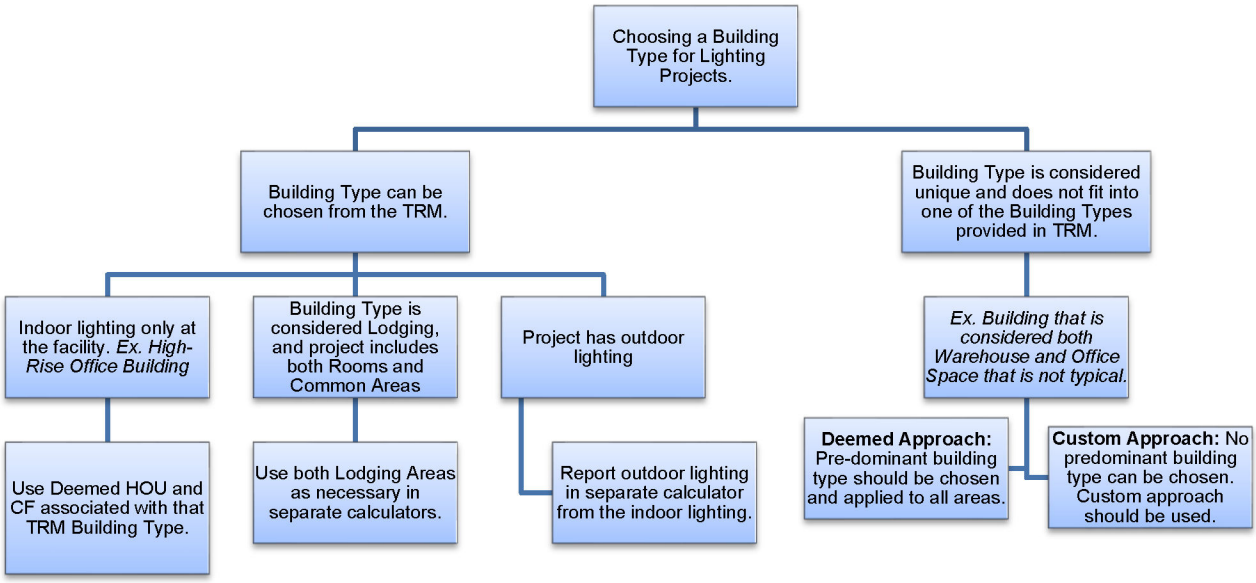
Lighting Calculator Building Type

This section provides additional guidance on Recommendation #1b in the 2013 Statewide Annual Portfolio Evaluation Report.[34]

The deemed lighting hours of use (HOU) and peak summer coincidence factors (CF) for utilities 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 8 through
Table 10. For the majority 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.[35] 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 2, has been provided to assist utilities in understanding how they can use the deemed methods to calculate lighting savings based on HOU and CF provided in the TRM. Additionally, it provides guidance on how to treat lodging facilities and outdoor lighting projects as well as unique building types.

Figure 2. Building Type Decision Making



Lodging sites. Lodging facilities (Hotel/Motel/Dormitories) have been identified in the TRM 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 utilities to use either or both building types for a single project.

[34] *Annual Statewide Portfolio Report for Program Year 2013 – Volume I*. Prepared for the Public Utility Commission of Texas. October 6, 2014.
[35] More information on how these values were created can be found in PUCT Docket #39146.

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 utilities should use the primary building type as their 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 TRM building types seem plausible, or a predominant TRM building type is unclear, the utilities have two choices:

- **Deemed approach.** The deemed approach is a simplified method where utilities should choose a TRM building type based on the "best fit" for the facility. This is determined by the largest interior area for the potential building types. Although, if that is not best fit, the utilities will use their best judgment to make this decision and provide sufficient, defensible documentation for their decision.
- **Custom approach.** In more unique situations, utilities should consider projects "custom" where (1) the deemed building types in the TRM may not represent the project's facility type, (2) the facility may represent multiple TRM building types without a clear predominant building type, or (3) the use of a predominant building type may be too conservative in the estimate of savings. The deemed methods are only applicable to specific scenarios and cannot be developed for all unique situations. Utilities should provide sufficient, defensible documentation for their HOU and CF values used in their savings calculations that can be reviewed by the EM&V team.

Interactive HVAC Factors (HVAC Energy, Demand)

Basic lighting savings are adjusted to account for 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 while increasing the heating load. Currently, the TRM only considers additional cooling savings, and the heating penalty or increase in usage is ignored.

As Table 11 shows, four conditioned space types are used for the Texas programs: single air-conditioned space type, two options for commercial refrigeration, and refrigerated warehouses: medium and low temperature. Utility procedures state that if the actual application falls between these values, 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 11. Deemed Energy and Demand Interactive HVAC Factors[36]

Space conditioning type	Energy interactive HVAC factor	Demand interactive HVAC factor
Refrigerated air	1.05	1.10
Evaporative cooling[37]	1.02	1.04
Medium-temperature refrigeration (33 to 41ºF)	1.25	1.25
Low-temperature refrigeration (-10 to 10ºF)	1.30	1.30
None (unconditioned/uncooled)	1.00	1.00

Upstream/Midstream Lighting

This section provides guidance on calculating and allocating savings at the sector-level for upstream/midstream lighting programs.

An increased number of utilities are offering or planning to offer upstream and/or midstream lighting programs in Texas. It is important that savings are calculated and reported consistently across utilities and in agreement with industry-standard practice and the Energy Efficiency Rule 16 TAC § 25.181.

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[38] and 2014 MECS[39] as well as lamp density and lamp type distribution survey data from the DOE 2015 U.S. Lighting Market Characterization (LMC)[40].

All general service, decorative, and reflector lamps with an equivalent wattage of 100 W or lower distributed though 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.[41] While only summer demand savings are specified for the commercial sector, winter demand savings are allowed for the portion of savings allocated to the residential sector.

---

[36] PUCT Docket 39146. Table 7 (page 17) and Table 12 (page 24).
[37] These factors are only applicable for projects in climate zones 1 and 5. They are derived by taking a ratio of total HVAC energy use for spaces with evaporative and refrigerated cooling then applying that ratio against the IEF factors specified for refrigerated air.
[38] 2012 Commercial Building Energy Consumption Survey (CBECS). https://www.eia.gov/consumption/commercial/. 2018 version not available until mid-2020.
[39] 2014 Manufacturing Energy Consumption Survey (MECS). https://www.eia.gov/consumption/manufacturing/.
[40] 2015 U.S. Lighting Market Characterization, Department of Energy. November 2017. https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.
[41] Weighting assumptions based on statewide evaluator review of LED purchasing behavior for similar program designs.

Table 12. Upstream/Midstream Assumptions by Lamp Type[42]

Lamp type	AOH	Coincidence factors					ISR
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	
General service lamp	3,748	0.69	0.69	0.73	0.73	0.71	0.98
Directional/reflector	3,774	0.78	0.79	0.78	0.79	0.82	1.00
LED tube	3,522	0.74	0.75	0.84	0.84	0.76	1.00
High-bay fixture	3,796	0.78	0.79	0.83	0.84	0.80	1.00
Garage	7,884	1.00	1.00	1.00	1.00	1.00	1.00
Outdoor	4,161	0.67	0.71	0.61	0.75	1.00	1.00

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.

Deemed Energy and Demand Savings Tables

This section is not applicable as these calculations are entirely dependent on site-specific parameters related to lighting system operation.

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The estimated useful life (EUL) values are defined for the following lamp/fixture types.[43] A separate new construction EUL has been established due 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: 9 years[44]
- LED fixtures: 15 years

[42] 2012 CBECS and 2014 MECS.
[43] PUCT Docket 36779.
[44] PUCT Docket 38023.

- LED corn cob lamps: 15 years
- LED tubes: 15 years
- Modular CFL and CCFL fixtures: 15 years
- T8 and T5 linear fluorescents: 15 years
- New construction interior fixtures/controls[45]: 14 years
- New construction exterior fixtures[46]: 15 years

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked by the program database to inform the evaluation and apply the savings properly.

- Decision/action type: retrofit or new construction
- Building or space type
- Optional: building or space funding source (state or private)
- **For new construction only:** light power density factor
- **For new construction only:** interior and/or exterior space square footage
- **For new construction only:** if applicable, verify if SECO compliance certification forms were filed[47]
- Conditioned space type: cooling equipment type, refrigerated space temperature range, heating fuel type, percent heated/cooled for NC Only (specified per control)
- Baseline fixture configuration
- Baseline lamp wattage
- Baseline ballast type
- Baseline lighting controls
- Baseline counts of operating fixtures
- Baseline counts of inoperable fixtures

[45] Based on review of new construction EULs claimed by Oncor and CenterPoint during the PY 2019 and 2020 weighted by energy savings.
[46] Ibid.
[47] 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.

- Post-retrofit manufacturer and model number[48]
- Post-retrofit fixture configuration
- Post-retrofit lamp wattage[49]
- Post-retrofit lamp specifications sheets: Post retrofit lamp product qualification information from DLC, ENERGY STAR®, or independent lab testing
- Post-retrofit ballast type
- Post-retrofit lighting controls
- Post-retrofit counts 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
- **For field adjustable light output fixtures only:** post-retrofit lumen readings for inspection sample
- Equipment operating hours
- Lighting measure group (from Measure Life groupings)
- **For retrofit only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed fixture; OR an evaluator pre-approved inspection approach
- **For new construction only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed fixture; as-built design drawings; lighting specifications package that provides detailed make and model information on installed lighting; OR an evaluator pre-approved inspection approach
- **For upstream/midstream only:** Qualified product list mapping efficient lighting products to baseline wattage assumptions

Lighting Measure Groups to be Used for Measure Summary Reports

The lighting measure groups, as defined in the Measure Life and Lifetime Savings list above, must be used for reporting summarized savings of lighting measures. Higher-level groupings of lighting technologies, such as "Non-LED" lighting, will not provide enough resolution for evaluation and cost-effectiveness analysis.

[48] See Eligibility Criteria section for additional information and exceptions related to reporting post-retrofit model number.
[49] See Eligibility Criteria section for additional information and exceptions related to reporting post-retrofit fixture wattage.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Describes EUL
- PUCT Docket 39146—Describes deemed values for energy and demand savings
- PUCT Docket 38023—Describes LED installation and efficiency standards for nonresidential LED products

Relevant Standards and Reference Sources

- 2015 International Energy Conservation Code. (Commercial Buildings)
- ANSI/ASHRAE/IESNA Standard 90.1-2013. Energy Standard for Buildings Except Low-Rise Residential Buildings. (Public/State buildings[50])
- ENERGY STAR® requirements for Commercial LED Lighting. http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=LTG.
- DesignLights Consortium. www.designlights.org.
- Consortium for Energy Efficiency. Commercial Lighting Qualifying Products List (for 4-foot lamps). http://library.cee1.org/content/Commercial-lighting-qualifying-products-lists.
- National Electrical Manufacturers Association. NEMA Premium Electronic Ballast Program. https://www.nema.org/Technical/Pages/NEMA-Premium.aspx.
- U.S. Lighting Market Characterization report, September 2002, http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lmc_vol1_final.pdf..
- United Illuminating Company and Connecticut Light and Power. Final Report, 2005 Coincidence Factor Study. https://library.cee1.org/content/united-illuminating-company-and-connecticut-light-power-final-report-2005-coincidence-factor.
- COMNET Appendix C—Schedules (Rev 3) https://comnet.org/appendix-c-schedules. Updated 07/25/2016.

[50] https://comptroller.texas.gov/programs/seco/code/state-funded.php. All state-funded agencies and institutions of higher education must comply with all errata sheets, as published by the ASHRAE Standard committee, so applicable values may differ from those shown in the tables as Errata are issued.

Document Revision History

Table 13. Nonresidential Lamps and Fixtures Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. *Measure Life section*: Added additional energy efficiency measures for consistency with the EUMMOT maintained list. *Calculator and Tools section*: Eliminated description of calculator output comparisons. *Tracking Data Requirements section:* Added lighting category requirements for measure summary reports.
v3.0	04/10/2015	TRM v3.0 update. Revised to eliminate T12 lamps as a valid baseline. *Measure Description section:* General clean-up of technology descriptions. *Program Tracking Data section:* Minor changes and clarifications.
v3.1	11/05/2015	TRM v3.1 update. *Revised to eliminate* T12 lamps as a valid baseline and eliminate the Oncor winter peak demand value to use the statewide average in all service territories. *Eligibility Criteria:* Adding sources for LED lamp and fixture eligibility.
v3.1	03/23/2016	TRM v3.1 March revision. Updated *Linear Fluorescent T12 Special Conditions* baseline table to include HO and VHO lamps. Updated criteria for miscellaneous length (e.g., 2-ft, 3-ft) T8s. Added footnote to explain how to account for non-rebated fixture lighting controls in savings calculations. Clarified some tracking data requirements.
v4.0	10/10/2016	TRM v4.0 update. Added LPD values and tracking data requirements for exterior space type Zones used in Codes and Standards.
v5.0	10/2017	TRM v5.0 update. Added two new building types (i.e., Data Centers, 24-Hr Restaurants), and updated the Manufacturing building type to separate 1, 2 and 3 shift operations. Updated sources and references. Completed code updates where applicable (IECC 2015 and ASHRAE 90.1-2013). Note that Texas adopted IECC 2015 for commercial, industrial, and residential buildings taller than three stories and ASHRAE 90.1-2013 for state-funded buildings.
v6.0	10/2018	TRM v6.0 update. Updated eligibility criteria to broaden the qualification paths for LED fixtures. Added rounding opt-in for LED wattages. Clarifications added for building type definitions, including the addition of an “Other” category for buildings that do not fit into the list of pre-defined building types. Updated peak coincident factors for the PDPF methodology outlined in Volume 1.
v7.0	10/2019	TRM v7.0 update. Merged relevant Volume 5 Implementation Guidance into the measure. Changed non-qualified lighting thresholds and accounting procedures for new construction projects. Added guidance for EISA baselines. Added Base Site Allowance for exterior new construction projects. Added equivalent metal halide guidance for exterior athletic fields and courts. Added new building types (Agriculture, Outdoor: Billboards, Education K-12 with partial summer session, Facility-Wide 24-Hour Lighting). Revised Outdoor: Athletic Field and Court factors. Added Midstream lighting guidance, assumptions, and calculations. Program tracking requirements updated.

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Updated EUL for new construction projects to apply to whole project. Updated dusk-to-dawn operating hours. Minor formula corrections. Updated DLC references to refer to v3.0 or later rather than explicit versions. Removed 10% nonqualified fixture threshold. Established lumens/watt assumptions for new construction baselines.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits. Added guidance for certification of incremented length products. Added upstream clarification. Combined greater and less than 100 W GSLs and reflectors for upstream/midstream. Adjusted upstream/midstream residential vs. commercial split and ISRs. Updated upstream/midstream outdoor hours of use. Added guidance for LED model number, performance characteristics certification, and dates of certification. Changed LSF references to fixture wattage table.

2.1.2 Lighting Controls Measure Overview

TRM Measure ID: NR-LT-LC

Market Sector: Commercial

Measure Category: Lighting

Applicable Building Types: All commercial, multifamily common areas

Fuels Affected: Electricity (interactive HVAC effects: electric/gas space heating)

Decision/Action Types: Retrofit, new construction

Program Delivery Type: Prescriptive, custom, direct install

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure promotes the installation of lighting controls in both new construction and retrofit applications. For retrofit applications, lighting controls are typically installed where there is no control other than a manual switch (wall or circuit panel). For new construction lighting systems, controls 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 with an energy adjustment factor (EAF) for kWh and a power adjustment factor (PAF) for kW.

Eligibility Criteria

Measures installed through utility programs must be one of the occupancy sensor, daylighting, and tuning controls that are described in Table 14. 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.[51] 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

[51] IECC 2015, Section C405.

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
- Employee lunch and break rooms
- Private offices
- Restrooms
- Storage rooms
- Janitorial closets
- Locker rooms
- Other spaces 30 square feet or less that are enclosed by floor-to-ceiling height partitions
- Warehouses

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.

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, daylighting, or tuning sensors.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The equations for lighting controls are similar to those used for lighting lamps and fixtures, 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).

$$Energy\ Savings = kW_{controlled} \times EAF \times Hours \times HVAC_{energy}$$

Equation 5

$$Peak\ Summer\ Demand\ Savings = kW_{controlled} \times \mathrm{PAF} \times CF \times HVAC_{demand}$$

Equation 6

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 8*
EAF	=	*Lighting control Energy Adjustment Factor, see Table 15*
PAF	=	*Lighting control Power Adjustment Factor, see Table 15*
CF	=	*Coincidence factor by building type, see Table 9 or Table 10*
$HVAC_{energy}$	=	*Energy Interactive HVAC factor by building type, see Table 11*
$HVAC_{demand}$	=	*Demand Interactive HVAC factor by building type, see Table 11*

See Section 2.1.1 of this volume 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 15. The EAF and PAF represent the reduction in energy and demand usage. For example, a factor of 0.24 would equate to 24 percent energy and demand savings. The same values from the referenced LBNL study are used for both EAF and PAF factors due to the lack of published data for demand factors.

Table 14. Lighting Controls Definitions

Control type	Description
None	No control
Occupancy	Adjusting 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)	Adjusting 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

Control type	Description
Personal tuning	Adjusting 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 15. Lighting Controls Energy and Power Adjustment Factors[52]

Control type	Sub-category	Control codes	EAF	PAF
None	Not applicable.	None	0.00	0.00
Occupancy	Not applicable.	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[53]	Not applicable.	Outdoor	0.00	0.00
Personal tuning	Not applicable.	PT	0.31	0.31
Institutional tuning	Not applicable.	IT	0.36	0.36
Multiple/combined types	Various combinations	Multiple[54]	0.47	0.47

Deemed Energy and Demand Savings Tables

Not applicable.

[52] Williams, Alison, Atkinson, Barbara, Barbesi, Karina, and Rubinstein, Francis, "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.

[53] 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.

[54] 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/.

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

Lighting controls savings for interior new construction projects should be claimed at the project level (combined fixture and controls savings) using a 14-year estimated useful life (EUL).[55] Lighting controls savings are not eligible for exterior new construction applications.

For retrofit applications, the EUL for lighting controls is provided by the 2007 GDS Associates Report.[56]

- Occupancy Sensor: 10 years
- Daylighting Control: 10 years
- Time Clock: 10 years
- Tuning Control: 10 years
- New Construction Interior Fixtures/Controls[57]: 14 years

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:

- 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 & installed lighting control type code[58]
- Lighting control mount type: wall, ceiling, integrated fixture, etc.

[55] Based on review of new construction EULs claimed by Oncor and CenterPoint during the PY 2019 and 2020 weighted by energy savings.

[56] 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.

[57] Based on review of new construction EULs claimed by Oncor and CenterPoint during the PY 2019 and 2020 weighted by energy savings.

[58] 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.

- Lighting control specification sheets
- Controlled fixture lamp type
- Controlled fixture wattage.
- **For retrofit only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed fixture; OR an evaluator pre-approved inspection approach
- **For new construction only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed fixture; as-built design drawings; lighting specifications package that provides detailed make and model information on installed lighting; OR an evaluator pre-approved inspection approach

References and Efficiency Standards

Petitions and Rulings

- "A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings." Williams, Alison, Atkinson, Barbara, Barbesi, Karina, and Rubinstein, Francis, Lawrence Berkeley National Laboratory (LBNL). September 2011. Table 6, p. 14. Weighted average by the number of "reviewed" and "non-reviewed" papers.
- PUCT Docket 40668—Describes deemed values to be used in energy and demand savings calculations.
- PUCT Docket 36779—Describes EUL.

Relevant Standards and Reference Sources

- 2015 International Energy Conservation Code (Commercial Buildings)
- ANSI/ASHRAE/IESNA Standard 90.1-2013. Energy Standard for Buildings Except Low-Rise Residential Buildings. (Public/State buildings.[59])

[59] https://comptroller.texas.gov/programs/seco/code/state-funded.php. All state-funded agencies and institutions of higher education must comply with all errata sheets, as published by the ASHRAE Standard committee, so applicable values may differ from those shown in the tables as Errata are issued.

Document Revision History

Table 16. Nonresidential Lighting Controls Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revisions.
v2.1	01/30/2015	TRM v2.1 update. Corrections to Equation 5 and Equation 6 to accurately reflect the energy and power adjustment factors and to reflect savings based on connected load rather than a delta load. Consolidation of algorithms for retrofit and new construction projects.
v3.0	04/10/2015	TRM v3.0 update. Update EAF and PAF factors with values from a more current and comprehensive controls study. Update equations to use a "controlled lighting watts" approach for both retrofit and new construction. Updated Program Tracking parameters for consistency with other Lighting measures and added interior/exterior location.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. Completed source and code updates where applicable (IECC 2015 and ASHRAE 90.1-2013). Note that Texas adopted IECC 2015 for commercial, industrial, and residential buildings taller than three stories and ASHRAE 90.1-2013 for state-funded buildings.
v6.0	10/2018	TRM v6.0 update. Revised multiple/combined control types EAF and PAF.
v7.0	10/2019	TRM v7.0 update. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Added eligibility criteria for new construction applications.

2.1.3 LED Traffic Signals Measure Overview

TRM Measure ID: NR-LT-TS

Market Sector: Commercial

Measure Category: Lighting

Applicable Building Types: Outdoor

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive, custom, direct install

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure is for the installation of light emitting diode (LED) traffic signals (typically available in red, yellow, green, and pedestrian formats) at traffic lights serving any intersection, in retrofit applications.

Eligibility Criteria

New construction applications are not eligible for this measure, as incandescent traffic signals are not compliant with the current federal standard[60], effective January 1, 2006.

Baseline Condition

For all retrofit applications, the baseline is a fixture with incandescent lamps.

High-Efficiency Condition

Due to the increased federal standard for traffic signals, the ENERGY STAR® Traffic Signal specification[61] was suspended effective May 1, 2007. ENERGY STAR® chose to suspend the specification rather than revise it due to minimal additional savings that would result from a revised specification. Because the ENERGY STAR® specification no longer exists, the efficiency standard is an equivalent LED fixture for the same application. The equivalent LED fixture must be compliant with the current federal standard except for yellow "ball" or "arrow" fixtures where there is no federal standard.

[60] Current federal standards for traffic and pedestrian signals can be found at the DOE website at: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=12.

[61] Memorandums related to this decision can be found on the ENERGY STAR® website at: https://www.energystar.gov/index.cfm?c=archives.traffic_signal_spec.

Table 17. Federal Standard Maximum Wattages[62] and Nominal Wattages[63]

Module type	Maximum wattage	Nominal wattage
12" red ball	17	11
8" red ball	13	8
12" red arrow	12	9
12" green ball	15	15
8" green ball	12	12
12" green arrow	11	11
Combination walking man/hand	16	13
Walking man	12	9
Orange hand	16	13

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

This section describes the deemed savings methodology for both energy and demand savings for all LED traffic signal projects.

$$Energy\ Savings = \left(kW_{pre} - kW_{installed}\right) \times Hours$$

Equation 7

$$Peak\ Summer\ Demand\ Savings = \left(kW_{pre} - kW_{installed}\right) \times CF$$

Equation 8

Where:

kW_{pre}	=	*Total kW of existing measure (fixture wattage multiplied by quantity)*
$kW_{installed}$	=	*Total kW of retrofit measure (fixture wattage multiplied by quantity)*
Hours	=	*Annual operating hours from Table 18*
CF	=	*Coincidence factor from Table 18*

[62] Maximum wattage is the wattage at which power consumed by the module after being operated for 60 minutes while mounted in a temperature testing chamber so that the lensed portion of the module is outside the chamber, all portions of the module behind the lens are within the chamber at a temperature of 74 °C, and the air temperature in front of the lens is maintained at a minimum of 49 °C.

[63] Nominal wattage is defined as power consumed by the module when it is operated within a chamber at a temperature of 25 °C after the signal has been operated for 60 minutes.

Table 18. Incandescent and LED Traffic Signal Savings Assumptions[64]

Fixture type	Incandescent wattage	LED wattage	AOH	CF[65]
8” red ball	86	8	4,746	0.54
8” green ball		10	3,751	0.43
8” yellow ball		13	263	0.03
12” red ball	149	11	4,746	0.54
12” green ball		12	3,751	0.43
12” yellow ball		10	263	0.03
8” red arrow	69	8	6,570	0.75
8” green arrow		8	1,825	0.21
8” yellow arrow	128	10	263	0.03
12” red arrow		7.5	7,771	0.89
12” green arrow		10	726	0.08
12” yellow arrow		10	263	0.03
Large (16”x18”) pedestrian signal	149	9	8,642	0.99
Small (12”x12”) pedestrian signal	107	9	8,642	0.99

[64] Northwest Power and Conservation Council: Regional Technical Forum. Commercial LED Traffic Signals measure workbook. Version 2.2 updated 6/29/2016. http://rtf.nwcouncil.org/measures/measure.asp?id=114&decisionid=37.

[65] Traffic signals operate consistently during each hour of the year. Therefore, CFs are calculated by dividing the assumed AOH value by 8,760 hours/year.

Deemed Energy and Demand Savings Tables

Table 19. LED Traffic Signal Deemed Savings per Fixture

Fixture type	kW savings	kWh savings
8” red ball	0.042	370
8” green ball	0.033	285
8” yellow ball	0.002	19
12” red ball	0.075	655
12” green ball	0.059	514
12” yellow ball	0.004	37
8” red arrow	0.046	401
8” green arrow	0.013	111
8” yellow arrow	0.004	31
12” red arrow	0.107	936
12” green arrow	0.010	86
12” yellow arrow	0.004	31
Large (16”x18”) pedestrian signal	0.138	1,210
Small (12”x12”) pedestrian signal	0.097	847

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

According to the Northwest Power and Conservation Council Regional Technical Forum, the EUL is 5 to 6 years depending on the installed fixture type, as shown in the following table.

Table 20. Incandescent and LED Traffic Signal EULs by Fixture Type[66]

Fixture type	EUL (years)
8” and 12” red, green, and yellow ball	6
8” and 12” red, green, and yellow arrow	
Large (16”x18”) pedestrian signal	5
Small (12”x12”) pedestrian signal	

[66] Northwest Power and Conservation Council: Regional Technical Forum. Commercial LED Traffic Signals measure workbook. Version 2.2 updated 6/29/2016. http://rtf.nwcouncil.org/measures/measure.asp?id=114&decisionid=37.

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked by the program database to inform the evaluation and apply the savings properly.

- Decision/Action Type: retrofit or NC (NC not eligible)
- Fixture type
- Quantity of installed fixtures
- Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed fixture; OR an evaluator pre-approved inspection approach

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- Traffic Signal Modules and Pedestrian Modules Federal Standard. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=12.
- Regional Technical Forum LED Traffic Signals savings workbook. https://rtf.nwcouncil.org/measure/led-traffic-signals?id=114&decisionid=37.

Document Revision History

Table 21. Nonresidential LED Traffic Signals Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. No revisions.

2.2 NONRESIDENTIAL: HVAC

2.2.1 Air Conditioner and Heat Pump Tune-Ups Measure Overview

TRM Measure ID: NR-HV-TU

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 30 through Table 36

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

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[67]

- Tighten all electrical connections, measure motor voltage and current
- Lubricate all moving parts, including motor and fan bearings
- Inspect and clean condensate drain
- Inspect controls of the system to ensure proper and safe operation; check startup/shutdown cycle of the equipment to assure the system starts, operates, and shuts off properly
- Clean evaporator and condenser coils

[67] Based on ENERGY STAR® HVAC Maintenance Checklist. www.energystar.gov/index.cfm?c=heat_cool.pr_maintenance.

- 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 manufacturers specifications
- Check refrigerant level and adjust to manufacturer specifications
- Check capacitor functionality and capacitance; compare to OEM specifications

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.

Baseline Condition

The baseline is a system with all or some of 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:

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

Equation 9

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

Equation 10

Where:

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

EL = *Efficiency loss due to 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 22.*

$HSPF_{pre}$ = *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 22.*

Table 22. Default EER and HSPF per Size Category[68]

Size category (Btuh/hr)	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

High-Efficiency Condition

After the tune-up, the equipment must be clean with airflows and refrigerant charges adjusted as appropriate and set forth above. Additionally, 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 for units less than 65,000 Btuh, which set a baseline of 13 SEER and 7.7 HSPF[69], and prior to January 1, 2010 for units greater than 65,000 Btuh. A 13 SEER is equivalent to approximately 11.2 EER[70] using the conversion developed by Lawrence Berkeley Lab and US DOE: EER = -0.02 x $SEER^2$ + 1.12 x 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 x COP.

[68] 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.

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

[70] 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.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Savings are based on an assumed efficiency loss factor of five percent due to dirty coils, dirty filters, improper airflow, and/or incorrect refrigerant charge.[71]

Heating energy savings are only applicable to heat pumps.

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

Equation 11

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

Equation 12

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

Equation 13

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 Table 22 [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 Table 22 [Btuh/W]*
$HSPF_{post}$	=	*Heating efficiency of the equipment after the tune-up [Btuh/W]*

[71] Energy Center of Wisconsin, May 2008; "Central Air-Conditioning in Wisconsin, A Compilation of Recent Field Research."

$$Summer\ Peak\ Demand\ [kW_{Savings,C}] = Capacity \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right) \times DF_C \times \frac{1\ kW}{1{,}000\ W}$$

Equation 14

$$Winter\ Peak\ Demand\ [kW_{Savings,H}] = Capacity \times \left(\frac{1}{HSPF_{pre}} - \frac{1}{HSPF_{post}}\right) \times DF_H \times \frac{1\ kW}{1{,}000\ W}$$

Equation 15

Where:

$EFLH_{C/H}$	=	*Cooling/heating equivalent full-load hours for appropriate climate zone [hours]; see Table 32 through Table 36 in Section 2.2.2*

Demand Savings Algorithms

Summer and winter demand savings are determined by applying a coincidence factor for each season. Winter peak demand savings are only applicable to heat pumps.

Where:

DF_C	=	*Cooling Demand factor; see Table 32 through Table 36 in Section 2.2.2*
DF_H	=	*Heating Demand factor; see Table 32 through Table 36 in Section 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.

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.

Deemed Winter 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.

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for a tune-up is 5 years.[72]

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:

- Manufacturer
- Model number
- Cooling capacity of the installed unit (tons)
- Climate zone or county of the site
- Type of unit
    - Air conditioner
    - Air source heat pump
- 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 a tune-up
    - Return and supply dry bulb and wet bulb temperatures
    - Before and after tune-up pictures of components illustrating condition change due to 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 nameplates are useful).

References and Efficiency Standards

Not applicable.

[72] 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.

Document Revision History

Table 23. Nonresidential AC-HP Tune-Ups Revision History

TRM version	Date	Description of change
v4.0	10/10/2016	TRM v4.0 origin.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions
v7.0	10/2019	TRM v7.0 update. No revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.

2.2.2 Split and Packaged Air Conditioners and Heat Pumps Measure Overview

TRM Measure ID: NR-HV-SP

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 30 through Table 36

Fuels Affected: Electricity

Decision/Action Type: Replace-on-burnout, early retirement, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Energy modeling, engineering algorithms, and estimates

Measure Description

This section summarizes the deemed savings methodology for the installation of air-cooled split system and single packaged air conditioning (AC) and heat pump (HP) systems. This document covers assumptions made for baseline equipment efficiencies for early retirement (ER) based on the age of the replaced equipment and for replace-on-burnout (ROB) and new construction (NC) situations based on efficiency standards. Savings calculations incorporate the use of both full-load and part-load efficiency values. 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 include:

- Packaged and split air conditioners (DX or air-cooled)
- Packaged and split heat pumps (air-cooled)

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 is electric.
- The building falls into one of the categories listed in Table 32 through Table 36. Building type descriptions and examples are provided in Table 30 and Table 31.

- For ER projects: ER projects involve the replacement of a working system. Additionally, the ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. A ROB approach should be used for these scenarios.
- If 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.

Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[73,74]

Baseline Condition

The baseline conditions related to efficiency and system capacity for ER and replace-on-burnout/new construction are as follows:

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 ROB/NC scenario. For the ER period, the baseline efficiency should be estimated using the values from Table 24 through Table 28 according to the capacity, system type, and age (based on year manufactured) of the replaced system.[75] When the system age can be determined (e.g., from nameplate, building prints, equipment inventory list), the baseline efficiency levels provided in Table 24 through Table 28 should be used. 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.[76] 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.

PUCT Docket 40885 provided baseline efficiencies for split and packaged systems replaced via ER.

---

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

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

[75] 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.

[76] 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.

ER baseline efficiency values represent the code-specified efficiency in effect at the time the system 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 and 2018, coinciding with the IECC 2009 and IECC 2015 code increases. The baseline efficiency levels shown in Table 24 through Table 28 are based on assumptions of the predominant heating types expected in the state. For air conditioners, baseline cooling efficiencies are displayed for a natural gas furnace heating section type. For heat pumps, baseline cooling efficiencies are displayed for electric resistance supplemental heating section type.

Table 24. ER Baseline Full-Load Efficiency for ACs

Year installed (replaced system)	Split systems < 5.4 tons (EER)[77]	Package system < 5.4 tons (EER)[78]	All systems 5.4 to < 11.3 tons (EER)[79]	All systems 11.3 to < 20 tons (EER)[53]	All systems 20 to < 63.3 tons (EER)[53]	All systems ≥ 63.3 tons (EER)[53]
≤ 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
2010–2017	11.2	11.2	11.0	10.8	9.8	9.5
≥ 2018	11.2	11.8	11.0	10.8	9.8	9.5

Table 25. ER Baseline Part-Load Efficiency for ACs[80]

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)[81]	All systems 11.3 to < 20 tons (IEER)	All systems 20 to < 63.3 tons (IEER)	All systems ≥ 63.3 tons (IEER)[81]
≤ 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
2010–2017	13.0	13.0	11.2	11.0	9.9	9.6
≥ 2018	13.0	14.0	12.6	12.2	11.4	11.0

[77] 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

[78] Ibid.

[79] Baseline EER values shown from ASHRAE/IECC assume Natural Gas heating for the predominant heating section type expected for Commercial facilities in Texas. For units installed from 2002 to present, 0.2 EER may be added for "Electric Resistance (or None)" heating types. For units installed before 2002 and greater than or equal to 11.3 tons, 0.2 EER may be added for no heating.

[80] IEER values were not added to the Standard until 2010, so IEERs for prior years are approximated as EER + 0.2 for systems between 5.4 tons and less than 20 tons and as EER + 0.1 for systems greater than 20 tons based on the relationship of EER to IEER from the current federal standard.

[81] Baseline IEER values shown from ASHRAE/IECC assume Natural Gas heating for the predominant heating section type expected for Commercial facilities in Texas. For units installed from 2002 to present, 0.2 IEER may be added for "Electric Resistance (or None)" heating types. For units installed before 2002 and greater than or equal to 11.3 tons, 0.2 IEER may be added for no heating.

Table 26. ER Baseline Full-Load Cooling Efficiency for HPs

Year installed (replaced system)	Split systems < 5.4 tons (EER)[82]	Package system < 5.4 tons (EER)[83]	All systems 5.4 to < 11.3 tons (EER)[84]	All systems 11.3 to < 20 tons (EER)[84]	All systems 20 to < 63.3 tons (EER)[84]	All systems ≥ 63.3 tons (EER)[84]
≤ 2005	9.2	9.0	10.1	9.3	9.0	9.0
2006–2009	11.2	11.2	10.1	9.3	9.0	9.0
2010–2017	11.2	11.2	11.0	10.6	9.5	9.5
≥ 2018	11.8	11.8	11.0	10.6	9.5	9.5

Table 27. ER Baseline Part-Load Cooling Efficiency for HPs[85]

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)[86]	All systems 11.3 to < 20 tons (IEER)[86]	All systems 20 to < 63.3 tons (IEER)[86]	All systems ≥ 63.3 tons (IEER)[86]
≤ 2005	10.0	9.7	10.3	9.5	9.1	9.1
2006–2009	13.0	13.0	10.3	9.5	9.1	9.1
2010–2017	13.0	13.0	11.2	10.7	9.6	9.6
≥ 2018	14.0	14.0	12.0	11.6	10.6	10.6

[82] 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.

[83] Ibid.

[84] Baseline EER values shown from ASHRAE/IECC assume Electric Resistance as the predominant heating section type expected for Commercial facilities in Texas. For units installed from 2002 to present, 0.2 EER may be subtracted for all other heating section types. For units installed before 2002 and greater than or equal to 11.3 tons, 0.2 EER may be subtracted for no heating.

[85] IEER values were not added to the Standard until 2010, so IEERs for prior years are approximated as EER + 0.2 for systems between 5.4 tons and less than 20 tons and as EER + 0.1 for systems greater than 20 tons based on the relationship of EER to IEER from the current federal standard.

[86] Baseline IEER values shown from ASHRAE/IECC assume Electric Resistance as the predominant heating section type expected for Commercial facilities in Texas. For units installed from 2002 to present, 0.2 IEER may be subtracted for all other heating section types. For units installed before 2002 and greater than or equal to 11.3 tons, 0.2 IEER may be subtracted for no heating.

Table 28. 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
2010–2017	7.7	7.7	3.3	3.2
≥ 2018	8.2	8.0	3.3	3.2

Replace-on-Burnout (ROB) and New Construction (NC)

Baseline efficiency levels for package and split DX air conditioners and heat pumps are provided in Table 29. These baseline efficiency levels reflect the latest minimum efficiency requirements from the current federal manufacturing standard and IECC 2015.

For air conditioners, baseline cooling efficiencies are displayed for a natural gas furnace heating section type. For heat pumps, baseline cooling efficiencies are displayed 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 29. Baseline Efficiency Levels for ROB and NC Air Conditioners and Heat Pumps[87]

System type	Capacity (tons)	Baseline efficiencies	Source[88]
Air conditioner	< 5.4	11.2 EER (split)[89] 13.0 SEER (split) 11.8 EER (packaged)[90] 14.0 SEER (packaged)	DOE Standards/ IECC 2015
	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	IECC 2015

[87] IECC 2015 Table C403.2.3(1) and C403.2.3(2).
[88] These baseline efficiency standards noted as "DOE Standards" are cited in the Code of Federal Regulations, 10 CFR 431.97. http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec431-97.pdf.
[89] There is no code specified EER for this size category. The code specified SEER value was converted to EER using EER = -0.02 x SEER^2 + 1.12 x 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.
[90] IECC 2015 Table C403.2.3(1) and C403.2.3(2).

System type	Capacity (tons)	Baseline efficiencies	Source[88]
Heat pump (cooling)[91]	< 5.4	11.8 EER[92] 14.0 SEER	DOE Standards/ IECC 2015
	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)[93]	< 5.4	8.2 HSPF (split) 8.0 HSPF (packaged)	DOE Standards/ IECC 2015
	5.4 to < 11.25	3.3 COP	
	≥ 11.3	3.2 COP	

High-Efficiency Condition

Split and packaged systems must exceed the minimum efficiencies specified in Table 29. 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®[94] and the Consortium for Energy Efficiency (CEE)[95] offer suggested guidelines for high-efficiency equipment. Additional conditions for replace-on-burnout, ER and new construction are as follows:

New Construction and Replace-on-Burnout

This scenario includes equipment used for new construction and retrofit/replacements that are not covered by ER, such as units that are replaced after natural failure.

---

[91] ASHRAE 90.1-2010 Table 6.8.1B. These systems larger than 5.4 tons, the minimum efficiency levels provided in this table are based on systems with heating type "No Heating or Electric Resistance Heating", excluding systems with "All Other Types of Heating".

[92] There is no code specified EER for this size category. The code specified SEER value converted to EER using EER = -0.02 x SEER^2 + 1.12 x 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.

[93] Heat pump retrofits must also exceed the baseline efficiency levels for heating efficiencies.

[94] ENERGY STAR® Heating & Cooling, https://www.energystar.gov/products/heating_cooling.

[95] CEE Program Resources, http://www.cee1.org/content/cee-program-resources.

Early Retirement

The high-efficiency retrofits must meet the following criteria:[96]

- For ER projects only, the installed equipment cooling capacity must be within 80 percent to 120 percent 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 percent. 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 are being installed that directly affect the operation of the cooling equipment (e.g., control sequences, cooling towers, and condensers).

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

$$Peak\ Demand\ (Summer)\ [kW_{Savings,C}] = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}}\right) \times DF_C \times \frac{1\ kW}{1{,}000\ W}$$

Equation 16

$$Peak\ Demand\ (\text{Winter})[kW_{Savings,H}] = \left(\frac{Cap_{H,pre}}{\eta_{baseline,H}} - \frac{Cap_{H,post}}{\eta_{installed,H}}\right) \times DF_H \times \frac{1\ kW}{3{,}412\ Btuh}$$

Equation 17

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

Equation 18

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

Equation 19

$$Energy\ (Heating)\ \left[kWh_{Savings,H}\right] = \left(\frac{Cap_{H,pre}}{\eta_{baseline,H}} - \frac{Cap_{H,post}}{\eta_{installed,H}}\right) \times EFLH_H \times \frac{1\ kWh}{3{,}412\ Btu}$$

Equation 20

[96] From PUCT Docket #41070.

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 equipment (ER) or standard equipment (ROB/NC) [Btuh/W]*

$\eta_{installed,C}$ = *Rated cooling efficiency of the newly installed equipment (kW /Ton)—(Must exceed ROB/NC baseline efficiency standards in Table 29) [Btuh/W]*

$\eta_{baseline,H}$ = *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 29) [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 using the following equation:

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

Equation 21

$DF_{C,/H}$ = *Seasonal peak demand factor for appropriate climate zone, building type, and equipment type (Table 32 through Table 36)*

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours for appropriate climate zone, building type, and equipment type [hours] (Table 32 through Table 36)*

Early Retirement Savings

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 weighted savings calculated over both the ER and ROB periods, accounting for both the EUL and RUL. 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 a "first-year" savings, but an "average annual savings over the lifetime (EUL) of the measure." These savings calculations are explained in Appendix A.

System Type Conversion

Chiller to AC: Conversions from chiller-based systems to a packaged/split AC system are covered under this measure. See the reference tables in the HVAC Chillers measure for the savings.

AC to heat pump: Conversions from AC to heat pump are acceptable in commercial applications. Use CAP_H, $\eta_{baseline,H}$, DF_H, and $EFLH_H$ values for the new heat pump as a proxy for the baseline AC heating savings coefficients.

Deemed Energy and Demand Savings Tables

Deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone. A description of the building types that are used for HVAC systems is presented in Table 30 and Table 31. These building types are derived from the EIA CBECS study.[97]

The DF and EFLH values for packaged and split AC and HP units are presented in Table 32 through Table 36. 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.

A description of the calculation method used to derive these values can be found in Docket No. 40885, Attachment B.

[97] 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 TRM 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 30. Commercial HVAC Building Type Descriptions and Examples

Building type	Principal building activity	Definition	Detailed business type examples[98]
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 the 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.	1) Hospital 2) 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).	1) Medical office 2) Clinic or outpatient health care 3) Veterinarian

[98] Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.

Building type	Principal building activity	Definition	Detailed business type examples[98]
Large multifamily	Midrise apartment	Buildings containing multifamily dwelling units, having multiple stories, and equipped with elevators.	No sub-categories collected.
Lodging	Large hotel	Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings.	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		
Mercantile	Stand-alone retail	Buildings used for the sale and display of goods other than food.	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	Shopping malls comprised of multiple connected establishments.	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		

Building type	Principal building activity	Definition	Detailed business type examples[98]
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
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.	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 talon 11) Copy center or printing shop 12) Kennel

Building type	Principal building activity	Definition	Detailed business type examples[98]
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 31. Commercial HVAC Floor Area and Floor Assumptions by Building Type[99]

Building type	Principal building activity	Average floor area (ft^2)	Average number of floors
Data center	Data center	Not specified	Not specified
Education	College/university	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

[99] Building prototype information from DOE Commercial Reference Buildings, "Not specified" means that a building prototype is not defined for that building type. http://energy.gov/eere/buildings/Commercial-reference-buildings.

Building type	Principal building activity	Average floor area (ft^2)	Average number of floors
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

Table 32. DF and EFLH Values for Amarillo (Climate Zone 1)

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[100]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Data center	Data center	0.89	2,048	0.89	2,048	--	--
Education	College/university	0.69	787	0.69	787	--	--
	Primary school	0.64	740	0.64	740	0.43	701
	Secondary school	0.69	535	0.69	535	0.43	736
Food sales	Convenience	0.73	884	0.73	884	--	--
	Supermarket	0.29	219	0.29	219	--	--
Food service	Full-service restaurant	0.83	1,020	0.83	1,020	0.43	1,123
	24-hour full-service	0.81	1,093	0.81	1,093	0.43	1,346
	Quick-service restaurant	0.73	765	0.73	765	0.48	1,029
	24-hour quick-service	0.74	817	0.74	817	0.48	1,300
Healthcare	Hospital	0.72	2,185	0.72	2,185	--	--
	Outpatient healthcare	0.71	2,036	0.71	2,036	0.27	579
Large multifamily	Midrise apartment	0.68	674	0.68	674	--	--
Lodging	Large hotel	0.58	1,345	0.58	1,345	0.86	1,095
	Nursing home	0.68	685	0.68	685	--	--
	Small hotel/motel	0.57	1,554	0.57	1,554	0.36	475
Mercantile	Stand-alone retail	0.68	623	0.68	623	0.99	907
	24-hour stand-alone retail	0.80	820	0.80	820	0.43	1,277
	Strip mall	0.75	687	0.75	687	0.39	753

[100] For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the "Other" building type for heating energy/demand savings.

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[100]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Office	Large office	0.90	2,058	0.90	2,058	--	--
	Medium office	0.64	925	0.64	925	0.72	576
	Small office	0.72	711	0.72	711	0.29	340
Public assembly	Public assembly	0.64	995	0.64	995	--	--
Religious worship	Religious worship	0.57	387	0.57	387	--	--
Service	Service	0.83	790	0.83	790	--	--
Warehouse	Warehouse	0.34	173	0.34	173	--	--
Other	Other	0.29	173	0.29	173	0.27	340

Table 33. DF and EFLH Values for Dallas (Climate Zone 2)

Building type	Principal building activity	Package and Split DX					
		Air Conditioner		Heat Pump[101]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Data center	Data center	1.08	3,401	1.08	3,401	--	--
Education	College/university	1.02	1,595	1.02	1,595	--	--
	Primary school	0.88	1,208	0.88	1,208	0.66	397
	Secondary school	1.02	1,084	1.02	1,084	0.59	489
Food sales	Convenience	1.08	1,835	1.08	1,835	--	--
	Supermarket	0.58	615	0.58	615	--	--
Food service	Full-service restaurant	1.09	1,823	1.09	1,823	0.50	688
	24-hour full-service	1.09	2,061	1.09	2,061	0.49	873
	Quick-service restaurant	1.08	1,588	1.08	1,588	0.61	631
	24-hour quick-service	1.08	1,765	1.08	1,765	0.60	794
Healthcare	Hospital	0.92	3,097	0.92	3,097	--	--
	Outpatient healthcare	0.80	2,532	0.80	2,532	0.28	310
Large multifamily	Midrise apartment	1.04	1,709	1.04	1,709	--	--
Lodging	Large hotel	0.70	2,079	0.70	2,079	0.82	464
	Nursing home	1.04	1,736	1.04	1,736	--	--
	Small hotel/motel	0.55	2,281	0.55	2,281	0.42	249

[101] For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the "Other" building type for heating energy/demand savings.

Building type	Principal building activity	Package and Split DX					
		Air Conditioner		Heat Pump[101]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Mercantile	Stand-alone retail	0.95	1,157	0.95	1,157	0.55	352
	24-hour stand-alone retail	1.01	1,539	1.01	1,539	0.57	632
	Strip mall	0.91	1,100	0.91	1,100	0.55	376
Office	Large office	1.03	2,379	1.03	2,379	--	--
	Medium office	0.76	1,236	0.76	1,236	0.66	262
	Small office	0.92	1,203	0.92	1,203	0.40	153
Public assembly	Public assembly	0.88	1,624	0.88	1,624	--	--
Religious worship	Religious worship	0.55	567	0.55	567	--	--
Service	Service	1.09	1,412	1.09	1,412	--	--
Warehouse	Warehouse	0.84	597	0.84	597	--	--
Other	Other	0.55	567	0.55	567	0.28	153

Table 34. DF and EFLH Values for Houston (Climate Zone 3)

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[102]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Data center	Data center	1.05	4,022	1.05	4,022	--	--
Education	College/university	0.98	1,843	0.98	1,843	--	--
	Primary school	0.88	1,443	0.88	1,443	0.50	239
	Secondary school	0.98	1,253	0.98	1,253	0.54	293
Food sales	Convenience	1.03	2,142	1.03	2,142	--	--
	Supermarket	0.60	744	0.60	744	--	--
Food service	Full-service restaurant	1.05	2,135	1.05	2,135	0.44	429
	24-hour full-service	1.06	2,426	1.06	2,426	0.44	559
	Quick-service restaurant	1.03	1,853	1.03	1,853	0.51	372
	24-hour quick-service	1.05	2,059	1.05	2,059	0.50	483
Healthcare	Hospital	0.90	3,490	0.90	3,490	--	--
	Outpatient healthcare	0.80	2,844	0.80	2,844	0.29	196
Large multifamily	Midrise apartment	1.00	2,031	1.00	2,031	--	--

[102] For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the "Other" building type for heating energy/demand savings.

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[102]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Lodging	Large hotel	0.70	2,531	0.70	2,531	0.33	250
	Nursing home	1.00	2,063	1.00	2,063	--	--
	Small hotel/motel	0.65	2,316	0.65	2,316	0.19	147
Mercantile	Stand-alone retail	0.95	1,399	0.95	1,399	0.43	204
	24-hour stand-alone retail	0.97	1,804	0.97	1,804	0.41	374
	Strip mall	0.92	1,330	0.92	1,330	0.42	218
Office	Large office	1.00	2,619	1.00	2,619	--	--
	Medium office	0.75	1,387	0.75	1,387	0.42	149
	Small office	0.88	1,338	0.88	1,338	0.28	69
Public assembly	Public assembly	0.88	1,940	0.88	1,940	--	--
Religious worship	Religious worship	0.65	576	0.65	576	--	--
Service	Service	1.05	1,653	1.05	1,653	--	--
Warehouse	Warehouse	0.84	633	0.84	633	--	--
Other	Other	0.60	576	0.60	576	0.19	69

Table 35. DF and EFLH Values for Corpus Christi (Climate Zone 4)

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[103]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Data center	Data center	0.97	4,499	0.97	4,499	--	--
Education	College/university	0.96	2,211	0.96	2,211	--	--
	Primary school	0.88	1,680	0.88	1,680	0.30	156
	Secondary school	0.96	1,503	0.96	1,503	0.35	196
Food sales	Convenience	0.94	2,510	0.94	2,510	--	--
	Supermarket	0.54	894	0.54	894	--	--
Food service	Full-service restaurant	0.98	2,530	0.98	2,530	0.35	292
	24-hour full-service	0.97	2,897	0.97	2,897	0.36	377
	Quick-service restaurant	0.94	2,172	0.94	2,172	0.34	232
	24-hour quick-service	0.93	2,440	0.93	2,440	0.34	296

[103] For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the "Other" building type for heating energy/demand savings.

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[103]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Healthcare	Hospital	0.86	3,819	0.86	3,819	--	--
	Outpatient healthcare	0.78	3,092	0.78	3,092	0.08	122
Large multifamily	Midrise apartment	0.92	2,236	0.92	2,236	--	--
Lodging	Large hotel	0.65	2,981	0.65	2,981	0.21	131
	Nursing home	0.92	2,271	0.92	2,271	--	--
	Small hotel/motel	0.58	2,530	0.58	2,530	0.10	82
Mercantile	Stand-alone retail	0.84	1,582	0.84	1,582	0.22	131
	24-hour stand-alone retail	0.86	2,118	0.86	2,118	0.25	255
	Strip mall	0.82	1,510	0.82	1,510	0.21	141
Office	Large office	0.91	2,778	0.91	2,778	--	--
	Medium office	0.66	1,523	0.66	1,523	0.24	83
	Small office	0.80	1,504	0.80	1,504	0.14	39
Public assembly	Public assembly	0.88	2,259	0.88	2,259	--	--
Religious worship	Religious worship	0.58	629	0.58	629	--	--
Service	Service	0.98	1,959	0.98	1,959	--	--
Warehouse	Warehouse	0.73	665	0.73	665	--	--
Other	Other	0.54	629	0.54	629	0.08	39

Table 36. DF and EFLH Values for El Paso (Climate Zone 5)

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[104]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Data center	Data center	0.88	2,547	0.88	2,547	--	--
Education	College/university	0.87	1,092	0.87	1,092	--	
	Primary school	0.91	996	0.91	996	0.37	408
	Secondary school	0.87	742	0.87	742	0.43	431
Food sales	Convenience	0.76	1,251	0.76	1,251	--	
	Supermarket	0.38	347	0.38	347	--	--

[104] For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the "Other" building type for heating energy/demand savings.

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[104]			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Food service	Full-service restaurant	0.76	1,276	0.76	1,276	0.28	613
	24-hour full-service	0.74	1,413	0.74	1,413	0.27	809
	Quick-service restaurant	0.76	1,082	0.76	1,082	0.26	522
	24-hour quick-service	0.77	1,171	0.77	1,171	0.26	697
Healthcare	Hospital	0.81	2,555	0.81	2,555	--	--
	Outpatient healthcare	0.81	2,377	0.81	2,377	0.04	320
Large multifamily	Midrise apartment	0.88	1,209	0.88	1,209	--	--
Lodging	Large hotel	0.63	1,701	0.63	1,701	0.21	440
	Nursing home	0.88	1,228	0.88	1,228	--	
	Small hotel/motel	0.63	1,921	0.63	1,921	0.06	185
Mercantile	Stand-alone retail	0.80	904	0.80	904	0.26	384
	24-hour stand-alone retail	0.86	1,228	0.86	1,228	0.28	808
	Strip mall	0.83	931	0.83	931	0.27	448
Office	Large office	0.98	2,423	0.98	2,423	--	--
	Medium office	0.77	1,173	0.77	1,173	0.27	256
	Small office	0.84	1,037	0.84	1,037	0.15	146
Public assembly	Public assembly	0.91	1,339	0.91	1,339	--	--
Religious worship	Religious worship	0.63	478	0.63	478	--	--
Service	Service	0.76	988	0.76	988	--	--
Warehouse	Warehouse	0.75	324	0.75	324	--	--
Other	Other	0.38	324	0.38	324	0.04	146

Claimed Peak Demand Savings

A summer peak-period value is used for this measure. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Upstream/Midstream Delivery

For upstream/midstream program delivery, use the EFLH and DF assumptions outlined in Table 37 and Table 38. Assumed values have been weighted based on building-type survey data from 2012 CBECS[105] and 2014 MECS[106].

For upstream/midstream program designs where the building type is known, use the savings coefficients from Table 32 through Table 36. For program designs where the building type is unknown, you may use the savings coefficients from Table 37 and Table 38. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

Table 37. Upstream/Midstream Assumptions for DX HVAC Cooling[107]

Savings coefficient	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
$EFLH_C$	1,062	1,543	1,752	1,947	1,338
DF_C	0.68	0.92	0.91	0.84	0.84

Table 38. Upstream/Midstream Assumptions for DX HVAC Heating[108]

Savings coefficient	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
$EFLH_H$	504	245	130	79	243
DF_H	0.37	0.39	0.27	0.14	0.13

Measure Life and Lifetime Savings

The EUL and RULs for this HVAC equipment are provided below. The reader should refer to the definitions of estimated useful life (EUL) and remaining useful life in the glossary in Volume 1 for guidance on how to determine the decision type for system installations.

Estimated Useful Life

The EUL for split and packaged air conditioners and heat pumps is 15 years.[109]

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 39. 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

[105] 2012 Commercial Building Energy Consumption Survey (CBECS). https://www.eia.gov/consumption/commercial/. 2018 version not available until mid-2020.
[106] 2014 Manufacturing Energy Consumption Survey (MECS). https://www.eia.gov/consumption/manufacturing/.
[107] 2012 CBECS and 2014 MECS.
[108] Ibid.
[109] The EUL of 15 years has been cited in several places - PUCT Docket No. 36779, DOE 77 FR 28928, 10 CFR Part 431, and in the DEER 2014 update.

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 Appendix A.

Table 39. Remaining Useful Life Early Retirement Systems[110,111]

Age of replaced system (years)	Split/packaged AC/HP systems RUL (years)	Age of replaced system (years)	Split/packaged AC/HP systems RUL (years)
1	14.0	10	5.7
2	13.0	11	5.0
3	12.0	12	4.4
4	11.0	13	3.8
5	10.0	14	3.3
6	9.1	15	2.8
7	8.2	16	2.0
8	7.3	17	1.0
9	6.5	18[112]	0.0

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data is recommended to be specified and tracked by the program database to inform the evaluation and apply the savings properly.

- Decision/action type: ER, ROB, NC, system type conversion
- Building type (except for upstream/midstream programs)
- Climate zone
- Baseline number of units
- Baseline equipment type
- Baseline rated cooling and heating capacities

[110] PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.

[111] Current New Construction 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 and should use the ROB baseline instead. These values are greyed out in the table and displayed for informational purposes only.

[112] 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.

- **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)
- Installed number of units
- Installed equipment type
- Installed equipment rated cooling and heating capacities
- Installed cooling and heating efficiency ratings
- Installed manufacturer and model
- Installed unit AHRI/DOE CCMS certificate or reference number
- **For retrofit only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging or installed unit(s); OR an evaluator pre-approved inspection approach
- **For new construction only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging or installed unit(s); as-built design drawings; HVAC specifications package that provides detailed make and model information on installed unit(s); OR an evaluator pre-approved inspection approach
- **For Other building types only**: A description of the actual building type, the primary business activity, the business hours, and the HVAC schedule

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for HVAC equipment.
- PUCT Docket 40083—Provides incorporation of ER savings for existing commercial HVAC SOP designs and updates for baseline equipment efficiency levels for ROB and new construction projects involving package and split systems.
- PUCT Docket 40885—Provides a petition to revise deemed savings values for commercial HVAC replacement measures. Items covered by this petition include the following:
- Updated baseline efficiencies use for estimating deemed savings for commercial PTAC/PTHP's, room air conditioners, and chilled water systems.
- Approved estimates of RUL of working chilled water systems.
- Updated demand and energy coefficients for all commercial HVAC systems.

- Updated EUL of centrifugal chilled water systems installed in ROB or new construction projects.
- Provide a method for utilizing the ER concept developed in the petition in Docket No. 40083 for packaged and split DX systems and applied to chilled water systems when the age of the system being replaced cannot be ascertained.
- PUCT Docket 41070—Provides energy and demand savings coefficients for an additional climate zone, El Paso, Texas. Prior to this filing, savings for the Dallas-Fort Worth area were used for El Paso, but Dallas-Fort Worth has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.
- PUCT Docket 43681—Updated the approach for calculating early replacement energy and demand savings using a Net Present Value (NPV) method. Documented in Appendix A

Relevant Standards and Reference Sources

- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1A through Table 6.8.1D.
- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1-1 and Table 6.8.1-2.
- 2015 International Energy Conservation Code. Table C403.2.3(1) and Table C403.2.3(2).
- Code of Federal Regulations. Title 10. Part 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=75&action=viewlive.

Document Revision History

Table 40. Nonresidential Split-System/Single-Packaged AC-HP Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Modified ER savings calculations and added references to Appendix A, which details those calculations. Added heat pump minimum required heating efficiencies for reference. Revised baseline efficiency standards based on updates to federal standards.
v2.1	01/30/2015	TRM v2.1 update. Minor text updates and clarification of ER requirements.
v3.0	04/10/2015	TRM v3.0 update. Update of savings method to allow for part-load efficiency calculations. For heat pumps: Added heating efficiencies and split EFLH into cooling and heating components.
v3.1	11/05/2015	TRM v3.1 update. Update the building type definitions and descriptions. Added "Other" building type for when building type is not explicitly listed.

TRM version	Date	Description of change
v4.0	10/10/2016	TRM v4.0 update. Used modeling approach to update DF and EFLH for applicable building types and climate zones. Updated baseline efficiency values for split and packaged units less than 5.4 tons to be consistent with updated federal standards.
v5.0	10/2017	TRM v5.0 update. Updated baseline efficiency values for IECC 2015 and added 24-hour building load shapes. Updated RUL table based on DOE survival curves. Updated baseline efficiency tables to include "Electric Resistance (or None)" heating section type EER/IEER values. Modified baseline cooling efficiency tables for heat pumps to assume Electric Resistance supplemental; corrected an error on the 11.3 to 20 tons category for the EER to IEER conversion.
v6.0	10/2018	Revised ER criteria for systems with an overall capacity change. Added Data Center as a new building type. Created methodology for heat pump projects without explicitly building type modeling.
v7.0	10/2019	TRM v7.0 update. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Clarified use of post capacity for ROB baselines. Verify M&V plan requirement for VRF and documentation requirements. Added unknown age defaults for ER.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits. Removed baseline efficiency splits between heating section types for air conditioners and defaulted to "All Other" efficiencies. Clarified approach for system types conversion to split/packaged AC systems. Updated EUL methodology. Incorporated building type weighted savings coefficients for upstream/midstream. Incremented RUL table for code compliance.

2.2.3 HVAC Chillers Measure Overview

TRM Measure ID: NR-HV-CH

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 54 through Table 58.

Fuels Affected: Electricity

Decision/Action Type: Replace-on-burnout, early retirement, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Energy modeling, engineering algorithms, and estimates

Measure Description

This document presents the deemed savings methodology for the installation of chillers. 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 both full-load and part-load efficiency values. 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. Minimum efficiencies are defined in units of kW/ton, the ratio of input power in kW to the cooling capacity in tons, or EER, the ratio of cooling capacity in Btu/h to input power in Watts.

Two paths are currently available for chiller compliance through the IECC and ASHRAE rating standards. Path A requires higher efficiency ratings for full-load operation, with lower ratings for part-load efficiency, and is most applicable to units that are expected to operate at or near full-load conditions. Path B requires higher efficiency ratings for part-load operation, with lower ratings for full-load efficiency, and is most applicable to units that are expected to operate primarily at part-load conditions with variable frequency drives. Either Path can be used for compliance on any particular chiller, but the chiller must meet the minimum requirements for both full and part-load efficiency that are set forth in the following sections.

Applicable efficient measure types include:[113]

- 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. If this type of retrofit is performed, reference the tables from the split/single packaged air conditioners and heat pumps measure.
- Chiller type conversions: 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.

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 is electric.
- The building falls into one of the categories listed in Table 54 through Table 58. Building type descriptions and examples are provided in Table 30 and Table 31.
- For early retirement projects: ER projects involve the replacement of a working system before natural burnout. Additionally, the ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. A ROB approach should be used for these scenarios.

If one of these conditions is not met, the deemed savings approach cannot be used, and the Simplified M&V Methodology or the Full M&V Methodology must be used.

Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[114, 115]

Baseline Condition

Early Retirement

Early retirement systems involve the replacement of a working system prior to natural burnout. The early retirement baseline cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred.

---

[113] Savings can also be claimed by a retrofit involving a change in equipment type (e.g., air-cooled packaged DX system to a water-cooled centrifugal chiller, or a split system air-cooled heat pump to an air-cooled non-centrifugal chiller). If this type of retrofit is performed, reference the tables from the following HVAC measure templates: HVAC-Chillers, Split System/Single Packaged Heat Pumps, and Air Conditioners

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

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

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/NC scenario. For the ER period, the baseline efficiency should be estimated using the values from Table 41 through Table 52 according to the capacity, chiller type, and age (based on year manufactured) of the replaced system.[116] When the chiller age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 41 through Table 52 should be used. 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 and 2018,[117] coinciding with the IECC 2009 and IECC 2015 code increases.

PUCT Docket 40885 provided baseline efficiencies for chillers replaced via early retirement programs and included a category for 1990-2001. However, the common practice for energy efficiency programs in Texas is to allow systems older than 1990 to use the same baseline efficiencies as those listed for 1990-2001. This practice is reflected in the baseline efficiency tables, by showing the Year Installed as ≤ 2001 rather than 1990-2001.

ER Baseline: Air-Cooled Chillers

Table 41. ER Baseline Full-Load Efficiency of All Path A Air-Cooled Chillers[118]

Year installed (replaced system)	< 75 tons (EER)	≥ 75 to 150 tons (EER)	≥ 150 to 300 tons (EER)	≥ 300 to 600 tons (EER)	≥ 600 tons (EER)
≤ 2001	*9.212*	*9.212*	*8.530*	*8.530*	*8.530*
2002–2009	9.562	9.562	9.562	9.562	9.562
2010–2017	9.562	9.562	9.562	9.562	9.562
≥ 2018	10.100	10.100	10.100	10.100	10.100

[116] 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.
[117] IECC 2015 not enforced in Texas until program year 2018.
[118] Code-specified efficiencies in effect prior to 2002 were given in COP and have been converted to EER using EER = COP x 3.412. Values in the "≤ 2001" row have been converted and are expressed in italics.

Table 42. ER Baseline Full-Load Efficiency of All Path B Air-Cooled Chillers[119]

Year installed (replaced system)	< 75 tons (EER)	≥ 75 to 150 tons (EER)	≥ 150 to 300 tons (EER)	≥ 300 to 600 tons (EER)	≥ 600 tons (EER)
≤ 2001	*9.212*	*9.212*	*8.530*	*8.530*	*8.530*
2002–2009	9.562	9.562	9.562	9.562	9.562
2010–2017	9.562	9.562	9.562	9.562	9.562
≥ 2018	9.700	9.700	9.700	9.700	9.700

Table 43. ER Baseline Part-Load Efficiency (IPLV) of All Path A Air-Cooled Chillers[120]

Year installed (replaced system)	< 75 tons (EER)	≥ 75 to 150 tons (EER)	≥ 150 to 300 tons (EER)	≥ 300 to 600 tons (EER)	≥ 600 tons (EER)
≤ 2001	*9.554*	*9.554*	*8.530*	*8.530*	*8.530*
2002–2009	10.416	10.416	10.416	10.416	10.416
2010–2017	12.500	12.500	12.500	12.500	12.500
≥ 2018	13.700	13.700	14.000	14.000	14.000

Table 44. ER Baseline Part-Load Efficiency (IPLV) of All Path B Air-Cooled Chillers[121]

Year installed (replaced system)	< 75 tons (EER)	≥ 75 to 150 tons (EER)	≥ 150 to 300 tons (EER)	≥ 300 to 600 tons (EER)	≥ 600 tons (EER)
≤ 2001	*9.554*	*9.554*	*8.530*	*8.530*	*8.530*
2002–2009	10.416	10.416	10.416	10.416	10.416
2010–2017	12.500	12.500	12.500	12.500	12.500
≥ 2018	15.800	15.800	16.100	16.100	16.100

ER Baseline: Centrifugal Water-Cooled Chillers

Table 45. ER Baseline Full-Load Efficiency of Centrifugal Path A Water-Cooled Chillers[122]

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to 150 tons (kW/ton)	≥ 150 to 300 tons (kW/ton)	≥ 300 to 400 tons (kW/ton)	≥ 400 to 600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	*0.925*	*0.925*	*0.837*	*0.748*	*0.748*	*0.748*
2002–2009	0.703	0.703	0.634	0.576	0.576	0.576
2010–2017	0.634	0.634	0.634	0.576	0.576	0.570
≥ 2018	0.610	0.610	0.610	0.560	0.560	0.560

[119] Ibid.
[120] Ibid.
[121] Ibid.
[122] Ibid.

Table 46. ER Baseline Full-Load Efficiency of Centrifugal Path B Water-Cooled Chillers[123]

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to 150 tons (kW/ton)	≥ 150 to 300 tons (kW/ton)	≥ 300 to 400 tons (kW/ton)	≥ 400 to 600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	*0.925*	*0.925*	*0.837*	*0.748*	*0.748*	*0.748*
2002–2009	0.703	0.703	0.634	0.576	0.576	0.576
2010–2017	0.639	0.639	0.639	0.600	0.600	0.590
≥ 2018	0.695	0.695	0.635	0.595	0.585	0.585

Table 47. ER Baseline Part-Load Efficiency (IPLV) of Centrifugal Path A Water-Cooled Chillers[124]

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to 150 tons (kW/ton)	≥ 150 to 300 tons (kW/ton)	≥ 300 to 400 tons (kW/ton)	≥ 400 to 600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	*0.902*	*0.902*	*0.781*	*0.733*	*0.733*	*0.733*
2002–2009	0.670	0.670	0.596	0.549	0.549	0.549
2010–2017	0.596	0.596	0.596	0.549	0.549	0.539
≥ 2018	0.550	0.550	0.550	0.520	0.500	0.500

Table 48. ER Baseline Part-Load Efficiency (IPLV) of Centrifugal Path B Water-Cooled Chillers[125]

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to 150 tons (kW/ton)	≥ 150 to 300 tons (kW/ton)	≥ 300 to 400 tons (kW/ton)	≥ 400 to 600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	*0.902*	*0.902*	*0.781*	*0.733*	*0.733*	*0.733*
2002–2009	0.670	0.670	0.596	0.549	0.549	0.549
2010–2017	0.450	0.450	0.450	0.400	0.400	0.400
≥ 2018	0.440	0.440	0.400	0.390	0.380	0.380

[123] Ibid.
[124] Ibid.
[125] Ibid.

ER Baseline: Positive-Displacement (Screw, Scroll, or Reciprocating) Water-Cooled Chillers

Table 49. ER Baseline Full-Load Efficiency of Screw/Scroll/Recip. Path A Water-Cooled Chillers[126]

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
2010–2017	0.780	0.775	0.680	0.620	0.620
≥ 2018	0.750	0.720	0.660	0.610	0.560

Table 50. ER Baseline Full-Load Efficiency of Screw/Scroll/Recip. Path B Water-Cooled Chillers[127]

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
2010–2017	0.800	0.790	0.718	0.639	0.639
≥ 2018	0.780	0.750	0.680	0.625	0.585

Table 51. ER Baseline Part-Load Efficiency (IPLV) of Screw/Scroll/Recip. Path A Water-Cooled Chillers[128]

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	*0.902*	*0.902*	*0.781*	*0.733*	*0.733*
2002–2009	0.676	0.676	0.628	0.572	0.572
2010–2017	0.630	0.615	0.580	0.540	0.540
≥ 2018	0.600	0.560	0.540	0.520	0.500

[126] Ibid.
[127] Ibid.
[128] Ibid.

Table 52. ER Baseline Part-Load Efficiency (IPLV) of Screw/Scroll/Recip. Path B Water-Cooled Chillers[129]

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	*0.902*	*0.902*	*0.781*	*0.733*	*0.733*
2002–2009	0.676	0.676	0.628	0.572	0.572
2010–2017	0.600	0.586	0.540	0.490	0.490
≥ 2018	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 53, which includes both full load and integrated part load value (IPLV) ratings. The IPLV accounts for chiller efficiency at part-load operation for a given duty cycle. These baseline efficiency levels reference standard ASHRAE 90.1-2010. This standard contains two paths for compliance, Path A or Path B. According to ASHRAE 90.1-2007 Addenda M, 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 significant time is spent at part-load operation (such as with a VSD chiller). Path A chillers are eligible to claim savings using the full-load efficiency conditions in the energy and demand savings algorithms.[130] Path B chillers are eligible to claim savings using the Path B chiller part-load baseline efficiencies with the demand and energy coefficients defined in this measure.

Table 53. Baseline Efficiencies for ROB and NC Air-Cooled and Water-Cooled Chillers[131]

System type (efficiency units)		Efficiency type	Capacity (tons)	Path A		Path B	
				Full-load	IPLV	Full-load	IPLV
Air-cooled chiller		EER	< 150	≥ 10.100	≥ 13.700	≥ 9.700	≥ 15.800
			≥ 150	≥ 10.100	≥ 14.000	≥ 9.700	≥ 16.100
Water-cooled chiller	Screw/ scroll/ recip.	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
	Centrifugal		< 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

[129] Ibid.
[130] According to ASHRAE 90.1-2007 Addenda M, 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 water-cooled chillers intended for applications where significant time is spent at part-load operation (such as with a VSD chiller).
[131] IECC 2015 Table C403.2.3(7).

High-Efficiency Condition

Chillers must exceed the minimum efficiencies specified in Table 53 for either Path A or Path B. For whichever path is used, the chiller must exceed the minimum baseline efficiency for both full-load and IPLV of that path to qualify. Additional conditions for replace-on-burnout, early retirement, and new construction are as follows:

New Construction and Replace-on-Burnout

This scenario includes chillers used for new construction and retrofit/replacements that are not covered by early retirement, such as units that are replaced after natural failure.

Early Retirement

The high-efficiency retrofits must meet the following criteria:[132]

- For early retirement projects only, the installed equipment cooling capacity must be within 80 percent to 120 percent 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, early retirement savings can still be claimed if the overall pre- and post-capacities for the total combination of systems are within ± 20 percent. In these cases, a custom calculation should be performed to establish the following weighted savings factors to be applied over the early retirement 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.
- No additional measures are being installed that directly affect the operation of the cooling equipment (e.g., control sequences, cooling towers, and condensers).

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Path A and B Air and Water-Cooled Chillers

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

Equation 22

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

Equation 23

[132] From PUCT Docket #41070.

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] – default values, based on system type, are given in Table 41 through Table 53; for efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 24 [kW/ton]*

$\eta_{installed}$ = *Rated efficiency of the newly installed equipment – must exceed efficiency standards, shown in Table 53; for efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 24 [kW/ton]*

Note: Use full-load efficiency (kW/ton) for kW demand savings calculations and part-load efficiency (IPLV) for kWh energy savings calculations.

$$\frac{kW}{Ton} = \frac{12}{EER}$$

Equation 24

DF = *Summer peak demand factor for appropriate climate zone, building type, and equipment type (Table 54 through Table 58)*

$EFLH_C$ = *Cooling equivalent full-load hours for appropriate climate zone, building type, and equipment type [hours] (Table 54 through Table 58)*

Air- to Water-Cooled Replacement: Adjustments for Auxiliary Equipment[133]

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:

$$kW_{adjust} = \left(HP_{CW\ pump} + HP_{CT\ fan}\right) \times \frac{0.746}{0.86} \times 0.80$$

Equation 25

$$kWh_{adjust} = kW \times 8{,}760$$

Equation 26

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	=	*Annual run-time hours*

The energy and demand of the condenser water pump and cooling tower fans are subtracted from the final savings, to reach the net savings:

$$kW_{savings,net} = kW_{Chiller} - kW_{adjust}$$

Equation 27

$$kWh_{savings,net} = kWh_{Chiller} - kWh_{adjust}$$

Equation 28

Early Retirement Savings

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 weighted savings calculated over both the ER period and the ROB period, accounting for the EUL and the RUL. The final reported savings for ER projects are not actually a "first-year" savings, but an "average annual savings over the lifetime (EUL) of the measure." These savings calculations are explained in Appendix A.

Table 54 through Table 58 present the demand and energy coefficients as well as the Part Load Factor. These HVAC coefficients vary by climate zone, building type, and equipment type. A description of the calculation method can be found in Docket No. 40885, Attachment B.

[133] This extra adjustment is noted in PUCT Docket No. 41070.

Deemed Energy and Demand Savings Tables

Deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone. A description of the building types that are used for HVAC systems is presented in Table 30 and Table 31. These building types are derived from the EIA CBECS study.[134]

Deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone for chillers in Table 54 through Table 58. 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 Other building type is used, a description of the actual building type, the primary business activity, the business operating 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 cannot use the deemed approach. A description of the calculation method can be found in Docket No. 40885, Attachment B.

Table 54. DF and EFLH for Amarillo (Climate Zone 1)

Building type	Principal building activity	Chiller[135]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
Data center	Data center	0.56	2,807	0.73	5,100
Education	College	0.87	1,115	0.68	1,243
	Primary school	0.44	576	0.53	971
	Secondary school	0.70	802	0.58	1,772
Healthcare	Hospital	0.70	2,006	0.65	2,711
Large multifamily	Midrise apartment	0.41	421	0.50	1,098
Lodging	Large hotel	0.58	1,283	0.59	1,553
	Nursing home	0.41	428	0.50	1,115
Mercantile	Stand-alone retail	0.52	489	0.54	719
	24-hour retail	0.67	681	0.62	974

[134] 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 TRM 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/.

[135] Coefficient values are derived from the petitions filed in Docket 40885 and Docket 30331. Coefficients were updated with Docket 40885, but not all building types (herein "principal building activities," or PBAs) that were originally available in Docket 30331 were updated in Docket 40885. Coefficient values for those PBAs that were not updated in Docket 40885 remain valid.

Building type	Principal building activity	Chiller[135]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
Office	Large office	0.70	1,208	0.61	1,506
Public assembly	Public assembly	0.44	774	0.53	1,306
Religious worship	Religious worship	0.52	294	0.54	433
Other	Other	0.41	294	0.50	433

Table 55. DF and EFLH for Dallas (Climate Zone 2)

Building type	Principal building activity	Chiller[136]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
Data center	Data center	0.54	2,791	0.77	4,906
Education	College	0.89	1,587	0.81	1,761
	Primary school	0.48	726	0.60	1,412
	Secondary school	0.84	1,170	0.54	2,234
Healthcare	Hospital	0.90	2,784	0.81	3,683
Large multifamily	Midrise apartment	0.68	1,060	0.66	2,053
Lodging	Large hotel	0.80	2,086	0.71	2,627
	Nursing home	0.68	1,077	0.66	2,085
Mercantile	Stand-alone retail	0.79	936	0.72	1,328
	24-hour retail	0.89	1,307	0.79	1,975
Office	Large office	0.92	1,711	0.70	2,062
Public assembly	Public assembly	0.48	976	0.60	1,898
Religious worship	Religious worship	0.79	563	0.72	799
Other	Other	0.48	563	0.54	799

Table 56. DF and EFLH for Houston (Climate Zone 3)

Building type	Principal building activity	Chiller[137]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
Data center	Data center	0.53	2,824	0.76	5,075
Education	College	0.80	1,858	0.84	2,099
	Primary school	0.45	818	0.60	1,627
	Secondary school	0.77	1,306	0.55	2,404
Healthcare	Hospital	0.85	3,116	0.79	4,171
Large multifamily	Midrise apartment	0.65	1,295	0.66	2,467
Lodging	Large hotel	0.71	2,499	0.73	3,201
	Nursing home	0.65	1,315	0.66	2,506

[136] Ibid.
[137] Ibid.

Building type	Principal building activity	Chiller[137]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
Mercantile	Stand-alone retail	0.83	1,224	0.78	1,712
	24-hour retail	0.80	1,513	0.74	2,427
Office	Large office	0.92	1,820	0.71	2,312
Public assembly	Public assembly	0.45	1,100	0.60	2,188
Religious worship	Religious worship	0.83	737	0.78	1,031
Other	Other	0.45	737	0.55	1,031

Table 57. DF and EFLH for Corpus Christi (Climate Zone 4)

Building type	Principal building activity	Chiller[138]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
Data center	Data center	0.48	2,881	0.77	5,266
Education	College	0.80	2,340	0.87	2,583
	Primary school	0.45	937	0.61	1,845
	Secondary school	0.68	1,503	0.55	2,577
Healthcare	Hospital	0.79	3,455	0.82	4,637
Large multifamily	Midrise apartment	0.61	1,534	0.67	2,840
Lodging	Large hotel	0.74	2,908	0.73	3,713
	Nursing home	0.61	1,558	0.67	2,884
Mercantile	Stand-alone retail	0.75	1,394	0.76	1,953
	24-hour retail	0.70	1,725	0.73	2,768
Office	Large office	0.82	2,027	0.72	2,570
Public assembly	Public assembly	0.45	1,260	0.61	2,481
Religious worship	Religious worship	0.75	839	0.76	1,176
Other	Other	0.45	839	0.55	1,176

Table 58. DF and EFLH for El Paso (Climate Zone 5)

Building type	Principal building activity	Chiller[139]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
Data center	Data center	0.56	2,950	0.71	5,137
Education	College	0.93	1,278	0.96	1,458
	Primary school	0.61	751	0.53	1,113
	Secondary school	0.77	1,039	0.54	2,196
Healthcare	Hospital	0.71	2,355	0.59	2,992
Large multifamily	Midrise apartment	0.56	841	0.52	1,553

[138] Ibid.
[139] Ibid.

Building type	Principal building activity	Chiller[139]			
		Air-cooled		Water-cooled	
		DF	$EFLH_c$	DF	$EFLH_c$
Lodging	Large hotel	0.63	1,815	0.58	2,038
	Nursing home	0.56	854	0.52	1,577
Mercantile	Stand-alone retail	0.64	722	0.55	948
	24-hour retail	0.61	884	0.60	1,371
Office	Large office	0.77	1,442	0.60	1,683
Public assembly	Public assembly	0.61	1,010	0.53	1,496
Religious worship	Religious worship	0.64	435	0.55	571
Other	Other	0.56	435	0.52	571

Claimed Peak Demand Savings

A summer peak-period value is used for this measure. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Upstream/Midstream Lighting

For upstream/midstream program delivery, use the EFLH and DF assumptions outlined in Table 59 and Table 60. Assumed values have been weighted based on building type survey data from 2012 CBECS[140] and 2014 MECS[141].

For upstream/midstream program designs where building type is known, use the savings coefficients from Table 54 through Table 58. For program designs where building type is unknown, you may use the savings coefficients from Table 59 and Table 60. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

Table 59. Upstream/Midstream Assumptions for Air-Cooled Chillers[142]

Savings coefficient	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
EFLHc	967	1,408	1,575	1,789	1,211
DFc	0.62	0.80	0.78	0.72	0.71

Table 60. Upstream/Midstream Assumptions for Water-Cooled Chillers[143]

Savings coefficient	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
$EFLH_C$	1,349	1,941	2,232	2,511	1,578
DF_C	0.58	0.68	0.70	0.70	0.59

[140] 2012 Commercial Building Energy Consumption Survey (CBECS). https://www.eia.gov/consumption/commercial/. 2018 version not available until mid-2020.
[141] 2014 Manufacturing Energy Consumption Survey (MECS). https://www.eia.gov/consumption/manufacturing/.
[142] 2012 CBECS and 2014 MECS.
[143] Ibid.

Measure Life and Lifetime Savings

Estimated Useful Life (EUL)

The EUL of HVAC equipment is provided below:

- Screw/scroll/reciprocating chillers: 20 years[144]
- Centrifugal chillers: 25 years.[145]

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 61. For ER units of unknown age, a default value of 20 years for non-centrifugal chillers and 25 years for centrifugal chillers should be used (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 early retirement projects for two distinct periods: The ER period (RUL) and the ROB period (EUL-RUL). The calculations for early retirement projects are extensive, and as such, are provided in Appendix A.

[144] PUCT Docket No. 36779. The original source was DEER 2008, but DEER 2014 provides the same value of 20 years for "High Efficiency Chillers". DEER does not differentiate between centrifugal and non-centrifugal chillers.

[145] PUCT Docket No. 40885, review of multiple studies looking at the lifetime of centrifugal chillers as detailed in petition workpapers.

Table 61. Remaining Useful Life of Early Retirement Systems[146,147]

Age of replaced system (years)	Non-centrifugal chillers RUL (years)	Centrifugal chillers RUL (years)
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
22	2.0	6.3
23	1.0	5.9
24[148]	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[149]	N/A	0.0

[146] PUCT Docket No. 40885, Attachment A describes the process in which the RUL of replaced systems has been calculated.

[147] Current New Construction 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 and should use the ROB baseline instead. These values are greyed out in the table and displayed for informational purposes only.

[148] 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.

[149] Ibid.

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data is recommended to be specified and tracked by the program database to inform the evaluation and apply the savings properly.

- Decision/action type: ER, ROB, NC, system type conversion
- Building type (except for upstream/midstream programs)
- Climate zone
- Baseline number of units
- Baseline equipment type (compressor/condenser type)
- Baseline equipment 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)
- Installed number of units
- Installed equipment type (compressor/condenser type)
- Installed path (Path A or Path B)
- Installed rated cooling capacity
- Installed cooling efficiency rating
- Installed manufacturer and model
- Installed unit AHRI/DOE CCMS certificate or reference number
- **For retrofit only:** Proof of purchase: invoice showing model number; photos of the model number on product packaging or installed unit(s); OR an evaluator pre-approved inspection approach
- **For new construction only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging or installed unit(s); as-built design drawings; HVAC specifications package that provides detailed make and model information on installed unit(s); OR an evaluator pre-approved inspection approach
- **For chiller type conversion only**: Condenser water pump HP and cooling tower fan HP
- **For Other building type only**: A description of the actual building type, the primary business activity, the business hours, and the HVAC schedule.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 30331—Established rules for energy efficiency programs, including factors for principal building activities (PBAs). Most PBA values were superseded by Docket 40885; however, some values from this docket remain valid.
- PUCT Docket 36779—Provides EUL for HVAC equipment.
- PUCT Docket 40083–Provides incorporation of early retirement savings for existing commercial HVAC SOP designs and updates for baseline equipment efficiency levels for ROB and new construction projects involving package and split systems.
- PUCT Docket 40885—Provides a petition to revise deemed savings values for commercial HVAC replacement measures. Items covered by this petition include the following:
- Updated baseline efficiencies use for estimating deemed savings for commercial PTAC/PTHP's, room air conditioners, and chilled water systems.
- Approved estimates of RUL of working chilled water systems.
- Updated demand and energy coefficients for all commercial HVAC systems.
- Updated EUL of centrifugal chilled water systems installed in ROB or new construction projects.
- Provide a method for utilizing the early retirement concept developed in the petition in Docket No. 40083 for packaged and split DX systems and applied to chilled water systems when the age of the system being replaced cannot be ascertained.
- PUCT Docket 41070—Provides energy and demand savings coefficients for an additional climate zone, El Paso, Texas. Previously these savings were taken from the Dallas-Fort Worth area, which has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.
- PUCT Docket 43681—Updated the approach for calculating early replacement energy and demand savings using a Net Present Value (NPV) method. Documented in Appendix A.

Relevant Standards and Reference Sources

- ANSI/ASHRAE/IES Standard 90.1-1989. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 10-7.
- ANSI/ASHRAE/IES Standard 90.1-2004. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1C.

- ANSI/ASHRAE/IES Standard 90.1-2007. Energy Standard for Buildings Except Low-Rise Residential Buildings, Addendum M. Table 6.8.1C.
- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1A through Table 6.8.1D.
- 2015 International Energy Conservation Code. Table C403.2.3(7).

Document Revision History

Table 62. Nonresidential HVAC Chillers Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Modified savings calculations surrounding early retirement programs, and revised details surrounding RUL and Measure Life. Added references to Appendix A for EUL and RUL discussion, and Net Present Value (NPV) equations.
v2.1	01/30/2015	TRM v2.1 update. Minor text updates and clarification of early retirement requirements.
v3.0	04/10/2015	TRM v3.0 update. Update of savings method to allow for part-load efficiency calculations.
v3.1	11/05/2015	TRM v3.1 update. Updated table references to clarify building types and RUL references. Added “Other” building type for when building type is not explicitly listed. Added Religious Worship building type to Climate Zone 5 for consistency with other zones.
v4.0	10/10/2016	TRM v4.0 update. Used modeling approach to update DF and EFLH for applicable building types and climate zones.
v5.0	10/2017	TRM v5.0 update. Included Path A and Path B compliance options for chillers. Added 24-hour Retail load shape. Updated RUL table based on DOE survival curves.
v6.0	10/2018	TRM v6.0 update. Revised Path A and B savings methodology for mid-year guidance memo. Added Data Center as a new building type. Updated early retirement guidance for projects with a total capacity change.
v7.0	10/2019	TRM v7.0 update. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Clarified use of post capacity for ROB baselines. Added unknown age defaults for early retirement.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits. Updated default age of system to match EUL. Incorporated upstream/midstream building-type weighting for savings coefficients. Incremented RUL table for code compliance.

2.2.4 Packaged Terminal Air Conditioners/Heat Pumps, and Room Air Conditioners Measure Overview

TRM Measure ID: NR-HV-PT

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 66 through Table 70

Fuels Affected: Electricity

Decision/Action Type: Replace-on-burnout, early retirement, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Energy modeling, engineering algorithms, and estimates

Measure Description

This section presents the deemed savings methodology for the installation of packaged terminal air conditioners (PTAC), packaged terminal heat pumps (PTHP), and room AC (RAC) systems. This document covers assumptions made for baseline equipment efficiencies for early retirement (ER) of PTAC/PTHPs, replace-on-burnout (ROB), and new construction (NC) situations 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 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 include all equipment configurations covered by the federal appliance standards, including with or without a reverse cycle, louvered or non-louvered sides, casement-only, and casement-slide.

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 is electric.
- The PTAC, PTHP, or RAC must be the primary cooling source for the space.
- For early retirement PTAC/PTHP projects: ER projects involve the replacement of a working system before natural burnout. Additionally, the ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. A ROB approach should be used for these scenarios.

If one of these conditions is not met, the deemed savings approach cannot be used, and the Simplified M&V Methodology or the Full M&V Methodology must be used.

Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[150,151]

Baseline Condition

Early Retirement for PTAC/PTHP Systems

Early retirement systems involve the replacement of a working system prior to natural burnout. The early retirement 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 a 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.[152] When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 63, 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.[153] A default RUL may be used exclusively if applied consistently for all

---

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

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

[152] 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.

[153] 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.

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 63. ER Baseline Efficiency Levels for Standard Size PTAC/PTHP Units[154]

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	$12.5 - (0.213 \times \text{Cap}/1000)$		
	>15,000	9.3		
PTHP	<7,000	10.8	3.0	--
	7,000-15,000	$12.3 - (0.213 \times \text{Cap}/1000)$	$3.2 - (0.026 \times \text{Cap}/1000)$	
	>15,000	9.1	2.8	

Replace-on-Burnout and New Construction

Table 64 provides minimum efficiency standards for PTAC/PTHP units and reflects the federal standards for packaged terminal air conditioners and heat pumps effective February 2013 and reflected in 10 CFR 431.

Table 64. Minimum Efficiency Levels for PTAC/PTHP ROB and NC Units[155,156]

Equipment	Category	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)	Minimum heating efficiency (COP)
PTAC	Standard Size	<7,000	11.9	--
		7,000-15,000	$14.0 - (0.300 \times Cap/1000)$	--
		>15,000	9.5	--
	Non-Standard Size	<7,000	9.4	--
		7,000-15,000	$10.9 - (0.213 \times Cap/1000)$	--
		>15,000	7.7	--

[154] 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.
[155] IECC 2015 Table C403.2.3(3).
[156] 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.

Equipment	Category	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)	Minimum heating efficiency (COP)
PTHP	Standard Size	<7,000	11.9	3.3
		7,000-15,000	$14.0 - (0.300 \times Cap/1000)$	$3.7 - (0.052 \times Cap/1000)$
		>15,000	9.5	2.9
	Non-Standard Size	<7,000	9.3	2.7
		7,000-15,000	$10.8 - (0.213 \times Cap/1000)$	$2.9 - (0.026 \times Cap/1000)$
		>15,000	7.6	2.5

Table 65 reflects the standards for room air conditioners, specified in 10 CFR 430.32(b).

Table 65. Minimum Efficiency Levels for Room Air Conditioners ROB and NC Units[157]

Category	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)
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	9.3
	≥ 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

[157] Direct final rule for new Room Air Conditioner Standards was published on April 21st, 2011 (76 FR 22454), effective August 19th, 2011, and are required starting June 1st, 2014. These are found in 10 CFR Part 430.

High-Efficiency Condition

The high-efficiency retrofits must exceed the minimum federal standards found in Table 64 and Table 65.

The high-efficiency retrofits must also meet the following criteria:[158]

- For early retirement projects only, the installed equipment cooling capacity must be within 80 percent to 120 percent 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, early retirement savings can still be claimed if the overall pre- and post-capacities for the total combination of systems are within ± 20 percent. In these cases, a custom calculation should be performed to establish the following weighted savings factors to be applied over the early retirement portion of the savings calculation: manufacturer year, EUL, RUL, 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 new construction
- No additional measures are being installed that directly affect the operation of the cooling equipment (e.g., control sequences)

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

$$Peak\ Demand\ (Summer)\ [kW_{Savings}] = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}}\right) \times DF_C \times \frac{1\ kW}{1{,}000\ W}$$

Equation 29

$$Peak\ Demand\ (Winter)\ [kW_{Savings}] = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}}\right) \times DF_H \times \frac{1\ kW}{3{,}412\ Btuh}$$

Equation 30

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

Equation 31

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

Equation 32

$$Energy\ (Heating)\ [kWh_{Savings,H}] = \left(\frac{Cap_{H,pre}}{\eta_{baseline,H}} - \frac{Cap_{H,post}}{\eta_{installed,H}}\right) \times EFLH_H \times \frac{1\ kWh}{3{,}412\ Btu}$$

Equation 33

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

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] (Table 63 through Table 65)*
$\eta_{baseline,H}$	=	*Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP] (Table 63 and Table 64)* [159]
$\eta_{installed,C}$	=	*Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h])—(Must exceed minimum federal standards found in Table 64 and Table 65)* [160]
$\eta_{installed,H}$	=	*Rated heating efficiency of the newly installed equipment [COP] (Must exceed minimum federal standards found in Table 64)*
$DF_{C,H}$	=	*Seasonal peak demand factor for appropriate climate zone, building type, and equipment type (Table 32 through Table 36)*
$EFLH_{C/H}$	=	*Cooling/heating equivalent full-load hours for newly installed equipment based on appropriate climate zone, building type, and equipment type [hours], see Table 66 through Table 70.*

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 a "first-year" savings, but an "average annual savings over the lifetime (EUL) of the measure." These savings calculations are explained in Appendix A.

Deemed Energy and Demand Savings Tables

Table 66 through Table 70 present the deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values for PTAC/PTHPs and RACs. These values are calculated by climate zone, building type, and equipment type. A description of the calculation method can also be found in Docket No. 40885, Attachment B.

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

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.

Table 66. PTAC/PTHP or RAC Equipment: DF and EFLH Values for Amarillo (CZ 1)

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Education	Primary school	0.56	686	0.56	686	0.43	322
	Secondary school	0.61	496	0.61	496	0.43	338
Food sales	Convenience	0.64	820	0.64	820	0.48	410
Food service	Full-service restaurant	0.73	946	0.73	946	0.43	516
	24-hour full-service	0.71	1,014	0.71	1,014	0.43	619
	Quick-service restaurant	0.64	710	0.64	710	0.48	473
	24-hour quick-service	0.65	758	0.65	758	0.48	598
Lodging	Large hotel	0.51	1,248	0.51	1,248	0.86	504
	Nursing home	0.60	635	0.60	635	0.50	256
	Small hotel	0.50	1,442	0.50	1,442	0.36	218
Mercantile	Strip mall	0.66	637	0.66	637	0.39	346
Office	Small office	0.63	660	0.63	660	0.29	156
Other	Other	0.50	496	0.50	496	0.29	156

Table 67. PTAC/PTHP or RAC Equipment: DF and EFLH Values for Dallas (CZ 2)

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Education	Primary school	0.85	1,016	0.85	1,016	0.66	231
	Secondary school	0.99	912	0.99	912	0.59	285
Food sales	Convenience	1.05	1,544	1.05	1,544	0.61	318

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Food service	Full-service restaurant	1.06	1,534	1.06	1,534	0.50	401
	24-hour full-service	1.06	1,734	1.06	1,734	0.49	509
	Quick-service restaurant	1.05	1,336	1.05	1,336	0.61	368
	24-hour quick-service	1.05	1,485	1.05	1,485	0.60	463
Lodging	Large hotel	0.68	1,749	0.68	1,749	0.82	270
	Nursing home	1.01	1,460	1.01	1,460	0.61	226
	Small hotel	0.53	1,919	0.53	1,919	0.42	145
Mercantile	Strip mall	0.88	925	0.88	925	0.55	219
Office	Small office	0.89	1,012	0.89	1,012	0.40	89
Other	Other	0.53	912	0.53	912	0.40	89

Table 68. PTAC/PTHP or RAC Equipment: DF and EFLH Values for Houston (CZ 3)

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Education	Primary school	0.71	1,186	0.71	1,186	0.50	52
	Secondary school	0.79	1,030	0.79	1,030	0.54	63
Food sales	Convenience	0.83	1,760	0.83	1,760	0.51	70
Food service	Full-service restaurant	0.85	1,755	0.85	1,755	0.44	93
	24-hour full-service	0.86	1,994	0.86	1,994	0.44	121
	Quick-service restaurant	0.83	1,523	0.83	1,523	0.51	80
	24-hour quick-service	0.85	1,692	0.85	1,692	0.50	104
Lodging	Large hotel	0.57	2,080	0.57	2,080	0.33	54
	Nursing home	0.81	1,695	0.81	1,695	0.24	44
	Small hotel	0.53	1,903	0.53	1,903	0.19	32
Mercantile	Strip mall	0.74	1,093	0.74	1,093	0.42	47
Office	Small office	0.71	1,100	0.71	1,100	0.28	15
Other	Other	0.53	1,030	0.53	1,030	0.28	15

Table 69. PTAC/PTHP or RAC Equipment: DF and EFLH Values for Corpus Christi (CZ 4)

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Education	Primary school	0.70	1,355	0.70	1,355	0.30	73
	Secondary school	0.76	1,212	0.76	1,212	0.35	92
Food sales	Convenience	0.74	2,025	0.74	2,025	0.34	94
Food service	Full-service restaurant	0.77	2,041	0.77	2,041	0.35	136
	24-hour full-service	0.77	2,337	0.77	2,337	0.36	176
	Quick-service restaurant	0.74	1,752	0.74	1,752	0.34	108
	24-hour quick-service	0.74	1,968	0.74	1,968	0.34	138
Lodging	Large hotel	0.51	2,404	0.51	2,404	0.21	61
	Nursing home	0.73	1,832	0.73	1,832	0.15	47
	Small hotel	0.46	2,041	0.46	2,041	0.10	38
Mercantile	Strip mall	0.65	1,218	0.65	1,218	0.21	66
Office	Small office	0.63	1,213	0.63	1,213	0.14	18
Other	Other	0.46	1,212	0.46	1,212	0.14	18

Table 70. PTAC/PTHP or RAC Equipment: DF and EFLH Values for El Paso (CZ 5)

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Education	Primary school	0.88	1,009	0.88	1,009	0.37	271
	Secondary school	0.84	751	0.84	751	0.43	286
Food sales	Convenience	0.74	1,267	0.74	1,267	0.26	300
Food service	Full-service restaurant	0.74	1,292	0.74	1,292	0.28	407
	24-hour full-service	0.72	1,431	0.72	1,431	0.27	538
	Quick-service restaurant	0.74	1,096	0.74	1,096	0.26	347
	24-hour quick-service	0.75	1,186	0.75	1,186	0.26	463
Lodging	Large hotel	0.61	1,723	0.61	1,723	0.21	292
	Nursing home	0.85	1,244	0.85	1,244	0.15	211
	Small hotel	0.61	1,945	0.61	1,945	0.06	123

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		DF_C	$EFLH_C$	DF_C	$EFLH_C$	DF_H	$EFLH_H$
Mercantile	Strip mall	0.80	943	0.80	943	0.27	298
Office	Small office	0.81	1,050	0.81	1,050	0.15	97
Other	Other	0.61	751	0.61	751	0.15	97

Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Upstream/Midstream Lighting

For upstream/midstream program delivery, use the following EFLH and DF assumptions. Assumed values have been weighted based on building type survey data from 2012 CBECS[161] and 2014 MECS[162].

For upstream/midstream program designs where building type is known, use the savings coefficients from Table 66 through Table 70. For program designs where building type is unknown, you may use the savings coefficients from Table 71 and Table 72. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

Table 71. Upstream/Midstream Assumptions for PTAC/PTHP or RAC Cooling[163]

Savings coefficient	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
$EFLH_C$	1,019	1,661	1,774	1,916	1,562
DF_C	0.55	0.78	0.68	0.60	0.73

Table 72. Upstream/Midstream Assumptions for PTHP Heating[164]

Savings coefficient	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
$EFLH_H$	247	193	40	46	176
DF_H	0.43	0.52	0.23	0.14	0.12

[161] 2012 Commercial Building Energy Consumption Survey (CBECS). https://www.eia.gov/consumption/commercial/. 2018 version not available until mid-2020.
[162] 2014 Manufacturing Energy Consumption Survey (MECS). https://www.eia.gov/consumption/manufacturing/.
[163] 2012 CBECS and 2014 MECS.
[164] Ibid.

Measure Life and Lifetime Savings

Estimated Useful Life (EUL)

The EUL of PTAC/PTHP units is 15 years, as specified in DEER 2014.[165]

The EUL of RAC units is 10 years based on current DOE Final Rule standards for room air conditioners. This value is consistent with the EUL reported in the Department of Energy Technical Support Document for Room Air conditioners.[166]

Remaining Useful Life (RUL) for PTAC/PTHP Systems

The RUL of ER replaced systems is provided according to system age in Table 73.

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 early retirement projects for two distinct periods: The ER period (RUL) and the ROB period (EUL-RUL). The calculations for early retirement projects are extensive, and as such, are provided in Appendix A.

Table 73. Remaining Useful Life of ER PTAC/PTHP Systems[167, 168]

Age of replaced system (years)	PTAC/PTHP RUL (years)	Age of replaced system(years)	PTAC/PTHP RUL (years)
1	14.0	10	5.7
2	13.0	11	5.0
3	12.0	12	4.4
4	11.0	13	3.8
5	10.0	14	3.3
6	9.1	15	2.8
7	8.2	16	2.0
8	7.3	17	1.0
9	6.5	18[169]	0.0

[165] http://www.deeresources.com/

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

[167] PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.

[168] Current federal standard effective date is 2/2013. Existing systems manufactured after this date are not eligible to use the early retirement baseline and should use the ROB baseline instead. These values are greyed out in the table and displayed for informational purposes only.

[169] 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.

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data is recommended to be specified and tracked by the program database to inform the evaluation and apply the savings properly.

- Decision/action type: ROB, NC, ER, system type conversion
- Building type (except for upstream/midstream programs)
- Climate zone
- Baseline number of units
- Baseline equipment type
- 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 or description documenting the reason why the nameplate photo was unobtainable (alternate forms of documentation can be approved at the evaluator's discretion)
- Installed number of units
- Installed equipment type (PTAC, PTHP, RAC)
- Equipment configuration category: Standard/non-standard or room AC
- Installed rated heating and cooling capacities
- Installed cooling and heating efficiency ratings
- Installed manufacturer and model
- Installed unit AHRI/DOE CCMS certificate or reference number
- **For retrofit only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed unit(s); OR an evaluator pre-approved inspection approach
- **For new construction only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed unit(s); as-built design drawings; HVAC specifications package that provides detailed make and model information on installed unit(s); OR an evaluator pre-approved inspection approach
- **For Other building type only**: A description of the actual building type, the primary business activity, the business hours, and the HVAC schedule

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for HVAC equipment.
- PUCT Docket 40083—Provides incorporation of early retirement savings for existing commercial HVAC SOP designs and updates for baseline equipment efficiency levels for ROB and new construction projects involving package and split systems.
- PUCT Docket 40885—Provides a petition to revise deemed savings values for commercial HVAC replacement measures. This petition updated demand and energy coefficients for all commercial HVAC systems.

Relevant Standards and Reference Sources

- ANSI/ASHRAE/IES Standard 90.1-2001 through ASHRAE 90.1-2007. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1D.
- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1D.
- Code of Federal Regulations. Title 10. Part 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=46
- Code of Federal Regulations. Title 10. Part 430—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=52
- 2015 International Energy Conservation Code. Table C403.2.3(3).

Document Revision History

Table 74. Nonresidential PTAC/PTHP and Room AC Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Updated EUL value for DX units, based on PUCT Docket No. 36779. Updated the minimum baseline efficiencies for Standard PTAC and PTHP based on new federal standards, 10 CFR 431.97, and updated the minimum efficiencies for Room AC units and added specifications for new Casement-only and Casement-slider equipment. Expanded application to “Hotel—Large” business type for PTAC/PTHP equipment and changed the RAC energy and demand coefficients to reference those for DX systems, rather than those for PTAC/PTHP systems.
v2.1	01/30/2015	TRM v2.1 update. Corrections to energy and demand coefficients for heat pumps in Climate Zone 3 (Houston).

TRM version	Date	Description of change
v3.0	04/10/2015	TRM v3.0 update. Added energy and demand coefficients for RAC units. Included text to allow for early retirement changes. For PTHPs: Added heating efficiencies and split EFLH into cooling and heating components.
v3.1	11/05/2015	TRM v3.1 update. Added updated building type definitions and descriptions, minor updates to text for clarification and consistency.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. Used modeling approach to update DF and EFLH for applicable building types and climate zones. Updated baseline efficiency values for IECC 2015 and added 24-hour building load shapes. Updated RUL table based on DOE survival curves. Added several new building types.
v6.0	10/2018	TRM v6.0 update. Revised early retirement criteria for systems with an overall capacity change.
v7.0	10/2019	TRM v7.0 update. Revised early retirement criteria for systems with an overall capacity change. Added clarification for PTHPs replacing PTACs with electric resistance heating. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Clarified use of post capacity for ROB baselines. Added unknown age defaults for early retirement.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits. Incorporated upstream/midstream building type weighted savings coefficients. Clarified default age and RUL. Incremented RUL table for code compliance.

2.2.5 Computer Room Air Conditioners Measure Overview

TRM Measure ID: NR-HV-CR

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 76 and Table 77

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Calculator

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 measure 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.

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 is electric.
- The building type is a network room or data center.
- For early retirement projects: ER projects involve the replacement of a working system. Additionally, the ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. A ROB approach should be used for these scenarios.
- In the event that 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.

Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[170,171]

Baseline Condition

The baseline conditions related to efficiency and system capacity for early retirement and replace-on-burnout/new construction are as follows:

Early Retirement

Early retirement projects should claim savings using the replace-on-burnout/new construction baseline, as no additional savings are specified for early retirement projects. This section will not apply until the current baseline is updated, allowing the measure to refer to the existing baseline for early retirement projects.

Replace-on-Burnout (ROB) and New Construction (NC)

Baseline efficiency levels for CRACs are provided in Table 75. These baseline efficiency levels reflect the minimum efficiency requirements from IECC 2015, which uses the Sensible Coefficient of Performance (SCOP) as the standard efficiency metric.

Table 75. Baseline Efficiency Levels for ROB and NC CRACs[172]

System type	Cooling capacity (Btu/hr)	Baseline efficiencies for downflow/upflow units (SCOP)	Source
Air conditioners, air-cooled	< 65,000	2.20 / 2.09	IECC 2015
	≥ 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 percent propylene glycol)	< 65,000	2.50 / 2.39	
	≥ 65,000 and < 240,000	2.15 / 2.04	
	≥ 240,000	2.10 / 1.99	

[170] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.
[171] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.
[172] IECC 2015 Table C403.2.3(9)

System type	Cooling capacity (Btu/hr)	Baseline efficiencies for downflow/upflow units (SCOP)	Source
Air conditioners, glycol cooled (rated at 40 percent 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	

High-Efficiency Condition

Package and split-systems must exceed the minimum efficiencies specified in Table 29.

Additional conditions for replace-on-burnout, early retirement, and new construction are as follows:

New Construction and Replace on Burnout

This scenario includes equipment used for new construction and retrofit/replacements that are not covered by early retirement, such as units that are replaced after natural failure.

Early Retirement

Early retirement projects should claim savings using the replace-on-burnout/new construction baseline, as no additional savings are specified for early retirement projects. This section will not apply until the current baseline is updated, allowing the measure to refer to the existing baseline for early retirement projects.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

$$Peak\ Demand\ [kW_{Savings,C}] = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}}\right) \times DF_C \times \frac{1\ kW}{3{,}412\ Btuh}$$

Equation 34

$$Energy\ (Cooling)\ [kWh_{Savings,C}] = \left(\frac{Cap_{C,pre}}{\eta_{baseline,C}} - \frac{Cap_{C,post}}{\eta_{installed,C}}\right) \times EFLH_C \times \frac{1\ kWh}{3{,}412\ Btu}$$

Equation 35

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 Btuh by multiplying kW by 3,412.

$\eta_{baseline,C}$ = *Cooling efficiency of existing equipment (ER) or standard equipment (ROB/NC) [SCOP]*

$\eta_{installed,C}$ = *Rated cooling efficiency of the newly installed equipment (SCOP)—(Must exceed ROB/NC baseline efficiency standards in Table 29) [SCOP]*

Note: Use SCOP for both kW and kWh savings calculations.

DF = *Seasonal peak demand factor for appropriate climate zone, and equipment type (Table 77)*

$EFLH_C$ = *Cooling equivalent full-load hours for appropriate climate zone, and equipment type [hours] (Table 77)*

Early Retirement Savings

Early retirement projects should claim savings using the replace-on-burnout/new construction baseline, as no additional savings are specified for early retirement projects. This section will not apply until the current baseline is updated, allowing the measure to refer to the existing baseline for early retirement projects.

Deemed Energy and Demand Savings Tables

Deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone. This measure is restricted to the data center building types, derived from the EIA CBECS study.[173]

The DF and EFLH values for CRAC units are presented in Table 77. A description of the calculation method used to derive these values can be found in Docket No. 40885, Attachment B.

Table 76. Commercial CRAC Building Type Descriptions and Examples

Building type	Principal building activity	Definition	Detailed business type examples[174]
Data center	Data center	Buildings used to house computer systems and associated components.	1) Data center

[173] 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 floor space to activity that is neither residential, manufacturing, industrial, nor agricultural. The high-level building types adopted for the TRM are adapted from this CBECS categorization, with some building types left out and one additional building type - Large Multifamily – included.*

[174] Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.

Table 77. DF and EFLH Values for All Climate Zones

Climate zone reference city	Building type and principal building activity	CRACs	
		DF_C	$EFLH_C$
Climate Zone 1: Amarillo	Data center	0.89	2,048
Climate Zone 2: Dallas		1.08	3,401
Climate Zone 3: Houston		1.05	4,022
Climate Zone 4: Corpus Christi		0.97	4,499
Climate Zone 5: El Paso		0.88	2,547

Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The EUL and RULs for this HVAC equipment are provided below. The reader should refer to the definitions of effective useful life and remaining useful life in the glossary in Volume 1 for guidance on how to determine the decision type for system installations.

Effective Useful Life (EUL)

The EUL for CRACs is 15 years, consistent with the EUL specified for split and packaged air conditioners and heat pumps.[175]

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.

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data is recommended to be specified and tracked by the program database to inform the evaluation and apply the savings properly.

- Decision/action type: ER, ROB, NC, system type conversion
- Climate zone
- Baseline number of units

[175] The EUL of 15 years has been cited in several places - PUCT Docket No. 36779, DOE 77 FR 28928, 10 CFR Part 431, and in the DEER 2014 update.

- Baseline equipment type
- Baseline equipment rated cooling capacity
- Installed number of units
- Installed equipment type
- Installed equipment rated cooling capacity
- Installed cooling efficiency ratings
- Installed manufacturer and model
- Installed unit AHRI/DOE CCMS certificate or reference number

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for HVAC equipment.
- PUCT Docket 40083– Provides incorporation of early retirement savings for existing commercial HVAC SOP designs and updates for baseline equipment efficiency levels for ROB and new construction projects involving package and split systems.
- PUCT Docket 40885—Provides a petition to revise deemed savings values for Commercial HVAC replacement measures. Items covered by this petition include the following:
- Updated baseline efficiencies use for estimating deemed savings for commercial PTAC/PTHP's, Room Air Conditioners, and chilled water systems.
- Approved estimates of RUL of working chilled water systems.
- Updated demand and energy coefficients for all commercial HVAC systems.
- Updated EUL of centrifugal chilled water systems installed in ROB or new construction projects.
- Provide a method for utilizing the early retirement concept developed in the petition in Docket No. 40083 for Packaged and Split DX systems and applied to chilled water systems when the age of the system being replaced cannot be ascertained.
- PUCT Docket 41070—Provides energy and demand savings coefficients for an additional climate zone, El Paso, TX. Prior to this filing, savings for the Dallas-Fort Worth area were used for El Paso, but Dallas-Fort Worth has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.
- PUCT Docket 43681—Updated the approach for calculating early replacement energy and demand savings using a net present value (NPV) method. Documented in Appendix A.

Relevant Standards and Reference Sources

- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1A through Table 6.8.1D.
- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1-1 and Table 6.8.1-2.
- 2015 International Energy Conservation Code. Table C403.2.3(1) and Table C403.2.3(2).
- Code of Federal Regulations. Title 10. Part 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=31.

Document Revision History

Table 78. Nonresidential Computer Room Air Conditioners Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed text referring to building types other than data centers.
v9.0	10/2021	TRM v9.0 update. Updated baseline table citation. Added capacity conversion from kW to btu/hr.

2.2.6 Computer Room Air Handler Motor Efficiency Measure Overview

TRM Measure ID: NS-HV-CM

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Data Centers

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed Savings Calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure involves improving the operational efficiency of a computer room air handler (CRAH) through the installation of a variable frequency drive (VFD) or electronically commutated motor (ECM). Savings for this measure include fan motor savings resulting from the ability to modulate the fan speed. Any associated cooling energy savings are not captured.

Eligibility Criteria

Eligible equipment includes fan motors and VFDs, 15 horsepower and smaller used to distribute conditioned air throughout a data center[176].

Baseline Condition

The CRAH baseline is a conventional AC motor driven, constant speed fan.

High-Efficiency Condition

The high-efficiency condition is the installation of a variable frequency drive (VFD) and/or electronically commutated motor (ECM).

[176] The existing associated computer room air conditioning (CRAC) unit condenser and evaporator are expected to remain in place for this measure. If those units are also replaced, reference the CRAC measure TRM entry.

Savings Algorithms and Input Variables

Energy and demand savings are estimated using input assumptions taken from site measured motor kW and operating hours for 243 CRAH units.[177]

Energy Savings Algorithms

$$Annual\ Energy\ Savings\ (kWh) = \left(kW_{pre} - kW/hp_{post} \times hp_{post}\right) \times hours$$

Equation 36

$$kW_{pre} = 0.746 \times hp_{pre} \times \frac{LF}{\eta}$$

Equation 37

Where:

hp_{pre} = *Rated horsepower of the existing motor*

LF = *Load factor—ratio of the operating load to the nameplate rating of the motor—assumed to be 75 percent at the fan or pump design 100 percent per DEER*

η = *Motor efficiency of a standard efficiency Open Drip Proof (ODP) motor operating at 1800 RPM taken from ASHRAE Standard 90.1-2013*

Table 79. Motor Efficiencies for Open Drip Proof Motors at 1,800 RPM

Motor horsepower	Full load efficiency
1	0.855
2	0.865
3	0.895
5	0.895
7.5	0.91
10	0.917
15	0.93

[177] Site data are sourced from 3 data centers in Oncor territory that replaced 243 CRAH fan motors either with ECMs or retrofitted with VFDs.

0.746	=	*HP to kW conversion factor*
kW/hp_{post}	=	*Efficient kW per motor hp, 0.27*[178]
hp_{post}	=	*Total efficient motor horsepower*
$hours$	=	*Annual operating hours, 8760*

Demand Savings Algorithms

$$Demand\ Savings\ (kW) = \frac{Annual\ Energy\ Savings\ (kWh)}{hours} \times CF$$

Equation 38

Where:

CF	=	*Peak coincidence factor, summer and winter: 0.11*[179]

Deemed Energy and Demand Savings Tables

There are no deemed savings tables for this measure.

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The median estimated useful life (EUL) for premium efficiency motors is 15 years.[180]

The EUL for HVAC VFD measure is 15 years.

[178] Oncor site data. Average kW/hp values are weighted by measure count.

[179] Peak coincidence factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using average hourly kW trends from Oncor site data. Summer and winter CF ranged from 0.10 to 0.12 across all climate zones, and the average value of 0.11 is used as the default input assumption for calculating demand savings.

[180] 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.

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data is recommended to be specified and tracked by the program database to inform the evaluation and apply the savings properly.

- Motor quantity, type, horsepower, and control; pre-installation
- Motor quantity, type, horsepower, and control; post-installation
- Climate zone

References and Efficiency Standards

Petitions and Rulings

None.

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 80. Nonresidential Computer Room Air Handler Motor Efficiency Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. No revisions.

2.2.7 HVAC Variable Frequency Drives Measure Overview

TRM Measure ID: NR-HV-VF

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 85 through Table 91

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

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.

Eligibility Criteria

Supply fans may not have variable pitch blades. Supply fans must be less than or equal to 100 hp. New construction systems are ineligible. Equipment used for process loads is ineligible.

Baseline Condition

The AHU supply fan baseline is a centrifugal supply fan with a single-speed motor on a direct expansion (DX) VAV or CAV air conditioning (AC) unit. The motor is a standard efficiency motor based on ASHRAE Standard 90.1-2013, which are provided by horsepower. The AC unit has standard cooling efficiency based on IECC 2015. The part-load fan control is an outlet damper, inlet damper, inlet guide vane, or no control (constant volume systems).

The HVAC pump baseline is a constant speed pump with a standard-efficiency motor. This measure is applicable to both primary and secondary hot or chilled water pumping systems.

High-Efficiency Condition

The high-efficiency condition is the 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.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Demand Savings are calculated for each hour over the course of the year:

Step 1: Determine the percent flow rate for each of the year (*i*)

For AHUs:

$$\%CFM_i = m \times t_{db,i} + b$$

Equation 39

Where:

$t_{db,i}$ = *The hourly dry bulb temperature (DBT) using TMY3[181] data*

m = *The slope of the relationship between DBT and CFM, see Table 81*

b = *The intercept of the relationship between DSBT and CFM, see Table 81*

The minimum flow rate is set to 60 percent cfm based on common design practice.[182] 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.[183]

[181] 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.

[182] 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%.

[183] ASHRAE 2017 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

Table 81. AHU Supply Fan VFD percentage of CFM Inputs

Climate zone	Condition	Minimum	Maximum	Slope (*m*)	Intercept (*b*)
Zone 1	Flow rate (%cfm)	60	100	1.19	-17.38
	Dry bulb T (°F)	65	98.6		
Zone 2	Flow rate (%cfm)	60	100	1.10	-11.43
	Dry bulb T (°F)	65	101.4		
Zone 3	Flow rate (%cfm)	60	100	1.23	-20.00
	Dry bulb T (°F)	65	97.5		
Zone 4	Flow rate (%cfm)	60	100	1.26	-21.76
	Dry bulb T (°F)	65	96.8		
Zone 5	Flow rate (%cfm)	60	100	1.11	-12.02
	Dry bulb T (°F)	65	101.1		

For chilled water pumps:

$$\%GPM_i = m \times t_{db\_i} + b$$

Equation 40

Where:

$t_{db,i}$ = *The hourly dry bulb temperature (DBT) using TMY3 data*

m = *The slope of the relationship between DBT and GPM, see Table 82*

b = *The intercept of the relationship between DSBT and GPM, see Table 82*

The minimum flow rate is set to 10 percent GPM based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.[184] 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.[185]

[184] PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.249, pump minimum speed default.

[185] ASHRAE 2017 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

Table 82. Chilled Water Pump VFD percentage of GPM Inputs

Climate zone	Condition	Minimum	Maximum	Slope (m)	Intercept (b)
Zone 1	Flow rate (%GPM)	10	100	2.68	-164.11
	Dry bulb T (°F)	65	98.6		
Zone 2	Flow rate (%GPM)	10	100	2.47	-150.71
	Dry bulb T (°F)	65	101.4		
Zone 3	Flow rate (%GPM)	10	100	2.77	-170.00
	Dry bulb T (°F)	65	97.5		
Zone 4	Flow rate (%GPM)	10	100	2.83	-173.96
	Dry bulb T (°F)	65	96.8		
Zone 5	Flow rate (%GPM)	10	100	2.49	-152.05
	Dry bulb T (°F)	65	101.1		

For hot water pumps:

$$\%GPM_i = m \times t_{db\_i} + b$$

Equation 41

Where:

$t_{db,i}$ = *The hourly dry bulb temperature (DBT) using TMY3 data*[181]

m = *The slope of the relationship between DBT and GPM, see Table 83*

b = *The intercept of the relationship between DSBT and GPM, see Table 83*

The minimum flow rate is set to 10 percent GPM based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.[186] Determination of the minimum dry bulb temperature assumes that heating will only operate below the heating reference temperature of 65°F dry bulb. The maximum DBT is the ASHRAE dry bulb design temperature.[187]

[186] PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.249, pump minimum speed default.

[187] ASHRAE 2017 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 99.6% Heating DB.