,694	2,381	2,067	1,754	**1,441**		
3.75-4.49	3,526	3,213	2,900	2,586	2,273	1,960	**1,646**	
4.50+	4,565	4,251	3,938	3,625	3,311	2,998	2,685	**2,058**

8.5-8.9 HSPF

10.0-10.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	423							
1.25-1.74	943	635						
1.75-2.24	1,462	1,154	847					
2.25-2.74	1,981	1,673	1,366	1,059				
2.75-3.24	2,500	2,193	1,885	1,578	1,270			
3.25-3.74	3,019	2,712	2,404	2,097	1,790	1,482		
3.75-4.49	3,538	3,231	2,923	2,616	2,309	2,001	1,694	
4.50+	4,576	4,269	3,962	3,654	3,347	3,040	2,732	2,117

10.5-10.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	435							
1.25-1.74	954	652						
1.75-2.24	1,473	1,172	870					
2.25-2.74	1,992	1,691	1,389	1,087				
2.75-3.24	2,511	2,210	1,908	1,607	1,305			
3.25-3.74	3,031	2,729	2,427	2,126	1,824	1,522		
3.75-4.49	3,550	3,248	2,946	2,645	2,343	2,041	1,740	
4.50+	4,588	4,286	3,985	3,683	3,381	3,080	2,778	2,175

8.5-8.9 HSPF

11.0-11.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**446**							
1.25-1.74	965	**669**						
1.75-2.24	1,484	1,188	**892**					
2.25-2.74	2,003	1,707	1,411	**1,115**				
2.75-3.24	2,522	2,226	1,930	1,634	**1,338**			
3.25-3.74	3,042	2,745	2,449	2,153	1,857	**1,561**		
3.75-4.49	3,561	3,265	2,968	2,672	2,376	2,080	**1,784**	
4.50+	4,599	4,303	4,007	3,711	3,414	3,118	2,822	**2,230**

11.5-11.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**457**							
1.25-1.74	976	**685**						
1.75-2.24	1,495	1,204	**913**					
2.25-2.74	2,014	1,723	1,432	**1,142**				
2.75-3.24	2,533	2,242	1,952	1,661	**1,370**			
3.25-3.74	3,052	2,761	2,471	2,180	1,889	**1,598**		
3.75-4.49	3,571	3,281	2,990	2,699	2,408	2,117	**1,827**	
4.50+	4,610	4,319	4,028	3,737	3,446	3,156	2,865	**2,283**

8.5-8.9 HSPF								
12.0+ HSPF								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**463**							
1.25-1.74	982	**694**						
1.75-2.24	1,501	1,213	**926**					
2.25-2.74	2,020	1,733	1,445	**1,157**				
2.75-3.24	2,539	2,252	1,964	1,676	**1,389**			
3.25-3.74	3,058	2,771	2,483	2,195	1,908	**1,620**		
3.75-4.49	3,578	3,290	3,002	2,714	2,427	2,139	**1,851**	
4.50+	4,616	4,328	4,040	3,753	3,465	3,177	2,890	**2,314**

Table 22.7-4: [Mini-Split HPs] Heating kWh Savings for 3.41 HSPF Baseline (ROB/ER of an Electric Resistance Furnace)

8.5-8.9 HSPF								
Size (tons) post	**< 1.25**	**1.25-1.74**	**1.75-2.24**	**2.25-2.74**	**2.75-3.24**	**3.25-3.74**	**3.75-4.49**	**4.50+**
Size (tons) pre								
< 1.25	**1,691**							
1.25-1.74	2,896	**2,536**						
1.75-2.24	4,100	3,741	**3,381**					
2.25-2.74	5,305	4,946	4,586	**4,227**				
2.75-3.24	6,510	6,151	5,791	5,431	**5,072**			
3.25-3.74	7,715	7,356	6,996	6,636	6,277	**5,917**		
3.75-4.49	8,920	8,561	8,201	7,841	7,482	7,122	**6,762**	
4.50+	11,330	10,970	10,611	10,251	9,892	9,532	9,172	**8,453**

8.5-8.9 HSPF

9.0-9.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,752**							
1.25-1.74	2,957	**2,627**						
1.75-2.24	4,161	3,832	**3,503**					
2.25-2.74	5,366	5,037	4,708	**4,379**				
2.75-3.24	6,571	6,242	5,913	5,584	**5,255**			
3.25-3.74	7,776	7,447	7,118	6,789	6,460	**6,130**		
3.75-4.49	8,981	8,652	8,323	7,994	7,665	7,335	**7,006**	
4.50+	11,391	11,062	10,733	10,404	10,074	9,745	9,416	**8,758**

9.5-9.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,783**							
1.25-1.74	2,988	**2,675**						
1.75-2.24	4,193	3,880	**3,566**					
2.25-2.74	5,398	5,085	4,771	**4,458**				
2.75-3.24	6,603	6,290	5,976	5,663	**5,350**			
3.25-3.74	7,808	7,495	7,181	6,868	6,555	**6,241**		
3.75-4.49	9,013	8,699	8,386	8,073	7,760	7,446	**7,133**	
4.50+	11,423	11,109	10,796	10,483	10,169	9,856	9,543	**8,916**

8.5-8.9 HSPF

10.0-10.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,795**							
1.25-1.74	3,000	**2,693**						
1.75-2.24	4,205	3,898	**3,590**					
2.25-2.74	5,410	5,103	4,795	**4,488**				
2.75-3.24	6,615	6,307	6,000	5,693	**5,385**			
3.25-3.74	7,820	7,512	7,205	6,898	6,590	**6,283**		
3.75-4.49	9,025	8,717	8,410	8,103	7,795	7,488	**7,180**	
4.50+	11,435	11,127	10,820	10,512	10,205	9,898	9,590	**8,976**

10.5-10.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,807**							
1.25-1.74	3,012	**2,710**						
1.75-2.24	4,216	3,915	**3,613**					
2.25-2.74	5,421	5,120	4,818	**4,516**				
2.75-3.24	6,626	6,325	6,023	5,721	**5,420**			
3.25-3.74	7,831	7,530	7,228	6,926	6,625	**6,323**		
3.75-4.49	9,036	8,735	8,433	8,131	7,830	7,528	**7,226**	
4.50+	11,446	11,144	10,843	10,541	10,239	9,938	9,636	**9,033**

8.5-8.9 HSPF

11.0-11.4 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	1,818							
1.25-1.74	3,023	2,726						
1.75-2.24	4,227	3,931	3,635					
2.25-2.74	5,432	5,136	4,840	4,544				
2.75-3.24	6,637	6,341	6,045	5,749	5,453			
3.25-3.74	7,842	7,546	7,250	6,954	6,658	6,362		
3.75-4.49	9,047	8,751	8,455	8,159	7,863	7,567	7,270	
4.50+	11,457	11,161	10,865	10,569	10,273	9,976	9,680	9,088

11.5-11.9 HSPF

Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	1,828							
1.25-1.74	3,033	2,742						
1.75-2.24	4,238	3,947	3,657					
2.25-2.74	5,443	5,152	4,861	4,571				
2.75-3.24	6,648	6,357	6,066	5,776	5,485			
3.25-3.74	7,853	7,562	7,271	6,981	6,690	6,399		
3.75-4.49	9,058	8,767	8,476	8,185	7,895	7,604	7,313	
4.50+	11,468	11,177	10,886	10,595	10,305	10,014	9,723	9,141

8.5-8.9 HSPF								
12.0+ HSPF								
Size (tons) post	< 1.25	1.25-1.74	1.75-2.24	2.25-2.74	2.75-3.24	3.25-3.74	3.75-4.49	4.50+
Size (tons) pre								
< 1.25	**1,834**							
1.25-1.74	3,039	**2,752**						
1.75-2.24	4,244	3,957	**3,669**					
2.25-2.74	5,449	5,162	4,874	**4,586**				
2.75-3.24	6,654	6,366	6,079	5,791	**5,503**			
3.25-3.74	7,859	7,571	7,284	6,996	6,708	**6,421**		
3.75-4.49	9,064	8,776	8,489	8,201	7,913	7,626	**7,338**	
4.50+	11,474	11,186	10,899	10,611	10,323	10,035	9,748	**9,172**

22.7.2 Deemed Summer Demand Savings Tables[778]

NCP Demand Savings

Refer to Appendix 22.6 Table 22.6-9 through Table 22.6-12.

CP Demand Savings

Refer to Appendix 22.6 Table 22.6-13 through Table 22.6-16.

4CP Demand Savings

Refer to Appendix 22.6 Table 22.6-17 through Table 22.6-20.

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[778] Rated capacity ranges are specified based on normal rounding convention between capacity categories (values at and above the midpoint round up, while values below the midpoint round down).

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