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[206] data*
m	=	*The slope of the relationship between DBT and CFM (see Table 85)*
b	=	*The intercept of the relationship between DSBT and CFM (see Table 85)*

The minimum flow rate is set to 60 percent cfm based on common design practice.[207] Determination of the minimum dry bulb temperature assumes that cooling will only operate above the cooling reference temperature of 65°F dry bulb. The maximum DBT is the ASHRAE dry bulb design temperature.[208]

[206] 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.

[207] 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%.

[208] ASHRAE ~~2017~~2021 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.

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

Climate zone	Condition	Minimum	Maximum	Slope (*m*)	Intercept (*b*)
Climate Zone 1	Flow rate (%cfm)	60	100	1.~~19~~18	~~-17.38~~16.92
	Dry bulb T (°F)	65	98.~~6~~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	~~-20.00~~19.75
	Dry bulb T (°F)	65	97.~~5~~6		
Climate Zone 4	Flow rate (%cfm)	60	100	1.25~~6~~	-21.50~~76~~
	Dry bulb T (°F)	65	96.~~8~~9		
Climate Zone 5	Flow rate (%cfm)	60	100	1.1~~1~~0	~~-12.02~~11.82
	Dry bulb T (°F)	65	101.~~1~~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[209]

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

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

[209] TMY3 data does not include wet bulb temperature. 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.

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

Climate zone	Condition	Minimum	Maximum	Slope (m)	Intercept (b)
Climate Zone 1	Flow rate (%cfm)	40	100	3.98	-184.25
	Wet bulb T (°F)	56.3	71.4		
Climate Zone 2	Flow rate (%cfm)	40	100	2.99	-135.13
	Wet bulb T (°F)	58.5	78.6		
Climate Zone 3	Flow rate (%cfm)	40	100	2.95	-136.58
	Wet bulb T (°F)	59.9	80.2		
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% cfm based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.[210] 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.[211]

For chilled water and condenser water pumps:

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

Equation 43

Where:

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

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

The minimum flow rate is set to 10 percent GPM based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.[212] Determination of the minimum dry bulb temperature assumes that cooling will only operate above the cooling reference

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

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

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

temperature of 65°F dry bulb. The maximum DBT is the ASHRAE dry bulb design temperature.[213]

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

Climate zone	Condition	Minimum	Maximum	Slope (*m*)	Intercept (*b*)
Climate Zone 1	Flow rate (%GPM)	10	100	2.6~~8~~6	-~~164.11~~163.08
	Dry bulb T (°F)	65	98.8~~6~~		
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	-~~170.00~~169.45
	Dry bulb T (°F)	65	97.~~5~~6		
Climate Zone 4	Flow rate (%GPM)	10	100	2.8~~3~~2	-173.~~96~~39
	Dry bulb T (°F)	65	96.9~~8~~		
Climate Zone 5	Flow rate (%GPM)	10	100	2.49	-~~152.05~~151.60
	Dry bulb T (°F)	65	101.~~1~~2		

For hot water pumps:

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

Equation 44

Where:

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

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

The minimum flow rate is set to 10 percent GPM based on the ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual.[214] 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.[215]

[213] ASHRAE 20~~17~~21 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 0.4% Cooling DB.
[214] PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, page 3.249, pump minimum speed default.
[215] ASHRAE 2017 Fundamentals, Ch 14 Appendix: design conditions for selected locations, 99.6% Heating DB.

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

Climate zone	Condition	Minimum	Maximum	Slope (*m*)	Intercept (*b*)
Climate Zone 1	Flow rate (%GPM)	10	100	-1.6~~4~~6	~~116.56~~117.93
	Dry bulb T (°F)	65	10.~~1~~8		
Climate Zone 2	Flow rate (%GPM)	10	100	-2.16	150.~~29~~63
	Dry bulb T (°F)	65	23.~~3~~4		
Climate Zone 3	Flow rate (%GPM)	10	100	-2.6~~5~~8	~~182.57~~184.11
	Dry bulb T (°F)	65	31.~~1~~4		
Climate Zone 4	Flow rate (%GPM)	10	100	~~-3.15~~2.96	~~214.55~~202.43
	Dry bulb T (°F)	65	34.6~~6.4~~		
Climate Zone 5	Flow rate (%GPM)	10	100	-2.2~~6~~9	~~156.62~~158.86
	Dry bulb T (°F)	65	25.~~1~~7		

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

Baseline Technologies

For AHU supply fan: [216]

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

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.

[216] 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, ~~and~~ hot ~~water~~, and condenser water pumps[217]:

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

Equation 49

VFD Technology

For AHU supply fan[218]:

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

Equation 50

For Cooling Tower[219]:

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

Equation 51

For chilled water, ~~and~~ hot water, and condenser pumps[220]:

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

Equation 52

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

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

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

Equation 53

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217 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.

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

219 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.

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

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

Equation 54

Where:

$\%power_i$	=	*Percentage of full load pump power at the i^{th} hour calculated by an equation based on the control type (outlet damper, inlet box damper, inlet guide vane-IGV, or VFD)*[221]
kW_{full}	=	*Motor power demand operating at the fan design 100 percent CFM or pump design 100 percent GPM*
kW_i	=	*Fan or Pump real-time power at the i^{th} hour of a year*
HP	=	*Rated horsepower of the motor*
LF	=	*Load factor—ratio of the operating load to the nameplate rating of the motor—assumed to be 75 percent*
η	=	*Motor efficiency of a standard efficiency Open Drip Proof (ODP) motor operating at 1800 RPM taken from ASHRAE Standard 90.1-2013*
0.746	=	*Constant to convert from HP to kW*

Table 89. HVAC VFDs—Motor Efficiencies for Open Drip Proof Motors at 1,800 RPM[222]

Motor horsepower	Full load efficiency
1	0.855
2	0.865
3	0.895
5	0.895
7.5	0.91
10	0.917
15	0.93
20	0.93
25	0.936
30	0.941
40	0.941
50	0.945
60	0.95

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

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

Motor horsepower	Full load efficiency
75	0.95
100	0.954

~~0.746 = Constant to convert from HP to kW~~

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

Hourly Savings Calculations

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

Equation 55

Where:

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

Table 90. HVAC VFDs—Yearly Motor Operation Hours by Building Type[223,224]

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

223 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.

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

Building type	Weekday schedule	Weekend schedule	Annual motor operation hours
		10am–7pm (Sunday)	
Restaurants	6am–2am	6am–2am	7,592
Warehouse	7am–7pm	closed	4,258
Assembly, worship	9am–11pm	9am–11pm	5,840
Other[225]	7am–7pm	closed	4,258

Average Peak Demand Saved Calculation, excluding interactive effects

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

Equation 56

Where:

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

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

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

Equation 57

Where:

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

Energy Savings are calculated in the following manner:

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

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

Equation 58

Where:

[225] 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.

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[226]

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

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,160~~1,159~~	1,101~~1,101~~	1,071~~1,070~~	1,047~~1,046~~	1,122~~1,121~~
Office—large, medium	724~~724~~	682~~682~~	659~~658~~	641~~640~~	695~~695~~
Office—small	576~~575~~	543~~543~~	522~~522~~	507~~506~~	552~~552~~
Education	633~~632~~	596~~596~~	577~~576~~	561~~560~~	606~~606~~
Convenience store, service, strip Mall	677~~676~~	637~~637~~	614~~613~~	599~~598~~	649~~648~~
Stand-alone retail, supermarket	728~~727~~	685~~685~~	661~~660~~	644~~643~~	698~~698~~
Restaurants	995~~994~~	941~~941~~	913~~912~~	892~~891~~	959~~958~~
Warehouse	548~~548~~	516~~516~~	496~~495~~	481~~480~~	526~~525~~
Assembly, worship	751~~750~~	707~~707~~	684~~683~~	668~~667~~	720~~720~~
Other	548~~548~~	516~~516~~	496~~495~~	481~~480~~	526~~525~~
Summer kW savings (kW per motor HP)					
All building types	0.041~~0.040~~	0.023~~0.023~~	0.020~~0.021~~	0.063~~0.063~~	0.042~~0.042~~

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

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,825~~1,824~~	1,672~~1,672~~	1,598~~1,596~~	1,535~~1,533~~	1,723~~1,722~~

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

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Office—large, medium	1,126~~1,125~~	1,024~~1,024~~	968~~967~~	923~~922~~	1,052~~1,051~~
Office—small	894~~893~~	813~~813~~	766~~765~~	727~~726~~	834~~833~~
Education	984~~983~~	895~~895~~	848~~847~~	808~~807~~	917~~916~~
Convenience store, service, strip mall	1,046~~1,045~~	950~~950~~	897~~896~~	859~~857~~	976~~975~~
Stand-alone retail, supermarket	1,128~~1,126~~	1,025~~1,025~~	967~~966~~	925~~924~~	1,052~~1,051~~
Restaurants	1,556~~1,555~~	1,420~~1,420~~	1,352~~1,351~~	1,298~~1,296~~	1,462~~1,461~~
Warehouse	850~~849~~	773~~773~~	727~~726~~	690~~689~~	794~~793~~
Assembly, worship	1,164~~1,163~~	1,057~~1,057~~	1,003~~1,001~~	961~~960~~	1,086~~1,085~~
Other	850~~849~~	773~~773~~	727~~726~~	690~~689~~	794~~793~~
Summer kW Savings (kW per Motor HP)					
All building types	0.045~~0.044~~	0.026~~0.026~~	0.024~~0.024~~	0.069~~0.069~~	0.047~~0.047~~

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

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	388~~388~~	345~~345~~	325~~324~~	307~~307~~	359~~359~~
Office—large, medium	237~~237~~	209~~209~~	194~~194~~	182~~182~~	217~~216~~
Office—small	188~~188~~	166~~166~~	154~~153~~	143~~143~~	171~~171~~
Education	207~~207~~	183~~183~~	170~~170~~	159~~159~~	189~~189~~
Convenience store, service, strip mall	219~~219~~	194~~194~~	179~~179~~	169~~168~~	200~~200~~
Stand-alone retail, supermarket	237~~237~~	209~~209~~	193~~193~~	182~~182~~	216~~216~~
Restaurants	329~~329~~	292~~292~~	273~~273~~	258~~258~~	303~~303~~
Warehouse	179~~179~~	158~~158~~	146~~145~~	135~~135~~	163~~163~~
Assembly, worship	245~~244~~	216~~216~~	201~~201~~	189~~189~~	223~~223~~
Other	179~~179~~	158~~158~~	146~~145~~	135~~135~~	163~~163~~
Summer kW savings (kW 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
All building types	0.009~~0.010~~	0.009~~0.009~~	0.005~~0.005~~	0.011~~0.012~~	0.013~~0.013~~

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

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	3,302~~3,299~~	3,034~~3,034~~	2,905~~2,902~~	2,794~~2,791~~	3,125~~3,123~~
Office—large, medium	2,038~~2,035~~	1,856~~1,856~~	1,757~~1,755~~	1,677~~1,675~~	1,907~~1,906~~
Office—small	1,617~~1,615~~	1,473~~1,473~~	1,389~~1,387~~	1,320~~1,318~~	1,511~~1,510~~
Education	1,780~~1,778~~	1,622~~1,622~~	1,540~~1,538~~	1,468~~1,465~~	1,663~~1,661~~
Convenience store, service, strip mall	1,893~~1,890~~	1,721~~1,721~~	1,626~~1,624~~	1,557~~1,554~~	1,768~~1,766~~
Stand-alone retail, supermarket	2,040~~2,038~~	1,856~~1,856~~	1,754~~1,752~~	1,679~~1,676~~	1,907~~1,906~~
Restaurants	2,817~~2,814~~	2,577~~2,577~~	2,457~~2,455~~	2,360~~2,357~~	2,651~~2,650~~
Warehouse	1,538~~1,536~~	1,401~~1,401~~	1,317~~1,316~~	1,251~~1,248~~	1,438~~1,437~~
Assembly, worship	2,106~~2,104~~	1,916~~1,916~~	1,819~~1,817~~	1,745~~1,742~~	1,969~~1,967~~
Other	1,538~~1,536~~	1,401~~1,401~~	1,317~~1,316~~	1,251~~1,248~~	1,438~~1,437~~
Summer kW savings (kW per motor HP)					
All building types	0.033~~0.0029~~	0.004~~0.004~~	0.027~~0.026~~	0.088~~0.086~~	0.025~~0.024~~

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

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,124	1,528	1,883	2,070	1,389
Office—large, medium	704	972	1,196	1,314	901
Office—small	558	788	955	1,039	712
Education	610	869	1,054	1,143	784
Convenience store, service, strip mall	663	925	1,142	1,248	858
Stand-alone retail, supermarket	712	986	1,216	1,332	915
Restaurants	966	1,323	1,632	1,792	1,215
Warehouse	534	749	908	986	676
Assembly, worship	733	1,020	1,264	1,380	946
Other	534	749	908	986	676
Summer kW savings (kW per motor HP)					
All building types	0.097	0.041	0.170	0.175	0.216

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

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	778~~777~~	1,154~~1,154~~	1,339~~1,337~~	1,482~~1,479~~	1,050~~1,049~~
Office—large, medium	564~~562~~	775~~775~~	882~~880~~	968~~966~~	735~~734~~
Office—small	456~~455~~	624~~624~~	703~~702~~	768~~766~~	592~~591~~
Education	491~~490~~	683~~683~~	768~~767~~	843~~841~~	647~~646~~
Convenience store, service, strip mall	554~~552~~	747~~747~~	848~~847~~	918~~917~~	706~~705~~
Stand-alone retail, supermarket	587~~585~~	795~~795~~	905~~904~~	982~~980~~	754~~753~~
Restaurants	723~~721~~	1,030~~1,030~~	1,183~~1,181~~	1,297~~1,295~~	960~~959~~
Warehouse	435~~433~~	594~~594~~	670~~669~~	730~~728~~	563~~563~~
Assembly, worship	601~~599~~	818~~818~~	933~~931~~	1,011~~1,009~~	773~~772~~

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
Other	435~~433~~	594~~594~~	670~~669~~	730~~728~~	563~~563~~
Summer kW savings (kW per motor HP)					
All building types	0.0487~~0.046~~	0.0183~~0.018~~	0.0293~~0.029~~	0.0920~~0.091~~	0.0439~~0.043~~

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

Building type	Climate zone				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Energy savings (kWh per motor HP)					
Hospitals, healthcare, nursing home, hotel (common areas), large multifamily (common areas)	1,298~~1,304~~	912~~912~~	721~~723~~	610~~597~~	1,038~~1,044~~
Office—large, medium	774~~777~~	536~~536~~	418~~419~~	338~~332~~	606~~609~~
Office—small	609~~612~~	423~~423~~	328~~329~~	266~~261~~	473~~475~~
Education	677~~679~~	468~~468~~	368~~369~~	301~~295~~	526~~528~~
Convenience store, service, strip mall	706~~708~~	482~~482~~	375~~376~~	306~~301~~	558~~560~~
Stand-alone retail, supermarket	764~~767~~	526~~527~~	410~~411~~	335~~330~~	606~~608~~
Restaurants	1,086~~1,091~~	756~~757~~	598~~600~~	500~~491~~	863~~867~~
Warehouse	579~~581~~	402~~403~~	309~~310~~	251~~246~~	449~~451~~
Assembly, worship	791~~794~~	544~~544~~	426~~427~~	351~~345~~	630~~632~~
Other	579~~581~~	402~~403~~	309~~310~~	251~~246~~	449~~451~~
Winter kW savings (kW per motor HP)					
All building types	0.118~~0.123~~	0.045~~0.045~~	0.045~~0.047~~	0.133~~0.108~~	0.225~~0.229~~

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.[227]

Program Tracking Data and Evaluation Requirements

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

- Building type
- Application type (AHU supply fan, hot water pump, chilled water pump)
- Climate zone
- 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 98. HVAC VFDs—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. Corrected ASHRAE 0.4 percent Dry Bulb Design Temperature references for three climate zone reference cities: DFW, El Paso, and Houston. Updated Valley climate zone reference city to Corpus Christi to be consistent with TRM guidance. Corrected Motor Load Factor to 75 percent.

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

TRM version	Date	Description of change
v4.0	10/10/2016	TRM v4.0 update. Added reference for percent power and corrected signs for variables in Equation 50.
v5.0	10/2017	TRM v5.0 update. Updated deemed energy/demand tables for revised peak demand definition.
v6.0	10/2018	TRM v6.0 update. Added no control device option for constant volume systems. Corrected error in previous kW and kWh deemed savings calculations for Outlet Damper baseline control.
v7.0	10/2019	TRM v7.0 update. Renamed measure to HVAC Variable Frequency Drives. Added methodology for chilled and hot water pumps.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Added motor efficiency default assumptions.
v9.0	10/2021	TRM v9.0 update. Expanded available building types and updated occupancy schedules.
v10.0	10/2022	TRM v10.0 update. Added guidance for rounding down motor size in the baseline efficiency lookup table.
v11.0	10/2021	TRM v11.0 update. Added cooling tower fan and condenser water pump applications. Updated maximum temperatures for linear regression equations to correspond with ASHRAE design conditions. Aligned building type names across all commercial measures.

2.2.8 Condenser Air Evaporative Pre-Cooling Measure Overview

TRM Measure ID: NR-HV-EP

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 100 through Table 104

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Applicable evaporative pre-cooling product types include:

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

Eligibility Criteria

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

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

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

Baseline Condition

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

High-Efficiency Condition

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

Table 99. Evaporative Pre-Cooling—Average Weather During Peak Conditions[228]

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 60

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

Equation 61

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

Where:

Cap_C	=	*Rated equipment cooling capacity of the existing equipment at AHRI-standard conditions [tons]; 1 ton = 12,000 Btuh*
η_C	=	*Cooling efficiency of existing equipment [kW/ton]*
		Note: For DX systems, use EER for kW savings calculations and SEER/IEER for kWh savings calculations. For air-cooled chillers, use full-load efficiency (kW/ton) for kW savings calculations and part-load efficiency (IPLV) for kWh savings calculations. In the cases where the full-load efficiency is provided in terms of EER or SEER/IEER rather than kW/ton and IPLV, a unit conversion to kW/ton needs to be performed using the following conversion:

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

Equation 62

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

Deemed Energy and Demand Savings Tables

Deemed peak demand reduction factor (DRF) and equivalent full-load hour reduction ($EFLH_{reduction}$) values are presented by building type and climate zone. A description of the building types that are used for HVAC systems is presented in Table 34. These building types are derived from the EIA CBECS study.[229]

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

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

description of the actual building type, the primary business activity, the business hours, and the HVAC schedule must be collected for the project site and stored in the utility tracking data system.

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

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

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		~~DR~~CF	$EFLH_{red}$	~~DR~~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	~~Hospital~~Inpatient	0.21	160	0.18	151
	Outpatient ~~healthcare~~	0.17	145	-	-
Large multifamily	Midrise apartment	0.18	113	0.10	59
Lodging	Large hotel	0.13	111	0.15	165
	Nursing home	0.18	115	0.10	60
	Small hotel/motel	0.13	104	-	-
Mercantile	Stand-alone retail	0.19	108	0.14	74
	Strip mall	0.21	121	-	-
Office	Large office	0.25	206	0.18	119
	Medium office	0.19	75	-	-
	Small office	0.20	111	-	-
Public assembly	Public assembly	0.20	112	0.13	93
Religious worship	Religious worship	0.19	65	0.14	45

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

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

Building type	Principal building activity	Direct expansion		Air-cooled chiller	
		DRCF	$EFLH_{red}$	DRCF	$EFLH_{red}$
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	~~Hospital~~Inpatient	0.24	230	0.22	216
	Outpatient ~~healthcare~~	0.19	174	-	-
Large multifamily	Midrise apartment	0.16	230	0.15	120
Lodging	Large hotel	0.15	137	0.18	212
	Nursing home	0.16	234	0.15	122
	Small hotel/motel	0.15	133	-	-
Mercantile	Stand-alone retail	0.24	158	0.19	120
	Strip mall	0.23	156	-	-
Office	Large office	0.26	220	0.23	231
	Medium office	0.20	102	-	-
	Small office	0.22	156	-	-
Public assembly	Public assembly	0.24	161	0.12	108
Religious worship	Religious worship	0.24	95	0.19	72
Service	Service: Excluding food	0.23	150	-	-
Warehouse	Warehouse	0.20	93	-	-
Other	Other	0.15	78	0.12	72

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

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

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

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

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

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

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

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

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

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

The estimated useful life (EUL) for an evaporative pre-cooling system is 10 years, consistent with the typical manufacturer warranty for evaporative pre-cooling equipment.[230]

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

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

Document Revision History

Table 105. Evaporative Pre-Cooling—Revision History

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

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

2.2.9 High-Volume Low-Speed Fans Measure Overview

TRM Measure ID: NR-HV-HF

Market Sector: Commercial

Measure Category: HVAC

Applicable Business Types: Agriculture

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

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

Eligibility Criteria

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

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

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

Baseline Condition

The baseline condition is an installation of conventional fans.

Retrofit (Early Retirement)

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

Replace on Burnout/New Construction

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

High-Efficiency Condition

HVLS fans with diameters of eight to 24 feet typically use 1 hp to 2 hp motors per fan and move between 50,000 CFM and 150,000 or more CFM.[231] To be eligible for this measure, HVLS fans shall be a minimum of 8 feet in diameter and move more cubic feet of air per watt than conventional circulating fans. The fan should be installed in a horizontal orientation and have the ability to operate at different speeds.

Energy and Demand Savings Methodology

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

Savings Algorithms and Input Variables

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

Equation 63

[231] 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.

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

Equation 64

Where:

W_{base} = *Power input required to move replaced fans at rated speed*

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

Hours = *Hours of operation in the project application, as described below*

CF_S = *Summer peak coincidence factor = 1.0, as fans are always operating in summer peak conditions*

1,000 = *Constant to convert from W to kW*

Retrofit (Early Retirement)

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

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

Equation 65

Where:

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

η_{base} = *Efficacy of replaced fans (CFM/watt)*

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

Replace-on-Burnout/New Construction

For replace-on-burnout or new construction projects, base case power requirements are estimated for conventional fans producing an equivalent/comparable airflow (CFM) as that of the HVLS fan(s) being installed. The efficiency of the baseline conventional fans shall be 22 CFM/watt.[232]

[232] 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, 230V circulating fans 48” diameter and larger. Available at http://www.bess.illinois.edu/currentc.asp.

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

Equation 66

Hours of Operation

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

Table 106. HVLS Fans—Hours of Circulating Fan Operation by Barn Type[233]

Climate zone	Hours
Climate Zone 1: Amarillo	2,215
Climate Zone 2: Dallas	3,969
Climate Zone 3: Houston	4,750
Climate Zone 4: Corpus Christi	5,375
Climate Zone 5: El Paso	3,034

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[234] suggests motors should last approximately 35,000 hours. The average annual hours of operation in dairy farms for the Texas TRM zones is about 3,870 hours. Accordingly, the EUL for HVLS fans in Texas is estimated to be 9 years.

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

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

All Projects:

- Barn type (animal)
- Climate zone
- Decision/action type: ROB, NC, or ER
- HVLS fan(s): diameter, rated HP, rated CFM, count
- **For early retirement only:** replaced fans: count, diameter, rated HP, rated CFM, rated CFM/watt

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 107. 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.

2.2.10 Small Commercial Evaporative Cooling Measure Overview

TRM Measure ID: NR-HV-EC

Market Sector: Small Commercial

Measure Category: HVAC

Applicable Building Types: See Table 34 through Table 40

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 108. Evaporative Cooling—NC/ROB Baseline Efficiency Levels for DX AC[235]

System type	Capacity (tons)	Heating section type	Baseline efficiencies	Source[236]
Packaged air conditioner	< 5.4	All	11.8 EER[237] 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 67

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

Equation 68

Where:

Cap_C	=	*Refrigerated cooling load for equivalent evaporative cooling system, default = 36,000 Btuh[238]; 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.

~~DF~~ CF_S	=	*Summer peak ~~demand~~ coincidence factor (see Table 40)*
$EFLH_C$	=	*Cooling equivalent full-load hours [hours] (see Table 40)*
CRF	=	*Consumption reduction factor[239] = 75%*

[235] IECC 2015 Table C403.2.3(1) and C403.2.3(2).
[236] 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.
[237] IECC 2015 Table C403.2.3(1) and C403.2.3(2).
[238] New Mexico TRM assumption based on DX AC cooling load for Las Cruces climate zone.
[239] Department of Energy, https://www.energy.gov/energysaver/evaporative-coolers.

Deemed Energy and Demand Savings Tables

Deemed peak ~~demand~~ coincidence factor (~~DF~~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 109. Evaporative Cooling—~~DF~~CF and EFLH Values for Climate Zone 5: El Paso

Building type	Principal building activity	DX AC	
		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	~~Hospital~~Inpatient	0.81	2,555
	Outpatient ~~healthcare~~	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 ~~stand-alone~~ 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
Public assembly	Public assembly	0.91	1,339
Religious worship	Religious worship	0.63	478

Building type	Principal building activity	DX AC	
		s	$EFLH_C$
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.[240]

Program Tracking Data and Evaluation Requirements

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

- Decision/action type: ROB 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
- **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

[240] DEER READI (Remote Ex-Ante Database Interface). 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 110. 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.

2.2.11 Small Commercial Smart Thermostats Measure Overview

TRM Measure ID: NR-HV-ST

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 34 through Table 40

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~~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.[241]

[241] 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)[242] 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 69

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

Equation 70

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

Equation 71

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

Equation 72

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

Equation 73

Where:

$CAP_{C/H}$ = *Controlled-HVAC rated cooling/heating capacity (Btuh)*[243]

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

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

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

Note: 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.[244]

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

C~~D~~$F_{S/W}$ = *Summer/winter ~~demand factor~~coincidence factor (see Table 36 through Table 40)*

CRF = *Cooling reduction factor = 10%*[245]

HRF = *Heating reduction factor = 8%*[246]

BAF = *Baseline adjustment factor (1.0 for manual baseline, 0.6 for programmable and new construction baselines, and 0.8 for unknown baseline)*[247,248]

Deemed Energy and Demand Savings Tables

Deemed peak ~~demand factor~~coincidence factor (~~DF~~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.

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

245 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.

246 Ibid.

247 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.

248 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.[249]

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
- Decision/action type (retrofit, new construction)
- Baseline thermostat type (manual, programmable, unknown)
- Manufacturer
- Model number
- Quantity of newly installed thermostats
- Building type
- HVAC equipment age (retrofit only)
- Cooling type (split AC, packaged AC, split HP, packaged HP)
- Heating type (gas, electric resistance, HP)
- Cooling capacity (~~btu~~Btuh)
- Heating capacity (~~btu~~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.

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

Document Revision History

Table 111. 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.

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.[250] Moving forward, installed roofing products will still be required to demonstrate compliance with the previous ENERGY STAR specification.[251] 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[252]

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

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

252 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) [253,254] and be listed on the CRRC Rated Roof Products Directory.[255] This is consistent with the former ENERGY STAR test criteria's allowances for products already participating in the CRRC Product Rating program[256] 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.[257]

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 112. 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

[253] 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.
[254] CRRC Roof Rating program. https://coolroofs.org/programs/roof-rating-program.
[255] CRRC Rated Roof Products Directory. https://coolroofs.org/directory/roof.
[256] CRRC Rated Products Directory: https://coolroofs.org/directory.
[257] 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 113.

Table 113. Cool Roofs—ENERGY STAR Specification[258]

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 ~~demand factor~~coincidence factors and EFLH and can be found from Table 115 through Table 119. The savings represent the difference of the modeled energy use of the baseline condition and the high-efficiency condition divided by the square foot of the roof area. The demand savings are calculated following the method described in TRM Volume 1.

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

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

Equation 74

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

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

Equation 75

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

Equation 76

Where:

Roof Area = *Total area of ENERGY STAR roof (sq. ft.)*

ESF = *Energy savings factor from Table 115 through Table 119 by building type, pre-/post-insulation levels, and heating/cooling system*

~~PSDF~~CF_S = *Peak summer ~~demand factor~~coincidence factor from Table 115 through Table 119 by building type, pre-/post-insulation levels, and heating/cooling system*

~~PWDF~~CF_W = *Peak ~~W~~winter ~~Demand Savings F~~coincidence factor from Table 115 through Table 119 by building type, pre/post insulation levels, and heating/cooling system*

If the insulation levels are unknown, use the mapping in Table 114 to estimate the R-value based on the construction year.

Table 114. Cool Roofs—Estimated R-Value Based on Construction Year

Construction Year	Estimated R-value[259]
Before 2011	R ≤ 13
Between 2011 - 2016	13 < R ≤ 20
After 2016	20 < R

Table 115. Cool Roofs—Savings Coefficients for Climate Zone 1: Amarillo

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
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

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

Building type	Pre-R-value	Post R-value	ESF		
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
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
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
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

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
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 116. Cool Roofs—Savings Coefficients for Climate Zone 2: Dallas

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
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
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
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

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
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
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
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 117. Cool Roofs—Savings Coefficients for Climate Zone 3: Houston

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
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		
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
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
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
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

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
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 118. Cool Roofs—Savings Coefficients for Climate Zone 4: Corpus Christi

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
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
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
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

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
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
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
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 119. Cool Roofs—Savings Coefficients for Climate Zone 5: El Paso

Building type	Pre-R-value	Post R-value	ESF	CF_S	CF_W
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		
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
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
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
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

Building type	Pre-R-value	Post R-value	ESF		
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.[260]

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 location
- Building type
- Total and treated roofing square footage (over conditioned space)
- Roof slope
- Existing roof insulation R-value, or year of building construction
- New roof insulation R-value, if adding insulation
- New roofing initial solar reflectance
- New roofing three-year solar reflectance
- New roofing rated life

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

- 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 120. Cool Roofs—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Clarified that reflectance is three years basis. Rounded off values, too many insignificant digits.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. Clarified eligibility criteria, baseline condition, and high-efficiency condition. Added R-values for more materials. Added new high-performance roof calculator for use in determining ENERGY STAR® roof savings.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. Changed savings methodology from algorithms to simulation models. Deemed savings are presented per square foot by building type and climate zone.
v7.0	10/2019	TRM v7.0 update. Minor error updates to Savings Factor Table for greater than and less than symbols. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Removed ENERGY STAR® qualification requirement and defers to meeting criteria.
v9.0	10/2021	TRM v9.0 update. Added building type to tracking data requirements. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. Changed eligibility criteria from strictly ENERGY STAR to CRRC certification.
v11.0	10/2023	TRM v11.0 update. No revision.

2.3.2 Window Treatments Measure Overview

TRM Measure ID: NR-BE-WT

Market Sector: Commercial

Measure Category: Building envelope

Applicable Building Types: All commercial building types

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This section presents the deemed savings methodology for the installation of window films and 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 121). This methodology may be adapted for windows with existing shading devices on an individual project basis with prior evaluator approval of baseline solar heat gain coefficient (SHGC).

Existing windows must have no solar films/screens, interior shades, or exterior awnings or overhangs, and must be installed in buildings that are mechanically cooled (direct expansion (or chilled water). While highly reflective louvered or Venetian blinds can help reduce solar heat gain, they must be completely lowered and closed to be as effective as more permanent shading devices.[261] They also do not prevent heat from entering the envelope in the space between the blinds and window. Therefore, windows with existing interior louvered or Venetian blinds are not excluded from using this measure.

~~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).~~

261 "Energy Efficient Window Coverings," U.S. 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 122.

High-Efficiency Condition

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

Energy and Demand Savings Methodology

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

Savings Algorithms and Input Variables

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

Equation 77

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

Equation 78

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

Equation 79

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

Equation 80

Where:

Demand Savings$_o$	=	*Peak demand savings per window orientation*
Energy Savings$_o$	=	*Energy savings per window orientation*
$A_{film,o}$	=	*Area of window film applied to orientation [ft^2]*
$SHGF_o$	=	*Peak solar heat gain factor for orientation of interest [Btu/hr-ft^2-year] (see Table 121)*

SHG_o	=	*Solar heat gain for orientation of interest [Btu/ft2-year] (see Table 121)*
$SHGC_{pre}$	=	*Solar heat gain coefficient for existing glass with no interior-shading device (see Table 122)*
$SHGC_{post}$	=	*Solar heat gain coefficient for new film/interior-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.[262]

COP	=	*Cooling equipment coefficient of performance (COP) based on Table 123 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 121. Windows Treatments—Solar Heat Gain Factors[263]

Orientation[264]	Solar heat gain (SHG) [Btu/ft²-year]	Peak hour solar heat gain (SHGF) [Btu/hr-ft²-year]				
		Climate Zone 1: Amarillo[265]	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

[262] 2001 ASHRAE Handbook: Fundamentals, p. 30–39.

[263] 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.

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

[265] 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 122. Windows Treatments—Recommended Clear Glass $SHGC_{pre}$ by Window Thickness[266]

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[267]	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 123. Windows Treatments—Recommended COP by HVAC System Type[268]

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.

[266] 2021~~17~~ ASHRAE Handbook: Fundamentals, Chapter 15 Fenestration, Table 10 Solar Heat Gain Coefficient (SHGC). https://www.ashrae.org/technical-resources/ashrae-handbook/ashrae-handbook-online.

[267] 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.

[268] Based on review applicable codes, including IECC 2000, 2009, and 2015.

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.[269]

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:

- 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 124. 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.

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

TRM version	Date	Description of change
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.
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 Ventian blinds. Added reduced baseline SHGC values for windows with louvered blinds.

2.3.3 Entrance and Exit Door Air Infiltration Measure Overview

TRM Measure ID: NR-BE-DI

Market Sector: Commercial

Measure Category: Building envelope

Applicable Building Types: All commercial building types

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

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

Energy and Demand Savings Methodology

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

Derivation of Pre-Retrofit Air Infiltration Rate

The pre-retrofit air infiltration rate for each crack width is calculated by applying the methodologies presented in Chapter 5 of the ASHRAE Cooling and Heating Load Calculation Manual (CHLCM).[270] Building type characteristics for a typical commercial building were found in the DOE study PNNL-20026,[271] 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 81

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 82

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 83

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

[271] 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 84

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

Equation 85

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

Equation 86

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

Equation 87

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 88

Where:

T_{design} = *Daytime and nighttime design temperature [°F] (see Table 126)*

$T_{avg\ outside\ ambient}$ = *Average outside ambient temperature, specified by month [°F] (see Table 125)*

Table 125. Air Infiltration—Average Monthly Ambient Temperatures (°F)[272]

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 126. 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[273]	78
Nighttime heating design temperature[274]	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 89

272 TMY3 climate data.
273 Assuming four-degree setback.
274 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 90

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

Equation 91

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 92

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

Equation 93

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

Equation 94

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 95

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 96

Where:

CFM_{pre} = *Calculated pre-retrofit air infiltration (cubic feet per minute)*

$CFM_{reduction}$	=	*59%*[275] *x TDF*
TDF	=	*Technical degradation factor = 85%*[276]
1.08	=	*Sensible heat equation conversion*[277]
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 linear foot of installed weather stripping or door sweep are specified below based on climate zone and existing door gap width. The length measurement should be initially measured to the nearest ¼ inch and converted to linear feet rounded to hundredths (0.02) including any segments that are not sealed due to corners, hinges, handles, or other obstructions. The width of the door gap should be rounded to nearest gap width in inches in Table 127 through Table 132. 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.

Table 127. Air Infiltration—Cooling Energy Savings/Lin. Ft. of Weather Stripping/Door Sweep

Climate zone	Gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	1.90	3.83	7.60	11.42
Climate Zone 2: Dallas	3.90	7.88	15.65	23.49
Climate Zone 3: Houston	3.01	6.09	12.09	18.14
Climate Zone 4: Corpus Christi	5.00	10.08	20.03	30.06
Climate Zone 5: El Paso	2.81	5.69	11.28	16.93

275 CLEAResult, "Commercial Door Air Infiltration Memo". March 18, 2015. Average reduction in Arkansas based on test results from the CLEAResult Brush Weather Stripping Testing Method and Results (59% infiltration reduction).
276 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.
277 2013 ASHRAE Handbook of Fundamentals; Equation 33, p. 16.11.

Table 128. Air Infiltration—ER Heating Energy Savings/Lin. Ft. of Weather Stripping/Door Sweep

Climate zone	Gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	101.26	204.24	405.72	609.05
Climate Zone 2: Dallas	48.90	98.82	196.15	294.44
Climate Zone 3: Houston	27.18	55.06	109.19	163.91
Climate Zone 4: Corpus Christi	22.78	46.02	91.35	137.13
Climate Zone 5: El Paso	45.59	92.23	182.99	274.69

Table 129. Air Infiltration—HP Heating Energy Savings/Lin. Ft. of Weather Stripping/Door Sweep

Climate zone	Gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	30.69	61.89	122.94	184.56
Climate Zone 2: Dallas	14.82	29.95	59.44	89.22
Climate Zone 3: Houston	8.24	16.69	33.09	49.67
Climate Zone 4: Corpus Christi	6.90	13.94	27.68	41.56
Climate Zone 5: El Paso	13.81	27.95	55.45	83.24

Table 130. Air Infiltration—Summer Demand Savings/Lin. Ft. of Weather Stripping/Door Sweep

Climate zone	Gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	0.0053	0.0105	0.0210	0.0315
Climate Zone 2: Dallas	0.0044	0.0090	0.0179	0.0269
Climate Zone 3: Houston	0.0043	0.0087	0.0173	0.0259
Climate Zone 4: Corpus Christi	0.0041	0.0082	0.0164	0.0246
Climate Zone 5: El Paso	0.0041	0.0083	0.0165	0.0247

Table 131. Air Infiltration—ER Winter Demand Savings/Lin. Ft. of Weather Stripping/Door Sweep

Climate zone	Gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	0.0268	0.0541	0.1074	0.1612
Climate Zone 2: Dallas	0.0412	0.0828	0.1648	0.2474
Climate Zone 3: Houston	0.0211	0.0425	0.0844	0.1267
Climate Zone 4: Corpus Christi	0.0190	0.0383	0.0762	0.1144
Climate Zone 5: El Paso	0.0099	0.0202	0.0400	0.0602

Table 132. Air Infiltration—HP Winter Demand Savings/Lin. Ft. of Weather Stripping/Door Sweep

Climate zone	Gap width (inches)			
	1/8	1/4	1/2	3/4
Climate Zone 1: Amarillo	0.0138	0.0277	0.0550	0.0825
Climate Zone 2: Dallas	0.0178	0.0357	0.0710	0.1066
Climate Zone 3: Houston	0.0102	0.0207	0.0410	0.0615
Climate Zone 4: Corpus Christi	0.0087	0.0175	0.0348	0.0523
Climate Zone 5: El Paso	0.0049	0.0099	0.0197	0.0296

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 11 years, as specified in the California Database of Energy Efficiency Resources (DEER) Remote Ex-Ante Database Interface (READI) tool for EUL ID BS-Wthr.[278] This measure life is consistent with the residential air infiltration measure in the Texas TRM.

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.

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

- Climate zone
- Existing gap width (1/8”, 1/4", 1/2", or 3/4")
- Installed measure (weather stripping or door sweep)
- Linear feet (to nearest 0.02 feet = 1/4”) of installed weather stripping or door sweep

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 133. 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.
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.

2.4 NONRESIDENTIAL: FOOD SERVICE EQUIPMENT

2.4.1 ENERGY STAR® Combination Ovens Measure Overview

TRM Measure ID: NR-FS-CO

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Business Types: See eligibility criteria

Fuels Affected: Electricity

Decision/Action Type: Retrofit, 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~~5~~ and ≤ 40~~20~~.[279, 280]

- 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.

[279] 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. ~~https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%203.0%20Commercial%20Ovens%20Final%20Specification.pdf.~~

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

- 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.

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.[281]

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 134.

[281] CEE Commercial Kitchens Initiative's overview of the Food Service Industry. https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf.

Table 134. Combination Ovens—ENERGY STAR Specification[282]

Operation	Idle rate (kW)[283]	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

Furthermore, pan capacity[284] 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 97

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

Equation 98

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

Equation 99

kWh_{ph}, kWh_{conv} and kWh_{st} are each calculated the same for both the baseline and ENERGY STAR cases, as shown in Equation 100, except they require their respective input assumptions relative to preheat, cooking and idle operation in convection and steam modes as seen in Table 135.

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

Equation 100

282 ENERGY STAR® Commercial Ovens Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ovens/key_product_criteria.

283 P = Pan capacity.

284 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.

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

Equation 101

Where:

kWh_{base}	=	*Baseline annual energy consumption [kWh]*
kWh_{ES}	=	*ENERGY STAR annual energy consumption [kWh]*
E_{ph}	=	*Preheat energy [Wh/BTU]*
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/day]*
η_{cook}	=	*Cooking energy efficiency [%]*
PC	=	*Production capacity per pan [lb/hr]*
t_{on}	=	*Equipment operating hours per day [hr/day]*
t_{days}	=	*Facility operating days per year [days/year]*
1,000	=	*Constant to convert from W to kW*
CF	=	*Peak coincidence factor*

Table 135. Combination Ovens—Savings Calculation Input Assumptions[285]

Parameter		Convection mode		Steam mode	
		Baseline	ENERGY STAR	Baseline	ENERGY STAR
E_{ph}	P < 15	3,000		1,500	
	P ≥ 15	3,750		2,000	
W_{food}	P < 15	200			
	P ≥ 15	250			
E_{food}		73.2		30.8	
η_{cook}	3 ≥ P < 5	70%	70%	49%	51%
	P ≥ 5	72%	78%	49%	55%
E_{idle}	3 ≥ P < 5	1,320	(0.05P + 0.55) x 1,000	5,260	0.60P x 1,000

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

Parameter		Convection mode		Steam mode	
		Baseline	ENERGY STAR	Baseline	ENERGY STAR
	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[286]	P < 15	79	119	126	177
	P ≥ 15	166	201	295	349
t_{on}		12			
t_{days}		365			
CF[287]		0.90			

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 133 are based on the input assumptions from Table 135.

Table 136. Combination Ovens—Energy and Peak Demand Savings[288]

Pan capacity	kWh Savings	kW Savings
3	1,080	0.125
4	843	0.074
5	4,338	0.789
6	4,999	0.923
7	5,677	1.060
8	6,370	1.200
9	7,079	1.343
10	7,804	1.490
11	8,545	1.640
12	9,303	1.793
13	10,076	1.950
14	10,865	2.110
15	11,670	2.273

Pan capacity	kWh Savings	kW Savings
22	17,755	3.507
23	18,689	3.696
24	19,638	3.889
25	20,603	4.085
26	21,585	4.284
27	22,582	4.487
28	23,595	4.693
29	24,625	4.902
30	25,670	5.114
31	26,732	5.330
32	27,809	5.549
33	28,902	5.771
34	30,012	5.997

286 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.

287 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.

288 ENERGY STAR® Savings Calculator for ENERGY STAR® Qualified Commercial Kitchen Equipment Calculator. http://www.energystar.gov/buildings/sites/default/uploads/files/Commercial_kitchen_equipment_calculator.xlsx.

Pan capacity	kWh Savings	kW Savings
16	12,492	2.439
17	13,329	2.609
18	14,182	2.782
19	15,051	2.958
20	15,937	3.138
21	16,838	3.320

Pan capacity	kWh Savings	kW Savings
35	31,137	6.226
36	32,279	6.458
37	33,436	6.693
38	34,609	6.932
39	35,799	7.174
40	37,004	7.420

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.[289]

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

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.

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

Document Revision History

Table 137. 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.

2.4.2 ENERGY STAR® Electric Convection Ovens Measure Overview

TRM Measure ID: NR-FS-CV

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Building Types: See eligibility criteria

Fuels Affected: Electricity

Decision/Action Type: Retrofit, 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:[290, 291]

- 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.

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290 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.

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

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.[292]

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
- ~~Conventional or standard ovens, conveyor, slow cook-and-hold, deck, range, rapid cook, and rotisserie~~

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 138.

Table 138. Convection Ovens—ENERGY STAR Specification[293]

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

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

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

Energy and Demand Savings Methodology

Savings Calculations and Input Variables

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

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

Equation 102

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

Equation 103

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

Equation 104

kWh_{ph}, kWh_{cook}, and kWh_{idle} are each calculated the same for both the baseline and ENERGY STAR® cases, as shown in Equation 105, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 139.

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

Equation 105

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

Equation 106

Where:

kWh_{base}	=	*Baseline annual energy consumption [kWh]*
kWh_{ES}	=	*ENERGY STAR annual energy consumption [kWh]*
E_{ph}	=	*Preheat energy [Wh/BTU]*
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/day]*
η_{cook}	=	*Cooking energy efficiency [%]*

PC = *Production capacity [lb/hr]*

t_{on} = *Operating hours per day [hr/day]*

t_{days} = *Facility operating days per year [days/year]*

1,000 = *Constant to convert from W to kW*

CF = *Coincidence factor*

Table 139. Convection Ovens—Savings Calculation Input Assumptions[294]

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}	100					
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
t_{on}	12					
t_{days}	365					
CF[295]	0.90					

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 137 are based on the input assumptions from Table 139.

Table 140. Convection Ovens—Energy and Peak Demand Savings

Oven size	kWh Savings	kW Savings
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.

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

295 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.

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.[296]

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

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 141. 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.

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

TRM version	Date	Description of change
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.

2.4.3 ENERGY STAR® Dishwashers Measure Overview

TRM Measure ID: NR-FS-DW

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Building Types: See eligibility criteria

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 commercial dishwashers. On average, commercial dishwashers that have earned ENERGY STAR certification are 25 percent more energy-efficient and 25 percent more water-efficient than standard models. The energy savings associated with ENERGY STAR commercial dishwashers are primarily due to reduced water use and reduced need to heat water. A commercial kitchen may have external booster water heaters, or booster water heaters may be internal to specific equipment. Both primary and booster water heaters may be either gas or electric; therefore, dishwasher programs need to ensure the savings calculations used are appropriate for the water heating equipment installed at the participating customer's facility. The energy and demand savings are determined on a per-dishwasher basis.

Eligibility Criteria

Eligible units must be compliant with the current ENERGY STAR specification and fall under one of the following categories.[297, 298] These categories are described in Table 142:

- Under counter dishwasher
- Stationary rack, single tank, door type dishwasher
- Single tank conveyor dishwasher
- Multiple tank conveyor dishwasher
- Pot, pan, and utensil

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[297] ENERGY STAR® Program Requirements Product Specifications for Commercial Dishwashers. Eligibility Criteria v3.0. https://www.energystar.gov/products/commercial_dishwashers/partners.

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

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate foodservice operations, healthcare, hospitality, and supermarkets.[299]

Dishwashers intended for use in residential or laboratory applications are not eligible for ENERGY STAR® under this product specification. Residential equipment is eligible for installation in commercial applications. In this scenario, refer to the residential savings methodology described in Volume 2. Steam, gas, and other non-electric models also do not qualify.

Additionally, though single- and multiple-tank flight-type conveyor dishwashing machines (where the dishes are loaded directly on the conveyor rather than transported within a rack—also referred to as a rackless conveyor) are eligible as per the version 3.0 specification, they are considered ineligible for this measure, since default values are not available for flight-type dishwashers in the ENERGY STAR Commercial Kitchen Equipment Calculator.

Table 142. Dishwashers—ENERGY STAR Equipment Type Descriptions

Equipment type	Equipment description
Under-counter dishwasher	A machine with an overall height of 38" or less, in which a rack of dishes remains stationary within the machine while being subjected to sequential wash and rinse sprays and is designed to be installed under food preparation workspaces. Under-counter dishwashers can be either chemical or hot-water sanitizing, with an internal booster heater for the latter. For purposes of this specification, only those machines designed for wash cycles of ten minutes or less can qualify for ENERGY STAR®.
Stationary-rack, single-tank, door-type dishwasher	A machine in which a rack of dishes remains stationary within the machine while subjected to sequential wash and rinse sprays. This definition also applies to machines in which the rack revolves on an axis during the wash and rinse cycles. Subcategories of stationary door type machines include single- and multiple-wash tank, double rack, pot, pan and utensil washers, chemical dump type, and hooded wash compartment ("hood type"). Stationary-rack, single-tank, door-type models are covered by this specification and can be either chemical or hot-water sanitizing, with an internal or external booster heater for the latter.
Single-tank conveyor dishwasher	A washing machine that employs a conveyor or similar mechanism to carry dishes through a series of wash and rinse sprays within the machine. Specifically, a single-tank conveyor machine has a tank for wash water followed by a final sanitizing rinse and does not have a pumped rinse tank. This type of machine may include a pre-washing section before the washing section. Single-tank conveyor dishwashers can either be chemical or hot-water sanitizing, with an internal or external booster heater for the latter.

[299] CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf

Equipment type	Equipment description
Multiple-tank conveyor dishwasher	A conveyor-type machine that has one or more tanks for wash water and one or more tanks for pumped rinse water, followed by a final sanitizing rinse. This type of machine may include one or more pre-washing sections before the washing section. Multiple-tank conveyor dishwashers can be either chemical or hot-water sanitizing, with an internal or external hot-water-booster heater for the latter.
Pot, pan, and utensil	A stationary-rack, door-type machine designed to clean and sanitize pots, pans, and kitchen utensils.

Baseline Condition

Baseline equipment is either a low-temperature[300] or high-temperature[301] machine as defined by Table 142, which is not used in a residential or laboratory setting. For low-temperature units, the DHW is assumed to be electrically heated. For high-temperature units, the DHW can either be heated by electric or natural gas methods. For units heated with natural gas, the unit shall have an electric booster heater attached to it.

High-Efficiency Condition

Qualifying equipment must be compliant with the current ENERGY STAR v3.0 specification, effective July 27, 2021. High-temperature equipment sanitizes using hot water and requires a booster heater. Low-temperature equipment uses chemical sanitization and does not require a booster heater. Qualified products must be less than or equal to the maximum idle energy rate and water consumption requirements from Table 143.

Table 143. Dishwashers—ENERGY STAR Specification[302]

Machine type	Low-temperature efficiency requirements		High-temperature efficiency requirements	
	Idle energy rate (kW)	Water consumption (gal/rack)	Idle energy rate (kW)	Water consumption (gal/rack)
Under counter (UC)	≤ 0.25	≤ 1.19	≤ 0.30	≤ 0.86
Stationary single-tank door (SSTD)	≤ 0.30	≤ 1.18	≤ 0.55	≤ 0.89
Single-tank conveyor (STC)	≤ 0.85	≤ 0.79	≤ 1.20	≤ 0.70
Multiple-tank conveyor (MTC)	≤ 1.00	≤ 0.54	≤ 1.85	≤ 0.54
Pot, pan, and utensil (PP&U)	–	–	≤ 0.90	≤ 0.58[303]

300 Low temperature machines apply a chemical sanitizing solution to the surface of the dishes to achieve sanitation.

301 High temperature machines apply only hot water to the surface of the dishes to achieve sanitation.

302 ENERGY STAR® Commercial Dishwashers Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_dishwashers/key_product_criteria.

303 Water consumption for pot, pan, and utensil is specified in gallons-per-square-foot rather than gallons-per-rack.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed savings values are calculated using the following algorithms:

$$Energy\ Savings\ [\Delta kWh] = (V_{base} - V_{ES}) \times \left(\frac{\Delta T_{DHW} + \Delta T_{boost}}{\eta_{DHW}}\right) \times \rho_{water} \times C_p \times \frac{1\ kWh}{3{,}412\ Btu} + (E_{idle,base} - E_{idle,ES}) \times \left(t_{on} - N_{racks} \times \frac{t_{wash}}{60}\right) \times t_{days}$$

Equation 107

$$V_{base} = t_{days} \times N_{racks} \times V_{rack,base}$$

Equation 108

$$V_{ES} = t_{days} \times N_{racks} \times V_{rack,ES}$$

Equation 109

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

Equation 110

Where:

ρ_{water}	=	*Density of water [lb/gallon]*
C_p	=	*Specific heat of water [Btu/lb °F]*
ΔT_{DHW}	=	*Inlet water temperature increase for building water heater [°F]*
ΔT_{boost}	=	*Inlet water temperature for booster water heater [°F]*
η_{DHW}	=	*Building electric water heater and booster heater efficiency [%]*
N_{racks}	=	*Number of racks washed per days*
V_{base}	=	*Baseline annual volume of water consumption [gal/year]*
V_{ES}	=	*ENERGY STAR annual volume of water consumption [gal/year]*
$V_{rack,base}$	=	*Baseline per rack volume of water consumption [gal/rack]*
$V_{rack,ES}$	=	*ENERGY STAR per rack volume of water consumption [gal/rack]*
$E_{Idle,base}$	=	*Baseline idle energy rate [kW]*
$E_{Idle,ES}$	=	*ENERGY STAR idle energy rate [kW]*
t_{wash}	=	*Wash time per rack [min]*
t_{on}	=	*Equipment operating hours per day [hr/day]*
t_{days}	=	*Facility operating days per year [days/year]*
3,412	=	*Constant to convert from Btu to kWh*

60 = *Constant to convert from minutes to hours*

CF = *Peak coincidence factor*

Table 144. Dishwashers—Savings Calculation Input Assumptions[304]

Inputs	UC	SSTD	STC	MTC	PP&U
ρ_{water}	61.4 ÷ 7.48 = 8.2				
C_p	1.0				
ΔT_{DHW}	Gas water heaters: 0ºF Electric water heaters: 70 ºF				
ΔT_{boost}	Gas booster heaters: 0 ºF Electric booster heaters: 40 ºF				
η_{DHW}	98%				
t_{on}	18				
t_{days}	365				
CF[305]	0.90				
Low-temperature units					
N_{racks}	75	280	400	600	–
$V_{rack,base}$	1.73	2.10	1.31	1.04	–
$V_{rack,ES}$	1.19	1.18	0.79	0.54	–
$E_{idle,base}$	0.50	0.60	1.60	2.00	–
$E_{idle,ES}$	0.25	0.30	0.85	1.00	–
t_{wash}	2.0	1.5	0.3	0.3	–
High-temperature units					
N_{racks}	75	280	400	600	280
$V_{rack,base}$	1.09	1.29	0.87	0.97	0.70
$V_{rack,ES}$	0.86	0.89	0.70	0.54	0.58
$E_{idle,base}$	0.76	0.87	1.93	2.59	1.20
$E_{idle,ES}$	0.30	0.55	1.20	1.85	0.90
t_{wash}	2.0	1.0	0.3	0.2	3.0

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

305 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.

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 145 are based on the input assumptions from Table 144.

Table 145. Dishwashers—Energy and Peak Demand Savings

Facility description	UC		SSTD		STC		MTC		PP&U	
	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW
Low temp./ electric water heater	3,955	0.542	17,362	2.378	17,426	2.387	24,292	3.328	–	–
High temp./ electric water heater with electric booster heater	4,303	0.589	12,596	1.726	10,966	1.502	29,751	4.075	3,750	0.514
High temp./ gas water heater with electric booster heater	3,221	0.441	5,572	0.763	6,700	0.918	13,569	1.859	1,642	0.225
High temp./ electric water heater with gas booster heater	3,684	0.505	8,582	1.176	8,528	1.168	20,504	2.809	2,545	0.349

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) varies per eligible dishwasher type, as stated in the ENERGY STAR Commercial Kitchen Equipment Savings Calculator.

Table 146. Dishwashers—Equipment Lifetime by Machine Type

Machine type	EUL (years)
Under counter	10
Stationary single-tank door	15
Single-tank conveyor	20
Multiple-tank conveyor	20
Pot, pan, and utensil	10

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
- Energy source for primary water heater (gas, electric)
- Energy source for booster water heater (gas, electric)
- ENERGY STAR idle rate
- ENERGY STAR water consumption
- Copy of ENERGY STAR certification or alternative
- Copy of proof of purchase including date of purchase, manufacturer, and model number

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 147. Dishwashers—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. Update savings based on the newest version of ENERGY STAR deemed input variables.
v2.1	01/30/2015	TRM v2.1 update. Corrections to Water Use per Rack in Table 2-90.
v3.0	04/30/2015	TRM v3.0 update. Aligned calculation approach with ENERGY STAR Commercial Dishwashers Program Requirements Version 2.0. Simplified methodology to a single representative building type consistent with the ENERGY STAR Commercial Kitchen Equipment Savings Calculator.
v4.0	10/10/2016	TRM v4.0 update. Added high-efficiency requirements for pots, pans, and utensils.
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.

TRM version	Date	Description of change
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. General reference checks and text edits. Updated ENERGY STAR specification and incorporated March 2021 calculator update. Updated variable definitions.
v10.0	10/2022	TRM v10.0 update. Corrected mismatch between formula definitions and variables. Replaced URL for ENERGY STAR listing.
v11.0	10/2023	TRM v11.0 update. Clarified that residential dishwashing equipment can be installed in commercial applications following the methodology in Volume 2 of TRM.

2.4.4 ENERGY STAR® Electric Griddles Measure Overview

TRM Measure ID: NR-FS-GR

Market Sector: Commercial

Measure Category: Food service equipment

Applicable Business Types: See eligibility criteria

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 commercial electric griddles. Commercial griddles are a versatile piece of cooking equipment with a flat cooking surface whose uses range from searing, browning, toasting, and warming. An energy-efficient commercial electric griddle reduces energy consumption primarily through application of advanced controls and improved temperature uniformity. The energy and demand savings are determined on a per-griddle basis and only considers electric commercial griddles.

Eligibility Criteria

Eligible units must comply with the current ENERGY STAR specifications.[306] The efficiency requirements for this appliance are evaluated on a per square foot basis.

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial food service operations, healthcare, hospitality, and supermarkets.[307]

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

- Gas or dual-fuel heat source griddles
- Dual technology griddles such as fry-top ranges

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

[307] "Commercial Kitchens Initiative," Consortium for Energy Efficiency (CEE). Section 2.2, p. 8. https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf.

Baseline Condition

There are currently no federal minimum standards for commercial griddles. Therefore, the baseline condition for retrofit situations is a single-sided or double-sided electric griddle that does not meet the ENERGY STAR key product criteria.

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v1.2 specification, effective January 1, 2011.[308] Qualified products must meet the minimum idle energy rate requirement from Table 134.

Table 148. Commercial Griddles—ENERGY STAR Specification[309]

Operation	Criteria
Cooking energy efficiency at heavy-load conditions	Reported
Normalized idle energy rate	≤ 320 watts/ft^2.

Furthermore, the ENERGY STAR qualification criteria does not specify a cooking-energy efficiency threshold and therefore shall only be recorded for evaluation of the energy savings.

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 111

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

Equation 112

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

Equation 113

308 ENERGY STAR Program Requirements for Commercial Griddles. Eligibility Criteria Version 1.2. https://www.energystar.gov/sites/default/files/Commercial%20Griddles%20Version%201.2%20%28Rev%20December%20-%202020%29.pdf.

309 ENERGY STAR Commercial Griddles Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_griddles/key_product_criteria.

kWh_{ph}, kWh_{cook}, and kWh_{idle} are each calculated the same for both the baseline and ENERGY STAR cases, as shown in Equation 100, except they require their respective input assumptions relative to preheat, cooking and idle operation as seen in Table 135.

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

Equation 114

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

Equation 115

Where:

kWh_{base}	=	*Baseline annual energy consumption [kWh]*
kWh_{ES}	=	*ENERGY STAR annual energy consumption [kWh]*
E_{ph}	=	*Preheat energy [Wh/day]*
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/day]*
η_{cook}	=	*Cooking energy efficiency [%]*
PC	=	*Production capacity per pan [lb/hr]*
t_{on}	=	*Equipment operating hours per day [hr/day]*
t_{days}	=	*Facility operating days per year [days/year]*
1,000	=	*Constant to convert from W to kW*
CF	=	*Peak coincidence factor*

Table 149. Griddles—Savings Calculation Input Assumptions[310]

Parameter	Single-sided Baseline	Single-sided ENERGY STAR	Double-sided Baseline	Double-sided ENERGY STAR
E_{ph} (Wh/ft^2)	667	333	667	333
W_{food} (lb/day/ ft^2)	17			
E_{food} (Wh/lb)	139	139		
η_{cook} (%)	65%	70%	65%	72%
E_{idle} (W/ft^2)	400	320	400	320
PC (lbs/hr/ft^2)	5.83	6.67	11.67	13.92
t_{on}	12			
t_{days}	365			
CF[311]	0.90			

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in the following table are based on the input assumptions from Table 135.

Table 150. Griddles—Energy and Peak Demand Savings[312]

Griddle size (ft^2)	Single-sided kWh	Single-sided kW	Double-sided kWh	Double-sided kW
4	1,759	0.26	2,120	0.34
6	2,639	0.39	3,179	0.50
8	3,519	0.52	4,239	0.67
10	4,398	0.65	5,299	0.84
12	5,278	0.78	6,359	1.01
14	6,158	0.92	7,418	1.17

Claimed Peak Demand Savings

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

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

311 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.

312 ENERGY STAR Savings Calculator for ENERGY STAR Qualified Commercial Kitchen Equipment Calculator. http://www.energystar.gov/buildings/sites/default/uploads/files/Commercial_kitchen_equipment_calculator.xlsx.

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-ElecGriddle.[313]

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
- Griddle top dimensions and surface area
- Griddle configuration (single-sided, double-sided)
- ENERGY STAR idle rate
- Copy of ENERGY STAR certification or alternative
- Copy of proof of purchase including date of purchase, manufacturer, and model number

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 151. ENERGY STAR Griddles—Revision History

TRM version	Date	Description of change
v11.0	10/2023	TRM v11.0 origin.

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

~~2.4.4~~2.4.5 ENERGY STAR® Electric Fryers Measure Overview

TRM Measure ID: NR-FS-EF

Market Sector: Commercial

Measure Category: Cooking equipment

Applicable Building Types: See eligibility criteria

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® electric fryers. Fryers that have earned ENERGY STAR® certification offer shorter cook times and higher production rates through advanced burner and heat exchanger designs. Fry pot insulation reduces standby losses resulting in a lower idle energy rate. The energy and demand savings are determined on a per-fryer basis.

Eligibility Criteria

Eligible units must ~~meet~~ be compliant with the current ENERGY STAR® specification, either counter-top or floor type designs, with standard-size and large vat fryers as defined below:[314, 315]

- Standard-size electric fryer: A fryer with a vat that measures ≥ 12 inches and < 18 inches wide, and a shortening capacity ≥ 25 pounds and ≤ 65 pounds
- Large vat electric fryer: A fryer with a vat that measures ≥ 18 inches and ≤ 24 inches wide, and a shortening capacity > 50 pounds

Eligible building types include independent restaurants, chain restaurants, elementary and secondary schools, colleges and universities, corporate and industrial foodservice operations, healthcare, hospitality, and supermarkets.[316]

314 ENERGY STAR® Program Requirements Product Specifications for Commercial Fryers. Eligibility Criteria Version 3.0. https://www.energystar.gov/sites/default/files/asset/document/Commercial%20Fryers%20Program%20Requirements.pdf.

315 ENERGY STAR® Qualified Product Listing: https://www.energystar.gov/productfinder/product/certified-commercial-fryers/results.

316 CEE Commercial Kitchens Initiative's overview of the Food Service Industry: https://forum.cee1.org/system/files/library/4203/CEE_CommKit_InitiativeDescription_Aug2021.pdf.

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

- Fryers with vats measuring < 12 inches wide, or > 24 inches wide

Baseline Condition

The baseline condition is an electric standard-size fryer ≥ 12 inches and < 18 inches wide or large vat fryer > 18 inches and < 24 inches wide that do not meet ENERGY STAR® key product criteria.

High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR® v3.0 specification, effective October 1, 2016. New electric standard fryers ≥ 12 inches and < 18 inches wide and large vat fryers > 18 inches and < 24 inches wide that meet or exceed the requirements listed in Table 152.

Table 152. Fryers—ENERGY STAR® Specification[317]

Inputs	Standard	Large-vat
Cooking energy efficiency	≥ 83%	≥ 80%
Idle energy rate (W)	≤ 800	≤ 1,100

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed values are calculated using the following algorithms:

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

Equation 116

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

Equation 117

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

Equation 118

317 ENERGY STAR® Commercial Fryers Key Product Criteria. https://www.energystar.gov/products/commercial_food_service_equipment/commercial_fryers/key_product_criteria.

kWh_{ph}, kWh_{cook}, and kWh_{idle} are each calculated the same for both the baseline and ENERGY STAR® cases, as shown in Equation 119, except they require their respective input assumptions relative to preheat, cooking, and idle operation as seen in Table 153.

$$kWh = \left(E_{ph} + \left(\frac{W_{food} \times E_{food}}{\eta_{cook}}\right) + E_{idle} \times \left(t_{on} - \frac{t_{ph}}{60} - \frac{W_{food}}{PC}\right)\right) \times \frac{t_{days}}{1{,}000}$$

Equation 119

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

Equation 120

Where:

kWh_{base}	=	*Baseline annual energy consumption [kWh]*
kWh_{ES}	=	*ENERGY STAR® annual energy consumption [kWh]*
E_{ph}	=	*Preheat energy [Wh/day]*
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/day]*
η_{cook}	=	*Cooking energy efficiency [%]*
PC	=	*Production capacity [lb/hr]*
t_{on}	=	*Equipment operating hours per day [hr/day]*
t_{ph}	=	*Preheat time [min/day]*
t_{days}	=	*Facility operating days per year [days/year]*
60	=	*Constant to convert from min to hr*
1,000	=	*Constant to convert from W to kW*
CF	=	*Peak coincidence factor*

Table 153. Fryers—Savings Calculation Input Assumptions[318]

Parameter	Standard-sized vat		Large vat	
	Baseline	ENERGY STAR®	Baseline	ENERGY STAR®
E_{ph}	2,400	1,900	2,400	1,900
W_{food}	150			
E_{food}	167			
η_{cook}	75%	83%	70%	80%
E_{idle}	1,200	800	1,350	1,100
PC	65	70	100	110
t_{on}	16		12	
t_{ph}	15			
t_{days}	365			
CF[319]	0.90			

Deemed Energy and Demand Savings Tables

Deemed energy and demand savings in Table 151 are based on the assumptions from Table 153.

Table 154. Fryers—Energy and Peak Demand Savings

Fryer type	kWh Savings	kW Savings
Standard	3,272	0.476
Large vat	2,696	0.516

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-ElecFryer.[320]

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

319 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.

320 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:

- Manufacturer and model number
- Fryer type (standard or large vat)
- ~~Fryer width~~
- 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

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for Electric Fryers.

Relevant Standards and Reference Sources

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

Document Revision History

Table 155. Fryers—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® Electric Fryers Program Requirements Version 2.1. Simplified calculation methodology to a single representative building type consistent with the ENERGY STAR® Commercial Kitchen Equipment Savings Calculator.
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. Savings and efficiencies revised for ENERGY STAR® 3.0 specifications. 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.