- Cooling capacity of the serviced unit (tons)
- Heating capacity of the serviced unit, if applicable (tons)
- 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

Petitions and Rulings

Not applicable.

Relevant Standards and Efficiency Sources

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 27. 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 revision.
v6.0	10/2018	TRM v6.0 update. No revision
v7.0	10/2019	TRM v7.0 update. No revision.
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.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Clarified eligibility criteria.

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 34 through Table 40

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 direct expansion (DX) ACs
- Packaged and split DX HPs

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 36 through Table 40. Building type descriptions and examples are provided in Table 34 and Table 35.

- 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 Air-Conditioning, Heating, and Refrigeration Institute (AHRI) or DOE CCMS certification must be provided.[94,95]

Baseline Condition

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

Early Retirement

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 28 through Table 32 according to the capacity, system type, and age (based on year manufactured) of the replaced system.[96] When the system age can be determined (e.g., from nameplate, building prints, equipment inventory list), the baseline efficiency levels provided in

Table 28 through Table 32 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.[97] 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.

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

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

[96] 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.

[97] 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.

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

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 28 through Table 32 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 HPs, baseline cooling efficiencies are displayed for electric resistance supplemental heating section type.

For units < 5.4 tons, EER, SEER, and HSPF values are converted to EER2, SEER2, and HSPF2 for consistency with the current federal standard. Unspecified EER2 are calculated by multiplying average EER/EER2 ratios, referencing EER2 values specified in the current federal standard for 12.2 and 11.7 EER. Unspecified SEER2 values are calculated by multiplying average SEER/SEER2 ratios, referencing SEER2 values specified for 14, 14.5, 15, and 16 SEER. Unspecified HSPF2 values are calculated by multiplying average HSPF/HSPF2 ratios, referencing HSPF2 values specified for 8.0 and 8.8 HSPF.

Refer to TRM 9.0 for exempted HPs < 5.4 tons referencing the previous federal standard. Units with a SEER2 rating are expected to comply with the guidelines outlined in this measure.

For 5.4+ ton units, 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 11.3+ tons, 0.2 EER may be added for no heating.

Table 28. DX HVAC—ER Baseline Full-Load Efficiency for ACs

Year installed (replaced system)	Split < 3.75 tons (EER2)	Split 3.75 to 5.42 tons (EER2)	Packaged < 5.42 tons (EER2)	All 5.42 to < 11.3 tons (EER)	All 11.3 to < 20 tons (EER)	All 20 to < 63.3 tons (EER)	All ≥ 63.3 tons (EER)
≤ 2005	7.8	7.8	7.5	10.1	9.5	9.3	9.0
2006–2009	10.1	10.1	10.1	10.1	9.5	9.3	9.0
2010–2017	10.1	10.1	10.1	11.0	10.8	9.8	9.5
2018–2022	10.1	10.1	10.9	11.0	10.8	9.8	9.5
≥ 2023	11.7	11.2	10.9	11.0	10.8	9.8	9.5

Table 29. DX HVAC—ER Baseline Part-Load Efficiency for ACs[98]

Year installed (replaced system)	Split < 3.75 tons (SEER2)	Split 3.75 to < 5.42 tons (SEER2)	Packaged < 5.42 tons (SEER2)	All 5.42 to < 11.3 tons (IEER)	All 11.3 to < 20 tons (IEER)	All 20 to < 63.3 tons (IEER)	All ≥ 63.3 tons (IEER)
≤ 2005	9.5	9.5	9.2	10.3	9.7	9.4	9.1
2006–2009	12.4	12.4	12.4	10.3	9.7	9.4	9.1
2010–2017	12.4	12.4	12.4	11.2	11.0	9.9	9.6
2018–2022	12.4	12.4	13.4	12.6	12.2	11.4	11.0
≥ 2023	14.3	13.8	13.4	14.6	14.0	13.0	11.0

Table 30. DX HVAC—ER Baseline Full-Load Cooling Efficiency for HPs

Year installed (replaced system)	Split < 5.42 tons (EER2)	Packaged < 5.42 tons (EER2)	All 5.42 to < 11.3 tons (EER)	All 11.3 to < 20 tons (EER)	All 20 to < 63.3 tons (EER)	All ≥ 63.3 tons (EER)
≤ 2005	7.8	7.5	10.1	9.3	9.0	9.0
2006–2009	10.1	10.1	10.1	9.3	9.0	9.0
2010–2017	10.1	10.1	11.0	10.6	9.5	9.5
2018–2022	10.9	10.9	11.0	10.6	9.5	9.5
≥ 2023	11.7	10.9	11.0	10.6	9.5	9.5

Table 31. DX HVAC—ER Baseline Part-Load Cooling Efficiency for HPs[99]

Year installed (replaced system)	Split < 5.42 tons (SEER2)	Packaged < 5.42 tons (SEER2)	All 5.42 to < 11.3 tons (IEER)	All 11.3 to < 20 tons (IEER)	All 20 to < 63.3 tons (IEER)	All ≥ 63.3 tons (IEER)
≤ 2005	9.5	9.2	10.3	9.5	9.1	9.1
2006–2009	12.4	12.4	10.3	9.5	9.1	9.1
2010–2017	12.4	12.4	11.2	10.7	9.6	9.6
2018-2022	13.4	13.4	12.0	11.6	10.6	10.6
≥ 2023	14.3	13.4	14.1	13.5	12.5	10.6

[98] 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.

[99] 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.

Table 32. DX HVAC—ER Baseline Heating Efficiency for HPs

Year installed (replaced system)	Split < 5.42 tons (HSPF2)	Packaged < 5.42 tons (HSPF2)	All 5.42 to < 11.3 tons (COP)	All 11.3 to < 20 tons (COP)	All ≥ 20 tons (COP)
≤ 2005	5.7	5.6	3.2	3.1	3.1
2006–2009	6.5	6.5	3.2	3.1	3.1
2010–2017	6.5	6.5	3.3	3.2	3.2
2018–2022	6.9	6.7	3.3	3.2	3.2
≥ 2023	7.5	6.7	3.4	3.3	3.2

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

Baseline efficiency levels for package and split DX ACs and HPs are provided in Table 33. The baseline part-load efficiency levels reflect the latest minimum efficiency requirements from the current federal standard, effective January 1, 2023, for units with a rated cooling capacity of less than 65,000 Btu/hour (Btuh) (5.42 tons) and for units rated between 65,000-759,999 Btuh. Full-load efficiency levels are estimated for < 65,000 Btuh systems using a comparison of AHRI SEER2 and EER2 efficiency ratings. Part-load efficiency for 760,000+ Btuh systems and full-load efficiency for 65,000+ Btuh systems are specified in IECC 2015.[100]

For ACs, baseline cooling efficiencies are displayed for a natural gas furnace heating section type. For HPs, 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 33. DX HVAC—NC/ROB Baseline Efficiency Levels[101]

System type	Capacity (tons)	Baseline efficiencies	Source[102]
Air conditioner	Split < 3.75	11.7 EER2 14.3 SEER2	DOE Standards
	Split ≥ 3.75	11.2 EER2 13.8 SEER2	
	Packaged < 5.4 tons	10.9 EER2[103] 13.4 SEER2	

[100] 2015 International Energy Conservation Code (IECC). https://codes.iccsafe.org/content/IECC2015.
[101] IECC 2015 Table C403.2.3(1) and C403.2.3(2).
[102] These baseline efficiency standards noted as "DOE Standards" are cited in the Code of Federal Regulations, 10 CFR 430.32 for < 65,000 Btu/h and 10 CFR 431.97 for 65,000-759,999 Btu/h.
[103] Unspecified EER2 values are calculated by multiplying average EER/EER2 ratios, referencing EER2 values specified in the current federal standard for 12.2 and 11.7 EER.

System type	Capacity (tons)	Baseline efficiencies	Source[102]
	All < 5.4 tons rated at ≧ 15.2 SEER2	9.8 EER2[104]	
	5.4 to < 11.3	11.0 EER 14.6 IEER	DOE Standards IECC 2015
	11.3 to < 20	10.8 EER 14.0 IEER	
	20 to < 63.3	9.8 EER 13.0 IEER	
	≥ 63.3	9.5 EER 11.0 IEER	IECC 2015
Heat pump (cooling)[105]	Split < 5.4	11.7 EER2 14.3 SEER2	DOE Standards
	Packaged < 5.4	10.9 EER2[106] 13.4 SEER2	
	All < 5.4 tons rated at ≧ 15.2 SEER2	9.8 EER2[107]	
	5.4 to < 11.3	11.0 EER 14.1 IEER	DOE Standards IECC 2015
	11.3 to < 20	10.6 EER 13.5 IEER	
	20 to < 63.3	9.5 EER 12.5 IEER	
	> 63.3	9.5 EER 10.6 IEER	IECC 2015

[104] When installing any system with a part-load efficiency rating of 15.2 SEER2 or higher, the reduced 9.8 EER2 full-load efficiency baseline should be applied in lieu of the applicable value presented earlier in the table except where the specified baseline EER2 value is lower than 9.8 EER2.

[105] 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”.

[106] Unspecified EER2 values are calculated by multiplying average EER/EER2 ratios, referencing values specified in the current federal standard for 12.2 and 11.7 EER.

[107] When installing any system with a part-load efficiency rating of 15.2 SEER2 or higher, the reduced 9.8 EER2 full-load efficiency baseline should be applied in lieu of the applicable value presented earlier in the table except where the specified baseline EER2 value is lower than 9.8 EER2.

System type	Capacity (tons)	Baseline efficiencies	Source[102]
Heat pump (heating)[108]	Split < 5.4	7.5 HSPF2	DOE Standards
	Packaged < 5.4	6.7 HSPF2	
	5.4 to < 11.25	3.3 COP	DOE Standards
	11.3 to < 20	3.3 COP	
	≥ 20	3.2 COP	IECC 2015

High-Efficiency Condition

Split and packaged systems must exceed the minimum efficiencies specified in Table 33. 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®[109] and the Consortium for Energy Efficiency (CEE)[110] offer suggested guidelines for high-efficiency equipment. Additional conditions for replace-on-burnout, ER and new construction are in the sections below.

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.

Early Retirement

The high-efficiency retrofits must meet the following criteria:[111]

- 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, coincidence factor, and EFLH. These factors should be weighted based on contribution to overall capacity.

[108] Heat pump retrofits must also exceed the baseline efficiency levels for heating efficiencies.
[109] ENERGY STAR Heating & Cooling, https://www.energystar.gov/products/heating_cooling.
[110] CEE Program Resources, http://www.cee1.org/content/cee-program-resources.
[111] From PUCT Docket #41070.

- 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

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

Equation 18

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

Equation 19

$$Total\ Energy\ Savings\ [kWh] = kWh_C + kWh_H$$

Equation 20

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

Equation 21

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

Equation 22

Where:

$Cap_{C/H,pre}$ = *For ER and ROB, rated equipment cooling/heating capacity of the existing equipment at AHRI-standard conditions with a maximum of 20 percent larger than the post capacity; for 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 with a maximum equal to the baseline pre-capacity [Btuh]; 1 ton = 12,000 Btuh*

Note: The capacity in the equations will not always match the capacity of the units.

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

$\eta_{installed,C}$ = *Rated cooling efficiency of the newly installed equipment (Must exceed ROB/NC baseline efficiency standards in Table 33) [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 33) [COP]*

Note: Use EER2/EER for summer kilowatt, SEER2/IEER for cooling kilowatt-hour, and COP for heating kilowatt-hour and winter kilowatt savings calculations. The COP expressed for units $\geq$ 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 23

$CF_{S/W}$ = *Summer/winter seasonal peak coincidence factor (see Table 36 through Table 40)*

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours [hours] (see Table 36 through Table 40)*

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

Deemed Energy and Demand Savings Tables

Deemed peak coincidence factor (CF) 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 34 and Table 35. These building types are derived from the EIA CBECS study.[112]

The CF and EFLH values for packaged and split AC and HP units are presented in Table 36 through Table 40.

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

Combination building types. 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.

  The following building type combinations are pre-authorized exceptions to this rule. For these combinations, individual fixtures can be reported as either specified building type based on location. All other interior space combinations should reference a single deemed building type unless authorized by the evaluator.

  - Office (any size): Warehouse
  - Hospital: Outpatient healthcare

  The *other* building type can be used for business types that are not explicitly listed. The CF and EFLH values used for *other* are the most conservative 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 with no values, a project with that specific combination should use the *other* building type.

- **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 only apply to specific scenarios and cannot be developed for all unique situations. Utilities should provide sufficient, defensible documentation for their EFLH and CF values used in their savings calculations that the EM&V team can review.

[112] 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 34. DX HVAC—Building Type Descriptions and Examples

Building type	Principal building activity	Definition	Detailed business type examples[113]
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 store	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	Inpatient	Buildings used as diagnostic and treatment facilities for inpatient care.	1) Hospital 2) Inpatient rehabilitation
	Outpatient	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
Large multifamily	Midrise apartment	Buildings containing multifamily dwelling units, having multiple stories, and equipped with elevators.	No sub-categories collected.

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

Building type	Principal building activity	Definition	Detailed business type examples[113]
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 and enclosed 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[113]
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: Excluding food	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[113]
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 35. DX HVAC—Building Type Floor Area and Number of Floors[114]

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 store	Not specified	1
	Supermarket	45,000	1
Food service	Full-service restaurant	5,500	1
	Quick-service restaurant	2,500	1
Healthcare	Inpatient	241,351	5
	Outpatient	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 and enclosed mall	22,500	1
Office	Large office	498,588	12
	Medium office	53,628	3
	Small office	5,500	1

[114] 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: Excluding food	Not specified	Not specified
Warehouse	Warehouse	52,045	1

Table 36. DX HVAC—CF and EFLH Values for Climate Zone 1: Amarillo

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[115]			
		CF_S	$EFLH_C$	CF_S	$EFLH_C$	CF_W	$EFLH_H$
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 store	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 restaurant	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 restaurant	0.74	817	0.74	817	0.48	1,300
Healthcare	Inpatient	0.72	2,185	0.72	2,185	–	–
	Outpatient	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 retail	0.80	820	0.80	820	0.43	1,277
	Strip and enclosed mall	0.75	687	0.75	687	0.39	753

[115] 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[115]			
		CF_S	$EFLH_C$	CF_S	$EFLH_C$	CF_W	$EFLH_H$
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: Excluding food	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 37. DX HVAC—CF and EFLH Values for Climate Zone 2: Dallas

Building type	Principal building activity	Package and Split DX					
		Air Conditioner		Heat Pump[116]			
		CF_S	$EFLH_C$	CF_S	$EFLH_C$	CF_W	$EFLH_H$
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 store	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 restaurant	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 restaurant	1.08	1,765	1.08	1,765	0.60	794
Healthcare	Inpatient	0.92	3,097	0.92	3,097	–	–
	Outpatient	0.80	2,532	0.80	2,532	0.28	310
Large multifamily	Midrise apartment	1.04	1,709	1.04	1,709	–	–

[116] 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[116]			
		CF_S	$EFLH_C$	CF_S	$EFLH_C$	CF_W	$EFLH_H$
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
Mercantile	Stand-alone retail	0.95	1,157	0.95	1,157	0.55	352
	24-hour retail	1.01	1,539	1.01	1,539	0.57	632
	Strip and enclosed 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: Excluding food	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 38. DX HVAC—CF and EFLH Values for Climate Zone 3: Houston

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[117]			
		CF_S	$EFLH_C$	CF_S	$EFLH_C$	CF_W	$EFLH_H$
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 store	1.03	2,142	1.03	2,142	–	–
	Supermarket	0.60	744	0.60	744	–	–

[117] 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[117]			
		CF_S	$EFLH_C$	CF_S	$EFLH_C$	CF_W	$EFLH_H$
Food service	Full-service restaurant	1.05	2,135	1.05	2,135	0.44	429
	24-hour full-service restaurant	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 restaurant	1.05	2,059	1.05	2,059	0.50	483
Healthcare	Inpatient	0.90	3,490	0.90	3,490	–	–
	Outpatient	0.80	2,844	0.80	2,844	0.29	196
Large multifamily	Midrise apartment	1.00	2,031	1.00	2,031	–	–
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 retail	0.97	1,804	0.97	1,804	0.41	374
	Strip and enclosed 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: Excluding food	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 39. DX HVAC—CF and EFLH Values for Climate Zone 4: Corpus Christi

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[118]			
		CF_S	$EFLH_C$	CF_S	$EFLH_C$	CF_W	$EFLH_H$
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 store	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 restaurant	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 restaurant	0.93	2,440	0.93	2,440	0.34	296
Healthcare	Inpatient	0.86	3,819	0.86	3,819	–	–
	Outpatient	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 retail	0.86	2,118	0.86	2,118	0.25	255
	Strip and enclosed 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: Excluding food	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

[118] 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.

Table 40. DX HVAC—CF and EFLH Values for Climate Zone 5: El Paso

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump[119]			
		CF_S	$EFLH_C$	CF_S	$EFLH_C$	CF_W	$EFLH_H$
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 store	0.76	1,251	0.76	1,251	–	–
	Supermarket	0.38	347	0.38	347	–	–
Food service	Full-service restaurant	0.76	1,276	0.76	1,276	0.28	613
	24-hour full-service restaurant	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 restaurant	0.77	1,171	0.77	1,171	0.26	697
Healthcare	Inpatient	0.81	2,555	0.81	2,555	–	–
	Outpatient	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 retail	0.86	1,228	0.86	1,228	0.28	808
	Strip and enclosed 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: Excluding food	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

[119] 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.

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 CF assumptions outlined in Table 41. Assumed values have been weighted based on building-type survey data from 2012 CBECS[120] and 2014 MECS[121].

For upstream/midstream program designs where the building type is known, use the savings coefficients from Table 36 through Table 40. For program designs where the building type is unknown, you may use the savings coefficients from Table 41. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

Table 41. DX HVAC—Upstream/Midstream Input Assumptions[122]

Savings coefficient	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
$EFLH_C$	1,062	1,543	1,752	1,947	1,338
$EFLH_H$	504	245	130	79	243
CF_S	0.68	0.92	0.91	0.84	0.84
CF_W	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 ACs and HPs is 15 years.[123]

[120] 2012 Commercial Building Energy Consumption Survey (CBECS). https://www.eia.gov/consumption/commercial/. 2018 version not available until mid-2020.
[121] 2014 Manufacturing Energy Consumption Survey (MECS). https://www.eia.gov/consumption/manufacturing/.
[122] 2012 CBECS and 2014 MECS.
[123] 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.

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 42. If individual system components were installed at different times, use the condenser age as a proxy for the entire system. For ER units of unknown age, assume a default value equal to the EUL. This corresponds to a default RUL of 2.8 years. Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. Both the RUL and EUL are needed to estimate savings for ER projects for two distinct periods: The ER period (RUL) and the ROB period (EUL – RUL). The calculations for ER projects are extensive, and as such, are provided in Appendix A.

Table 42. DX HVAC—RUL of Early Retirement Systems[124,125]

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[126]	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 or county

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

125 Current new construction baseline matches the baseline for existing systems manufactured in 2023. Existing systems manufactured after 1/1/2023 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.

126 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.

- 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 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 exempted HPs < 5.4 tons referencing the previous federal standard, a copy of the AHRI certificate or manufacturer specification sheet with date corresponding to time of application or purchase demonstrating that unit does not have a SEER2 efficiency rating is required.
- **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

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 43. DX HVAC—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	TRM v6.0 update. 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.
v10.0	10/2022	TRM v10.0 update. Added additional guidance for selection of building types for complex projects. Incremented RUL table for code compliance.
v11.0	10/2023	TRM v11.0 update. Removed < 5.4 ton HP sell-through exception. Updated ER baselines for compliance with updated federal standard. Updated NC/ROB 5.4+ ton baselines to incorporate current federal standard. Clarified pre- and post-capacity limits. Aligned building type names across all commercial measures. 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 57 through Table 61.

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:[127]

- 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 57 through Table 61. Building type descriptions and examples are provided in Table 34 and Table 35.
- 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.
- For redundant chiller configurations, the installed chiller must not be exclusively sequenced as a standby chiller. As an example, for N+1 configurations where the redundant chiller is rotated, the deemed savings approach should only be used for N chillers, where N is the total number of chillers in the redundant chiller configuration minus one. Multiple chillers sequenced in a lead-lag or base-trim configuration are eligible to use the deemed savings.

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.

[127] 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

Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[128, 129]

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.

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 44 through Table 55 according to the capacity, chiller type, and age (based on year manufactured) of the replaced system.[130] When the chiller age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 44 through Table 55 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,[131] 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.

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[128] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.
[129] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.
[130] 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.
[131] IECC 2015 not enforced in Texas until program year 2018.

ER Baseline: Air-Cooled Chillers

Table 44. Chillers—Air-Cooled Path A ER Baseline Full-Load Efficiency[132]

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

Table 45. Chillers—Air-Cooled Path B ER Baseline Full-Load Efficiency[133]

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 46. Chillers—Air-Cooled Path A ER Baseline Part-Load Efficiency (IPLV)[134]

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

[132] 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.

[133] Ibid.

[134] Ibid.

Table 47. Chillers—Air-Cooled Path B ER Baseline Part-Load Efficiency (IPLV)[135]

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 48. Chillers—Water-Cooled Centrifugal Path A ER Baseline Full-Load Efficiency[136]

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

Table 49. Chillers—Water-Cooled Centrifugal Path B ER Baseline Full-Load Efficiency[137]

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

[135] Ibid.
[136] Ibid.
[137] Ibid.

Table 50. Chillers—Water-Cooled Centrifugal Path A ER Baseline Part-Load Efficiency (IPLV)[138]

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 51. Chillers—Water-Cooled Centrifugal Path B ER Baseline Part-Load Efficiency (IPLV)[139]

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

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

Table 52. Chillers—Water-Cooled Screw/Scroll/Recip. Path A ER Baseline Full-Load Efficiency[140]

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

[138] Ibid.
[139] Ibid.
[140] Ibid.

Table 53. Chillers—Water-Cooled Screw/Scroll/Recip. Path B ER Baseline Full-Load Efficiency[141]

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 54. Chillers—Water-Cooled Screw/Scroll/Recip. Path A ER Baseline Part-Load Efficiency (IPLV)[142]

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

Table 55. Chillers—Water-Cooled Screw/Scroll/Recip. Path B ER Baseline Part-Load Efficiency (IPLV)[143]

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 56, 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-

[141] Ibid.
[142] Ibid.
[143] Ibid.

load efficiency conditions in the energy and demand savings algorithms.[144] 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 56. Chillers—NC/ROB Baseline Efficiencies[145]

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

High-Efficiency Condition

Chillers must exceed the minimum efficiencies specified in Table 56 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:[146]

- 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

[144] 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).

[145] IECC 2015 Table C403.2.3(7).

[146] From PUCT Docket #41070.

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, coincidence 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

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

Equation 24

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

Equation 25

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 44 through Table 56; for efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 26 [kW/ton]*

$\eta_{installed}$ = *Rated efficiency of the newly installed equipment – must exceed efficiency standards, shown in Table 56; for efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 26 [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 26

CF_S	=	Summer peak coincidence factor (see Table 57 through Table 61)
$EFLH_C$	=	Cooling equivalent full-load hours [hours] (see Table 57 through Table 61)

Air- to Water-Cooled Replacement: Adjustments for Auxiliary Equipment[147]

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 27

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

Equation 28

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 29

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

Equation 30

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

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

over the lifetime (EUL) of the measure.” These savings calculations are explained in Appendix A. Table 57 through Table 61 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.

Deemed Energy and Demand Savings Tables

Deemed peak coincidence factor (CF) 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 34 and Table 35. These building types are derived from the EIA CBECS study.[148]

Deemed peak CF and EFLH values are presented by building type and climate zone for chillers in Table 57 through Table 61. These tables also include an “Other” building type, which can be used for business types that are not explicitly listed. The CF 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 57. Chillers—CF and EFLH for Climate Zone 1: Amarillo

Building type	Principal building activity	Chiller[149]			
		Air-cooled		Water-cooled	
		CF	$EFLH_C$	CF	$EFLH_C$
Data center	Data center	0.56	2,807	0.73	5,100
Education	College/university	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	Inpatient	0.70	2,006	0.65	2,711
Large multifamily	Midrise apartment	0.41	421	0.50	1,098

[148] 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/.

[149] 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[149]			
		Air-cooled		Water-cooled	
		CF	$EFLH_c$	CF	$EFLH_c$
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
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 58. Chillers—CF and EFLH for Climate Zone 2: Dallas

Building type	Principal building activity	Chiller[150]			
		Air-cooled		Water-cooled	
		CF	$EFLH_c$	CF	$EFLH_c$
Data center	Data center	0.54	2,791	0.77	4,906
Education	College/university	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	Inpatient	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 59. Chillers—CF and EFLH for Climate Zone 3: Houston

Building type	Principal building activity	Chiller[151]			
		Air-cooled		Water-cooled	
		CF	$EFLH_c$	CF	$EFLH_c$
Data center	Data center	0.53	2,824	0.76	5,075
Education	College/university	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

[150] Ibid.
[151] Ibid.

Building type	Principal building activity	Chiller[151]			
		Air-cooled		Water-cooled	
		CF	$EFLH_c$	CF	$EFLH_c$
Healthcare	Inpatient	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
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 60. Chillers—CF and EFLH for Climate Zone 4: Corpus Christi

Building type	Principal building activity	Chiller[152]			
		Air-cooled		Water-cooled	
		CF	$EFLH_c$	CF	$EFLH_c$
Data center	Data center	0.48	2,881	0.77	5,266
Education	College/university	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	Inpatient	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

[152] Ibid.

Table 61. Chillers—CF and EFLH for Climate Zone 5: El Paso

Building type	Principal building activity	Chiller[153]			
		Air-cooled		Water-cooled	
		CF	$EFLH_c$	CF	$EFLH_c$
Data center	Data center	0.56	2,950	0.71	5,137
Education	College/university	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	Inpatient	0.71	2,355	0.59	2,992
Large multifamily	Midrise apartment	0.56	841	0.52	1,553
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 CF assumptions outlined in Table 59 and Table 60. Assumed values have been weighted based on building type survey data from 2012 CBECS[154] and 2014 MECS[155].

For upstream/midstream program designs where building type is known, use the savings coefficients from Table 57 through Table 61. For program designs where building type is unknown, you may use the savings coefficients from Table 62 and Table 63. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

[153] Ibid.
[154] 2012 Commercial Building Energy Consumption Survey (CBECS). https://www.eia.gov/consumption/commercial/. 2018 version not available until mid-2020.
[155] 2014 Manufacturing Energy Consumption Survey (MECS). https://www.eia.gov/consumption/manufacturing/.

Table 62. Chillers—Air-Cooled Upstream/Midstream Input Assumptions[156]

Savings coefficient	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
$EFLH_C$	967	1,408	1,575	1,789	1,211
CF_S	0.62	0.80	0.78	0.72	0.71

Table 63. Chillers—Water-Cooled Upstream/Midstream Input Assumptions[157]

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

Measure Life and Lifetime Savings

Estimated Useful Life (EUL)

The EUL of HVAC equipment is provided below:

- Screw/scroll/reciprocating chillers: 20 years[158]
- Centrifugal chillers: 25 years.[159]

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 64. 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.

156 2012 CBECS and 2014 MECS.
157 Ibid.
158 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.
159 PUCT Docket No. 40885, review of multiple studies looking at the lifetime of centrifugal chillers as detailed in petition workpapers.

Table 64. Chillers—RUL of Early Retirement Systems[160,161]

Age of replaced system (years)	Non-centrifugal chillers RUL (years)	Centrifugal chillers RUL (years)	Age of replaced system (years)	Non-centrifugal chillers RUL (years)	Centrifugal chillers RUL (years)
1	18.7	23.9	17	5.0	8.7
2	17.7	22.9	18	4.5	8.1
3	16.7	21.9	19	4.0	7.5
4	15.7	20.9	20	3.6	7.1
5	14.7	19.9	21	3.0	6.6
6	13.7	18.9	22	2.0	6.3
7	12.7	17.9	23	1.0	5.9
8	11.8	16.9	24[162]	0.0	5.6
9	10.9	15.9	25	–	5.4
10	10.0	14.9	26	–	5.0
11	9.1	13.9	27	–	4.0
12	8.3	12.9	28	–	3.0
13	7.5	11.9	29	–	2.0
14	6.8	10.9	30	–	1.0
15	6.2	10.1	31[163]	–	0.0
16	5.5	9.3			

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

161 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.

162 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.

163 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 or county
- 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)
- Is the installed chiller a standby unit in a redundant chiller configuration? (yes, no)
- 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

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 65. 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.
v10.0	10/2022	TRM v10.0 update. Added guidance for redundant chiller configurations. Incremented RUL table for code compliance.
v11.0	10/2022	TRM v11.0 update. Aligned building type names across all commercial measures. Incremented RUL table for code compliance.

2.2.4 Packaged Terminal Air Conditioners/Heat Pumps, Single Package Vertical 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 70 through Table 74

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), single package vertical air conditioners (SPVAC), single package vertical heat pumps (SPVHP), 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.

Single Package Vertical Air Conditioners and Heat Pumps. All cooling capacities less than 240,000 Btu/hr are covered.

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, SPVAC, SPVHP, 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. An 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.[164,165]

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.[166] When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 66, 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.[167] A default RUL may be used exclusively if applied consistently for all

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

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

[166] 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.

[167] 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

projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

Existing standard size PTAC systems manufactured as of January 1, 2017and standard size PTHP systems manufactured as of October 8, 2012, are not eligible for early retirement. All non-standard size PTAC/PTHPs are not eligible for early retirement.

Table 66. PTAC/PTHPs—ER Baseline Efficiency Levels for Standard Size Units[168]

Equipment	Cooling capacity (Btuh)	Baseline cooling efficiency (EER)	Baseline heating efficiency (COP) (No built-in ER heat)	Baseline heating efficiency (COP) (with built-in ER heat)
PTAC	<7,000	11.0	–	1.0
	7,000-15,000	12.5 – (0.213 x Cap/1,000)		
	>15,000	9.3		
PTHP	<7,000	10.8	3.0	–
	7,000-15,000	12.3 – (0.213 x Cap/1,000)	3.2 – (0.026 x Cap/1,000)	
	>15,000	9.1	2.8	

Replace-on-Burnout and New Construction

Table 67 provides federal minimum efficiency standards for PTAC/PTHP units reflected in 10 CFR 431. The effective date for standard size PTACs is January 1, 2017, and the effective date for standard size PTHPs is October 8, 2012. The effective date for all non-standard PTAC/PTHPs is October 7, 2010.

Table 67. PTAC/PTHPs—NC/ROB Baseline Efficiency Levels[169,170]

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 x Cap/1,000)	–
		>15,000	9.5	–

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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.

[168] 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.

[169] IECC 2015 Table C403.2.3(3).

[170] 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)
	Non-Standard Size	<7,000	9.4	–
		7,000-15,000	10.9 – (0.213 x Cap/1,000)	–
		>15,000	7.7	–
PTHP	Standard Size	<7,000	11.9	3.3
		7,000-15,000	14.0 – (0.300 x Cap/1,000)	3.7 – (0.052 x Cap/1,000)
		>15,000	9.5	2.9
	Non-Standard Size	<7,000	9.3	2.7
		7,000-15,000	10.8 – (0.213 x Cap/1,000)	2.9 – (0.026 x Cap/1,000)
		>15,000	7.6	2.5

Table 68 provides federal minimum efficiency standards for SPVAC/SPVHP units reflected in 10 CFR 431. The effective date for the Final Rule was November 23, 2015. Compliance with the standards for SPVAC/SPVHPs with cooling capacities less than 65,000 Btu/hr was September 23, 2019; compliance with the standard for SPVAC/SPVHPs with cooling capacities between 65,000 and 135,000 Btu/hr was October 9, 2015; and compliance with the standard for SPVAC/SPVHPs with cooling capacities between 135,000 and 240,000 Btu/hr was October 9, 2016.

Table 68. SPVAC/SPVHPs—NC/ROB Baseline Efficiency Levels[171]

Equipment Type	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)	Minimum heating efficiency (COP)
Single package vertical air conditioners	< 65,000	11.0	–
	≥ 65,000 and <240,000	10.0	–
Single package vertical air heat pumps	< 65,000	11.0	3.3
	≥ 65,000 and <240,000	10.0	3.0

Table 69 reflects the standards for room air conditioners, specified in 10 CFR 430.32(b). A new federal standard went into effect on August 30, 2023. However, this standard does not require manufacturer compliance until May 26, 2026.[172]

[171] Table 11 to 10 CFR 431.97.
[172] Current DOE minimum efficiency standard for residential room air conditioners. https://www.regulations.gov/document/EERE-2014-BT-STD-0059-0057.

Table 69. Room ACs—NC/ROB Baseline Efficiency Levels[173]

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

High-Efficiency Condition

The high-efficiency retrofits must exceed the minimum federal standards found in Table 67 and Table 69.

The high-efficiency retrofits must also meet the following criteria:[174]

- 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, coincidence

[173] 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.

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

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

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

Equation 31

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

Equation 32

$$Total\ Energy\ Savings\ [kWh] = kWh_C + kWh_H$$

Equation 33

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

Equation 34

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

Equation 35

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 66 through Table 69)*

$\eta_{baseline,H}$ = *Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP] (Table 66 and Table 67)* [175]

$\eta_{installed,C}$ = *Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h])—(Must exceed minimum federal standards found in Table 67 and Table 69)* [176]

$\eta_{installed,H}$ = *Rated heating efficiency of the newly installed equipment [COP] (Must exceed minimum federal standards found in Table 67)*

$CF_{S/W}$ = *Summer/winter seasonal peak coincidence factor (see Table 36 through Table 40)*

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours [hours] (see Table 70 through Table 74)*

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 70 through Table 74 present the deemed peak coincidence factor (CF) and equivalent full-load hour (EFLH) values for PTAC/PTHPs, SPVAC/SPVHPs, 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.

These tables also include an *other* building type, which can be used for business types that are not explicitly listed. The CF 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 <u>must</u> 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.

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

[176] Ibid.

Table 70. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF and EFLH Values for Climate Zone 1: Amarillo

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF_S	$EFLH_C$	CF_S	$EFLH_C$	CF_W	$EFLH_H$
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 store	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 restaurant	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 restaurant	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 71. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF and EFLH Values for Climate Zone 2: Dallas

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF_S	$EFLH_C$	CF_S	$EFLH_C$	CF_W	$EFLH_H$
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 store	1.05	1,544	1.05	1,544	0.61	318
Food service	Full-service restaurant	1.06	1,534	1.06	1,534	0.50	401
	24-hour full-service restaurant	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 restaurant	1.05	1,485	1.05	1,485	0.60	463

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CFs	EFLHc	CFs	EFLHc	CFw	EFLHH
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 72. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF and EFLH Values for Climate Zone 3: Houston

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CFs	EFLHc	CFs	EFLHc	CFw	EFLHH
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 store	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 restaurant	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 restaurant	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 73. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF and EFLH Values for Climate Zone 4: Corpus Christi

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF_S	$EFLH_C$	CF_S	$EFLH_C$	CF_W	$EFLH_H$
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 store	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 restaurant	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 restaurant	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 74. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF and EFLH Values for Climate Zone 5: El Paso

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF_S	$EFLH_C$	CF_S	$EFLH_C$	CF_W	$EFLH_H$
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 store	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 restaurant	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 restaurant	0.75	1,186	0.75	1,186	0.26	463

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF_S	$EFLH_C$	CF_S	$EFLH_C$	CF_W	$EFLH_H$
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
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 EFLH and CF assumptions from Table 75. Assumed values have been weighted based on building type survey data from 2012 CBECS[177] and 2014 MECS[178].

For upstream/midstream program designs where building type is known, use the savings coefficients from Table 70 through Table 74. For program designs where building type is unknown, you may use the savings coefficients from Table 75. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

Table 75. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—Upstream/Midstream Input Assumptions[179]

Savings coefficient	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
$EFLH_C$	1,019	1,661	1,774	1,916	1,562
$EFLH_H$	247	193	40	46	176
CF_S	0.55	0.78	0.68	0.60	0.73
CF_W	0.43	0.52	0.23	0.14	0.12

[177] 2012 Commercial Building Energy Consumption Survey (CBECS). https://www.eia.gov/consumption/commercial/. 2018 version not available until mid-2020.
[178] 2014 Manufacturing Energy Consumption Survey (MECS). https://www.eia.gov/consumption/manufacturing/.
[179] 2012 CBECS and 2014 MECS.

Measure Life and Lifetime Savings

Estimated Useful Life (EUL)

The EUL of PTAC/PTHP units is 15 years, as specified in DEER 2014.[180]

The EUL of SPVAC/SPVHP units is 15 years, as determined by the DOE in its September 2015 final rule.[181]

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.[182]

Remaining Useful Life (RUL) for PTAC/PTHP Systems

The RUL of ER replaced systems is provided according to system age in Table 76.

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 76. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—RUL of Early Retirement Standard Size PTACs[183,184]

Age of replaced system (years)	RUL (years)	Age of replaced system (years)	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

180 http://www.deeresources.com/

181 Department of Energy, Energy Conservation Program: Energy Conservation Standards for Single Package Vertical Air Conditioners and Single Package Vertical Heat Pumps, 80 FR 57467 https://www.federalregister.gov/documents/2015/09/23/2015-23029/energy-conservation-program-energy-conservation-standards-for-single-package-vertical-air

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

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

184 Current federal standard effective date is 1/1/2017. 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.

Age of replaced system (years)	RUL (years)	Age of replaced system (years)	RUL (years)
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[185]	0.0

Table 77. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—RUL of Early Retirement Standard Size PTHPs[186,187]

Age of replaced system (years)	RUL (years)	Age of replaced system (years)	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[188]	0.0

[185] 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.

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

[187] Current federal standard effective date is 10/8/2012. 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.

[188] 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 or county
- 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, SPVAC, SPVHP, 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

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 78. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—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).
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 revision.
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.

TRM version	Date	Description of 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.
v10.0	10/2022	TRM v10.0 update. Incremented RUL table for code compliance.
v11.0	10/2023	TRM v11.0 update. Added SPVAC and SPVHP units to measure. Corrected current federal standard effective date. Added separate RUL table for PTHP. Aligned building type names across all commercial measures. 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 80 and Table 81

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.[189,190]

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 79. 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.

Note: A new federal standard became effective August 1, 2023, with full compliance required by May 28, 2024. An update to the efficiency levels has been delayed to PY2025 to allow for sell-through.

Table 79. CRACs—NC/ROB Baseline Efficiency Levels[191]

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	

189 Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.
190 Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.
191 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)	< 65,000	2.50 / 2.39	
	≥ 65,000 and < 240,000	2.15 / 2.04	
	≥ 240,000	2.10 / 1.99	
Air conditioners, glycol cooled (rated at 40 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 33. 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

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

Equation 36

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

Equation 37

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 33) [SCOP]*

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

CF_S = *Summer peak coincidence factor (see Table 81)*

$EFLH_C$ = *Cooling equivalent full-load hours [hours] (see Table 81)*

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 coincident coincidence factor (CF) 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.[192]

The CF and EFLH values for CRAC units are presented in Table 81. A description of the calculation method used to derive these values can be found in Docket No. 40885, Attachment B.

[192] 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.*

Table 80. CRACs—Building Type Descriptions and Examples

Building type	Principal building activity	Definition	Detailed business type examples[193]
Data center	Data center	Buildings used to house computer systems and associated components.	1) Data center

Table 81. CRACs—CF and EFLH Values

Climate zone	Building type and principal building activity	CF_S	$EFLH_C$
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.[194]

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.

[193] Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.
[194] 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.

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 or county
- Baseline number of units
- 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

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 82. CRACs—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.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Added reference to new standard and plan to incorporate in PY2025.

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[195].

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).

[195] 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.[196]

Energy Savings Algorithms

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

Equation 38

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

Equation 39

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 83. CRAHs—Motor Efficiencies for Open Drip Proof Motors at 1,800 RPM[197]

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

0.746	=	*Constant to convert from hp to kW*
kW/hp_{post}	=	*Efficient kW per motor hp[198] = 0.27*

[196] Site data are sourced from 3 data centers in Oncor territory that replaced 243 CRAH fan motors either with ECMs or retrofitted with VFDs.
[197] For unlisted motor horsepower values, round down to the next lowest horsepower value.
[198] Oncor site data. Average kW/hp values are weighted by measure count.

hp_{post}	=	*Total efficient motor horsepower*
hours	=	*Annual operating hours = 8,760*

Demand Savings Algorithms

$$Peak\ Demand\ Savings\ [kW] = \frac{Annual\ Energy\ Savings\ (kWh)}{hours} \times DF_{S/W}$$

Equation 40

Where:

$CF_{S/W}$	=	*Summer/winter seasonal peak coincidence factor = 0.11*[199]

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.[200]

The EUL for HVAC VFD measure is 15 years.

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 or county

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[199] 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.

[200] US 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.

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 84. CRAHs—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 revision.
v10.0	10/2022	TRM v10.0 update. Added guidance for rounding down motor size in the baseline efficiency lookup table.
v11.0	10/2023	TRM v11.0 update. No revision.

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 90 through Table 97

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 and condenser pumps
- Cooling tower fans

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. Custom applications are more appropriate for applications above 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.

The cooling tower fan baseline control is either fan cycling or any fan design that enables two-speed operation.

High-Efficiency Condition

The high-efficiency condition is the installation of a VFD on an AHU supply fan, cooling tower fan, condenser water pump, 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 41

Where:

$t_{db,i}$	=	*The hourly dry bulb temperature (DBT) using TMY3*[201] *data*
m	=	*The slope of the relationship between DBT and CFM (see Table 85)*
b	=	*The intercept of the relationship between DSBT and CFM (see Table 85)*

The minimum flow rate is set to 60 percent cfm based on common design practice.[202] 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.[203]

[201] 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.

[202] 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%.

[203] ASHRAE 2021 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

Table 85. HVAC VFDs—AHU Supply Fan VFD percentage of CFM Inputs

Climate zone	Condition	Minimum	Maximum	Slope (*m*)	Intercept (*b*)
Climate Zone 1	Flow rate (%cfm)	60	100	1.18	16.92
	Dry bulb T (°F)	65	98.8		
Climate Zone 2	Flow rate (%cfm)	60	100	1.10	-11.43
	Dry bulb T (°F)	65	101.4		
Climate Zone 3	Flow rate (%cfm)	60	100	1.23	19.75
	Dry bulb T (°F)	65	97.6		
Climate Zone 4	Flow rate (%cfm)	60	100	1.25	-21.50
	Dry bulb T (°F)	65	96.9		
Climate Zone 5	Flow rate (%cfm)	60	100	1.10	11.82
	Dry bulb T (°F)	65	101.2		

For cooling towers:

$$\%CFM_i = m \times t_{wb\_i} + b$$

Equation 42

Where:

t_{wb_i} = the hourly wet bulb temperature (WBT) based on TMY3 data[204]

m = the slope of the relationship between WBT and cfm (see *Table 86*)

b = the intercept of the relationship between WBT and cfm (see *Table 86*)

Table 86. HVAC VFDs—Cooling Tower VFD Percentage of CFM Inputs

Climate zone	Condition	Minimum	Maximum	Slope (*m*)	Intercept (*b*)
Climate Zone 1	Flow rate (%cfm)	40	100	3.98	-184.25
	Wet bulb T (°F)	56.3	71.4		
Climate Zone 2	Flow rate (%cfm)	40	100	2.99	-135.13
	Wet bulb T (°F)	58.5	78.6		
Climate Zone 3	Flow rate (%cfm)	40	100	2.95	-136.58
	Wet bulb T (°F)	59.9	80.2		

204 TMY3 data does not include WBT. WBT was calculated from TMY3 data using the empirical formula from "Wet-bulb temperature from relative humidity and air temperature", *Journal of Applied Meteorology and Climatology*, https://doi.org/10.1175/JAMC-D-11-0143.1.

Climate zone	Condition	Minimum	Maximum	Slope (*m*)	Intercept (*b*)
Climate Zone 4	Flow rate (%cfm)	40	100	2.92	-137.43
	Wet bulb T (°F)	60.8	81.3		
Climate Zone 5	Flow rate (%cfm)	40	100	3.31	-130.71
	Wet bulb T (°F)	51.6	69.8		

The minimum flow rate is set to 40 percent cfm based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.[205] Determination of the minimum WBT assumes that the cooling tower will only operate above the cooling reference temperature of 65°F dry bulb. The minimum WBT is calculated using TMY3 data as the average WBT when the DBT is between 64°F and 65°F dry bulb. The maximum WBT is the ASHRAE wet bulb design temperature.[206]

For chilled water and condenser water pumps:

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

Equation 43

Where:

m = *The slope of the relationship between DBT and GPM (see Table 87)*

b = *The intercept of the relationship between DSBT and GPM (see Table 87)*

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.[207] 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.[208]

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[205] PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.240, cooling tower minimum speed default.

[206] ASHRAE 2021 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Evaporation WB

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

[208] ASHRAE 2021 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

Table 87. HVAC VFDs—Chilled Water and Condenser Water Pumps VFD percentage of GPM Inputs

Climate zone	Condition	Minimum	Maximum	Slope (*m*)	Intercept (*b*)
Climate Zone 1	Flow rate (%GPM)	10	100	2.66	163.08
	Dry bulb T (°F)	65	98.8		
Climate Zone 2	Flow rate (%GPM)	10	100	2.47	-150.71
	Dry bulb T (°F)	65	101.4		
Climate Zone 3	Flow rate (%GPM)	10	100	2.77	169.45
	Dry bulb T (°F)	65	97.6		
Climate Zone 4	Flow rate (%GPM)	10	100	2.82	-173.39
	Dry bulb T (°F)	65	96.9		
Climate Zone 5	Flow rate (%GPM)	10	100	2.49	151.60
	Dry bulb T (°F)	65	101.2		

For hot water pumps:

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

Equation 44

Where:

m = *The slope of the relationship between DBT and GPM (see Table 88)*

b = *The intercept of the relationship between DSBT and GPM (see Table 88)*

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.[209] 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.[210]

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

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

Table 88. HVAC VFDs—Hot Water Pump VFD %GPM Inputs

Climate zone	Condition	Minimum	Maximum	Slope (*m*)	Intercept (*b*)
Climate Zone 1	Flow rate (%GPM)	10	100	-1.66	117.93
	Dry bulb T (°F)	65	10.8		
Climate Zone 2	Flow rate (%GPM)	10	100	-2.16	150.63
	Dry bulb T (°F)	65	23.4		
Climate Zone 3	Flow rate (%GPM)	10	100	-2.68	184.11
	Dry bulb T (°F)	65	31.4		
Climate Zone 4	Flow rate (%GPM)	10	100	2.96	202.43
	Dry bulb T (°F)	65	34.6		
Climate Zone 5	Flow rate (%GPM)	10	100	-2.29	158.86
	Dry bulb T (°F)	65	25.7		

<u>Step 2</u> - Calculate the percentage of power (%power) for the applicable baseline and the new VFD technology:

<u>Baseline Technologies</u>

For AHU supply fan: [211]

$$\%power_{i,OutletDamper} = 0.00745 \times \%CFM_i^{\,2} + 0.10983 \times \%CFM_i + 20.41905$$

Equation 45

$$\%power_{i,InletDamper} = 0.00013 \times \%CFM_i^{\,3} - 0.01452 \times \%CFM_i^{\,2} + 0.71648 \times \%CFM_i + 50.25833$$

Equation 46

$$\%power_{i,InletGuideVane} = 0.00009 \times \%CFM_i^{\,3} - 0.00128 \times \%CFM_i^{\,2} + 0.06808 \times \%CFM_i + 20$$

Equation 47

Note: %power for constant volume baseline technologies with no fan control is set equal to 1 for each hour where %power is less than 1 for the other baseline control types. When %power exceeds 1 for the other baseline control types, %power for no fan control is set equal to the maximum value from the other baseline control types.

[211] https://focusonenergy.com/sites/default/files/Focus%20on%20Energy_TRM_January2015.pdf, page 225. Please note, the CFM^2 coefficients in Equation 38 and Equation 39 have the wrong sign in the reference document.

For cooling tower:

$$\%power_{i,fan\ cycling} = if\ t_{wb\_i} > t_{wb\_min}, then\ 1, otherwise\ 0$$

Equation 48

For chilled, hot, and condenser water pumps[212]:

$$\%power_{base} = 2.5294 \times \%GPM_i^{\ 3} - 4.7443 \times \%GPM_i^{\ 2} + 3.2485 \times \%GPM_i + 0$$

Equation 49

<u>VFD Technology</u>

For AHU supply fan[213]:

$$\%power_{VFD} = 0.00004 \times \%CFM_i^{\ 3} + 0.00766 \times \%CFM_i^{\ 2} - 0.19567 \times \%CFM_i + 5.9$$

Equation 50

For cooling tower[214]:

$$if\ t_{wb\_i} > t_{wb\_min}, then\ \%power_{VFD} = 0.9484823 \times \%CFM_i^{\ 3} + 0.60556507 \times \%CFM_i^{\ 2} - 0.88567609 \times \%CFM_i + 0.33162901, otherwise\ 0$$

Equation 51

For chilled water, hot water, and condenser pumps[215]:

$$\%power_{VFD} = 0.7347 \times \%GPM_i^{\ 3} - 0.301 \times \%GPM_i^{\ 2} + 0.5726 \times \%GPM_i + 0$$

Equation 52

Note: for all applications, baseline %power should use a minimum of zero.

<u>Step 3</u> - Calculate kW_{full} using the hp from the motor nameplate, load factor, and the applicable motor efficiency from ASHRAE 2013, Table 10.8-1 Minimum Nominal Efficiency for General Purpose Electric Motors; Use that result and the %power results to determine power consumption at each hour:

$$kW_{full} = 0.746 \times HP \times \frac{LF}{\eta}$$

Equation 53

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212 PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, Table 87 Default Part-load CIRC-PUMP-FPLR Coefficients – Constant Speed, no VSD.

213 https://focusonenergy.com/sites/default/files/Focus%20on%20Energy_TRM_January2015.pdf, page 225.

214 PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, Table 85 Default Efficiency TWR-FAN-PLR Coefficients – VSD on Cooling Tower Fan.

215 PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, Table 87 Default Part-load CIRC-PUMP-FPLR Coefficients – Default (VSD, No Reset).

$$kW_i = kW_{full} \times \%power_i$$

Equation 54

Where:

$\%power_i$	=	*Percentage of full load pump power at the i^{th} hour calculated by an equation based on the control type (outlet damper, inlet box damper, inlet guide vane-IGV, or VFD)*[216]
kW_{full}	=	*Motor power demand operating at the fan design 100 percent CFM or pump design 100 percent GPM*
kW_i	=	*Fan or Pump real-time power at the i^{th} hour of a year*
HP	=	*Rated horsepower of the motor*
LF	=	*Load factor—ratio of the operating load to the nameplate rating of the motor—assumed to be 75 percent*
η	=	*Motor efficiency of a standard efficiency Open Drip Proof (ODP) motor operating at 1800 RPM taken from ASHRAE Standard 90.1-2013*
0.746	=	*Constant to convert from HP to kW*

Table 89. HVAC VFDs—Motor Efficiencies for Open Drip Proof Motors at 1,800 RPM[217]

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
20	0.93
25	0.936
30	0.941
40	0.941
50	0.945
60	0.95

[216] Fan curves by control type are provided in the BPA ASD Calculator, https://www.bpa.gov/-/media/Aep/energy-efficiency/industrial/Industrial-files/ASDCalculators.

[217] For unlisted motor horsepower values, round down to the next lowest horsepower value.

Motor horsepower	Full load efficiency
75	0.95
100	0.954

Step 4 - Calculate the kW savings for each of the top 20 hours within the applicable peak probability analysis for the building's climate zone from Volume 1. Sum the kW savings for each hour multiplied by the peak demand probability factor from the 20 individual hourly calculations, then divide by the sum of the PDPF for the 20 hours to get the average peak demand impact, and then calculate the total peak demand saved by adding peak demand interactive effects:

Hourly Savings Calculations

$$(kW_i)_{Saved} = [(kW_i)_{Baseline} - (kW_i)_{VFD}] \times schedule_i$$

Equation 55

Where:

$schedule_i$ = *1 when building is occupied, 0.2 when building is unoccupied (see Table 90)*

Table 90. HVAC VFDs—Yearly Motor Operation Hours by Building Type[218,219]

Building type	Weekday schedule	Weekend schedule	Annual motor operation hours
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	24-hr	24-hr	8,760
Office—large, medium	7am–11pm	7am–7pm (Saturday)	5,592
Office—small	7am–8pm	closed	4,466
Education	8am–11pm	closed	4,884
Convenience store, service, strip mall	9am–10pm	9am–8pm (Saturday) 10am–7pm (Sunday)	5,298
Stand-alone retail, supermarket	8am–10pm	8am–11pm (Saturday) 10am–7pm (Sunday)	5,674

[218] Hours for all building types except for Assembly come from the Department of Energy Commercial Building Prototype Models, Scorecards, HVAC Operation Schedule. Motor hours are set to equal 1 when the HVAC Operation Schedule is "on" and 0.2 when the HVAC Operation Schedule is "off." https://www.energycodes.gov/development/commercial/prototype_models. Assembly occupied hours come from COMNET Appendix C—Schedules (Rev 3) https://comnet.org/appendix-c-schedules, updated 07/25/2016.

[219] Data centers are covered in 2.2.6 Computer Room Air Handler Motor Efficiency.

Building type	Weekday schedule	Weekend schedule	Annual motor operation hours
Restaurants	6am–2am	6am–2am	7,592
Warehouse	7am–7pm	closed	4,258
Assembly, worship	9am–11pm	9am–11pm	5,840
Other[220]	7am–7pm	closed	4,258

Average Peak Demand Saved Calculation, excluding interactive effects

$$kW_{PDPF,Saved} = \frac{\sum_{i=1}^{20}(kW_i)_{Saved} * PDPF_i)}{\sum_{i=1}^{20}(PDPF_i)}$$

Equation 56

Where:

$PDPF_i$ = *Peak demand probability factor from the applicable climate zone table in Volume 1*

Total Peak Demand Saved Calculation, including interactive effects. This applies only to AHU supply fans. Total peak demand savings for pumps are found using Equation 56 above:

$$kW_{TotalSaved} = kW_{PDPF,Saved} \times (1 + \frac{3.412}{Cooling_{EER}})$$

Equation 57

Where:

$Cooling_{EER}$ = *Air conditioner full-load cooling efficiency, assumed at 11.2, based on IECC 2015 minimum efficiency of a unitary AC system between 5 and 11.3 tons*

Energy Savings are calculated in the following manner:

Step 1 – For both the baseline and new technology, calculate the sum of individual kWh consumption in each hour of the year:

$$Energy\ Savings\ [kWh] = \sum_{i=1}^{8,760}(kW_i \times schedule_i)$$

Equation 58

Where:

8,760 = *Total of hours per year*

[220] The "other" building type may be used when none of the listed building types apply. The values used for other are the most conservative of the listed building types.

Step 2 - Subtract the Annual kWh_{new} from the Annual $kWh_{baseline}$ to get the Energy Savings:

$$Energy\ Savings\ [kWh] = kWh_{baseline} - kWh_{new}$$

Equation 59

Deemed Energy and Demand Savings Tables[221]

Table 91. HVAC VFDs—AHU Supply Fan Outlet Damper Baseline Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,160	1,101	1,071	1,047	1,122
Office—large, medium	724	682	659	641	695
Office—small	576	543	522	507	552
Education	633	596	577	561	606
Convenience store, service, strip Mall	677	637	614	599	649
Stand-alone retail, supermarket	728	685	661	644	698
Restaurants	995	941	913	892	959
Warehouse	548	516	496	481	526
Assembly, worship	751	707	684	668	720
Other	548	516	496	481	526
Summer kW savings (kW per motor HP)					
All building types	0.041	0.023	0.020	0.063	0.042

Table 92. HVAC VFDs—AHU Supply Fan Inlet Damper Baseline Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,825	1,672	1,598	1,535	1,723
Office—large, medium	1,126	1,024	968	923	1,052
Office—small	894	813	766	727	834

[221] Data centers are covered in Section 2.2.6 Computer Room Air Handler Motor Efficiency.

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Education	984	895	848	808	917
Convenience store, service, strip mall	1,046	950	897	859	976
Stand-alone retail, supermarket	1,128	1,025	967	925	1,052
Restaurants	1,556	1,420	1,352	1,298	1,462
Warehouse	850	773	727	690	794
Assembly, worship	1,164	1,057	1,003	961	1,086
Other	850	773	727	690	794
Summer kW Savings (kW per Motor HP)					
All building types	0.045	0.026	0.024	0.069	0.047

Table 93. HVAC VFDs—AHU Supply Fan Inlet Guide Vane Baseline Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	388	345	325	307	359
Office—large, medium	237	209	194	182	217
Office—small	188	166	154	143	171
Education	207	183	170	159	189
Convenience store, service, strip mall	219	194	179	169	200
Stand-alone retail, supermarket	237	209	193	182	216
Restaurants	329	292	273	258	303
Warehouse	179	158	146	135	163
Assembly, worship	245	216	201	189	223
Other	179	158	146	135	163
Summer kW savings (kW per motor HP)					
All building types	0.009	0.009	0.005	0.011	0.013

Table 94. HVAC VFDs—AHU Supply Fan No Control Baseline Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	3,302	3,034	2,905	2,794	3,125
Office—large, medium	2,038	1,856	1,757	1,677	1,907
Office—small	1,617	1,473	1,389	1,320	1,511
Education	1,780	1,622	1,540	1,468	1,663
Convenience store, service, strip mall	1,893	1,721	1,626	1,557	1,768
Stand-alone retail, supermarket	2,040	1,856	1,754	1,679	1,907
Restaurants	2,817	2,577	2,457	2,360	2,651
Warehouse	1,538	1,401	1,317	1,251	1,438
Assembly, worship	2,106	1,916	1,819	1,745	1,969
Other	1,538	1,401	1,317	1,251	1,438
Summer kW savings (kW per motor HP)					
All building types	0.033	0.004	0.027	0.088	0.025

Table 95. HVAC VFDs—Cooling Tower Fans Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,124	1,528	1,883	2,070	1,389
Office—large, medium	704	972	1,196	1,314	901
Office—small	558	788	955	1,039	712
Education	610	869	1,054	1,143	784
Convenience store, service, strip mall	663	925	1,142	1,248	858
Stand-alone retail, supermarket	712	986	1,216	1,332	915
Restaurants	966	1,323	1,632	1,792	1,215
Warehouse	534	749	908	986	676

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Assembly, worship	733	1,020	1,264	1,380	946
Other	534	749	908	986	676
Summer kW savings (kW per motor HP)					
All building types	0.097	0.041	0.170	0.175	0.216

Table 96. HVAC VFDs—Chilled Water Pump Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	778	1,154	1,339	1,482	1,050
Office—large, medium	564	775	882	968	735
Office—small	456	624	703	768	592
Education	491	683	768	843	647
Convenience store, service, strip mall	554	747	848	918	706
Stand-alone retail, supermarket	587	795	905	982	754
Restaurants	723	1,030	1,183	1,297	960
Warehouse	435	594	670	730	563
Assembly, worship	601	818	933	1,011	773
Other	435	594	670	730	563
Summer kW savings (kW per motor HP)					
All building types	0.0487	0.0183	0.0293	0.0920	0.0439

Table 97. HVAC VFDs—Hot Water Pump Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,298	912	721	610	1,038
Office—large, medium	774	536	418	338	606

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Office—small	609	423	328	266	473
Education	677	468	368	301	526
Convenience store, service, strip mall	706	482	375	306	558
Stand-alone retail, supermarket	764	526	410	335	606
Restaurants	1,086	756	598	500	863
Warehouse	579	402	309	251	449
Assembly, worship	791	544	426	351	630
Other	579	402	309	251	449
Winter kW savings (kW per motor HP)					
All building types	0.118	0.045	0.045	0.133	0.225

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) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HVAC-VSD-fan.[222]

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.

- Building type
- Application type (AHU supply fan, hot water pump, chilled water pump)
- Climate zone or county
- Motor horsepower
- **For AHU supply fans only**: Baseline part-load control type (e.g., outlet damper, inlet damper, inlet guide vane, constant volume/no control).

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

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for VFD equipment
- PUCT Docket 40668—Provides details on deemed savings calculations for VFDs.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 98. HVAC VFDs—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 revision.
v3.0	04/10/2015	TRM v3.0 update. Corrected ASHRAE 0.4 percent Dry Bulb Design Temperature references for three climate zone reference cities: DFW, El Paso, and Houston. Updated Valley climate zone reference city to Corpus Christi to be consistent with TRM guidance. Corrected Motor Load Factor to 75 percent.
v4.0	10/10/2016	TRM v4.0 update. Added reference for percent power and corrected signs for variables in Equation 50.
v5.0	10/2017	TRM v5.0 update. Updated deemed energy/demand tables for revised peak demand definition.
v6.0	10/2018	TRM v6.0 update. Added no control device option for constant volume systems. Corrected error in previous kW and kWh deemed savings calculations for Outlet Damper baseline control.
v7.0	10/2019	TRM v7.0 update. Renamed measure to HVAC Variable Frequency Drives. Added methodology for chilled and hot water pumps.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Added motor efficiency default assumptions.
v9.0	10/2021	TRM v9.0 update. Expanded available building types and updated occupancy schedules.
v10.0	10/2022	TRM v10.0 update. Added guidance for rounding down motor size in the baseline efficiency lookup table.
v11.0	10/2021	TRM v11.0 update. Added cooling tower fan and condenser water pump applications. Updated maximum temperatures for linear regression equations to correspond with ASHRAE design conditions. Aligned building type names across all commercial measures.

2.2.8 Condenser Air Evaporative Pre-Cooling Measure Overview

TRM Measure ID: NR-HV-EP

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 100 through Table 104

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This section summarizes the deemed savings methodology for the installation of an evaporative pre-cooling system onto HVAC equipment. This process reduces the temperature of the outside air before it is used to cool the condenser coil for direct expansion (DX) units or air-cooled chillers. The temperature reduction is achieved by having the incoming air pass through a saturated media or mist wall, which will increase the humidity ratio under adiabatic conditions. This allows the dry bulb temperature to decrease while the wet bulb temperature remains constant, effectively increasing the heat rejection capacity from the condenser coils into the air. This measure is not applicable to the replacement of an air-cooled condenser with an evaporative condenser.

Applicable evaporative pre-cooling product types include:

- Evaporative media panels that incoming air must pass through
- Misting based system that sprays fine droplets into the air in front of the air intake area.

Eligibility Criteria

For a measure to be eligible to use this deemed savings approach, the following conditions must be met:

- Must have chemical or mechanical water treatment
  - Must have periodic purge control for sump-based systems
- Must have a control system for operation
  - Minimum temperature controls for sump-based systems
  - Minimum enthalpy controls for mist-based systems
- All air to condenser coils must pass through the evaporative pre-cooling system
- Systems must be installed by a qualified contractor and must be commissioned

- Evaporative effectiveness performance of greater than or equal to 0.75 (i.e., 75 percent) for average dry bulb temperature and humidity during peak hours
- Operation manuals must be provided
- 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.

Baseline Condition

The baseline conditions are the operation of a direct expansion (DX) unit or air-cooled chiller without evaporative pre-cooling.

High-Efficiency Condition

Evaporative pre-cooling systems must exceed the evaporative effectiveness performance of 75 percent for average dry bulb temperature humidity during peak hours. Table 99 contains values that can be used as a reference for evaluating evaporative effectiveness.

Table 99. Evaporative Pre-Cooling—Average Weather During Peak Conditions[223]

Climate zone	Temperature (°F)	Humidity (%)
Climate Zone 1: Amarillo	95.8	25
Climate Zone 2: Dallas	101.2	34
Climate Zone 3: Houston	99.1	37
Climate Zone 4: Corpus Christi	92.5	49
Climate Zone 5: El Paso	97.4	15

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

$$Energy\ Savings\ [kWh] = (Cap_C \times \eta_C) \times EFLH_{red}$$

Equation 60

$$Peak\ Demand\ Savings\ [kW] = (Cap_C \times \eta_C) \times DRF$$

Equation 61

[223] Extracted from weather data from building models that were used to create summer peak period value used for this measure.

Where:

Cap_C	=	*Rated equipment cooling capacity of the existing equipment at AHRI-standard conditions [tons]; 1 ton = 12,000 Btuh*
η_C	=	*Cooling efficiency of existing equipment [kW/ton]*

Note: For DX systems, use EER for kW savings calculations and SEER/IEER for kWh savings calculations. For air-cooled chillers, use full-load efficiency (kW/ton) for kW savings calculations and part-load efficiency (IPLV) for kWh savings calculations. In the cases where the full-load efficiency is provided in terms of EER or SEER/IEER rather than kW/ton and IPLV, a unit conversion to kW/ton needs to be performed using the following conversion:

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

Equation 62

$EFLH_{red}$	=	*Annual cooling energy reduction divided by the rated full loaded demand. Annual cooling energy reduction is determined according to the same method as other HVAC coefficients contained in the TRM. Rated full loaded demand is the Cap_C divided by its rated full load efficiency (see Table 100 through Table 104)*
CF	=	*Seasonal peak coincidence factor. The average peak hour energy reduction divided by the rated full loaded demand (see Table 100 through Table 104)*

Deemed Energy and Demand Savings Tables

Deemed peak demand reduction factor (DRF) and equivalent full-load hour reduction ($EFLH_{reduction}$) 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 34. These building types are derived from the EIA CBECS study.[224]

The DRF and $EFLH_{reduction}$ values for packaged and split AC are presented in Table 100 through Table 104. These tables also include an "Other" building type, which can be used for business types that are not explicitly listed. The DRF and $EFLH_{reduction}$ values used for Other are the most conservative values from the explicitly listed building types. When the Other building type is used, a

[224] 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.*

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.

Deemed savings are estimated using building simulation models, which estimate the hourly impacts of installing an evaporative pre-cooling system (i.e., modeling the difference between base and change case). The base models are the same models used to derive values for the other commercial HVAC sections of the TRM. Adjustments are made for the evaporative pre-cooling measure by updating all existing HVAC equipment to operate with evaporative pre-cooling when the outside temperature is above 70°F.

Table 100. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 1: Amarillo

		Direct expansion		Air-cooled chiller	
Building type	Principal building activity	CF	$EFLH_{red}$	CF	$EFLH_{red}$
Education	College/university	0.19	130	0.17	150
	Primary school	0.20	83	0.13	69
	Secondary school	0.19	89	0.17	102
Food sales	Convenience store	0.18	125	-	-
	Supermarket	0.08	37	-	-
Food service	Full-service restaurant	0.21	134	-	-
	Quick-service restaurant	0.18	109	-	-
Healthcare	Inpatient	0.21	160	0.18	151
	Outpatient	0.17	145	-	-
Large multifamily	Midrise apartment	0.18	113	0.10	59
Lodging	Large hotel	0.13	111	0.15	165
	Nursing home	0.18	115	0.10	60
	Small hotel/motel	0.13	104	-	-
Mercantile	Stand-alone retail	0.19	108	0.14	74
	Strip mall	0.21	121	-	-
Office	Large office	0.25	206	0.18	119
	Medium office	0.19	75	-	-
	Small office	0.20	111	-	-
Public assembly	Public assembly	0.20	112	0.13	93
Religious worship	Religious worship	0.19	65	0.14	45

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	$EFLH_{red}$	CF	$EFLH_{red}$
Service	Service: Excluding food	0.21	104	-	-
Warehouse	Warehouse	0.12	34	-	-
Other	Other	0.08	34	0.10	45

Table 101. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 2: Dallas

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	$EFLH_{red}$	CF	$EFLH_{red}$
Education	College/university	0.21	192	0.19	195
	Primary school	0.24	120	0.12	80
	Secondary school	0.21	131	0.19	132
Food sales	Convenience store	0.24	214	-	-
	Supermarket	0.15	78	-	-
Food service	Full-service restaurant	0.23	194	-	-
	Quick-service restaurant	0.24	185	-	-
Healthcare	Inpatient	0.24	230	0.22	216
	Outpatient	0.19	174	-	-
Large multifamily	Midrise apartment	0.16	230	0.15	120
Lodging	Large hotel	0.15	137	0.18	212
	Nursing home	0.16	234	0.15	122
	Small hotel/motel	0.15	133	-	-
Mercantile	Stand-alone retail	0.24	158	0.19	120
	Strip mall	0.23	156	-	-
Office	Large office	0.26	220	0.23	231
	Medium office	0.20	102	-	-
	Small office	0.22	156	-	-
Public assembly	Public assembly	0.24	161	0.12	108
Religious worship	Religious worship	0.24	95	0.19	72
Service	Service: Excluding food	0.23	150	-	-
Warehouse	Warehouse	0.20	93	-	-
Other	Other	0.15	78	0.12	72

Table 102. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 3: Houston

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	$EFLH_{red}$	CF	$EFLH_{red}$
Education	College/university	0.20	173	0.17	175
	Primary school	0.21	118	0.10	74
	Secondary school	0.20	118	0.17	119
Food sales	Convenience store	0.22	193	-	-
	Supermarket	0.14	76	-	-
Food service	Full-service restaurant	0.21	171	-	-
	Quick-service restaurant	0.22	167	-	-
Healthcare	Inpatient	0.21	202	0.19	187
	Outpatient	0.18	157	-	-
Large multifamily	Midrise apartment	0.17	257	0.14	105
Lodging	Large hotel	0.14	120	0.14	193
	Nursing home	0.17	261	0.14	107
	Small hotel/motel	0.13	113	-	-
Mercantile	Stand-alone retail	0.22	152	0.19	128
	Strip mall	0.21	152	-	-
Office	Large office	0.24	203	0.23	150
	Medium office	0.19	94	-	-
	Small office	0.20	138	-	-
Public assembly	Public assembly	0.21	159	0.10	99
Religious worship	Religious worship	0.22	92	0.19	77
Service	Service: Excluding food	0.21	132	-	-
Warehouse	Warehouse	0.18	81	-	-
Other	Other	0.13	76	0.10	74

Table 103. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 4: Corpus Christi

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	$EFLH_{red}$	CF	$EFLH_{red}$
Education	College/university	0.13	161	0.11	160
	Primary school	0.14	113	0.07	68
	Secondary school	0.13	110	0.11	109

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	$EFLH_{red}$	CF	$EFLH_{red}$
Food sales	Convenience store	0.14	188	-	-
	Supermarket	0.08	74	-	-
Food service	Full-service restaurant	0.13	157	-	-
	Quick-service restaurant	0.14	162	-	-
Healthcare	Inpatient	0.15	199	0.09	169
	Outpatient	0.12	150	-	-
Large multifamily	Midrise apartment	0.14	181	0.09	104
Lodging	Large hotel	0.08	116	0.10	179
	Nursing home	0.14	183	0.09	106
	Small hotel/motel	0.08	109	-	-
Mercantile	Stand-alone retail	0.14	148	0.12	120
	Strip mall	0.13	146	-	-
Office	Large office	0.16	192	0.13	137
	Medium office	0.11	90	-	-
	Small office	0.13	131	-	-
Public assembly	Public assembly	0.14	152	0.07	92
Religious worship	Religious worship	0.14	89	0.12	72
Service	Service: Excluding food	0.13	122	-	-
Warehouse	Warehouse	0.12	74	-	-
Other	Other	0.08	74	0.07	68

Table 104. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 5: El Paso

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	$EFLH_{red}$	CF	$EFLH_{red}$
Education	College/university	0.27	240	0.22	254
	Primary school	0.30	161	0.17	120
	Secondary school	0.27	163	0.22	172
Food sales	Convenience store	0.25	232	-	-
	Supermarket	0.12	76	-	-
Food service	Full-service restaurant	0.25	223	-	-
	Quick-service restaurant	0.25	201	-	-

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	$EFLH_{red}$	CF	$EFLH_{red}$
Healthcare	Inpatient	0.26	273	0.20	247
	Outpatient	0.23	259	-	-
Large multifamily	Midrise apartment	0.28	264	0.15	140
Lodging	Large hotel	0.19	201	0.19	300
	Nursing home	0.28	268	0.15	142
	Small hotel/motel	0.17	193	-	-
Mercantile	Stand-alone retail	0.25	198	0.18	131
	Strip mall	0.26	207	-	-
Office	Large office	0.32	314	0.22	199
	Medium office	0.25	137	-	-
	Small office	0.26	215	-	-
Public assembly	Public assembly	0.30	217	0.17	162
Religious worship	Religious worship	0.25	119	0.18	79
Service	Service: Excluding food	0.25	173	-	-
Warehouse	Warehouse	0.25	82	-	-
Other	Other	0.12	76	0.15	79

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

Pre-cooling components may consist of pumps, sprayers, electronic controllers, and evaporative media, with the evaporative media requiring periodic replacement.

The estimated useful life (EUL) for an evaporative pre-cooling system is 10 years, consistent with the typical manufacturer warranty for evaporative pre-cooling equipment.[225]

[225] ET13SCE1020: Evaporative Condenser Air Pre-Coolers, Southern California Edison. December 2015. https://wcec.ucdavis.edu/wp-content/uploads/2016/06/et13sce1020_evaporative_pre-cooler_final.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.

- Decision/action type: Retrofit or new construction
- Climate zone or county
- Building type
- Baseline equipment type
- Baseline equipment rated cooling capacity
- Baseline equipment cooling efficiency ratings
- Baseline number of units
- Baseline manufacturer and model
- Installed number of units
- Installed evaporative pre-cooling system manufacturer and model
- Installed evaporative pre-cooling system evaporative effectiveness
- Copy of operation manuals
- **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 47612—Provides deemed savings for Condenser Evaporative Pre-cooling

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 105. Evaporative Pre-Cooling—Revision History

TRM version	Date	Description of change
v5.0	10/2017	TRM v5.0 origin.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 update. Specified that formulas use tons and kW/ton values and added conversion factors from other units.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Aligned building type names across all commercial measures.

2.2.9 High-Volume Low-Speed Fans Measure Overview

TRM Measure ID: NR-HV-HF

Market Sector: Commercial

Measure Category: HVAC

Applicable Business Types: Agriculture

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

Circulation fans are used in agricultural applications such as dairy, swine, or poultry barns to destratify air, reduce animal heat stress, control insects, dry surfaces, and cool people and animals. This measure applies to the installation of high-volume low-speed (HVLS) fans in a horizontal orientation in such agricultural applications. HVLS fans may be installed in lieu of conventional (small diameter) circulation fans in new construction applications or in replacement of existing (still functioning) conventional circulation fans in retrofit projects.

Deemed savings are provided for displaced fan load only: applications in which HVLS fans are installed to reduce air conditioning requirements may be considered in the future: for now, such applications would require additional M&V to demonstrate (and claim) complete savings.

Eligibility Criteria

While many applications exist for HVLS fans, the guidance in this measure is specific to agricultural operations. Savings estimates may be developed for other applications in future iterations of the TRM.

HVLS fans may be used to replace existing conventional circulating fans or installed in new barns. To claim savings for a retrofit, the conventional fans being replaced should be in proper working condition.

Default values are provided for dairy applications while other facility types are eligible and should use the dairy values until other livestock specific factors are developed.

Baseline Condition

The baseline condition is an installation of conventional fans.

Retrofit (Early Retirement)

When replacing existing (working) fans, the baseline is set by the number of fans to be replaced, with power requirements calculated according to their operating airflow rates (CFM), and rated efficiency (e.g., CFM/watt).

Replace on Burnout/New Construction

When existing fans are reaching the end of their useful life, or for new construction, the baseline assumes installation of conventional fans that would produce a comparable total airflow (CFM) as the HVLS fan to be installed.

High-Efficiency Condition

HVLS fans with diameters of eight to 24 feet typically use 1 hp to 2 hp motors per fan and move between 50,000 CFM and 150,000 or more CFM.[226] To be eligible for this measure, HVLS fans shall be a minimum of 8 feet in diameter and move more cubic feet of air per watt than conventional circulating fans. The fan should be installed in a horizontal orientation and have the ability to operate at different speeds.

Energy and Demand Savings Methodology

Savings are estimated assuming operation of the baseline (conventional) and high efficiency (HVLS) fans at their rated speed and power input during all hours of expected use.

Savings Algorithms and Input Variables

$$Energy\ Savings[kWh] = \left(\frac{W_{base} - W_{HVLS}}{1{,}000}\right) \times Hours$$

Equation 63

[226] Motor hp from manufacturer product specification sheets available from https://macroairfans.com/downloads/ and https://www.bigassfans.com/aedownloads/. Airflow range from Kammel et al, "Design of High Volume Low Speed Fan Supplemental Cooling System in Dairy Free Stall Barns," available at https://www.researchgate.net/publication/271433461_Design_of_high_volume_low_speed_fan_supplemental_cooling_system_in_dairy_freestall_barns, and from MacroAir Fans "Horse Barn Ventilation Systems" white paper, available at http://www.ergingreentech.com/pdf/MacroAir/Horseventilationwhitepaper.pdf.