

| Building types | Principal building activity | Packaged terminal unit |                   |                 |                   |                 |                   |
|----------------|-----------------------------|------------------------|-------------------|-----------------|-------------------|-----------------|-------------------|
|                |                             | Air conditioner        |                   | Heat pump       |                   |                 |                   |
|                |                             | CF <sub>s</sub>        | EFLH <sub>c</sub> | CF <sub>s</sub> | EFLH <sub>c</sub> | CF <sub>w</sub> | EFLH <sub>h</sub> |
|                | 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/EFLH Values for Climate Zone 3: Houston**

| Building types | Principal building activity      | Packaged terminal unit |                   |                 |                   |                 |                   |
|----------------|----------------------------------|------------------------|-------------------|-----------------|-------------------|-----------------|-------------------|
|                |                                  | Air conditioner        |                   | Heat pump       |                   |                 |                   |
|                |                                  | CF <sub>s</sub>        | EFLH <sub>c</sub> | CF <sub>s</sub> | EFLH <sub>c</sub> | CF <sub>w</sub> | EFLH <sub>h</sub> |
| 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/EFLH Values for Climate Zone 4: Corpus Christi**

| Building types | Principal building activity | Packaged terminal unit |                   |                 |                   |                 |                   |
|----------------|-----------------------------|------------------------|-------------------|-----------------|-------------------|-----------------|-------------------|
|                |                             | Air conditioner        |                   | Heat pump       |                   |                 |                   |
|                |                             | CF <sub>s</sub>        | EFLH <sub>c</sub> | CF <sub>s</sub> | EFLH <sub>c</sub> | CF <sub>w</sub> | EFLH <sub>h</sub> |
| 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                |

| Building types | Principal building activity      | Packaged terminal unit |                   |                 |                   |                 |                   |
|----------------|----------------------------------|------------------------|-------------------|-----------------|-------------------|-----------------|-------------------|
|                |                                  | Air conditioner        |                   | Heat pump       |                   |                 |                   |
|                |                                  | CF <sub>s</sub>        | EFLH <sub>c</sub> | CF <sub>s</sub> | EFLH <sub>c</sub> | CF <sub>w</sub> | EFLH <sub>H</sub> |
| 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/EFLH Values for Climate Zone 5: El Paso**

| Building types | Principal building activity      | Packaged terminal unit |                   |                 |                   |                 |                   |
|----------------|----------------------------------|------------------------|-------------------|-----------------|-------------------|-----------------|-------------------|
|                |                                  | Air conditioner        |                   | Heat pump       |                   |                 |                   |
|                |                                  | CF <sub>s</sub>        | EFLH <sub>c</sub> | CF <sub>s</sub> | EFLH <sub>c</sub> | CF <sub>w</sub> | EFLH <sub>H</sub> |
| 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               |
| Lodging        | Large hotel                      | 0.61                   | 1,723             | 0.61            | 1,723             | 0.21            | 292               |
|                | Nursing home                     | 0.85                   | 1,244             | 0.85            | 1,244             | 0.15            | 211               |
|                | Small hotel                      | 0.61                   | 1,945             | 0.61            | 1,945             | 0.06            | 123               |

| Building types | Principal building activity | Packaged terminal unit |                   |                 |                   |                 |                   |
|----------------|-----------------------------|------------------------|-------------------|-----------------|-------------------|-----------------|-------------------|
|                |                             | Air conditioner        |                   | Heat pump       |                   |                 |                   |
|                |                             | CF <sub>s</sub>        | EFLH <sub>c</sub> | CF <sub>s</sub> | EFLH <sub>c</sub> | CF <sub>w</sub> | EFLH <sub>H</sub> |
| 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<sup>186</sup> and 2014 MECS<sup>187</sup>.

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<sup>188</sup>**

| Savings coefficient | Climate Zone 1            | Climate Zone 2            | Climate Zone 3            | Climate Zone 4            | Climate Zone 5            |
|---------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| EFLH <sub>c</sub>   | <del>1,033</del><br>1,019 | <del>1,681</del><br>1,661 | <del>1,791</del><br>1,774 | <del>1,929</del><br>1,916 | <del>1,586</del><br>1,562 |
| EFLH <sub>H</sub>   | <del>238247</del>         | <del>186193</del>         | <del>3840</del>           | <del>4346</del>           | <del>168476</del>         |
| CF <sub>s</sub>     | 0.55                      | <del>0.778</del>          | <del>0.670-68</del>       | 0.60                      | 0.73                      |
| CF <sub>w</sub>     | 0.43                      | 0.52                      | <del>0.220-23</del>       | <del>0.130-14</del>       | <del>0.110-12</del>       |

<sup>186</sup> 2012 Commercial Building Energy Consumption Survey (CBECS).

<https://www.eia.gov/consumption/commercial/>. 2018 version not available until mid-2020.

<sup>187</sup> 2014 Manufacturing Energy Consumption Survey (MECS).

<https://www.eia.gov/consumption/manufacturing/>.

<sup>188</sup> 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.<sup>189</sup>

The EUL of SPVAC/SPVHP units is 15 years, as determined by the DOE in its September 2015 final rule.<sup>190</sup>

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.<sup>191</sup>

### *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<sup>192,193</sup>**

| 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         |

<sup>189</sup> <http://www.deeresources.com/>

<sup>190</sup> 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>

<sup>191</sup> Technical Support Document: Room Air Conditioners, June 2020, p. ES-14. <https://www.regulations.gov/document/EERE-2014-BT-STD-0059-0013>.

<sup>192</sup> PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.

<sup>193</sup> 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 <sup>194</sup>              | 0.0         |

**Table 77. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—RUL of Early Retirement Standard Size PTHPs<sup>195,196</sup>**

| 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 <sup>197</sup>              | 0.0         |

<sup>194</sup> RULs are capped at the 75<sup>th</sup> 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.

<sup>195</sup> PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.

<sup>196</sup> 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.

<sup>197</sup> RULs are capped at the 75<sup>th</sup> 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. |
| <u>v12.0</u> | <u>10/2024</u> | <u>TRM 12.0 update. Updated early retirement age eligibility and criteria related to downsizing and updated midstream building type weighting assumptions.</u>   |



## 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 81 and Table 82~~ Data centers

**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 sensible COP coefficient of performance (SCOP) for units manufactured before May 28, 2024, and net sensible coefficient of performance (NSenCOP) for units manufactured as of May 28, 2024. 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.<sup>198,199</sup>

## 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.~~ 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.

**Table 79. CRACs—ER Baseline Efficiency Levels<sup>200</sup>**

| <u>System type</u>  | <u>Cooling capacity (Btu/hr)</u>    | <u>Baseline efficiencies for downflow/upflow units (SCOP)</u> |
|---|-------------------------------------|---|
| <u>Air conditioners, air-cooled</u>   | <u>&lt; 65,000</u>                  | <u>2.20 / 2.09</u>  |
|   | <u>&gt; 65,000 and &lt; 240,000</u> | <u>2.10 / 1.99</u>  |
|   | <u>&gt; 240,000</u>                 | <u>1.90 / 1.79</u>  |
| <u>Air conditioners, water-cooled</u>   | <u>&lt; 65,000</u>                  | <u>2.60 / 2.49</u>  |
|   | <u>&gt; 65,000 and &lt; 240,000</u> | <u>2.50 / 2.39</u>  |
|   | <u>&gt; 240,000</u>                 | <u>2.40 / 2.29</u>  |
| <u>Air conditioners, water-cooled with fluid economizer</u>                   | <u>&lt; 65,000</u>                  | <u>2.55 / 2.44</u>  |
|   | <u>&gt; 65,000 and &lt; 240,000</u> | <u>2.45 / 2.34</u>  |
|   | <u>&gt; 240,000</u>                 | <u>2.35 / 2.24</u>  |
| <u>Air conditioners, glycol cooled (rated at 40 percent propylene glycol)</u> | <u>&lt; 65,000</u>                  | <u>2.50 / 2.39</u>  |
|   | <u>&gt; 65,000 and &lt; 240,000</u> | <u>2.15 / 2.04</u>  |
|   | <u>&gt; 240,000</u>                 | <u>2.10 / 1.99</u>  |

<sup>198</sup> Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: <https://www.ahridirectory.org/>.

<sup>199</sup> Department of Energy Compliance Certification Management System (DOE CCMS): <https://www.regulations.doe.gov/certification-data/>.

<sup>200</sup> [IECC 2015 Table C403.2.3\(9\)](#)

| <u>System type</u>  | <u>Cooling capacity (Btu/hr)</u>    | <u>Baseline efficiencies for downflow/upflow units (SCOP)</u> |
|---|-------------------------------------|---|
| <u>Air conditioners, glycol cooled (rated at 40 percent propylene glycol) with fluid economizer</u> | <u>&lt; 65,000</u>                  | <u>2.45 / 2.34</u>  |
|   | <u>&gt; 65,000 and &lt; 240,000</u> | <u>2.10 / 1.99</u>  |
|   | <u>&gt; 240,000</u>                 | <u>2.05 / 1.94</u>  |

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

Baseline efficiency levels for CRACs are provided in Table 80. These baseline efficiency levels reflect the minimum efficiency requirements from [Department of Energy \(DOE\) 10 CFR 431, referencing ASHRAE 90.1-2019](#). This standard updates the standard efficiency metric from [IECC 2015, which uses the Sensible Coefficient of Performance \(SCOP\) to NSenCOP as the standard efficiency metric](#). The current federal standard is effective August 1, 2023, with full compliance required by [May 28, 2024](#).

**Table 80. CRACs—NC/ROB Baseline Efficiency Levels<sup>201</sup>**

| <u>System type</u>                      | <u>Duct Location</u>     | <u>Cooling capacity (Btu/hr)</u>  | <u>Baseline efficiency [NSenCOP]</u> |
|---|--------------------------|-----------------------------------|--------------------------------------|
| <b><u>Floor Mounted CRACs</u></b>       |                          |                                   |                                      |
| <u>Air cooled</u>                       | <u>Downflow</u>          | <u>&lt; 80,000</u>                | <u>2.70</u>                          |
|   |                          | <u>≥ 80,000 and &lt; 295,000</u>  | <u>2.58</u>                          |
|   |                          | <u>≥ 295,000 and &lt; 930,000</u> | <u>2.36</u>                          |
|   | <u>Upflow ducted</u>     | <u>&lt; 80,000</u>                | <u>2.67</u>                          |
|   |                          | <u>≥ 80,000 and &lt; 295,000</u>  | <u>2.55</u>                          |
|   |                          | <u>≥ 295,000 and &lt; 930,000</u> | <u>2.33</u>                          |
|   | <u>Upflow non-ducted</u> | <u>&lt; 65,000</u>                | <u>2.16</u>                          |
|   |                          | <u>≥ 65,000 and &lt; 240,000</u>  | <u>2.04</u>                          |
|   |                          | <u>≥ 240,000 and &lt; 760,000</u> | <u>1.89</u>                          |
|   | <u>Horizontal</u>        | <u>&lt; 65,000</u>                | <u>2.65</u>                          |
|   |                          | <u>≥ 65,000 and &lt; 240,000</u>  | <u>2.55</u>                          |
|   |                          | <u>≥ 240,000 and &lt; 760,000</u> | <u>2.47</u>                          |
| <u>Air-cooled with fluid economizer</u> | <u>Downflow</u>          | <u>&lt; 80,000</u>                | <u>2.70</u>                          |

<sup>201</sup> [DOE 10 CFR 431: Table I-1 & I-2](#); [IECC 2015 Table C403.2.3\(9\)](#), <https://www.federalregister.gov/documents/2022/03/07/2022-04151/energy-conservation-program-energy-conservation-standards-for-computer-room-air-conditioners>.

| System type                               | Duct Location            | Cooling capacity (Btu/hr)      | Baseline efficiency (NSenCOP)  |             |
|---|--------------------------|--------------------------------|--------------------------------|-------------|
|   |                          | $\geq 80,000$ and $< 295,000$  | <u>2.58</u>                    |             |
|   |                          | $\geq 295,000$ and $< 930,000$ | <u>2.36</u>                    |             |
|   |                          |                                |                                |             |
|   | <u>Upflow ducted</u>     | $< 80,000$                     | <u>2.67</u>                    |             |
|   |                          | $\geq 80,000$ and $< 295,000$  | <u>2.55</u>                    |             |
|   |                          | $\geq 295,000$ and $< 930,000$ | <u>2.33</u>                    |             |
|   | <u>Upflow non-ducted</u> | $< 65,000$                     | <u>2.09</u>                    |             |
|   |                          | $\geq 65,000$ and $< 240,000$  | <u>1.99</u>                    |             |
|   |                          | $\geq 240,000$ and $< 760,000$ | <u>1.81</u>                    |             |
|   | <u>Horizontal</u>        | $< 65,000$                     | <u>2.65</u>                    |             |
|   |                          | $\geq 65,000$ and $< 240,000$  | <u>2.55</u>                    |             |
|   |                          | $\geq 240,000$ and $< 760,000$ | <u>2.47</u>                    |             |
|   | <u>Water-cooled</u>      | <u>Downflow</u>                | $< 80,000$                     | <u>2.82</u> |
|   |                          |                                | $\geq 80,000$ and $< 295,000$  | <u>2.73</u> |
|   |                          |                                | $\geq 295,000$ and $< 930,000$ | <u>2.67</u> |
| <u>Upflow ducted</u>                      |                          | $< 80,000$                     | <u>2.79</u>                    |             |
|   |                          | $\geq 80,000$ and $< 295,000$  | <u>2.70</u>                    |             |
|   |                          | $\geq 295,000$ and $< 930,000$ | <u>2.645</u>                   |             |
| <u>Upflow non-ducted</u>                  |                          | $< 65,000$                     | <u>2.43</u>                    |             |
|   |                          | $\geq 65,000$ and $< 240,000$  | <u>2.32</u>                    |             |
|   |                          | $\geq 240,000$ and $< 760,000$ | <u>2.20</u>                    |             |
| <u>Horizontal</u>                         |                          | $< 65,000$                     | <u>2.79</u>                    |             |
|   |                          | $\geq 65,000$ and $< 240,000$  | <u>2.68</u>                    |             |
|   |                          | $\geq 240,000$ and $< 760,000$ | <u>2.60</u>                    |             |
| <u>Water-cooled with fluid economizer</u> |                          | <u>Downflow</u>                | $< 80,000$                     | <u>2.77</u> |
|   |                          |                                | $\geq 80,000$ and $< 295,000$  | <u>2.68</u> |
|   |                          |                                | $\geq 295,000$ and $< 930,000$ | <u>2.61</u> |
|   | <u>Upflow ducted</u>     | $< 80,000$                     | <u>2.74</u>                    |             |
|   |                          | $\geq 80,000$ and $< 295,000$  | <u>2.65</u>                    |             |
|   |                          | $\geq 295,000$ and $< 930,000$ | <u>2.58</u>                    |             |
|   | <u>Upflow non-ducted</u> | $< 65,000$                     | <u>2.35</u>                    |             |
|   |                          | $\geq 65,000$ and $< 240,000$  | <u>2.24</u>                    |             |

| System type                                | Duct Location            | Cooling capacity (Btu/hr)                                      | Baseline efficiency [NSenCOP] |
|--|--------------------------|--|-------------------------------|
|  | <u>Horizontal</u>        | <u><math>\geq 240,000</math> and <math>&lt; 760,000</math></u> | <u>2.12</u>                   |
|  |                          | <u><math>&lt; 65,000</math></u>                                | <u>2.71</u>                   |
|  |                          | <u><math>\geq 65,000</math> and <math>&lt; 240,000</math></u>  | <u>2.60</u>                   |
|  |                          | <u><math>\geq 240,000</math> and <math>&lt; 760,000</math></u> | <u>2.54</u>                   |
| <u>Glycol cooled</u>                       | <u>Downflow</u>          | <u><math>&lt; 80,000</math></u>                                | <u>2.56</u>                   |
|  |                          | <u><math>\geq 80,000</math> and <math>&lt; 295,000</math></u>  | <u>2.24</u>                   |
|  |                          | <u><math>\geq 295,000</math> and <math>&lt; 930,000</math></u> | <u>2.21</u>                   |
|  | <u>Upflow ducted</u>     | <u><math>&lt; 80,000</math></u>                                | <u>2.53</u>                   |
|  |                          | <u><math>\geq 80,000</math> and <math>&lt; 295,000</math></u>  | <u>2.21</u>                   |
|  |                          | <u><math>\geq 295,000</math> and <math>&lt; 930,000</math></u> | <u>2.18</u>                   |
|  | <u>Upflow non-ducted</u> | <u><math>&lt; 65,000</math></u>                                | <u>2.08</u>                   |
|  |                          | <u><math>\geq 65,000</math> and <math>&lt; 240,000</math></u>  | <u>1.90</u>                   |
|  |                          | <u><math>\geq 240,000</math> and <math>&lt; 760,000</math></u> | <u>1.81</u>                   |
|  | <u>Horizontal</u>        | <u><math>&lt; 65,000</math></u>                                | <u>2.48</u>                   |
|  |                          | <u><math>\geq 65,000</math> and <math>&lt; 240,000</math></u>  | <u>2.18</u>                   |
|  |                          | <u><math>\geq 240,000</math> and <math>&lt; 760,000</math></u> | <u>2.18</u>                   |
| <u>Glycol-cooled with fluid economizer</u> | <u>Downflow</u>          | <u><math>&lt; 80,000</math></u>                                | <u>2.51</u>                   |
|  |                          | <u><math>\geq 80,000</math> and <math>&lt; 295,000</math></u>  | <u>2.19</u>                   |
|  |                          | <u><math>\geq 295,000</math> and <math>&lt; 930,000</math></u> | <u>2.15</u>                   |
|  | <u>Upflow ducted</u>     | <u><math>&lt; 80,000</math></u>                                | <u>2.48</u>                   |
|  |                          | <u><math>\geq 80,000</math> and <math>&lt; 295,000</math></u>  | <u>2.16</u>                   |
|  |                          | <u><math>\geq 295,000</math> and <math>&lt; 930,000</math></u> | <u>2.12</u>                   |
|  | <u>Upflow non-ducted</u> | <u><math>&lt; 65,000</math></u>                                | <u>2.00</u>                   |
|  |                          | <u><math>\geq 65,000</math> and <math>&lt; 240,000</math></u>  | <u>1.82</u>                   |
|  |                          | <u><math>\geq 240,000</math> and <math>&lt; 760,000</math></u> | <u>1.73</u>                   |
|  | <u>Horizontal</u>        | <u><math>&lt; 65,000</math></u>                                | <u>2.44</u>                   |
|  |                          | <u><math>\geq 65,000</math> and <math>&lt; 240,000</math></u>  | <u>2.10</u>                   |
|  |                          | <u><math>\geq 240,000</math> and <math>&lt; 760,000</math></u> | <u>2.10</u>                   |

| System type  | Duct Location     | Cooling capacity (Btu/hr)        | Baseline efficiency (NSenCOP) |
|--|-------------------|----------------------------------|-------------------------------|
| <b><u>Ceiling-Mounted CRACs</u></b>                                      |                   |                                  |                               |
| <u>Air-cooled with free air discharge condenser</u>                      | <u>Ducted</u>     | <u>&lt; 29,000</u>               | <u>2.05</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>2.02</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>1.92</u>                   |
|  | <u>Non-ducted</u> | <u>&lt; 29,000</u>               | <u>2.08</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>2.05</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>1.94</u>                   |
| <u>Air-cooled with free air discharge condenser and fluid economizer</u> | <u>Ducted</u>     | <u>&lt; 29,000</u>               | <u>2.01</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>1.97</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>1.87</u>                   |
|  | <u>Non-ducted</u> | <u>&lt; 29,000</u>               | <u>2.04</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>2.00</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>1.89</u>                   |
| <u>Air-cooled with ducted condenser</u>                                  | <u>Ducted</u>     | <u>&lt; 29,000</u>               | <u>1.86</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>1.83</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>1.73</u>                   |
|  | <u>Non-ducted</u> | <u>&lt; 29,000</u>               | <u>1.89</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>1.86</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>1.75</u>                   |
| <u>Air-cooled with ducted condenser and fluid economizer</u>             | <u>Ducted</u>     | <u>&lt; 29,000</u>               | <u>1.82</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>1.78</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>1.68</u>                   |
|  | <u>Non-ducted</u> | <u>&lt; 29,000</u>               | <u>1.85</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>1.81</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>1.70</u>                   |
| <u>Water-cooled</u>  | <u>Ducted</u>     | <u>&lt; 29,000</u>               | <u>2.38</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>2.28</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>2.18</u>                   |
|  | <u>Non-ducted</u> | <u>&lt; 29,000</u>               | <u>2.41</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>2.31</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>2.20</u>                   |

| System type                                | Duct Location     | Cooling capacity (Btu/hr)        | Baseline efficiency [NSenCOP] |
|--|-------------------|----------------------------------|-------------------------------|
| <u>Water-cooled with fluid economizer</u>  | <u>Ducted</u>     | <u>&lt; 29,000</u>               | <u>2.33</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>2.23</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>2.13</u>                   |
|  | <u>Non-ducted</u> | <u>&lt; 29,000</u>               | <u>2.36</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>2.26</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>2.16</u>                   |
| <u>Glycol-cooled</u>                       | <u>Ducted</u>     | <u>&lt; 29,000</u>               | <u>1.97</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>1.93</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>1.78</u>                   |
|  | <u>Non-ducted</u> | <u>&lt; 29,000</u>               | <u>2.00</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>1.98</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>1.81</u>                   |
| <u>Glycol-cooled with fluid economizer</u> | <u>Ducted</u>     | <u>&lt; 29,000</u>               | <u>1.92</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>1.88</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>1.73</u>                   |
|  | <u>Non-ducted</u> | <u>&lt; 29,000</u>               | <u>1.95</u>                   |
|  |                   | <u>≥ 29,000 and &lt; 65,000</u>  | <u>1.93</u>                   |
|  |                   | <u>≥ 65,000 and &lt; 760,000</u> | <u>1.76</u>                   |

## High-Efficiency Condition

Package and split-systems must exceed the minimum efficiencies specified in Table 80. 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. When downsizing, the pre-installed cooling capacity is limited to a maximum of 120 percent of the new equipment's cooling capacity. There is no cap~~

when upsizing because the savings are calculated using the lower pre-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 compliant with the above guidance. 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, baseline efficiency, demand factor, and EFLH. These factors should be weighted based on contribution to overall capacity.

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

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

**Equation 36**

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

**Equation 37**

Where:

$\text{Cap}_{C,\text{pre}}$  = For ER and ROB, rated equipment cooling capacity of the newly installed equipment at AHRI-standard conditions with a maximum of 20 percent larger than the post-capacity; for NC, rated equipment cooling capacity of the new equipment at AHRI-standard conditions [Btuh]; 1 ton = 12,000 Btuh

$\text{Cap}_{C,\text{post}}$  = Rated equipment cooling 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 may not always match the capacity of the units. AHRI may rate cooling capacity in kW. In these cases, convert from kW to Btuh by multiplying kW by 3,412.

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

$\eta_{\text{installed},C}$  = Rated cooling efficiency of the newly installed equipment (SCOP)—(Must exceed ROB/NC baseline efficiency standards in Table 80 Table 33) [NSenCOP]

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

$DF_S$  = Summer peak demand factor (see Table 82)

$EFLH_C$  = Cooling equivalent full-load hours [hours] (see Table 82)



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

### Deemed Energy and Demand Savings Tables

Deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone. This measure is restricted to the data center building types, derived from the EIA CBECS study.<sup>202</sup>

The DF and EFLH values for CRAC units are presented in Table 82. A description of the calculation method used to derive these values can be found in Docket No. 40885, Attachment B.

**Table 81. CRACs—Building Type Descriptions and Examples**

| Building type | Principal building activity | Definition  | Detailed business type examples <sup>203</sup> |
|---------------|-----------------------------|---|--|
| Data center   | Data center                 | Buildings used to house computer systems and associated components. | 1) Data center                                 |

**Table 82. CRACs—DF and EFLH Values**

| Climate zone             | Building type and principal building activity | DF <sub>s</sub> | EFLH <sub>c</sub> |
|--------------------------|---|-----------------|-------------------|
| Climate Zone 1: Amarillo | Data center                                   | 0.89            | 2,048             |
| Climate Zone 2: Dallas   |   | 1.08            | 3,401             |
| Climate Zone 3:          |   | 1.05            | 4,022             |

<sup>202</sup> 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.*

<sup>203</sup> Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.

| Climate zone                   | Building type and principal building activity | DF <sub>s</sub> | EFLH <sub>c</sub> |
|--------------------------------|---|-----------------|-------------------|
| Houston                        |   |                 |                   |
| 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.<sup>204</sup>

<sup>204</sup> 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)

This section will not apply unless the current baseline is updated, allowing the measure to refer to the existing baseline for early retirement projects. The RUL of replaced systems is provided according to system age in Table 83. 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 83. CRACs—Remaining Useful Life Early Retirement Systems<sup>205,206</sup>**

| <u>Age of replaced system (years)</u> | <u>Split/package AC/HP systems RUL (years)</u> | <u>Age of replaced system (years)</u> | <u>Split/package AC/HP systems RUL (years)</u> |
|---------------------------------------|--|---------------------------------------|--|
| <u>1</u>                              | <u>14.0</u>                                    | <u>10</u>                             | <u>5.7</u>                                     |
| <u>2</u>                              | <u>13.0</u>                                    | <u>11</u>                             | <u>5.0</u>                                     |
| <u>3</u>                              | <u>12.0</u>                                    | <u>12</u>                             | <u>4.4</u>                                     |
| <u>4</u>                              | <u>11.0</u>                                    | <u>13</u>                             | <u>3.8</u>                                     |
| <u>5</u>                              | <u>10.0</u>                                    | <u>14</u>                             | <u>3.3</u>                                     |
| <u>6</u>                              | <u>9.1</u>                                     | <u>15</u>                             | <u>2.8</u>                                     |
| <u>7</u>                              | <u>8.2</u>                                     | <u>16</u>                             | <u>2.0</u>                                     |
| <u>8</u>                              | <u>7.3</u>                                     | <u>17</u>                             | <u>1.0</u>                                     |
| <u>9</u>                              | <u>6.5</u>                                     | <u>18<sup>207</sup></u>               | <u>0.0</u>                                     |

## 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

<sup>205</sup> PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.

<sup>206</sup> Existing CRAC systems manufactured after 5/28/2024 are subject to the current federal standard. They are not eligible to use the early retirement baseline and should use the ROB baseline instead. These values are grayed out in the table and displayed for informational purposes only.

<sup>207</sup> RULs are capped at the 75<sup>th</sup> 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 equipment rated cooling capacity
- 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)
- New manufacturer, and model, and manufacturing date
- ~~Installed~~New number of units
- ~~Installed~~New equipment type
- ~~Installed~~New equipment rated cooling capacity
- ~~Installed~~New rated cooling efficiency ratings (NSenCOP)
- ~~Installed manufacturer and model~~
- ~~Installed~~New 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 84. 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.  |
| <u>v12.0</u> | <u>10/2024</u> | <u>TRM v12.0 update. Added early retirement criteria related to downsizing, updated early retirement and new construction/ROB baseline efficiency levels.</u> |

## 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 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<sup>208</sup>.

### 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).

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<sup>208</sup> 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.<sup>209</sup>

### Energy Savings Algorithms

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

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

Table 85. CRAHs—Motor Efficiencies for Open Drip Proof Motors at 1,800 RPM<sup>210</sup>

| 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  $hp^{211} = 0.27$

<sup>209</sup> Site data are sourced from 3 data centers in Oncor territory that replaced 243 CRAH fan motors either with ECMs or retrofitted with VFDs.

<sup>210</sup> For unlisted motor horsepower values, round down to the next lowest horsepower value.

<sup>211</sup> Oncor site data. Average kW/hp values are weighted by measure count.

$$\begin{aligned}
 hp_{post} &= \text{Total efficient motor horsepower} \\
 \text{hours} &= \text{Annual operating hours} = 8,760
 \end{aligned}$$

### **Demand Savings Algorithms**

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

**Equation 40**

Where:

$$CF_{s/w} = \text{Summer/winter seasonal peak coincidence factor} = 0.11^{212}$$

### **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.<sup>213</sup>

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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<sup>212</sup> 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.

<sup>213</sup> 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 86. CRAHs—Revision History**

| <b>TRM version</b> | <b>Date</b>    | <b>Description of change</b>   |
|--------------------|----------------|--|
| 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.   |
| <u>v12.0</u>       | <u>10/2024</u> | <u>TRM v12.0 update. No revision.</u>  |

## 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 92 through Table 99~~ All commercial

**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:

|            |   |  |
|------------|---|--|
| $t_{db,i}$ | = | <i>The hourly dry bulb temperature (DBT) using TMY3<sup>214</sup> data</i>   |
| $m$        | = | <i>The slope of the relationship between DBT and CFM (see Table 87)</i>      |
| $b$        | = | <i>The intercept of the relationship between DSBT and CFM (see Table 87)</i> |

The minimum flow rate is set to 60 percent cfm based on common design practice.<sup>215</sup> 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.<sup>216</sup>

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<sup>214</sup> 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>.

<sup>215</sup> 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%.

<sup>216</sup> ASHRAE 2021 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

**Table 87. 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<sup>217</sup>
- $m$  = the slope of the relationship between WBT and cfm (see *Table 88*)
- $b$  = the intercept of the relationship between WBT and cfm (see *Table 88*)

**Table 88. 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    |           |               |

<sup>217</sup> 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 ( <i>m</i> ) | Intercept ( <i>b</i> ) |
|----------------|------------------|---------|---------|--------------------|------------------------|
| 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.<sup>218</sup> 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.<sup>219</sup>

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 89)

*b* = The intercept of the relationship between DSBT and GPM (see Table 89)

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.<sup>220</sup> 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.<sup>221</sup>

<sup>218</sup> PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.240, cooling tower minimum speed default.

<sup>219</sup> ASHRAE 2021 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Evaporation WB

<sup>220</sup> PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.249, pump minimum speed default.

<sup>221</sup> ASHRAE 2021 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

**Table 89. HVAC VFDs—Chilled Water and Condenser Water Pumps VFD percentage of GPM Inputs**

| Climate zone   | Condition        | Minimum | Maximum | Slope ( <i>m</i> ) | Intercept ( <i>b</i> ) |
|----------------|------------------|---------|---------|--------------------|------------------------|
| 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 90)

*b* = The intercept of the relationship between DSBT and GPM (see Table 90)

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.<sup>222</sup> 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.<sup>223</sup>

<sup>222</sup> PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.249, pump minimum speed default.

<sup>223</sup> ASHRAE 2017 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 99.6% Heating DB.

**Table 90. HVAC VFDs—Hot Water Pump VFD %GPM Inputs**

| Climate zone   | Condition        | Minimum | Maximum | Slope ( <i>m</i> ) | Intercept ( <i>b</i> ) |
|----------------|------------------|---------|---------|--------------------|------------------------|
| 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    |                    |                        |

**Step 2** - Calculate the percentage of power (%power) for the applicable baseline and the new VFD technology:

Baseline Technologies

For AHU supply fan:<sup>224</sup>

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

**Equation 45**

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

**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.

<sup>224</sup> [https://focusonenergy.com/sites/default/files/Focus%20on%20Energy\\_TRM\\_January2015.pdf](https://focusonenergy.com/sites/default/files/Focus%20on%20Energy_TRM_January2015.pdf), page 225. Please note, the CFM<sup>2</sup> coefficients in Equation 38 and Equation 39 have the wrong sign in the reference document.

For cooling tower:

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

**Equation 48**

For chilled, hot, and condenser water pumps<sup>225</sup>:

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

**Equation 49**

### VFD Technology

For AHU supply fan<sup>226</sup>:

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

**Equation 50**

For cooling tower<sup>227</sup>:

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

**Equation 51**

For chilled water, hot water, and condenser pumps<sup>228</sup>:

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

**Equation 52**

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

**Step 3** - Calculate kW<sub>full</sub> 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**

<sup>225</sup> 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.

<sup>226</sup> [https://focusonenergy.com/sites/default/files/Focus%20on%20Energy\\_TRM\\_January2015.pdf](https://focusonenergy.com/sites/default/files/Focus%20on%20Energy_TRM_January2015.pdf), page 225.

<sup>227</sup> 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.

<sup>228</sup> 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)<sup>229</sup>
- $kW_{full}$  = 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
- $\eta$  = 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 91. HVAC VFDs—Motor Efficiencies for Open Drip Proof Motors at 1,800 RPM<sup>230</sup>**

| 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                 |

<sup>229</sup> Fan curves by control type are provided in the BPA ASD Calculator, <https://www.bpa.gov/-/media/Aep/energy-efficiency/industrial/Industrial-files/ASDCalculators>.

<sup>230</sup> 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 PDF 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

$$(kW_i)_{\text{saved}} = [(kW_i)_{\text{Baseline}} - (kW_i)_{\text{VFD}}] \times \text{schedule}_i$$

**Equation 55**

Where:

$\text{schedule}_i$  = 1 when building is occupied, 0.2 when building is unoccupied (see Table 92)

**Table 92. HVAC VFDs—Yearly Motor Operation Hours by Building Type<sup>231,232</sup>**

| Building type   | Weekday schedule    | Weekend schedule                                      | Annual motor operation hours |
|---|---------------------|---|------------------------------|
| <u>Assembly, worship</u>  | <u>9am–11pm</u>     | <u>9am–11pm</u>                                       | <u>5,840</u>                 |
| <u>Convenience store, service, strip mall</u>   | <u>9am–10pm</u>     | <u>9am–8pm (Saturday)</u><br><u>10am–7pm (Sunday)</u> | <u>5,298</u>                 |
| <u>Education</u>  | <u>8am–11pm</u>     | <u>closed</u>   | <u>4,884</u>                 |
| 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                        |
| <del>Education</del>  | <del>8am–11pm</del> | <del>closed</del>                                     | <del>4,884</del>             |
| <del>Convenience store, service, strip mall</del>   | <del>9am–10pm</del> | <del>9am–8pm (Saturday)</del>                         | <del>5,298</del>             |

<sup>231</sup> 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](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.

<sup>232</sup> Data centers are covered in 2.2.6 Computer Room Air Handler Motor Efficiency.

| Building type                   | Weekday schedule | Weekend schedule                               | Annual motor operation hours |
|---------------------------------|------------------|--|------------------------------|
|                                 |                  | 10am–7pm<br>(Sunday)                           |                              |
| Restaurants                     | 6am–2am          | 6am–2am  | 7,592                        |
| Stand-alone retail, supermarket | 8am–10pm         | 8am–11pm<br>(Saturday)<br>10am–7pm<br>(Sunday) | 5,674                        |
| Restaurants                     | 6am–2am          | 6am–2am  | 7,592                        |
| Warehouse                       | 7am–7pm          | closed   | 4,258                        |
| Assembly, worship               | 9am–11pm         | 9am–11pm                                       | 5,840                        |
| Other <sup>233</sup>            | 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:

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

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:

<sup>233</sup> 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.

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

Equation 58

Where:

$$8,760 = \text{Total of hours per year}$$

**Step 2** - Subtract the Annual kWh<sub>new</sub> from the Annual kWh<sub>baseline</sub> to get the Energy Savings:

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

Equation 59

## Deemed Energy and Demand Savings Tables<sup>234</sup>

Table 93. 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 |
| <b>Energy savings (kWh per motor HP)</b>  |                          |                        |                         |                                |                         |
| <u>Assembly, worship</u>  | <u>751</u>               | <u>707</u>             | <u>684</u>              | <u>668</u>                     | <u>720</u>              |
| <u>Convenience store, service, strip Mall</u>   | <u>677</u>               | <u>637</u>             | <u>614</u>              | <u>599</u>                     | <u>649</u>              |
| <u>Education</u>  | <u>633</u>               | <u>596</u>             | <u>577</u>              | <u>561</u>                     | <u>606</u>              |
| 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                     |
| <u>Education</u>  | <u>633</u>               | <u>596</u>             | <u>577</u>              | <u>561</u>                     | <u>606</u>              |
| <u>Convenience store, service, strip Mall</u>   | <u>677</u>               | <u>637</u>             | <u>614</u>              | <u>599</u>                     | <u>649</u>              |
| <u>Stand-alone retail, supermarket</u>  | <u>728</u>               | <u>685</u>             | <u>661</u>              | <u>644</u>                     | <u>698</u>              |
| Restaurants   | 995                      | 941                    | 913                     | 892                            | 959                     |
| <u>Stand-alone retail, supermarket</u>  | <u>728</u>               | <u>685</u>             | <u>661</u>              | <u>644</u>                     | <u>698</u>              |
| Warehouse   | 548                      | 516                    | 496                     | 481                            | 526                     |
| <u>Assembly, worship</u>  | <u>751</u>               | <u>707</u>             | <u>684</u>              | <u>668</u>                     | <u>720</u>              |
| Other   | 548                      | 516                    | 496                     | 481                            | 526                     |

<sup>234</sup> 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 |
| <b>Summer kW savings (kW per motor HP)</b> |                          |                        |                         |                                |                         |
| All building types                         | 0.041                    | 0.023                  | 0.020                   | 0.063                          | 0.042                   |

**Table 94. 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 |
| <b>Energy savings (kWh per motor HP)</b>  |                          |                        |                         |                                |                         |
| <u>Assembly, worship</u>  | <u>1,164</u>             | <u>1,057</u>           | <u>1,003</u>            | <u>961</u>                     | <u>1,086</u>            |
| <u>Convenience store, service, strip mall</u>   | <u>1,046</u>             | <u>950</u>             | <u>897</u>              | <u>859</u>                     | <u>976</u>              |
| <u>Education</u>  | <u>984</u>               | <u>895</u>             | <u>848</u>              | <u>808</u>                     | <u>917</u>              |
| 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                     |
| <u>Education</u>  | <u>984</u>               | <u>895</u>             | <u>848</u>              | <u>808</u>                     | <u>917</u>              |
| <u>Convenience store, service, strip mall</u>   | <u>1,046</u>             | <u>950</u>             | <u>897</u>              | <u>859</u>                     | <u>976</u>              |
| <u>Stand-alone retail, supermarket</u>  | <u>1,128</u>             | <u>1,025</u>           | <u>967</u>              | <u>925</u>                     | <u>1,052</u>            |
| Restaurants   | 1,556                    | 1,420                  | 1,352                   | 1,298                          | 1,462                   |
| <u>Stand-alone retail, supermarket</u>  | <u>1,128</u>             | <u>1,025</u>           | <u>967</u>              | <u>925</u>                     | <u>1,052</u>            |
| Warehouse   | 850                      | 773                    | 727                     | 690                            | 794                     |
| <u>Assembly, worship</u>  | <u>1,164</u>             | <u>1,057</u>           | <u>1,003</u>            | <u>961</u>                     | <u>1,086</u>            |
| Other   | 850                      | 773                    | 727                     | 690                            | 794                     |
| <b>Summer kW Savings (kW per Motor HP)</b>  |                          |                        |                         |                                |                         |
| All building types  | 0.045                    | 0.026                  | 0.024                   | 0.069                          | 0.047                   |

**Table 95. 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 |
| <b>Energy savings (kWh per motor HP)</b> |                          |                        |                         |                                |                         |
| <u>Assembly, worship</u>                 | <u>245</u>               | <u>216</u>             | <u>201</u>              | <u>189</u>                     | <u>223</u>              |

| 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 |
| <u>Convenience store, service, strip mall</u>   | <u>219</u>               | <u>194</u>             | <u>179</u>              | <u>169</u>                     | <u>200</u>              |
| <u>Education</u>  | <u>207</u>               | <u>183</u>             | <u>170</u>              | <u>159</u>                     | <u>189</u>              |
| 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                     |
| <del>Education</del>  | <del>207</del>           | <del>183</del>         | <del>170</del>          | <del>159</del>                 | <del>189</del>          |
| <del>Convenience store, service, strip mall</del>   | <del>219</del>           | <del>194</del>         | <del>179</del>          | <del>169</del>                 | <del>200</del>          |
| <del>Stand-alone retail, supermarket</del>  | <del>237</del>           | <del>209</del>         | <del>193</del>          | <del>182</del>                 | <del>216</del>          |
| Restaurants   | 329                      | 292                    | 273                     | 258                            | 303                     |
| <u>Stand-alone retail, supermarket</u>  | <u>237</u>               | <u>209</u>             | <u>193</u>              | <u>182</u>                     | <u>216</u>              |
| Warehouse   | 179                      | 158                    | 146                     | 135                            | 163                     |
| <del>Assembly, worship</del>  | <del>245</del>           | <del>216</del>         | <del>201</del>          | <del>189</del>                 | <del>223</del>          |
| Other   | 179                      | 158                    | 146                     | 135                            | 163                     |
| <b>Summer kW savings (kW per motor HP)</b>  |                          |                        |                         |                                |                         |
| All building types  | 0.009                    | 0.009                  | 0.005                   | 0.011                          | 0.013                   |

**Table 96. 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 |
| <b>Energy savings (kWh per motor HP)</b>  |                          |                        |                         |                                |                         |
| <u>Assembly, worship</u>  | <u>2,106</u>             | <u>1,916</u>           | <u>1,819</u>            | <u>1,745</u>                   | <u>1,969</u>            |
| <u>Convenience store, service, strip mall</u>   | <u>1,893</u>             | <u>1,721</u>           | <u>1,626</u>            | <u>1,557</u>                   | <u>1,768</u>            |
| <u>Education</u>  | <u>1,780</u>             | <u>1,622</u>           | <u>1,540</u>            | <u>1,468</u>                   | <u>1,663</u>            |
| 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                   |
| <del>Education</del>  | <del>1,780</del>         | <del>1,622</del>       | <del>1,540</del>        | <del>1,468</del>               | <del>1,663</del>        |
| <del>Convenience store, service, strip mall</del>   | <del>1,893</del>         | <del>1,721</del>       | <del>1,626</del>        | <del>1,557</del>               | <del>1,768</del>        |

| 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 |
| <del>Stand-alone retail, supermarket</del> | <del>2,040</del>         | <del>1,856</del>       | <del>1,754</del>        | <del>1,679</del>               | <del>1,907</del>        |
| Restaurants                                | 2,817                    | 2,577                  | 2,457                   | 2,360                          | 2,651                   |
| <u>Stand-alone retail, supermarket</u>     | <u>2,040</u>             | <u>1,856</u>           | <u>1,754</u>            | <u>1,679</u>                   | <u>1,907</u>            |
| Warehouse                                  | 1,538                    | 1,401                  | 1,317                   | 1,251                          | 1,438                   |
| <del>Assembly, worship</del>               | <del>2,106</del>         | <del>1,916</del>       | <del>1,819</del>        | <del>1,745</del>               | <del>1,969</del>        |
| Other                                      | 1,538                    | 1,401                  | 1,317                   | 1,251                          | 1,438                   |
| <b>Summer kW savings (kW per motor HP)</b> |                          |                        |                         |                                |                         |
| All building types                         | 0.033                    | 0.004                  | 0.027                   | 0.088                          | 0.025                   |

**Table 97. 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 |
| <b>Energy savings (kWh per motor HP)</b>  |                          |                        |                         |                                |                         |
| Assembly, worship   | 733                      | 1,020                  | 1,264                   | 1,380                          | 946                     |
| Convenience store, service, strip mall  | <del>667663</del>        | <del>928925</del>      | <del>1,1501,142</del>   | <del>1,2551,248</del>          | <del>862858</del>       |
| <u>Education</u>  | <u>613</u>               | <u>871</u>             | <u>1,058</u>            | <u>1,147</u>                   | <u>785</u>              |
| 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                      | <del>975972</del>      | <del>1,2021,196</del>   | <del>1,3181,314</del>          | 901                     |
| Office—small  | <del>558</del>           | <del>792788</del>      | <del>959955</del>       | <del>1,0401,039</del>          | <del>712</del>          |
| <del>Education</del>  | <del>610</del>           | <del>871869</del>      | <del>1,0581,054</del>   | <del>1,1471,143</del>          | <del>784</del>          |
| <del>Convenience store, service, strip mall</del>   | <del>663</del>           | <del>925</del>         | <del>1,142</del>        | <del>1,248</del>               | <del>858</del>          |
| <del>Stand-alone retail, supermarket</del>  | <del>712</del>           | <del>986</del>         | <del>1,216</del>        | <del>1,332</del>               | <del>915</del>          |
| Restaurants   | <del>968966</del>        | <del>1,3251,323</del>  | <del>1,6351,632</del>   | <del>1,7901,792</del>          | <del>1,2191,215</del>   |
| Stand-alone retail, supermarket   | <u>713712</u>            | <u>988986</u>          | <u>1,2261,216</u>       | <u>1,3381,332</u>              | <u>919915</u>           |
| Warehouse   | <del>530534</del>        | <del>753749</del>      | <del>912908</del>       | <del>989986</del>              | <del>680676</del>       |

| 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   |
| <del>Assembly, worship</del>        | <del>733</del>           | <del>1,020</del>       | <del>1,264</del>          | <del>1,380</del>               | <del>946</del>            |
| Other                               | 530534                   | 753749                 | 912908                    | 989986                         | 680676                    |
| Summer kW savings (kW per motor HP) |                          |                        |                           |                                |                           |
| All building types                  | 0.097                    | 0.041                  | <del>0.1320-17</del><br>0 | 0.175                          | <del>0.1610-24</del><br>6 |

Table 98. 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)   |                            |                            |                            |                                |                            |
| <del>Assembly, worship</del>  | <del>601</del>             | <del>818</del>             | <del>933</del>             | <del>1,011</del>               | <del>773</del>             |
| <del>Convenience store, service, strip mall</del>   | <del>554</del>             | <del>747</del>             | <del>848</del>             | <del>918</del>                 | <del>706</del>             |
| <del>Education</del>  | <del>491</del>             | <del>683</del>             | <del>768</del>             | <del>843</del>                 | <del>647</del>             |
| 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                        |
| <del>Education</del>  | <del>491</del>             | <del>683</del>             | <del>768</del>             | <del>843</del>                 | <del>647</del>             |
| <del>Convenience store, service, strip mall</del>   | <del>554</del>             | <del>747</del>             | <del>848</del>             | <del>918</del>                 | <del>706</del>             |
| <del>Stand-alone retail, supermarket</del>  | <del>587</del>             | <del>795</del>             | <del>905</del>             | <del>982</del>                 | <del>754</del>             |
| Restaurants   | 723                        | 1,030                      | 1,183                      | 1,297                          | 960                        |
| <del>Stand-alone retail, supermarket</del>  | <del>587</del>             | <del>795</del>             | <del>905</del>             | <del>982</del>                 | <del>754</del>             |
| Warehouse   | 435                        | 594                        | 670                        | 730                            | 563                        |
| <del>Assembly, worship</del>  | <del>601</del>             | <del>818</del>             | <del>933</del>             | <del>1,011</del>               | <del>773</del>             |
| Other   | 435                        | 594                        | 670                        | 730                            | 563                        |
| Summer kW savings (kW per motor HP)   |                            |                            |                            |                                |                            |
| All building types  | <del>0.0490-04</del><br>87 | <del>0.0180-01</del><br>83 | <del>0.0290-02</del><br>93 | <del>0.0920-09</del><br>20     | <del>0.0440-04</del><br>39 |



Table 99. 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 |
| <b>Energy savings (kWh per motor HP)</b>  |                          |                        |                         |                                |                         |
| <u>Assembly, worship</u>  | <u>791</u>               | <u>544</u>             | <u>426</u>              | <u>351</u>                     | <u>630</u>              |
| <u>Convenience store, service, strip mall</u>   | <u>706</u>               | <u>482</u>             | <u>375</u>              | <u>306</u>                     | <u>558</u>              |
| <u>Education</u>  | <u>677</u>               | <u>468</u>             | <u>368</u>              | <u>301</u>                     | <u>526</u>              |
| 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                     |
| Office—small  | 609                      | 423                    | 328                     | 266                            | 473                     |
| <u>Education</u>  | <u>677</u>               | <u>468</u>             | <u>368</u>              | <u>301</u>                     | <u>526</u>              |
| <u>Convenience store, service, strip mall</u>   | <u>706</u>               | <u>482</u>             | <u>375</u>              | <u>306</u>                     | <u>558</u>              |
| <u>Stand-alone retail, supermarket</u>  | <u>764</u>               | <u>526</u>             | <u>410</u>              | <u>335</u>                     | <u>606</u>              |
| Restaurants   | 1,086                    | 756                    | 598                     | 500                            | 863                     |
| <u>Stand-alone retail, supermarket</u>  | <u>764</u>               | <u>526</u>             | <u>410</u>              | <u>335</u>                     | <u>606</u>              |
| Warehouse   | 579                      | 402                    | 309                     | 251                            | 449                     |
| <u>Assembly, worship</u>  | <u>791</u>               | <u>544</u>             | <u>426</u>              | <u>351</u>                     | <u>630</u>              |
| Other   | 579                      | 402                    | 309                     | 251                            | 449                     |
| <b>Winter kW savings (kW per motor HP)</b>  |                          |                        |                         |                                |                         |
| All building types  | 0.118                    | <u>0.0320-04</u><br>5  | 0.045                   | 0.133                          | <u>0.2120-22</u><br>5   |

## 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.<sup>235</sup>

<sup>235</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

## **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, cooling tower fans)
- 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).

## **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 100. HVAC VFDs—Revision History**

| <b>TRM version</b> | <b>Date</b> | <b>Description of change</b>   |
|--------------------|-------------|--|
| 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.  |

| TRM version  | Date           | Description of change  |
|--------------|----------------|--|
| 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        | 10/2023        | 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. |
| <u>v12.0</u> | <u>10/2024</u> | <u>TRM v12.0 update. Savings calculations moved to Excel.</u><br><u>Reviewed hours of operation and using same fan and pump hours referenced in the existing measure.</u>  |

## 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 102 through Table 106 All commercial

**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 101 contains values that can be used as a reference for evaluating evaporative effectiveness.

**Table 101. Evaporative Pre-Cooling—Average Weather During Peak Conditions<sup>236</sup>**

| 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

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

Equation 61

<sup>236</sup> 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

$\eta_c$  = 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 102 through Table 106)

$CF$  = Seasonal peak coincidence factor. The average peak hour energy reduction divided by the rated full loaded demand (see Table 102 through Table 106)

## Deemed Energy and Demand Savings Tables

The Deemed peak demand reduction factor ( $DRFCF$ ) 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.<sup>237</sup>

The  $DRFCF$  and  $EFLH_{reduction}$  values for packaged and split AC are presented in Table 102 through Table 106. These tables also include an “Other” building type, which can be used for business types that are not explicitly listed. The  $DRFCF$  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

<sup>237</sup> 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 102. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 1: Amarillo**

| Building type     | Principal building activity | Direct expansion |                     | Air-cooled chiller |                     |
|-------------------|-----------------------------|------------------|---------------------|--------------------|---------------------|
|                   |                             | CF               | EFLH <sub>red</sub> | CF                 | EFLH <sub>red</sub> |
| 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 <sub>red</sub> | CF                 | EFLH <sub>red</sub> |
| Service       | Service: Excluding food     | 0.21             | 104                 | -                  | -                   |
| Warehouse     | Warehouse                   | 0.12             | 34                  | -                  | -                   |
| Other         | Other                       | 0.08             | 34                  | 0.10               | 45                  |

**Table 103. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 2: Dallas**

| Building type     | Principal building activity | Direct expansion |                     | Air-cooled chiller |                     |
|-------------------|-----------------------------|------------------|---------------------|--------------------|---------------------|
|                   |                             | CF               | EFLH <sub>red</sub> | CF                 | EFLH <sub>red</sub> |
| 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 104. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 3: Houston**

| Building type     | Principal building activity | Direct expansion |                     | Air-cooled chiller |                     |
|-------------------|-----------------------------|------------------|---------------------|--------------------|---------------------|
|                   |                             | CF               | EFLH <sub>red</sub> | CF                 | EFLH <sub>red</sub> |
| 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 105. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 4: Corpus Christi**

| Building type | Principal building activity | Direct expansion |                     | Air-cooled chiller |                     |
|---------------|-----------------------------|------------------|---------------------|--------------------|---------------------|
|               |                             | CF               | EFLH <sub>red</sub> | CF                 | EFLH <sub>red</sub> |
| 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 <sub>red</sub> | CF                 | EFLH <sub>red</sub> |
| 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 106. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 5: El Paso**

| Building type | Principal building activity | Direct expansion |                     | Air-cooled chiller |                     |
|---------------|-----------------------------|------------------|---------------------|--------------------|---------------------|
|               |                             | CF               | EFLH <sub>red</sub> | CF                 | EFLH <sub>red</sub> |
| 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 <sub>red</sub> | CF                 | EFLH <sub>red</sub> |
| 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.<sup>238</sup>

<sup>238</sup> 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](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 107. Evaporative Pre-Cooling—Revision History**

| <b>TRM version</b> | <b>Date</b> | <b>Description of change</b>                              |
|--------------------|-------------|---|
| 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. |

| <b>TRM version</b> | <b>Date</b> | <b>Description of change</b>   |
|--------------------|-------------|--|
| 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.                                      |
| v12.0              | 10/2024     | TRM v12.0 update. Minor text edits.  |

## 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:** ~~See eligibility criteria~~ Agriculture All commercial, 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. This measure applies to HVLS fans installed in any non-residential application. Use the "Other" building type for anything not explicitly listed in Table 109 and Table 110.~~

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.<sup>239</sup> 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.

The current federal standard<sup>240</sup> requires that all ceiling fans manufactured on or after January 21, 2020 must comply with the minimum requirements in Table 108.

**Table 108. HVLS Fans—Circulating Fan Minimum Efficiency Requirements**

| Fan type                      | Blade (CFM/W)           | Blade (CFEI) <sup>241</sup>           |
|-------------------------------|-------------------------|---------------------------------------|
| Standard                      | $0.65 \times D + 38.03$ | =                                     |
| Large-diameter <sup>242</sup> | =                       | 1.00 (high speed)<br>1.31 (40% speed) |

<sup>239</sup> 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](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>.

<sup>240</sup> Current federal standard for ceiling fans. <https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32>.

<sup>241</sup> CFEI is a ratio of the input power of a baseline reference fan divided by the input power of the rated fan.

<sup>242</sup> Large-diameter ceiling fan means a ceiling fan that is not a highly-decorative ceiling fan or belt-driven ceiling fan and has a represented value of blade span, as determined in 10 CFR 429.32(a)(3)(i), greater than seven feet. <https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B/appendix-Appendix%20U%20to%20Subpart%20B%20of%20Part%20430>.

The efficiency of the baseline conventional fans used in agricultural applications is assumed to be 22 CFM/watt.<sup>243</sup>

## **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**

For agricultural applications and all other fans with efficiency rated in CFM/W:

$$W_{base} = \frac{CFM_{HVLS}}{\eta_{base}} \quad \text{Equation 63}$$

$$Energy\ Savings[\Delta kWh] = \left( \frac{W_{base} - W_{HVLS}}{1,000} \right) \times AOH_{hours} \times HDF \quad \text{Equation 64}$$

$$Peak\ Demand\ Savings\ [\Delta kW] = \left( \frac{W_{base} - W_{HVLS}}{1,000} \right) \times CF_S \quad \text{Equation 65}$$

Other fans with efficiency rated in CFEI:

$$Energy\ Savings[\Delta kWh] = \frac{W_{HVLS}}{1,000} \times (\eta_{HVLS,HS} - 1) \times AOH \quad \text{Equation 66}$$

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{W_{HVLS}}{1,000} \times (\eta_{HVLS,HS} - 1) \times CF_S \quad \text{Equation 67}$$

Where:

$W_{base}$  = Power input required to move replaced fans at rated speed (see Equation 63)

$W_{HVLS}$  = Power input required to move installed HVLS fans at rated speed

$CFM_{HVLS}$  = Airflow rate produced by installed HVLS fans

<sup>243</sup> Database of circulating fans tested by the Bioenvironmental and Structural Systems Laboratory of the Agricultural and Biological Engineering Dept., University of Illinois at Urbana-Champaign including 231 fan models by 17 manufacturers. Average efficacy ratio (CFM/watt) of single-phase, 230V circulating fans 48" diameter and larger. Available at <http://www.bess.illinois.edu/currentc.asp>.



$\eta_{base}$  = Baseline fan efficiency [CFM/W] = 22 for agricultural applications; see Table 108 for all other applications

$\eta_{HVLS,HS}$  = HVLS fan rated efficiency at high speed [CFM/W]<sup>244</sup>

AOHours = Annual operating hours (see Table 109) Hours of operation in the project application, as described below

$CF_s$  = Summer peak coincidence factor (see Table 110) = 1.0, as fans are always operating in summer peak conditions

1,000 = Constant to convert from W to kW

**Table 109. HVLS Fans—Circulating Fan Annual Operating Hours<sup>245</sup>**

| <u>Building Type</u>                            | <u>Climate zone 1; Amarillo</u> | <u>Climate zone 2; Dallas</u> | <u>Climate zone 3; Houston</u> | <u>Climate zone 4; Corpus Christi</u> | <u>Climate zone 5; El Paso</u> |
|---|---------------------------------|-------------------------------|--------------------------------|---------------------------------------|--------------------------------|
| <u>Agriculture<sup>246</sup></u>                | <u>2,215</u>                    | <u>3,969</u>                  | <u>4,750</u>                   | <u>5,375</u>                          | <u>3,034</u>                   |
| <u>Food service: Full-service restaurant</u>    |                                 |                               |                                |                                       | <u>4,368</u>                   |
| <u>Manufacturing: 1 shift (&lt;70hr/week)</u>   |                                 |                               |                                |                                       | <u>2,786</u>                   |
| <u>Manufacturing: 2 shift (70-120 hr/week)</u>  |                                 |                               |                                |                                       | <u>5,188</u>                   |
| <u>Manufacturing: 3 shift (&gt;120 hr/week)</u> |                                 |                               |                                |                                       | <u>6,414</u>                   |
| <u>Warehouse</u>                                |                                 |                               |                                |                                       | <u>3,501</u>                   |
| <u>Other</u>                                    |                                 |                               |                                |                                       | <u>2,638</u>                   |

**Table 110. HVLS Fans—Circulating Fan Coincident Factors<sup>247,248</sup>**

| <u>Building Type</u> | <u>Climate zone 1; Amarillo</u> | <u>Climate zone 2; Dallas</u> | <u>Climate zone 3; Houston</u> | <u>Climate zone 4; Corpus Christi</u> | <u>Climate zone 5; El Paso</u> |
|----------------------|---------------------------------|-------------------------------|--------------------------------|---------------------------------------|--------------------------------|
| <u>Agriculture</u>   |                                 |                               |                                |                                       | <u>1.00</u>                    |

<sup>244</sup> U.S. DOE Compliance Certification Management System (CCMS) Ceiling Fan product listing. [https://www.regulations.doe.gov/certification-data/CCMS-4-Ceiling\\_Fans.html#q=Product\\_Group\\_s%3A%22Ceiling%20Fans%22](https://www.regulations.doe.gov/certification-data/CCMS-4-Ceiling_Fans.html#q=Product_Group_s%3A%22Ceiling%20Fans%22).

<sup>245</sup> AOH for non-agricultural applications are based on assumptions from measure 2.1.1 Lamps and Fixtures based on the assumption that fan operation will coincide with lighting operation.

<sup>246</sup> Docket No. 40885 provides demand and energy savings by building type and cooling equipment for the four different climate zones. This original petition was dated 10/29/2012. An amended petition dated 11/13/2012 was approved, which provides the original energy and demand coefficients (Table 2 18: CF and EFLH Values for Amarillo (Climate Zone 1) through Table 2-16, but also amended Tables (B3a through B3d and B4a through B4d).

<sup>247</sup> Summer CFs for agricultural applications assume continuous operation during peak conditions.

<sup>248</sup> Summer CFs for non-agricultural applications are based on assumptions from measure 2.1.1 Lamps and Fixtures based on the assumption that fan operation will coincide with lighting operation.

| Building Type                           | Climate zone 1: Amarillo | Climate zone 2: Dallas | Climate zone 3: Houston | Climate zone 4: Corpus Christi | Climate zone 5: El Paso |
|---|--------------------------|------------------------|-------------------------|--------------------------------|-------------------------|
| Food service: Full-service restaurant   |                          |                        |                         |                                | 0.90                    |
| Manufacturing: 1 shift (<70hr/week)     | 0.83                     | 0.84                   | 0.83                    | 0.85                           | 0.85                    |
| Manufacturing: 2 shift (70-120 hr/week) |                          |                        |                         |                                | 0.85                    |
| Manufacturing: 3 shift (>120 hr/week)   |                          |                        |                         |                                | 0.85                    |
| Warehouse                               | 0.79                     | 0.81                   | 0.79                    | 0.80                           | 0.85                    |
| Other                                   |                          |                        |                         |                                | 0.65                    |

### Retrofit (Early Retirement)

For early retirement projects, the base wattage ( $W_{base}$ ) is estimated according to the number of fans replaced and their rated efficiency:

$$W_{base,ER} = \frac{CFM_{base} * N_{base}}{\eta_{base}}$$

Equation 65

Where:

$CFM_{base}$  = Airflow rate produced by replaced fans

$\eta_{base}$  = Efficacy of replaced fans (CFM/watt)

Note: For retrofit projects where the baseline equipment ratings cannot be determined, the use of the replace-on-burnout/new construction calculation procedure is permitted.

### Replace-on-Burnout/New Construction

For replace-on-burnout or new construction projects, base case power requirements are estimated for conventional fans producing an equivalent/comparable airflow (CFM) as that of the HVLS fan(s) being installed. The efficiency of the baseline conventional fans shall be 22 CFM/watt.<sup>249</sup>

$$W_{base,ROB/NC} = \frac{CFM_{HVLS}}{22 \text{ CFM/W}}$$

### Equation Hours of Operation

Table 106 provides the hours to be used in calculating energy savings for HVLS fan installation by climate zone.

<sup>249</sup> Database of circulating fans tested by the Bioenvironmental and Structural Systems Laboratory of the Agricultural and Biological Engineering Dept., University of Illinois at Urbana-Champaign including 231 fan models by 17 manufacturers. Average efficacy ratio (CFM/watt) of single-phase, 230V circulating fans 48" diameter and larger. Available at <http://www.bess.illinois.edu/currentc.asp>.

**Table 106. HVLS Fans—Hours of Circulating Fan /CFs Operation by Barn Type<sup>250</sup>**

| Climate zone                   | H  |
|--------------------------------|----|
| Climate Zone 1: Amarillo       | 2, |
| Climate Zone 2: Dallas         | 3, |
| Climate Zone 3: Houston        | 4, |
| Climate Zone 4: Corpus Christi | 5, |
| Climate Zone 5: El Paso        | 3, |

## 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.

## Deemed Energy and Demand Savings Tables

This section is not applicable as these calculations are entirely dependent on site-specific parameters.

<sup>250</sup> Docket No. 40885 provides demand and energy savings by building type and cooling equipment for the four different climate zones. This original petition was dated 10/29/2012. An amended petition dated 11/13/2012 was approved, which provides the original energy and demand coefficients (Table 2-18: CF and EFLH Values for Amarillo (Climate Zone 1) through Table 2-16, but also amended Tables (B3a through B3d and B4a through B4d).

## Measure Life and Lifetime Savings

The EUL of an HVLS fan is closely related to that of its motor. The US DOE Advanced Manufacturing Office's Motor Systems Tip Sheet #3<sup>251</sup> suggests motors should last approximately 35,000 hours. ~~The average annual hours of operation in dairy farms for the Texas TRM zones is about 3,870 hours. Accordingly, Based on the average annual operations across the available building types,~~ the EUL for HVLS fans ~~in Texas~~ is estimated to be 9 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.

### All Projects:

- Climate zone or county
- Decision/action type: Retrofit or NC
- Building type (specify if other)
- For agricultural only: Barn type (animal)
- ~~Climate zone or county~~
- ~~Decision/action type: ROB, NC, or ER~~
- HVLS fan(s): quantity, diameter, rated HP, rated CFM, ~~rated efficiency, count~~
- Fan operating hours (customer-reported estimated)
- For early retirement only: ~~replaced fans: count, diameter, rated HP, rated CFM, rated CFM/watt~~ Screenshot of CCMS product listing
- Proof of purchase (e.g., invoice showing model number and quantity)

## 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.

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<sup>251</sup> DOE Motor Systems Tip Sheet #3 available at [https://www.energy.gov/sites/prod/files/2014/04/f15/extend\\_motor\\_operlife\\_motor\\_systemts3.pdf](https://www.energy.gov/sites/prod/files/2014/04/f15/extend_motor_operlife_motor_systemts3.pdf).

## Document Revision History

Table 111. HVLS Fans—Revision History

| TRM version  | Date           | Description of change  |
|--------------|----------------|--|
| v7.0         | 10/2019        | TRM v7.0 origin.   |
| v8.0         | 10/2020        | TRM v8.0 update. General reference checks and text edits.  |
| v9.0         | 10/2021        | TRM v9.0 update. No revision.  |
| v10.0        | 10/2022        | TRM v10.0 update. No revision.   |
| v11.0        | 10/2023        | TRM v11.0 update. No revision.   |
| <u>v12.0</u> | <u>10/2024</u> | <u>TRM v12.0 update. Expanded measure to apply to non-agricultural end uses. Incorporated new efficiency metric for large-diameter fans.</u> |

## 2.2.10 Small Commercial Evaporative Cooling Measure Overview

**TRM Measure ID:** NR-HV-EC

**Market Sector:** Small Commercial

**Measure Category:** HVAC

**Applicable Building Types:** See Table 34 through Table 40 Small commercial

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, 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 direct evaporative coolers instead of refrigerated air conditioning systems in small commercial applications. This measure applies to both retrofit and new construction applications.

### Eligibility Criteria

Direct evaporative cooling must be the primary whole-building cooling source. Installed systems must have a saturation efficiency of 0.85 or greater. Portable, window, indirect, and hybrid systems are not eligible.

### Baseline Condition

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

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

Baseline efficiency levels for packaged DX air conditioners < 65,000 Btuh are provided in Table 33. These baseline efficiency levels reflect the latest minimum efficiency requirements from the current federal manufacturing standard and IECC 2015.

Table 112. Evaporative Cooling—NC/ROB Baseline Efficiency Levels for DX AC<sup>252</sup>

| System type              | Capacity (tons) | Heating section type | Baseline efficiencies                | Source <sup>253</sup>       |
|--------------------------|-----------------|----------------------|--------------------------------------|-----------------------------|
| Packaged air conditioner | < 5.4           | All                  | 11.8 EER <sup>254</sup><br>14.0 SEER | DOE Standards/<br>IECC 2015 |

## High-Efficiency Condition

The high-efficiency condition is a direct evaporative cooling system(s) with a saturation efficiency of at least 0.85.

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

$$\text{Summer Peak Demand Savings [kW]} = Cap_C \times \frac{1}{\eta_{baseline,C}} \times DF_S \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times CRF$$

**Equation 68**

$$\text{Energy Savings [kWh]} = Cap_C \times \frac{1}{\eta_{baseline,C}} \times EFLH_C \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times CRF$$

**Equation 69**

Where:

- $Cap_C$  = Refrigerated cooling load for equivalent evaporative cooling system, default = 36,000 Btuh<sup>255</sup>; 1 ton = 12,000 Btuh
- $\eta_{baseline,C}$  = Cooling efficiency of standard equipment (ROB/NC) [Btuh/W] (see Table 33)
- Note: Use EER for kW savings calculations and SEER for kWh savings calculations.
- $CF_S$  = Summer peak coincidence factor (see Table 40)
- $EFLH_C$  = Cooling equivalent full-load hours [hours] (see Table 40)
- $CRF$  = Consumption reduction factor<sup>256</sup> = 75%

<sup>252</sup> IECC 2015 Table C403.2.3(1) and C403.2.3(2).

<sup>253</sup> These baseline efficiency standards noted as “DOE Standards” are cited in the Code of Federal Regulations, 10 CFR 431.97. <http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec431-97.pdf>.

<sup>254</sup> IECC 2015 Table C403.2.3(1) and C403.2.3(2).

<sup>255</sup> New Mexico TRM assumption based on DX AC cooling load for Las Cruces climate zone.

<sup>256</sup> Department of Energy, <https://www.energy.gov/energysaver/evaporative-coolers>.

## Deemed Energy and Demand Savings Tables

Deemed peak coincidence factor (CF) and equivalent full-load hour (EFLH) values match those previously defined for commercial direct expansion (DX) HVAC measures. See Section 2.2.2, Split and Packaged Air Conditioners and Heat Pumps Measure Overview.

This measure is restricted to climate zone 5.

**Table 113. Evaporative Cooling—CF and EFLH Values for Climate Zone 5: El Paso**

| Building type     | Principal building activity      | DX AC           |                   |
|-------------------|----------------------------------|-----------------|-------------------|
|                   |                                  | CF <sub>s</sub> | EFLH <sub>c</sub> |
| Data center       | Data center                      | 0.88            | 2,547             |
| Education         | College/university               | 0.87            | 1,092             |
|                   | Primary school                   | 0.91            | 996               |
|                   | Secondary school                 | 0.87            | 742               |
| Food sales        | Convenience store                | 0.76            | 1,251             |
|                   | Supermarket                      | 0.38            | 347               |
| Food service      | Full-service restaurant          | 0.76            | 1,276             |
|                   | 24-hour full-service restaurant  | 0.74            | 1,413             |
|                   | Quick-service restaurant         | 0.76            | 1,082             |
|                   | 24-hour quick-service restaurant | 0.77            | 1,171             |
| Healthcare        | Inpatient                        | 0.81            | 2,555             |
|                   | Outpatient                       | 0.81            | 2,377             |
| Large multifamily | Midrise apartment                | 0.88            | 1,209             |
| Lodging           | Large hotel                      | 0.63            | 1,701             |
|                   | Nursing home                     | 0.88            | 1,228             |
|                   | Small hotel/motel                | 0.63            | 1,921             |
| Mercantile        | Stand-alone retail               | 0.80            | 904               |
|                   | 24-hour retail                   | 0.86            | 1,228             |
|                   | Strip mall                       | 0.83            | 931               |
| Office            | Large office                     | 0.98            | 2,423             |
|                   | Medium office                    | 0.77            | 1,173             |
|                   | Small office                     | 0.84            | 1,037             |



| Building type     | Principal building activity | DX AC           |                   |
|-------------------|-----------------------------|-----------------|-------------------|
|                   |                             | CF <sub>s</sub> | EFLH <sub>c</sub> |
| Public assembly   | Public assembly             | 0.91            | 1,339             |
| Religious worship | Religious worship           | 0.63            | 478               |
| Service           | Service: Excluding food     | 0.76            | 988               |
| Warehouse         | Warehouse                   | 0.75            | 324               |
| Other             | Other                       | 0.38            | 324               |

## 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 estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HV-EvapCool.<sup>257</sup>

## 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.

- Climate zone or county
- Decision/action type: ROB or NC
- Building type
- Baseline number of units
- Baseline rated cooling capacity (CFM)
- Installed number of units
- Installed equipment cooling capacity (CFM)
- Installed manufacturer and model
- **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

<sup>257</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

- **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**

Not applicable.

### **Relevant Standards and Reference Sources**

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

### **Document Revision History**

**Table 114. Evaporative Cooling—Revision History**

| <b>TRM version</b> | <b>Date</b>    | <b>Description of change</b>  |
|--------------------|----------------|---|
| v9.0               | 10/2021        | TRM v9.0 origin.  |
| 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. |
| <u>v12.0</u>       | <u>10/2024</u> | <u>TRM v12.0 update. No revision.</u>   |

## 2.2.11 Small Commercial Smart Thermostats Measure Overview

**TRM Measure ID:** NR-HV-ST

**Market Sector:** Commercial

**Measure Category:** HVAC

**Applicable Building Types:** See Table 34 through Table 40 Small commercial

**Fuels Affected:** Electricity

**Decision/Action Types:** Retrofit, 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 a smart thermostat in small commercial applications.

### Eligibility Criteria

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

The thermostat must control a single-zone direct expansion (DX) split or packaged air conditioner (AC) or heat pump (HP) limited to 10 tons (120,000 Btu/hr) or lower.

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

No demand savings should be claimed if the customer is participating in a utility load management program offering.

### Baseline Condition

The baseline condition for retrofit applications is a manual or programmable thermostat. The baseline condition for new construction applications is a programmable thermostat.<sup>258</sup>

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<sup>258</sup> IECC 2015 C40.2.4.2.

## High-Efficiency Condition

The high-efficiency condition is a single-zone HVAC system being controlled by a smart or connected thermostat. The ENERGY STAR qualified product listing (QPL)<sup>259</sup> does not include units marketed for commercial applications; until those units are included, all products marketed as commercial smart or connected thermostats are allowed to use the savings methodology specified in this measure.

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

This section describes the deemed savings methodology for energy and demand savings for small commercial smart thermostats.

$$\text{Total Energy Savings [kWh]} = kWh_c + kWh_H \quad \text{Equation 70}$$

$$\text{Cooling Energy Savings [kWh}_c] = CAP_c \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times \frac{1}{\eta_c} \times EFLH_c \times CRF \times BAF \quad \text{Equation 71}$$

$$\text{Heating Energy Savings [kWh}_H] = CAP_H \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times \frac{1}{\eta_H} \times EFLH_c \times HRF \times BAF \quad \text{Equation 72}$$

$$\text{Summer Peak Demand Savings [kW]} = CAP_c \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times \frac{1}{\eta_c} \times CF_S \times CRF \times BAF \quad \text{Equation 73}$$

$$\text{Winter Peak Demand Savings [kW]} = CAP_H \times \frac{1 \text{ kW}}{1,000 \text{ W}} \times \frac{1}{\eta_H} \times CF_W \times HRF \times BAF \quad \text{Equation 74}$$

Where:

|              |   |  |
|--------------|---|--|
| $CAP_{C/H}$  | = | Controlled-HVAC rated cooling/heating capacity (Btuh) <sup>260</sup>   |
| $\eta_{C/H}$ | = | HVAC rated cooling/heating efficiency (see Table 33 for retrofit applications; use rated system efficiencies from AHRI or equivalent certification for new construction) |

<sup>259</sup> ENERGY STAR QPL. <https://www.energystar.gov/productfinder/product/certified-connected-thermostats/results>.

<sup>260</sup> Eligible cooling and heating capacity is capped at 10 tons (or 120,000 btu/hr).

Note: Use EER2/EER for summer kW, SEER2/IEER for cooling kWh, and HSPF2/HSPF for heating kWh and winter kW savings calculations. For heating equipment rated in COP, convert to HSPF by multiplying by 3.412. Heating efficiency should be converted from 1.0 COP and set to 3.412 HSPF when thermostat is installed in combination with centrally-controlled electric resistance heat.<sup>261</sup>

|              |   |  |
|--------------|---|--|
| $EFLH_{C/H}$ | = | Cooling/heating equivalent full-load hours (see Table 36 through Table 40)   |
| $CF_{S/W}$   | = | Summer/winter coincidence factor (see Table 36 through Table 40)   |
| $CRF$        | = | Cooling reduction factor = 10% <sup>262</sup>  |
| $HRF$        | = | Heating reduction factor = 8% <sup>263</sup>   |
| $BAF$        | = | Baseline adjustment factor (1.0 for manual baseline, 0.6 for programmable and new construction baselines, and 0.8 for unknown baseline) <sup>264,265</sup> |

## 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 in the *split and packaged air conditioners and heat pumps* measure in Table 36 through Table 40.

## Claimed Peak Demand Savings

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

## Claimed Peak Demand Savings

Not applicable.

<sup>261</sup> COP converted to HSPF using  $HSPF = COP \div 1,055 \text{ J/Btu} \times 3,600 \text{ J/W-h} = COP \times 3.412$ .

<sup>262</sup> The lower 95 percent confidence limit of weighted national average assumed for *residential connected thermostats* measure in Volume 2. While not directly applicable to commercial applications, this approach was used by the Illinois TRM as a precursor to sector specific data collection. Additionally, the deemed value falls between the range observed in other state TRMs (from 2–5 percent in the Mid-Atlantic TRM to 14–20 percent in the Wisconsin TRM). This factor is approved on a probationary basis with intent to review consumption data of sampling of participating projects after at least two years of measure availability.

<sup>263</sup> Ibid.

<sup>264</sup> This factor represents the ratio of thermostat adjustment savings to thermostat replacement savings. It is based on actual thermostat algorithm data (i.e., degrees of setback, hours values, fan models) from two years of ComEd AirCare Plus program data (PY9+ and CY2018), including 382 thermostat adjustment installations and 3,847 thermostat replacement installations.

<sup>265</sup> A review of ComEd's 2020 Baseline Study and 2019–2020 Program Data indicates that replacement thermostats are approximately 50 percent manual and 50 percent programmable. The unknown value may be applied as a default if applied consistently for all thermostats in a program year.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 11 years as specified in the California Database of Energy Efficiency Resources (DEER) Remote Ex-Ante Database Interface (READI) tool for EUL ID HV-ProgTstat.<sup>266</sup>

## Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Building type
- Decision/action type (retrofit, new construction)
- Baseline thermostat type (manual, programmable, unknown)
- Manufacturer and model number
- Quantity of newly installed thermostats
- HVAC equipment age (retrofit only)
- Cooling type (split AC, packaged AC, split HP, packaged HP)
- Heating type (gas, electric resistance, HP)
- Cooling capacity (Btuh)
- Heating capacity (Btuh)
- Rated cooling efficiency (new construction only)
- Rated heating efficiency (new construction only)

## 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.

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<sup>266</sup> DEER READI. <http://www.deeresources.com/index.php/ready>.

## Document Revision History

Table 115. Smart Thermostats—Revision History

| TRM version  | Date           | Description of change                               |
|--------------|----------------|---|
| v10.0        | 10/2022        | TRM v10.0 origin.                                   |
| v11.0        | 10/2023        | TRM v11.0 update. No revision.                      |
| <u>v12.0</u> | <u>10/2024</u> | <u>TRM v11.0 update. Minor footnote correction.</u> |

## 2.3 NONRESIDENTIAL: BUILDING ENVELOPE

### 2.3.1 Cool Roofs Measure Overview

**TRM Measure ID:** NR-BE-CR

**Market Sector:** Commercial

**Measure Category:** Building envelope

**Applicable Building Types:** All commercial

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Energy modeling, engineering algorithms, and estimates

### Measure Description

Reflective roofing materials reduce the overall heat load on a building by reducing the total heat energy absorbed into the building system from incident solar radiation. This reduction in total load provides space cooling energy savings during the cooling season but reduces free heat during the heating season, so the measure saves energy in the summer but uses more energy in winter. Cool roofs are most beneficial in warmer climates and may not be recommended for buildings where the primary heat source is electric resistance. The measure is for retrofit of existing buildings.

### Eligibility Criteria

The ENERGY STAR® Roofing Products Certification program was discontinued effective June 1, 2022.<sup>267</sup> Moving forward, installed roofing products will still be required to demonstrate compliance with the previous ENERGY STAR specification.<sup>268</sup> For nonresidential facilities, these criteria for a high-efficiency roof include:

- An existing roof undergoing retrofit conditions as further defined under the High-Efficiency Condition section below; a roof installed in a new construction application is not eligible for applying these methodologies.
- A roof with a low slope of 2:12 inches or less<sup>269</sup>

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<sup>267</sup> ENERGY STAR Roof Products Sunset Decision Memo.  
<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Roof%20Products%20Sunset%20Decision%20Memo.pdf>.

<sup>268</sup> ENERGY STAR Program Requirements for Roof Products v2.1.  
[https://www.energystar.gov/ia/partners/product\\_specs/program\\_reqs/roofs\\_prog\\_req.pdf](https://www.energystar.gov/ia/partners/product_specs/program_reqs/roofs_prog_req.pdf).

<sup>269</sup> As defined in proposed ASTN Standard E 1918-97.



- An initial solar reflectance of greater than or equal to 65 percent
- A three-year solar reflectance of greater than or equal to 50 percent
- 75 percent of the roof surface over conditioned space must be replaced
- No significant obstruction of direct sunlight to roof
- The facility must be conditioned with central cooling, heating, or both

In lieu of the former ENERGY STAR list of qualified products, roofing product must now have a performance rating that is validated by the Cool Roof Rating Council (CRRC)<sup>270,271</sup> and be listed on the CRRC Rated Roof Products Directory.<sup>272</sup> This is consistent with the former ENERGY STAR test criteria’s allowances for products already participating in the CRRC Product Rating program<sup>273</sup> to submit solar reflectance and thermal emittance product information derived from CRRC certification. 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.

## Baseline Condition

The baseline is the thermal resistance (i.e., R-value) of the existing roof makeup and the solar reflectance and emissivity of the surface layer. The R-value is estimated based on code envelope requirements applicable in the construction year. Solar reflectance and emissivity of the surface layer are assumed to be 0.2 and 0.9, respectively, based on roof properties listed in the Lawrence Berkeley National Lab (LBLN) Cool Roofing Materials Database.<sup>274</sup>

The cooling and heating efficiencies are assumed based on the space conditioning of the top floor of the building and typical code requirements applicable in the construction year.

**Table 116. Cool Roofs—Assumed Cooling and Heating Efficiencies (COP)**

| Construction year;<br>applicable code | RTU | PTHP<br>cooling | PTHP<br>heating | Air-cooled<br>chiller | Water-cooled<br>chiller |
|---------------------------------------|-----|-----------------|-----------------|-----------------------|-------------------------|
| Before 2011; 2000 IECC                | 2.9 | 2.9             | 2.9             | 2.5                   | 4.2                     |
| Between 2011-2016; 2009 IECC          | 3.8 | 3.1             | 2.9             | 2.8                   | 5.5                     |
| After 2016; 2015 IECC                 | 3.8 | 3.1             | 2.9             | 2.8                   | 5.5                     |

<sup>270</sup> CRRC guidance for roof rating alternative to discontinued ENERGY STAR program. <https://coolroofs.org/documents/CRRC-ENERGY-STAR-Sunset-Info-Sheet-2022-03-07.pdf>.

<sup>271</sup> CRRC Roof Rating program. <https://coolroofs.org/programs/roof-rating-program>.

<sup>272</sup> CRRC Rated Roof Products Directory. <https://coolroofs.org/directory/roof>.

<sup>273</sup> CRRC Rated Products Directory: <https://coolroofs.org/directory>.

<sup>274</sup> Lawrence Berkeley National Lab Cool Roofing Material Database. <https://heatisland.lbl.gov/resources/cool-roofing-materials-database>.

## High-Efficiency Condition

The high-efficiency condition depends on the project scope. The project scope is defined as one of the following:

- Adding surface layer only,
- Adding insulation and surface layer, and
- Rebuilding entire roof assembly.

If the project scope is only to add a new CRRC-rated material as the new surface layer, then the R-value used for the baseline condition is used for the high-efficiency condition. If the project scope is to add insulation and a CRRC-rated material as the new surface layer, then the R-value of the additional insulation is added to the R-value used for the baseline condition. If the entire roof assembly is rebuilt, then the R-value for each layer of the new roof construction is summed to get a total new R-value.

The measure requires installation of roof products that have been rated by the CRRC and demonstrate compliance with the previous ENERGY STAR-certified roof product performance specifications for the relevant roof application. Initial and three-year reflectance ratings must meet or exceed the minimum thresholds specified in Table 117.

**Table 117. Cool Roofs—ENERGY STAR Specification<sup>275</sup>**

| Roof slope          | Characteristic               | Performance specification |
|---------------------|------------------------------|---------------------------|
| Low slope<br>≤ 2/12 | Initial solar reflectance    | ≥ 0.65                    |
|                     | Three-year solar reflectance | ≥ 0.50                    |

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

Energy savings are estimated using EnergyPlus v8.3.0 whole-building simulation. The prototype building characteristics match those used for developing commercial HVAC coincidence factors and EFLH and can be found from Table 119 through Table 123. The savings represent the difference of the modeled energy use of the baseline condition and the high-efficiency condition divided by the square foot of the roof area. The demand savings are calculated following the method described in TRM Volume 1.

The deemed energy and demand savings factors are used in the following formulas to calculate savings:

$$\text{Energy Savings [kWh]} = \text{Roof Area} \times \text{ESF}$$

**Equation 75**

<sup>275</sup> ENERGY STAR Roof Products Specification.

[https://www.energystar.gov/products/building\\_products/roof\\_products/key\\_product\\_criteria](https://www.energystar.gov/products/building_products/roof_products/key_product_criteria).

$$\text{Summer Peak Demand Savings [kW]} = \text{Roof Area} \times CF_s \times 10^{-5}$$

**Equation 76**

$$\text{Winter Peak Demand Savings [kW]} = \text{Roof Area} \times CF_w \times 10^{-6}$$

**Equation 77**

Where:

- Roof Area* = Total area of ENERGY STAR roof (sq. ft.)
- ESF* = Energy savings factor from Table 119 through Table 123 by building type, pre-/post-insulation levels, and heating/cooling system
- CF<sub>s</sub>* = Peak summer coincidence factor from Table 119 through Table 123 by building type, pre-/post-insulation levels, and heating/cooling system
- CF<sub>w</sub>* = Peak winter coincidence factor from Table 119 through Table 123 by building type, pre/post insulation levels, and heating/cooling system

If the insulation levels are unknown, use the mapping in Table 118 to estimate the R-value based on the construction year.

**Table 118. Cool Roofs—Estimated R-Value Based on Construction Year**

| Construction Year   | Estimated R-value <sup>276</sup> |
|---------------------|----------------------------------|
| Before 2011         | R ≤ 13                           |
| Between 2011 - 2016 | 13 < R ≤ 20                      |
| After 2016          | 20 < R                           |

**Table 119. Cool Roofs—Savings Coefficients for Climate Zone 1: Amarillo**

| Building type       | Pre-R-value | Post R-value | ESF  | CF <sub>s</sub> | CF <sub>w</sub> |
|---------------------|-------------|--------------|------|-----------------|-----------------|
| Education - chiller | R ≤ 13      | R ≤ 13       | 0.65 | 11.80           | 8.31            |
|                     | R ≤ 13      | 13 < R ≤ 20  | 1.10 | 21.76           | 31.52           |
|                     | R ≤ 13      | 20 < R       | 1.25 | 25.53           | 37.31           |
|                     | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.26 | 4.85            | 4.59            |
|                     | 13 < R ≤ 20 | 20 < R       | 0.38 | 7.80            | 9.20            |
|                     | 20 < R      | 20 < R       | 0.17 | 3.40            | 1.17            |
| Education - RTU     | R ≤ 13      | R ≤ 13       | 0.26 | 8.26            | 2.62            |
|                     | R ≤ 13      | 13 < R ≤ 20  | 0.43 | 15.47           | 12.49           |
|                     | R ≤ 13      | 20 < R       | 0.49 | 18.20           | 14.02           |

<sup>276</sup> Estimates R-values are based on applicable code requirements in the construction year.

| Building type    | Pre-R-value | Post R-value | ESF  | CF <sub>s</sub> | CF <sub>w</sub> |
|------------------|-------------|--------------|------|-----------------|-----------------|
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.12 | 4.11            | 2.05            |
|                  | 13 < R ≤ 20 | 20 < R       | 0.18 | 6.67            | 3.58            |
|                  | 20 < R      | 20 < R       | 0.08 | 2.91            | 0.28            |
| Hotel            | R ≤ 13      | R ≤ 13       | 0.07 | 1.33            | -2.60           |
|                  | R ≤ 13      | 13 < R ≤ 20  | 0.07 | 1.83            | 6.98            |
|                  | R ≤ 13      | 20 < R       | 0.07 | 2.03            | 11.77           |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.04 | 0.81            | -1.45           |
|                  | 13 < R ≤ 20 | 20 < R       | 0.04 | 1.00            | 3.39            |
|                  | 20 < R      | 20 < R       | 0.03 | 0.60            | -1.12           |
|                  | 20 < R      | 20 < R       | 0.03 | 0.60            | -1.12           |
| Office - chiller | R ≤ 13      | R ≤ 13       | 0.21 | 6.80            | 1.43            |
|                  | R ≤ 13      | 13 < R ≤ 20  | 0.31 | 3.44            | 3.50            |
|                  | R ≤ 13      | 20 < R       | 0.33 | 19.30           | 3.87            |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.09 | 16.58           | 0.11            |
|                  | 13 < R ≤ 20 | 20 < R       | 0.11 | 5.94            | 0.47            |
|                  | 20 < R      | 20 < R       | 0.06 | 2.36            | 0.08            |
| Office - RTU     | R ≤ 13      | R ≤ 13       | 0.28 | 7.46            | 11.88           |
|                  | R ≤ 13      | 13 < R ≤ 20  | 0.87 | 15.48           | 168.51          |
|                  | R ≤ 13      | 20 < R       | 1.10 | 18.61           | 236.76          |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.15 | 4.12            | -1.23           |
|                  | 13 < R ≤ 20 | 20 < R       | 0.38 | 6.73            | 67.02           |
|                  | 20 < R      | 20 < R       | 0.11 | 2.92            | -2.61           |
| Retail           | R ≤ 13      | R ≤ 13       | 0.72 | 19.28           | 31.74           |
|                  | R ≤ 13      | 13 < R ≤ 20  | 1.26 | 36.23           | 36.71           |
|                  | R ≤ 13      | 20 < R       | 1.25 | 38.58           | 35.31           |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.13 | 4.81            | 1.88            |
|                  | 13 < R ≤ 20 | 20 < R       | 0.12 | 6.47            | 0.48            |
|                  | 20 < R      | 20 < R       | 0.09 | 3.32            | 1.30            |
| Warehouse        | R ≤ 13      | R ≤ 13       | 0.04 | 3.83            | -0.20           |
|                  | R ≤ 13      | 13 < R ≤ 20  | 0.11 | 6.99            | 3.89            |
|                  | R ≤ 13      | 20 < R       | 0.14 | 8.07            | 5.35            |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.01 | 1.35            | -0.10           |
|                  | 13 < R ≤ 20 | 20 < R       | 0.04 | 2.24            | 1.36            |
|                  | 20 < R      | 20 < R       | 0.01 | 0.90            | -0.07           |
| Other            | R ≤ 13      | R ≤ 13       | 0.04 | 1.33            | -2.60           |
|                  | R ≤ 13      | 13 < R ≤ 20  | 0.07 | 1.83            | 3.50            |
|                  | R ≤ 13      | 20 < R       | 0.07 | 2.03            | 3.87            |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.01 | 0.81            | -1.45           |

| Building type | Pre-R-value | Post R-value | ESF  | CF <sub>s</sub> | CF <sub>w</sub> |
|---------------|-------------|--------------|------|-----------------|-----------------|
|               | 13 < R ≤ 20 | 20 < R       | 0.04 | 1.00            | 0.47            |
|               | 20 < R      | 20 < R       | 0.01 | 0.60            | -2.61           |

**Table 120. Cool Roofs—Savings Coefficients for Climate Zone 2: Dallas**

| Building type       | Pre-R-value | Post R-value | ESF  | CF <sub>s</sub> | CF <sub>w</sub> |
|---------------------|-------------|--------------|------|-----------------|-----------------|
| Education - chiller | R ≤ 13      | R ≤ 13       | 0.56 | 10.49           | 5.11            |
|                     | R ≤ 13      | 13 < R ≤ 20  | 0.82 | 16.50           | 8.60            |
|                     | R ≤ 13      | 20 < R       | 0.92 | 18.86           | 11.17           |
|                     | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.29 | 5.41            | 2.36            |
|                     | 13 < R ≤ 20 | 20 < R       | 0.36 | 7.28            | 4.55            |
|                     | 20 < R      | 20 < R       | 0.24 | 4.37            | 1.88            |
| Education - RTU     | R ≤ 13      | R ≤ 13       | 0.27 | 10.65           | 1.53            |
|                     | R ≤ 13      | 13 < R ≤ 20  | 0.39 | 18.31           | 3.68            |
|                     | R ≤ 13      | 20 < R       | 0.43 | 21.33           | 4.89            |
|                     | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.17 | 7.21            | 0.77            |
|                     | 13 < R ≤ 20 | 20 < R       | 0.21 | 10.08           | 1.97            |
|                     | 20 < R      | 20 < R       | 0.13 | 5.88            | 0.60            |
| Hotel               | R ≤ 13      | R ≤ 13       | 0.07 | 1.71            | -0.64           |
|                     | R ≤ 13      | 13 < R ≤ 20  | 0.07 | 2.30            | 0.78            |
|                     | R ≤ 13      | 20 < R       | 0.07 | 2.56            | 1.39            |
|                     | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.05 | 1.17            | -0.46           |
|                     | 13 < R ≤ 20 | 20 < R       | 0.05 | 1.42            | 0.17            |
|                     | 20 < R      | 20 < R       | 0.05 | 1.01            | -0.36           |
| Office - chiller    | R ≤ 13      | R ≤ 13       | 0.23 | 11.99           | 0.81            |
|                     | R ≤ 13      | 13 < R ≤ 20  | 0.33 | 27.48           | 1.78            |
|                     | R ≤ 13      | 20 < R       | 0.34 | 30.55           | 1.93            |
|                     | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.13 | 6.68            | 0.10            |
|                     | 13 < R ≤ 20 | 20 < R       | 0.15 | 9.76            | 0.26            |
|                     | 20 < R      | 20 < R       | 0.10 | 6.01            | 0.08            |
| Office - RTU        | R ≤ 13      | R ≤ 13       | 0.27 | 12.14           | 14.86           |
|                     | R ≤ 13      | 13 < R ≤ 20  | 0.52 | 24.53           | 84.63           |
|                     | R ≤ 13      | 20 < R       | 0.62 | 29.45           | 112.16          |
|                     | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.18 | 7.25            | 11.53           |
|                     | 13 < R ≤ 20 | 20 < R       | 0.28 | 11.09           | 39.06           |
|                     | 20 < R      | 20 < R       | 0.15 | 6.03            | 8.66            |

| Building type | Pre-R-value | Post R-value | ESF  | CF <sub>s</sub> | CF <sub>w</sub> |
|---------------|-------------|--------------|------|-----------------|-----------------|
| Retail        | R ≤ 13      | R ≤ 13       | 0.61 | 22.03           | 13.53           |
|               | R ≤ 13      | 13 < R ≤ 20  | 0.97 | 37.67           | 17.30           |
|               | R ≤ 13      | 20 < R       | 0.98 | 40.54           | 17.32           |
|               | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.16 | 7.57            | 1.28            |
|               | 13 < R ≤ 20 | 20 < R       | 0.17 | 9.67            | 1.29            |
|               | 20 < R      | 20 < R       | 0.13 | 6.22            | 1.04            |
| Warehouse     | R ≤ 13      | R ≤ 13       | 0.05 | 4.01            | -0.07           |
|               | R ≤ 13      | 13 < R ≤ 20  | 0.09 | 6.54            | 1.47            |
|               | R ≤ 13      | 20 < R       | 0.16 | 11.16           | 2.38            |
|               | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.02 | 1.18            | -0.05           |
|               | 13 < R ≤ 20 | 20 < R       | 0.08 | 4.94            | 0.86            |
|               | 20 < R      | 20 < R       | 0.01 | 1.02            | -0.03           |
| Other         | R ≤ 13      | R ≤ 13       | 0.05 | 1.71            | -0.64           |
|               | R ≤ 13      | 13 < R ≤ 20  | 0.07 | 2.30            | 0.78            |
|               | R ≤ 13      | 20 < R       | 0.07 | 2.56            | 1.39            |
|               | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.02 | 1.17            | -0.46           |
|               | 13 < R ≤ 20 | 20 < R       | 0.05 | 1.42            | 0.17            |
|               | 20 < R      | 20 < R       | 0.01 | 1.01            | -0.36           |

**Table 121. Cool Roofs—Savings Coefficients for Climate Zone 3: Houston**

| Building type       | Pre-R-value | Post R-value | ESF  | CF <sub>s</sub> | CF <sub>w</sub> |
|---------------------|-------------|--------------|------|-----------------|-----------------|
| Education - chiller | R ≤ 13      | R ≤ 13       | 0.62 | 9.56            | -0.28           |
|                     | R ≤ 13      | 13 < R ≤ 20  | 0.87 | 15.28           | 3.52            |
|                     | R ≤ 13      | 20 < R       | 0.95 | 17.53           | 4.52            |
|                     | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.33 | 5.04            | -0.28           |
|                     | 13 < R ≤ 20 | 20 < R       | 0.39 | 6.81            | 0.50            |
|                     | 20 < R      | 20 < R       | 0.26 | 4.05            | -0.29           |
| Education - RTU     | R ≤ 13      | R ≤ 13       | 0.29 | 9.39            | -0.03           |
|                     | R ≤ 13      | 13 < R ≤ 20  | 0.40 | 15.76           | 0.90            |
|                     | R ≤ 13      | 20 < R       | 0.44 | 18.26           | 1.08            |
|                     | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.18 | 6.21            | -0.01           |
|                     | 13 < R ≤ 20 | 20 < R       | 0.22 | 8.58            | 0.16            |
|                     | 20 < R      | 20 < R       | 0.14 | 5.08            | -0.07           |

| Building type    | Pre-R-value | Post R-value | ESF' | CF <sub>s</sub> | CF <sub>w</sub> |
|------------------|-------------|--------------|------|-----------------|-----------------|
| Hotel            | R ≤ 13      | R ≤ 13       | 0.08 | 1.69            | 0.54            |
|                  | R ≤ 13      | 13 < R ≤ 20  | 0.07 | 2.26            | 0.17            |
|                  | R ≤ 13      | 20 < R       | 0.07 | 2.50            | -0.02           |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.06 | 1.21            | 0.37            |
|                  | 13 < R ≤ 20 | 20 < R       | 0.05 | 1.43            | 0.21            |
|                  | 20 < R      | 20 < R       | 0.05 | 1.03            | 0.32            |
| Office - chiller | R ≤ 13      | R ≤ 13       | 0.25 | 9.45            | 0.70            |
|                  | R ≤ 13      | 13 < R ≤ 20  | 0.33 | 21.39           | 1.26            |
|                  | R ≤ 13      | 20 < R       | 0.34 | 23.54           | 1.23            |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.17 | 10.75           | 0.65            |
|                  | 13 < R ≤ 20 | 20 < R       | 0.18 | 12.84           | 0.61            |
|                  | 20 < R      | 20 < R       | 0.12 | 4.54            | 0.12            |
| Office - RTU     | R ≤ 13      | R ≤ 13       | 0.28 | 8.30            | 6.91            |
|                  | R ≤ 13      | 13 < R ≤ 20  | 0.46 | 18.66           | 37.60           |
|                  | R ≤ 13      | 20 < R       | 0.54 | 22.36           | 50.18           |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.19 | 5.42            | 4.29            |
|                  | 13 < R ≤ 20 | 20 < R       | 0.26 | 8.39            | 16.87           |
|                  | 20 < R      | 20 < R       | 0.15 | 4.35            | 3.35            |
| Retail           | R ≤ 13      | R ≤ 13       | 0.62 | 17.21           | 9.86            |
|                  | R ≤ 13      | 13 < R ≤ 20  | 1.00 | 29.60           | 17.11           |
|                  | R ≤ 13      | 20 < R       | 1.01 | 31.61           | 16.52           |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.41 | 10.43           | 7.67            |
|                  | 13 < R ≤ 20 | 20 < R       | 0.41 | 11.89           | 7.07            |
|                  | 20 < R      | 20 < R       | 0.14 | 4.66            | 1.07            |
| Warehouse        | R ≤ 13      | R ≤ 13       | 0.05 | 2.96            | -0.09           |
|                  | R ≤ 13      | 13 < R ≤ 20  | 0.09 | 5.13            | 0.76            |
|                  | R ≤ 13      | 20 < R       | 0.16 | 9.21            | 1.26            |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.02 | 1.32            | -0.07           |
|                  | 13 < R ≤ 20 | 20 < R       | 0.08 | 4.66            | 0.43            |
|                  | 20 < R      | 20 < R       | 0.01 | 0.79            | 0.08            |
| Other            | R ≤ 13      | R ≤ 13       | 0.05 | 1.69            | -0.28           |
|                  | R ≤ 13      | 13 < R ≤ 20  | 0.07 | 2.26            | 0.17            |
|                  | R ≤ 13      | 20 < R       | 0.07 | 2.50            | -0.02           |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.02 | 1.21            | -0.28           |
|                  | 13 < R ≤ 20 | 20 < R       | 0.05 | 1.43            | 0.16            |
|                  | 20 < R      | 20 < R       | 0.01 | 0.79            | -0.29           |

**Table 122. Cool Roofs—Savings Coefficients for Climate Zone 4: Corpus Christi**

| <b>Building type</b> | <b>Pre-R-value</b> | <b>Post R-value</b> | <b>ESF</b> | <b>CF<sub>s</sub></b> | <b>CF<sub>w</sub></b> |
|----------------------|--------------------|---------------------|------------|-----------------------|-----------------------|
| Education - chiller  | R ≤ 13             | R ≤ 13              | 0.60       | 8.46                  | 0.28                  |
|                      | R ≤ 13             | 13 < R ≤ 20         | 0.83       | 13.55                 | 17.33                 |
|                      | R ≤ 13             | 20 < R              | 0.90       | 15.49                 | 30.14                 |
|                      | 13 < R ≤ 20        | 13 < R ≤ 20         | 0.31       | 4.48                  | -3.69                 |
|                      | 13 < R ≤ 20        | 20 < R              | 0.36       | 6.00                  | 6.37                  |
|                      | 20 < R             | 20 < R              | 0.24       | 3.64                  | -0.06                 |
| Education - RTU      | R ≤ 13             | R ≤ 13              | 0.28       | 7.34                  | -0.41                 |
|                      | R ≤ 13             | 13 < R ≤ 20         | 0.38       | 11.78                 | 5.15                  |
|                      | R ≤ 13             | 20 < R              | 0.41       | 13.53                 | 8.09                  |
|                      | 13 < R ≤ 20        | 13 < R ≤ 20         | 0.17       | 4.64                  | -1.46                 |
|                      | 13 < R ≤ 20        | 20 < R              | 0.20       | 6.29                  | 1.47                  |
|                      | 20 < R             | 20 < R              | 0.14       | 3.77                  | -0.14                 |
| Hotel                | R ≤ 13             | R ≤ 13              | 0.07       | 1.13                  | 1.99                  |
|                      | R ≤ 13             | 13 < R ≤ 20         | 0.07       | 1.44                  | -1.23                 |
|                      | R ≤ 13             | 20 < R              | 0.07       | 1.57                  | -2.70                 |
|                      | 13 < R ≤ 20        | 13 < R ≤ 20         | 0.05       | 0.78                  | 1.36                  |
|                      | 13 < R ≤ 20        | 20 < R              | 0.05       | 0.90                  | 0.00                  |
|                      | 20 < R             | 20 < R              | 0.04       | 0.67                  | 1.19                  |
| Office - chiller     | R ≤ 13             | R ≤ 13              | 0.22       | 6.44                  | 2.33                  |
|                      | R ≤ 13             | 13 < R ≤ 20         | 0.31       | 13.55                 | 2.86                  |
|                      | R ≤ 13             | 20 < R              | 0.32       | 15.30                 | 2.47                  |
|                      | 13 < R ≤ 20        | 13 < R ≤ 20         | 0.17       | 6.34                  | 1.78                  |
|                      | 13 < R ≤ 20        | 20 < R              | 0.18       | 7.96                  | 1.40                  |
|                      | 20 < R             | 20 < R              | 0.10       | 3.27                  | 0.45                  |
| Office - RTU         | R ≤ 13             | R ≤ 13              | 0.26       | 5.02                  | 23.11                 |
|                      | R ≤ 13             | 13 < R ≤ 20         | 0.40       | 8.66                  | 78.05                 |
|                      | R ≤ 13             | 20 < R              | 0.45       | 10.09                 | 100.16                |
|                      | 13 < R ≤ 20        | 13 < R ≤ 20         | 0.18       | 3.61                  | 15.10                 |
|                      | 13 < R ≤ 20        | 20 < R              | 0.24       | 4.83                  | 37.21                 |
|                      | 20 < R             | 20 < R              | 0.15       | 2.95                  | 10.35                 |



| Building type | Pre-R-value | Post R-value | ESF  | CF <sub>s</sub> | CF <sub>w</sub> |
|---------------|-------------|--------------|------|-----------------|-----------------|
| Retail        | R ≤ 13      | R ≤ 13       | 0.62 | 13.05           | 54.33           |
|               | R ≤ 13      | 13 < R ≤ 20  | 0.99 | 21.99           | 35.94           |
|               | R ≤ 13      | 20 < R       | 1.00 | 23.21           | 34.63           |
|               | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.41 | 8.08            | 16.20           |
|               | 13 < R ≤ 20 | 20 < R       | 0.41 | 8.95            | 14.89           |
|               | 20 < R      | 20 < R       | 0.13 | 3.42            | 2.05            |
| Warehouse     | R ≤ 13      | R ≤ 13       | 0.05 | 2.10            | 0.22            |
|               | R ≤ 13      | 13 < R ≤ 20  | 0.09 | 3.51            | 1.39            |
|               | R ≤ 13      | 20 < R       | 0.16 | 6.54            | 1.35            |
|               | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.02 | 1.21            | 0.28            |
|               | 13 < R ≤ 20 | 20 < R       | 0.08 | 3.71            | 0.24            |
|               | 20 < R      | 20 < R       | 0.01 | 0.70            | -0.07           |
| Other         | R ≤ 13      | R ≤ 13       | 0.05 | 1.13            | -0.41           |
|               | R ≤ 13      | 13 < R ≤ 20  | 0.07 | 1.44            | -1.23           |
|               | R ≤ 13      | 20 < R       | 0.07 | 1.57            | -2.70           |
|               | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.02 | 0.78            | -3.69           |
|               | 13 < R ≤ 20 | 20 < R       | 0.05 | 0.90            | 0.00            |
|               | 20 < R      | 20 < R       | 0.01 | 0.67            | -0.14           |

**Table 123. Cool Roofs—Savings Coefficients for Climate Zone 5: El Paso**

| Building type       | Pre-R-value | Post R-value | ESF  | CF <sub>s</sub> | CF <sub>w</sub> |
|---------------------|-------------|--------------|------|-----------------|-----------------|
| Education - chiller | R ≤ 13      | R ≤ 13       | 0.69 | 9.09            | 3.85            |
|                     | R ≤ 13      | 13 < R ≤ 20  | 0.97 | 14.42           | 4.87            |
|                     | R ≤ 13      | 20 < R       | 1.07 | 16.52           | 5.43            |
|                     | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.36 | 4.80            | 1.87            |
|                     | 13 < R ≤ 20 | 20 < R       | 0.44 | 6.47            | 2.34            |
|                     | 20 < R      | 20 < R       | 0.28 | 3.91            | 1.19            |
| Education - RTU     | R ≤ 13      | R ≤ 13       | 0.30 | 8.21            | 3.09            |
|                     | R ≤ 13      | 13 < R ≤ 20  | 0.42 | 13.43           | 4.02            |
|                     | R ≤ 13      | 20 < R       | 0.46 | 15.49           | 4.27            |
|                     | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.18 | 5.16            | 1.47            |
|                     | 13 < R ≤ 20 | 20 < R       | 0.22 | 7.09            | 1.72            |
|                     | 20 < R      | 20 < R       | 0.14 | 4.14            | 0.86            |
| Hotel               | R ≤ 13      | R ≤ 13       | 0.10 | 1.33            | 7.04            |
|                     | R ≤ 13      | 13 < R ≤ 20  | 0.08 | 1.58            | 1.80            |
|                     | R ≤ 13      | 20 < R       | 0.08 | 1.68            | -0.78           |
|                     | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.07 | 0.95            | 4.98            |

| Building type    | Pre-R-value | Post R-value | ESF  | CF <sub>s</sub> | CF <sub>w</sub> |
|------------------|-------------|--------------|------|-----------------|-----------------|
|                  | 13 < R ≤ 20 | 20 < R       | 0.06 | 1.04            | 2.57            |
|                  | 20 < R      | 20 < R       | 0.06 | 0.81            | 4.27            |
| Office - chiller | R ≤ 13      | R ≤ 13       | 0.29 | 9.72            | 7.27            |
|                  | R ≤ 13      | 13 < R ≤ 20  | 0.39 | 17.57           | 12.46           |
|                  | R ≤ 13      | 20 < R       | 0.42 | 20.35           | 13.25           |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.17 | 6.68            | 0.12            |
|                  | 13 < R ≤ 20 | 20 < R       | 0.20 | 9.22            | 0.79            |
|                  | 20 < R      | 20 < R       | 0.14 | 5.39            | 2.02            |
|                  |             |              |      |                 |                 |
| Office - RTU     | R ≤ 13      | R ≤ 13       | 0.31 | 9.93            | 24.02           |
|                  | R ≤ 13      | 13 < R ≤ 20  | 0.55 | 16.57           | 105.15          |
|                  | R ≤ 13      | 20 < R       | 0.64 | 19.26           | 135.96          |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.20 | 5.75            | 16.21           |
|                  | 13 < R ≤ 20 | 20 < R       | 0.29 | 7.78            | 47.02           |
|                  | 20 < R      | 20 < R       | 0.16 | 4.70            | 12.77           |
| Retail           | R ≤ 13      | R ≤ 13       | 0.67 | 16.55           | 42.72           |
|                  | R ≤ 13      | 13 < R ≤ 20  | 1.01 | 26.85           | 67.80           |
|                  | R ≤ 13      | 20 < R       | 1.02 | 28.78           | 65.27           |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.19 | 5.83            | 6.64            |
|                  | 13 < R ≤ 20 | 20 < R       | 0.19 | 7.24            | 4.12            |
|                  | 20 < R      | 20 < R       | 0.15 | 4.74            | 5.40            |
| Warehouse        | R ≤ 13      | R ≤ 13       | 0.04 | 2.76            | -0.61           |
|                  | R ≤ 13      | 13 < R ≤ 20  | 0.09 | 4.91            | 1.33            |
|                  | R ≤ 13      | 20 < R       | 0.15 | 8.27            | 2.06            |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.02 | 1.31            | -0.42           |
|                  | 13 < R ≤ 20 | 20 < R       | 0.07 | 3.98            | 0.30            |
|                  | 20 < R      | 20 < R       | 0.01 | 0.76            | -0.19           |
| Other            | R ≤ 13      | R ≤ 13       | 0.04 | 1.33            | -0.61           |
|                  | R ≤ 13      | 13 < R ≤ 20  | 0.08 | 1.58            | 1.33            |
|                  | R ≤ 13      | 20 < R       | 0.08 | 1.68            | -0.78           |
|                  | 13 < R ≤ 20 | 13 < R ≤ 20  | 0.02 | 0.95            | -0.42           |
|                  | 13 < R ≤ 20 | 20 < R       | 0.06 | 1.04            | 0.30            |
|                  | 20 < R      | 20 < R       | 0.01 | 0.76            | -0.19           |

## Deemed Energy and Demand Savings Tables

There are no deemed energy or demand savings tables for this measure. Please use algorithms and inputs, as described above.

## 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) Remote Ex-Ante Database Interface (READI) tool for EUL ID BldgEnv-CoolRoof.<sup>277</sup>

## Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Building type
- Total and treated roofing square footage (over conditioned space)
- Roof slope
- Existing roof insulation R-value, or year of building construction
- New roof insulation R-value, if adding insulation
- New roofing initial solar reflectance
- New roofing three-year solar reflectance
- New roofing rated life
- Copy of CRRC certification
- Copy of proof of purchase including date of purchase, manufacturer, and model

## Building Type References and Efficiency Standards

### Petitions and Rulings

- PUCT Docket 36779—Provides EUL for Commercial Cool Roof.

### Relevant Standards and Reference Sources

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

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<sup>277</sup> DEER READI. <http://www.deeresources.com/index.php/readi>.

## Document Revision History

**Table 124. Cool Roofs—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. Clarified that reflectance is three years basis. Rounded off values, too many insignificant digits.  |
| v3.0         | 04/10/2015     | TRM v3.0 update. No revision.   |
| v4.0         | 10/10/2016     | TRM v4.0 update. Clarified eligibility criteria, baseline condition, and high-efficiency condition. Added R-values for more materials. Added new high-performance roof calculator for use in determining ENERGY STAR® roof savings. |
| v5.0         | 10/2017        | TRM v5.0 update. No revision.   |
| v6.0         | 10/2018        | TRM v6.0 update. Changed savings methodology from algorithms to simulation models. Deemed savings are presented per square foot by building type and climate zone.  |
| v7.0         | 10/2019        | TRM v7.0 update. Minor error updates to Savings Factor Table for greater than and less than symbols. Program tracking requirements updated.   |
| v8.0         | 10/2020        | TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR® qualification requirement and defers to meeting criteria.  |
| v9.0         | 10/2021        | TRM v9.0 update. Added building type to tracking data requirements. Updated EUL reference.  |
| v10.0        | 10/2022        | TRM v10.0 update. Changed eligibility criteria from strictly ENERGY STAR to CRRRC certification.  |
| v11.0        | 10/2023        | TRM v11.0 update. No revision.  |
| <u>v12.0</u> | <u>10/2024</u> | <u>TRM v12.0 update. Reordering of building types in tables.</u>  |

## 2.3.2 Window Treatments Measure Overview

TRM Measure ID: NR-BE-WT

Market Sector: Commercial

Measure Category: Building envelope

Applicable Building Types: All commercial **building types**

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 section presents the deemed savings methodology for the installation of window films and **fixed** solar screens. The installation of window treatments decreases the window-shading coefficient and reduces the solar heat transmitted to the building space. During months when perimeter cooling is required in the building, this measure decreases cooling energy use and summer demand.

### Eligibility Criteria

This measure is applicable for treatment of single or double-paned clear glass windows without reflective or low-e coatings in south or west facing orientations (as specified in Table 125). **The treatment can be a film applied to the window or a permanent, fixed interior or exterior solar screen.** This methodology may be adapted for windows with existing shading devices on an individual project basis with prior evaluator approval of baseline solar heat gain coefficient (SHGC).

Existing windows must have no solar films/screens, interior shades, or exterior awnings or overhangs, and must be installed in buildings that are mechanically cooled (direct expansion (or chilled water). While highly reflective louvered or Venetian blinds can help reduce solar heat gain, they must be completely lowered and closed to be as effective as ~~more~~ permanent shading devices.<sup>278</sup> **The louvered or Venetian blinds are not eligible for the measure, although windows y also do not prevent heat from entering the envelope in the space between the blinds and window. Therefore, windows** with existing interior louvered or Venetian blinds are not excluded from using this measure.

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<sup>278</sup> "Energy Efficient Window Coverings," US Department of Energy.  
[https://www.energy.gov/energysaver/energy-efficient-window-coverings#:~:text=Window%20blinds%E2%80%94vertical%20\(Venetian%20blinds,while%20providing%20good%20daylight%20indoors.](https://www.energy.gov/energysaver/energy-efficient-window-coverings#:~:text=Window%20blinds%E2%80%94vertical%20(Venetian%20blinds,while%20providing%20good%20daylight%20indoors.)

## Baseline Condition

The baseline condition is single-pane clear glass, without existing window treatments. However, existing windows with interior louvered or Venetian blinds are an allowable baseline with reduced SHGC values from Table 126.

## High-Efficiency Condition

The high-efficiency condition is an eligible window treatment applied to eligible windows.

## Energy and Demand Savings Methodology

The demand and energy savings equations in this section originated in calculations by the Electric Utility Marketing Managers of Texas (EUMMOT) utilities, as presented in the EUMMOT program manual *Commercial Standard Offer Program: Measurement and Verification Guidelines for Retrofit and New Construction Projects*. The method estimates the reduction in solar heat gain/insolation attributable to a given window treatment using shading coefficients for the treated and untreated window and solar heat gain estimates by window orientation, according to ASHRAE Fundamentals. The reduction in building energy use attributable to the reduction in cooling system energy use is estimated based on the reduced heat removal requirement for a standard efficiency cooling system.

## Savings Algorithms and Input Variables

$$Demand\ Savings_o\ [kW] = \frac{A_{film,o} \times SHGF_o \times (SHGC_{pre,o} - SHGC_{post,o})}{3,412 \times COP}$$

**Equation 78**

$$Peak\ Demand\ Savings\ [kW] = DemandSavings_{o,max}$$

**Equation 79**

$$Energy\ Savings_o\ [kWh] = \frac{A_{film,o} \times SHG_o \times (SHGC_{pre,o} - SHGC_{post,o})}{3,412 \times COP}$$

**Equation 80**

$$Total\ Energy\ Savings\ [kWh] = \sum Energy\ Savings_o$$

**Equation 81**

Where:

|                                   |   |  |
|-----------------------------------|---|--|
| <i>Demand Savings<sub>o</sub></i> | = | <i>Peak demand savings per window orientation</i>                                  |
| <i>Energy Savings<sub>o</sub></i> | = | <i>Energy savings per window orientation</i>                                       |
| <i>A<sub>film,o</sub></i>         | = | <i>Area of window <u>treatment</u>film applied to orientation [ft<sup>2</sup>]</i> |

$SHGF_o$  = Peak solar heat gain factor for orientation of interest [Btu/hr-ft<sup>2</sup>-year] (see Table 125)

$SHG_o$  = Solar heat gain for orientation of interest [Btu/ft<sup>2</sup>-year] (see Table 125)

$SHGC_{pre}$  = Solar heat gain coefficient for existing glass with no interior-shading device (see Table 126)

$SHGC_{post}$  = Solar heat gain coefficient for new film ~~interior~~/fixed-shading device, from manufacturer specs

Note: Shading coefficients (SC) have been retired, but if a product specification lists SC instead of SHGC, you can convert to SHGC by multiplying SC by 0.87.<sup>279</sup>

COP = Cooling equipment coefficient of performance (COP) based on Table 127 or actual COP equipment, whichever is greater; if building construction year is unknown, assume IECC 2009 as applicable code

3,412 = Constant to convert from Btu to kWh

**Table 125. Windows Treatments—Solar Heat Gain Factors<sup>280</sup>**

| Orientation <sup>281</sup> | Solar heat gain (SHG) [Btu/ft <sup>2</sup> -year] | Peak hour solar heat gain (SHGF) [Btu/hr-ft <sup>2</sup> -year] |                        |                         |                                |                         |
|----------------------------|---|---|------------------------|-------------------------|--------------------------------|-------------------------|
|                            |   | Climate Zone 1: Amarillo <sup>282</sup>                         | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
| SE                         | 158,844   | 28  | 30                     | 26                      | 27                             | 35                      |
| SSE                        | 134,794   | 28  | 31                     | 28                      | 28                             | 37                      |
| S                          | 120,839   | 37  | 44                     | 47                      | 45                             | 56                      |
| SSW                        | 134,794   | 88  | 94                     | 113                     | 113                            | 101                     |
| SW                         | 158,844   | 152   | 151                    | 170                     | 173                            | 141                     |
| WSW                        | 169,696   | 191   | 184                    | 201                     | 206                            | 160                     |
| W                          | 163,006   | 202   | 189                    | 201                     | 207                            | 155                     |
| WNW                        | 139,615   | 183   | 167                    | 171                     | 178                            | 128                     |
| NW                         | 107,161   | 136   | 120                    | 115                     | 121                            | 85                      |

<sup>279</sup> 2001 ASHRAE Handbook: Fundamentals, p. 30–39.

<sup>280</sup> Values are taken from the 1997 ASHRAE Fundamentals, Chapter 29 Table 17, based on the amount of solar radiation transmitted through single-pane clear glass for a cloudless day at 32°N Latitude for the 21<sup>st</sup> day of each month by hour of day and solar orientation. The SHG values listed above have been aggregated into daily totals for weekdays during the months of April through October.

<sup>281</sup> N = North, S = South, E = East, and W = West.

<sup>282</sup> Coincidence factors specific to Climate Zone 1 could not be calculated since utility load data is not currently available for this region. In their absence, Climate Zone 2 values may be used.

**Table 126. Windows Treatments—Recommended Clear Glass SHGC<sub>pre</sub> by Window Thickness<sup>283</sup>**

| Existing window configuration    | Louvered Blinds    | SHGC <sub>pre</sub> |
|----------------------------------|--------------------|---------------------|
| Single-pane 1/8-inch clear glass | No                 | 0.86                |
| Single-pane 1/4-inch clear glass |                    | 0.81                |
| Double-pane 1/8-inch clear glass |                    | 0.76                |
| Double-pane 1/4-inch clear glass |                    | 0.70                |
| Single-pane 1/8-inch clear glass | Yes <sup>284</sup> | 0.64                |
| Single-pane 1/4-inch clear glass |                    | 0.60                |
| Double-pane 1/8-inch clear glass |                    | 0.61                |
| Double-pane 1/4-inch clear glass |                    | 0.57                |

**Table 127. Windows Treatments—Recommended COP by HVAC System Type<sup>285</sup>**

| Construction year; applicable code | AC/HP | PTAC/PTHP | Air-cooled chiller | Water-cooled chiller |
|------------------------------------|-------|-----------|--------------------|----------------------|
| Before 2011; 2000 IECC             | 2.9   | 2.9       | 2.5                | 4.2                  |
| Between 2011-2016; 2009 IECC       | 3.8   | 3.1       | 2.8                | 5.5                  |
| After 2016; 2015 IECC              | 3.8   | 3.1       | 2.8                | 5.5                  |

## Deemed Energy and Demand Savings Tables

There are no deemed energy or demand savings tables for this measure. Please use algorithms and inputs, as described above.

## 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 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GlazDaylt-WinFilm.<sup>286</sup>

<sup>283</sup> 2021 ASHRAE Handbook: Fundamentals, Chapter 15 Fenestration, Table 10 Solar Heat Gain Coefficient (SHGC). <https://www.ashrae.org/technical-resources/ashrae-handbook/ashrae-handbook-online>.

<sup>284</sup> 2021 ASHRAE Handbook: Fundamentals, Chapter 15 Fenestration, Table 14A IAC Values for Louvered Shades: Uncoated Single Glazings, Table 14B IAC Values for Louvered Shades: Uncoated Double Glazings. <https://www.ashrae.org/technical-resources/ashrae-handbook/ashrae-handbook-online>.

<sup>285</sup> Based on review applicable codes, including IECC 2000, 2009, and 2015.

<sup>286</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.



## **Program Tracking Data and Evaluation Requirements**

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

- Climate zone or county
- Existing window type, thickness, and SHGC
- Description of existing window presence of exterior shading from other buildings or obstacles
- Window film or solar screen SHGC
- Eligible window treatment application area by orientation (e.g., S, SSW, SW)
- Construction year, if available
- Cooling equipment type
- Cooling equipment rated efficiency

## **References and Efficiency Standards**

### **Petitions and Rulings**

- PUCT Docket 36779—Provides EUL for reflective window films and sunscreens.

### **Relevant Standards and Reference Sources**

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

### **Document Revision History**

**Table 128. Windows Treatments—Revision History**

| <b>TRM version</b> | <b>Date</b> | <b>Description of change</b>  |
|--------------------|-------------|---|
| v1.0               | 11/25/2013  | TRM v1.0 origin.  |
| v2.0               | 04/18/2014  | TRM v2.0 update. Eliminated east-facing windows from consideration for energy savings.  |
| v3.0               | 04/10/2015  | TRM v3.0 update. References to EPE-specific deemed savings removed (EPE to adopt methods used by the other utilities). Demand savings: Frontier Energy updated to incorporate new peak demand definition. Provided deemed values for shading coefficients and HVAC efficiencies. SHGF: Used CZ2 savings for CZ1 until better values can be developed. |
| v4.0               | 10/10/2016  | TRM v4.0 update. No revision.   |
| v5.0               | 10/2017     | TRM v5.0 update. No revision.   |
| v6.0               | 10/2018     | TRM v6.0 update. No revision.   |

| TRM version  | Date           | Description of change   |
|--------------|----------------|---|
| v7.0         | 10/2019        | TRM v7.0 update. No revision.   |
| v8.0         | 10/2020        | TRM v8.0 update. General reference checks and text edits. Updated peak demand values for climate zones and PDPF values.   |
| v9.0         | 10/2021        | TRM v9.0 update. Corrected footnote for SC to SHGC conversion. Updated performance factors to 2017 ASHRAE Fundamentals. Updated EUL reference.                    |
| v10.0        | 10/2022        | TRM v10.0 update. No revision.  |
| v11.0        | 10/2023        | TRM v11.0 update. Extended eligibility to windows with existing louvered or Venetian blinds. Added reduced baseline SHGC values for windows with louvered blinds. |
| <u>v12.0</u> | <u>10/2024</u> | <u>TRM v12.0 update. Updated measure to indicate solar screen must be permanent, fixed and interior or exterior.</u>  |

### 2.3.3 Entrance and Exit Door Air Infiltration Measure Overview

**TRM Measure ID:** NR-BE-DI

**Market Sector:** Commercial

**Measure Category:** Building envelope

**Applicable Building Types:** All commercial building types

**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 applies to the installation of weather stripping or door sweeps on entrance and exit doors for a contained, pressurized space. Entrance and exit doors often leave clearance gaps to allow for proper operation. The gaps around the doors allow for the infiltration of unconditioned air into the building, adding to the cooling and heating load of the HVAC system. Weatherstripping and door sweeps are designed to be installed along the bottom and jambs of exterior doors to prevent air infiltration to conditioned space.

#### Eligibility Criteria

Weatherstripping or doors sweeps must be installed on doors of a conditioned and/or heated space. Treated doors must have visible gaps of 1/8–3/4 inches along the outside edge of the door. Spaces with interior vestibule doors are not eligible.

#### Baseline Condition

The baseline standard for this measure is a commercial building with exterior doors that are not sealed from unconditioned space.

#### High-Efficiency Condition

The high-efficiency condition for this measure is a commercial building with exterior doors that have been sealed from unconditioned space using weather stripping and/or brush style door sweeps.

#### Energy and Demand Savings Methodology

This savings methodology was derived by analyzing TMY3 weather data for each Texas weather zone representative city.

## Derivation of Pre-Retrofit Air Infiltration Rate

The pre-retrofit air infiltration rate for each crack width is calculated by applying the methodologies presented in Chapter 5 of the ASHRAE Cooling and Heating Load Calculation Manual (CHLCM).<sup>287</sup> Building type characteristics for a typical commercial building were found in the DOE study PNNL-20026,<sup>288</sup> and an average building height of 20 feet is assumed for the deemed savings approach.

Because air infiltration is a function of differential pressure due to stack effect, wind speed, velocity head, and the design conditions of the building, TMY3 for each Texas weather zone reference city was applied to account for the varying weather conditions that are characteristic throughout an average year.

Figure 5.13 from the ASHRAE CHLCM provides the infiltration rate based on various crack width and the corresponding pressure difference across a door. Figures 5.1 and 5.2 (CHLCM) provide the differential pressure due to stack and wind pressure necessary to determine the total pressure difference across the door.

Applying a regression analysis to Figure 5.1 returns an equation that allows solving for the pressure difference due to stack effect,  $\Delta p_s$ . The aggregate curve fit for Figure 5.1 is shown below where  $x$  is based on the dry bulb temperature from the TMY3 data, and the design temperature based on the appropriate seasonal condition.

$$\Delta p_s / C_d = 0.0000334003x - 0.00014468$$

**Equation 82**

Where  $C_d$  is an assumed constant, 0.63, and the neutral pressure distance is 10 feet.

From Figure 5.2,  $\Delta p_w / C_p$  is determined by applying a polynomial regression, which returns an equation for solving for the pressure difference due to wind,  $\Delta p_w$ . The curve fit for Figure 5.2 is shown below where  $x$  is the wind velocity based on TMY3 data.

$$\Delta p_w / C_p = 0.00047749x^2 - 0.00013041x$$

**Equation 83**

Where  $C_p$  is an assumed constant, 0.13 (average wind pressure coefficient from Table 5.5 from CHLCM).

This yields the total pressure difference across the door,  $\Delta p_{Total}$ :

$$\Delta p_{Total} = \Delta p_s + \Delta p_w$$

**Equation 84**

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<sup>287</sup> ASHRAE Cooling and Heating Load Calculation Manual, p. 5.8. 1980.  
[http://portal.hud.gov/hudportal/documents/huddoc?id=doc\\_10603.pdf](http://portal.hud.gov/hudportal/documents/huddoc?id=doc_10603.pdf).

<sup>288</sup> Cho, H., K. Gowri, and B. Liu, "Energy Saving Impact of ASHRAE 90.1 Vestibule Requirements: Modeling of Air Infiltration through Door Openings." November 2010.  
[http://www.pnl.gov/main/publications/external/technical\\_reports/PNNL-20026.pdf](http://www.pnl.gov/main/publications/external/technical_reports/PNNL-20026.pdf).

Solving for  $\Delta p_{Total}$  allows for the air infiltration rate per linear foot to be determined in Figure 5.13 (CHLCM). Applying a power regression analysis for each crack width (described in inches) represented in Figure 5.13 (CHLCM) returns the equations listed below. In these equations,  $Q$  is the infiltration rate in cubic feet per minute through cracks around the door, and  $P$  is the perimeter of the door in feet.

$$Q/P_{1/8"} = 41.572x^{0.5120}$$

**Equation 85**

$$Q/P_{1/4"} = 81.913x^{0.5063}$$

**Equation 86**

$$Q/P_{1/2"} = 164.26x^{0.5086}$$

**Equation 87**

$$Q/P_{3/4"} = 246.58x^{0.5086}$$

**Equation 88**

These infiltration rates were further disaggregated based on TMY3 average monthly day and night conditions.

## Derivation of Design and Average Outside Ambient Temperatures

Taking average daytime and nighttime outdoor temperature values, standard set points, and setbacks for daytime and nighttime design cooling and heating will yield the temperature difference needed for the sensible heat equation:

$$\Delta T = T_{design} - T_{avg\ outside\ ambient}$$

**Equation 89**

Where:

- $T_{design}$  = Daytime and nighttime design temperature [°F] (see Table 130)
- $T_{avg\ outside\ ambient}$  = Average outside ambient temperature, specified by month [°F] (see Table 129)

**Table 129. Air Infiltration—Average Monthly Ambient Temperatures (°F)<sup>289</sup>**

| Month | Climate Zone 1:<br>Amarillo |       | Climate Zone 2:<br>Dallas |       | Climate Zone 3:<br>Houston |       | Climate Zone 4:<br>Corpus Christi |       | Climate Zone 5:<br>El Paso |       |
|-------|-----------------------------|-------|---------------------------|-------|----------------------------|-------|-----------------------------------|-------|----------------------------|-------|
|       | Day                         | Night | Day                       | Night | Day                        | Night | Day                               | Night | Day                        | Night |
| Jan   | 41.5                        | 31.5  | 48.1                      | 40.3  | 54.8                       | 47.0  | 58.1                              | 50.9  | 50.9                       | 42.4  |
| Feb   | 44.9                        | 34.5  | 52.8                      | 44.8  | 59.4                       | 50.5  | 61.7                              | 54.4  | 55.8                       | 45.2  |
| Mar   | 52.9                        | 40.7  | 63.6                      | 54.4  | 65.5                       | 56.8  | 69.1                              | 61.3  | 61.0                       | 48.2  |
| April | 65.4                        | 52.7  | 71.4                      | 62.7  | 73.1                       | 64.7  | 75.9                              | 67.7  | 72.7                       | 60.5  |
| May   | 69.2                        | 57.2  | 77.6                      | 68.7  | 79.4                       | 71.1  | 80.5                              | 72.0  | 80.9                       | 69.0  |
| June  | 79.9                        | 69.7  | 85.3                      | 75.0  | 85.1                       | 76.2  | 86.4                              | 77.9  | 88.2                       | 76.1  |
| July  | 84.5                        | 72.1  | 90.4                      | 80.6  | 87.8                       | 78.0  | 88.6                              | 78.0  | 86.7                       | 76.5  |
| Aug   | 81.4                        | 69.7  | 89.1                      | 79.2  | 88.0                       | 77.5  | 88.0                              | 78.4  | 84.2                       | 74.4  |
| Sept  | 75.3                        | 64.3  | 84.5                      | 73.8  | 85.5                       | 73.6  | 85.0                              | 75.2  | 80.9                       | 67.3  |
| Oct   | 63.6                        | 50.4  | 70.2                      | 59.9  | 75.4                       | 61.8  | 77.5                              | 67.9  | 70.2                       | 59.7  |
| Nov   | 48.5                        | 38.5  | 59.3                      | 52.3  | 67.6                       | 57.9  | 72.3                              | 63.8  | 57.3                       | 47.0  |
| Dec   | 41.8                        | 32.4  | 49.5                      | 41.8  | 59.2                       | 50.0  | 60.4                              | 53.7  | 49.1                       | 39.4  |

**Table 130. Air Infiltration—Daytime and Nighttime Design Temperatures**

| Temperature description                             | T <sub>design</sub> (°F) |
|---|--------------------------|
| Daytime cooling design temperature                  | 74                       |
| Daytime heating design temperature                  | 72                       |
| Nighttime cooling design temperature <sup>290</sup> | 78                       |
| Nighttime heating design temperature <sup>291</sup> | 68                       |

## Savings Algorithms and Input Variables

To calculate HVAC load associated with air infiltration, the following sensible heat equation is used:

### Electric Cooling Energy Savings

$$\begin{aligned}
 & \text{Cooling Energy Savings [kWh]}_{\text{Day}} \\
 &= \frac{CFM_{pre,day} \times CFM_{reduction} \times 1.08 \times \Delta T \times 1.0 \frac{kW}{ton} \times \text{Hours}_{day}}{12,000 \text{ Btuh/ton}}
 \end{aligned}$$

**Equation 90**

<sup>289</sup> TMY3 climate data.

<sup>290</sup> Assuming four-degree setback.

<sup>291</sup> Ibid.

$$\begin{aligned} & \text{Cooling Energy Savings [kWh]}_{\text{Night}} \\ &= \frac{CFM_{\text{pre,night}} \times CFM_{\text{reduction}} \times 1.08 \times \Delta T \times 1.0 \frac{\text{kW}}{\text{ton}} \times \text{Hours}_{\text{night}}}{12,000 \text{ Btuh/ton}} \end{aligned}$$

**Equation 91**

$$\begin{aligned} & \text{Cooling Energy Savings [kWh]} \\ &= \text{Cooling Energy Savings [kWh]}_{\text{Day}} + \text{Cooling Energy Savings [kWh]}_{\text{Night}} \end{aligned}$$

**Equation 92**

### **Electric Heating Energy Savings**

$$\begin{aligned} & \text{Heating Energy Savings [kWh]}_{\text{Day}} \\ &= \frac{CFM_{\text{pre,day}} \times CFM_{\text{reduction}} \times 1.08 \times \Delta T \times 1.0 \frac{\text{kW}}{\text{ton}} \times \text{Hours}_{\text{day}}}{COP \times 3,412 \text{ Btuh/kW}} \end{aligned}$$

**Equation 93**

$$\begin{aligned} & \text{Heating Energy Savings [kWh]}_{\text{Night}} \\ &= \frac{CFM_{\text{pre,night}} \times CFM_{\text{reduction}} \times 1.08 \times \Delta T \times 1.0 \frac{\text{kW}}{\text{ton}} \times \text{Hours}_{\text{night}}}{COP \times 3,412 \text{ Btuh/kW}} \end{aligned}$$

**Equation 94**

$$\begin{aligned} & \text{Heating Energy Savings [kWh]} \\ &= \text{Cooling Energy Savings [kWh]}_{\text{Day}} + \text{Cooling Energy Savings [kWh]}_{\text{Night}} \end{aligned}$$

**Equation 95**

### **Electric Cooling Demand Savings (weighted by climate zone peak hour probability)**

$$\text{Summer Peak Demand Savings [kW]}_{\text{Day}} = \frac{CFM_{\text{pre,day}} \times CFM_{\text{reduction}} \times 1.08 \times \Delta T \times 1.0 \frac{\text{kW}}{\text{ton}}}{12,000 \text{ Btuh/ton}}$$

**Equation 96**

### **Electric Heating Demand Savings (weighted by climate zone peak hour probability)**

$$\begin{aligned} & \text{Winter Peak Demand Savings [kW]}_{\text{Day/Night}} \\ &= \frac{CFM_{\text{pre,day/night}} \times CFM_{\text{reduction}} \times 1.08 \times \Delta T \times 1.0 \frac{\text{kW}}{\text{ton}}}{COP \times 3,412 \text{ Btuh/kW}} \end{aligned}$$

**Equation 97**

Where:

|                   |   |  |
|-------------------|---|--|
| $CFM_{pre}$       | = | Calculated pre-retrofit air infiltration (cubic feet per minute)                       |
| $CFM_{reduction}$ | = | $59\%^{292} \times TDF$  |
| $TDF$             | = | Technical degradation factor = $85\%^{293}$  |
| 1.08              | = | Sensible heat equation conversion <sup>294</sup>                                       |
| $\Delta T$        | = | Change in temperature across gap barrier [°F]  |
| $Hours_{day}$     | = | 12-hour cycles per day, per month = 4,380 hours  |
| $Hours_{night}$   | = | 12-hour cycles per night, per month = 4,380 hours                                      |
| $COP$             | = | Heating coefficient of performance; 1.0 for electric resistance and 3.3 for heat pumps |

## Deemed Energy and Demand Savings Tables

Deemed energy and demand savings per ~~linear foot of installed weather stripping or door sweep standard door<sup>295</sup>~~ are specified below based on climate zone and existing door gap width. ~~The gap width shall be measured on each of the four edges of the door-length measurement should be initially measured~~ to the nearest ¼ inch. ~~The reported gap width for the door should reflect the average of the four measurements, and converted to linear feet rounded to hundredths (0.02) including any segments that are not sealed due to corners, hinges, handles, or other obstructions.~~ The average width of the door gap width should be rounded to nearest gap width in inches in Table 131 through Table 136. Projects that have more than 10 doors at the same project site, can provide a sample of measurements of 20 percent of the claimed doors and apply the average to all doors in the project.

Heating savings are specified for both electric resistance (ER) and heat pump (HP) heating. Cooling savings are available for buildings with electric cooling and gas heat, but no heating savings should be claimed for buildings with gas heat.

<sup>292</sup> CLEARResult, “Commercial Door Air Infiltration Memo”. March 18, 2015. Average reduction in Arkansas based on test results from the CLEARResult Brush Weather Stripping Testing Method and Results (59% infiltration reduction).

<sup>293</sup> This factor is applied to account for the difference between the laboratory test from the “Commercial Door Air Infiltration Memo” and the real-world ability to seal the openings around a door. In the absence of research regarding the actual difference, this factor was set to 0.85.

<sup>294</sup> 2013 ASHRAE Handbook of Fundamentals; Equation 33, p. 16.11.

<sup>295</sup> Standard door circumference calculated as (36” width + 80” height) ÷ 12 in/ft x 2 = 19.3 linear ft.



**Table 131. Air Infiltration—Cooling Energy Savings/DoorLin.-Ft. of Weather Stripping/Door Sweep**

| Climate zone                   | Average Gap width (inches) |                 |                 |                 |
|--------------------------------|----------------------------|-----------------|-----------------|-----------------|
|                                | 1/8                        | 1/4             | 1/2             | 3/4             |
| Climate Zone 1: Amarillo       | <u>374.90</u>              | <u>743.83</u>   | <u>1477.60</u>  | <u>22144.42</u> |
| Climate Zone 2: Dallas         | <u>753.90</u>              | <u>1527.88</u>  | <u>30345.65</u> | <u>45423.49</u> |
| Climate Zone 3: Houston        | <u>583.04</u>              | <u>1186.09</u>  | <u>23442.09</u> | <u>35148.14</u> |
| Climate Zone 4: Corpus Christi | <u>975.00</u>              | <u>19540.08</u> | <u>38720.03</u> | <u>58130.06</u> |
| Climate Zone 5: El Paso        | <u>542.81</u>              | <u>1105.69</u>  | <u>21844.28</u> | <u>32746.93</u> |

**Table 132. Air Infiltration—ER Heating Energy Savings/DoorLin.-Ft. of Weather Stripping/Door Sweep**

| Climate zone                   | Average Gap width (inches) |                    |                    |                     |
|--------------------------------|----------------------------|--------------------|--------------------|---------------------|
|                                | 1/8                        | 1/4                | 1/2                | 3/4                 |
| Climate Zone 1: Amarillo       | <u>1,958404.26</u>         | <u>3,949204.24</u> | <u>7,844405.72</u> | <u>11,775609.05</u> |
| Climate Zone 2: Dallas         | <u>94548.90</u>            | <u>1,91198.82</u>  | <u>3,792496.45</u> | <u>5,693294.44</u>  |
| Climate Zone 3: Houston        | <u>52527.18</u>            | <u>1,06455.06</u>  | <u>2,111409.49</u> | <u>3,169463.94</u>  |
| Climate Zone 4: Corpus Christi | <u>44022.78</u>            | <u>89046.02</u>    | <u>1,76694.35</u>  | <u>2,651437.43</u>  |
| Climate Zone 5: El Paso        | <u>88145.59</u>            | <u>1,78392.23</u>  | <u>3,538482.99</u> | <u>5,311274.69</u>  |

**Table 133. Air Infiltration—HP Heating Energy Savings/DoorLin.-Ft. of Weather Stripping/Door Sweep**

| Climate zone                   | Average Gap width (inches) |                   |                    |                    |
|--------------------------------|----------------------------|-------------------|--------------------|--------------------|
|                                | 1/8                        | 1/4               | 1/2                | 3/4                |
| Climate Zone 1: Amarillo       | <u>59330.69</u>            | <u>1,19764.89</u> | <u>2,377422.94</u> | <u>3,568484.56</u> |
| Climate Zone 2: Dallas         | <u>28744.82</u>            | <u>57929.95</u>   | <u>1,14959.44</u>  | <u>1,72589.22</u>  |
| Climate Zone 3: Houston        | <u>1598.24</u>             | <u>32346.69</u>   | <u>64033.09</u>    | <u>96049.67</u>    |
| Climate Zone 4: Corpus Christi | <u>1336.90</u>             | <u>27043.94</u>   | <u>53527.68</u>    | <u>80344.56</u>    |
| Climate Zone 5: El Paso        | <u>26743.84</u>            | <u>54027.95</u>   | <u>1,07255.45</u>  | <u>1,60983.24</u>  |

**Table 134. Air Infiltration—Summer Demand Savings/~~Door~~Lin. Ft. of Weather Stripping/Door Sweep**

| Climate zone                   | Average Gap width (inches) |                        |                        |                        |
|--------------------------------|----------------------------|------------------------|------------------------|------------------------|
|                                | 1/8                        | 1/4                    | 1/2                    | 3/4                    |
| Climate Zone 1: Amarillo       | <del>0.100</del> -0053     | <del>0.200</del> -0405 | <del>0.410</del> -0240 | <del>0.610</del> -0345 |
| Climate Zone 2: Dallas         | <del>0.090</del> -0044     | <del>0.170</del> -0090 | <del>0.350</del> -0179 | <del>0.520</del> -0269 |
| Climate Zone 3: Houston        | <del>0.080</del> -0043     | <del>0.170</del> -0087 | <del>0.330</del> -0173 | <del>0.500</del> -0259 |
| Climate Zone 4: Corpus Christi | <del>0.080</del> -0044     | <del>0.160</del> -0082 | <del>0.320</del> -0164 | <del>0.480</del> -0246 |
| Climate Zone 5: El Paso        | <del>0.080</del> -0044     | <del>0.160</del> -0083 | <del>0.320</del> -0165 | <del>0.480</del> -0247 |

**Table 135. Air Infiltration—ER Winter Demand Savings/~~Door~~Lin. Ft. of Weather Stripping/Door Sweep**

| Climate zone                   | Average Gap width (inches) |                        |                        |                        |
|--------------------------------|----------------------------|------------------------|------------------------|------------------------|
|                                | 1/8                        | 1/4                    | 1/2                    | 3/4                    |
| Climate Zone 1: Amarillo       | <del>0.520</del> -0268     | <del>1.050</del> -0544 | <del>2.080</del> -1074 | <del>3.120</del> -1612 |
| Climate Zone 2: Dallas         | <del>0.800</del> -0412     | <del>1.600</del> -0828 | <del>3.190</del> -1648 | <del>4.780</del> -2474 |
| Climate Zone 3: Houston        | <del>0.410</del> -0211     | <del>0.820</del> -0425 | <del>1.630</del> -0844 | <del>2.450</del> -1267 |
| Climate Zone 4: Corpus Christi | <del>0.370</del> -0190     | <del>0.740</del> -0383 | <del>1.470</del> -0762 | <del>2.210</del> -1144 |
| Climate Zone 5: El Paso        | <del>0.190</del> -0099     | <del>0.390</del> -0202 | <del>0.770</del> -0400 | <del>1.160</del> -0602 |

**Table 136. Air Infiltration—HP Winter Demand Savings/~~Door~~Lin. Ft. of Weather Stripping/Door Sweep**

| Climate zone                   | Average Gap width (inches) |                        |                        |                        |
|--------------------------------|----------------------------|------------------------|------------------------|------------------------|
|                                | 1/8                        | 1/4                    | 1/2                    | 3/4                    |
| Climate Zone 1: Amarillo       | <del>0.270</del> -0138     | <del>0.540</del> -0277 | <del>1.060</del> -0550 | <del>1.600</del> -0825 |
| Climate Zone 2: Dallas         | <del>0.340</del> -0178     | <del>0.690</del> -0357 | <del>1.370</del> -0740 | <del>2.060</del> -1066 |
| Climate Zone 3: Houston        | <del>0.200</del> -0102     | <del>0.400</del> -0207 | <del>0.790</del> -0410 | <del>1.190</del> -0645 |
| Climate Zone 4: Corpus Christi | <del>0.170</del> -0087     | <del>0.340</del> -0175 | <del>0.670</del> -0348 | <del>1.010</del> -0523 |
| Climate Zone 5: El Paso        | <del>0.090</del> -0049     | <del>0.190</del> -0099 | <del>0.380</del> -0197 | <del>0.570</del> -0296 |

## 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 11 years, as specified in the California Database of Energy Efficiency Resources (DEER) Remote Ex-Ante Database Interface (READI) tool for EUL ID BS-Wthr.<sup>296</sup> This measure life is consistent with the residential air infiltration measure in the Texas TRM.

<sup>296</sup> DEER READI. <http://www.deeresources.com/index.php/readi>.

## **Program Tracking Data and Evaluation Requirements**

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

- Climate zone or county
- Treated door quantity
- Existing gap width on each of edge of the door
- ~~Existing-Reported average~~ gap width (1/8", 1/4", 1/2", or 3/4")
- Existing weatherization measure (full, partial, none)
- ~~Installed~~New weatherization measure (weather stripping or door sweep)
- ~~Linear feet (to nearest 0.02 feet = 1/4") of installed weather stripping or door sweep~~
- Cooling type (central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
  - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach):

## **References and Efficiency Standards**

### **Petitions and Rulings**

- Docket No. 48265. Petition of AEP Texas Inc., CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company. *Petition to Approve Deemed Savings for New Nonresidential Door Air Infiltration, Nonresidential Door Gaskets, and Residential ENERGY STAR® Connected Thermostats*. Public Utility Commission of Texas.

### **Relevant Standards and Reference Sources**

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

### **Document Revision History**

Table 137. Air Infiltration—Revision History

| TRM version | Date    | Description of change                  |
|-------------|---------|--|
| v6.0        | 10/2018 | TRM v6.0 origin.                       |
| v7.0        | 10/2019 | TRM v7.0 update. Minor text revisions. |

| TRM version  | Date           | Description of change  |
|--------------|----------------|--|
| v8.0         | 10/2020        | TRM v8.0 update. General reference checks and text edits. Degradation factor added to deemed savings values. Guidance clarified for measuring gap sizes. |
| 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. No revision.   |
| <u>v12.0</u> | <u>10/2024</u> | <u>TRM v12.0 update. Adjusted savings normalization from per linear foot to per standard door. Updated documentation requirements.</u>                   |