System type	Duct location	Cooling capacity (Btu/hr)	Baseline efficiency [NSenCOP]
Air-cooled with fluid economizer	Downflow	< 80,000	2.70
		≥ 80,000 and < 295,000	2.58
		≥ 295,000 and < 930,000	2.36
	Upflow ducted	< 80,000	2.67
		≥ 80,000 and < 295,000	2.55
		≥ 295,000 and < 930,000	2.33
	Upflow non-ducted	< 65,000	2.09
		≥ 65,000 and < 240,000	1.99
		≥ 240,000 and < 760,000	1.81
	Horizontal	< 65,000	2.65
		≥ 65,000 and < 240,000	2.55
		≥ 240,000 and < 760,000	2.47
Water-cooled	Downflow	< 80,000	2.82
		≥ 80,000 and < 295,000	2.73
		≥ 295,000 and < 930,000	2.67
	Upflow ducted	< 80,000	2.79
		≥ 80,000 and < 295,000	2.70
		≥ 295,000 and < 930,000	2.64
	Upflow non-ducted	< 65,000	2.43
		≥ 65,000 and < 240,000	2.32
		≥ 240,000 and < 760,000	2.20
	Horizontal	< 65,000	2.79
		≥ 65,000 and < 240,000	2.68
		≥ 240,000 and < 760,000	2.60

System type	Duct location	Cooling capacity (Btu/hr)	Baseline efficiency [NSenCOP]
Water-cooled with fluid economizer	Downflow	< 80,000	2.77
		≥ 80,000 and < 295,000	2.68
		≥ 295,000 and < 930,000	2.61
	Upflow ducted	< 80,000	2.74
		≥ 80,000 and < 295,000	2.65
		≥ 295,000 and < 930,000	2.58
	Upflow non-ducted	< 65,000	2.35
		≥ 65,000 and < 240,000	2.24
		≥ 240,000 and < 760,000	2.12
	Horizontal	< 65,000	2.71
		≥ 65,000 and < 240,000	2.60
		≥ 240,000 and < 760,000	2.54
Glycol cooled	Downflow	< 80,000	2.56
		≥ 80,000 and < 295,000	2.24
		≥ 295,000 and < 930,000	2.21
	Upflow ducted	< 80,000	2.53
		≥ 80,000 and < 295,000	2.21
		≥ 295,000 and < 930,000	2.18
	Upflow non-ducted	< 65,000	2.08
		≥ 65,000 and < 240,000	1.90
		≥ 240,000 and < 760,000	1.81
	Horizontal	< 65,000	2.48
		≥ 65,000 and < 240,000	2.18
		≥ 240,000 and < 760,000	2.18

System type	Duct location	Cooling capacity (Btu/hr)	Baseline efficiency [NSenCOP]
Glycol-cooled with fluid economizer	Downflow	< 80,000	2.51
		≥ 80,000 and < 295,000	2.19
		≥ 295,000 and < 930,000	2.15
	Upflow ducted	< 80,000	2.48
		≥ 80,000 and < 295,000	2.16
		≥ 295,000 and < 930,000	2.12
	Upflow non-ducted	< 65,000	2.00
		≥ 65,000 and < 240,000	1.82
		≥ 240,000 and < 760,000	1.73
	Horizontal	< 65,000	2.44
		≥ 65,000 and < 240,000	2.10
		≥ 240,000 and < 760,000	2.10
Ceiling-mounted CRACs			
Air-cooled with free air discharge condenser	Ducted	< 29,000	2.05
		≥ 29,000 and < 65,000	2.02
		≥ 65,000 and < 760,000	1.92
	Non-ducted	< 29,000	2.08
		≥ 29,000 and < 65,000	2.05
		≥ 65,000 and < 760,000	1.94
Air-cooled with free air discharge condenser and fluid economizer	Ducted	< 29,000	2.01
		≥ 29,000 and < 65,000	1.97
		≥ 65,000 and < 760,000	1.87
	Non-ducted	< 29,000	2.04
		≥ 29,000 and < 65,000	2.00
		≥ 65,000 and < 760,000	1.89
Air-cooled with ducted condenser	Ducted	< 29,000	1.86
		≥ 29,000 and < 65,000	1.83
		≥ 65,000 and < 760,000	1.73
	Non-ducted	< 29,000	1.89
		≥ 29,000 and < 65,000	1.86
		≥ 65,000 and < 760,000	1.75

System type	Duct location	Cooling capacity (Btu/hr)	Baseline efficiency [NSenCOP]
Air-cooled with ducted condenser and fluid economizer	Ducted	< 29,000	1.82
		≥ 29,000 and < 65,000	1.78
		≥ 65,000 and < 760,000	1.68
	Non-ducted	< 29,000	1.85
		≥ 29,000 and < 65,000	1.81
		≥ 65,000 and < 760,000	1.70
Water-cooled	Ducted	< 29,000	2.38
		≥ 29,000 and < 65,000	2.28
		≥ 65,000 and < 760,000	2.18
	Non-ducted	< 29,000	2.41
		≥ 29,000 and < 65,000	2.31
		≥ 65,000 and < 760,000	2.20
Water-cooled with fluid economizer	Ducted	< 29,000	2.33
		≥ 29,000 and < 65,000	2.23
		≥ 65,000 and < 760,000	2.13
	Non-ducted	< 29,000	2.36
		≥ 29,000 and < 65,000	2.26
		≥ 65,000 and < 760,000	2.16
Glycol-cooled	Ducted	< 29,000	1.97
		≥ 29,000 and < 65,000	1.93
		≥ 65,000 and < 760,000	1.78
	Non-ducted	< 29,000	2.00
		≥ 29,000 and < 65,000	1.98
		≥ 65,000 and < 760,000	1.81
Glycol-cooled with fluid economizer	Ducted	< 29,000	1.92
		≥ 29,000 and < 65,000	1.88
		≥ 65,000 and < 760,000	1.73
	Non-ducted	< 29,000	1.95
		≥ 29,000 and < 65,000	1.93
		≥ 65,000 and < 760,000	1.76

High-Efficiency Condition

Package and split-systems must exceed the minimum efficiencies specified in Table 80. Additional conditions for replace-on-burnout, early retirement, and new construction are as follows:

New Construction and Replace on Burnout

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

Early Retirement

When downsizing, the pre-installed cooling capacity is limited to a maximum of 120 percent of the new equipment's cooling capacity. There is no cap when upsizing because the savings are calculated using the lower pre-capacity. For scenarios involving the replacement of a combination of systems by an alternate combination of systems of varying capacities, ER savings can still be claimed if the overall pre- and post-capacities for the total combination of systems are compliant with the above guidance. In these cases, a custom calculation should be performed to establish the following weighted savings factors to be applied over the ER portion of the savings calculation: manufacturer year, EUL, RUL, baseline efficiency, demand factor, and EFLH. These factors should be weighted based on contribution to overall capacity.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 36

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

Equation 37

Where:

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

$Cap_{C,post}$ = *Rated equipment cooling capacity of the newly installed equipment at AHRI-standard conditions with a maximum equal to the baseline pre-capacity [Btuh]; 1 ton = 12,000 Btuh*

Note: The capacity in the equations may not always match the capacity of the units. AHRI may rate cooling capacity in kW. In these cases, convert from kW to Btuh by multiplying kW by 3,412.

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

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

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

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

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

Early Retirement Savings

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

Deemed Energy and Demand Savings Tables

Deemed peak demand factor (DF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone. This measure is restricted to the data center building types, derived from the EIA CBECS study.[201]

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

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

Table 81. CRACs—Building Type Descriptions and Examples

Building type	Principal building activity	Definition	Detailed business type examples[202]
Data center	Data center	Buildings used to house computer systems and associated components.	1) Data center

Table 82. CRACs—DF and EFLH Values

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

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

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

Effective Useful Life (EUL)

The EUL for CRACs is 15 years, consistent with the EUL specified for split and packaged air conditioners and heat pumps.[203]

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

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

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 83. If individual system components were installed at different times, use the condenser age as a proxy for the entire system. For ER units of unknown age, assume a default value equal to the EUL. This corresponds to a default RUL of 2.8 years. Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. Both the RUL and EUL are needed to estimate savings for ER projects for two distinct periods: The ER period (RUL) and the ROB period (EUL – RUL). The calculations for ER projects are extensive, and as such, are provided in Appendix A.

Table 83. CRACs—Remaining Useful Life Early Retirement Systems[204,205]

Age of replaced system (years)	Split/packaged AC/HP systems RUL (years)	Age of replaced system (years)	Split/packaged AC/HP systems RUL (years)
1	14.0	10	5.7
2	13.0	11	5.0
3	12.0	12	4.4
4	11.0	13	3.8
5	10.0	14	3.3
6	9.1	15	2.8
7	8.2	16	2.0
8	7.3	17	1.0
9	6.5	18[206]	0.0

Program Tracking Data and Evaluation Requirements

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

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

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

[205] Existing CRAC systems manufactured after May 28, 2024, are subject to the current federal standard. They are not eligible to use the early retirement baseline and should use the ROB baseline instead. These values are grayed out in the table and displayed for informational purposes only.

[206] RULs are capped at the 75th percentile of equipment age, 18 years, as determined based on DOE survival curves. Systems older than 18 years should use the ROB baseline. See the January 2015 memo, “Considerations for Early Replacement of Residential Equipment,” for further detail.

- Baseline equipment type
- Baseline equipment rated cooling capacity
- **For ER only**: Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available)
- **For ER only**: Photograph of retired unit nameplate demonstrating model number, serial number, and manufacturer if blueprints are not provided; if photograph of nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (alternate forms of documentation can be approved at the evaluator’s discretion)
- New manufacturer, model, and manufacturing date
- New number of units
- New equipment type, duct location, and mounting location
- New equipment rated cooling capacity
- New rated cooling efficiency rating (NSenCOP)
- New unit AHRI/DOE CCMS certificate or reference number

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for HVAC equipment.
- PUCT Docket 40083– Provides incorporation of early retirement savings for existing commercial HVAC SOP designs and updates for baseline equipment efficiency levels for ROB and new construction projects involving package and split systems.
- PUCT Docket 40885—Provides a petition to revise deemed savings values for Commercial HVAC replacement measures. Items covered by this petition include the following:
- Updated baseline efficiencies use for estimating deemed savings for commercial PTAC/PTHP’s, Room Air Conditioners, and chilled water systems.
- Approved estimates of RUL of working chilled water systems.
- Updated demand and energy coefficients for all commercial HVAC systems.
- Updated EUL of centrifugal chilled water systems installed in ROB or new construction projects.
- Provide a method for utilizing the early retirement concept developed in the petition in Docket No. 40083 for Packaged and Split DX systems and applied to chilled water systems when the age of the system being replaced cannot be ascertained.

- PUCT Docket 41070—Provides energy and demand savings coefficients for an additional climate zone, El Paso, TX. Prior to this filing, savings for the Dallas-Fort Worth area were used for El Paso, but Dallas-Fort Worth has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.
- PUCT Docket 43681—Updated the approach for calculating early replacement energy and demand savings using a net present value (NPV) method. Documented in Appendix A.

Relevant Standards and Reference Sources

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

Document Revision History

Table 84. CRACs—Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed text referring to building types other than data centers.
v9.0	10/2021	TRM v9.0 update. Updated baseline table citation. Added capacity conversion from kW to Btu/hr.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Added reference to new standard and plan to incorporate in PY2025.
v12.0	10/2024	TRM v12.0 update. Added early retirement criteria related to downsizing, updated early retirement and new construction/ROB baseline efficiency levels.

2.2.6 Computer Room Air Handler Motor Efficiency Measure Overview

TRM Measure ID: NS-HV-CM

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Data centers

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed Savings Calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

Eligible equipment includes fan motors and VFDs, 15 horsepower and smaller used to distribute conditioned air throughout a data center[207].

Baseline Condition

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

High-Efficiency Condition

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

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

Savings Algorithms and Input Variables

Energy and demand savings are estimated using input assumptions taken from site measured motor kW and operating hours for 243 CRAH units.[208]

Energy Savings Algorithms

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

Equation 38

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

Equation 39

Where:

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

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

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

Table 85. CRAHs—Motor Efficiencies for Open Drip Proof Motors at 1,800 RPM[209]

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

[208] Site data are sourced from 3 data centers in Oncor territory that replaced 243 CRAH fan motors either with ECMs or retrofitted with VFDs.
[209] For unlisted motor horsepower values, round down to the next lowest horsepower value.

0.746	=	*Constant to convert from hp to kW*
kW/hp_{post}	=	*Efficient kW per motor hp*[210] *= 0.27*
hp_{post}	=	*Total efficient motor horsepower*
hours	=	*Annual operating hours = 8,760*

Demand Savings Algorithms

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

Equation 40

Where:

$CF_{S/W}$	=	*Summer/winter seasonal peak coincidence factor = 0.11*[211]

Deemed Energy and Demand Savings Tables

There are no deemed savings tables for this measure.

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The median estimated useful life (EUL) for premium efficiency motors is 15 years.[212]

The EUL for HVAC VFD measure is 15 years.

210 Oncor site data. Average kW/hp values are weighted by measure count.

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

212 US DOE, Technical Support Document, "Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors", Median of "Table 8.2.23 Average Application Lifetime". Download TSD at: https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf.

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 86. CRAHs—Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. No revision.
v10.0	10/2022	TRM v10.0 update. Added guidance for rounding down motor size in the baseline efficiency lookup table.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. No revision.

2.2.7 HVAC Variable Frequency Drives Measure Overview

TRM Measure ID: NR-HV-VF

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: All commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure involves the installation of a variable frequency drive (VFD) in a commercial HVAC application. Eligible applications include:

- AHU supply fan on a split or packaged HVAC system. The fan is in a variable air volume (VAV) system with terminal VAV boxes or constant air volume (CAV) unit with no control device.
- Hot water distribution pumps
- Chilled water distribution and condenser pumps
- Cooling tower fans

This measure does not apply to controls installed on the HVAC compressor. This measure accounts for the interactive air conditioning demand savings during the utility defined summer peak period. The savings are on a per-control basis, and the lookup tables show the total savings for eligible scenarios.

Eligibility Criteria

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

Baseline Condition

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

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

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

High-Efficiency Condition

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

For AHU supply fans, when applicable, the existing damper or inlet guide vane will be removed or set completely open permanently after installation. The VFD will maintain a constant static pressure by adjusting fan speed and delivering the same amount of air as the baseline condition.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

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

For AHUs:

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

Equation 41

Where:

$t_{db,i}$ = *The hourly dry bulb temperature (DBT) using TMY3[213] data*

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

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

The minimum flow rate is set to 60 percent cfm based on common design practice.[214] Determination of the minimum dry bulb temperature assumes that cooling will only operate above the cooling reference temperature of 65°F dry bulb. The maximum DBT is the ASHRAE dry bulb design temperature.[215]

213 National Renewable Energy Laboratory's (NREL) National Solar Radiation Data Base: 1991- 2005 Update for Typical Meteorological Year 3 (TMY3). Available at https://sam.nrel.gov/weather-data.html.

214 For AHU, a 60% minimum setpoint strategy is assumed, so any results below 60% are set to 60%. Similarly, any results greater than 100% are set to 100%.

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

Table 87. HVAC VFDs—AHU Supply Fan VFD Percentage of CFM Inputs

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

For cooling towers:

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

Equation 42

Where:

t_{wb_i} = the hourly wet bulb temperature (WBT) based on TMY3 data[216]

m = the slope of the relationship between WBT and cfm (see *Table 88*)

b = the intercept of the relationship between WBT and cfm (see *Table 88*)

Table 88. HVAC VFDs—Cooling Tower VFD Percentage of CFM Inputs

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

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

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

The minimum flow rate is set to 40 percent cfm based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.[217] Determination of the minimum WBT assumes that the cooling tower will only operate above the cooling reference temperature of 65°F dry bulb. The minimum WBT is calculated using TMY3 data as the average WBT when the DBT is between 64°F and 65°F dry bulb. The maximum WBT is the ASHRAE wet bulb design temperature.[218]

For chilled water and condenser water pumps:

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

Equation 43

Where:

m = *The slope of the relationship between DBT and GPM (see Table 89)*

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

The minimum flow rate is set to 10 percent GPM based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.[219] Determination of the minimum dry bulb temperature assumes that cooling will only operate above the cooling reference temperature of 65°F dry bulb. The maximum DBT is the ASHRAE dry bulb design temperature.[220]

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

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

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

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

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

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

For hot water pumps:

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

Equation 44

Where:

m = *The slope of the relationship between DBT and GPM (see Table 90)*

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

The minimum flow rate is set to 10 percent GPM based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.[221] Determination of the minimum dry bulb temperature assumes that heating will only operate below the heating reference temperature of 65°F dry bulb. The maximum DBT is the ASHRAE dry bulb design temperature.[222]

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

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

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

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

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

Baseline Technologies

For AHU supply fan: [223]

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

Equation 45

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

Equation 46

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

Equation 47

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

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

For cooling tower:

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

Equation 48

For chilled, hot, and condenser water pumps[224]:

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

Equation 49

<u>VFD Technology</u>

For AHU supply fan[225]:

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

Equation 50

For cooling tower[226]:

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

Equation 51

For chilled water, hot water, and condenser pumps[227]:

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

Equation 52

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

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

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

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

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

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

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

Equation 53

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

Equation 54

Where:

$\%power_i$ = *Percentage of full load pump power at the i^{th} hour calculated by an equation based on the control type (outlet damper, inlet box damper, inlet guide vane-IGV, or VFD)*[228]

kW_{full} = *Motor power demand operating at the fan design 100 percent CFM or pump design 100 percent GPM*

kW_i = *Fan or Pump real-time power at the i^{th} hour of a year*

HP = *Rated horsepower of the motor*

LF = *Load factor—ratio of the operating load to the nameplate rating of the motor—assumed to be 75 percent*

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

0.746 = *Constant to convert from HP to kW*

Table 91. HVAC VFDs—Motor Efficiencies for Open Drip Proof Motors at 1,800 RPM[229]

Motor horsepower	Full load efficiency
1	0.855
2	0.865
3	0.895
5	0.895
7.5	0.91
10	0.917
15	0.93
20	0.93
25	0.936
30	0.941

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

229 For unlisted motor horsepower values, round down to the next lowest horsepower value.

Motor horsepower	Full load efficiency
40	0.941
50	0.945
60	0.95
75	0.95
100	0.954

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

Hourly Savings Calculations

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

Equation 55

Where:

$schedule_i$ = *1 when building is occupied, 0.2 when building is unoccupied (see Table 92)*

Table 92. HVAC VFDs—Yearly Motor Operation Hours by Building Type[230,231]

Building type	Weekday schedule	Weekend schedule	Annual motor operation hours
Assembly, worship	9am–11pm	9am–11pm	5,840
Convenience store, service, strip mall	9am–10pm	9am–8pm (Saturday) 10am–7pm (Sunday)	5,298
Education	8am–11pm	closed	4,884
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	24-hr	24-hr	8,760

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

231 Data centers are covered in 2.2.6 Computer Room Air Handler Motor Efficiency.

Building type	Weekday schedule	Weekend schedule	Annual motor operation hours
Office—large, medium	7am–11pm	7am–7pm (Saturday)	5,592
Office—small	7am–8pm	closed	4,466
Restaurants	6am–2am	6am–2am	7,592
Stand-alone retail, supermarket	8am–10pm	8am–11pm (Saturday) 10am–7pm (Sunday)	5,674
Warehouse	7am–7pm	closed	4,258
Other[232]	7am–7pm	closed	4,258

Average Peak Demand Saved Calculation, excluding interactive effects

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

Equation 56

Where:

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

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

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

Equation 57

Where:

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

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

Energy Savings are calculated in the following manner:

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

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

Equation 58

Where:

8,760 = *Total of hours per year*

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

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

Equation 59

Deemed Energy and Demand Savings Tables[233]

Table 93. HVAC VFDs—AHU Supply Fan Outlet Damper Baseline Savings per Motor HP

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

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

Table 94. HVAC VFDs—AHU Supply Fan Inlet Damper Baseline Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Assembly, worship	1,164	1,057	1,003	961	1,086
Convenience store, service, strip mall	1,046	950	897	859	976
Education	984	895	848	808	917
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,825	1,672	1,598	1,535	1,723
Office—large, medium	1,126	1,024	968	923	1,052
Office—small	894	813	766	727	834
Restaurants	1,556	1,420	1,352	1,298	1,462
Stand-alone retail, supermarket	1,128	1,025	967	925	1,052
Warehouse	850	773	727	690	794
Other	850	773	727	690	794
Summer kW Savings (kW per Motor HP)					
All building types	0.045	0.026	0.024	0.069	0.047

Table 95. HVAC VFDs—AHU Supply Fan Inlet Guide Vane Baseline Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Assembly, worship	245	216	201	189	223
Convenience store, service, strip mall	219	194	179	169	200
Education	207	183	170	159	189
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	388	345	325	307	359
Office—large, medium	237	209	194	182	217

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Office—small	188	166	154	143	171
Restaurants	329	292	273	258	303
Stand-alone retail, supermarket	237	209	193	182	216
Warehouse	179	158	146	135	163
Other	179	158	146	135	163
Summer kW savings (kW per motor HP)					
All building types	0.009	0.009	0.005	0.011	0.013

Table 96. HVAC VFDs—AHU Supply Fan No Control Baseline Savings per Motor HP

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

Table 97. HVAC VFDs—Cooling Tower Fans Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Assembly, worship	733	1,020	1,264	1,380	946
Convenience store, service, strip mall	667	928	1,150	1,255	862
Education	613	871	1,058	1,147	785
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,124	1,528	1,883	2,070	1,389
Office—large, medium	704	975	1,202	1,318	901
Office—small	556	792	959	1,040	715
Restaurants	968	1,325	1,635	1,790	1,219
Stand-alone retail, supermarket	713	988	1,226	1,338	919
Warehouse	530	753	912	989	680
Other	530	753	912	989	680
Summer kW savings (kW per motor HP)					
All building types	0.097	0.041	0.132	0.175	0.161

Table 98. HVAC VFDs—Chilled Water Pump Savings per Motor HP

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

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Warehouse	435	594	670	730	563
Other	435	594	670	730	563
Summer kW savings (kW per motor HP)					
All building types	0.049	0.018	0.029	0.092	0.044

Table 99. HVAC VFDs—Hot Water Pump Savings per Motor HP

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Assembly, worship	791	544	426	351	630
Convenience store, service, strip mall	706	482	375	306	558
Education	677	468	368	301	526
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,298	912	721	610	1,038
Office—large, medium	774	536	418	338	606
Office—small	609	423	328	266	473
Restaurants	1,086	756	598	500	863
Stand-alone retail, supermarket	764	526	410	335	606
Warehouse	579	402	309	251	449
Other	579	402	309	251	449
Winter kW savings (kW per motor HP)					
All building types	0.118	0.032	0.045	0.133	0.212

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HVAC-VSD-fan.[234]

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

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 100. HVAC VFDs—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. Corrected ASHRAE 0.4 percent Dry Bulb Design Temperature references for three climate zone reference cities: DFW, El Paso, and Houston. Updated Valley climate zone reference city to Corpus Christi to be consistent with TRM guidance. Corrected Motor Load Factor to 75 percent.
v4.0	10/10/2016	TRM v4.0 update. Added reference for percent power and corrected signs for variables in Equation 50.
v5.0	10/2017	TRM v5.0 update. Updated deemed energy/demand tables for revised peak demand definition.
v6.0	10/2018	TRM v6.0 update. Added no control device option for constant volume systems. Corrected error in previous kW and kWh deemed savings calculations for Outlet Damper baseline control.

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 update. Renamed measure to HVAC Variable Frequency Drives. Added methodology for chilled and hot water pumps.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Added motor efficiency default assumptions.
v9.0	10/2021	TRM v9.0 update. Expanded available building types and updated occupancy schedules.
v10.0	10/2022	TRM v10.0 update. Added guidance for rounding down motor size in the baseline efficiency lookup table.
v11.0	10/2023	TRM v11.0 update. Added cooling tower fan and condenser water pump applications. Updated maximum temperatures for linear regression equations to correspond with ASHRAE design conditions. Aligned building type names across all commercial measures.
v12.0	10/2024	TRM v12.0 update. Savings calculations moved to Excel. Reviewed hours of operation and using same fan and pump hours referenced in the existing measure.

2.2.8 Condenser Air Evaporative Pre-Cooling Measure Overview

TRM Measure ID: NR-HV-EP

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: All commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Applicable evaporative pre-cooling product types include:

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

Eligibility Criteria

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

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

- Evaporative effectiveness performance of greater than or equal to 0.75 (i.e., 75 percent) for average dry bulb temperature and humidity during peak hours
- Operation manuals must be provided
- If these conditions are not met, the deemed savings approach cannot be used, and the Simplified M&V Methodology or the Full M&V Methodology must be used.

Baseline Condition

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

High-Efficiency Condition

Evaporative pre-cooling systems must exceed the evaporative effectiveness performance of 75 percent for average dry bulb temperature humidity during peak hours**.** Table 101 contains values that can be used as a reference for evaluating evaporative effectiveness.

Table 101. Evaporative Pre-Cooling—Average Weather During Peak Conditions[235]

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 60

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

Equation 61

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

Where:

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

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

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

Equation 62

$EFLH_{red}$	=	*Annual cooling energy reduction divided by the rated full loaded demand. Annual cooling energy reduction is determined according to the same method as other HVAC coefficients contained in the TRM. Rated full loaded demand is the Cap_C divided by its rated full load efficiency (see Table 102 through Table 106)*
CF	=	*Seasonal peak coincidence factor. The average peak hour energy reduction divided by the rated full loaded demand (see Table 102 through Table 106)*

Deemed Energy and Demand Savings Tables

The CF and $EFLH_{red}$ values are presented by building type and climate zone. A description of the building types that are used for HVAC systems is presented in Table 34. These building types are derived from the EIA CBECS study.[236]

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

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

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

Table 102. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 1: Amarillo

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	$EFLH_{red}$	CF	$EFLH_{red}$
Education	College/university	0.19	130	0.17	150
	Primary school	0.20	83	0.13	69
	Secondary school	0.19	89	0.17	102
Food sales	Convenience store	0.18	125	-	-
	Supermarket	0.08	37	-	-
Food service	Full-service restaurant	0.21	134	-	-
	Quick-service restaurant	0.18	109	-	-
Healthcare	Inpatient	0.21	160	0.18	151
	Outpatient	0.17	145	-	-
Large multifamily	Midrise apartment	0.18	113	0.10	59
Lodging	Large hotel	0.13	111	0.15	165
	Nursing home	0.18	115	0.10	60
	Small hotel/motel	0.13	104	-	-
Mercantile	Stand-alone retail	0.19	108	0.14	74
	Strip mall	0.21	121	-	-
Office	Large office	0.25	206	0.18	119
	Medium office	0.19	75	-	-
	Small office	0.20	111	-	-
Public assembly	Public assembly	0.20	112	0.13	93
Religious worship	Religious worship	0.19	65	0.14	45
Service	Service: Excluding food	0.21	104	-	-
Warehouse	Warehouse	0.12	34	-	-
Other	Other	0.08	34	0.10	45

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

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

Table 104. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 3: Houston

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	$EFLH_{red}$	CF	$EFLH_{red}$
Education	College/university	0.20	173	0.17	175
	Primary school	0.21	118	0.10	74
	Secondary school	0.20	118	0.17	119

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

Table 105. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 4: Corpus Christi

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	$EFLH_{red}$	CF	$EFLH_{red}$
Education	College/university	0.13	161	0.11	160
	Primary school	0.14	113	0.07	68
	Secondary school	0.13	110	0.11	109
Food sales	Convenience store	0.14	188	-	-
	Supermarket	0.08	74	-	-
Food service	Full-service restaurant	0.13	157	-	-
	Quick-service restaurant	0.14	162	-	-

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

Table 106. Evaporative Pre-Cooling—Savings Coefficients for Climate Zone 5: El Paso

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		CF	$EFLH_{red}$	CF	$EFLH_{red}$
Education	College/university	0.27	240	0.22	254
	Primary school	0.30	161	0.17	120
	Secondary school	0.27	163	0.22	172
Food sales	Convenience store	0.25	232	-	-
	Supermarket	0.12	76	-	-
Food service	Full-service restaurant	0.25	223	-	-
	Quick-service restaurant	0.25	201	-	-
Healthcare	Inpatient	0.26	273	0.20	247
	Outpatient	0.23	259	-	-
Large multifamily	Midrise apartment	0.28	264	0.15	140

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

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

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

The estimated useful life (EUL) for an evaporative pre-cooling system is 10 years, consistent with the typical manufacturer warranty for evaporative pre-cooling equipment.[237]

Program Tracking Data and Evaluation Requirements

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

- Decision/action type: Retrofit or new construction
- Climate zone or county

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

- Building type
- Baseline equipment type
- Baseline equipment rated cooling capacity
- Baseline equipment cooling efficiency ratings
- Baseline number of units
- Baseline manufacturer and model
- Installed number of units
- Installed evaporative pre-cooling system manufacturer and model
- Installed evaporative pre-cooling system evaporative effectiveness
- Copy of operation manuals
- **For Other building types only**: A description of the actual building type, the primary business activity, the business hours, and the HVAC schedule.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 47612—Provides deemed savings for Condenser Evaporative Pre-cooling

Relevant Standards and Reference Sources

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

Document Revision History

Table 107. Evaporative Pre-Cooling—Revision History

TRM version	Date	Description of change
v5.0	10/2017	TRM v5.0 origin.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Specified that formulas use tons and kW/ton values and added conversion factors from other units.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Aligned building type names across all commercial measures.
v12.0	10/2024	TRM v12.0 update. Minor text edits.

2.2.9 High-Volume Low-Speed Fans Measure Overview

TRM Measure ID: NR-HV-HF

Market Sector: Commercial

Measure Category: HVAC

Applicable Business Types: All commercial, agriculture

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

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

Eligibility Criteria

This measure applies to HVLS fans installed in any nonresidential application. Use the *other* building type for anything not explicitly listed in Table 109 and Table 110.

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

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

Baseline Condition

The baseline condition is an installation of conventional fans.

Retrofit (Early Retirement)

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

Replace on Burnout/New Construction

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

High-Efficiency Condition

HVLS fans with diameters of eight to 24 feet typically use 1 hp to 2 hp motors per fan and move between 50,000 CFM and 150,000 or more CFM.[238] To be eligible for this measure, HVLS fans shall be a minimum of 8 feet in diameter and move more cubic feet of air per watt than conventional circulating fans. The fan should be installed in a horizontal orientation and have the ability to operate at different speeds.

The current federal standard[239] requires that all ceiling fans manufactured on or after January 21, 2020, must comply with the minimum requirements in Table 108.

Table 108. HVLS Fans—Circulating Fan Minimum Efficiency Requirements

Fan type	η_{base} (CFM/W)	η_{base} (CFEI)[240]
Standard	0.65 x D + 38.03	–
Large-diameter[241]	–	1.00 (high speed)
		1.31 (40% speed)

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

[239] Current federal standard for ceiling fans. https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32.

[240] CFEI is a ratio of the input power of a baseline reference fan divided by the input power of the rated fan.

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

The efficiency of the baseline conventional fans used in agricultural applications is assumed to be 22 CFM/W.[242]

Energy and Demand Savings Methodology

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

Savings Algorithms and Input Variables

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

$$W_{base} = \frac{CFM_{HVLS}}{\eta_{base}}$$

Equation 63

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

Equation 64

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

Equation 65

Other fans with efficiency rated in CFEI:

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

Equation 66

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

Equation 67

Where:

W_{base}	=	*Power input required to move replaced fans at rated speed (see Equation 63)*
W_{HVLS}	=	*Power input required to move installed HVLS fans at rated speed*
CFM_{HVLS}	=	*Airflow rate produced by installed HVLS fans*

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

η_{base}	=	*Baseline fan efficiency [CFM/W] = 22 for agricultural applications; see Table 108 for all other applications*
$\eta_{HVLS,HS}$	=	*HVLS fan rated efficiency at high speed [CFM/W]*[243]
AOH	=	*Annual operating hours (see Table 109)*
CF_S	=	*Summer peak coincidence factor (see Table 110)*
1,000	=	*Constant to convert from W to kW*

Table 109. HVLS Fans—Circulating Fan Annual Operating Hours[244]

Building Type	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Agriculture[245]	2,215	3,969	4,750	5,375	3,034
Food service: Full-service restaurant					4,368
Manufacturing: 1 shift (<70hr/week)					2,786
Manufacturing: 2 shift (70-120 hr/week)					5,188
Manufacturing: 3 shift (>120 hr/week)					6,414
Warehouse					3,501
Other					2,638

Table 110. HVLS Fans—Circulating Fan Coincident Factors[246,247]

Building Type	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Agriculture					1.00
Food service: Full-service restaurant					0.90
Manufacturing: 1 shift (<70hr/week)	0.83	0.84	0.83	0.85	0.85

[243] US DOE Compliance Certification Management System (CCMS) Ceiling Fan product listing. https://www.regulations.doe.gov/certification-data/CCMS-4-Ceiling_Fans.html#q=Product_Group_s%3A%22Ceiling%20Fans%22.

[244] AOH for non-agricultural applications are based on assumptions from measure 2.1.1 *Lamps and Fixtures* based on the assumption that fan operation will coincide with lighting operation.

[245] 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 October 29, 2012. An amended petition dated November 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).

[246] Summer CFs for agricultural applications assume continuous operation during peak conditions.

[247] Summer CFs for non-agricultural applications are based on assumptions from measure 2.1.1 *Lamps and Fixtures* based on the assumption that fan operation will coincide with lighting operation.

Building Type	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Manufacturing: 2 shift (70-120 hr/week)	0.85				
Manufacturing: 3 shift (>120 hr/week)					
Warehouse	0.79	0.81	0.79	0.80	0.85
Other	0.65				

Claimed Peak Demand Savings

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

Deemed Energy and Demand Savings Tables

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

Measure Life and Lifetime Savings

The EUL of an HVLS fan is closely related to that of its motor. The US DOE Advanced Manufacturing Office's Motor Systems Tip Sheet #3[248] suggests motors should last approximately 35,000 hours. Based on the average annual operations across the available building types, the EUL for HVLS fans is estimated to be nine years.

Program Tracking Data and Evaluation Requirements

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

All Projects:

- Climate zone or county
- Decision/action type: Retrofit or NC
- Building type (specify if other)
- **For agricultural only:** Barn type (animal)
- HVLS fan(s): quantity, diameter, rated HP, rated CFM, rated efficiency
- Fan operating hours (customer-reported estimated)

[248] DOE Motor Systems Tip Sheet #3 available at https://www.energy.gov/sites/prod/files/2014/04/f15/extend_motor_operlife_motor_systemts3.pdf.

- Screenshot of CCMS product listing
- Proof of purchase (e.g., invoice showing model number and quantity)

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 111. HVLS Fans—Revision History

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

2.2.10 Small Commercial Evaporative Cooling Measure Overview

TRM Measure ID: NR-HV-EC

Market Sector: Small Commercial

Measure Category: HVAC

Applicable Building Types: Small commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Energy modeling, engineering algorithms, and estimates

Measure Description

This section summarizes the deemed savings methodology for the installation of direct evaporative coolers instead of refrigerated air conditioning systems in small commercial applications. This measure applies to both retrofit and new construction applications.

Eligibility Criteria

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

Baseline Condition

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

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

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

Table 112. Evaporative Cooling—NC/ROB Baseline Efficiency Levels for DX AC[249]

System type	Capacity (tons)	Heating section type	Baseline efficiencies	Source[250]
Packaged air conditioner	< 5.4	All	11.8 EER[251] 14.0 SEER	DOE Standards/ IECC 2015

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 68

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

Equation 69

Where:

Cap_C = *Refrigerated cooling load for equivalent evaporative cooling system, default = 36,000 Btuh[252]; 1 ton = 12,000 Btuh*

$\eta_{baseline,C}$ = *Cooling efficiency of standard equipment (ROB/NC) [Btuh/W] (see Table 33)*

Note: Use EER for kW savings calculations and SEER for kWh savings calculations.

CF_S = *Summer peak coincidence factor (see Table 40)*

$EFLH_C$ = *Cooling equivalent full-load hours [hours] (see Table 40)*

CRF = *Consumption reduction factor[253] = 75%*

[249] IECC 2015 Table C403.2.3(1) and C403.2.3(2).
[250] 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.
[251] IECC 2015 Table C403.2.3(1) and C403.2.3(2).
[252] New Mexico TRM assumption based on DX AC cooling load for Las Cruces climate zone.
[253] Department of Energy, https://www.energy.gov/energysaver/evaporative-coolers.

Deemed Energy and Demand Savings Tables

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

This measure is restricted to climate zone 5.

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

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

Building type	Principal building activity	DX AC	
		CF_S	$EFLH_C$
Public assembly	Public assembly	0.91	1,339
Religious worship	Religious worship	0.63	478
Service	Service: Excluding food	0.76	988
Warehouse	Warehouse	0.75	324
Other	Other	0.38	324

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HV-EvapCool.[254]

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Decision/action type: ROB or NC
- Building type
- Baseline number of units
- Baseline rated cooling capacity (CFM)
- Installed number of units
- Installed equipment cooling capacity (CFM)
- Installed manufacturer and model
- **For retrofit only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging or installed unit(s); OR an evaluator pre-approved inspection approach

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

- **For new construction only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging or installed unit(s); as-built design drawings; HVAC-specifications package that provides detailed make and model information on installed unit(s); OR an evaluator pre-approved inspection approach
- **For Other building types only**: A description of the actual building type, the primary business activity, the business hours, and the HVAC schedule

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 114. Evaporative Cooling—Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Aligned building type names across all commercial measures.
v12.0	10/2024	TRM v12.0 update. No revision.

2.2.11 Small Commercial Smart Thermostats Measure Overview

TRM Measure ID: NR-HV-ST

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Small commercial

Fuels Affected: Electricity

Decision/Action Types: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Energy modeling, engineering algorithms and estimates

Measure Description

This section summarizes the deemed savings methodology for the installation of a smart thermostat in small commercial applications.

Eligibility Criteria

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

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

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

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

Baseline Condition

The baseline condition for retrofit applications is a manual or programmable thermostat. The baseline condition for new construction applications is a programmable thermostat.[255]

[255] IECC 2015 C40.2.4.2.

High-Efficiency Condition

The high-efficiency condition is a single-zone HVAC system being controlled by a smart or connected thermostat. The ENERGY STAR qualified product listing (QPL)[256] does not include units marketed for commercial applications; until those units are included, all products marketed as commercial smart or connected thermostats are allowed to use the savings methodology specified in this measure.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

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

Equation 70

$$Cooling\ Energy\ Savings\ [kWh_C] = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times \frac{1}{\eta_C} \times EFLH_C \times CRF \times BAF$$

Equation 71

$$Heating\ Energy\ Savings\ [kWh_H] = CAP_H \times \frac{1\ kW}{1{,}000\ W} \times \frac{1}{\eta_H} \times EFLH_C \times HRF \times BAF$$

Equation 72

$$Summer\ Peak\ Demand\ Savings\ [kW] = CAP_C \times \frac{1\ kW}{1{,}000\ W} \times \frac{1}{\eta_C} \times CF_S \times CRF \times BAF$$

Equation 73

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

Equation 74

Where:

$CAP_{C/H}$ = *Controlled-HVAC rated cooling/heating capacity (Btuh)*[257]

$\eta_{C/H}$ = *HVAC rated cooling/heating efficiency (see Table 33 for retrofit applications; use rated system efficiencies from AHRI or equivalent certification for new construction)*

256 ENERGY STAR QPL. https://www.energystar.gov/productfinder/product/certified-connected-thermostats/results.

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

Note: Use EER2/EER for summer kW, SEER2/IEER for cooling kWh, and HSPF2/HSPF for heating kWh and winter kW savings calculations. For heating equipment rated in COP, convert to HSPF by multiplying by 3.412. Heating efficiency should be converted from 1.0 COP and set to 3.412 HSPF when thermostat is installed in combination with centrally-controlled electric resistance heat.[258]

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

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

CRF = *Cooling reduction factor = 10%*[259]

HRF = *Heating reduction factor = 8%*[260]

BAF = *Baseline adjustment factor (1.0 for manual baseline, 0.6 for programmable and new construction baselines, and 0.8 for unknown baseline)*[261,262]

Deemed Energy and Demand Savings Tables

Deemed peak coincidence factor (CF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone in the *split and packaged air conditioners and heat pumps* measure in Table 36 through Table 40.

Claimed Peak Demand Savings

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

Claimed Peak Demand Savings

Not applicable.

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258 COP converted to HSPF using HSPF = COP ÷1,055 J/Btu x 3,600 J/W-h = COP x 3.412.

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

260 Ibid.

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

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 11 years as specified in the California Database of Energy Efficiency Resources (DEER) Remote Ex-Ante Database Interface (READI) tool for EUL ID HV-ProgTstat.[263]

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

[263] DEER READI. http://www.deeresources.com/index.php/ready.

Document Revision History

Table 115. Smart Thermostats—Revision History

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

2.3 NONRESIDENTIAL: BUILDING ENVELOPE

2.3.1 Cool Roofs Measure Overview

TRM Measure ID: NR-BE-CR

Market Sector: Commercial

Measure Category: Building envelope

Applicable Building Types: All commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Energy modeling, engineering algorithms, and estimates

Measure Description

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

Eligibility Criteria

The ENERGY STAR® Roofing Products Certification program was discontinued effective June 1, 2022.[264] Moving forward, installed roofing products will still be required to demonstrate compliance with the previous ENERGY STAR specification.[265] For nonresidential facilities, these criteria for a high-efficiency roof include:

- An existing roof undergoing retrofit conditions as further defined under the High-Efficiency Condition section below; a roof installed in a new construction application is not eligible for applying these methodologies.
- A roof with a low slope of 2:12 inches or less[266]

[264] ENERGY STAR Roof Products Sunset Decision Memo. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Roof%20Products%20Sunset%20Decision%20Memo.pdf.

[265] ENERGY STAR Program Requirements for Roof Products v2.1. https://www.energystar.gov/ia/partners/product_specs/program_reqs/roofs_prog_req.pdf.

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

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

In lieu of the former ENERGY STAR list of qualified products, roofing product must now have a performance rating that is validated by the Cool Roof Rating Council (CRRC) [267,268] and be listed on the CRRC Rated Roof Products Directory.[269] This is consistent with the former ENERGY STAR test criteria's allowances for products already participating in the CRRC Product Rating program[270] to submit solar reflectance and thermal emittance product information derived from CRRC certification. If one of these conditions is not met, the deemed savings approach cannot be used, and the Simplified M&V methodology or the Full M&V methodology must be used.

Baseline Condition

The baseline is the thermal resistance (i.e., R-value) of the existing roof makeup and the solar reflectance and emissivity of the surface layer. The R-value is estimated based on code envelope requirements applicable in the construction year. Solar reflectance and emissivity of the surface layer are assumed to be 0.2 and 0.9, respectively, based on roof properties listed in the Lawrence Berkeley National Lab (LBLN) Cool Roofing Materials Database.[271]

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

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

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

[267] CRRC guidance for roof rating alternative to discontinued ENERGY STAR program. https://coolroofs.org/documents/CRRC-ENERGY-STAR-Sunset-Info-Sheet-2022-03-07.pdf.
[268] CRRC Roof Rating program. https://coolroofs.org/programs/roof-rating-program.
[269] CRRC Rated Roof Products Directory. https://coolroofs.org/directory/roof.
[270] CRRC Rated Products Directory: https://coolroofs.org/directory.
[271] Lawrence Berkeley National Lab Cool Roofing Material Database. https://heatisland.lbl.gov/resources/cool-roofing-materials-database.

High-Efficiency Condition

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

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

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

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

Table 117. Cool Roofs—ENERGY STAR Specification[272]

Roof slope	Characteristic	Performance specification
Low slope $\leq$ 2/12	Initial solar reflectance	$\geq$ 0.65
	Three-year solar reflectance	$\geq$ 0.50

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

[272] ENERGY STAR Roof Products Specification. https://www.energystar.gov/products/building_products/roof_products/key_product_criteria.

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

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

Equation 75

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

Equation 76

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

Equation 77

Where:

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

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

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

Construction Year	Estimated R-value[273]
Before 2011	R ≤ 13
Between 2011 - 2016	13 < R ≤ 20
After 2016	20 < R

[273] Estimates R-values are based on applicable code requirements in the construction year.

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

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
Education - chiller	R ≤ 13	R ≤ 13	0.65	11.80	8.31
	R ≤ 13	13 < R ≤ 20	1.10	21.76	31.52
	R ≤ 13	20 < R	1.25	25.53	37.31
	13 < R ≤ 20	13 < R ≤ 20	0.26	4.85	4.59
	13 < R ≤ 20	20 < R	0.38	7.80	9.20
	20 < R	20 < R	0.17	3.40	1.17
Education - RTU	R ≤ 13	R ≤ 13	0.26	8.26	2.62
	R ≤ 13	13 < R ≤ 20	0.43	15.47	12.49
	R ≤ 13	20 < R	0.49	18.20	14.02
	13 < R ≤ 20	13 < R ≤ 20	0.12	4.11	2.05
	13 < R ≤ 20	20 < R	0.18	6.67	3.58
	20 < R	20 < R	0.08	2.91	0.28
Hotel	R ≤ 13	R ≤ 13	0.07	1.33	-2.60
	R ≤ 13	13 < R ≤ 20	0.07	1.83	6.98
	R ≤ 13	20 < R	0.07	2.03	11.77
	13 < R ≤ 20	13 < R ≤ 20	0.04	0.81	-1.45
	13 < R ≤ 20	20 < R	0.04	1.00	3.39
	20 < R	20 < R	0.03	0.60	-1.12
Office - chiller	R ≤ 13	R ≤ 13	0.21	6.80	1.43
	R ≤ 13	13 < R ≤ 20	0.31	3.44	3.50
	R ≤ 13	20 < R	0.33	19.30	3.87
	13 < R ≤ 20	13 < R ≤ 20	0.09	16.58	0.11
	13 < R ≤ 20	20 < R	0.11	5.94	0.47
	20 < R	20 < R	0.06	2.36	0.08
Office - RTU	R ≤ 13	R ≤ 13	0.28	7.46	11.88
	R ≤ 13	13 < R ≤ 20	0.87	15.48	168.51
	R ≤ 13	20 < R	1.10	18.61	236.76
	13 < R ≤ 20	13 < R ≤ 20	0.15	4.12	-1.23
	13 < R ≤ 20	20 < R	0.38	6.73	67.02
	20 < R	20 < R	0.11	2.92	-2.61
Retail	R ≤ 13	R ≤ 13	0.72	19.28	31.74
	R ≤ 13	13 < R ≤ 20	1.26	36.23	36.71
	R ≤ 13	20 < R	1.25	38.58	35.31
	13 < R ≤ 20	13 < R ≤ 20	0.13	4.81	1.88
	13 < R ≤ 20	20 < R	0.12	6.47	0.48
	20 < R	20 < R	0.09	3.32	1.30

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
Warehouse	R ≤ 13	R ≤ 13	0.04	3.83	-0.20
	R ≤ 13	13 < R ≤ 20	0.11	6.99	3.89
	R ≤ 13	20 < R	0.14	8.07	5.35
	13 < R ≤ 20	13 < R ≤ 20	0.01	1.35	-0.10
	13 < R ≤ 20	20 < R	0.04	2.24	1.36
	20 < R	20 < R	0.01	0.90	-0.07
Other	R ≤ 13	R ≤ 13	0.04	1.33	-2.60
	R ≤ 13	13 < R ≤ 20	0.07	1.83	3.50
	R ≤ 13	20 < R	0.07	2.03	3.87
	13 < R ≤ 20	13 < R ≤ 20	0.01	0.81	-1.45
	13 < R ≤ 20	20 < R	0.04	1.00	0.47
	20 < R	20 < R	0.01	0.60	-2.61

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

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
Education - chiller	R ≤ 13	R ≤ 13	0.56	10.49	5.11
	R ≤ 13	13 < R ≤ 20	0.82	16.50	8.60
	R ≤ 13	20 < R	0.92	18.86	11.17
	13 < R ≤ 20	13 < R ≤ 20	0.29	5.41	2.36
	13 < R ≤ 20	20 < R	0.36	7.28	4.55
	20 < R	20 < R	0.24	4.37	1.88
Education - RTU	R ≤ 13	R ≤ 13	0.27	10.65	1.53
	R ≤ 13	13 < R ≤ 20	0.39	18.31	3.68
	R ≤ 13	20 < R	0.43	21.33	4.89
	13 < R ≤ 20	13 < R ≤ 20	0.17	7.21	0.77
	13 < R ≤ 20	20 < R	0.21	10.08	1.97
	20 < R	20 < R	0.13	5.88	0.60
Hotel	R ≤ 13	R ≤ 13	0.07	1.71	-0.64
	R ≤ 13	13 < R ≤ 20	0.07	2.30	0.78
	R ≤ 13	20 < R	0.07	2.56	1.39
	13 < R ≤ 20	13 < R ≤ 20	0.05	1.17	-0.46
	13 < R ≤ 20	20 < R	0.05	1.42	0.17
	20 < R	20 < R	0.05	1.01	-0.36

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
Office - chiller	R ≤ 13	R ≤ 13	0.23	11.99	0.81
	R ≤ 13	13 < R ≤ 20	0.33	27.48	1.78
	R ≤ 13	20 < R	0.34	30.55	1.93
	13 < R ≤ 20	13 < R ≤ 20	0.13	6.68	0.10
	13 < R ≤ 20	20 < R	0.15	9.76	0.26
	20 < R	20 < R	0.10	6.01	0.08
Office - RTU	R ≤ 13	R ≤ 13	0.27	12.14	14.86
	R ≤ 13	13 < R ≤ 20	0.52	24.53	84.63
	R ≤ 13	20 < R	0.62	29.45	112.16
	13 < R ≤ 20	13 < R ≤ 20	0.18	7.25	11.53
	13 < R ≤ 20	20 < R	0.28	11.09	39.06
	20 < R	20 < R	0.15	6.03	8.66
Retail	R ≤ 13	R ≤ 13	0.61	22.03	13.53
	R ≤ 13	13 < R ≤ 20	0.97	37.67	17.30
	R ≤ 13	20 < R	0.98	40.54	17.32
	13 < R ≤ 20	13 < R ≤ 20	0.16	7.57	1.28
	13 < R ≤ 20	20 < R	0.17	9.67	1.29
	20 < R	20 < R	0.13	6.22	1.04
Warehouse	R ≤ 13	R ≤ 13	0.05	4.01	-0.07
	R ≤ 13	13 < R ≤ 20	0.09	6.54	1.47
	R ≤ 13	20 < R	0.16	11.16	2.38
	13 < R ≤ 20	13 < R ≤ 20	0.02	1.18	-0.05
	13 < R ≤ 20	20 < R	0.08	4.94	0.86
	20 < R	20 < R	0.01	1.02	-0.03
Other	R ≤ 13	R ≤ 13	0.05	1.71	-0.64
	R ≤ 13	13 < R ≤ 20	0.07	2.30	0.78
	R ≤ 13	20 < R	0.07	2.56	1.39
	13 < R ≤ 20	13 < R ≤ 20	0.02	1.17	-0.46
	13 < R ≤ 20	20 < R	0.05	1.42	0.17
	20 < R	20 < R	0.01	1.01	-0.36

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

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
Education - chiller	R ≤ 13	R ≤ 13	0.62	9.56	-0.28
	R ≤ 13	13 < R ≤ 20	0.87	15.28	3.52
	R ≤ 13	20 < R	0.95	17.53	4.52
	13 < R ≤ 20	13 < R ≤ 20	0.33	5.04	-0.28
	13 < R ≤ 20	20 < R	0.39	6.81	0.50
	20 < R	20 < R	0.26	4.05	-0.29
Education - RTU	R ≤ 13	R ≤ 13	0.29	9.39	-0.03
	R ≤ 13	13 < R ≤ 20	0.40	15.76	0.90
	R ≤ 13	20 < R	0.44	18.26	1.08
	13 < R ≤ 20	13 < R ≤ 20	0.18	6.21	-0.01
	13 < R ≤ 20	20 < R	0.22	8.58	0.16
	20 < R	20 < R	0.14	5.08	-0.07
Hotel	R ≤ 13	R ≤ 13	0.08	1.69	0.54
	R ≤ 13	13 < R ≤ 20	0.07	2.26	0.17
	R ≤ 13	20 < R	0.07	2.50	-0.02
	13 < R ≤ 20	13 < R ≤ 20	0.06	1.21	0.37
	13 < R ≤ 20	20 < R	0.05	1.43	0.21
	20 < R	20 < R	0.05	1.03	0.32
Office - chiller	R ≤ 13	R ≤ 13	0.25	9.45	0.70
	R ≤ 13	13 < R ≤ 20	0.33	21.39	1.26
	R ≤ 13	20 < R	0.34	23.54	1.23
	13 < R ≤ 20	13 < R ≤ 20	0.17	10.75	0.65
	13 < R ≤ 20	20 < R	0.18	12.84	0.61
	20 < R	20 < R	0.12	4.54	0.12
Office - RTU	R ≤ 13	R ≤ 13	0.28	8.30	6.91
	R ≤ 13	13 < R ≤ 20	0.46	18.66	37.60
	R ≤ 13	20 < R	0.54	22.36	50.18
	13 < R ≤ 20	13 < R ≤ 20	0.19	5.42	4.29
	13 < R ≤ 20	20 < R	0.26	8.39	16.87
	20 < R	20 < R	0.15	4.35	3.35
Retail	R ≤ 13	R ≤ 13	0.62	17.21	9.86
	R ≤ 13	13 < R ≤ 20	1.00	29.60	17.11
	R ≤ 13	20 < R	1.01	31.61	16.52
	13 < R ≤ 20	13 < R ≤ 20	0.41	10.43	7.67
	13 < R ≤ 20	20 < R	0.41	11.89	7.07
	20 < R	20 < R	0.14	4.66	1.07

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
Warehouse	R ≤ 13	R ≤ 13	0.05	2.96	-0.09
	R ≤ 13	13 < R ≤ 20	0.09	5.13	0.76
	R ≤ 13	20 < R	0.16	9.21	1.26
	13 < R ≤ 20	13 < R ≤ 20	0.02	1.32	-0.07
	13 < R ≤ 20	20 < R	0.08	4.66	0.43
	20 < R	20 < R	0.01	0.79	0.08
Other	R ≤ 13	R ≤ 13	0.05	1.69	-0.28
	R ≤ 13	13 < R ≤ 20	0.07	2.26	0.17
	R ≤ 13	20 < R	0.07	2.50	-0.02
	13 < R ≤ 20	13 < R ≤ 20	0.02	1.21	-0.28
	13 < R ≤ 20	20 < R	0.05	1.43	0.16
	20 < R	20 < R	0.01	0.79	-0.29

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

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
Education - chiller	R ≤ 13	R ≤ 13	0.60	8.46	0.28
	R ≤ 13	13 < R ≤ 20	0.83	13.55	17.33
	R ≤ 13	20 < R	0.90	15.49	30.14
	13 < R ≤ 20	13 < R ≤ 20	0.31	4.48	-3.69
	13 < R ≤ 20	20 < R	0.36	6.00	6.37
	20 < R	20 < R	0.24	3.64	-0.06
Education - RTU	R ≤ 13	R ≤ 13	0.28	7.34	-0.41
	R ≤ 13	13 < R ≤ 20	0.38	11.78	5.15
	R ≤ 13	20 < R	0.41	13.53	8.09
	13 < R ≤ 20	13 < R ≤ 20	0.17	4.64	-1.46
	13 < R ≤ 20	20 < R	0.20	6.29	1.47
	20 < R	20 < R	0.14	3.77	-0.14
Hotel	R ≤ 13	R ≤ 13	0.07	1.13	1.99
	R ≤ 13	13 < R ≤ 20	0.07	1.44	-1.23
	R ≤ 13	20 < R	0.07	1.57	-2.70
	13 < R ≤ 20	13 < R ≤ 20	0.05	0.78	1.36
	13 < R ≤ 20	20 < R	0.05	0.90	0.00
	20 < R	20 < R	0.04	0.67	1.19

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
Office - chiller	R ≤ 13	R ≤ 13	0.22	6.44	2.33
	R ≤ 13	13 < R ≤ 20	0.31	13.55	2.86
	R ≤ 13	20 < R	0.32	15.30	2.47
	13 < R ≤ 20	13 < R ≤ 20	0.17	6.34	1.78
	13 < R ≤ 20	20 < R	0.18	7.96	1.40
	20 < R	20 < R	0.10	3.27	0.45
Office - RTU	R ≤ 13	R ≤ 13	0.26	5.02	23.11
	R ≤ 13	13 < R ≤ 20	0.40	8.66	78.05
	R ≤ 13	20 < R	0.45	10.09	100.16
	13 < R ≤ 20	13 < R ≤ 20	0.18	3.61	15.10
	13 < R ≤ 20	20 < R	0.24	4.83	37.21
	20 < R	20 < R	0.15	2.95	10.35
Retail	R ≤ 13	R ≤ 13	0.62	13.05	54.33
	R ≤ 13	13 < R ≤ 20	0.99	21.99	35.94
	R ≤ 13	20 < R	1.00	23.21	34.63
	13 < R ≤ 20	13 < R ≤ 20	0.41	8.08	16.20
	13 < R ≤ 20	20 < R	0.41	8.95	14.89
	20 < R	20 < R	0.13	3.42	2.05
Warehouse	R ≤ 13	R ≤ 13	0.05	2.10	0.22
	R ≤ 13	13 < R ≤ 20	0.09	3.51	1.39
	R ≤ 13	20 < R	0.16	6.54	1.35
	13 < R ≤ 20	13 < R ≤ 20	0.02	1.21	0.28
	13 < R ≤ 20	20 < R	0.08	3.71	0.24
	20 < R	20 < R	0.01	0.70	-0.07
Other	R ≤ 13	R ≤ 13	0.05	1.13	-0.41
	R ≤ 13	13 < R ≤ 20	0.07	1.44	-1.23
	R ≤ 13	20 < R	0.07	1.57	-2.70
	13 < R ≤ 20	13 < R ≤ 20	0.02	0.78	-3.69
	13 < R ≤ 20	20 < R	0.05	0.90	0.00
	20 < R	20 < R	0.01	0.67	-0.14

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

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
Education - chiller	R ≤ 13	R ≤ 13	0.69	9.09	3.85
	R ≤ 13	13 < R ≤ 20	0.97	14.42	4.87
	R ≤ 13	20 < R	1.07	16.52	5.43
	13 < R ≤ 20	13 < R ≤ 20	0.36	4.80	1.87
	13 < R ≤ 20	20 < R	0.44	6.47	2.34
	20 < R	20 < R	0.28	3.91	1.19
Education - RTU	R ≤ 13	R ≤ 13	0.30	8.21	3.09
	R ≤ 13	13 < R ≤ 20	0.42	13.43	4.02
	R ≤ 13	20 < R	0.46	15.49	4.27
	13 < R ≤ 20	13 < R ≤ 20	0.18	5.16	1.47
	13 < R ≤ 20	20 < R	0.22	7.09	1.72
	20 < R	20 < R	0.14	4.14	0.86
Hotel	R ≤ 13	R ≤ 13	0.10	1.33	7.04
	R ≤ 13	13 < R ≤ 20	0.08	1.58	1.80
	R ≤ 13	20 < R	0.08	1.68	-0.78
	13 < R ≤ 20	13 < R ≤ 20	0.07	0.95	4.98
	13 < R ≤ 20	20 < R	0.06	1.04	2.57
	20 < R	20 < R	0.06	0.81	4.27
Office - chiller	R ≤ 13	R ≤ 13	0.29	9.72	7.27
	R ≤ 13	13 < R ≤ 20	0.39	17.57	12.46
	R ≤ 13	20 < R	0.42	20.35	13.25
	13 < R ≤ 20	13 < R ≤ 20	0.17	6.68	0.12
	13 < R ≤ 20	20 < R	0.20	9.22	0.79
	20 < R	20 < R	0.14	5.39	2.02
Office - RTU	R ≤ 13	R ≤ 13	0.31	9.93	24.02
	R ≤ 13	13 < R ≤ 20	0.55	16.57	105.15
	R ≤ 13	20 < R	0.64	19.26	135.96
	13 < R ≤ 20	13 < R ≤ 20	0.20	5.75	16.21
	13 < R ≤ 20	20 < R	0.29	7.78	47.02
	20 < R	20 < R	0.16	4.70	12.77
Retail	R ≤ 13	R ≤ 13	0.67	16.55	42.72
	R ≤ 13	13 < R ≤ 20	1.01	26.85	67.80
	R ≤ 13	20 < R	1.02	28.78	65.27
	13 < R ≤ 20	13 < R ≤ 20	0.19	5.83	6.64
	13 < R ≤ 20	20 < R	0.19	7.24	4.12
	20 < R	20 < R	0.15	4.74	5.40

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
Warehouse	R ≤ 13	R ≤ 13	0.04	2.76	-0.61
	R ≤ 13	13 < R ≤ 20	0.09	4.91	1.33
	R ≤ 13	20 < R	0.15	8.27	2.06
	13 < R ≤ 20	13 < R ≤ 20	0.02	1.31	-0.42
	13 < R ≤ 20	20 < R	0.07	3.98	0.30
	20 < R	20 < R	0.01	0.76	-0.19
Other	R ≤ 13	R ≤ 13	0.04	1.33	-0.61
	R ≤ 13	13 < R ≤ 20	0.08	1.58	1.33
	R ≤ 13	20 < R	0.08	1.68	-0.78
	13 < R ≤ 20	13 < R ≤ 20	0.02	0.95	-0.42
	13 < R ≤ 20	20 < R	0.06	1.04	0.30
	20 < R	20 < R	0.01	0.76	-0.19

Deemed Energy and Demand Savings Tables

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

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) Remote Ex-Ante Database Interface (READI) tool for EUL ID BldgEnv-CoolRoof.[274]

Program Tracking Data and Evaluation Requirements

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

- Climate zone or county
- Building type
- Total and treated roofing square footage (over conditioned space)
- Roof slope
- Existing roof insulation R-value, or year of building construction

[274] DEER READI. http://www.deeresources.com/index.php/readi.

- New roof insulation R-value, if adding insulation
- New roofing initial solar reflectance
- New roofing three-year solar reflectance
- New roofing rated life
- Copy of CRRC certification
- Copy of proof of purchase including date of purchase, manufacturer, and model

Building Type References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 124. Cool Roofs—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Clarified that reflectance is three years basis. Rounded off values, too many insignificant digits.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. Clarified eligibility criteria, baseline condition, and high-efficiency condition. Added R-values for more materials. Added new high-performance roof calculator for use in determining ENERGY STAR® roof savings.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. Changed savings methodology from algorithms to simulation models. Deemed savings are presented per square foot by building type and climate zone.
v7.0	10/2019	TRM v7.0 update. Minor error updates to Savings Factor Table for greater than and less than symbols. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR® qualification requirement and defers to meeting criteria.

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 update. Added building type to tracking data requirements. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Changed eligibility criteria from strictly ENERGY STAR to CRRC certification.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. Reordering of building types in tables.

2.3.2 Window Treatments Measure Overview

TRM Measure ID: NR-BE-WT

Market Sector: Commercial

Measure Category: Building envelope

Applicable Building Types: All commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

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

Existing windows must have no solar films/screens, interior shades, or exterior awnings or overhangs, and must be installed in buildings that are mechanically cooled (direct expansion (or chilled water). While highly reflective louvered or Venetian blinds can help reduce solar heat gain, they must be completely lowered and closed to be as effective as permanent shading devices.[275] The louvered or Venetian blinds are not eligible for the measure, although windows with existing interior louvered or Venetian blinds are not excluded from using this measure.

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

Baseline Condition

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

High-Efficiency Condition

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

Energy and Demand Savings Methodology

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

Savings Algorithms and Input Variables

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

Equation 78

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

Equation 79

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

Equation 80

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

Equation 81

Where:

Demand Savings$_o$ = *Peak demand savings per window orientation*

Energy Savings$_o$ = *Energy savings per window orientation*

$A_{film,o}$ = *Area of window treatment applied to orientation [ft^2]*

$SHGF_o$ = *Peak solar heat gain factor for orientation of interest [Btu/hr-ft²-year] (see Table 125)*

SHG_o = *Solar heat gain for orientation of interest [Btu/ft2-year] (see Table 125)*

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

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

Note: Shading coefficients (SC) have been retired, but if a product specification lists SC instead of SHGC, you can convert to SHGC by multiplying SC by 0.87.[276]

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

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

Table 125. Windows Treatments—Solar Heat Gain Factors[277]

Orientation[278]	Solar heat gain (SHG) [Btu/ft²-year]	Peak hour solar heat gain (SHGF) [Btu/hr-ft²-year]				
		Climate Zone 1: Amarillo[279]	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
SE	158,844	28	30	26	27	35
SSE	134,794	28	31	28	28	37
S	120,839	37	44	47	45	56
SSW	134,794	88	94	113	113	101
SW	158,844	152	151	170	173	141
WSW	169,696	191	184	201	206	160
W	163,006	202	189	201	207	155
WNW	139,615	183	167	171	178	128
NW	107,161	136	120	115	121	85

[276] 2001 ASHRAE Handbook: Fundamentals, p. 30–39.

[277] 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 32ºN 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.

[278] N = North, S = South, E = East, and W = West.

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

Table 126. Windows Treatments—Recommended Clear Glass $SHGC_{pre}$ by Window Thickness[280]

Existing window configuration	Louvered Blinds	$SHGC_{pre}$
Single-pane 1/8-inch clear glass	No	0.86
Single-pane 1/4-inch clear glass		0.81
Double-pane 1/8-inch clear glass		0.76
Double-pane 1/4-inch clear glass		0.70
Single-pane 1/8-inch clear glass	Yes[281]	0.64
Single-pane 1/4-inch clear glass		0.60
Double-pane 1/8-inch clear glass		0.61
Double-pane 1/4-inch clear glass		0.57

Table 127. Windows Treatments—Recommended COP by HVAC System Type[282]

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

Deemed Energy and Demand Savings Tables

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

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID GlazDaylt-WinFilm.[283]

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280 2021 ASHRAE Handbook: Fundamentals, Chapter 15 Fenestration, Table 10 Solar Heat Gain Coefficient (SHGC). https://www.ashrae.org/technical-resources/ashrae-handbook/ashrae-handbook-online.

281 2021 ASHRAE Handbook: Fundamentals, Chapter 15 Fenestration, Table 14A IAC Values for Louvered Shades: Uncoated Single Glazings, Table 14B IAC Values for Louvered Shades: Uncoated Double Glazings. https://www.ashrae.org/technical-resources/ashrae-handbook/ashrae-handbook-online.

282 Based on review applicable codes, including IECC 2000, 2009, and 2015.

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

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 128. Windows Treatments—Revision History

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

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

2.3.3 Entrance and Exit Door Air Infiltration Measure Overview

TRM Measure ID: NR-BE-DI

Market Sector: Commercial

Measure Category: Building envelope

Applicable Building Types: All commercial

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

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

Energy and Demand Savings Methodology

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

Derivation of Pre-Retrofit Air Infiltration Rate

The pre-retrofit air infiltration rate for each crack width is calculated by applying the methodologies presented in Chapter 5 of the ASHRAE Cooling and Heating Load Calculation Manual (CHLCM).[284] Building type characteristics for a typical commercial building were found in the DOE study PNNL-20026,[285] and an average building height of 20 feet is assumed for the deemed savings approach.

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

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

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

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

Equation 82

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

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

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

Equation 83

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

This yields the total pressure difference across the door, Δp_{Total}:

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

Equation 84

284 ASHRAE Cooling and Heating Load Calculation Manual, p. 5.8. 1980. http://portal.hud.gov/hudportal/documents/huddoc?id=doc_10603.pdf.

285 Cho, H., K. Gowri, and B. Liu, "Energy Saving Impact of ASHRAE 90.1 Vestibule Requirements: Modeling of Air Infiltration through Door Openings." November 2010. http://www.pnl.gov/main/publications/external/technical_reports/PNNL-20026.pdf.

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

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

Equation 85

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

Equation 86

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

Equation 87

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

Equation 88

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

Derivation of Design and Average Outside Ambient Temperatures

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

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

Equation 89

Where:

T_{design} = *Daytime and nighttime design temperature [°F] (see Table 130)*

$T_{avg\ outside\ ambient}$ = *Average outside ambient temperature, specified by month [°F] (see Table 129)*

Table 129. Air Infiltration—Average Monthly Ambient Temperatures (°F)[286]

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

Table 130. Air Infiltration—Daytime and Nighttime Design Temperatures

Temperature description	T_{design} (°F)
Daytime cooling design temperature	74
Daytime heating design temperature	72
Nighttime cooling design temperature[287]	78
Nighttime heating design temperature[288]	68

Savings Algorithms and Input Variables

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

Electric Cooling Energy Savings

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

Equation 90

[286] TMY3 climate data.
[287] Assuming four-degree setback.
[288] Ibid.

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

Equation 91

$$Cooling\ Energy\ Savings\ [kWh] = Cooling\ Energy\ Savings\ [kWh]_{Day} + Cooling\ Energy\ Savings\ [kWh]_{Night}$$

Equation 92

Electric Heating Energy Savings

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

Equation 93

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

Equation 94

$$Heating\ Energy\ Savings\ [kWh] = Cooling\ Energy\ Savings\ [kWh]_{Day} + Cooling\ Energy\ Savings\ [kWh]_{Night}$$

Equation 95

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

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

Equation 96

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

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

Equation 97

Where:

CFM_{pre}	=	*Calculated pre-retrofit air infiltration (cubic feet per minute)*
$CFM_{reduction}$	=	*59%[289] x TDF*
TDF	=	*Technical degradation factor = 85%[290]*
1.08	=	*Sensible heat equation conversion[291]*
ΔT	=	*Change in temperature across gap barrier [°F]*
$Hours_{day}$	=	*12-hour cycles per day, per month = 4,380 hours*
$Hours_{night}$	=	*12-hour cycles per night, per month = 4,380 hours*
COP	=	*Heating coefficient of performance; 1.0 for electric resistance and 3.3 for heat pumps*

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings per standard door[292] are specified below based on climate zone and existing door gap width. The gap width shall be measured on each of the four edges of the door to the nearest ¼ inch. The reported gap width for the door should reflect the average of the four measurements. The average gap width should be rounded to nearest gap width in inches in Table 131 through Table 136. Projects that have more than ten doors at the same project site can provide a sample of measurements of 20 percent of the claimed doors and apply the average to all doors in the project.

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

289 CLEAResult, “Commercial Door Air Infiltration Memo”. March 18, 2015. Average reduction in Arkansas based on test results from the CLEAResult Brush Weatherstripping Testing Method and Results (59% infiltration reduction).

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

291 2013 ASHRAE Handbook of Fundamentals; Equation 33, p. 16.11.

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

Table 131. Air Infiltration—Cooling Energy Savings/Door of Weatherstripping/Door Sweep

Climate zone	Average gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	37	74	147	221
Climate Zone 2: Dallas	75	152	303	454
Climate Zone 3: Houston	58	118	234	351
Climate Zone 4: Corpus Christi	97	195	387	581
Climate Zone 5: El Paso	54	110	218	327

Table 132. Air Infiltration—ER Heating Energy Savings/Door of Weatherstripping/Door Sweep

Climate zone	Average gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	1,958	3,949	7,844	11,775
Climate Zone 2: Dallas	945	1,911	3,792	5,693
Climate Zone 3: Houston	525	1,064	2,111	3,169
Climate Zone 4: Corpus Christi	440	890	1,766	2,651
Climate Zone 5: El Paso	881	1,783	3,538	5,311

Table 133. Air Infiltration—HP Heating Energy Savings/Door of Weatherstripping/Door Sweep

Climate zone	Average gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	593	1,197	2,377	3,568
Climate Zone 2: Dallas	287	579	1,149	1,725
Climate Zone 3: Houston	159	323	640	960
Climate Zone 4: Corpus Christi	133	270	535	803
Climate Zone 5: El Paso	267	540	1,072	1,609

Table 134. Air Infiltration—Summer Demand Savings/Door of Weatherstripping/Door Sweep

Climate zone	Average gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	0.10	0.20	0.41	0.61
Climate Zone 2: Dallas	0.09	0.17	0.35	0.52
Climate Zone 3: Houston	0.08	0.17	0.33	0.50
Climate Zone 4: Corpus Christi	0.08	0.16	0.32	0.48
Climate Zone 5: El Paso	0.08	0.16	0.32	0.48

Table 135. Air Infiltration—ER Winter Demand Savings/Door of Weatherstripping/Door Sweep

Climate zone	Average gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	0.52	1.05	2.08	3.12
Climate Zone 2: Dallas	0.80	1.60	3.19	4.78
Climate Zone 3: Houston	0.41	0.82	1.63	2.45
Climate Zone 4: Corpus Christi	0.37	0.74	1.47	2.21
Climate Zone 5: El Paso	0.19	0.39	0.77	1.16

Table 136. Air Infiltration—HP Winter Demand Savings/Door of Weatherstripping/Door Sweep

Climate zone	Average gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	0.27	0.54	1.06	1.60
Climate Zone 2: Dallas	0.34	0.69	1.37	2.06
Climate Zone 3: Houston	0.20	0.40	0.79	1.19
Climate Zone 4: Corpus Christi	0.17	0.34	0.67	1.01
Climate Zone 5: El Paso	0.09	0.19	0.38	0.57

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 11 years, as specified in the California Database of Energy Efficiency Resources (DEER) Remote Ex-Ante Database Interface (READI) tool for EUL ID BS-Wthr.[293] This measure life is consistent with the residential air infiltration measure in the Texas TRM.

293 DEER READI. http://www.deeresources.com/index.php/readi.

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 137. Air Infiltration—Revision History

TRM version	Date	Description of change
v6.0	10/2018	TRM v6.0 origin.
v7.0	10/2019	TRM v7.0 update. Minor text revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Degradation factor added to deemed savings values. Guidance clarified for measuring gap sizes.

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. Adjusted savings normalization from per-linear-foot to per-standard-door. Updated documentation requirements.

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: All commercial kitchens

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This section covers the deemed savings methodology for the installation of ENERGY STAR combination ovens. Combination ovens are convection ovens that include the added capability to inject steam into the oven cavity and typically offer 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, and straight pressure-less steamer. The energy and demand savings are determined on a per-oven basis.

Eligibility Criteria

Eligible units must be compliant with the current ENERGY STAR specifications, with half-size and full-size ovens as defined below and a pan capacity ≥ 3 and ≤ 40.[294, 295]

- Full-size combination oven: capable of accommodating two 12.7 x 20.8 x 2.5-inch steam table pans per rack position, loaded from front-to-back or lengthwise.
- Half-size combination oven: capable of accommodating a single 12.7 x 20.8 x 2.5-inch steam table pan per rack position, loaded from front-to-back or lengthwise.
- Two-thirds-size combination ovens were added to the current ENERGY STAR specification but are excluded from this measure until the ENERGY STAR food service calculator is updated to include category-specific input assumptions.

294 ENERGY STAR Program Requirements for Commercial Ovens. Eligibility Criteria Version 3.0. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification_0.pdf.

295 ENERGY STAR Qualified Product Listing: https://www.energystar.gov/productfinder/product/certified-commercial-ovens/results.

Eligible building types include any nonresidential application.

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

- Dual-fuel heat source combination ovens
- Hybrid ovens not defined as eligible above (e.g., those incorporating microwave settings)
- Conventional or standard ovens, conveyor, slow cook-and-hold, deck, hearth, microwave, range, rapid cook, reel-type, and rotisserie
- Full- and half-size gas combination ovens with a pan capacity of < 5 or > 40
- Full- and half-size electric combination ovens with a pan capacity of < 3 or > 40
- Two-thirds-size combination ovens with a pan capacity > 5
- Mini and quadruple gas rack ovens
- Electric rack ovens

Baseline Condition

The baseline condition for retrofit situations is a half-size or full-size combination oven with a pan capacity ≥ 5 and ≤ 20 that does not meet ENERGY STAR key product criteria.

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v3.0 specification, effective January 12, 2023. Qualified products must meet the minimum energy efficiency and idle energy rate requirements from Table 138.

Table 138. Combination Ovens—ENERGY STAR Specification[296]

Operation	Idle rate (kW)[297]	Cooking energy efficiency (%)
Full-size and half-size ovens with 5–40 pan capacity		
Steam mode	≤ 0.133P + 0.64	≥ 55
Convection mode	≤ 0.083P + 0.35	≥ 78
Full-size and half-size ovens with 3–4 pan capacity		
Steam mode	≤ 0.60P	≥ 51
Convection mode	≤ 0.05P + 0.55	≥ 70

[296] ENERGY STAR Commercial Ovens Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria.

[297] P = Pan capacity.

Furthermore, pan capacity[298] must be ≥ 3 and ≤ 40 (for both half- and full-size combination ovens). Pan capacity must be ≥ 3 and ≤ 5 for two-thirds-size combination ovens.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The deemed values are calculated by using the following algorithms:

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

Equation 98

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

Equation 99

$$kWh_{ES} = kWh_{ph,ES} + kWh_{conv,ES} + kWh_{st,ES}$$

Equation 100

kWh_{ph}, kWh_{conv} and *kWh_{st}* are each calculated the same for both the baseline and ENERGY STAR cases, as shown in Equation 101, except they require their respective input assumptions relative to preheat, cooking and idle operation in convection and steam modes as seen in Table 139.

$$kWh = \left(E_{ph} + \left(\frac{W_{food} \times DOH \times E_{food} \times 50\%}{\eta_{cook}}\right) + E_{idle} \times \left(\left(DOH - \frac{W_{food} \times DOH}{PC}\right) \times 50\%\right)\right) \times \frac{AOD}{1{,}000}$$

Equation 101

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\Delta kWh - \left(\frac{\Delta E_{ph} \times AOD}{1{,}000}\right)}{DOH \times AOD} \times CF$$

Equation 102

Where:

kWh_{base}	=	*Baseline annual energy consumption [kWh]*
kWh_{ES}	=	*ENERGY STAR annual energy consumption [kWh]*
E_{ph}	=	*Preheat energy [Wh]*
ΔE_{ph}	=	*Difference in baseline and ENERGY STAR preheat energy*

[298] Pan capacity is defined as the number of steam table pans the combination oven can accommodate as per the ASTM F-1495-05 standard specification.

E_{food}	=	*ASTM energy to food of energy absorbed by food product during cooking [Wh/lb]*
E_{Idle}	=	*Idle energy rate [W]*
W_{food}	=	*Pounds of food cooked per hour [lb/hr]*
η_{cook}	=	*Cooking energy efficiency [%]*
PC	=	*Production capacity per pan [lb/hr]*
DOH	=	*Equipment daily operating hours [hr/day]*
AOD_s	=	*Facility annual operating days [days/year]*
1,000	=	*Constant to convert from W to kW*
CF	=	*Peak coincidence factor*

Table 139. Combination Ovens—Savings Calculation Input Assumptions[299]

Parameter		Convection mode		Steam mode	
		Baseline	ENERGY STAR	Baseline	ENERGY STAR
E_{ph}	P < 5	410		600	
	5 ≥ P < 15	3,000	1,500	3,000	1,500
	P ≥ 15	3,750	2,000	3,750	2,000
W_{food}	P < 5	10.4			
	5 ≥ P < 15	16.7			
	P ≥ 15	20.8			
E_{food}		73.2		30.8	
η_{cook}	3 ≥ P < 5	65%	70%	47%	51%
	P ≥ 5	72%	78%	52%	55%
E_{idle}	3 ≥ P < 5	680	(0.05P + 0.55) x 1,000	2,090	0.60P x 1,000
	5 ≥ P < 15	1,320	(0.083P + 0.35) x 1,000	5,260	(0.133P + 0.64) x 1,000
	P ≥ 15	2,280		8,710	
PC[300]	P < 5	29	37	45	59
	P ≥ 5	107	174	151	247
CF[301]		0.90			

299 ENERGY STAR Commercial Food Service Equipment Calculator. March 2024 update. https://www.energystar.gov/products/commercial_food_service_equipment.

300 The 3/2021 ENERGY STAR calculator update no longer varies C_{cap} by pan capacity. However, this is assumed to be an error. The values specified for pan capacity of 15 or greater are specified in the previous calculator version.

301 Itron, Inc., "2004-2005 Database for Energy Efficiency Resources (DEER) Update Study. Final Report." Prepared for Southern California Edison. December 2005. Table 3-14, p. 3-17.

Table 140. Combination Ovens—Operating Schedule Assumptions[302]

Building type	DOH	AOD
Education: K-12	6	180
Education: College and university	10	260
All other	12	365

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in the following tables are based on the input assumptions specified above.

Table 141. Combination Ovens—Energy and Peak Demand Savings (Education: K-12)

Pan capacity	kWh savings	kW savings	Pan capacity	kWh savings	kW savings
3	104	0.086	22	3,005	1.979
4[303]	104	0.086	23	2,900	1.892
5	2,740	1.833	24	2,795	1.804
6	2,632	1.743	25	2,690	1.716
7	2,524	1.654	26	2,584	1.629
8	2,417	1.564	27	2,479	1.541
9	2,309	1.475	28	2,374	1.453
10	2,202	1.385	29	2,269	1.366
11	2,094	1.295	30	2,164	1.278
12	1,987	1.206	31	2,058	1.190
13	1,879	1.116	32	1,953	1.103
14	1,772	1.027	33	1,848	1.015
15	3,742	2.593	34	1,743	0.927
16	3,637	2.505	35	1,637	0.840
17	3,531	2.418	36	1,532	0.752
18	3,426	2.330	37	1,427	0.664
19	3,321	2.242	38	1,322	0.577
20	3,216	2.155	39	1,217	0.489
21	3,111	2.067	40	1,111	0.401

302 Fisher-Nickel, Inc., "Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report." Prepared for the California Energy Commission. October 2014. Appendix E.

303 Four-pan capacity savings are set as identical to three-pan capacity savings, as ENERGY STAR calculator reports negative savings.

Table 142. Combination Ovens—Energy and Peak Demand Savings (Education: College and university)

Pan capacity	kWh savings	kW savings	Pan capacity	kWh savings	kW savings
3	249	0.086	22	6,628	1.979
4[304]	249	0.086	23	6,375	1.892
5	6,075	1.833	24	6,122	1.804
6	5,816	1.743	25	5,868	1.716
7	5,557	1.654	26	5,615	1.629
8	5,299	1.564	27	5,362	1.541
9	5,040	1.475	28	5,108	1.453
10	4,781	1.385	29	4,855	1.366
11	4,522	1.295	30	4,602	1.278
12	4,264	1.206	31	4,349	1.190
13	4,005	1.116	32	4,095	1.103
14	3,746	1.027	33	3,842	1.015
15	8,401	2.593	34	3,589	0.927
16	8,148	2.505	35	3,335	0.840
17	7,895	2.418	36	3,082	0.752
18	7,641	2.330	37	2,829	0.664
19	7,388	2.242	38	2,576	0.577
20	7,135	2.155	39	2,322	0.489
21	6,882	2.067	40	2,069	0.401

Table 143. Combination Ovens—Energy and Peak Demand Savings (All Other)

Pan capacity	kWh savings	kW savings	Pan capacity	kWh savings	kW savings
3	420	0.086	22	10,911	1.979
4[305]	420	0.086	23	10,484	1.892
5	10,015	1.833	24	10,057	1.804
6	9,579	1.743	25	9,630	1.716
7	9,143	1.654	26	9,204	1.629
8	8,707	1.564	27	8,777	1.541
9	8,271	1.475	28	8,350	1.453

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304 Four-pan capacity savings are set as identical to three-pan capacity savings, as ENERGY STAR calculator reports negative savings.

305 Four-pan capacity savings are set as identical to three-pan capacity savings, as ENERGY STAR calculator reports negative savings.

Pan capacity	kWh savings	kW savings
10	7,835	1.385
11	7,399	1.295
12	6,963	1.206
13	6,527	1.116
14	6,091	1.027
15	13,898	2.593
16	13,471	2.505
17	13,044	2.418
18	12,617	2.330
19	12,191	2.242
20	11,764	2.155
21	11,337	2.067

Pan capacity	kWh savings	kW savings
29	7,924	1.366
30	7,497	1.278
31	7,070	1.190
32	6,644	1.103
33	6,217	1.015
34	5,790	0.927
35	5,363	0.840
36	4,937	0.752
37	4,510	0.664
38	4,083	0.577
39	3,657	0.489
40	3,230	0.401

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) Remote Ex-Ante Database Interface (READI) tool for EUL ID Cook-ElecCombOven.[306]

Program Tracking Data and Evaluation Requirements

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

- Manufacturer and model number
- Pan capacity
- ENERGY STAR idle rate
- ENERGY STAR cooking efficiency
- Copy of ENERGY STAR certification or alternative
- Copy of proof of purchase including date of purchase, manufacturer, and model number
- Facility type (Education: K-12, Education: College and university, All other)

[306] DEER READI. http://www.deeresources.com/index.php/readi.

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 144. Combination Ovens—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. 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	TRM v3.1 update. Updated title to reflect ENERGY STAR measure.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR qualification requirement and defers to meeting criteria.
v9.0	10/2021	TRM v9.0 update. Incorporated March 2021 calculator updates. Corrected ENERGY STAR idle rate formulas. Updated tracking system requirements and EUL reference.
v10.0	10/2022	TRM v10.0 update. Updated specification and deemed savings to comply with ENERGY STAR Commercial Ovens Program Requirements Version 3.0.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. Specified reduced operating schedule for education applications. Aligned deemed savings tables and calculations input assumptions to ENERGY STAR March 2024 update.

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: All commercial kitchens

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This section covers the savings from retrofit or new installation of a full-size or half-size ENERGY STAR electric convection ovens. 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 on oven energy rates, cooking efficiencies, operating hours, production capacities, and building type. Average energy and demand consumption, used to calculate the savings, are determined using these assumed default input values on a per-oven basis.

Eligibility Criteria

Eligible units must be compliant with the current ENERGY STAR specification, with half-size and full-size electric ovens as defined below:[307, 308]

- Full-size convection oven: capable of accommodating standard full-size sheet pans measuring 18 x 26 x 1-inch.
- Half-size convection oven: capable of accommodating half-size sheet pans measuring 18 x 13 x 1-inch.

Eligible building types include any nonresidential application.[309]

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[307] ENERGY STAR Program Requirements for Commercial Ovens. Eligibility Criteria Version 3.0. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification_0.pdf.

[308] ENERGY STAR Qualified Product Listing. https://www.energystar.gov/productfinder/product/certified-commercial-ovens/results.

[309] CEE Commercial Kitchens Initiative's overview of the food service industry. https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf

Convection ovens eligible for rebate do not include ovens that can heat the cooking cavity with saturated or superheated steam. However, eligible convection ovens may have moisture injection capabilities (e.g., baking ovens and moisture-assist ovens). Ovens that include a “hold feature” are eligible under this specification if convection is the only method used to fully cook the food.

Products listed below are excluded from the ENERGY STAR eligibility criteria:

- Half-size gas convection ovens
- Hybrid ovens not defined as eligible above (e.g., those incorporating microwave settings)
- Conventional or standard ovens, conveyor, slow cook-and-hold, deck, hearth, microwave, range, rapid cook, reel-type, and rotisserie
- Mini and quadruple gas rack ovens
- Electric rack ovens

Baseline Condition

The baseline condition for retrofit situations is an electric convection oven that does not meet ENERGY STAR key product criteria.

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v3.0 specification, effective January 12, 2023. Qualified products must meet the minimum energy efficiency and idle energy rate requirements from Table 145.

Table 145. Convection Ovens—ENERGY STAR Specification[310]

Oven size	Idle rate (W)	Cooking energy efficiency (%)
Full size ≥ 5 pans	≤ 1,400	≥ 76
Full size < 5 pans	≤ 1,000	
Half size	≤ 1,000	≥ 71

Energy and Demand Savings Methodology

Savings Calculations and Input Variables

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

[310] ENERGY STAR Commercial Ovens Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria.

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

Equation 103

$$kWh_{base} = kWh_{ph,base} + kWh_{cook,base} + kWh_{idle,base}$$

Equation 104

$$kWh_{ES} = kWh_{ph,ES} + kWh_{cook,ES} + kWh_{idle,ES}$$

Equation 105

kWh_{ph}, kWh_{cook}, and kWh_{idle} are each calculated the same for both the baseline and ENERGY STAR cases, as shown in Equation 106, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 146.

$$kWh = \left(E_{ph} + \left(\frac{W_{food} \times DOH \times E_{food}}{\eta_{cook}}\right) + E_{idle} \times \left(DOH - \frac{W_{food} \times DOH}{PC}\right)\right) \times \frac{AOD}{1{,}000}$$

Equation 106

$$Peak\ Demand\ [\Delta kW] = \frac{\Delta kWh - \left(\frac{\Delta E_{ph} \times AOD}{1{,}000}\right)}{DOH \times AOD} \times CF$$

Equation 107

Where:

kWh_{base}	=	*Baseline annual energy consumption [kWh]*
kWh_{ES}	=	*ENERGY STAR annual energy consumption [kWh]*
E_{ph}	=	*Preheat energy [Wh]*
ΔE_{ph}	=	*Difference in baseline and ENERGY STAR preheat energy*
E_{food}	=	*ASTM energy to food of energy absorbed by food product during cooking [Wh/lb]*
E_{Idle}	=	*Idle energy rate [W]*
W_{food}	=	*Pounds of food cooked per day [lb/hr]*
η_{cook}	=	*Cooking energy efficiency [%]*
PC	=	*Production capacity [lb/hr]*
DOH	=	*Equipment daily operating hours [hr/day]*
AOD	=	*Facility annual operating days [days/year]*
1,000	=	*Constant to convert from W to kW*
CF	=	*Coincidence factor*

Table 146. Convection Ovens—Savings Calculation Input Assumptions[311]

Parameter	Full size ≥ 5 pans		Full size < 5 pans		Half size	
	Baseline	ENERGY STAR	Baseline	ENERGY STAR	Baseline	ENERGY STAR
E_{ph}	1,563	1,389	1,563	1,389	890	700
W_{food}	8.33					
E_{food}	73.2					
η_{cook}	65%	76%	65%	76%	68%	70.67%
E_{idle}	2,000	1,400	2,000	1,000	1,030	1,000
PC	90	90	90	90	45	50
CF[312]	0.90					

Table 147. Convection Ovens—Operating Schedule Assumptions[313]

Building type	DOH	AOD
Education: K-12	6	180
Education: College and university	10	260
All other	12	365

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in the following tables are based on the input assumptions specified above.

Table 148. Convection Ovens—Energy and Peak Demand Savings

Building type	Oven size	kWh savings	kW savings
Education: K-12	Full size ≥ 5 pans	766	0.612
	Full size < 5 pans	1,158	0.939
	Half size	77	0.036
Education: College and university	Full size ≥ 5 pans	1,814	0.612
	Full size < 5 pans	2,758	0.939
	Half size	153	0.036

311 ENERGY STAR Commercial Food Service Equipment Calculator. 7/15/21 amendment to March 2021 update. https://www.energystar.gov/products/commercial_food_service_equipment.

312 Itron, Inc., "2004-2005 Database for Energy Efficiency Resources (DEER) Update Study. Final Report." Prepared for Southern California Edison. December 2005. Table 3-14, p. 3-17.

313 Fisher-Nickel, Inc., "Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Food Service Equipment. Final Project Report." Prepared for the California Energy Commission. October 2014. Appendix E.

Building type	Oven size	kWh savings	kW savings
All other	Full size ≥ 5 pans	3,043	0.612
	Full size < 5 pans	4,633	0.939
	Half size	244	0.036

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID Cook-ElecConvOven.[314]

Program Tracking Data and Evaluation Requirements

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

- Manufacturer and model number
- Pan capacity
- Oven size
- ENERGY STAR idle rate
- ENERGY STAR cooking efficiency
- Copy of ENERGY STAR certification or alternative
- Copy of proof of purchase including date of purchase, manufacturer, and model number
- Facility type (Education: K-12, Education: College and university, All other)

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

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

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

Document Revision History

Table 149. Convection Ovens—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. Updated to newer ENERGY STAR Commercial Ovens Program Requirements Version 2.1. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR Commercial Kitchen Equipment Savings Calculator.
v3.1	11/05/2015	TRM v3.1 update. Updated title to reflect ENERGY STAR Measure.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Corrected convection oven definitions. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR qualification requirement and defers to meeting criteria.
v9.0	10/2021	TRM v9.0 update. Incorporated changes from March 2021 calculator update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Updated specification and deemed savings to comply with ENERGY STAR Commercial Ovens Program Requirements Version 3.0.
v11.0	10/2023	TRM v11.0 update. No revision.
v12.0	10/2024	TRM v12.0 update. Specified reduced operating schedule for education applications and updated corresponding deemed savings tables.