- Consortium for Energy Efficiency. Commercial Lighting Qualifying Products List (for 4-foot lamps). http://library.cee1.org/content/commercial-lighting-qualifying-products-lists Accessed 02/09/2016.
- U.S. Lighting Market Characterization report, September 2002, http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lmc_vol1_final.pdf. Accessed 9/19/2013.
- United Illuminating Company and Connecticut Light & Power. Final Report, 2005 Coincidence Factor Study. http://webapps.cee1.org/sites/default/files/library/8828/CEE_Eval_CTCoincidenceFactorsC&ILightsHVAC_4Jan2007.PDF. Accessed 09/19/2013.


## Document Revision History

**Table 2-7: Nonresidential Lighting-Lamps and Fixtures Revision History**

| TRM Version | Date | Description of Change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin |
| v2.0 | 04/18/2014 | *Measure Life section*: Added additional energy efficiency measures for consistency with the EUMMOT maintained list. *Calculator and Tools section*: Eliminated description of calculator output comparisons. *Tracking Data Requirements section:* Added lighting category requirements for measure summary reports. |
| v3.0 | 04/10/2015 | Revised to eliminate T12 lamps as a valid baseline. *Measure Description section:* General clean-up of technology descriptions. *Program Tracking Data section:* Minor changes and clarifications. |
| v3.1 | 11/05/2015 | *Revised to eliminate* T12 lamps as a valid baseline and eliminate the Oncor winter peak demand value to use the statewide average in all service territories. *Eligibility Criteria:* Adding sources for LED lamp and fixture eligibility. |
| v3.1 | 03/23/2016 | Updated *Linear Fluorescent T12 Special Conditions* baseline table to include HO and VHO lamps. Updated criteria for miscellaneous length (e.g. 2-ft, 3-ft) T8s. Added footnote to explain how to account for non-rebated fixture lighting controls in savings calculations. Clarified some tracking data requirements, |
| v4.0 | 10/10/2016 | Added LPD values and tracking data requirements for exterior space type Zones used in Codes and Standards. |

## 2.1.2 Lighting Controls Measure Overview

**TRM Measure ID:** NR-LT-LC

**Market Sector:** Commercial

**Measure Category:** Lighting

**Applicable Building Types:** All Commercial, Multifamily common areas

**Fuels Affected:** Electricity (Interactive HVAC effects: Electric/Gas space heating)

**Decision/Action Types:** Retrofit (RET), New Construction (NC)

**Program Delivery Type:** Prescriptive, Custom, Direct Install

**Deemed Savings Type:** Deemed Savings Calculation

**Savings Methodology:** Calculator

### Measure Description

This measure promotes the installation of lighting controls in both new construction and retrofit applications. For retrofit applications, lighting controls would typically be installed where there is no control other than a manual switch (wall or circuit panel). For new construction lighting systems, they would be added where they are not already required by existing energy or building codes. Promoted technologies include occupancy sensors and daylight dimming controls. Energy and peak demand savings are calculated for these technologies via an energy adjustment factor (EAF) for kWh, and a power adjustment factor (PAF) for kW.

### Eligibility Criteria

Measures installed through utility programs must be one of the occupancy sensor, daylighting, and tuning controls that are described in Table 2-8.

### Baseline Condition

The baseline condition assumes no existing or code required (new construction) automatic lighting controls are installed on the existing lighting fixtures (i.e. they are only manually switched).

### High-Efficiency Condition

The energy-efficient condition is properly installed (not bypassed or overridden) and calibrated lighting controls that control overhead lighting in a facility based on occupancy, day lighting, or tuning sensors.

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

The equations for lighting controls are similar to those used for lighting lamps and fixtures, with the addition of the EAF and PAF multipliers, as shown below. Additionally, the pre/post kW difference is replaced by a single kW value (the total fixture wattage controlled by the device).

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

**Equation 5**

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

**Equation 6**

*Where:*

| | | |
|---|---|---|
| $kW_{controlled}$ | = | *Total kW of controlled fixtures (Fixture wattage from Standard wattage table multiplied by quantity of fixtures)* |
| *Hours* | = | *Hours by building type from Table 2-4* |
| *EAF* | = | *Lighting control Energy Adjustment Factor, see Table 2-9* |
| *PAF* | = | *Lighting control Power Adjustment Factor, see Table 2-9* |
| *CF* | = | *Coincidence factor by building type, see Table 2-4* |
| $HVAC_{energy}$ | = | *Energy Interactive HVAC factor by building type, see Table 2-5* |
| $HVAC_{demand}$ | = | *Demand Interactive HVAC factor by building type, see Table 2-5* |

See section 2.1.1 for a full explanation of the non-control variables and their corresponding values. The lighting controls EAFs and PAFs for different building types are presented inTable 2-9. The EAF and PAF represent the reduction in energy and demand usage. For example, a factor of 0.24 would equate to a 24% energy and demand savings. The same values from the referenced LBNL study are used for both EAF and PAF factors due to the lack of published data for demand factors.

**Table 2-8: Lighting Controls Definitions**

| Control Type | Description |
|---|---|
| None | No control |
| Occupancy | Adjusting light levels according to the presence of occupants<br>-Wall or Ceiling-Mounted Occupancy Sensors<br>-Integrated Fixture Occupancy Sensors<br>-Time Clocks<br>-Energy Management Systems |
| Daylighting (Indoor) | Adjusting light levels automatically in response to the presence of natural light<br>-Photosensors |
| Outdoor | Outdoor on/off photosensor/time clock controls; no savings attributed because already required by code |
| Personal Tuning | Adjusting individual light levels by occupants according to their personal preference; applies to private offices, workstation-specific lighting in open-plan offices, and classrooms<br>-Dimmers<br>-Wireless ON/OFF switches<br>-Personal computer based controls<br>-Pre-set scene selection |
| Institutional Tuning | Adjustment of light levels through commissioning or provision of switches or controls for areas or groups of occupants<br>-Dimmable ballasts<br>-On/Off or dimmer switches for non-personal tuning |
| Multiple Types | Any combination of the types described above |

**Table 2-9: Lighting Controls Energy and Power Adjustment Factors[17]**

| Control Type | Sub-Category | Control Codes | EAF | PAF |
|---|---|---|---|---|
| None | n/a | None | 0.00 | 0.00 |
| Occupancy | n/a | OS | 0.24 | 0.24 |
| Daylighting (Indoor) | Continuous dimming | DL-Cont | 0.28 | 0.28 |
| | Multiple step dimming | DL-Step | | |
| | ON/OFF | DL-ON/OFF | | |
| Outdoor[18] | n/a | Outdoor | 0.00 | 0.00 |
| Personal Tuning | n/a | PT | 0.31 | 0.31 |
| Institutional Tuning | n/a | IT | 0.36 | 0.36 |
| Multiple/Combined Types | Various combinations | Multiple[19] | 0.38 | 0.38 |

## Deemed Energy and Demand Savings Tables

This section is not applicable.

[17] Williams, Alison, Atkinson, Barbara, Garbesi, Karina; & Rubinstein, Francis, "A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings". Lawrence Berkeley National Laboratory. September 2011. Table 6, p. 14. Weighted average by number of "reviewed" and "non reviewed" papers.

## Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) for lighting controls is provided by the 2007 GDS Associates Report[20]:

- Occupancy Sensor: 10 years
- Daylighting Control: 10 years
- Time Clock: 10 years
- Tuning Control: 10 years

## Program Tracking Data & Evaluation Requirements

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

- Building Type
- Decision/Action Type: Retrofit or NC
- Conditioned Space Type: cooling equipment type, refrigerated space temperature range, heating fuel type (specified per control)
- Location of Controlled Lighting: Interior or Exterior (specified per control)
- Baseline Lighting Control Type Code
- Installed Lighting Control Type Code[21]
- Lighting Control Mount Type: Wall, Ceiling, Integrated Fixture, etc.

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[18] No control savings are allowed for outdoor controls because they are already required by code. ASHRAE 90.1-1989, Section 6.4.2.8 specifies that exterior lighting not intended for 24-hour continuous use shall be automatically switched by timer, photocell, or a combination of timer and photocell. This is consistent with current specifications in ASHRAE 90.1-2010, Section 9.4.1.3, which specifies that lighting for all exterior applications shall have automatic controls capable of turning off exterior lighting when sufficient daylight is available or when the lighting is not required during nighttime hours.

[19] For multiple control types, specify the installed control types by combining the control codes for the individual control types.

[20] GDS Associates. Measure Life Report – Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for the New England State Program Working Group (SPWG). June 2007. This report only specifies an EUL for Occupancy Sensors and Photocells, so it is assumed that the same EUL was applied to time clocks. http://library.cee1.org/content/measure-life-report-residential-and-commercialindustrial-lighting-and-hvac-measures.

[21] For a control type that combines multiple features (e.g. occupancy + daylighting), specify the installed control types by combining the control codes for the individual control types.

- Lighting Control Specification Sheets
- Controlled Fixture Configuration
- Controlled Fixture Lamp Type
- Controlled Fixture Wattage

## References and Efficiency Standards

## Petitions and Rulings

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

## Relevant Standards and Reference Sources

- 2009 IECC (Commercial buildings)
- ASHRAE 90.1-2010 (Public/State buildings)
- ANSI/ASHRAE/IESNA Standard 90.1 -2007

## Document Revision History

**Table 2-10: Nonresidential Lighting Controls Revision History**

| TRM Version | Date | Description of Change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin |
| v2.0 | 04/18/2014 | No revisions |
| v2.1 | 01/30/2015 | Corrections to Equation 5 and Equation 6 to accurately reflect the energy and power adjustment factors and to reflect savings based on connected load rather than a delta load. Consolidation of algorithms for Retrofit and New Construction projects. |
| v3.0 | 04/10/2015 | Update EAF and PAF factors with values from a more current and comprehensive controls study. Update equations to use a "controlled lighting watts" approach for both retrofit and new construction. Updated Program Tracking parameters for consistency with other Lighting measure and added interior/exterior location. |
| v4.0 | 10/10/2016 | No revisions |

## 2.2 NONRESIDENTIAL: HVAC

### 2.2.1 Air Conditioner or Heat Pump Tune-up Measure Overview

**TRM Measure ID:** To be determined

**Market Sector:** Commercial

**Measure Category:** HVAC

**Applicable Building Types:** See Table 2-19 through Table 2-25

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed Savings Calculations

**Savings Methodology:** Engineering Algorithms and Estimates

## Measure Description

This measure applies to direct expansion central air conditioners and heat pumps of any configuration as long as everything on the checklist below can be completed. An AC tune-up involves checking, cleaning, adjusting, and resetting the equipment to factory conditions in the understanding that such measures restore operating efficiencies, on average, closer to as-new performance. This measure applies to all commercial applications.

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

**Air Conditioner Inspection and Tune-Up Checklist**[22]

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

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

Clean evaporator and condenser coils

Clean indoor blower fan components

Inspect and clean or change air filters; replacement preferred best practice.

Measure airflow via static pressure across the cooling coil and adjust to manufacturers specifications.

Check refrigerant level and adjust to manufacturer specifications

- Check capacitor functionality and capacitance and compare to OEM specifications

## Eligibility Criteria

All commercial customers are eligible for this measure if they have direct expansion refrigerated air conditioning that has not been serviced in the last 5 years. This measure does not apply to chillers.

## Baseline Condition

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

- Dirty condenser coil

  Dirty evaporator coil

  Dirty blower wheel

  Dirty filter

  Improper airflow
- Incorrect refrigerant charge

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

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

**Equation 7**

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

**Equation 8**

Where:

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

$EL$ = Efficiency loss due to dirty coils, blower, filter, improper airflow, and/or incorrect refrigerant charge = 0.05

$EER_{post}$ = Deemed cooling efficiency of the equipment after tune-up. See Table 2-11.

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

$HSPF_{post}$ = Deemed heating efficiency of air source heat pumps after tune-up. See Table 2-11.

**Table 2-11: Default EER and HSPF per Size Category[23]**

| Size Category (Btuh/hr) | AC Only Default EER | Heat Pump Default EER | Default HSPF |
|---|---|---|---|
| < 65,000 | 11.2 | 11.2 | 7.7 |
| ≥ 65,000 and < 135,000 | 10.1 | 9.9 | 10.9 |
| ≥ 135,000 and < 240,000 | 9.5 | 9.1 | 10.6 |
| ≥ 240,000 and < 760,000 | 9.3 | 8.8 | 10.6 |
| ≥ 760,000 | 9.0 | 8.8 | 10.6 |

## High-Efficiency Condition

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

The efficiency standard, or efficiency after the tune-up, is deemed to be the manufacturer specified energy efficiency ratio (EER) of the existing central air conditioner or heat pump, which has been determined using the following logic and standards. The useful life of an AC unit is 19 years. The useful life of a heat pump is 16 years. Therefore, it is conservatively thought that the majority of existing, functioning units were installed under the federal standard in place between January 23, 2006 and January 1, 2015 for units less than 65,000 Btuh, which set a baseline of 13 SEER and 7.7[24] HSPF; and prior to January 1, 2010 for units greater than 65,000 Btuh. A 13 SEER is equivalent to approximately 11.2 EER[25] using the conversion developed by Lawrence Berkeley Lab and US DOE: EER = -0.02 x $SEER^2$ + 1.12 x SEER. A 3.2 and 3.1 COP is equivalent to approximately 10.9 and 10.6 HSPF respectively using the conversion of HSPF = 3.412 x COP.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Savings are based on an assumed efficiency loss factor of five percent due to dirty coils, dirty filters, improper airflow, and/or incorrect refrigerant charge.[26]

[23] Code specified EER and HSPF value from ASHRAE 90.1-2010 (efficiency value effective January 23, 2006 for units < 65,000 Btu/hr and prior to January 1, 2010 for units ≥ 65,000 Btu/hr). HSPF converted from COP x 3.412.

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

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

[26] Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of

## ***Energy Savings Algorithms***

Heating energy savings are only applicable to heat pumps.

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

**Equation 9**

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

**Equation 10**

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

**Equation 11**

*Where:*

| | | |
|---|---|---|
| *Capacity* | = | *Rated cooling capacity of the equipment based on model number [Btuh] (1 ton = 12,000 Btuh)* |
| $EER_{pre}$ | = | *Cooling efficiency of the equipment pre-tune-up using Equation10 [Btuh/W]* |
| $EER_{post}$ | = | *Cooling efficiency of the equipment after the tune-up [Btuh/W]* |
| $HSPF_{pre}$ | = | *Heating efficiency of the equipment pre-tune-up using Equation 11 [Btuh/W]* |
| $HSPF_{post}$ | = | *Heating efficiency of the equipment after the tune-up [Btuh/W]* |
| $EFLH_{C/H}$ | = | *Cooling/heating equivalent full-load hours for appropriate climate zone [hours]. See Table 2-21 through 2-25 in Section 2.* |

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

**Equation 12**

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

**Equation 13**

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Recent Field Research."

### *Demand Savings Algorithms*

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

*Where:*

$DF_C$ = *Cooling Demand factor. See Table 2-21 through Table 2-25 in Section 2.2.2.*

$DF_H$ = *Heating Demand factor. See Table 2-21 through Table 2-25 in Section 2.2.2.*

## Deemed Energy Savings Tables

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

## Deemed Summer Demand Savings Tables

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

## Deemed Winter Demand Savings Tables

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

## Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

## Additional Calculators and Tools

This section is not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) for a tune-up is 5 years.[27]

According to the 2014 California Database for Energy Efficiency Resources (DEER), the estimated useful life of cleaning condenser and evaporator coils is 3 years[28], and the estimated useful life of refrigerant charge adjustment is 10 years.[29] The other parts of the tune-up checklist

[27] GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group; Page 1-3, Table 1.

[28] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx.

[29] ibid

are not listed in DEER, therefore 5 years, as referenced by the Measure Life Report, is used as the best representation of the entire tune-up.

## Program Tracking Data & Evaluation Requirements

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

- Manufacturer
- Model Number
- Cooling capacity of the installed unit (tons)
- Climate zone or county of the site
- Type of unit
  - air conditioner
  - air source heat pump
- Recommended:
  - serial number
  - refrigerant type
  - target superheat or subcooling
  - post tune-up superheat or subcooling
  - amount of refrigerant added or removed
  - static pressures before and after tune-up
  - return and supply dry bulb and wet bulb temperatures
  - before and after tune-up pictures of components illustrating condition change due to cleanings (Note: pictures that include well-placed familiar objects like hand tools often provide a sense of scale and a reference for color/shading comparisons. Pictures of equipment name plates are useful.)

## References and Efficiency Standards

## Petitions and Rulings

This section is not applicable.

## Document Revision History

**Table 2-12: Nonresidential HVAC Single-Zone AC-HP History**

| TRM Version | Date | Description of Change |
|---|---|---|
| v4.0 | 10/10/2016 | TRM v4.0 origin |

## 2.2.2 Split System/Single Packaged Air Conditioners and Heat Pumps Measure Overview

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

**Market Sector:** Commercial

**Measure Category:** HVAC

**Applicable Building Types:** See Table 2-19 through Table 2-25

**Fuels Affected:** Electricity

**Decision/Action Type:** Replace-on-Burnout (ROB), Early Retirement (ER), and New Construction (NC)

**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 air-cooled Split System and Single Packaged Air Conditioning (AC) and Heat Pump (HP) systems. This document covers assumptions made for baseline equipment efficiencies for early retirement (ER) based on the age of the replaced equipment, and replace-on-burnout (ROB) and new construction (NC) situations based on efficiency standards. Savings calculations incorporate the use of both full-load and part-load efficiency values. For ER, the actual age of the baseline system should be determined from the equipment nameplate or other physical documentation whenever possible. In the event that the actual age of the unit is unknown, default values are provided.

Applicable efficient measure types include:

- Packaged and Split air conditioners (DX or air-cooled)
- Packaged and Split heat pumps (air-cooled)
- System Type Conversions. Retrofits involving a change from a chiller-based system to a packaged/split system are also covered under this measure. In the event that this type of retrofit is performed, the tables from the HVAC Chillers measure will need to be referenced.

## Eligibility Criteria

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

- The existing and proposed cooling equipment are electric.
- The climate zone is determined from the county-to-climate-zone mapping table.

- The building falls into one of the categories listed in Table 2-21 through Table 2-25. Building type descriptions and examples are provided in Table 2-19 and Table 2-20.
- For early retirement projects: ER projects involve the replacement of a working system that is at least five years old before natural burnout. Additionally, the ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. An ROB approach should be used for these scenarios.

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.

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

Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL-RUL) period. For the ROB period, the baseline efficiency is the same as for an ROB/NC scenario. For the ER period, the baseline efficiency should be estimated using the values from Table 2-13 through Table 2-17 according to the capacity, system type, and age (based on year of manufacture) of the replaced system.[30] When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 2-13 through Table 2-17 should be used. These tables will be updated every few years so that systems greater than five years old will be eligible for early retirement. When the system age is unknown, assume an age of 17 years.[31]

Regarding the ER baseline efficiency tables, PUCT Docket 40885 provided baseline efficiencies for split and packaged systems replaced via early retirement programs, and included a category for 1990-1991. However, common practice for energy efficiency programs in Texas is to allow systems older than 1990 to use the same baseline efficiencies as those listed for 1990-1991. This practice is reflected in the ER baseline efficiency tables, by showing the Year Installed as "≤ 1991" rather than 1990-1991.

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

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

**Table 2-13: ER Baseline Full-Load Efficiency for ACs**

| Year Installed (Replaced System) | Split Systems < 5.4 tons [EER][32] | Package System < 5.4 tons [EER][33] | All Systems 5.4 to < 11.3 tons [EER] | All Systems 11.3 to < 20 tons [EER] | All Systems 20 to < 63.3 tons [EER] | All Systems ≥ 63.3 tons [EER] |
|---|---|---|---|---|---|---|
| ≤ 1991 | 9.2 | 9.0 | 8.9 | 8.0 | 8.0 | 7.8 |
| 1992 – 2001 | 9.2 | 9.0 | 8.9 | 8.3 | 8.3 | 8.0 |
| 2002 – 2005 | 9.2 | 9.0 | 10.1 | 9.5 | 9.3 | 9.0 |
| 2006 – 2009 | 11.2 | 11.2 | 10.1 | 9.5 | 9.3 | 9.0 |
| 2010 – 2012 | 11.2 | 11.2 | 11.0 | 10.8 | 9.8 | 9.5 |

**Table 2-14: ER Baseline Part-Load Efficiency for ACs[34]**

| Year Installed (Replaced System) | Split Systems < 5.4 tons [SEER] | Package System < 5.4 tons [SEER] | All Systems 5.4 to < 11.3 tons [IEER] | All Systems 11.3 to < 20 tons [IEER] | All Systems 20 to < 63.3 tons [IEER] | All Systems ≥ 63.3 tons [IEER] |
|---|---|---|---|---|---|---|
| ≤ 1991 | 10.0 | 9.7 | 9.1 | 8.2 | 8.1 | 7.9 |
| 1992 – 2001 | 10.0 | 9.7 | 9.1 | 8.5 | 8.4 | 8.1 |
| 2002 – 2005 | 10.0 | 9.7 | 10.3 | 9.7 | 9.4 | 9.1 |
| 2006 – 2009 | 13.0 | 13.0 | 10.3 | 9.7 | 9.4 | 9.1 |
| 2010 – 2012 | 13.0 | 13.0 | 11.2 | 11.0 | 9.9 | 9.6 |

[32] The standards do not include an EER requirement for this size range, so the code specified SEER value was converted to EER using EER = -0.02 x SEER² + 1.12 x SEER. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf

[33] Ibid.

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

**Table 2-15: ER Baseline Full-Load Cooling Efficiency for HPs**

| Year Installed (Replaced System) | Split Systems < 5.4 tons [EER][35] | Package System < 5.4 tons [EER][36] | All Systems 5.4 to < 11.3 tons [EER] | All Systems 11.3 to < 20 tons [EER] | All Systems 20 to < 63.3 tons [EER] | All Systems ≥ 63.3 tons [EER] |
|---|---|---|---|---|---|---|
| ≤ 1991 | 9.2 | 9.0 | 8.9 | 8.0 | 8.0 | 7.8 |
| 1992 – 2001 | 9.2 | 9.0 | 8.9 | 8.3 | 8.3 | 8.5 |
| 2002 – 2005 | 9.2 | 9.0 | 9.9 | 9.1 | 8.8 | 8.8 |
| 2006 – 2009 | 11.2 | 11.2 | 9.9 | 9.1 | 8.8 | 8.8 |
| 2010 – 2012 | 11.2 | 11.2 | 10.8 | 10.4 | 9.3 | 9.3 |

**Table 2-16: ER Baseline Part-Load Cooling Efficiency for HPs[37]**

| Year Installed (Replaced System) | Split Systems < 5.4 tons [SEER] | Package System < 5.4 tons [SEER] | All Systems 5.4 to < 11.3 tons [IEER] | All Systems 11.3 to < 20 tons [IEER] | All Systems 20 to < 63.3 tons [IEER] | All Systems ≥ 63.3 tons [IEER] |
|---|---|---|---|---|---|---|
| ≤ 1991 | 10.0 | 9.7 | 9.1 | 8.1 | 8.1 | 7.9 |
| 1992 – 2001 | 10.0 | 9.7 | 9.1 | 8.4 | 8.4 | 8.6 |
| 2002 – 2005 | 10.0 | 9.7 | 10.1 | 9.2 | 8.9 | 8.9 |
| 2006 – 2009 | 13.0 | 13.0 | 10.1 | 9.2 | 8.9 | 8.9 |
| 2010 – 2012 | 13.0 | 13.0 | 11.0 | 10.5 | 9.4 | 9.4 |

**Table 2-17: ER Baseline Heating Efficiency for HPs**

| Year Installed (Replaced System) | Split Systems < 5.4 tons [HSPF] | Package System < 5.4 tons [HSPF] | All Systems 5.4 to < 11.3 tons [COP] | All Systems ≥ 11.3 tons [COP] |
|---|---|---|---|---|
| ≤ 1998 | 6.8 | 6.6 | 3.0 | 3.0 |
| 1999 – 2000 | 6.8 | 6.6 | 3.0 | 2.9 |
| 2001 – 2005 | 6.8 | 6.6 | 3.2 | 3.1 |
| 2006 – 2009 | 7.7 | 7.7 | 3.2 | 3.1 |

[35] The standards do not include an EER requirement for this size range, so the code specified SEER value was converted to EER using EER = -0.02 x $SEER^2$ + 1.12 x SEER. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

[36] Ibid.

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

| | | | | |
|---|---|---|---|---|
| 2010 – 2012 | 7.7 | 7.7 | 3.3 | 3.2 |

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

Baseline efficiency levels for package and split DX air conditioners and heat pumps are provided in Table 2-18. These baseline efficiency levels reflect the latest minimum efficiency requirements from the current federal manufacturing standard and ASHRAE 90.1-2010.

**Table 2-18: Baseline Efficiency Levels for ROB and NC Air Conditioners and Heat Pumps**

| System Type | Capacity [Tons] | Heating Section Type | Baseline Efficiencies | Source[38] |
|---|---|---|---|---|
| Air Conditioner | < 5.4 | All | 11.8 EER[39]<br>13.0 SEER (3-phase)<br>14.0 SEER (1-phase) | DOE Standards/ ASHRAE 90.1-2010 |
| | 5.4 to < 11.3 | None or Electric Resistance | 11.2 EER<br>11.4 IEER | |
| | | All Other | 11.0 EER<br>11.2 IEER | |
| | 11.3 to < 20 | None or Electric Resistance | 11.0 EER<br>11.2 IEER | |
| | | All Other | 10.8 EER<br>11.0 IEER | |
| | 20 to < 63.3 | None or Electric Resistance | 10.0 EER<br>10.1 IEER | |
| | | All Other | 9.8 EER<br>9.9 IEER | |
| | ≥ 63.3 | None or Electric Resistance | 9.7 EER<br>9.8 IEER | ASHRAE 90.1-2010 |
| | | All Other | 9.5 EER<br>9.6 IEER | |

[38] 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.

[39] There is no code specified EER for this size category. The code specified SEER value was converted to EER using EER = -0.02 x SEER$^2$ + 1.12 x SEER for systems < 5.4 tons. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

| System Type | Capacity [Tons] | Heating Section Type | Baseline Efficiencies | Source[38] |
|---|---|---|---|---|
| Heat Pump (cooling)[40] | < 5.4 | Heat Pump | 11.8 EER[41]<br>14.0 SEER | DOE Standards/ ASHRAE 90.1-2010 |
| | 5.4 to < 11.3 | | 11.0 EER<br>11.2 IEER | |
| | 11.3 to < 20 | | 10.6 EER<br>10.7 IEER | |
| | ≥ 20 | | 9.5 EER<br>9.6 IEER | |
| Heat Pump (heating)[42] | < 5.4 | Heat Pump | 8.2 HSPF (split)<br>8.0 HSPF (packaged) | DOE Standards |
| | 5.4 to < 11.25 | | 3.3 COP | |
| | ≥ 11.3 | | 3.2 COP | |

## High-Efficiency Condition

Package and split-systems must exceed the minimum efficiencies specified in Table 2-18.

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

The high-efficiency retrofits must meet the following criteria[43]:

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

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

[41] There is no code specified EER for this size category. The code specified SEER value converted to EER using EER = -0.02 x SEER$^2$ + 1.12 x SEER for systems < 5.4 tons. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

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

[43] From PUCT Docket #41070.

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

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

**Equation 14**

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

**Equation 15**

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

**Equation 16**

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

**Equation 17**

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

**Equation 18**

*Where:*

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

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

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

$\eta_{installed,C}$ = *Rated cooling efficiency of the newly installed equipment (kW/Ton) - (Must exceed ROB/NC baseline efficiency standards in* Table 2-18*) [Btuh/W]*

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

$\eta_{installed,H}$ = *Rated heating efficiency of the newly installed equipment (Must exceed baseline efficiency standards in* Table 2-18*) [COP]*

*Note: Use EER for kW savings calculations and SEER/IEER and COP for kWh savings calculations. The COP expressed for units ≥ 5.4 tons is a full-load COP. Heating efficiencies expressed as HSPF will be approximated as a seasonal COP and should be converted using the following equation:*

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

**Equation 19**

*DF* = *Seasonal peak demand factor for appropriate climate zone, building type, and equipment type (*Table 2-21 *through* Table 2-25*)*

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours for appropriate climate zone, building type, and equipment type [hours] (*Table 2-21 *through* Table 2-25*)*

## ***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 a weighted savings calculated over both the ER and ROB periods taking the EUL and RUL into account. The ER savings are applied over the remaining useful life (RUL) period, and the ROB savings are applied over the remaining period (EUL-RUL). The final reported savings for ER projects are not actually a "first-year" savings, but an "average annual savings over the lifetime (EUL) of the measure". These savings calculations are explained in Appendix D.

## Deemed Energy and Demand Savings Tables

Deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone. A description of the building types that are used for HVAC systems are presented in Table 2-19 and Table 2-20. These building types are derived from the EIA CBECS study.[44]

The DF and EFLH values for packaged and split AC and HP units are presented in Table 2-21 through Table 2-25. These tables also include an "Other" building type, which can be used for business types that are not explicitly listed. The DF and EFLH values used for Other are the most conservative values from the explicitly listed building types. When the Other building type is used, a description of the actual building type, the primary business activity, the business hours, and the HVAC schedule must be collected for the project site, and stored in the utility tracking data system.

For those combinations of technology, climate zone, and building type where no values are present, a project with that specific combination cannot use the deemed approach.

[44] The Commercial Building Energy Consumption Survey (CBECS) implemented by the US Energy Information Administration includes a principal building activity categorization scheme that separates the commercial sector into 29 categories and 51 subcategories based on principal building activity (PBA). For its purposes, the CBECS defines commercial buildings as those *buildings greater than 1,000 square feet that devote more than half of their floorspace to activity that is neither residential, manufacturing, industrial, nor agricultural. The high-level building types adopted for the TRM are adapted from this CBECS categorization, with some building types left out and one additional building type - Large Multifamily – included.*

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

**Table 2-19: Commercial HVAC Building Type Descriptions and Examples**

| Building Type | Principal Building Activity | Definition | Detailed Business Type Examples[45] |
|---|---|---|---|
| Education | College | Buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools, and classroom buildings on college or university campuses. Buildings on education campuses for which the main use is not classroom are included in the category relating to their use. For example, administration buildings are part of "Office," dormitories are "Lodging," and libraries are "Public Assembly." | 1) College or University<br>2) Career or Vocational Training<br>3) Adult Education |
| | Primary School | | 1) Elementary or Middle School<br>2) Preschool or Daycare |
| | Secondary School | | 1) High School<br>2) Religious Education |
| Food Sales | Convenience | Buildings used for retail or wholesale of food. | 1) Gas Station with a Convenience Store<br>2) Convenience Store |
| | Supermarket | | 1) Grocery Store or Food Market |
| Food Service | Full-Service Restaurant | Buildings used for preparation and sale of food and beverages for consumption. | 1) Restaurant or Cafeteria |
| | Quick-Service Restaurant | | 1) Fast Food |
| Healthcare | Hospital | Buildings used as diagnostic and treatment facilities for inpatient care. | 1) Hospital<br>2) Inpatient Rehabilitation |
| | Outpatient Healthcare | Buildings used as diagnostic and treatment facilities for outpatient care. Medical offices are included here if they use any type of diagnostic medical equipment (if they do not, they are categorized as an office building). | 1) Medical Office<br>2) Clinic or Outpatient Health Care<br>3) Veterinarian |
| Large Multifamily | Midrise Apartment | Buildings containing multifamily dwelling units, having multiple stories, and equipped with elevators. | No sub-categories collected. |

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

| Building Type | Principal Building Activity | Definition | Detailed Business Type Examples[45] |
|---|---|---|---|
| Lodging | Large Hotel | Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings. | 1) Motel or Inn<br>2) Hotel<br>3) Dormitory, Fraternity, or Sorority<br>4) Retirement Home, Nursing Home, Assisted Living, or other Residential Care<br>5) Convent or Monastery |
| | Nursing Home | | |
| | Small Hotel/Motel | | |
| Mercantile | Stand-Alone Retail | Buildings used for the sale and display of goods other than food. | 1) Retail Store<br>2) Beer, Wine, or Liquor Store<br>3) Rental Center<br>4) Dealership or Showroom for Vehicles or Boats<br>5) Studio or Gallery |
| | Strip Mall | Shopping malls comprised of multiple connected establishments. | 1) Strip Shopping Center<br>2) Enclosed Malls |
| Office | Large Office | Buildings used for general office space, professional office, or administrative offices. Medical offices are included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient health care building). | 1) Administrative or Professional Office<br>2) Government Office<br>3) Mixed-Use Office<br>4) Bank or Other Financial Institution<br>5) Medical Office<br>6) Sales Office<br>7) Contractor's Office (e.g. Construction, Plumbing, HVAC)<br>8) Non-Profit or Social Services<br>9) Research and Development<br>10) City Hall or City Center<br>11) Religious Office<br>12) Call Center |
| | Medium Office | | |
| | Small Office | | |

| Building Type | Principal Building Activity | Definition | Detailed Business Type Examples[45] |
|---|---|---|---|
| Public Assembly | Public Assembly | Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls. | 1) Social or Meeting (e.g. Community Center, Lodge, Meeting Hall, Convention Center, Senior Center)<br>2) Recreation (e.g. Gymnasium, Health Club, Bowling Alley, Ice Rink, Field House, Indoor Racquet Sports)<br>3) Entertainment or Culture (e.g. Museum, Theater, Cinema, Sports Arena, Casino, Night Club)<br>4) Library<br>5) Funeral Home<br>6) Student Activities Center<br>7) Armory<br>8) Exhibition Hall<br>9) Broadcasting Studio<br>10) Transportation Terminal |
| Religious Worship | Religious Worship | Buildings in which people gather for religious activities, (such as chapels, churches, mosques, synagogues, and temples). | No sub-categories collected. |

| Building Type | Principal Building Activity | Definition | Detailed Business Type Examples[45] |
|---|---|---|---|
| Service | Service | Buildings in which some type of service is provided, other than food service or retail sales of goods. | 1) Vehicle Service or Vehicle Repair Shop<br>2) Vehicle Storage/Maintenance<br>3) Repair Shop<br>4) Dry Cleaner or Laundromat<br>5) Post Office or Postal Center<br>6) Car Wash<br>7) Gas Station with no Convenience Store<br>8) Photo Processing Shop<br>9) Beauty Parlor or Barber Shop<br>10) Tanning Salon<br>11) Copy Center or Printing Shop<br>12) Kennel |
| Warehouse | Warehouse | Buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage). | 1) Refrigerated Warehouse<br>2) Non-refrigerated warehouse<br>3) Distribution or Shipping Center |
| Other | Other | For building types not explicilited listed. | Values used for Other are the most conservative values from the explicitly listed building types. |

**Table 2-20: Commercial HVAC Floor Area and Floor Assumptions by Building Type[46]**

| Building Type | Principal Building Activity | Average Floor Area ($ft^2$) | Average # of Floors |
|---|---|---|---|
| Education | College | Not specified | Not specified |
| | Primary School | 73,960 | 1 |
| | Secondary School | 210,887 | 2 |
| Food Sales | Convenience | Not specified | 1 |
| | Supermarket | 45,000 | 1 |
| Food Service | Full-Service Restaurant | 5,500 | 1 |
| | Quick-Service Restaurant | 2,500 | 1 |
| Healthcare | Hospital | 241,351 | 5 |
| | Outpatient Healthcare | 40,946 | 3 |
| Large Multifamily | Midrise Apartment | 33,740 | 4 |
| Lodging | Large Hotel | 122,120 | 6 |
| | Nursing Home | Not specified | Not specified |
| | Small Hotel/Motel | 43,200 | 4 |
| Mercantile | Stand-Alone Retail | 24,962 | 1 |
| | Strip Mall | 22,500 | 1 |
| Office | Large Office | 498,588 | 12 |
| | Medium Office | 53,628 | 3 |
| | Small Office | 5,500 | 1 |
| Public Assembly | Public Assembly | Not specified | Not specified |
| Religious Worship | Religious Worship | Not specified | Not specified |
| Service | Service | Not specified | Not specified |
| Warehouse | Warehouse | 52,045 | 1 |

[46] Building prototype information from DOE Commercial Reference Buildings, "Not specified" means that a building prototype is not defined for that building type. http://energy.gov/eere/buildings/commercial-reference-buildings, last accessed 10/20/2015.

**Table 2-21: DF and EFLH Values for Amarillo (Climate Zone 1)**

| Building Type | Principal Building Activity | Package and Split DX | | | | | |
|---|---|---|---|---|---|---|---|
| | | Air Conditioner | | Heat Pump | | | |
| | | DF | $EFLH_C$ | DF | $EFLH_C$ | $DF_H$ | $EFLH_H$ |
| Education | College | 0.69 | 787 | -- | -- | -- | -- |
| | Primary School | 0.64 | 740 | 0.64 | 740 | 0.43 | 701 |
| | Secondary School | 0.69 | 535 | 0.69 | 535 | 0.43 | 736 |
| Food Sales | Convenience | 0.73 | 884 | -- | -- | -- | -- |
| | Supermarket | 0.29 | 219 | -- | -- | -- | -- |
| Food Service | Full-Service Restaurant | 0.83 | 1,020 | 0.83 | 1,020 | 0.43 | 1,123 |
| | Quick-Service Restaurant | 0.73 | 765 | 0.73 | 765 | 0.48 | 1,029 |
| Healthcare | Hospital | 0.72 | 2,185 | -- | -- | -- | -- |
| | Outpatient Healthcare | 0.71 | 2,036 | 0.71 | 2,036 | 0.27 | 579 |
| Large Multifamily | Midrise Apartment | 0.68 | 674 | -- | -- | -- | -- |
| Lodging | Large Hotel | 0.58 | 1,345 | 0.58 | 1,345 | 0.86 | 1,095 |
| | Nursing Home | 0.68 | 685 | -- | -- | -- | -- |
| | Small Hotel/Motel | 0.57 | 1,554 | 0.57 | 1,554 | 0.36 | 475 |
| Mercantile | Stand-Alone Retail | 0.68 | 623 | 0.68 | 623 | 0.99 | 907 |
| | Strip Mall | 0.75 | 687 | 0.75 | 687 | 0.39 | 753 |
| Office | Large Office | 0.90 | 2,058 | -- | -- | -- | -- |
| | Medium Office | 0.64 | 925 | 0.64 | 925 | 0.72 | 576 |
| | Small Office | 0.72 | 711 | 0.72 | 711 | 0.29 | 340 |
| Public Assembly | Public Assembly | 0.64 | 995 | -- | -- | -- | -- |
| Religious Worship | Religious Worship | 0.57 | 387 | -- | -- | -- | -- |
| Service | Service | 0.83 | 790 | -- | -- | -- | -- |
| Warehouse | Warehouse | 0.34 | 173 | -- | -- | -- | -- |
| Other | Other | 0.29 | 173 | 0.29 | 173 | 0.27 | 340 |

**Table 2-22: DF and EFLH Values for Fort Worth (Climate Zone 2)**

| Building Type | Principal Building Activity | Package and Split DX | | | | | |
|---|---|---|---|---|---|---|---|
| | | Air Conditioner | | Heat Pump | | | |
| | | DF | $EFLH_C$ | DF | $EFLH_C$ | $DF_H$ | $EFLH_H$ |
| Education | College | 1.02 | 1,595 | -- | -- | -- | -- |
| | Primary School | 0.88 | 1,208 | 0.88 | 1,208 | 0.66 | 397 |
| | Secondary School | 1.02 | 1,084 | 1.02 | 1,084 | 0.59 | 489 |
| Food Sales | Convenience | 1.08 | 1,835 | -- | -- | -- | -- |
| | Supermarket | 0.58 | 615 | -- | -- | -- | -- |
| Food Service | Full-Service Restaurant | 1.09 | 1,823 | 1.09 | 1,823 | 0.50 | 688 |
| | Quick-Service Restaurant | 1.08 | 1,588 | 1.08 | 1,588 | 0.61 | 631 |
| Healthcare | Hospital | 0.92 | 3,097 | -- | -- | -- | -- |
| | Outpatient Healthcare | 0.80 | 2,532 | 0.80 | 2,532 | 0.28 | 310 |
| Large Multifamily | Midrise Apartment | 1.04 | 1,709 | -- | -- | -- | -- |
| Lodging | Large Hotel | 0.70 | 2,079 | 0.70 | 2,079 | 0.82 | 464 |
| | Nursing Home | 1.04 | 1,736 | -- | -- | -- | -- |
| | Small Hotel/Motel | 0.55 | 2,281 | 0.55 | 2,281 | 0.42 | 249 |
| Mercantile | Stand-Alone Retail | 0.95 | 1,157 | 0.95 | 1,157 | 0.55 | 352 |
| | Strip Mall | 0.91 | 1,100 | 0.91 | 1,100 | 0.55 | 376 |
| Office | Large Office | 1.03 | 2,379 | -- | -- | -- | -- |
| | Medium Office | 0.76 | 1,236 | 0.76 | 1,236 | 0.66 | 262 |
| | Small Office | 0.92 | 1,203 | 0.92 | 1,203 | 0.40 | 153 |
| Public Assembly | Public Assembly | 0.88 | 1,624 | -- | -- | -- | -- |
| Religious Worship | Religious Worship | 0.55 | 567 | | | | |
| Service | Service | 1.09 | 1,412 | | | | |
| Warehouse | Warehouse | 0.84 | 597 | -- | -- | -- | -- |
| Other | Other | 0.55 | 567 | 0.55 | 567 | 0.28 | 153 |

**Table 2-23: DF and EFLH Values for Houston (Climate Zone 3)**

| Building Type | Principal Building Activity | Package and Split DX | | | | | |
|---|---|---|---|---|---|---|---|
| | | Air Conditioner | | Heat Pump | | | |
| | | DF | $EFLH_C$ | DF | $EFLH_C$ | $DF_H$ | $EFLH_H$ |
| Education | College | 0.98 | 1,843 | -- | -- | -- | -- |
| | Primary School | 0.88 | 1,443 | 0.88 | 1,443 | 0.50 | 239 |
| | Secondary School | 0.98 | 1,253 | 0.98 | 1,253 | 0.54 | 293 |
| Food Sales | Convenience | 1.03 | 2,142 | -- | -- | -- | -- |
| | Supermarket | 0.60 | 744 | -- | -- | -- | -- |
| Food Service | Full-Service Restaurant | 1.05 | 2,135 | 1.05 | 2,135 | 0.44 | 429 |
| | Quick-Service Restaurant | 1.03 | 1,853 | 1.03 | 1,853 | 0.51 | 372 |
| Healthcare | Hospital | 0.90 | 3,490 | -- | -- | -- | -- |
| | Outpatient Healthcare | 0.80 | 2,844 | 0.80 | 2,844 | 0.29 | 196 |
| Large Multifamily | Midrise Apartment | 1.00 | 2,031 | -- | -- | -- | -- |
| Lodging | Large Hotel | 0.70 | 2,531 | 0.70 | 2,531 | 0.33 | 250 |
| | Nursing Home | 1.00 | 2,063 | -- | -- | -- | -- |
| | Small Hotel/Motel | 0.65 | 2,316 | 0.65 | 2,316 | 0.19 | 147 |
| Mercantile | Stand-Alone Retail | 0.95 | 1,399 | 0.95 | 1,399 | 0.43 | 204 |
| | Strip Mall | 0.92 | 1,330 | 0.92 | 1,330 | 0.42 | 218 |
| Office | Large Office | 1.00 | 2,619 | -- | -- | -- | -- |
| | Medium Office | 0.75 | 1,387 | 0.75 | 1,387 | 0.42 | 149 |
| | Small Office | 0.88 | 1,338 | 0.88 | 1,338 | 0.28 | 69 |
| Public Assembly | Public Assembly | 0.88 | 1,940 | -- | -- | -- | -- |
| Religious Worship | Religious Worship | 0.65 | 576 | -- | -- | -- | -- |
| Service | Service | 1.05 | 1,653 | -- | -- | -- | -- |
| Warehouse | Warehouse | 0.84 | 633 | -- | -- | -- | -- |
| Other | Other | 0.60 | 576 | 0.60 | 576 | 0.19 | 69 |

**Table 2-24: DF and EFLH Values for Brownsville (Climate Zone 4)**

| Building Type | Principal Building Activity | Package and Split DX | | | | | |
|---|---|---|---|---|---|---|---|
| | | Air Conditioner | | Heat Pump | | | |
| | | DF | $EFLH_C$ | DF | $EFLH_C$ | $DF_H$ | $EFLH_H$ |
| Education | College | 0.96 | 2,211 | -- | -- | -- | -- |
| | Primary School | 0.88 | 1,680 | 0.88 | 1,680 | 0.30 | 156 |
| | Secondary School | 0.96 | 1,503 | 0.96 | 1,503 | 0.35 | 196 |
| Food Sales | Convenience | 0.94 | 2,510 | -- | -- | -- | -- |
| | Supermarket | 0.54 | 894 | -- | -- | -- | -- |
| Food Service | Full-Service Restaurant | 0.98 | 2,530 | 0.98 | 2,530 | 0.35 | 292 |
| | Quick-Service Restaurant | 0.94 | 2,172 | 0.94 | 2,172 | 0.34 | 232 |
| Healthcare | Hospital | 0.86 | 3,819 | -- | -- | -- | -- |
| | Outpatient Healthcare | 0.78 | 3,092 | 0.78 | 3,092 | 0.08 | 122 |
| Large Multifamily | Midrise Apartment | 0.92 | 2,236 | -- | -- | -- | -- |
| Lodging | Large Hotel | 0.65 | 2,981 | 0.65 | 2,981 | 0.21 | 131 |
| | Nursing Home | 0.92 | 2,271 | -- | -- | -- | -- |
| | Small Hotel/Motel | 0.58 | 2,530 | 0.58 | 2,530 | 0.10 | 82 |
| Mercantile | Stand-Alone Retail | 0.84 | 1,582 | 0.84 | 1,582 | 0.22 | 131 |
| | Strip Mall | 0.82 | 1,510 | 0.82 | 1,510 | 0.21 | 141 |
| Office | Large Office | 0.91 | 2,778 | -- | -- | -- | -- |
| | Medium Office | 0.66 | 1,523 | 0.66 | 1,523 | 0.24 | 83 |
| | Small Office | 0.80 | 1,504 | 0.80 | 1,504 | 0.14 | 39 |
| Public Assembly | Public Assembly | 0.88 | 2,259 | -- | -- | -- | -- |
| Religious Worship | Religious Worship | 0.58 | 629 | | | | |
| Service | Service | 0.98 | 1,959 | | | | |
| Warehouse | Warehouse | 0.73 | 665 | -- | -- | -- | -- |
| Other | Other | 0.54 | 629 | 0.54 | 629 | 0.08 | 39 |

**Table 2-25: DF and EFLH Values for El Paso (Climate Zone 5)**

| Building Type | Principal Building Activity | Package and Split DX | | | | | |
|---|---|---|---|---|---|---|---|
| | | Air Conditioner | | Heat Pump | | | |
| | | DF | $EFLH_C$ | DF | $EFLH_C$ | $DF_H$ | $EFLH_H$ |
| Education | College | 0.87 | 1,092 | -- | -- | -- | |
| | Primary School | 0.91 | 996 | 0.91 | 996 | 0.37 | 408 |
| | Secondary School | 0.87 | 742 | 0.87 | 742 | 0.43 | 431 |
| Food Sales | Convenience | 0.76 | 1,251 | -- | -- | -- | |
| | Supermarket | 0.38 | 347 | -- | -- | -- | -- |
| Food Service | Full-Service Restaurant | 0.76 | 1,276 | 0.76 | 1,276 | 0.28 | 613 |
| | Quick-Service Restaurant | 0.76 | 1,082 | 0.76 | 1,082 | 0.26 | 522 |
| Healthcare | Hospital | 0.81 | 2,555 | -- | -- | -- | -- |
| | Outpatient Healthcare | 0.81 | 2,377 | 0.81 | 2,377 | 0.04 | 320 |
| Large Multifamily | Midrise Apartment | 0.88 | 1,209 | -- | -- | -- | -- |
| Lodging | Large Hotel | 0.63 | 1,701 | 0.63 | 1,701 | 0.21 | 440 |
| | Nursing Home | 0.88 | 1,228 | -- | -- | -- | |
| | Small Hotel/Motel | 0.63 | 1,921 | 0.63 | 1,921 | 0.06 | 185 |
| Mercantile | Stand-Alone Retail | 0.80 | 904 | 0.80 | 904 | 0.26 | 384 |
| | Strip Mall | 0.83 | 931 | 0.83 | 931 | 0.27 | 448 |
| Office | Large Office | 0.98 | 2,423 | -- | -- | -- | -- |
| | Medium Office | 0.77 | 1,173 | 0.77 | 1,173 | 0.27 | 256 |
| | Small Office | 0.84 | 1,037 | 0.84 | 1,037 | 0.15 | 146 |
| Public Assembly | Public Assembly | 0.91 | 1,339 | -- | -- | -- | -- |
| Religious Worship | Religious Worship | 0.63 | 478 | -- | -- | -- | -- |
| Service | Service | 0.76 | 988 | -- | -- | -- | -- |
| Warehouse | Warehouse | 0.75 | 324 | -- | -- | -- | -- |
| Other | Other | 0.38 | 324 | 0.38 | 324 | 0.04 | 146 |

## Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation 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 Split and Packaged Air Conditioners and Heat Pumps is 15 years.[47]

### *Remaining Useful Life (RUL)*

The RUL of replaced systems is provided according to system age in Table 2-26. As previously noted, for ER units of unknown age, a default value of 17 years should be used. 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 D.

**Table 2-26: Remaining Useful Life Early Retirement Systems[48]**

| Age of Replaced System (years) | Split/Packaged AC/HP Systems RUL (years) | Age of Replaced System (years) | Split/Packaged AC/HP Systems RUL (years) |
|---|---|---|---|
| 5 | 10 | 15 | 2.8 |
| 6 | 9.1 | 16 | 2.5 |
| 7 | 8.2 | 17 | 2.2 |
| 8 | 7.3 | 18 | 1.9 |
| 9 | 6.5 | 19 | 1.7 |
| 10 | 5.7 | 20 | 1.5 |
| 11 | 5.0 | 21 | 1.3 |
| 12 | 4.4 | 22 | 1.1 |
| 13 | 3.8 | 23 | 1.0 |
| 14 | 3.3 | | |

[47] 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.

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

## Program Tracking Data & Evaluation Requirements

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

- Decision/Action Type; ER, ROB, NC, System Type Conversion
- Building Type
- Climate Zone
- Baseline Equipment Type
- Baseline Equipment Rated Cooling and Heating Capacity
- Baseline Number of Units
- For ER ONLY: Baseline Age and Method of Determination (e.g. nameplate, blueprints, customer reported, not available)
- Installed Equipment Type
- Installed Equipment Rated Cooling and Heating Capacities
- Installed Number of Units
- Installed Cooling and Heating Efficiency Ratings
- Installed Make & Model
- For Other building types ONLY: A description of the actual building type, the primary business activity, the business hours, and the HVAC schedule

## References and Efficiency Standards

### Petitions and Rulings

- PUCT Docket 36779 – Provides EUL for HVAC equipment.
- PUCT Docket 40083– Provides incorporation of 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 D.

## Relevant Standards and Reference Sources

- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1A through Table 6.8.1D.
- Code of Federal Regulations. Title 10. Part 431 – Energy Efficiency Program for Certain Commercial and Industrial Equipment. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/77.

## Document Revision History

**Table 2-27: Nonresidential HVAC Single-Zone AC-HP History**

| TRM Version | Date | Description of Change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin |
| v2.0 | 04/18/2014 | Modified Early Retirement savings calculations and added references to Appendix D which details those calculations. Added heat pump minimum required heating efficiencies for reference. Revised baseline efficiency standards based on updates to federal standards. |
| v2.1 | 01/30/2015 | Minor text updates and clarification of early retirement requirements. |
| v3.0 | 04/10/2015 | Update of savings method to allow for part-load efficiency calculations. For heat pumps: Added heating efficiencies and split EFLH into cooling and heating components. |
| v3.1 | 11/05/2015 | Update the building type definitions and descriptions. Added "Other" building type for when building type is not explicitly listed. |
| v4.0 | 10/10/2016 | Used modeling approach to update DF and EFLH for applicable building types and climate zones. Updated baseline efficiency values for split and packaged units less than 5.4 tons to be consistent with updated federal standards. |

## 2.2.3 HVAC Chillers Measure Overview

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

**Market Sector:** Commercial

**Measure Category:** HVAC

**Applicable Building Types:** See Table 2-35 through Table 2-39.

**Fuels Affected:** Electricity

**Decision/Action Type:** Replace on Burnout (ROB), Early Retirement (ER), and New Construction (NC)

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed Savings Calculation

**Savings Methodology:** Calculator

## Measure Description

This document presents the deemed savings methodology for the installation of chillers. This document covers assumptions made for baseline equipment efficiencies for early retirement (ER) based on the age of the replaced equipment, and replace-on-burnout (ROB) and new construction (NC) situations based on efficiency standards.

Savings calculations incorporate the use of both full-load and part-load efficiency values. For ER, the actual age of the baseline system should be determined from the equipment nameplate or other physical documentation whenever possible. In the event that the actual age of the unit is unknown, default values are provided.

Applicable efficient measure types include[49]:

- Compressor Types: Centrifugal or Positive-displacement (Screw, Scroll, or Reciprocating)
- Condenser/Heat Rejection Type: Air-cooled or Water-cooled System Type Conversions. Retrofits involving a change from a chiller-based system to a packaged/split system are also covered under this measure. In the event that this type of retrofit is performed, the tables from the Split/Single Packaged Air Conditioners and Heat Pumps measure will need to be referenced.
- Chiller Type Conversions: Conversion from an air-cooled chiller system to a water-cooled chiller system is also addressed in this measure. An additional adjustment is

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

made to the basic chiller savings to account for the auxiliary equipment associated with a water-cooled chiller.

## Eligibility Criteria

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

- The existing and proposed cooling equipment are electric.
- The climate zone is determined from the county-to-climate-zone mapping table. [50]
- The building falls into one of the categories listed in Table 2-35 through Table 2-39. Building type descriptions and examples are provided in Table 2-19 and Table 2-20.
- For early retirement projects: ER projects involve the replacement of a working system that is at least five years old before natural burnout. Additionally, the ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. An ROB approach should be used for these scenarios.

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

## Baseline Condition

### *Early Retirement*

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

Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL-RUL) period. For the ROB period, the baseline efficiency is the same as for an ROB/NC scenario. For the ER period, the baseline efficiency should be estimated using the values from Table 2-28 through Table 2-33 according to the capacity, chiller type, and age (based on year of manufacture) of the replaced system.[51] When the chiller age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 2-28 through Table 2-33 should be used. These tables will be updated every few years so that systems greater than 5 years old will be eligible for early retirement. When the system age is unknown, assume 21 years for Non-Centrifugal chillers and 26 years for Centrifugal chillers.

ER baseline efficiency values represent the code-specified efficiency in effect at the time the chiller was installed. Prior to 2002, code-specified efficiencies from ASHRAE 90.1-1989 were in effect. Code-specified efficiencies increased in 2002, approximating the effective date of ASHRAE 90.1-1999, which went into effect on October 29, 2001. Code-specified efficiencies increased again in 2010, coinciding with the ASHRAE90.1-2010 code increase (Path A).

[50] The TRM climate zone/regions and county-level assignments were created and are currently maintained by Frontier for the Electric Utilities Marketing Managers of Texas (EUMMOT).

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

Code-specified efficiencies in effect prior to 2010 (ASHRAE 90.1-2010), efficiencies were given in COP and have been converted to EER and kW/ton in the tables below using EER = COP x 3.412 and kW/ton = 3.516 ÷ COP. Values in the "≤ 2001" and "2002-2009" rows of Table 2-28, Table 2-30, Table 2-32 have been converted and are expressed in italics.

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

**Table 2-28: ER Baseline Full-Load Efficiency of All Air-Cooled Chillers[52]**

| Year Installed (Replaced System) | < 75 tons [EER] | ≥ 75 to 150 tons [EER] | ≥ 150 to 300 tons [EER] | ≥ 300 to 600 tons [EER] | ≥ 600 tons [EER] |
|---|---|---|---|---|---|
| ≤ 2001 | *9.212* | *9.212* | *8.530* | *8.530* | *8.530* |
| 2002 - 2009 | *9.554* | *9.554* | *9.554* | *9.554* | *9.554* |
| 2010 - 2012 | 9.562 | 9.562 | 9.562 | 9.562 | 9.562 |

**Table 2-29: ER Baseline Part-Load Efficiency of All Air-Cooled Chillers**

| Year Installed (Replaced System) | < 75 tons [IPLV] | ≥ 75 to 150 tons [IPLV] | ≥ 150 to 300 tons [IPLV] | ≥ 300 to 600 tons [IPLV] | ≥ 600 tons [IPLV] |
|---|---|---|---|---|---|
| ≤ 2001 | *9.554* | *9.554* | *8.530* | *8.530* | *8.530* |
| 2002 - 2009 | *10.407* | *10.407* | *10.407* | *10.407* | *10.407* |
| 2010 - 2012 | 12.750 | 12.750 | 12.750 | 12.750 | 12.750 |

*ER Baseline: Centrifugal Water-Cooled Chillers*

**Table 2-30: ER Baseline Full-Load Efficiency of Centrifugal Water-Cooled Chillers[53]**

| Year Installed (Replaced System) | < 75 tons [kW/ton] | ≥ 75 to 150 tons [kW/ton] | ≥ 150 to 300 tons [kW/ton] | ≥ 300 to 600 tons [kW/ton] | ≥ 600 tons [kW/ton] |
|---|---|---|---|---|---|
| ≤ 2001 | *0.925* | *0.925* | *0.837* | *0.748* | *0.748* |
| 2002 - 2009 | *0.703* | *0.703* | *0.634* | *0.576* | *0.576* |
| 2010 - 2012 | 0.634 | 0.634 | 0.634 | 0.576 | 0.570 |

[52] Code-specified efficiencies in effect prior to 2010 (ASHRAE 90.1-2010) were given in COP and have been converted to EER using EER = COP x 3.412. Values in the "≤ 2001" and "2002-2009" rows have been converted and are expressed in italics.

[53] Code-specified efficiencies in effect prior to 2010 (ASHRAE 90.1-2010) were given in COP and have been converted to kW/ton using kW/ton = 3.516 ÷ COP. Values in the "≤ 2001" and "2002-2009" rows have been converted and are expressed in italics.

**Table 2-31: ER Baseline Part-Load Efficiency of Centrifugal Water-Cooled Chillers**

| Year Installed (Replaced System) | < 75 tons [IPLV] | ≥ 75 to 150 tons [IPLV] | ≥ 150 to 300 tons [IPLV] | ≥ 300 to 600 tons [IPLV] | ≥ 600 tons [IPLV] |
|---|---|---|---|---|---|
| ≤ 2001 | *0.902* | *0.902* | *0.781* | *0.733* | *0.733* |
| 2002 - 2009 | *0.670* | *0.670* | *0.596* | *0.549* | *0.549* |
| 2010 - 2012 | 0.596 | 0.596 | 0.596 | 0.549 | 0.539 |

*ER Baseline: Positive-Displacement Water-Cooled Chillers*

**Table 2-32: ER Baseline Full-Load Efficiency of Screw/Scroll/Recip. Water-Cooled Chillers[54]**

| Year Installed (Replaced System) | < 75 tons [kW/ton] | ≥ 75 to 150 tons [kW/ton] | ≥ 150 to 300 tons [kW/ton] | ≥ 300 to 600 tons [kW/ton] | ≥ 600 tons [kW/ton] |
|---|---|---|---|---|---|
| ≤ 2001 | *0.925* | *0.925* | *0.837* | *0.748* | *0.748* |
| 2002 - 2009 | *0.790* | *0.790* | *0.718* | *0.639* | *0.639* |
| 2010 - 2012 | 0.780 | 0.775 | 0.680 | 0.620 | 0.620 |

**Table 2-33: ER Baseline Part-Load Efficiency of Screw/Scroll/Recip. Water-Cooled Chillers**

| Year Installed (Replaced System) | < 75 tons [IPLV] | ≥ 75 to 150 tons [IPLV] | ≥ 150 to 300 tons [IPLV] | ≥ 300 to 600 tons [IPLV] | ≥ 600 tons [IPLV] |
|---|---|---|---|---|---|
| ≤ 2001 | *0.902* | *0.902* | *0.781* | *0.733* | *0.733* |
| 2002 - 2009 | *0.676* | *0.676* | *0.628* | *0.572* | *0.572* |
| 2010 - 2012 | 0.630 | 0.615 | 0.580 | 0.540 | 0.540 |

## ***Replace-on-Burnout and New Construction***

New baseline efficiency levels for chillers are provided in Table 2-34, which includes both full load and Integrated Part Load Value (IPLV) ratings. The IPLV accounts for chiller efficiency at part-load operation for a given duty cycle. These baseline efficiency levels reference standard ASHRAE 90.1-2010. This standard contains two paths for compliance, Path A or Path B, however Path A is the method chosen for consistency with the full-load efficiency conditions used in the savings algorithms.[55] Path B chillers are eligible to claim savings using the Path A chiller baseline efficiencies and demand and energy coefficients defined in this measure.

[54] Code-specified efficiencies in effect prior to 2010 (ASHRAE 90.1-2010) were given in COP and have been converted to kW/ton using kW/ton = 3.516 ÷ COP. Values in the "≤ 2001" and "2002-2009" rows have been converted and are expressed in italics.

[55] According to ASHRAE 90.1-2007 Addenda M, Path A is intended for applications where significant operating time is expected at full-load conditions, while Path B is an alternative set of efficiency levels for water-cooled chillers intended for applications where significant time is spent at part-load operation (such as with a VSD chiller).

Table 2-34: Baseline Efficiencies for ROB and NC Air-Cooled and Water-Cooled Chillers[56]

| System Type [Efficiency Units] | | Efficiency Type | Capacity [Tons] | Path A | |
|---|---|---|---|---|---|
| | | | | Full-Load | IPLV |
| Air-Cooled Chiller | | EER | < 150 | ≥ 9.562 | ≥ 12.750 |
| | | | ≥ 150 | ≥ 9.562 | ≥ 12.750 |
| Water-Cooled Chiller | Electrically-Operated, Positive Displacement (Screw/Scroll/ Reciprocating) | kW/ton | <75 | ≤ 0.780 | ≤ 0.630 |
| | | | ≥ 75 and < 150 | ≤ 0.775 | ≤ 0.615 |
| | | | ≥ 150 and < 300 | ≤ 0.680 | ≤0.580 |
| | | | ≥ 300 | ≤ 0.620 | ≤0.540 |
| | Electrically-Operated, Centrifugal | | < 300 | ≤ 0.634 | ≤ 0.596 |
| | | | ≥ 300 and < 600 | ≤ 0.576 | ≤ 0.549 |
| | | | ≥ 600 | ≤ 0.570 | ≤ 0.539 |

## High-Efficiency Condition

Chillers must exceed the minimum efficiencies specified in Table 2-34. Additional conditions for replace-on-burnout, early retirement and new construction are as follows:

### *New Construction and Replace on Burnout*

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

### *Early Retirement*

The high-efficiency retrofits must meet the following criteria[57]:

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

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

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

**Equation 20**

[56] For ASHRAE 90.1-2010, a 2013 Supplement Addenda ch was filed which is effective January 1st, 2015. This Addenda contains revised full-load and part-load baseline efficiency standards for both Path A and Path B chillers, but the revisions are not reflected in these tables.

[57] From PUCT Docket #41070.

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

**Equation 21**

*Where:*

| | | |
|---|---|---|
| $Cap_{C,pre}$ | = | *Rated equipment cooling capacity of the existing equipment at AHRI standard conditions [Tons]* |
| $Cap_{C,post}$ | = | *Rated equipment cooling capacity of the newly installed equipment at AHRI standard conditions [Tons]* |
| $\eta_{baseline}$ | = | *Efficiency of existing equipment (ER) or standard equipment (ROB/NC) [kW/Ton]* |
| $\eta_{installed}$ | = | *Rated efficiency of the newly installed equipment [kW/Ton] - (Must exceed efficiency standards, shown in Table 2-34)* |

*Note: Use full-load efficiency (kW/ton) for kW savings calculations and part-load efficiency (IPLV) for kWh savings calculations. Table 2-28 through Table 2-33 provide efficiency ratings for baseline equipment and the efficiency ratings are given in terms of EER, kW/ton, or IPLV. In the cases where the full-load efficiency is provided in terms of EER rather than kW/ton, a conversion to kW/ton needs to be performed using the following conversion:*

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

**Equation 22**

*DF = Summer peak demand factor for appropriate climate zone, building type, and equipment type (Table 2-35 through Table 2-39)*

*$EFLH_C$ = Cooling equivalent full-load hours for appropriate climate zone, building type, and equipment type [hours] (Table 2-35 through Table 2-39)*

## ***Air-to Water-Cooled Replacement: Adjustments for Auxiliary Equipment[58]:***

The equipment efficiency for an air-cooled chiller includes condenser fans, but the equipment efficiency for a water-cooled chiller does not include the condenser water pump and cooling tower (auxiliary equipment). Therefore, when an air-cooled chiller is replaced with a water-cooled chiller, the savings must be reduced to account for the impact of the water-cooled system's additional equipment. This type of retrofit is only applicable for ER situations. The following equations are used:

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

**Equation 23**

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

$$kWh = kW \times 8,760$$

**Equation 24**

Where:

| | | |
|---|---|---|
| $HP_{CW\ pump}$ | = | *Horsepower of the condenser water pump* |
| $HP_{CT\ fan}$ | = | *Horsepower of the cooling tower fan* |
| *0.746* | = | *Conversion from HP to kW [kW/HP]* |
| *0.86* | = | *Assumed equipment efficiency* |
| *0.80* | = | *Assumed load factor* |
| *8,760* | = | *Annual run time hours* |

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

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

**Equation 25**

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

**Equation 26**

### ***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 a weighted savings calculated over both the early retirement period and the replace-on-burnout period, and take into account the EUL and the RUL. The final reported savings for ER projects are not actually a "first-year" savings, but an "average annual savings over the lifetime (EUL) of the measure". These savings calculations are explained in Appendix D.

Table 2-35 through Table 2-39 present the demand and energy coefficients. These HVAC coefficients vary by climate zone, building type, and equipment type. A description of the calculation method can be found in Docket No. 40885, Attachment B

## Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

## Deemed Energy and Demand Savings Tables

Deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values are presented building type and climate zone for chillers in Table 2-35 through Table 2-39. These tables also include an "Other" building type, which can be used for business types that are not explicitly listed. The DF and EFLH values used for Other are the most conservative values from the explicitly listed building types. When the Other building type is used, a description of the actual building type, the primary business activity, the business operating hours, and the HVAC schedule must be collected for the project site, and stored in the utility tracking data system.

For those combinations of technology, climate zone, and building type where no values are present, a project with that specific combination cannot used the deemed approach. A description of the calculation method can be found in Docket No. 40885, Attachment B.

**Table 2-35: DF and EFLH for Amarillo (Climate Zone 1)**

| Building Type | Principal Building Activity | Chiller[59] | | | |
|---|---|---|---|---|---|
| | | Air Cooled | | Water Cooled | |
| | | DF | $EFLH_c$ | DF | $EFLH_c$ |
| Education | College | 0.87 | 1,115 | 0.68 | 1,243 |
| | Primary School | 0.44 | 576 | 0.53 | 971 |
| | Secondary School | 0.62 | 802 | 0.58 | 1,772 |
| Healthcare | Hospital | 0.70 | 2,006 | 0.65 | 2,711 |
| Large Multifamily | Midrise Apartment | 0.41 | 421 | 0.50 | 1,098 |
| Lodging | Large Hotel | 0.58 | 1,283 | 0.59 | 1,553 |
| | Nursing Home | 0.41 | 428 | 0.50 | 1,115 |
| Mercantile | Stand-Alone Retail | 0.52 | 489 | 0.54 | 719 |
| Office | Large Office | 0.70 | 1,208 | 0.61 | 1,506 |
| Public Assembly | Public Assembly | 0.44 | 774 | 0.53 | 1,306 |
| Religious Worship | Religious Worship | 0.52 | 294 | 0.54 | 433 |
| Other | Other | 0.41 | 294 | 0.50 | 433 |

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

**Table 2-36: DF and EFLH for Fort Worth (Climate Zone 2)**

| Building Type | Principal Building Activity | Chiller[60] | | | |
|---|---|---|---|---|---|
| | | Air Cooled | | Water Cooled | |
| | | DF | $EFLH_c$ | DF | $EFLH_c$ |
| Education | College | 0.89 | 1,587 | 0.81 | 1,761 |
| | Primary School | 0.48 | 726 | 0.60 | 1,412 |
| | Secondary School | 0.77 | 1,170 | 0.54 | 2,234 |
| Healthcare | Hospital | 0.90 | 2,784 | 0.81 | 3,683 |
| Large Multifamily | Midrise Apartment | 0.68 | 1,060 | 0.66 | 2,053 |
| Lodging | Large Hotel | 0.80 | 2,086 | 0.71 | 2,627 |
| | Nursing Home | 0.68 | 1,077 | 0.66 | 2,085 |
| Mercantile | Stand-Alone Retail | 0.79 | 936 | 0.72 | 1,328 |
| Office | Large Office | 0.92 | 1,711 | 0.70 | 2,062 |
| Public Assembly | Public Assembly | 0.48 | 976 | 0.60 | 1,898 |
| Religious Worship | Religious Worship | 0.79 | 563 | 0.72 | 799 |
| Other | Other | 0.48 | 563 | 0.54 | 799 |

**Table 2-37: DF and EFLH for Houston (Climate Zone 3)**

| Building Type | Principal Building Activity | Chiller | | | |
|---|---|---|---|---|---|
| | | Air Cooled | | Water Cooled | |
| | | DF | $EFLH_c$ | DF | $EFLH_c$ |
| Education | College | 0.80 | 1,858 | 0.84 | 2,099 |
| | Primary School | 0.45 | 818 | 0.60 | 1,627 |
| | Secondary School | 0.73 | 1,306 | 0.55 | 2,404 |
| Healthcare | Hospital | 0.85 | 3,116 | 0.79 | 4,171 |
| Large Multifamily | Midrise Apartment | 0.65 | 1,295 | 0.66 | 2,467 |
| Lodging | Large Hotel | 0.71 | 2,499 | 0.73 | 3,201 |
| | Nursing Home | 0.65 | 1,315 | 0.66 | 2,506 |
| Mercantile | Stand-Alone Retail | 0.83 | 1,224 | 0.78 | 1,712 |
| Office | Large Office | 0.92 | 1,820 | 0.71 | 2,312 |
| Public Assembly | Public Assembly | 0.45 | 1,100 | 0.60 | 2,188 |
| Religious Worship | Religious Worship | 0.83 | 737 | 0.78 | 1,031 |
| Other | Other | 0.45 | 737 | 0.55 | 1,031 |

[60] Ibid.

**Table 2-38: DF and EFLH for Brownsville (Climate Zone 4)**

| Building Type | Principal Building Activity | Chiller[61] | | | |
|---|---|---|---|---|---|
| | | Air Cooled | | Water Cooled | |
| | | DF | $EFLH_c$ | DF | $EFLH_c$ |
| Education | College | 0.80 | 2,340 | 0.87 | 2,583 |
| | Primary School | 0.45 | 937 | 0.61 | 1,845 |
| | Secondary School | 0.70 | 1,503 | 0.55 | 2,577 |
| Healthcare | Hospital | 0.79 | 3,455 | 0.82 | 4,637 |
| Large Multifamily | Midrise Apartment | 0.61 | 1,534 | 0.67 | 2,840 |
| Lodging | Large Hotel | 0.74 | 2,908 | 0.73 | 3,713 |
| | Nursing Home | 0.61 | 1,558 | 0.67 | 2,884 |
| Mercantile | Stand-Alone Retail | 0.75 | 1,394 | 0.76 | 1,953 |
| Office | Large Office | 0.82 | 2,027 | 0.72 | 2,570 |
| Public Assembly | Public Assembly | 0.45 | 1,260 | 0.61 | 2,481 |
| Religious Worship | Religious Worship | 0.75 | 839 | 0.76 | 1,176 |
| Other | Other | 0.45 | 839 | 0.55 | 1,176 |

**Table 2-39: DF and EFLH for El Paso (Climate Zone 5)**

| Building Type | Principal Building Activity | Chiller[62] | | | |
|---|---|---|---|---|---|
| | | Air Cooled | | Water Cooled | |
| | | DF | $EFLH_c$ | DF | $EFLH_c$ |
| Education | College | 0.93 | 1,278 | 0.96 | 1,458 |
| | Primary School | 0.61 | 751 | 0.53 | 1,113 |
| | Secondary School | 0.78 | 1,039 | 0.54 | 2,196 |
| Healthcare | Hospital | 0.71 | 2,355 | 0.59 | 2,992 |
| Large Multifamily | Midrise Apartment | 0.56 | 841 | 0.52 | 1,553 |
| Lodging | Large Hotel | 0.63 | 1,815 | 0.58 | 2,038 |
| | Nursing Home | 0.56 | 854 | 0.52 | 1,577 |
| Mercantile | Stand-Alone Retail | 0.64 | 722 | 0.55 | 948 |
| Office | Large Office | 0.77 | 1,442 | 0.60 | 1,683 |
| Public Assembly | Public Assembly | 0.61 | 1,010 | 0.53 | 1,496 |
| Religious Worship | Religious Worship | 0.64 | 435 | 0.55 | 571 |
| Other | Other | 0.56 | 435 | 0.52 | 571 |

[61] Ibid.

[62] Coefficient values are derived from the petitions filed in Docket 41070, 40885, and 30331. The only coefficients that were developed specific to Climate Zone 5 are those filed in Docket 41070; however, the petition in that docket did not include coefficients for all building types (herein "principal building activities," or PBAs). Prior to filing of Docket 41070, deemed savings for what is now Climate Zone 5 were the Climate Zone 2 deemed savings. As such, chiller deemed savings for those PBAs not addressed in docket 41070 (Nursing Home and Religious Worship) are derived from Climate Zone 2 values from the prior petitions. Coefficient values for those PBAs that were not updated in either of Docket 41070 or 40885 remain valid.

## Measure Life and Lifetime Savings

### *Effective Useful Life (EUL)*

The EUL of HVAC equipment is provided below:

- Screw / Scroll / Reciprocating Chillers – 20 years[63]
- Centrifugal Chillers – 25 years[64]

### *Remaining Useful Life (RUL)*

The RUL of replaced systems is provided according to system age in Table 2-40. As previously noted, for ER units of unknown age, a default value of 21 years for Non-Centrifugal chillers and 26 years for Centrifugal chillers should be used. 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 D.

**Table 2-40: Remaining Useful Life of Early Retirement Systems[65]**

| Age of Replaced System (years) | Non-Centrifugal Chillers RUL (years) | Centrifugal Chillers RUL (years) | Age of Replaced System (years) | Non-Centrifugal Chillers RUL (years) | Centrifugal Chillers RUL (years) |
|---|---|---|---|---|---|
| 5 | 14.7 | 19.9 | 21 | 3.2 | 6.6 |
| 6 | 13.7 | 18.9 | 22 | 2.9 | 6.3 |
| 7 | 12.7 | 17.9 | 23 | 2.6 | 5.9 |
| 8 | 11.8 | 16.9 | 24 | 2.4 | 5.6 |
| 9 | 10.9 | 15.9 | 25 | 2.1 | 5.4 |
| 10 | 10.0 | 14.9 | 26 | 1.9 | 5.1 |
| 11 | 9.1 | 13.9 | 27 | 1.8 | 4.9 |
| 12 | 8.3 | 12.9 | 28 | 1.6 | 4.7 |
| 13 | 7.5 | 11.9 | 29 | 1.5 | 4.5[66] |
| 14 | 6.8 | 10.9 | 30 | 1.3 | 4.3 |
| 15 | 6.2 | 10.1 | 31 | 1.2 | 4.1 |
| 16 | 5.5 | 9.3 | 32 | N/A | 4 |
| 17 | 5.0 | 8.7 | 33 | N/A | 3.8 |
| 18 | 4.5 | 8.1 | 34 | N/A | 3.7 |
| 19 | 4.0 | 7.5 | 35 | N/A | 3.6 |
| 20 | 3.6 | 7.1 | 36 | N/A | 3.5 |

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

[64] PUCT Docket No. 40885, review of multiple studies looking at the lifetime of Centrifugal Chillers as detailed in petition workpapers.

[65] PUCT Docket No. 40085, Attachment A describes the process in which the RUL of replaced systems has been calculated.

[66] The correct value is listed in this table, and differs from Table 5 of PUC Petition 40885 due to a typographical error in the petition.

## 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, Conversion
- Building Type
- Climate Zone
- Baseline Equipment Type (Compressor/Condenser Type)
- Baseline Equipment Rated Capacity
- Baseline Number of Units
- For ER ONLY: Baseline Age of System and Method of Determination (e.g. nameplate, blueprints, customer reported, not available)
- Installed Equipment Type (Compressor/Condenser Type)
- Installed Equipment Rated Capacity
- Installed Number of Units
- Installed Efficiency Rating
- Installed Make & Model
- For Chiller Type Conversion ONLY: Condenser water pump HP and cooling tower fan HP
- For Other building type ONLY: A description of the actual building type, the primary business activity, the business hours, and the HVAC schedule

## References and Efficiency Standards

## Petitions and Rulings

- PUCT Docket 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. Previously these savings were taken from the Dallas-Fort Worth area, which has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.
- PUCT Docket 43681 – Updated the approach for calculating early replacement energy and demand savings using a Net Present Value (NPV) method. Documented in Appendix D.

## Relevant Standards and Reference Sources

- ANSI/ASHRAE/IES Standard 90.1-1989. Energy Standard for Buildings except Low-Rise Residential Buildings. Table 10-7.
- ANSI/ASHRAE/IES Standard 90.1-2004. Energy Standard for Buildings except Low-Rise Residential Buildings. Table 6.8.1C.
- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings except Low-Rise Residential Buildings. Table 6.8.1A through Table 6.8.1D.

## Document Revision History

**Table 2-41: Nonresidential HVAC-Chillers History**

| TRM Version | Date | Description of Change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin |
| v2.0 | 04/18/2014 | Modified savings calculations surrounding Early Retirement programs, and revised details surrounding RUL and Measure Life. Added references to Appendix D for EUL and RUL discussion, and Net Present Value (NPV) equations. |
| v2.1 | 01/30/2015 | Minor text updates and clarification of early retirement requirements. |
| v3.0 | 04/10/2015 | Update of savings method to allow for part-load efficiency calculations. |
| v3.1 | 11/05/2015 | Updated table references to clarify building types and RUL references. Added "Other" building type for when building type is not explicitly listed. Added Religious Worship building type to Climate Zone 5 for consistency with other zones. |
| v4.0 | 10/10/2016 | Used modeling approach to update DF and EFLH for applicable building types and climate zones. |

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

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

**Market Sector:** Commercial

**Measure Category:** HVAC

**Applicable Building Types:** Large Hotel and Small Hotel/Motel

**Fuels Affected:** Electricity

**Decision/Action Type:** Replace-on-Burnout (ROB), Early Retirement (ER), and New Construction (NC)

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed Savings Calculations

**Savings Methodology:** Calculator

## Measure Description

This section presents the deemed savings methodology for the installation of Packaged Terminal Air Conditioners (PTAC), Packaged Terminal Heat Pumps (PTHP), and Room AC (RAC) systems. This document covers assumptions made for baseline equipment efficiencies for early retirement (ER) of PTAC/PTHPs, replace-on-burnout (ROB), and new construction (NC) situations based current and previous on efficiency standards. For ER, the actual age of the baseline system should be determined from the equipment nameplate or other physical documentation whenever possible. In the event that the actual age of the unit is unknown, default values are provided.

Applicable efficient measure types include:

**Packaged Terminal Air Conditioners and Heat Pumps.** Both Standard and Non-Standard size equipment types are covered. *Standard Size* refers to equipment with wall sleeve dimensions having an external wall opening greater than, equal to 16 inches high or greater than, or equal to 42 inches wide and a cross sectional area greater than 670 $in^2$. *Non-Standard Size* refers to equipment with existing wall sleeve dimensions having an external wall opening of less than 16 inches high or less than 42 inches wide and a cross sectional area less than 670 $in^2$.

**Room Air Conditioners.** Includes all equipment configurations covered by the federal appliance standards, including with or without reverse cycle, louvered or non-louvered sides, casement-only, and casement-slide.

## Eligibility Criteria

For a measure to be eligible for this deemed savings approach the following conditions will be met:

- The existing and proposed cooling equipment are electric.[67]
- The climate zone is determined from the county-to-climate-zone mapping table.
- For PTAC/PTHP and RAC equipment types, the eligible building types are "Large Hotel" and "Small Hotel/Motel[68]. Building type descriptions and examples are provided in Table 2-19 and Table 2-20.
- For early retirement PTAC/PTHP projects: ER projects involve the replacement of a working system that is at least five years old before natural burnout. Additionally, the ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. An ROB approach should be used for these scenarios

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

## Baseline Condition

### ***Early Retirement for PTAC/PTHP Systems***

An early retirement scenario is only applicable for Standard Size PTAC/PTHP system types replacing system types with an equivalent cooling capacity or reduced cooling capacity (within 80% of existing capacity).

Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL-RUL) period. For the ROB period, the baseline efficiency is that same as for an ROB/NC scenario. For the ER period, the baseline efficiency should be estimated according to the capacity, system type (PTAC or PTHP), and age (based on year of manufacture) of the replaced system.[69] When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 2-42, reflecting ASHRAE Standard 90.1-2001 through 90.1-2007, should be used. When the system age is unknown, assume 17 years.[70]

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[67] The TRM climate zone/regions and county-level assignments were created and are currently maintained by Frontier for the Electric Utilities Marketing Managers of Texas (EUMMOT).

[68] The original petition did not include the "Large Hotel" business type. This application was added in TRMv2 as a short-term, conservative savings estimate, but more accurate savings estimates should be developed for a future TRM.

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

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

**Table 2-42: ER Baseline Efficiency Levels for Standard Size PTAC/PTHP Units[71]**

| Equipment | Cooling Capacity [Btuh] | Baseline Cooling Efficiency [EER] | Baseline Heating Efficiency [COP] |
|---|---|---|---|
| PTAC | <7,000 | 11.0 | -- |
| | 7,000-15,000 | $12.5 - (0.213 \times \text{Cap}/1000)$ | -- |
| | >15,000 | 9.3 | -- |
| PTHP | <7,000 | 10.8 | 3.0 |
| | 7,000-15,000 | $12.3 - (0.213 \times \text{Cap}/1000)$ | $3.2 - (0.026 \times \text{Cap}/1000)$ |
| | >15,000 | 9.1 | 2.8 |

## ***Replace-on-Burnout and New Construction***

Table 2-43 provides minimum efficiency standards for PTAC/PTHP units and reflects the federal standards for Packaged Terminal Air Conditioners and Heat Pumps effective February 2013 and reflected in 10 CFR 431.

**Table 2-43: Minimum Efficiency Levels for PTAC/PTHP ROB and NC Units**

| Equipment | Category | Cooling Capacity [Btuh] | Minimum Cooling Efficiency [EER] | Minimum Heating Efficiency [COP] |
|---|---|---|---|---|
| PTAC | Standard Size | <7,000 | *11.7* | -- |
| | | 7,000-15,000 | $13.8 - (0.300 \times \text{Cap}/1000)$ | -- |
| | | >15,000 | *9.3* | |
| | Non-Standard Size | <7,000 | *9.4* | |
| | | 7,000-15,000 | $10.9 - (0.213 \times \text{Cap}/1000)$ | |
| | | >15,000 | *7.7* | -- |
| PTHP | Standard Size | <7,000 | *11.9* | *3.3* |
| | | 7,000-15,000 | $14.0 - (0.300 \times \text{Cap}/1000)$ | $3.7 - (0.052 \times \text{Cap}/1000)$ |
| | | >15,000 | *9.5* | *2.9* |
| | Non-Standard Size | <7,000 | *9.3* | *2.7* |
| | | 7,000-15,000 | $10.8 - (0.213 \times \text{Cap}/1000)$ | $2.9 - (0.026 \times \text{Cap}/1000)$ |
| | | >15,000 | *7.6* | *2.5* |

[71] ER only applies to Standard Size units because the minimum efficiency requirements for Non-Standard systems have never changed, making the ER baseline efficiency the same as for ROB.

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

Table 2-44 reflects the standards for Room Air Conditioners, specified in 10 CFR 430.32(b).

**Table 2-44: Minimum Efficiency Levels for Room Air Conditioners ROB and NC Units[73]**

| Category | Cooling Capacity [Btuh] | Minimum Cooling Efficiency [EER] |
|---|---|---|
| Without reverse cycle, with louvered sides | < 8,000 | 11.0 |
| | ≥ 8,000 and < 14,000 | 10.9 |
| | ≥ 14,000 and < 20,000 | 10.7 |
| | ≥ 20,000 and < 25,000 | 9.4 |
| | ≥ 25,000 | 9.0 |
| Without reverse cycle, without louvered sides | < 8,000 | 10.0 |
| | ≥ 8,000 and < 11,000 | 9.6 |
| | ≥ 11,000 and < 14,000 | 9.5 |
| | ≥ 14,000 and < 20,000 | 9.3 |
| | ≥ 20,000 | 9.4 |
| With reverse cycle, with louvered sides | < 20,000 | 9.8 |
| | ≥ 20,000 | 9.3 |
| With reverse cycle, without louvered sides | < 14,000 | 9.3 |
| | ≥ 14,000 | 8.7 |
| Casement-only | All capacities | 9.5 |
| Casement-slider | All capacities | 10.4 |

## High-Efficiency Condition

The high-efficiency retrofits must exceed the minimum federal standards found in Table 2-43 and Table 2-44.

The high-efficiency retrofits must also meet the following criteria[74]:

- For early retirement PTAC/PTHPs only, the high-efficiency equipment cooling capacity must be equal to or no less than 80% of the existing capacity. Equipment with a cooling capacity larger than the existing equipment must use the replace-on-burnout baseline.
- Non-Standard Size PTAC/PTHPs cannot be used for New Construction.
- No additional measures are being installed that directly affect the operation of the cooling equipment (i.e. control sequences).

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

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

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

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

**Equation 27**

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

**Equation 28**

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

**Equation 29**

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

**Equation 30**

Where:

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

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

$\eta_{baseline,C}$ = *Cooling efficiency of existing (ER) or standard (ROB/NC) equipment [EER, Btu/W-h] (Table 2-42 through Table 2-44)*

$\eta_{baseline,H}$ = *Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP] (Table 2-42 and Table 2-43)*

$\eta_{installed,C}$ = *Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h]) - (Must exceed minimum federal standards found in Table 2-43 and Table 2-44* $\eta_{installed,H}$ = *Rated heating efficiency of the newly installed equipment [COP] (Must exceed minimum federal standards found in Table 2-43)*

$DF$ = *Seasonal peak demand factor for appropriate climate zone, building type, and equipment type (Table 2-21 through Table 2-25)*

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours for newly installed equipment based on appropriate climate zone, building type, and equipment type [hours], see Table 2-45and Table 2-46.*

The first year savings algorithms in the above equations are used for all HVAC projects, across NC, ROB, and ER projects. However, ER projects require a weighted savings calculated over both the ER and ROB periods taking the EUL and RUL into account. The ER savings are applied over the remaining useful life (RUL) period, and the ROB savings are applied over the remaining period (EUL-RUL). The final reported savings for ER projects are not actually a "first-year" savings, but an "average annual savings over the lifetime (EUL) of the measure". These savings calculations are explained in Appendix D.

## Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

## Deemed Energy and Demand Savings Tables

Table 2-45 and Table 2-46 present the deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values for PTAC/PTHPs and RACs. These values are calculated by climate zone, building type, and equipment type. A description of the calculation method can also be found in Docket No. 40885, Attachment B.

**Table 2-45:PTAC/PTHP Equipment: DF and EFLH Values by Climate Zone for Hotel – Small and Hotel – Large Building Types[75]**

| Climate Zone | Packaged Terminal Unit | | | | |
|---|---|---|---|---|---|
| | Air Conditioner | | Heat Pump | | |
| | DF | $EFLH_C$ | DF | $EFLH_C$ | $EFLH_H$ |
| Amarillo (Climate Zone 1) | 0.51 | 1,359 | 0.51 | 1,359 | 361 |
| Fort Worth (Climate Zone 2) | 0.61 | 1,834 | 0.61 | 1,834 | 208 |
| Houston (Climate Zone 3) | 0.55 | 1,992 | 0.55 | 1,992 | 43 |
| Brownsville (Climate Zone 4) | 0.49 | 2,223 | 0.49 | 2,223 | 50 |
| El Paso (Climate Zone 5)[76] | 0.61 | 1,834 | 0.61 | 1,834 | 208 |

[75] 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).

[76] No values have been published for this measure for El Paso, Climate Zone 5, but per a comment received from Frontier, Climate Zone 5 has historically used the Fort Worth (Climate Zone 2) weather values

**Table 2-46: RAC Equipment: DF and EFLH Values[77]**

| Climate Zone | Room/Window Air Conditioner | |
|---|---|---|
| | DF | $EFLH_C$ |
| Amarillo (Climate Zone 1) | 0.51 | 1,359 |
| Fort Worth (Climate Zone 2) | 0.61 | 1,834 |
| Houston (Climate Zone 3) | 0.55 | 1,992 |
| Brownsville (Climate Zone 4) | 0.49 | 2,223 |
| El Paso (Climate Zone 5) | 0.61 | 1,834 |

## Measure Life and Lifetime Savings

### *Effective Useful Life (EUL)*

The EUL of PTAC/PTHP units is 15 years as specified in DEER 2014. The EUL of RAC units is 11 years based on current DOE Final Rule standards for residential room air conditioners.[78]

### *Remaining Useful Life (RUL) for PTAC/PTHP Systems*

The RUL of ER replaced systems is provided according to system age in Table 2-47.

As previously noted, for ER units of unknown age, a default value of 17 years should be used. 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 D.

[77] PUCT Docket 40885 did not explicitly specify energy and demand coefficients for RAC units. PTAC/PTHP units are the most similar available equipment type. Therefore, RAC units will use the PTAC/PTHP coefficients. RAC-specific coefficients should be developed in a future TRM.

[78] The updates were made in Federal Register, 76 FR 22582-22584, but the reference to the EUL is found here: http://www.regulations.gov/contentStreamer?objectId=0900006480c34c55&disposition=attachment&contentType=pdf. Accessed 04/02/2014. This value is listed as 10.5 years, and has been rounded up to 11.

Table 2-47: Remaining Useful Life of ER PTAC/PTHP Systems[79]

| Age of Replaced System (Years) | PTAC/PTHP RUL (Years) | Age of Replaced System (Years) | PTAC/PTHP RUL (Years) |
|---|---|---|---|
| 5 | 10.0 | 15 | 2.8 |
| 6 | 9.1 | 16 | 2.5 |
| 7 | 8.2 | 17 | 2.2 |
| 8 | 7.3 | 18 | 1.9 |
| 9 | 6.5 | 19 | 1.7 |
| 10 | 5.7 | 20 | 1.5 |
| 11 | 5.0 | 21 | 1.3 |
| 12 | 4.4 | 22 | 1.1 |
| 13 | 3.8 | 23 | 1.0 |
| 14 | 3.3 | | |

## Program Tracking Data & 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.

- Equipment Type: PTAC, PTHP, or RAC
- Equipment Configuration Category: Standard/Non-Standard or Room AC
- Decision/Action Type: ROB, NC, or ER
- Building Type
- Climate Zone
- Baseline Equipment Rated Cooling and Heating Capacities
- Baseline Number of Units
- Baseline Cooling and Heating Efficiency Rating
- Baseline Make & Model
- For ER ONLY: Baseline Age and Method of Determination (e.g. nameplate, blueprints, customer reported, not available)
- Installed Equipment Type
- Installed Equipment Rated Capacity
- Installed Number of Units

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

- Installed Efficiency Rating
- Installed Make & Model

## References and Efficiency Standards

## Petitions and Rulings

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

## Relevant Standards and Reference Sources

- ANSI/ASHRAE/IES Standard 90.1-2001 through ASHRAE 90.1-2007. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1D.
- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1D.
- Code of Federal Regulations. Title 10. Part 431 – Energy Efficiency Program for Certain Commercial and Industrial Equipment. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/45
- Code of Federal Regulations. Title 10. Part 430 – Energy Efficiency Program for Certain Commercial and Industrial Equipment. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41

## Document Revision History

**Table 2-48: Nonresidential HVAC PTAC-PTHP/Room AC History**

| TRM Version | Date | Description of Change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin |
| v2.0 | 04/18/2014 | 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 | Corrections to energy and demand coefficients for heat pumps in Climate Zone 3 (Houston). |
| v3.0 | 04/10/2015 | 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 | Added updated building type definitions and descriptions, minor updates to text for clarification and consistency. |
| v4.0 | 10/10/2016 | No revisions |

## 2.2.5 HVAC Variable Frequency Drive (VFD) on Air Handler Unit (AHU) Supply Fans Measure Overview

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

**Market Sector:** Commercial

**Measure Category:** HVAC

**Applicable Building Types:** See Table 2-50

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit (RET)

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed Savings Values

**Savings Methodology:** Look-up Tables (fan type, motor hp, Climate Zone, Building Type)

### Measure Description

This measure involves the installation of a VFD on an existing AHU supply fan to replace either outlet damper or inlet guide vane part-load control. The fan is in a variable air volume (VAV) system with terminal VAV boxes. 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 particular eligible scenarios.

### Eligibility Criteria

Supply fans may not have variable pitch blades. New construction and constant-volume systems are ineligible. Supply fans must be less than or equal to 100 HP.

### Baseline Condition

The baseline is a centrifugal supply fan with a single-speed motor, a direct expansion (DX) air-conditioning (AC) unit, and VAV boxes. The motor is a standard efficiency motor based on ASHRAE Standard 90.1-2004 standards which are provided by horsepower. The AC unit has standard cooling efficiency based on ASHRAE 90.1-2004. The part-load fan control is an outlet damper, inlet damper or inlet guide vane.

### High-Efficiency Condition

The high efficiency condition is installation of a VFD on an AHU supply fan. 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 %CFM for the hour, *i*[80];

$$\%CFM_i = 1.25 \times t_i + b$$

**Equation 31**

Where:

$$b = 100 - (1.25 \times t_{dbd}))$$

**Equation 32**

Step 2 – Calculate the %power[81] for the applicable baseline and the new VFD technology:

**Baseline Technologies**

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

**Equation 33**

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

**Equation 34**

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

**Equation 35**

**VFD Technology**

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

**Equation 36**

Step 3 – Calculate $kW_{full}$ using the HP from the motor nameplate, LF (75%), and the applicable motor efficiency from ASHRAE 2004, Table 10.8 Minimum Nominal Efficiency for General Purpose Design A and Design B Motors; Use that result and the %power results to determine power consumption at each hour:

[80] A 60% minimum setpoint strategy is assumed, so any results below 60% are set to 60%.

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

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

**Equation 37**

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

**Equation 38**

Step 4 – Calculate the kW savings for each hour within the 510-hr summer peak period, sum the kW savings from the 510 individual hourly calculations, divide by 510 to get the average peak demand impact, and then calculate the total peak demand saved by adding peak demand interactive effects:

**Hourly Savings Calculations**

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

**Equation 39**

Average Peak Demand Saved Calculation, excluding interactive effects

$$kW_{AVG,Saved} = \sum_{i=1}^{510} (kW_i)_{Saved} \div 510)$$

**Equation 40**

Total Peak Demand Saved Calculation, including interactive effects

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

**Equation 41**

Energy Savings are calculated in the following manner:

Step 1 – Calculate the individual kWh consumption in each hour of the year and sum them; This is done for both the baseline and the new technologies:

$$Annual\ kWh = \sum_{i=1}^{8760} (kW_i \times schedule_i)$$

**Equation 42**

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

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

**Equation 43**

Where:

$\%CFM_i$ = *Part-load fan airflow at the $i^{th}$ hour of the year*

$t_i$ = *Dry bulb air temperature at $i^{th}$ hour taken from TMY3 hourly weather data*

$t_{dbd}$ = *ASHRAE 0.4% Cooling Dry Bulb Design Temperature for the reference city from 1997 ASHRAE Handbook – Fundamentals, Table 26.1B*

$\%power_i$ = *Percentage of full load 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)*[82]

$kW_{full}$ = *Fan motor power demand operating at the fan design 100% CFM*

$kW_i$ = *Fan 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% at the fan design 100% per DEER 2005*

$\eta$ = *Motor efficiency of a standard efficiency Open Drip Proof (ODP) motor operating at 1800 RPM taken from ASHRAE Standard 90.1-2004*

*0.746* = *HP to kW conversion factor*

*schedule* = *1 when building is occupied, 0.2 when building is unoccupied, see Table 2-49*

$Cooling_{SEER}$ = *Air conditioner cooling efficiency, assumed at 11.2, based on ASHRAE Standard 90.1 – 2004 minimum efficiency of a unitary AC system between 5 and 10 tons*

510 = Total number of hours during the utility defined summer peak period (Weekdays from 1-7 PM during months of June, July August and September)[83]

8760 = Total number of hours in a year

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[82] Fan curves by control type are provided in the BPA ASD Calculator, http://www.bpa.gov/EE/Sectors/Industrial/Documents/ASDCalculators.xls.

[83] The day of the week is not determined by a specific year, but by the Month and Year for the particular location based on the TMY3 weather data file.

## Deemed Energy and Demand Savings Tables

**Table 2-49: Yearly Motor Operation Hours by Building Type[84]**

| Building Type | Weekday Schedule | Weekend Schedule | Annual Building Occupied Hours | Annual Motor Operation Hours* |
|---|---|---|---|---|
| Office – Large | 8am–8pm | 8am–10am | 3,340 | 4,424 |
| Office – Small | 8am-6pm | 8am-10am | 2,818 | 4,007 |
| Hospitals & Healthcare | 24 hr | 24 hr | 8,760 | 8,760 |
| Education – K-12 | 7am-5pm | 8am-12pm | 2,630 | 3,856 |
| Education – College & University | 8am-8pm | 8am-12pm | 3,548 | 4,591 |
| Retail | 9am-10pm | 9am-10pm | 4,745 | 5,548 |
| Restaurants- Fast Food | 6am-11pm | 6am-11pm | 6,205 | 6,716 |
| Restaurants – Sit Down | 11am-11pm | 11am-11pm | 4,380 | 5,256 |

* Motor operation hours are building occupied hours plus 20% of unoccupied hours

**Table 2-50: Deemed Energy and Demand Savings Values for Outlet Damper Part-Load Fan Control by Climate Region**

| HP | Dallas | | El Paso | | Houston | | Corpus Christi | | Amarillo | |
|---|---|---|---|---|---|---|---|---|---|---|
| | kW | kWh | kW | kWh | kW | kWh | kW | kWh | kW | kWh |
| | | | | | Hospital & Healthcare | | | | | |
| 1 | 0.105 | 1,240 | 0.126 | 1,278 | 0.097 | 1,167 | 0.090 | 1,120 | 0.117 | 1,273 |
| 2 | 0.207 | 2,436 | 0.248 | 2,510 | 0.191 | 2,292 | 0.176 | 2,200 | 0.229 | 2,500 |
| 3 | 0.301 | 3,549 | 0.361 | 3,656 | 0.278 | 3,339 | 0.256 | 3,205 | 0.334 | 3,642 |
| 5 | 0.497 | 5,847 | 0.595 | 6,023 | 0.458 | 5,502 | 0.422 | 5,280 | 0.550 | 6,001 |
| 7.5 | 0.736 | 8,671 | 0.882 | 8,933 | 0.679 | 8,159 | 0.626 | 7,831 | 0.816 | 8,900 |
| 10 | 0.971 | 11,432 | 1.163 | 11,777 | 0.895 | 10,757 | 0.826 | 10,325 | 1.076 | 11,734 |
| 15 | 1.433 | 16,866 | 1.716 | 17,374 | 1.321 | 15,870 | 1.218 | 15,232 | 1.587 | 17,311 |
| 20 | 1.910 | 22,488 | 2.288 | 23,166 | 1.761 | 21,160 | 1.624 | 20,309 | 2.116 | 23,081 |
| 25 | 2.369 | 27,895 | 2.838 | 28,736 | 2.184 | 26,248 | 2.015 | 25,193 | 2.625 | 28,631 |
| 30 | 2.822 | 33,221 | 3.380 | 34,222 | 2.601 | 31,259 | 2.399 | 30,002 | 3.126 | 34,097 |
| 40 | 3.738 | 44,009 | 4.477 | 45,335 | 3.446 | 41,410 | 3.178 | 39,745 | 4.141 | 45,170 |
| 50 | 4.672 | 55,011 | 5.596 | 56,669 | 4.308 | 51,762 | 3.973 | 49,681 | 5.177 | 56,462 |
| 60 | 5.571 | 65,590 | 6.673 | 67,567 | 5.136 | 61,716 | 4.737 | 59,236 | 6.172 | 67,320 |
| 75 | 6.927 | 81,552 | 8.296 | 84,010 | 6.386 | 76,735 | 5.890 | 73,651 | 7.674 | 83,703 |
| 100 | 9.235 | 108,736 | 11.062 | 112,014 | 8.515 | 102,314 | 7.853 | 98,201 | 10.232 | 111,605 |

[84] The building hours of operation were noted in PUCT Docket 40668 to have been referenced from Commercial Building Energy Consumption Survey (CBECS) 2003. The specific analysis/report could not be confirmed.

| HP | Dallas | | El Paso | | Houston | | Corpus Christi | | Amarillo | |
|---|---|---|---|---|---|---|---|---|---|---|
| | kW | kWh | kW | kWh | kW | kWh | kW | kWh | kW | kWh |
| Office - Large | | | | | | | | | | |
| 1 | 0.105 | 601 | 0.126 | 622 | 0.097 | 557 | 0.090 | 530 | 0.117 | 618 |
| 2 | 0.207 | 1,181 | 0.248 | 1,222 | 0.191 | 1,095 | 0.176 | 1,041 | 0.229 | 1,214 |
| 3 | 0.301 | 1,720 | 0.361 | 1,781 | 0.278 | 1,595 | 0.256 | 1,516 | 0.334 | 1,768 |
| 5 | 0.497 | 2,834 | 0.595 | 2,934 | 0.458 | 2,627 | 0.422 | 2,498 | 0.550 | 2,913 |
| 7.5 | 0.736 | 4,203 | 0.882 | 4,351 | 0.679 | 3,897 | 0.626 | 3,705 | 0.816 | 4,321 |
| 10 | 0.971 | 5,542 | 1.163 | 5,736 | 0.895 | 5,138 | 0.826 | 4,885 | 1.076 | 5,697 |
| 15 | 1.433 | 8,176 | 1.716 | 8,463 | 1.321 | 7,579 | 1.218 | 7,207 | 1.587 | 8,404 |
| 20 | 1.910 | 10,901 | 2.288 | 11,284 | 1.761 | 10,106 | 1.624 | 9,609 | 2.116 | 11,206 |
| 25 | 2.369 | 13,523 | 2.838 | 13,997 | 2.184 | 12,536 | 2.015 | 11,920 | 2.625 | 13,900 |
| 30 | 2.822 | 16,104 | 3.380 | 16,669 | 2.601 | 14,929 | 2.399 | 14,196 | 3.126 | 16,554 |
| 40 | 3.738 | 21,334 | 4.477 | 22,082 | 3.446 | 19,777 | 3.178 | 18,805 | 4.141 | 21,929 |
| 50 | 4.672 | 26,667 | 5.596 | 27,603 | 4.308 | 24,721 | 3.973 | 23,507 | 5.177 | 27,411 |
| 60 | 5.571 | 31,796 | 6.673 | 32,911 | 5.136 | 29,475 | 4.737 | 28,027 | 6.172 | 32,683 |
| 75 | 6.927 | 39,533 | 8.296 | 40,920 | 6.386 | 36,648 | 5.890 | 34,848 | 7.674 | 40,637 |
| 100 | 9.235 | 52,711 | 11.062 | 54,560 | 8.515 | 48,864 | 7.853 | 46,464 | 10.232 | 54,182 |
| Office - Small | | | | | | | | | | |
| 1 | 0.088 | 544 | 0.107 | 563 | 0.080 | 501 | 0.073 | 476 | 0.098 | 559 |
| 2 | 0.173 | 1,068 | 0.209 | 1,106 | 0.156 | 984 | 0.144 | 935 | 0.193 | 1,098 |
| 3 | 0.252 | 1,555 | 0.305 | 1,611 | 0.228 | 1,433 | 0.209 | 1,361 | 0.281 | 1,599 |
| 5 | 0.415 | 2,563 | 0.502 | 2,654 | 0.375 | 2,362 | 0.345 | 2,243 | 0.462 | 2,634 |
| 7.5 | 0.616 | 3,800 | 0.745 | 3,937 | 0.556 | 3,502 | 0.512 | 3,327 | 0.686 | 3,907 |
| 10 | 0.812 | 5,011 | 0.982 | 5,190 | 0.734 | 4,618 | 0.675 | 4,386 | 0.904 | 5,151 |
| 15 | 1.198 | 7,392 | 1.448 | 7,657 | 1.082 | 6,812 | 0.996 | 6,470 | 1.334 | 7,599 |
| 20 | 1.598 | 9,856 | 1.931 | 10,209 | 1.443 | 9,083 | 1.328 | 8,627 | 1.779 | 10,132 |
| 25 | 1.982 | 12,226 | 2.396 | 12,664 | 1.790 | 11,267 | 1.647 | 10,702 | 2.206 | 12,569 |
| 30 | 2.360 | 14,560 | 2.853 | 15,082 | 2.132 | 13,418 | 1.961 | 12,745 | 2.627 | 14,968 |
| 40 | 3.127 | 19,288 | 3.779 | 19,979 | 2.824 | 17,776 | 2.598 | 16,883 | 3.481 | 19,829 |
| 50 | 3.909 | 24,110 | 4.724 | 24,974 | 3.530 | 22,220 | 3.248 | 21,104 | 4.351 | 24,786 |
| 60 | 4.660 | 28,746 | 5.633 | 29,777 | 4.208 | 26,493 | 3.872 | 25,163 | 5.188 | 29,553 |
| 75 | 5.794 | 35,742 | 7.003 | 37,023 | 5.233 | 32,940 | 4.814 | 31,286 | 6.450 | 36,745 |
| 100 | 7.726 | 47,656 | 9.338 | 49,364 | 6.977 | 43,920 | 6.419 | 41,715 | 8.600 | 48,993 |
| Education - K-12 | | | | | | | | | | |
| 1 | 0.036 | 545 | 0.044 | 561 | 0.030 | 501 | 0.030 | 477 | 0.041 | 559 |
| 2 | 0.070 | 1,070 | 0.086 | 1,101 | 0.059 | 984 | 0.058 | 938 | 0.081 | 1,097 |
| 3 | 0.103 | 1,559 | 0.125 | 1,604 | 0.086 | 1,433 | 0.084 | 1,366 | 0.118 | 1,598 |
| 5 | 0.169 | 2,569 | 0.206 | 2,642 | 0.141 | 2,360 | 0.139 | 2,251 | 0.194 | 2,633 |
| 7.5 | 0.251 | 3,809 | 0.306 | 3,919 | 0.209 | 3,501 | 0.206 | 3,338 | 0.287 | 3,905 |
| 10 | 0.330 | 5,022 | 0.403 | 5,167 | 0.276 | 4,615 | 0.272 | 4,401 | 0.379 | 5,148 |
| 15 | 0.488 | 7,409 | 0.595 | 7,623 | 0.407 | 6,809 | 0.401 | 6,493 | 0.559 | 7,595 |
| 20 | 0.650 | 9,879 | 0.793 | 10,163 | 0.542 | 9,079 | 0.535 | 8,657 | 0.745 | 10,127 |
| 25 | 0.806 | 12,255 | 0.984 | 12,607 | 0.673 | 11,262 | 0.664 | 10,739 | 0.924 | 12,562 |
| 30 | 0.960 | 14,594 | 1.171 | 15,014 | 0.801 | 13,412 | 0.790 | 12,789 | 1.100 | 14,960 |
| 40 | 1.272 | 19,333 | 1.552 | 19,890 | 1.061 | 17,767 | 1.047 | 16,942 | 1.458 | 19,818 |
| 50 | 1.590 | 24,167 | 1.940 | 24,862 | 1.327 | 22,209 | 1.309 | 21,177 | 1.822 | 24,772 |
| 60 | 1.896 | 28,814 | 2.313 | 29,643 | 1.582 | 26,480 | 1.560 | 25,250 | 2.173 | 29,536 |
| 75 | 2.357 | 35,827 | 2.876 | 36,857 | 1.967 | 32,924 | 1.940 | 31,395 | 2.701 | 36,724 |
| 100 | 3.143 | 47,769 | 3.834 | 49,143 | 2.622 | 43,898 | 2.587 | 41,860 | 3.602 | 48,966 |

| HP | Dallas | | El Paso | | Houston | | Corpus Christi | | Amarillo | |
|---|---|---|---|---|---|---|---|---|---|---|
| | kW | kWh | kW | kWh | kW | kWh | kW | kWh | kW | kWh |
| | | | | | Education - College & University | | | | | |
| 1 | 0.105 | 624 | 0.126 | 646 | 0.097 | 577 | 0.090 | 548 | 0.117 | 641 |
| 2 | 0.207 | 1,225 | 0.248 | 1,268 | 0.191 | 1,133 | 0.176 | 1,077 | 0.229 | 1,260 |
| 3 | 0.301 | 1,785 | 0.361 | 1,848 | 0.278 | 1,651 | 0.256 | 1,569 | 0.334 | 1,835 |
| 5 | 0.497 | 2,941 | 0.595 | 3,044 | 0.458 | 2,720 | 0.422 | 2,585 | 0.550 | 3,023 |
| 7.5 | 0.736 | 4,362 | 0.882 | 4,515 | 0.679 | 4,034 | 0.626 | 3,834 | 0.816 | 4,483 |
| 10 | 0.971 | 5,750 | 1.163 | 5,953 | 0.895 | 5,318 | 0.826 | 5,055 | 1.076 | 5,911 |
| 15 | 1.433 | 8,483 | 1.716 | 8,782 | 1.321 | 7,845 | 1.218 | 7,458 | 1.587 | 8,720 |
| 20 | 1.910 | 11,311 | 2.288 | 11,709 | 1.761 | 10,461 | 1.624 | 9,944 | 2.116 | 11,626 |
| 25 | 2.369 | 14,031 | 2.838 | 14,525 | 2.184 | 12,976 | 2.015 | 12,335 | 2.625 | 14,422 |
| 30 | 2.822 | 16,710 | 3.380 | 17,298 | 2.601 | 15,453 | 2.399 | 14,690 | 3.126 | 17,175 |
| 40 | 3.738 | 22,136 | 4.477 | 22,915 | 3.446 | 20,471 | 3.178 | 19,461 | 4.141 | 22,753 |
| 50 | 4.672 | 27,670 | 5.596 | 28,643 | 4.308 | 25,589 | 3.973 | 24,326 | 5.177 | 28,441 |
| 60 | 5.571 | 32,991 | 6.673 | 34,152 | 5.136 | 30,510 | 4.737 | 29,004 | 6.172 | 33,910 |
| 75 | 6.927 | 41,020 | 8.296 | 42,463 | 6.386 | 37,935 | 5.890 | 36,062 | 7.674 | 42,163 |
| 100 | 9.235 | 54,693 | 11.062 | 56,617 | 8.515 | 50,580 | 7.853 | 48,083 | 10.232 | 56,217 |
| | | | | | Retail | | | | | |
| 1 | 0.105 | 753 | 0.126 | 779 | 0.097 | 699 | 0.090 | 668 | 0.117 | 774 |
| 2 | 0.207 | 1,479 | 0.248 | 1,530 | 0.191 | 1,373 | 0.176 | 1,312 | 0.229 | 1,521 |
| 3 | 0.301 | 2,154 | 0.361 | 2,228 | 0.278 | 2,000 | 0.256 | 1,911 | 0.334 | 2,216 |
| 5 | 0.497 | 3,549 | 0.595 | 3,671 | 0.458 | 3,295 | 0.422 | 3,149 | 0.550 | 3,651 |
| 7.5 | 0.736 | 5,263 | 0.882 | 5,445 | 0.679 | 4,887 | 0.626 | 4,670 | 0.816 | 5,414 |
| 10 | 0.971 | 6,939 | 1.163 | 7,179 | 0.895 | 6,443 | 0.826 | 6,157 | 1.076 | 7,138 |
| 15 | 1.433 | 10,237 | 1.716 | 10,590 | 1.321 | 9,505 | 1.218 | 9,083 | 1.587 | 10,531 |
| 20 | 1.910 | 13,650 | 2.288 | 14,120 | 1.761 | 12,674 | 1.624 | 12,110 | 2.116 | 14,042 |
| 25 | 2.369 | 16,932 | 2.838 | 17,516 | 2.184 | 15,721 | 2.015 | 15,022 | 2.625 | 17,418 |
| 30 | 2.822 | 20,164 | 3.380 | 20,860 | 2.601 | 18,723 | 2.399 | 17,890 | 3.126 | 20,743 |
| 40 | 3.738 | 26,712 | 4.477 | 27,634 | 3.446 | 24,802 | 3.178 | 23,700 | 4.141 | 27,479 |
| 50 | 4.672 | 33,390 | 5.596 | 34,542 | 4.308 | 31,003 | 3.973 | 29,625 | 5.177 | 34,349 |
| 60 | 5.571 | 39,812 | 6.673 | 41,185 | 5.136 | 36,965 | 4.737 | 35,322 | 6.172 | 40,955 |
| 75 | 6.927 | 49,500 | 8.296 | 51,207 | 6.386 | 45,961 | 5.890 | 43,918 | 7.674 | 50,921 |
| 100 | 9.235 | 66,000 | 11.062 | 68,277 | 8.515 | 61,281 | 7.853 | 58,557 | 10.232 | 67,895 |
| | | | | | Restaurant - Fast Food | | | | | |
| 1 | 0.105 | 928 | 0.126 | 958 | 0.097 | 864 | 0.090 | 827 | 0.117 | 954 |
| 2 | 0.207 | 1,822 | 0.248 | 1,882 | 0.191 | 1,698 | 0.176 | 1,624 | 0.229 | 1,874 |
| 3 | 0.301 | 2,654 | 0.361 | 2,742 | 0.278 | 2,473 | 0.256 | 2,365 | 0.334 | 2,729 |
| 5 | 0.497 | 4,373 | 0.595 | 4,517 | 0.458 | 4,074 | 0.422 | 3,896 | 0.550 | 4,497 |
| 7.5 | 0.736 | 6,486 | 0.882 | 6,699 | 0.679 | 6,042 | 0.626 | 5,779 | 0.816 | 6,669 |
| 10 | 0.971 | 8,551 | 1.163 | 8,832 | 0.895 | 7,967 | 0.826 | 7,619 | 1.076 | 8,792 |
| 15 | 1.433 | 12,615 | 1.716 | 13,030 | 1.321 | 11,753 | 1.218 | 11,240 | 1.587 | 12,971 |
| 20 | 1.910 | 16,820 | 2.288 | 17,374 | 1.761 | 15,670 | 1.624 | 14,986 | 2.116 | 17,295 |
| 25 | 2.369 | 20,864 | 2.838 | 21,551 | 2.184 | 19,438 | 2.015 | 18,590 | 2.625 | 21,454 |
| 30 | 2.822 | 24,847 | 3.380 | 25,666 | 2.601 | 23,149 | 2.399 | 22,139 | 3.126 | 25,549 |
| 40 | 3.738 | 32,916 | 4.477 | 34,000 | 3.446 | 30,667 | 3.178 | 29,328 | 4.141 | 33,846 |
| 50 | 4.672 | 41,145 | 5.596 | 42,500 | 4.308 | 38,333 | 3.973 | 36,660 | 5.177 | 42,308 |
| 60 | 5.571 | 49,058 | 6.673 | 50,673 | 5.136 | 45,705 | 4.737 | 43,710 | 6.172 | 50,444 |
| 75 | 6.927 | 60,996 | 8.296 | 63,005 | 6.386 | 56,828 | 5.890 | 54,347 | 7.674 | 62,719 |
| 100 | 9.235 | 81,328 | 11.062 | 84,007 | 8.515 | 75,771 | 7.853 | 72,463 | 10.232 | 83,626 |

| HP | Dallas | | El Paso | | Houston | | Corpus Christi | | Amarillo | |
|---|---|---|---|---|---|---|---|---|---|---|
| | kW | kWh | kW | kWh | kW | kWh | kW | kWh | kW | kWh |
| Restaurant - Sit down | | | | | | | | | | |
| 1 | 0.105 | 715 | 0.126 | 739 | 0.097 | 864 | 0.090 | 641 | 0.117 | 735 |
| 2 | 0.207 | 1,404 | 0.248 | 1,451 | 0.191 | 1,698 | 0.176 | 1,259 | 0.229 | 1,444 |
| 3 | 0.301 | 2,045 | 0.361 | 2,114 | 0.278 | 2,473 | 0.256 | 1,834 | 0.334 | 2,104 |
| 5 | 0.497 | 3,370 | 0.595 | 3,483 | 0.458 | 4,074 | 0.422 | 3,022 | 0.550 | 3,466 |
| 7.5 | 0.736 | 4,998 | 0.882 | 5,166 | 0.679 | 6,042 | 0.626 | 4,481 | 0.816 | 5,140 |
| 10 | 0.971 | 6,589 | 1.163 | 6,811 | 0.895 | 7,967 | 0.826 | 5,909 | 1.076 | 6,777 |
| 15 | 1.433 | 9,721 | 1.716 | 10,047 | 1.321 | 11,753 | 1.218 | 8,717 | 1.587 | 9,998 |
| 20 | 1.910 | 12,961 | 2.288 | 13,397 | 1.761 | 15,670 | 1.624 | 11,622 | 2.116 | 13,330 |
| 25 | 2.369 | 16,077 | 2.838 | 16,618 | 2.184 | 19,438 | 2.015 | 14,417 | 2.625 | 16,535 |
| 30 | 2.822 | 19,147 | 3.380 | 19,790 | 2.601 | 23,149 | 2.399 | 17,169 | 3.126 | 19,692 |
| 40 | 3.738 | 25,364 | 4.477 | 26,217 | 3.446 | 30,667 | 3.178 | 22,745 | 4.141 | 26,087 |
| 50 | 4.672 | 31,706 | 5.596 | 32,771 | 4.308 | 38,333 | 3.973 | 28,431 | 5.177 | 32,608 |
| 60 | 5.571 | 37,803 | 6.673 | 39,073 | 5.136 | 45,705 | 4.737 | 33,898 | 6.172 | 38,879 |
| 75 | 6.927 | 47,002 | 8.296 | 48,582 | 6.386 | 56,828 | 5.890 | 42,148 | 7.674 | 48,341 |
| 100 | 9.235 | 62,670 | 11.062 | 64,776 | 8.515 | 75,771 | 7.853 | 56,197 | 10.232 | 64,455 |

**Table 2-51: Deemed Energy and Demand Savings Values for Inlet Damper Part-Load Fan Control by Climate Region**

| HP | Dallas | | El Paso | | Houston | | Corpus Christi | | Amarillo | |
|---|---|---|---|---|---|---|---|---|---|---|
| | kW | kWh | kW | kWh | kW | kWh | kW | kWh | kW | kWh |
| Hospital & Healthcare | | | | | | | | | | |
| 1 | 0.125 | 1,905 | 0.158 | 1,991 | 0.115 | 1,729 | 0.103 | 1,619 | 0.150 | 1,995 |
| 2 | 0.246 | 3,742 | 0.311 | 3,911 | 0.225 | 3,397 | 0.202 | 3,180 | 0.295 | 3,919 |
| 3 | 0.359 | 5,451 | 0.452 | 5,697 | 0.328 | 4,948 | 0.294 | 4,632 | 0.430 | 5,708 |
| 5 | 0.591 | 8,981 | 0.745 | 9,387 | 0.541 | 8,153 | 0.484 | 7,632 | 0.709 | 9,405 |
| 7.5 | 0.876 | 13,319 | 1.106 | 13,922 | 0.803 | 12,092 | 0.719 | 11,318 | 1.051 | 13,948 |
| 10 | 1.155 | 17,561 | 1.458 | 18,355 | 1.058 | 15,942 | 0.947 | 14,923 | 1.386 | 18,390 |
| 15 | 1.704 | 25,907 | 2.150 | 27,078 | 1.561 | 23,519 | 1.398 | 22,015 | 2.045 | 27,130 |
| 20 | 2.272 | 34,542 | 2.867 | 36,104 | 2.081 | 31,358 | 1.863 | 29,353 | 2.727 | 36,174 |
| 25 | 2.819 | 42,848 | 3.557 | 44,786 | 2.582 | 38,899 | 2.311 | 36,411 | 3.382 | 44,872 |
| 30 | 3.357 | 51,029 | 4.236 | 53,336 | 3.075 | 46,325 | 2.753 | 43,362 | 4.028 | 53,438 |
| 40 | 4.447 | 67,599 | 5.611 | 70,656 | 4.073 | 61,368 | 3.647 | 57,444 | 5.336 | 70,791 |
| 50 | 5.558 | 84,499 | 7.014 | 88,320 | 5.091 | 76,710 | 4.558 | 71,805 | 6.670 | 88,489 |
| 60 | 6.627 | 100,749 | 8.363 | 105,304 | 6.070 | 91,461 | 5.435 | 85,613 | 7.953 | 105,506 |
| 75 | 8.240 | 125,267 | 10.398 | 130,931 | 7.548 | 113,719 | 6.758 | 106,448 | 9.888 | 131,182 |
| 100 | 10.987 | 167,022 | 13.864 | 174,575 | 10.063 | 151,626 | 9.010 | 141,930 | 13.184 | 174,909 |
| Office - Large | | | | | | | | | | |
| 1 | 0.125 | 909 | 0.158 | 953 | 0.115 | 809 | 0.103 | 750 | 0.150 | 953 |
| 2 | 0.246 | 1,786 | 0.311 | 1,871 | 0.225 | 1,590 | 0.202 | 1,474 | 0.295 | 1,872 |
| 3 | 0.359 | 2,602 | 0.452 | 2,725 | 0.328 | 2,316 | 0.294 | 2,147 | 0.430 | 2,727 |
| 5 | 0.591 | 4,286 | 0.745 | 4,490 | 0.541 | 3,816 | 0.484 | 3,537 | 0.709 | 4,492 |
| 7.5 | 0.876 | 6,357 | 1.106 | 6,659 | 0.803 | 5,659 | 0.719 | 5,245 | 1.051 | 6,662 |
| 10 | 1.155 | 8,381 | 1.458 | 8,780 | 1.058 | 7,461 | 0.947 | 6,915 | 1.386 | 8,784 |
| 15 | 1.704 | 12,365 | 2.150 | 12,953 | 1.561 | 11,006 | 1.398 | 10,202 | 2.045 | 12,959 |
| 20 | 2.272 | 16,486 | 2.867 | 17,271 | 2.081 | 14,675 | 1.863 | 13,603 | 2.727 | 17,278 |
| 25 | 2.819 | 20,451 | 3.557 | 21,424 | 2.582 | 18,204 | 2.311 | 16,874 | 3.382 | 21,433 |
| 30 | 3.357 | 24,355 | 4.236 | 25,514 | 3.075 | 21,679 | 2.753 | 20,095 | 4.028 | 25,525 |
| 40 | 4.447 | 32,264 | 5.611 | 33,799 | 4.073 | 28,719 | 3.647 | 26,621 | 5.336 | 33,813 |
| 50 | 5.558 | 40,330 | 7.014 | 42,248 | 5.091 | 35,899 | 4.558 | 33,276 | 6.670 | 42,267 |
| 60 | 6.627 | 48,085 | 8.363 | 50,373 | 6.070 | 42,803 | 5.435 | 39,675 | 7.953 | 50,395 |
| 75 | 8.240 | 59,787 | 10.398 | 62,632 | 7.548 | 53,219 | 6.758 | 49,330 | 9.888 | 62,659 |
| 100 | 10.987 | 79,716 | 13.864 | 83,509 | 10.063 | 70,959 | 9.010 | 65,773 | 13.184 | 83,545 |

| HP | Dallas | | El Paso | | Houston | | Corpus Christi | | Amarillo | |
|---|---|---|---|---|---|---|---|---|---|---|
| | kW | kWh | kW | kWh | kW | kWh | kW | kWh | kW | kWh |
| Office - Small | | | | | | | | | | |
| 1 | 0.104 | 822 | 0.132 | 862 | 0.094 | 727 | 0.084 | 673 | 0.126 | 862 |
| 2 | 0.204 | 1,615 | 0.260 | 1,693 | 0.184 | 1,427 | 0.164 | 1,322 | 0.247 | 1,693 |
| 3 | 0.298 | 2,352 | 0.378 | 2,467 | 0.268 | 2,079 | 0.239 | 1,925 | 0.360 | 2,466 |
| 5 | 0.491 | 3,876 | 0.623 | 4,064 | 0.441 | 3,426 | 0.394 | 3,172 | 0.594 | 4,063 |
| 7.5 | 0.728 | 5,748 | 0.925 | 6,027 | 0.654 | 5,080 | 0.584 | 4,704 | 0.880 | 6,026 |
| 10 | 0.960 | 7,578 | 1.219 | 7,946 | 0.863 | 6,698 | 0.770 | 6,201 | 1.161 | 7,945 |
| 15 | 1.416 | 11,180 | 1.798 | 11,723 | 1.273 | 9,882 | 1.136 | 9,149 | 1.712 | 11,722 |
| 20 | 1.888 | 14,906 | 2.398 | 15,631 | 1.697 | 13,176 | 1.515 | 12,198 | 2.283 | 15,629 |
| 25 | 2.341 | 18,491 | 2.974 | 19,389 | 2.105 | 16,344 | 1.879 | 15,132 | 2.832 | 19,387 |
| 30 | 2.788 | 22,021 | 3.542 | 23,091 | 2.507 | 19,464 | 2.238 | 18,021 | 3.373 | 23,088 |
| 40 | 3.694 | 29,172 | 4.693 | 30,589 | 3.322 | 25,785 | 2.964 | 23,872 | 4.468 | 30,585 |
| 50 | 4.617 | 36,464 | 5.866 | 38,236 | 4.152 | 32,231 | 3.705 | 29,840 | 5.585 | 38,232 |
| 60 | 5.505 | 43,477 | 6.994 | 45,590 | 4.951 | 38,429 | 4.418 | 35,579 | 6.659 | 45,584 |
| 75 | 6.845 | 54,057 | 8.696 | 56,684 | 6.155 | 47,781 | 5.493 | 44,237 | 8.280 | 56,677 |
| 100 | 9.127 | 72,076 | 11.594 | 75,579 | 8.207 | 63,708 | 7.324 | 58,983 | 11.040 | 75,569 |
| Education - K-12 | | | | | | | | | | |
| 1 | 0.043 | 834 | 0.055 | 868 | 0.035 | 734 | 0.034 | 681 | 0.054 | 871 |
| 2 | 0.084 | 1,638 | 0.109 | 1,706 | 0.069 | 1,441 | 0.066 | 1,338 | 0.107 | 1,711 |
| 3 | 0.122 | 2,386 | 0.158 | 2,485 | 0.100 | 2,099 | 0.096 | 1,949 | 0.155 | 2,492 |
| 5 | 0.201 | 3,931 | 0.261 | 4,094 | 0.165 | 3,458 | 0.159 | 3,212 | 0.256 | 4,106 |
| 7.5 | 0.298 | 5,829 | 0.387 | 6,071 | 0.244 | 5,128 | 0.235 | 4,763 | 0.380 | 6,090 |
| 10 | 0.393 | 7,686 | 0.510 | 8,005 | 0.322 | 6,761 | 0.310 | 6,280 | 0.501 | 8,029 |
| 15 | 0.579 | 11,339 | 0.752 | 11,809 | 0.475 | 9,975 | 0.457 | 9,265 | 0.739 | 11,845 |
| 20 | 0.772 | 15,118 | 1.003 | 15,746 | 0.634 | 13,300 | 0.610 | 12,354 | 0.985 | 15,793 |
| 25 | 0.958 | 18,754 | 1.244 | 19,532 | 0.786 | 16,498 | 0.756 | 15,324 | 1.222 | 19,591 |
| 30 | 1.141 | 22,334 | 1.482 | 23,261 | 0.937 | 19,648 | 0.901 | 18,250 | 1.455 | 23,331 |
| 40 | 1.512 | 29,586 | 1.963 | 30,814 | 1.241 | 26,028 | 1.193 | 24,176 | 1.927 | 30,907 |
| 50 | 1.890 | 36,983 | 2.454 | 38,518 | 1.551 | 32,535 | 1.491 | 30,220 | 2.409 | 38,634 |
| 60 | 2.253 | 44,095 | 2.926 | 45,925 | 1.849 | 38,792 | 1.778 | 36,031 | 2.873 | 46,064 |
| 75 | 2.801 | 54,826 | 3.638 | 57,102 | 2.299 | 48,232 | 2.211 | 44,800 | 3.572 | 57,274 |
| 100 | 3.735 | 73,101 | 4.850 | 76,136 | 3.065 | 64,309 | 2.948 | 59,733 | 4.762 | 76,365 |
| Education - College & University | | | | | | | | | | |
| 1 | 0.125 | 943 | 0.158 | 988 | 0.115 | 837 | 0.103 | 776 | 0.150 | 989 |
| 2 | 0.246 | 1,853 | 0.311 | 1,941 | 0.225 | 1,644 | 0.202 | 1,524 | 0.295 | 1,942 |
| 3 | 0.359 | 2,699 | 0.452 | 2,827 | 0.328 | 2,395 | 0.294 | 2,220 | 0.430 | 2,829 |
| 5 | 0.591 | 4,447 | 0.745 | 4,658 | 0.541 | 3,947 | 0.484 | 3,657 | 0.709 | 4,661 |
| 7.5 | 0.876 | 6,595 | 1.106 | 6,908 | 0.803 | 5,853 | 0.719 | 5,424 | 1.051 | 6,913 |
| 10 | 1.155 | 8,695 | 1.458 | 9,107 | 1.058 | 7,717 | 0.947 | 7,151 | 1.386 | 9,114 |
| 15 | 1.704 | 12,828 | 2.150 | 13,436 | 1.561 | 11,385 | 1.398 | 10,550 | 2.045 | 13,445 |
| 20 | 2.272 | 17,103 | 2.867 | 17,915 | 2.081 | 15,180 | 1.863 | 14,066 | 2.727 | 17,927 |
| 25 | 2.819 | 21,216 | 3.557 | 22,222 | 2.582 | 18,830 | 2.311 | 17,449 | 3.382 | 22,238 |
| 30 | 3.357 | 25,266 | 4.236 | 26,465 | 3.075 | 22,424 | 2.753 | 20,780 | 4.028 | 26,483 |
| 40 | 4.447 | 33,471 | 5.611 | 35,059 | 4.073 | 29,706 | 3.647 | 27,528 | 5.336 | 35,083 |
| 50 | 5.558 | 41,839 | 7.014 | 43,823 | 5.091 | 37,133 | 4.558 | 34,410 | 6.670 | 43,854 |
| 60 | 6.627 | 49,885 | 8.363 | 52,251 | 6.070 | 44,274 | 5.435 | 41,027 | 7.953 | 52,287 |
| 75 | 8.240 | 62,025 | 10.398 | 64,967 | 7.548 | 55,048 | 6.758 | 51,011 | 9.888 | 65,011 |
| 100 | 10.987 | 82,700 | 13.864 | 86,622 | 10.063 | 73,397 | 9.010 | 68,015 | 13.184 | 86,682 |
| Retail | | | | | | | | | | |

| HP | Dallas | | El Paso | | Houston | | Corpus Christi | | Amarillo | |
|---|---|---|---|---|---|---|---|---|---|---|
| | kW | kWh | kW | kWh | kW | kWh | kW | kWh | kW | kWh |
| 1 | 0.125 | 1,137 | 0.158 | 1,190 | 0.115 | 1,016 | 0.103 | 947 | 0.150 | 1,194 |
| 2 | 0.246 | 2,234 | 0.311 | 2,337 | 0.225 | 1,996 | 0.202 | 1,859 | 0.295 | 2,345 |
| 3 | 0.359 | 3,254 | 0.452 | 3,404 | 0.328 | 2,907 | 0.294 | 2,708 | 0.430 | 3,416 |
| 5 | 0.591 | 5,362 | 0.745 | 5,609 | 0.541 | 4,790 | 0.484 | 4,462 | 0.709 | 5,628 |
| 7.5 | 0.876 | 7,952 | 1.106 | 8,318 | 0.803 | 7,104 | 0.719 | 6,618 | 1.051 | 8,347 |
| 10 | 1.155 | 10,484 | 1.458 | 10,967 | 1.058 | 9,366 | 0.947 | 8,726 | 1.386 | 11,005 |
| 15 | 1.704 | 15,467 | 2.150 | 16,179 | 1.561 | 13,817 | 1.398 | 12,873 | 2.045 | 16,235 |
| 20 | 2.272 | 20,623 | 2.867 | 21,572 | 2.081 | 18,423 | 1.863 | 17,163 | 2.727 | 21,647 |
| 25 | 2.819 | 25,582 | 3.557 | 26,759 | 2.582 | 22,853 | 2.311 | 21,291 | 3.382 | 26,852 |
| 30 | 3.357 | 30,466 | 4.236 | 31,868 | 3.075 | 27,216 | 2.753 | 25,355 | 4.028 | 31,978 |
| 40 | 4.447 | 40,359 | 5.611 | 42,216 | 4.073 | 36,053 | 3.647 | 33,589 | 5.336 | 42,362 |
| 50 | 5.558 | 50,449 | 7.014 | 52,770 | 5.091 | 45,067 | 4.558 | 41,986 | 6.670 | 52,953 |
| 60 | 6.627 | 60,150 | 8.363 | 62,918 | 6.070 | 53,733 | 5.435 | 50,060 | 7.953 | 63,136 |
| 75 | 8.240 | 74,789 | 10.398 | 78,230 | 7.548 | 66,810 | 6.758 | 62,243 | 9.888 | 78,500 |
| 100 | 10.987 | 99,718 | 13.864 | 104,306 | 10.063 | 89,079 | 9.010 | 82,990 | 13.184 | 104,667 |
| Restaurant - Fast Food | | | | | | | | | | |
| 1 | 0.125 | 1,410 | 0.158 | 1,475 | 0.115 | 1,265 | 0.103 | 1,179 | 0.150 | 1,480 |
| 2 | 0.246 | 2,771 | 0.311 | 2,897 | 0.225 | 2,484 | 0.202 | 2,316 | 0.295 | 2,907 |
| 3 | 0.359 | 4,036 | 0.452 | 4,220 | 0.328 | 3,619 | 0.294 | 3,374 | 0.430 | 4,234 |
| 5 | 0.591 | 6,649 | 0.745 | 6,954 | 0.541 | 5,962 | 0.484 | 5,558 | 0.709 | 6,977 |
| 7.5 | 0.876 | 9,861 | 1.106 | 10,313 | 0.803 | 8,842 | 0.719 | 8,243 | 1.051 | 10,347 |
| 10 | 1.155 | 13,002 | 1.458 | 13,597 | 1.058 | 11,658 | 0.947 | 10,868 | 1.386 | 13,642 |
| 15 | 1.704 | 19,181 | 2.150 | 20,059 | 1.561 | 17,198 | 1.398 | 16,034 | 2.045 | 20,125 |
| 20 | 2.272 | 25,575 | 2.867 | 26,745 | 2.081 | 22,931 | 1.863 | 21,378 | 2.727 | 26,834 |
| 25 | 2.819 | 31,724 | 3.557 | 33,176 | 2.582 | 28,445 | 2.311 | 26,519 | 3.382 | 33,286 |
| 30 | 3.357 | 37,781 | 4.236 | 39,510 | 3.075 | 33,876 | 2.753 | 31,582 | 4.028 | 39,641 |
| 40 | 4.447 | 50,049 | 5.611 | 52,340 | 4.073 | 44,876 | 3.647 | 41,837 | 5.336 | 52,513 |
| 50 | 5.558 | 62,562 | 7.014 | 65,425 | 5.091 | 56,095 | 4.558 | 52,297 | 6.670 | 65,641 |
| 60 | 6.627 | 74,593 | 8.363 | 78,007 | 6.070 | 66,883 | 5.435 | 62,354 | 7.953 | 78,265 |
| 75 | 8.240 | 92,745 | 10.398 | 96,990 | 7.548 | 83,159 | 6.758 | 77,528 | 9.888 | 97,311 |
| 100 | 10.987 | 123,660 | 13.864 | 129,321 | 10.063 | 110,879 | 9.010 | 103,371 | 13.184 | 129,748 |
| Restaurant - Sit Down | | | | | | | | | | |
| 1 | 0.125 | 1,082 | 0.158 | 1,131 | 0.115 | 1,265 | 0.103 | 912 | 0.150 | 1,135 |
| 2 | 0.246 | 2,124 | 0.311 | 2,221 | 0.225 | 2,484 | 0.202 | 1,792 | 0.295 | 2,230 |
| 3 | 0.359 | 3,095 | 0.452 | 3,235 | 0.328 | 3,619 | 0.294 | 2,610 | 0.430 | 3,248 |
| 5 | 0.591 | 5,099 | 0.745 | 5,331 | 0.541 | 5,962 | 0.484 | 4,300 | 0.709 | 5,352 |
| 7.5 | 0.876 | 7,561 | 1.106 | 7,906 | 0.803 | 8,842 | 0.719 | 6,377 | 1.051 | 7,938 |
| 10 | 1.155 | 9,969 | 1.458 | 10,423 | 1.058 | 11,658 | 0.947 | 8,408 | 1.386 | 10,465 |
| 15 | 1.704 | 14,707 | 2.150 | 15,377 | 1.561 | 17,198 | 1.398 | 12,404 | 2.045 | 15,439 |
| 20 | 2.272 | 19,610 | 2.867 | 20,503 | 2.081 | 22,931 | 1.863 | 16,539 | 2.727 | 20,586 |
| 25 | 2.819 | 24,325 | 3.557 | 25,433 | 2.582 | 28,445 | 2.311 | 20,516 | 3.382 | 25,536 |
| 30 | 3.357 | 28,969 | 4.236 | 30,289 | 3.075 | 33,876 | 2.753 | 24,432 | 4.028 | 30,411 |
| 40 | 4.447 | 38,377 | 5.611 | 40,124 | 4.073 | 44,876 | 3.647 | 32,366 | 5.336 | 40,286 |
| 50 | 5.558 | 47,971 | 7.014 | 50,156 | 5.091 | 56,095 | 4.558 | 40,458 | 6.670 | 50,357 |
| 60 | 6.627 | 57,196 | 8.363 | 59,801 | 6.070 | 66,883 | 5.435 | 48,238 | 7.953 | 60,041 |
| 75 | 8.240 | 71,115 | 10.398 | 74,354 | 7.548 | 83,159 | 6.758 | 59,978 | 9.888 | 74,653 |
| 100 | 10.987 | 94,820 | 13.864 | 99,138 | 10.063 | 110,879 | 9.010 | 79,970 | 13.184 | 99,537 |

**Table 2-52: Deemed Energy and Demand Savings Values for Inlet Guide Vane Part-Load Fan Control by Climate Region**

| HP | Dallas | | El Paso | | Houston | | Corpus Christi | | Amarillo | |
|---|---|---|---|---|---|---|---|---|---|---|
| | kW | kWh | kW | kWh | kW | kWh | kW | kWh | kW | kWh |
| Hospital & Healthcare | | | | | | | | | | |
| 1 | 0.021 | 397 | 0.027 | 420 | 0.019 | 350 | 0.017 | 320 | 0.027 | 423 |
| 2 | 0.041 | 780 | 0.053 | 825 | 0.038 | 687 | 0.033 | 629 | 0.053 | 832 |
| 3 | 0.059 | 1,137 | 0.078 | 1,202 | 0.055 | 1,001 | 0.048 | 916 | 0.078 | 1,211 |
| 5 | 0.098 | 1,873 | 0.128 | 1,981 | 0.090 | 1,649 | 0.079 | 1,509 | 0.128 | 1,996 |
| 7.5 | 0.145 | 2,778 | 0.190 | 2,938 | 0.134 | 2,445 | 0.117 | 2,238 | 0.190 | 2,960 |
| 10 | 0.191 | 3,663 | 0.251 | 3,873 | 0.177 | 3,224 | 0.155 | 2,950 | 0.251 | 3,902 |
| 15 | 0.282 | 5,403 | 0.370 | 5,714 | 0.261 | 4,756 | 0.228 | 4,352 | 0.370 | 5,757 |
| 20 | 0.376 | 7,204 | 0.494 | 7,619 | 0.348 | 6,342 | 0.304 | 5,803 | 0.493 | 7,676 |
| 25 | 0.466 | 8,937 | 0.612 | 9,451 | 0.431 | 7,867 | 0.377 | 7,199 | 0.612 | 9,521 |
| 30 | 0.555 | 10,643 | 0.729 | 11,255 | 0.513 | 9,368 | 0.449 | 8,573 | 0.729 | 11,339 |
| 40 | 0.736 | 14,099 | 0.966 | 14,910 | 0.680 | 12,410 | 0.595 | 11,357 | 0.966 | 15,021 |
| 50 | 0.920 | 17,624 | 1.207 | 18,637 | 0.850 | 15,513 | 0.744 | 14,196 | 1.207 | 18,777 |
| 60 | 1.097 | 21,013 | 1.440 | 22,221 | 1.014 | 18,496 | 0.887 | 16,926 | 1.439 | 22,387 |
| 75 | 1.363 | 26,127 | 1.790 | 27,629 | 1.260 | 22,998 | 1.102 | 21,045 | 1.789 | 27,836 |
| 100 | 1.818 | 34,836 | 2.387 | 36,839 | 1.680 | 30,664 | 1.470 | 28,060 | 2.386 | 37,114 |
| Office - Large | | | | | | | | | | |
| 1 | 0.021 | 187 | 0.027 | 198 | 0.019 | 161 | 0.017 | 146 | 0.027 | 200 |
| 2 | 0.041 | 368 | 0.053 | 389 | 0.038 | 316 | 0.033 | 287 | 0.053 | 392 |
| 3 | 0.059 | 536 | 0.078 | 567 | 0.055 | 461 | 0.048 | 418 | 0.078 | 571 |
| 5 | 0.098 | 883 | 0.128 | 934 | 0.090 | 759 | 0.079 | 688 | 0.128 | 941 |
| 7.5 | 0.145 | 1,310 | 0.190 | 1,385 | 0.134 | 1,126 | 0.117 | 1,020 | 0.190 | 1,396 |
| 10 | 0.191 | 1,727 | 0.251 | 1,826 | 0.177 | 1,485 | 0.155 | 1,345 | 0.251 | 1,841 |
| 15 | 0.282 | 2,548 | 0.370 | 2,694 | 0.261 | 2,190 | 0.228 | 1,985 | 0.370 | 2,716 |
| 20 | 0.376 | 3,398 | 0.494 | 3,592 | 0.348 | 2,920 | 0.304 | 2,646 | 0.493 | 3,621 |
| 25 | 0.466 | 4,215 | 0.612 | 4,455 | 0.431 | 3,623 | 0.377 | 3,283 | 0.612 | 4,492 |
| 30 | 0.555 | 5,019 | 0.729 | 5,306 | 0.513 | 4,314 | 0.449 | 3,909 | 0.729 | 5,349 |
| 40 | 0.736 | 6,649 | 0.966 | 7,029 | 0.680 | 5,715 | 0.595 | 5,179 | 0.966 | 7,086 |
| 50 | 0.920 | 8,311 | 1.207 | 8,786 | 0.850 | 7,144 | 0.744 | 6,474 | 1.207 | 8,858 |
| 60 | 1.097 | 9,910 | 1.440 | 10,475 | 1.014 | 8,518 | 0.887 | 7,719 | 1.439 | 10,561 |
| 75 | 1.363 | 12,321 | 1.790 | 13,024 | 1.260 | 10,591 | 1.102 | 9,597 | 1.789 | 13,131 |
| 100 | 1.818 | 16,428 | 2.387 | 17,366 | 1.680 | 14,121 | 1.470 | 12,796 | 2.386 | 17,508 |

| HP | Dallas | | El Paso | | Houston | | Corpus Christi | | Amarillo | |
|---|---|---|---|---|---|---|---|---|---|---|
| | kW | kWh | kW | kWh | kW | kWh | kW | kWh | kW | kWh |
| Office - Small | | | | | | | | | | |
| 1 | 0.017 | 169 | 0.023 | 179 | 0.016 | 145 | 0.014 | 131 | 0.023 | 181 |
| 2 | 0.034 | 333 | 0.044 | 352 | 0.031 | 284 | 0.027 | 257 | 0.045 | 355 |
| 3 | 0.049 | 485 | 0.065 | 513 | 0.045 | 414 | 0.039 | 374 | 0.065 | 517 |
| 5 | 0.081 | 799 | 0.106 | 845 | 0.074 | 681 | 0.065 | 617 | 0.107 | 852 |
| 7.5 | 0.120 | 1,185 | 0.158 | 1,254 | 0.110 | 1,011 | 0.096 | 915 | 0.159 | 1,263 |
| 10 | 0.158 | 1,562 | 0.208 | 1,653 | 0.145 | 1,332 | 0.127 | 1,206 | 0.210 | 1,666 |
| 15 | 0.234 | 2,304 | 0.307 | 2,439 | 0.214 | 1,966 | 0.187 | 1,779 | 0.310 | 2,458 |
| 20 | 0.312 | 3,073 | 0.409 | 3,252 | 0.285 | 2,621 | 0.249 | 2,372 | 0.413 | 3,277 |
| 25 | 0.386 | 3,811 | 0.508 | 4,034 | 0.354 | 3,251 | 0.309 | 2,943 | 0.513 | 4,065 |
| 30 | 0.460 | 4,539 | 0.605 | 4,804 | 0.422 | 3,872 | 0.368 | 3,505 | 0.611 | 4,841 |
| 40 | 0.610 | 6,013 | 0.801 | 6,363 | 0.559 | 5,129 | 0.488 | 4,643 | 0.809 | 6,412 |
| 50 | 0.762 | 7,516 | 1.001 | 7,954 | 0.698 | 6,411 | 0.609 | 5,803 | 1.011 | 8,016 |
| 60 | 0.909 | 8,962 | 1.194 | 9,484 | 0.833 | 7,644 | 0.727 | 6,919 | 1.206 | 9,557 |
| 75 | 1.130 | 11,143 | 1.484 | 11,792 | 1.035 | 9,504 | 0.903 | 8,603 | 1.499 | 11,883 |
| 100 | 1.507 | 14,857 | 1.979 | 15,723 | 1.380 | 12,672 | 1.205 | 11,471 | 1.999 | 15,844 |
| Education - K-12 | | | | | | | | | | |
| 1 | 0.007 | 173 | 0.010 | 182 | 0.006 | 147 | 0.005 | 133 | 0.010 | 184 |
| 2 | 0.014 | 340 | 0.019 | 358 | 0.011 | 289 | 0.011 | 262 | 0.020 | 361 |
| 3 | 0.020 | 496 | 0.027 | 521 | 0.017 | 420 | 0.015 | 381 | 0.029 | 527 |
| 5 | 0.033 | 817 | 0.045 | 859 | 0.027 | 693 | 0.026 | 628 | 0.047 | 868 |
| 7.5 | 0.049 | 1,212 | 0.067 | 1,274 | 0.041 | 1,027 | 0.038 | 932 | 0.070 | 1,287 |
| 10 | 0.064 | 1,597 | 0.088 | 1,680 | 0.054 | 1,354 | 0.050 | 1,228 | 0.092 | 1,696 |
| 15 | 0.095 | 2,357 | 0.130 | 2,479 | 0.079 | 1,998 | 0.074 | 1,812 | 0.136 | 2,502 |
| 20 | 0.126 | 3,142 | 0.173 | 3,305 | 0.106 | 2,664 | 0.098 | 2,416 | 0.182 | 3,337 |
| 25 | 0.157 | 3,898 | 0.215 | 4,099 | 0.131 | 3,304 | 0.122 | 2,997 | 0.226 | 4,139 |
| 30 | 0.187 | 4,642 | 0.256 | 4,882 | 0.156 | 3,935 | 0.145 | 3,570 | 0.269 | 4,929 |
| 40 | 0.247 | 6,149 | 0.339 | 6,467 | 0.207 | 5,213 | 0.192 | 4,729 | 0.356 | 6,530 |
| 50 | 0.309 | 7,687 | 0.423 | 8,084 | 0.258 | 6,516 | 0.240 | 5,911 | 0.445 | 8,162 |
| 60 | 0.369 | 9,165 | 0.505 | 9,639 | 0.308 | 7,769 | 0.286 | 7,048 | 0.530 | 9,732 |
| 75 | 0.458 | 11,395 | 0.628 | 11,984 | 0.383 | 9,660 | 0.356 | 8,763 | 0.659 | 12,100 |
| 100 | 0.611 | 15,193 | 0.837 | 15,979 | 0.511 | 12,880 | 0.474 | 11,684 | 0.879 | 16,133 |
| Education - College & University | | | | | | | | | | |
| 1 | 0.021 | 194 | 0.027 | 205 | 0.019 | 167 | 0.017 | 151 | 0.027 | 207 |
| 2 | 0.041 | 382 | 0.053 | 403 | 0.038 | 327 | 0.033 | 296 | 0.053 | 407 |
| 3 | 0.059 | 556 | 0.078 | 588 | 0.055 | 476 | 0.048 | 432 | 0.078 | 593 |
| 5 | 0.098 | 916 | 0.128 | 968 | 0.090 | 785 | 0.079 | 711 | 0.128 | 977 |
| 7.5 | 0.145 | 1,359 | 0.190 | 1,436 | 0.134 | 1,164 | 0.117 | 1,055 | 0.190 | 1,449 |
| 10 | 0.191 | 1,792 | 0.251 | 1,893 | 0.177 | 1,535 | 0.155 | 1,390 | 0.251 | 1,910 |
| 15 | 0.282 | 2,643 | 0.370 | 2,793 | 0.261 | 2,264 | 0.228 | 2,051 | 0.370 | 2,818 |
| 20 | 0.376 | 3,524 | 0.494 | 3,724 | 0.348 | 3,019 | 0.304 | 2,735 | 0.493 | 3,757 |
| 25 | 0.466 | 4,372 | 0.612 | 4,619 | 0.431 | 3,745 | 0.377 | 3,393 | 0.612 | 4,660 |
| 30 | 0.555 | 5,206 | 0.729 | 5,501 | 0.513 | 4,460 | 0.449 | 4,040 | 0.729 | 5,550 |
| 40 | 0.736 | 6,897 | 0.966 | 7,288 | 0.680 | 5,908 | 0.595 | 5,352 | 0.966 | 7,352 |
| 50 | 0.920 | 8,621 | 1.207 | 9,110 | 0.850 | 7,385 | 0.744 | 6,690 | 1.207 | 9,190 |
| 60 | 1.097 | 10,279 | 1.440 | 10,861 | 1.014 | 8,806 | 0.887 | 7,977 | 1.439 | 10,957 |
| 75 | 1.363 | 12,780 | 1.790 | 13,505 | 1.260 | 10,949 | 1.102 | 9,918 | 1.789 | 13,624 |
| 100 | 1.818 | 17,040 | 2.387 | 18,006 | 1.680 | 14,598 | 1.470 | 13,225 | 2.386 | 18,165 |
| Retail | | | | | | | | | | |

| HP | Dallas | | El Paso | | Houston | | Corpus Christi | | Amarillo | |
|---|---|---|---|---|---|---|---|---|---|---|
| | kW | kWh | kW | kWh | kW | kWh | kW | kWh | kW | kWh |
| 1 | 0.021 | 234 | 0.027 | 247 | 0.019 | 202 | 0.017 | 184 | 0.027 | 250 |
| 2 | 0.041 | 460 | 0.053 | 485 | 0.038 | 398 | 0.033 | 362 | 0.053 | 491 |
| 3 | 0.059 | 670 | 0.078 | 707 | 0.055 | 579 | 0.048 | 527 | 0.078 | 716 |
| 5 | 0.098 | 1,104 | 0.128 | 1,164 | 0.090 | 954 | 0.079 | 869 | 0.128 | 1,179 |
| 7.5 | 0.145 | 1,637 | 0.190 | 1,727 | 0.134 | 1,415 | 0.117 | 1,289 | 0.190 | 1,749 |
| 10 | 0.191 | 2,159 | 0.251 | 2,277 | 0.177 | 1,866 | 0.155 | 1,699 | 0.251 | 2,306 |
| 15 | 0.282 | 3,185 | 0.370 | 3,359 | 0.261 | 2,752 | 0.228 | 2,506 | 0.370 | 3,402 |
| 20 | 0.376 | 4,247 | 0.494 | 4,478 | 0.348 | 3,670 | 0.304 | 3,342 | 0.493 | 4,536 |
| 25 | 0.466 | 5,268 | 0.612 | 5,555 | 0.431 | 4,552 | 0.377 | 4,145 | 0.612 | 5,626 |
| 30 | 0.555 | 6,273 | 0.729 | 6,616 | 0.513 | 5,422 | 0.449 | 4,937 | 0.729 | 6,700 |
| 40 | 0.736 | 8,311 | 0.966 | 8,764 | 0.680 | 7,182 | 0.595 | 6,540 | 0.966 | 8,876 |
| 50 | 0.920 | 10,388 | 1.207 | 10,955 | 0.850 | 8,978 | 0.744 | 8,175 | 1.207 | 11,095 |
| 60 | 1.097 | 12,386 | 1.440 | 13,062 | 1.014 | 10,704 | 0.887 | 9,747 | 1.439 | 13,229 |
| 75 | 1.363 | 15,400 | 1.790 | 16,241 | 1.260 | 13,309 | 1.102 | 12,118 | 1.789 | 16,449 |
| 100 | 1.818 | 20,533 | 2.387 | 21,655 | 1.680 | 17,745 | 1.470 | 16,158 | 2.386 | 21,931 |
| Restaurant - Fast Food | | | | | | | | | | |
| 1 | 0.021 | 292 | 0.027 | 308 | 0.019 | 253 | 0.017 | 231 | 0.027 | 312 |
| 2 | 0.041 | 573 | 0.053 | 605 | 0.038 | 497 | 0.033 | 453 | 0.053 | 612 |
| 3 | 0.059 | 835 | 0.078 | 882 | 0.055 | 725 | 0.048 | 660 | 0.078 | 892 |
| 5 | 0.098 | 1,376 | 0.128 | 1,453 | 0.090 | 1,194 | 0.079 | 1,088 | 0.128 | 1,469 |
| 7.5 | 0.145 | 2,040 | 0.190 | 2,154 | 0.134 | 1,770 | 0.117 | 1,613 | 0.190 | 2,178 |
| 10 | 0.191 | 2,690 | 0.251 | 2,840 | 0.177 | 2,334 | 0.155 | 2,126 | 0.251 | 2,872 |
| 15 | 0.282 | 3,969 | 0.370 | 4,190 | 0.261 | 3,443 | 0.228 | 3,137 | 0.370 | 4,237 |
| 20 | 0.376 | 5,292 | 0.494 | 5,587 | 0.348 | 4,591 | 0.304 | 4,183 | 0.493 | 5,650 |
| 25 | 0.466 | 6,564 | 0.612 | 6,930 | 0.431 | 5,695 | 0.377 | 5,189 | 0.612 | 7,008 |
| 30 | 0.555 | 7,817 | 0.729 | 8,253 | 0.513 | 6,782 | 0.449 | 6,179 | 0.729 | 8,346 |
| 40 | 0.736 | 10,356 | 0.966 | 10,933 | 0.680 | 8,985 | 0.595 | 8,186 | 0.966 | 11,056 |
| 50 | 0.920 | 12,945 | 1.207 | 13,667 | 0.850 | 11,231 | 0.744 | 10,232 | 1.207 | 13,820 |
| 60 | 1.097 | 15,434 | 1.440 | 16,295 | 1.014 | 13,391 | 0.887 | 12,200 | 1.439 | 16,478 |
| 75 | 1.363 | 19,190 | 1.790 | 20,260 | 1.260 | 16,650 | 1.102 | 15,169 | 1.789 | 20,488 |
| 100 | 1.818 | 25,587 | 2.387 | 27,014 | 1.680 | 22,200 | 1.470 | 20,225 | 2.386 | 27,317 |
| Restaurant - Sit down | | | | | | | | | | |
| 1 | 0.021 | 223 | 0.027 | 235 | 0.019 | 253 | 0.017 | 178 | 0.027 | 238 |
| 2 | 0.041 | 438 | 0.053 | 462 | 0.038 | 497 | 0.033 | 350 | 0.053 | 468 |
| 3 | 0.059 | 638 | 0.078 | 673 | 0.055 | 725 | 0.048 | 510 | 0.078 | 682 |
| 5 | 0.098 | 1,051 | 0.128 | 1,109 | 0.090 | 1,194 | 0.079 | 840 | 0.128 | 1,123 |
| 7.5 | 0.145 | 1,559 | 0.190 | 1,644 | 0.134 | 1,770 | 0.117 | 1,246 | 0.190 | 1,666 |
| 10 | 0.191 | 2,055 | 0.251 | 2,168 | 0.177 | 2,334 | 0.155 | 1,642 | 0.251 | 2,196 |
| 15 | 0.282 | 3,032 | 0.370 | 3,198 | 0.261 | 3,443 | 0.228 | 2,423 | 0.370 | 3,240 |
| 20 | 0.376 | 4,043 | 0.494 | 4,264 | 0.348 | 4,591 | 0.304 | 3,230 | 0.493 | 4,320 |
| 25 | 0.466 | 5,015 | 0.612 | 5,289 | 0.431 | 5,695 | 0.377 | 4,007 | 0.612 | 5,359 |
| 30 | 0.555 | 5,972 | 0.729 | 6,299 | 0.513 | 6,782 | 0.449 | 4,772 | 0.729 | 6,382 |
| 40 | 0.736 | 7,912 | 0.966 | 8,344 | 0.680 | 8,985 | 0.595 | 6,321 | 0.966 | 8,454 |
| 50 | 0.920 | 9,890 | 1.207 | 10,430 | 0.850 | 11,231 | 0.744 | 7,902 | 1.207 | 10,568 |
| 60 | 1.097 | 11,792 | 1.440 | 12,436 | 1.014 | 13,391 | 0.887 | 9,421 | 1.439 | 12,600 |
| 75 | 1.363 | 14,661 | 1.790 | 15,462 | 1.260 | 16,650 | 1.102 | 11,714 | 1.789 | 15,666 |
| 100 | 1.818 | 19,548 | 2.387 | 20,616 | 1.680 | 22,200 | 1.470 | 15,619 | 2.386 | 20,888 |

## Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) for this VFD measure is 15 years per both the PUCT-approved Texas EUL filing (Docket No. 36779) and DEER 2014 (EUL ID – HVAC-VSD-fan).

# Program Tracking Data & 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
- Climate Zone
- Motor Horsepower
- Baseline Part-load Control Type (outlet damper, inlet damper, inlet guide vane)

# 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

- ASHRAE Fundamentals 1997: Chapter 26, Table 1B - Cooling and Dehumidification Design Conditions – United States
- ASHRAE Standard 90.1-2004: Table 10.8 Minimum Nominal Efficiency for General Purpose Design A and Design B Motors
- National Renewable Energy Laboratory's (NREL) National Solar Radiation Data Base: 1991- 2005 Update for Typical Meteorological Year 3 (TMY3). Accessed at http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/
- California Public Utility Commission. Database for Energy Efficiency Resources, 2005
- Bonneville Power Authority Adjustable Speed Drive Calculator – Fan curves utilized from that calculator were derived from "Flow Control", a Westinghouse publication, Bulletin B-851, F/86/Rev-CMS 8121. http://www.bpa.gov/EE/Sectors/Industrial/Documents/ASDCalculators.xls. Accessed 12/12/2014.

## Document Revision History

**Table 2-53: Nonresidential HVAC-VFD History**

| TRM version | Date | Description of Change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin |
| v2.0 | 04/18/2014 | No revisions |
| v3.0 | 04/10/2015 | Corrected ASHRAE 0.4% 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%. |
| v4.0 | 10/10/2016 | Added reference for % power and corrected signs for variables in Equation 36. |

# 2.3 NONRESIDENTIAL: BUILDING ENVELOPE

## 2.3.1 ENERGY STAR® Roofs Measure Overview

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

**Market Sector:** Commercial

**Measure Category:** Building Envelope

**Applicable Building Types:** Specific building types defined by each utility[85]

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit (RET)

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed Savings Calculation

**Savings Methodology:** Calculators, Worksheets

### Measure Description

This section presents the deemed savings methodology for the installation of an ENERGY STAR® certified roof. The installation of an ENERGY STAR® roof decreases the roofing heat transfer coefficient and reduces the solar heat transmitted to the building space. During hours when cooling is required in the building, this measure decreases the cooling energy use. During hours when heating is required in the building, this measure may increase or decrease the heating energy use depending on the project.

### Eligibility Criteria

Measures installed through utility programs must be a roof that meets ENERGY STAR® specifications. For nonresidential facilities, these criteria for a high-efficiency roof include:

- An existing roof undergoing retrofit conditions as further defined under high-efficiency condition below; a roof installed in a new construction application is not eligible for applying these methodologies.
- A roof with a low-slope of 2:12 or less[86].
- An initial solar reflectance of greater than or equal to 65%.
- A maintenance of solar reflectance of greater than or equal to 50% three years after installation under normal conditions.

[85] Building Types are specified in the respective calculators. These building types differ for utilities. It is believed that the cooling EFLH changes based on the building type, but it is unclear as to the reference of the EFLH being used for each.

[86] As defined in proposed ASTN Standard E 1918-97.

- 75 percent of the roof surface over conditioned space must be replaced.
- No significant obstruction of direct sunlight to roof.
- The facility must be conditioned with cooling, heating, or both.
- Be listed on the ENERGY STAR® list of qualified products.[87]

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

## Baseline Condition

The baseline is the thermal resistance (i.e. R-value) of the existing roof make-up, and the solar reflectance and emissivity of the surface layer. If the existing roof layers are known, the R-value of each layer in Table 2-56 is added together to get a total R-value of the roof assembly. If the existing layers are undetermined, the coefficient of heat transfer (i.e. U-value) of the roof assembly is assumed to be 0.066[88] and R-value is estimated to be 1/U (R=1/0.066=15.15). If the solar reflectance and emissivity are known, then they are used. If they are unknown, then they are determined by the surface layer material in Table 2-55.

The cooling and heating efficiencies are assumed based on the space conditioning of the top floor of the building. The unit type and average tonnage determine the kW/ton efficiency based on ASHRAE 90.1-1989.

**Table 2-54. Assumed cooling and heating efficiencies**

| System Type | Capacity [Tons] | Other Qualifier | Efficiencies |
|---|---|---|---|
| Unitary Air Conditioner | < 5.42 | Split | 10.0 SEER |
| | | Packaged | 9.7 SEER |
| | 5.42 to 11.25 | | 8.9 EER |
| | 11.25 to 20 | | 8.3 EER |
| | 20 to 63.33 | | 8.3 EER |
| | ≥ 63.3 | | 8.0 EER |
| Unitary Heat Pump (cooling) | < 5.42 | Split | 10.0 SEER |
| | | Packaged | 9.7 SEER |
| | 5.42 to 11.25 | | 8.9 EER |
| | 11.25 to 20 | | 8.3 EER |
| | 20 to 63.33 | | 8.3 EER |

[87] ENERGY STAR® Certified Roofs. http://www.energystar.gov/productfinder/product/certified-roof-products/. Accessed 08/15/2016.

[88] Post-1980 building vintage for Houston, TX in Table 19 of U.S. Department of Energy Commercial Reference Building Models of the National Building Stock. NREL. February 2011.

| System Type | Capacity [Tons] | Other Qualifier | Efficiencies |
|---|---|---|---|
| Unitary Heat Pump (heating) | ≥ 63.3 | | 8.5 EER |
| | < 5.42 | Split | 6.8 HSPF |
| | | Packaged | 6.6 HSPF |
| | 5.4 to 11.25 | | 3.0 COP |
| | ≥ 11.25 | | 2.9 COP |
| Air Cooled Chiller | < 150 | Including Condenser | 2.7 COP |
| | ≥ 150 | Including Condenser | 2.5 COP |
| Water Cooled Chiller | < 150 | | 3.8 COP |
| | 150 to 300 | Centrifugal | 4.2 COP |
| | > 300 | | 4.7 COP |
| | All | Reciprocating | 3.8 COP |
| | < 150 | | 3.8 COP |
| | 150 to 300 | Rotary, Screw or Scroll | 4.2 COP |
| | > 300 | | 4.7 COP |
| Room Air Conditioner | < 0.5 | | 8.0 EER |
| | 0.5 to 0.67 | | 8.5 EER |
| | 0.67 to 1.17 | With Louvered Sides | 9.0 EER |
| | 1.17 to 1.66 | | 8.8 EER |
| | ≥ 1.67 | | 8.2 EER |
| | < 0.5 | | 8.0 EER |
| | 0.5 to 1.67 | Without Louvered Sides | 8.5 EER |
| | ≥ 1.67 | | 8.2 EER |

| System Type | Capacity [Tons] | Other Qualifier | Efficiencies |
|---|---|---|---|
| Room Heat Pump (Cooling) | < 1.67 | With Louvered Sides | 8.5 EER |
| | > 1.67 | | 8.5 EER |
| | < 1.17 | Without Louvered Sides | 8.0 EER |
| | > 1.17 | | 8.0 EER |
| Room Heat Pump (Heating) | < 1.67 | With Louvered Sides | 8.5 HSPF |
| | > 1.67 | | 8.5 HSPF |
| | < 1.17 | Without Louvered Sides | 8.0 HSPF |
| | > 1.17 | | 8.0 HSPF |
| Packaged Terminal Air Conditioner | < 2.00 | | 10.9 – 0.213 * CAP EER |
| Packaged Terminal Heat Pump (Cooling) | < 2.00 | | 10.8 – 0.213 * CAP EER |
| Packaged Terminal Heat Pump (Heating) | < 2.00 | | 2.9 – 0.026 * CAP COP |
| Electric Resistance Heat | All | | 1 COP |
| Gas Heat | All | | 0.80 AFUE |

## High-Efficiency Condition

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

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

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

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Across the Texas utilities, there are several ways of calculating energy and demand savings for ENERGY STAR® roofs. Each of these is described further below. In addition, a new high performance roofing calculator was developed in 2016. While one industry accepted roofing savings calculator would be ideal, such a calculator is not available at this time. Until then, a single calculator should be used for all projects by a utility.

Oncor and AEP use the algorithms below in their calculators to calculate their savings.

$$\textit{Demand Savings}\ [kW] = \frac{A}{COP} \times \left[\left(\left(\frac{1}{R_{exist} + \left(\frac{1}{h_{in,air}}\right)}\right) - \left(\frac{1}{R_{prop} + \left(\frac{1}{h_{in,air}}\right)}\right)\right)\left(t_o - \frac{\varepsilon \Delta R}{h_o} - t_{in}\right) + \frac{(1-\rho_{exist})E_{tP}}{R_{exist} + \left(\frac{1}{h_{in,air}}\right)h_o} - \frac{(1-\rho_{prop})E_{tP}}{R_{prop} + \left(\frac{1}{h_{in,air}}\right)h_o}\right]$$

**Equation 44**

$$\textit{Energy Savings}\ [kWh] = \frac{A}{COP} \times \left[\left(\frac{1}{R_{exist} + \left(\frac{1}{h_{in,air}}\right) - R_{prop} + \left(\frac{1}{h_{in,air}}\right)}\right)\left(\sum_{i=1}^{n} t_{o,i} - n \times \frac{\varepsilon \Delta R}{h_o} - n \times t_{in}\right) + \frac{(1-\rho_{exist})\sum_{i=1}^{n} E_{t,i}}{R_{exist} + \left(\frac{1}{h_{in,air}}\right)h_o} - \frac{(1-\rho_{prop})\sum_{i=1}^{n} E_{t,i}}{R_{prop} + \left(\frac{1}{h_{in,air}}\right)h_o}\right]$$

**Equation 45**

*Where:*

| | | |
|---|---|---|
| *A* | = | *Roof Area [ft²]* |
| *$h_o$* | = | *coefficient of heat transfer by long-wave radiation and convection at outer surface [Btu/hr-°F-ft²], assumed to be 3.* |
| *COP* | = | *Equipment cooling efficiency [kW/ton], when efficiency ratings use a value that do not have the units of kW/ton, a conversion to kW/ton needs to be performed. For EER, divide 12 by EER (i.e. kW/ton=12/=EER. For Coefficient of Performance, multiple COP by 3.412 to get EER, then divide 12 by EER.)* |
| *R* | = | *The total thermal resistance value (R-value) of the roof [hr-°F-ft²/Btu]. See Table 2-56.* |

| | | |
|---|---|---|
| $h_{in,air}$ | = | *The heat transfer coefficient for indoor air [Btu/hr-°F-ft²], assumed to be 1.68.* |
| $\rho$ | = | *Reflectance of surface (after three years) for solar radiation* |
| $E_{t,P}$ | = | *Total peak solar radiation incident on surface during a cooling period [Btu/hr-ft²]. See Table 2-57.* |
| $\Sigma E_{t,I}$ | = | *The sum of the hourly solar radiation incident during a cooling period [Btu/hr-ft²]. See Table 2-57.* |
| $n$ | = | *The number of total cooling hours when solar radiation exist = 636*[89] |
| $\varepsilon$ | = | *Emittance of surface for solar radiation* |
| $\Delta R$ | = | *Difference between long-wave radiation incident on surface from sky and radiation emitted by blackbody at outdoor air temperature [Btu/hr-ft²], assumed to be 20.* |
| $t_o$ | = | *Outdoor air temperature* |
| $t_{in}$ | = | *Indoor air temperature, assumed to be 75°F* |

CenterPoint Electric and Xcel Energy also use calculator-based method; however, their method is slightly different, and uses the following algorithms. These algorithms are pulled from their calculator.

$$\Delta Q\left[\frac{Btu}{hr}\right] = \Delta U \times A \times \Delta T = \left(\frac{1}{R_1} - \frac{1}{R_2}\right) \times A \times \Delta T$$

**Equation 46**

$$\Delta T = T_{sol-air} - T_{space} = T_{oa} + \frac{\propto}{h_o} \times \frac{I_{DT}}{24} - \frac{\varepsilon \times \Delta R}{h_o} - T_{space}$$

**Equation 47**

$$\Delta kW = \Delta Q \times 1.0 \times \frac{1}{12,000}$$

**Equation 48**

$$\Delta kWh = \Delta kW \times EFLH$$

**Equation 49**

[89] Peak hours are set as the months of May to September, 1pm to 7pm weekdays.

*Where:*

| | | |
|---|---|---|
| $A$ | = | *Roof Area [ft$^2$]* |
| $\Delta U$ | = | *Difference in pre- and post-retrofit overall coefficient of heat transfer* |
| $\Delta Q$ | = | *Heat transfer [Btu/hr]* |
| $\Delta T$ | = | *Temperature difference [°F]* |
| $R_1$ | = | *Thermal resistance pre-retrofit* |
| $R_2$ | = | *Thermal resistance post-retrofit* |
| $\alpha$ | = | *Absorptance of surface for solar radiation*[90] |
| $h_o$ | = | *Coefficient of heat transfer by long-wave radiation and convection at outer surface*[90] |
| $I_{DT}$ | = | *Hourly solar radiation incident on surface*[90]*, deemed at 1,122* |
| $\varepsilon$ | = | *Hemispherical emittance of the surface, assumed to be 1.0* |
| $T_{oa}$ | = | *Outdoor air temperature [°F]* |
| $T_{sol}$ | = | *Sol-air temperature [°F]*[91] |
| $T_{space}$ | = | *Indoor temperature [°F]* |
| $\Delta R$ | = | *Difference between long-wave radiation incident on surface from sky and surroundings and radiation emitted by blackbody at outdoor air temperature* |
| *1.0* | = | *Assumed cooling efficiency [kW/ton]* |
| *1/12,000* | = | *Conversion from Btu to Tons/hr* |
| *EFLH* | = | *Effective full load hours [hours], assumed to be 2,000 hours* |

Finally, El Paso Electric uses the methodology found in Docket No. 41070. This docket outlines a deemed method for calculating savings. Their algorithm and deemed input variables used to calculate savings are shown below:

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[90] $I_{DT} = \frac{\alpha}{h_o} \times 1.15$. Per the C&I Standard Offer Program Calculator, ASHRAE recommended values for light colored surfaces = 0.15, for medium-colored surfaces = 0.23, and for dark-colored surfaces = 0.30. These values have been approximated using SHGF for a horizontal surface at 32° north latitude as described in 1993 ASHRAE Fundamentals, Chapter 27, Tables 14.

[91] Defined by ASHRAE as the temperature that would yield the same amount of heat transfer as the combination of incident solar radiation, radiant energy exchange with the surroundings, and convective heat exchange with the outdoor air.

$$Cooling\ Energy\ Savings\left[\frac{kWh}{ft^2}\right] = \frac{1}{EER} \times \frac{(\rho_{new} - \rho_{old}) \times E_{t,cooling}}{(R_{ins} + R_{cons} + R_{airfilm}) \times h_o} \times 0.001$$

**Equation 50**

$$Heating\ Energy\ Penalty\left[\frac{kWh}{ft^2}\right] = \frac{1}{COP} \times \frac{(\rho_{old} - \rho_{new}) \times E_{t,heating}}{(R_{ins} + R_{cons} + R_{airfilm}) \times h_o} \times \frac{1}{3412}$$

**Equation 51**

$$Total\ Energy\ Savings^{92} = Cooling\ Energy\ Savings - Heating\ Energy\ Penalty$$

**Equation 52**

$$Peak\ Demand\ Savings\left[\frac{kW}{ft^2}\right] = \frac{1}{EER} \times \frac{(\rho_{new} - \rho_{old}) \times l_t}{(R_{ins} + R_{cons} + R_{airfilm}) \times h_o} \times 0.001$$

**Equation 53**

*Where:*

| | | |
|---|---|---|
| *EER* | = | *Energy efficiency ratio of the buildings air conditioner [Btu/W-hr]* |
| $E_{t,cooling}$ | = | *Total solar radiation incident on the surface throughout the time when a building is in cooling mode [Btu/ft²]* |
| $\rho_{new}$ | = | *Reflectance (at three years) of the new roof membrane* |
| $\rho_{old}$ | = | *Reflectance of the original roof membrane* |
| $R_{ins}$ | = | *R-value of the roof insulation [h-ft²-°F/Btu]* |
| $R_{cons}$ | = | *R-value of the roof construction [h-ft²-°F/Btu]* |
| $R_{airfilm}$ | = | *R-value of the air film [h-ft²-°F/Btu]* |
| $h_o$ | = | *Coefficient of heat transfer by long-wave radiation and convection at outer surface* |
| *0.001* | = | *Conversion kWh per Watt-Hr* |
| *COP* | = | *Coefficient of performance of building's electric heating system* |
| $E_{t,heating}$ | = | *Total solar radiation incident on the surface throughout the time when a building is in heating mode [Btu/ft²]* |
| *3412* | = | *Conversion Btu per kWh* |

[92] For buildings with electric resistance heating.

$I_t$ = *Total solar radiation incident on the surface during the summer peak hour [Btu/ft$^2$-hr]*

Stipulated reflectance, emissivity, and R-values and solar data used for the calculations are presented next:

**Table 2-55: Reflectance and Emissivity of Surfaces**

| Roofing Type | New Reflectance | Aged Reflectance[93] | Emissivity |
|---|---|---|---|
| Black EPDM[94] | 0.062 | 0.062 | 0.86 |
| Gray EPDM | 0.231 | 0.222 | 0.87 |
| White EPDM | 0.687 | 0.541 | 0.87 |
| Smooth Bitumen | 0.058 | 0.058 | 0.86 |
| White Granular Bitumen | 0.258 | 0.241 | 0.92 |
| Dark Gravel on Built-Up Roof[95] | 0.120 | 0.120 | 0.90 |
| Light Gravel on Built-Up Roof | 0.340 | 0.298 | 0.90 |
| White-Coated Gravel on Built-Up Roof | 0.650 | 0.515 | 0.90 |

[93] Calculated based on Aged Reflectance=0.2+ß (New Reflectance – 0.20), where ß=0.7 non-field applied coatings per http://coolroofs.org/resources/california-title-24 and https://publications.lbl.gov/islandora/object/ir%3A157365/datastream/PDF/view

[94] First 5 in list from Laboratory Testing of the Reflectance Properties of Roofing Materials. Florida Solar Energy Center. Parker, McIlvaine, Barkaszi, Beal, Anello. http://www.fsec.ucf.edu/en/publications/html/FSEC-CR-670-00/

[95] Last 3 in list from Lawrence Berkley National Laboratory. http://energy.lbl.gov/coolroof/membrane.htm#membrane

**Table 2-56: R-Values of Different Material [hr-ft²-°F/Btu][96]**

| Roofing Material | R-Value | Membrane | R-Value |
|---|---|---|---|
| Asbestos – cement shingles | 0.21 | Permeable Felt | 0.06 |
| Asphalt Roll Roofing | 0.15 | Seal, 2 layers of mopped 15 lb felt | 0.12 |
| Asphalt Shingles | 0.44 | Sel, plastic film | 0.00 |
| Built-up Roofing (0.375") | 0.33 | **Insulation Material** | **R-Value (per inch)** |
| Slate (0.5") | 0.05 | None | 0.00 |
| Wood Shingles | 0.94 | Cellulose | 3.70 |
| **Construction Material** | **R-Value** | Fiberboard | 2.78 |
| Concrete 4" | 0.08 | Fiberglass | 3.20 |
| Concrete 8" | 1.11 | Perlite | 2.78 |
| Concrete 12" | 1.23 | Polystyrene | 4.00 |
| Brick 4" | 0.80 | Polyurethane | 6.25 |
| Wood Frame | 0.10 | Polyisocyanurate | 7.00 |
| Metal Frame | 0.00 | Polyisocyanurate Composite | 4.17 |
| | | Polystyrene Bead Board | 3.57 |
| | | Polystyrene Composite Board | 3.32 |
| **Ceiling Material** | **R-Value** | Rock Wool | 3.10 |
| Acoustic Tile | 0.06 | Vermiculite | 2.13 |
| Drywall Finish | 0.45 | Cork | 3.57 |
| Plaster Finish | 0.45 | | |
| **Plenum** | **R-Value** | | |
| Yes | 0.61 | | |
| No | 0.00 | | |

**Table 2-57: TMY2 Solar Data**

| Climate Zone | Peak Total Solar Radiation Incident [Btu/hr-ft²] | Total Solar Radiation Incident [Btu/ft²] |
|---|---|---|
| Amarillo, TX | 329 | 124,314 |
| Brownsville, TX | 326 | 113,022 |
| Dallas/Fort Worth, TX | 335 | 117,686 |
| Houston, TX | 325 | 101,734 |
| Austin, TX | 342 | 116,511 |

[96] These values are listed in both the Oncor and the CalcSmart calculators, but a source for all of the values have not been provided.

**Table 2-58: Deemed Values used in Algorithm for El Paso Electric[97]**

| Variable | Assumed Value |
|---|---|
| EER | 8.5[98] |
| COP | 1.0[99] |
| $\rho_{new}$ | 0.7[100] |
| $\rho_{old}$ | 0.062[101] |
| $E_{t,cooling}$ | 469,199[102] |
| $E_{t,heating}$ | 185,347[102] |
| $I_t$ | 217[103] |
| $R_{ins}$ | 16[104] |
| $R_{cons}$ | 2[105] |
| $R_{airfilm}$ | 0.92[106] |
| $h_o$ | 3[107] |

## Deemed Energy and Demand Savings Tables

The resulting deemed energy and demand savings values are presented in Table 2-59. Note that cool roofs have a negative heating impact, as reflected in the lower deemed savings value for Electric Resistance Heat versus Gas Heat.

**Table 2-59: Cool Roof Deemed Savings for El Paso Electric**

| Region | Electric A/C and Gas Heat [kWh/ft$^2$] | Electric A/C and Electric Resistance Heat [kWh/ft$^2$] | Summer Peak (Electric A/C) [kW/ft$^2$] | Winter Peak (Electric Resistance Heat) [kW/ft$^2$] |
|---|---|---|---|---|
| West | 0.6205 | 0.0099 | 0.0003 | 0.00 |

[97] All values and their sources were found in Docket No. 41070.
[98] Federal minimum for split and packaged systems, 11.25-20 tons from January 1st, 1994 through December 31st, 2009.
[99] Value for electric resistance heat.
[100] Minimum required by EPE Cool Roof Program.
[101] Reflectance of ethylene propylene diene monomer (EPDM) rubber. Sourced from http://www.fsec.ucf.edu/en/publications/html/FSEC-CR-670-00. Accessed 09/12/2013.
[102] Total global horizontal irradiance when temperature is over 65°F (typical building's thermal balance point) per El Paso TMY3 file.
[103] Total global horizontal irradiance during summer peak hour per El Paso TMY3 file.
[104] IECC 2000 Table 802.2(17).
[105] Typical value.
[106] ASHRAE Fundamentals 2006 27.2.
[107] ASHRAE Fundamentals 2006 18.22.

## Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

## Measure Life and Lifetime Savings

Estimated Useful Life is 15 years for cool roofs, as discussed in PUCT Docket Nos. 36779 and 41070. The DEER 2014 update also provides a 15-year life for cool roofs (EUL ID – BldgEnv-CoolRoof).

## Program Tracking Data & Evaluation Requirements

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

- Climate Zone or County Location
- Roofing Square Foot (Conditioned Area)
- Existing Roofing Amount of Construction, if possible
- Existing Roofing Amount of Slope
- Existing Roofing Surface layer or
    - Existing Roofing Reflectance and
    - Existing Roofing Emissivity
- New Roofing Construction, if rebuilding entire roof assembly
- New Insulation Type and Thickness, if adding insulation
- ENERGY STAR® Roofing Initial Solar Reflectance
- ENERGY STAR® Roofing Solar Reflectance after three years
- ENERGY STAR® Roofing Rated Life
- Building Type
- Cooling Equipment Type Serving Top Floor
- Heating System Type Serving Top Floor
- Average HVAC Equipment Tonnage of each unit serving top floor
- HVAC Equipment Rated Efficiency

## References and Efficiency Standards

## Petitions and Rulings

- PUCT Docket 41070 – Provides deemed energy and demand savings values for El Paso, TX.
- PUCT Docket 36779 – Provides EUL for commercial Cool Roof.

Relevant Standards and Reference Sources

- Oncor Technical Resource Manual. 2013.
- ENERGY STAR® Certified Cool Roof Products. http://www.energystar.gov/productfinder/product/certified-roof-products/. Accessed 09/12/2013.
- IECC 2000 Table 802.2(17)
- 2006 ASHRAE Fundamentals
- EUMMOT Commercial Standard Offer Program. Measurement and Verification Guidelines for Retrofit and New Construction Projects. http://www.aepefficiency.com/cisop/downloads/2013_C&I_SOP_Appendices.pdf. Accessed 09/10/2013
- DEER 2014 EUL update

## Document Revision History

**Table 2-60: Nonresidential Cool Roof History**

| TRM Version | Date | Description of Change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin |
| v2.0 | 04/18/2014 | Clarified that reflectance is three years basis. Table 2-56 through Table 2-59: Rounded off values, too many insignificant digits. |
| v3.0 | 04/10/2015 | No revisions |
| v4.0 | 10/10/2016 | Clarified eligibility criteria, baseline condition, and high-efficiency condition. Added R-values for more materials to Table 2-56. Added new high performance roof calculator for use in determining ENERGY STAR® roof savings. |

## 2.3.2 Window Treatments Measure Overview

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

**Market Sector:** Commercial

**Measure Category:** Building Envelope

**Applicable Building Types:** All Commercial Building Types

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit (RET)

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed Savings Calculations

**Savings Methodology:** Algorithms

### Measure Description

This section presents the deemed savings methodology for the installation of window films and solar screens. The installation of window film 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. Demand and energy savings result in demand and energy use of cooling equipment.

### Eligibility Criteria

This measure is applicable for treatment of single-paned windows in south or west facing orientations (as specified in Table 2-61 that do not have existing solar films or solar screens, are not shaded by exterior awnings, curtains, or overhangs, in buildings that are mechanically cooled (DX or chilled water).

### Baseline Condition

The baseline condition is single-pane clear glass, without existing window treatment. Interior and exterior shading is acceptable, but should be considered in the savings calculation.

### 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 EUMMOT utilities as presented in the EUMMOT program manual *Commercial Standard Offer Program: Measurement and Verification Guidelines for Retrofit and New Construction*

*Projects.*[108] The method estimates reduction in solar heat gain/insolation attributable to a given window treatment using shading coefficients for the treated and untreated window and solar heat gain estimates by window orientation according to ASHRAE Fundamentals. The reduction in building energy use attributable to reduction in cooling system energy use is estimated based on the reduced heat removal requirement for a standard efficiency cooling system.

## Savings Algorithms and Input Variables

$$\boldsymbol{Demand\ Savings_o}\ [\boldsymbol{kW}] = \frac{\boldsymbol{A_{film,o} \times SHGF_o \times (SC_{pre,o} - SC_{post,o})}}{\boldsymbol{3413 \times COP}}$$

**Equation 54**

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

**Equation 55**

$$\boldsymbol{Energy\ Savings_o}\ [\boldsymbol{kWh}] = \frac{\boldsymbol{A_{film,o} \times SHG_o \times (SC_{pre,o} - SC_{post,o})}}{\boldsymbol{3413 \times COP}}$$

**Equation 56**

$$\boldsymbol{Energy\ Savings}\ [\boldsymbol{kWh}] = \sum \boldsymbol{Energy\ Savings_o}$$

**Equation 57**

*Where:*

| | | |
|---|---|---|
| *Demand Savings* | = | *Peak demand savings per window orientation* |
| *Energy Savings* | = | *Energy savings per window orientation* |
| $A_{film,o}$ | = | *Area of window film applied to orientation [ft²]* |
| $SHGF_o$ | = | *Peak solar heat gain factor for orientation of interest [Btu/hr-ft²-year]. See Table 2-61.* |
| $SHG_o$ | = | *Solar heat gain for orientation of interest [Btu/ ft²-year]. See Table 2-61.* |
| *SCpre* | = | *Shading coefficient for existing glass/interior-shading device. See Table 2-62.* |
| *SCpost* | = | *Shading coefficient for new film/interior-shading device, from manufacturer specs* |

[108] See, for example, section 5.4 of the Equipment Efficiency Standards Appendices to the AEP companies' 2013 Commercial & Industrial Standard Offer Program Manual. Online. Available: http://www.aepefficiency.com/cisop/downloads/2013_C&I_SOP_Appendices.pdf

| | | |
|---|---|---|
| *COP* | = | *Cooling equipment COP based on Table 2-63 or actual COP equipment, whichever is greater* |
| *3413* | = | *Conversion factor [Btu/kW]* |

**Table 2-61: Solar Heat Gain Factors[109]**

| Orientation | Solar Heat Gain {SHG) [Btu/ft$^2$-year] | Peak Hour Solar Heat Gain (SHGF) [Btu/hr-ft$^2$-year] | | | | |
|---|---|---|---|---|---|---|
| | | Zone 1[110] | Zone 2 | Zone 3 | Zone 4 | Zone 5 |
| South-East | 158,844 | 25 | 25 | 25 | 25 | 34 |
| South-South-East | 134,794 | 26 | 26 | 26 | 26 | 38 |
| South | 120,839 | 33 | 33 | 44 | 44 | 57 |
| South-South-West | 134,794 | 87 | 87 | 106 | 111 | 102 |
| South-West | 158,844 | 152 | 152 | 164 | 173 | 143 |
| West-South-West | 169,696 | 192 | 192 | 196 | 207 | 163 |
| West | 163,006 | 204 | 204 | 198 | 211 | 158 |
| West-North-West | 139,615 | 185 | 185 | 170 | 183 | 131 |
| North-West | 107,161 | 139 | 139 | 117 | 126 | 89 |

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

[110] Coincidence factors specific to Climate Zone 1 could not be calculated since utility load data are not currently available for this region. In their absence, Climate Zone 2 values may be used.

**Table 2-62: Recommended Shading Coefficient (SC) for Different Pre-Existing Shade Types**

| Shading Type | Shading Coefficient | Source[111] |
|---|---|---|
| None | 0.95 | Table 29: Based on ¼" clear single-pane glass |
| Roller Shade | 0.81 | Table 25: Based on clear glass, dark opacity |
| Venetian Blinds | 0.74 | Table 25: Based on clear glass, medium-color blinds |
| Louvered Exterior Shades | 0.59 | Table 24: Based on Profile Angle ≤ $10^0$, Group 4 |
| Draperies – Open Weave | 0.65 | Table 29: Based on ¼" clear single-pane glass, Option D |
| Draperies – Closed Weave | 0.53 | Table 29: Based on ¼" clear single-pane glass, Option F/G |

**Table 2-63: Recommended COP for Different HVAC System Types**

| HVAC Type | COP | Source[112] |
|---|---|---|
| Air Conditioners & Heat Pumps | 3.02 | Table 6.2.1A: Air Conditioner, ≥19 kW and <40 kW |
| Air-Cooled Chillers | 3.1 | Table 6.2.1C: Air Cooled Chiller w/o Condenser <528kW |
| Water-Cooled Chiller | 5.0 | Table 6.2.1C: Water-Cooled Centrifugal Chiller <528 kW |
| Room Air Conditioner | 2.84 | Table 6.2.1D: Room A/C w/ Louvered Sides, < 2.3 kW |
| PTAC/PTHP | 3.66 | Table 6.2.1D: PTAC (New Construction), 2.3 kW |

## Measure Life and Lifetime Savings

Estimated Useful Life is 10 years for solar screens, as discussed in PUCT Docket Nos. 36779 and 41070. The DEER 2014 update also provides a EUL of 10 years for this measure (EUL ID – GlazDaylt-WinFilm).

## Program Tracking Data & Evaluation Requirements

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

- Existing Window Shading Coefficients
- Existing Window Interior Shading Type
- Description of Existing Window Presence of Exterior Shading from other Buildings or Obstacles
- Window Film or Solar Screen Shading Coefficient
- Eligible Window Treatment Application Area by Orientation (e.g. S, SSW, SW...)
- Cooling Equipment Type
- Cooling Equipment Rated Efficiency

[111] Table numbers and shading coefficients provided are from 1997 ASHRAE Fundamentals Handbook, Chapter 29.
[112] Table numbers and COP provided are from ASHRAE 90.1-1999.

## References and Efficiency Standards

### Petitions and Rulings

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

### Relevant Standards and Reference Sources

- 1997 ASHRAE Fundamentals, Chapter 29, Table 17.
- ASHRAE Standard 90.1-1999
- DEER 2014 EUL update

### Document Revision History

**Table 2-64: Nonresidential Window Treatment History**

| TRM Version | Date | Description of Change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin |
| v2.0 | 04/18/2014 | Eliminated east-facing windows from consideration for energy savings. |
| v3.0 | 04/10/2015 | References to EPE-specific deemed savings removed (EPE to adopt methods used by the other utilities). Demand savings: Frontier 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 | No revisions |

## 2.4 NONRESIDENTIAL: FOOD SERVICE EQUIPMENT

### 2.4.1 ENERGY STAR® Combination Ovens Measure Overview

**TRM Measure ID:** NR-FS-CO

**Market Sector:** Commercial

**Measure Category:** Food Service Equipment

**Applicable Business Types:** See Eligibility Criteria

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, Replace-on-Burnout or New Construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed Savings Values

**Savings Methodology:** Look-up Tables

## Measure Description

This section presents the deemed savings methodology for the installation of High Efficiency Combination Ovens. Combination ovens are convection ovens that include the added capability to inject steam into the oven cavity and typically offers at least three distinct cooking modes; combination mode to roast or bake with moist heat, convection mode to operate purely as a convection oven providing dry heat, or as a straight pressure-less steamer. The energy and demand savings are determined on a per-oven basis.

## Eligibility Criteria

Eligible units must meet ENERGY STAR® qualifications, with half-size and full-size ovens as defined by ENERGY STAR® and a pan capacity ≥ 5 and ≤ 20113.

- Half-Size Combination Oven: A combination oven capable of accommodating a single 12 x 20 x 2½-inch steam table pan per rack position, loaded from front-to-back or lengthwise.
- Full-Size Combination Oven: A combination oven capable of accommodating two 12 x 20 x 2½-inch steam table pans per rack position, loaded from front-to-back or lengthwise.

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets [114]

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[113] ENERGY STAR® Program Requirements for Commercial Ovens. https://www.energystar.gov/sites/default/files/specs//private/Commercial%20Ovens%20Program%20Requirements%20V2%201.pdf. Accessed January 26th, 2015.

[114] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: http://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_June2014.pdf. Accessed 04/30/2015.

The following products are excluded from the ENERGY STAR® eligibility criteria:

- 2/3-sized combination ovens,
- Dual-fuel heat source combination ovens,
- Gas combination ovens, and
- Electric combination ovens with a pan capacity < 5 and >20.

## Baseline Condition

Eligible baseline condition for retrofit situations is a half-size or full-size combination oven with a pan capacity ≥ 5 and ≤ 20.

## High-Efficiency Condition

The high-efficiency combination ovens must be ENERGY STAR® rated. To do so, they meet the following minimum energy efficiency and idle energy rate requirements, as shown in Table 2-65 below.

**Table 2-65: Cooking Energy-Efficiency and Idle Energy Rate Requirements[115]**

| Operation | Idle Rate (kW) | Cooking Energy Efficiency (%) |
|---|---|---|
| Steam Mode | ≤ 0.133P + 0.6400 | ≥ 55 |
| Convection Mode | ≤ 0.080P + 0.4989 | ≥ 76 |

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

The calculation for these deemed values are calculated based on the following algorithms:

$$Energy\ Savings\ [kWh] = kWh_{base} - kWh_{post}$$

**Equation 58**

$$Peak\ Demand\ [kW] = \frac{\Delta kWh}{t_{hrs} \times t_{days}} \times CF$$

**Equation 59**

$$kWh_{base} = kWh_{conv} + kWh_{st}$$

**Equation 60**

$$kWh_{post} = kWh_{conv} + kWh_{st}$$

**Equation 61**

[115] ENERGY STAR®. Savings Calculator for ENERGY STAR® Qualified Commercial Kitchen Equipment. Calculator: http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

$kWh_{conv}$ and $kWh_{st}$ are each calculated the same for both the base (baseline) and post (ENERGY STAR®) cases, as shown in Equation 62, except they require their respective *η (Cooking Efficiencies), $E_{Idle}$ (Idle Energy Rates) and $C_{cao}$ (Production Capacity) relative to Convection and Steam Modes as seen in* Table 2-66.

$$kWh = \left( \left( W_{food} \times \frac{E_{food} \times 50\%}{\eta_{cooking}} \right) + E_{idle} \times \left( \left( t_{hours} - \frac{W_{food}}{C_{cap}} \right) \times 50\% \right) \right) \times \frac{t_{days}}{1000}$$

**Equation 62**

Where:

| | | |
|---|---|---|
| $kWh_{base}$ | = | *Baseline annual energy consumption [kWh]* |
| $kWh_{post}$ | = | *Post annual energy consumption [kWh]* |
| $t_{days}$ | = | *Facility operating days per year* |
| $t_{hours}$ | = | *Equipment operating hours per day* |
| *CF* | = | *Peak coincidence factor* |
| $W_{food}$ | = | *Pounds of food cooked per day [lb/day]* |
| $E_{food}$ | = | *ASTM energy to food [Wh/lb]. (Differs for Convection-Mode and Steam-Mode®. See Table 2-66)* |
| $E_{Idle}$ | = | *Idle energy rate [W]. (Differs for Convection-Mode and Steam-Mode, for Baseline and ENERGY STAR®. See Table 2-66* |
| *ηcooking* | = | *Cooking energy efficiency [%]. (Differs for Convection-Mode and Steam-Mode, for Baseline and ENERGY STAR®. See Table 2-66)* |
| *CCap* | = | *Production capacity per pan [lb/hr]. (Differs for Convection-Mode and Steam-Mode, for Baseline and ENERGY STAR®. See Table 2-66)* |
| *1000* | = | *Wh to kWh conversion* |

**Table 2-66: Deemed Variables for Energy and Demand Savings Calculations**

| Parameter | Convection-Mode | | Steam-Mode | |
|---|---|---|---|---|
| | Baseline | ENERGY STAR® | Baseline | ENERGY STAR® |
| kWhbase | See Table 2-67 | | | |
| kWhpost | | | | |
| Wfood | 200 | | | |
| thours | 12 | | | |
| tDays | 365 | | | |
| Npans | 10 | | | |
| CF116 | 0.92 | | | |
| Efood | 73.2 | | 30.8 | |
| ηcooking | 72% | 76% | 49% | 55% |
| EidleB | 1,320 | 1,299 | 5,260 | 1,970 |
| CCap | 79 | 119 | 126 | 177 |

## Deemed Energy and Demand Savings Tables

The energy and demand savings of High Efficiency Combination Ovens in Table 2-67 are calculated in the Savings Calculator for ENERGY STAR® Qualified Commercial Kitchen Equipment using the default parameters shown above in Table 2-66.

**Table 2-67: Deemed Energy and Demand Savings Values[117]**

| $kWh_{base}$ | $kWh_{post}$ | Annual Energy Savings [kWh] | Peak Demand Savings [kW] |
|---|---|---|---|
| 18,282 | 11,914 | 6,368 | 1.338 |

## Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

## Measure Life and Lifetime Savings

The EUL has been defined for this measure as 12 years, consistent with ENERGY STAR® calculator and with the DEER 2014 EUL update (EUL ID – Cook-ElecCombOven).

[116] California End Use Survey (CEUS), Building workbooks with load shapes by end use. Accessed July 12, 2012, http://capabilities.the EM&V team.com/CeusWeb/Chart.aspx.

[117] ENERGY STAR®. Savings Calculator for ENERGY STAR® Qualified Commercial Kitchen Equipment Calculator: http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. Accessed 01/27/2015.

## Program Tracking Data & Evaluation Requirements

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

- High Efficiency Manufacturer Make and Model
- High Efficiency Heavy Load Cooking Efficiency
- High Efficiency Equipment Idle Rate
- Oven Size
- Verification of ENERGY STAR® certification

## References and Efficiency Standards

### Petitions and Rulings

N/A

### Relevant Standards and Reference Sources

- ENERGY STAR® Equipment Standards for Commercial Ovens. http://www.energystar.gov/products/certified-products/detail/commercial-ovens
- DEER 2014 EUL update

### Document Revision History

**Table 2-68: Nonresidential High-Efficiency Combination Oven History**

| TRM Version | Date | Description of Change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin |
| v2.0 | 04/18/2014 | No revisions |
| v3.0 | 04/10/2015 | Updated previous method based upon the Food Service Technology Center (FSTC) assumptions to an approach using the newly developed ENERGY STAR® Commercial Ovens Program Requirements Version 2.1, which added combination ovens under this version. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator. |
| v3.1 | 11/05/2015 | Updated title to reflect ENERGY STAR® measure. |
| v4.0 | 10/10/2016 | No revisions |

## 2.4.2 ENERGY STAR® Electric Convection Ovens Measure Overview

**TRM Measure ID:** NR-FS-CV

**Market Sector:** Commercial

**Measure Category:** Food Service Equipment

**Applicable Building Types:** See Eligibility Criteria

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, Replace-on-Burnout, or New Construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed Savings Values

**Savings Methodology:** Look-up Tables

### Measure Description

This section covers the savings from retrofit (early retirement), replacement, or new installation of a full-size high efficiency electric convection oven. Convection ovens cook their food by forcing hot dry air over the surface of the food product. The rapidly moving hot air strips away the layer of cooler air next to the food and enables the food to absorb the heat energy. The energy and demand savings are deemed, and based off of energy rates of the oven, cooking efficiencies, operating hours, production capacities and building type. An average energy and demand consumption has been calculated based on these default values to create a stipulated savings value. The energy and demand savings are determined on a per-oven basis.

### Eligibility Criteria

Eligible units must meet ENERGY STAR® qualifications, with half-size and full-size electric ovens as defined by ENERGY STAR®118.

- Half-Size Combination Oven: A combination oven capable of accommodating half-size sheet pans measuring 18 x 13 x 1-inch.
- Full-Size Combination Oven: A combination oven capable of accommodating standard full-size sheet pans measuring 18 x 26 x 1-inch.

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.119

Convection ovens eligible for rebate do not include ovens that have the ability to heat the cooking cavity with saturated or superheated steam.

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[118] ENERGY STAR® Program Requirements for Commercial Ovens.https://www.energystar.gov/sites/default/files/specs/private/Commercial_Ovens_Program_Requirements_V2_1.pdf. Accessed January 26th, 2015.

[119] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: http://library.cee1.org/sites/default/files/library/4203/CEE_CommKit_InitiativeDescription_June2014.pdf. Accessed 04/30/2015.

## Baseline Condition

Eligible baseline condition for retrofit situations is an electric convection oven.

## High-Efficiency Condition

The high-efficiency convection ovens must be ENERGY STAR® rated and therefore must meet the following minimum energy efficiency and idle energy rate requirements, as shown in Table 2-69 below:

**Table 2-69: Convection Oven Cooking Energy Efficiency and Idle Energy Requirements**

| Oven Capacity | Idle Rate (W) | Cooking Energy Efficiency (%) |
|---|---|---|
| Half-Size | ≤ 1,000 | ≥ 71 |
| Full-Size | ≤ 1,600 | ≥ 71 |

## Energy and Demand Savings Methodology

## Savings Calculations and Input Variables

The deemed savings from these ovens are based on the following algorithms:

$$Energy\ [kWh] = (E_{base} - E_{HE}) \times \frac{days}{1000}$$

**Equation 63**

$$Peak\ Demand\ [kW] = \frac{(E_{base} - E_{HE})}{T_{on}} \times \frac{CF}{1000}$$

**Equation 64**

$$E_{base} = \frac{LB \times E_{Food}}{EFF_{base}} + \left[IDLE_{base} \times \left(T_{on} - \frac{LB}{PC_{base}}\right)\right]$$

**Equation 65**

$$E_{HE} = \frac{LB \times E_{Food}}{EFF_{HE}} + \left[IDLE_{HE} \times \left(T_{on} - \frac{LB}{PC_{HE}}\right)\right]$$

**Equation 66**

Where:

$E_{base}$ = *Baseline daily energy consumption (kWh/day)*

$E_{HE}$ = *High efficiency daily energy consumption (kWh/day)*

*LB* = *Pounds of food cooked per day [lb/day]*

*Days* = *Number of operating days per year [days/yr]*

*CF* = *Coincidence Factor*

| | | |
|---|---|---|
| *Efood* | = | *ASTM energy to food of energy absorbed by food product during cooking [Wh/lb]* |
| $EFF_{base}$ | = | *Baseline heavy load cooking energy efficiency [%]* |
| $EFF_{HE}$ | = | *High efficiency heavy load cooking energy efficiency [%]* |
| $IDLE_{base}$ | = | *Baseline idle energy rate [kW]* |
| $IDLE_{HE}$ | = | *High efficiency idle energy rate [kW]* |
| $T_{on}$ | = | *Operating hours per day [hrs/day]* |
| $PC_{base}$ | = | *Baseline production capacity [lbs/hr]* |
| $PC_{HE}$ | = | *High efficiency production capacity [lbs/hr]* |

**Table 2-70: Deemed Variables for Energy and Demand Savings Calculations[120]**

| Variable | Full-Size | Half-Size |
|---|---|---|
| LB[122] | 100 | |
| Days | 365 | |
| CF[121] | 0.92 | |
| $E_{food}$[122] | 73.2 | |
| $EFF_{base}$[122] | 65% | 68% |
| $EFF_{HE}$[122] | 71% | |
| $IDLE_{base}$[122] | 2,000 | 1,030 |
| $IDLE_{HE}$[122] | 1,600 | 1,000 |
| $T_{on}$ | 12 | |
| $PC_{base}$[122] | 90 | 45 |
| $PC_{HE}$[122] | 90 | 50 |

[120] The FSTC "Electric Combination Oven Life-Cycle Cost Calculator" was used to determine the annual energy consumption of both baseline and energy efficient electric combination ovens. The FSTC calculator uses oven performance parameters based on ASTM Standard Test Method F2861. The FSTC calculator default values assume equipment is operating 12 hours a day, 365 days year. In an effort to account for variations in operation of different facility kitchens, calculator inputs for equipment operating hours and annual days of operation were assumed based on the facility types shown in Table 2-66.

[121] California End Use Survey (CEUS), Building workbooks with load shapes by end use. Accessed July12, 2012, http://capabilities.the EM&V team.com/CeusWeb/Chart.asnx.

[122] Default values in ENERGY STAR® calculator for Full Size Ovens.