ΔkW = gross coincident demand reductions

$Quantity_{baseline}$ = quantity of existing or baseline fixtures/lamps

$Quantity_{installed}$ = quantity of installed fixtures/lamps

$watts_{baseline}$ = load of the existing or baseline fixture/lamp on a per unit basis, measured in watts

$watts_{installed}$ = load of installed fixture/lamps on a per unit basis, measured in watts

Ratio = ratio of the installed condtion to the baseline, dimensionless.

HOU = annual operating hours of the fixtures/lamps

WHFe = waste heat factor for energy to account for cooling savings from efficient lighting
WHFd = waste heat factor for demand to account for cooling savings from efficient lighting

CF = summer peak coincidence factor. The CF used for demand reductions will depend on the fixture that is delamped/removed as shown in in Table 32,

Table 133 and Table 135.
ISR = in-service rate is the percentage of rebated measures actually installed

Input Variables

Table 32: Input Values for Lighting Fixtures and Lamps

Component	Type	Value	Unit	Source(s)
$\text{Quantity}_{\text{baseline}}$	Variable	See customer application	-	Customer application
$\text{Quantity}_{\text{installed}}$	Variable	See customer application	-	Customer application
$\text{watts}_{\text{baseline}}$	Variable	See customer application	watts	Customer application
$\text{watts}_{\text{installed}}$	Variable	See customer application	watts	Customer application
Ratio	Variable	Table 33. Default Ratio for Calculating Baseline Lighting Wattage Multiplied with Baseline Quantity	-	Dominion non-residential lighting systems and controls participant data through year-end 2016
CF	Fixed	Measure with "24/7" in fixture name, treat as "LED Exit Sign " in Table 133 Measure with "exterior" in fixture name: Table 133 Measure without "exterior" or "24/7" in fixture name: Table 135	-	Mid-Atlantic 2017, p. 271, 308, 320, and 335, [133]
HOU	Variable	Measure with "24/7" in fixture name, treat as "LED Exit Sign " in Table 133 Measure with "exterior" in fixture name: Table 133 Measure without "exterior" or "24/7" in fixture name: Table 135	hours/ year	Mid-Atlantic 2017, p. 504
WHF_{e}	Variable	Measure with "24/7" in fixture name, treat as "LED Exit Sign " in Table 133 Measure with "exterior" in fxiture name: Table 133 Measure without "exterior" or "24/7" in fixture name: Table 135	-	Mid-Atlantic TRM 2016 p. 464-465[134]

Component	Type	Value	Unit	Source(s)
WHF_d	Variable	Measure with "24/7" in fixture name, treat as "LED Exit Sign " in Table 133 Measure with "exterior" in fixture name: Table 133 Measure without "exterior" or "24/7" in fixture name: Table 135	-	Mid-Atlantic TRM 2016 p. 464-465[135]
ISR	Fixed	1.00	-	Mid-Atlantic TRM 2017 p. 272

Table 33. Default Ratio for Calculating Baseline Lighting Wattage Multiplied with Baseline Quantity[136]

New Fixture	Base Fixture	Ratio
T8 - 2 - 2ft 17watt Lamps with Reflector & NB	2 Bi-ax Lamps in 2x2, 2U-bends	2.3
T8 - 3 - 2ft 17watt Lamps with Reflector & NB	2 Bi-ax Lamps in 2x2, 2U-bends	1.6
T8 Enclosed Fixture - 2 Lamp NB No Reflector 24/7	75W – 100W HID	2.9
T8 Enclosed Fixture - 3 Lamp NB No Reflector 24/7	150W – 175W HID	2.6
T8 Enclosed Fixture - 4 Lamp HB Miro Reflector	T8 – 4ft 4 Lamp	
T8 High-Bay - 4ft 3 lamp	150W – 175W HID	2.2
T8 High-Bay - 4ft 4 lamp	250W HID	2.1
T8 High-Bay - 4ft 6 lamp	400W HID	2.3
T8 High-Bay - 4ft 8 lamp	400W HID	1.4

133 The LED measures were grouped with other lighting applications' coincident factors based on their similar function or usage. LED downlights are assumed to be replacing CFL and T8 fixtures; LED or induction HE garage fixtures would be expected to replace PSMH in garage applications, and exterior LEDs replace exterior fixtures.

134 Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 COP typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

135 Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

136 Use the default New Fixture Type, if there is no ratio available for the specific new fixture type.

New Fixture	Base Fixture	Ratio
T8 High-Bay - Double Fixture 4ft 6 lamp	1,000W HID	3.2
T8 High-Bay - Double Fixture 4ft 8 lamp	1,000W HID	1.8
LW HPT8 4ft 1 lamp	T8	1.5
LW HPT8 4ft 2 lamp	T8	1.7
LW HPT8 4ft 3 lamp	T8	1.4
LW HPT8 4ft 4 lamp	T8	1.4
HPT8 T8 4ft 2 lamp	T12HO – 8ft 1 Lamp	2.2
HPT8 T8 4ft 4 lamp	T12HO – 8ft 2 Lamp	2.0
T5 HO Enclosed - 1 lamp 24/7	75W – 100W HID	
T5 HO Enclosed - 2 lamp 24/7	150W – 175W HID	
T5 HO Enclosed - 3 lamp 24/7	250W HID	
2 Lamp T5 28W 24/7	75W – 150W HID	
T5 HO Enclosed - 2 lamp Miro Reflector 24/7	250W HID	
T5 2 - 2ft lamps 24 watts	75W – 100W HID	2.1
T5 3 - 2ft lamps 24 watts	150W HID	
T5 4 - 2ft lamps 24 watts	175W HID	
T5 3 - 4ft HO Lamps	250W HID	1.3
T5 HO - Highbay 2L	150W – 175W HID	2.2
T5 HO - Highbay 3L	250W HID	1.9
T5 HO - Highbay 4L	400W HID	2.1
T5 HO - Highbay 6L	400W HID	1.4
T5HO - Double fixture Highbay 5L	1,000W HID	
T5HO - Double Fixture Highbay 6L	1,000W HID	1.5
CFL - Screw In (bulb only) - <30W	Incandescent (EISA Standard)	3.5
CFL - Screw In (bulb only) - 30W or greater	Incandescent (EISA Standard)	2.6
CFL - Fixture/Wallpack		5.2
CFL - Hardwired fixture	Incandescent (EISA Standard)	
LED Exit Signs	Standard Exit Sign	8.8
LED Downlight Fixture >=31W	2x4 T8 Fluorescent	3.7
LED Downlight 13-30W (excludes screw-in lamps)	Incandescent Downlight 76W – 150W (EISA Standard)	4.3
LED 2X4 FIXTURE (39-80W)	2x4 T8 Fluorescent	3.0
LED Fixture (2x2 or 1x4)	2 2x2 Bi-ax Lamps, 2U-bends, 2L 4ft T8	3.4
LED Lamps (<= 7W)	≤ 30W Equiv. (EISA Standard)	5.0

New Fixture	Base Fixture	Ratio
LED Lamps (>7W up to 12W) (excludes screw-in lamps)	31W – 75W Lamps (EISA Standard)	5.3
LED or Induction HE		3.0
LED or Induction HE Exterior		3.2
LED or Induction HE Garage		3.9
T8 to HPT8 Conver, reduce bulbs, add reflector		2.7
LED Exterior New Fixture		3.6
LED Interior New Fixture		3.9
LED 24/7		2.1
LED		2.5
LED Highbay		2.0
LED Panels		2.2
LED Panels on Belly Pan		2.2
LED Display Case Lighting		2.5
LED Screw In		5.3
LW HPT8 – 4ft 2 Lamp with Reflector and Delamp		2.3
LW HPT8 – 4ft 3 Lamp with Reflector and Delamp	T8 – 3 Lamp	2.3
LW HPT8 – 4ft 1 Lamp with Reflector and Delamp	T8 – 2 Lamp	2.5
LED – 4 linear 4ft Tube/Bar	T8 – 4ft 4 Lamp	2.1
LED – 3 linear 4ft Tube/Bar	T8 – 4ft 3 Lamp	1.8
LED – 2 linear 4ft Tube/Bar	T8 – 4ft 2 Lamp	2.0
LED – 1 linear 4ft Tube/Bar	LED – 1 Linear 4ft Tube/Bar T8 – 4ft 1 Lamp	2.1
LED – 1 linear 4ft Tube/Bar – 1 T8 Delamp	LED – 1 Linear 4ft Tube/Bar T8 – 4ft 1 Lamp	2.8
LED – 2 linear 4ft Tube/Bar – 1 T8 Delamp	T8 – 4ft 2 Lamp	2.5
LED – 3 linear 4ft Tube/Bar – 1 T8 Delamp	T8 – 4ft 3 Lamp	2.4
LED – 2 linear 4ft Tube/Bar – 2 T8 Delamp	T8 – 4ft 4 Lamp	3.2
LED Linear/Bar		2.0
Default[137]		3.6

[137] The default fixture type is based on the weighted average ratio for all fixture types in the table.

Default Savings

No default savings will be awarded for this measure if the proper values are not provided in the customer application.

Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2017, p. 271 – 341, p. 462 – 465.

9.1.2 Sensors and Controls

Measure Description

This measure defines the savings associated with installing occupancy sensors Wall-, fixture, or remote-mounted occupancy sensors switch lights off after a brief delay when they do not detect occupancy.

This measure is offered in both the Non-Residential Lighting Systems and Controls program as well as the Non-Residential Small Business Improvement program, described in Section 15.

Savings Estimation Approach

Gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh/year = Quantity_{sensors} \times \frac{Watts_{connected}}{1{,}000\,W/kW} \times HOU \times SVGe \times WHF_e \times ISR$$

Gross coincident demand reductions are calculated according to the following equation:

$$\Delta kW = Quantity_{sensors} \times \frac{Watts_{connected}}{1{,}000\,W/kW} \times SVGd \times CF \times WHF_d \times ISR$$

Where:

ΔkWh/year = gross annual electric energy savings
ΔkW = gross coincident demand reductions
$Quantity_{sensors}$ = number of occupancy sensors installed
$watts_{connected}$ = total connected load of the lighting controlled by each sensor
HOU = average hours of use per year
SVG_e = Percentage of annual lighting energy saved by lighting control
SVGd = Percentage of lighting demand saved by lighting control
WHFe = waste heat factor for energy to account for cooling savings from efficient lighting
WHFd = waste heat factor for demand to account for cooling savings from efficient lighting
CF = summer peak coincidence factor
ISR = in-service rate is the percentage of rebated measures actually installed

Input Variables

Table 34: Input Values, Lighting Sensors and Controls

Component	Type	Value	Unit	Source(s)
$watts_{connected}$	Variable	See customer application	watt	Customer application
HOU	Variable	See Table 135	hours/year	Mid-Atlantic TRM 2017, p. 462
$Quantity_{sensors}$	Variable	See customer application	-	Customer application
SVG_e	Fixed	0.28	-	Mid-Atlantic TRM 2017 p. 283
SVG_d	Fixed	Occupancy sensor = 0.14	-	Mid-Atlantic TRM 2017 p. 284 for occupancy sesnor, daylighting sensor Mid-Atlantic TRM 2017 p. 287
CF	Fixed	See Table 135	-	Mid-Atlantic TRM 2017, p. 463
WHFe[138]	Variable	See Table 135	-	Mid-Atlantic TRM 2017 p. 464-465
WHFd[139]	Variable	See Table 135	-	Mid-Atlantic TRM 2017 p. 464-465
ISR	Fixed	1.00	-	Mid-Atlantic TRM 2017 p. 283-284

Default Savings

No default savings will be awarded for this measure if the proper values are not provided in the customer application.

Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic 2017, p. 283-286.

[138] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 COP typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[139] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

9.1.3 Reach-In Unit Occupancy Sensor

Measure Description

This measure realizes energy savings by adding occupancy sensors to reach-in refrigerated display case lighting. Occupancy sensors reduce energy usage by turning off lights when customers are not present. Savings and assumptions are based on the lighting load controlled by each occupancy sensor.

Savings Estimation Approach

Gross annual electric energy savings are calculated according to the following equation:

$$\frac{\Delta kWh}{year} = Quantity_{sensors} \times \frac{Watts}{1{,}000\ W/kW} \times OSS \times HOU \times WHF_e$$

Gross coincident demand reductions are calculated according to the following equation:

$$\Delta kW = Quantity_{sensors} \times \frac{Watts}{1{,}000\ W/kW} \times OSS \times\times WHF_d \times CF$$

Where:

ΔkWh/year = gross annual electric energy savings, kWh/year
ΔkW = gross coincident demand reductions, kW
$Quantity_{sensors}$ = number of occupancy sensors installed
watts = connected lighting load controlled by occupancy sensor, W
OSS = occupancy sensor savings, resulting from a reduction in operating hours, dimentionless
WHFe = Waste Heat Factor for Energy; represents the increased savings due to reduced waste heat from lights that must be rejected by the refrigeration equipment, dimensionless
WHFd = Waste Heat Factor for Demand; represents the increased savings due to reduced waste heat from lights that must be rejected by the refrigeration equipment, dimensionlessHOU = annual lighting hours of use, hrs/year
CF = peak coincidence factor, dimensionless

Input Variables

Table 35: Input Values for Reach-In Unit Occupancy Sensors Savings Calculations

Component	Type	Value	Unit	Source(s)
watts	Variable	See customer application	watts	Customer application
		Default = 38		Same default as from LED Case lighting measure $watts_{ee}$ for five foot lamp
$Quantity_{sensors}$	Variable	See customer application	-	Customer application
OSS	Fixed	0.307	-	Efficiency Maine Commercial TRM 2017, p. 40[140]
HOU	Variable	See Table 135 for grocery building type	hours/year	Mid-Atlantic TRM 2017, p. 462[141]
WHF_e	Fixed	Low Temp (-35°F - -1°F): 1.76 Med Temp (0°F - 30°F): 1.76 High Temp (31°F - 55°F): 1.38	-	Mid-Atlantic TRM 2017, p. 411
WHF_d	Fixed	Low Temp (-35°F - -1°F): 1.76 Med Temp (0°F - 30°F): 1.76 High Temp (31°F - 55°F): 1.38	-	Mid-Atlantic TRM 2017, p. 411
CF	Fixed	0.96	-	Mid-Atlantic TRM 2016, p. 505[142]

Default Savings

If the proper values are not supplied, a default savings may be applied using conservative input values.

The default gross annual electric energy savings will be assigned according to the following calculations:

$$\Delta kWh/year = \frac{Watts}{1{,}000\ W/kW} \times OSS \times HOU \times WHF_e$$

[140] This value is consistent across all Maine TRM versions. It refers to "US DOE, "Demonstration Assessment of Light-Emitting Diode (LED) Freezer Case Lighting." Refrigerated cases were metered for 12 days to determine savings from occupancy sensors. Assumes that refrigerated freezers and refrigerated coolers will see the same amount of savings from sensors. The nature of the savings is not explained. Showcase controls often keep a fixed number of lights on to reduce the "dark aisle" conditions. We will assume that this value accounts for both reduction in operating hours and incremental reduction in power.

[141] No default HOU was provided in the Maine TRM 2016.2. It refers to data collected from the application. Since the STEP Manual does not use customer application HOU data, a default was assigned using annual hours from the Mid-Atlantic TRM 2017.

[142] CFS_{SP} value for "grocery" building type.

$$= \frac{38\, watts}{1{,}000\, W/kW} \times 0.307 \times 7{,}134\, hours/year \times 1.38$$

$$= 115\ kWh/year$$

The default gross coincident demand reductions will be assigned according to the following calculations:

$$\Delta kW = \frac{Watts}{1{,}000\, W/kW} \times OSS \times\times WHF_d \times CF$$

$$= \frac{38\, watts}{1{,}000\, W/kW} \times 0.307 \times 1.38 \times 0.96$$

$$= 0.015\, kW$$

Source(s)

The primary sources for this deemed savings approach are the Efficiency Maine Commercial TRM 2017, p. 40-41 and Mid-Atlantic TRM 2017 p. 411 and p. 462-463.

10 NON-RESIDENTIAL HEATING AND COOLING EFFICIENCY PROGRAM

The Non-Residential Heating and Cooling Efficiency (CHV2) program is offered in Virginia beginning August 1, 2014, and in North Carolina beginning January 1, 2015. The program provides incentives to non-residential customers to implement new and upgrade existing HVAC equipment to more efficient HVAC technologies.

Many types of HVAC systems are eligible, including the following:

- Unitary and split HVAC systems including air conditioner (AC) units, air-source/ground-source heat pump (HP) units;
- Packaged terminal AC and HP units;
- Water and air-cooled chillers;
- Variable frequency drive (VFD) applications; and
- Economizers.

The algorithms to calculate heating, cooling, and demand reductions for each of these measures are described in this section.

10.1.1 Unitary/Split HVAC and Heat Pumps

Measure Description

This measure relates to the installation of new high-efficiency unitary/split HVAC units and heat pumps in place of a standard efficiency unitary/split HVAC units and heat pumps. For the standard (baseline) efficiencies, refer to 2010 ASHRAE 90.1 Table 6.8.1A for unitary air conditioners and condensing units and Table 6.8.1B for unitary and applied heat pumps. The measure efficiencies are based on the installed unit's efficiency provided by the application. The measure savings include both heating and cooling electric energy savings.

This measure is offered in both the Non-Residential Heating and Cooling Efficiency program as well as the Non-Residential Small Business Improvement program, described in Section 15.

Savings Estimation Approach

Algorithms and inputs to calculate heating, cooling savings, and demand reductions for unitary/split HVAC and package terminal AC systems are provided below. Gross annual electric energy savings are calculated according to the following equations:

Cooling Energy Savings:

For air-source heat pumps and AC units <65kBtu/h:

$$\Delta kWh/year_{cool,<65kBtuh} = \frac{Size\ in\ Btu/hour_{install} \times \left[\frac{1}{SEER_{base}} - \frac{1}{SEER_{install}}\right] \times FLH_{cool}}{1{,}000\ Btuh/kBtuh}$$

For air-source heat pumps and AC units ≥65 kBtu/h, and all ground-source heat pumps:

$$\Delta kWh/year_{cool,\geq 65kBtuh} = \frac{Size\ in\ Btu/hour_{install} \times \left[\frac{1}{IEER_{base}} - \frac{1}{IEER_{install}}\right] \times FLH_{cool}}{1{,}000\ Btuh/kBtuh}$$

See Equation 1 and Equation 2, in Appendix E, to convert between tons and Btu/h or kBtu/h, or vice versa.

Heating Energy Savings:

For air-source and ground-source heat pumps:

$$\Delta kWh/year_{heat,\geq 65kBtuh} = \frac{Size\ in\ Btu/hour_{install} \times \left[\frac{1}{COP_{base}} - \frac{1}{COP_{install}}\right] \times FLH_{heat}}{1{,}000\ Btuh/kBtuh}$$

For air-source heat pumps <65 kBtu/h, use Equation 5, in Appendix E: General Equations, to convert from HSPF to COP.

Heating and cooling energy savings are added to calculate the total electricity impact:

$$\Delta kWh/year = \Delta kWh/year_{cool} + \Delta kWh/year_{heat}$$

Gross coincident demand reductions are calculated according to the following equation:

$$\Delta kW = \frac{Size\ in\ Btu/h_{install} \times \left[\frac{1}{EER_{base}} - \frac{1}{EER_{install}}\right] \times CF}{1{,}000\ Btuh/kBtuh}$$

See , in Appendix E: General Equations, to convert between SEER and EER. See Equation 4, in Appendix E: General Equations, to convert between IEER and EER.

Where:

ΔkWh/year = gross annual electric energy savings

$\Delta kWh/year_{cool,<65kBtuh}$ = gross annual electric cooling energy savings for systems that are less than 65 kBtu/h

$\Delta kWh/year_{cool,\geq 65kBtuh}$ = gross annual electric cooling energy savings for systems that are greater than or equal to 65 kBtu/h

$\Delta kWh/year_{heat,<65kBtuh}$ = gross annual electric heating energy savings for systems that are less than 65 kBtu/h

$\Delta kWh/year_{heat,\geq 65kBtuh}$ = gross annual electric heating energy savings for systems that are greater than or equal to 65 kBtu/h

ΔkW = gross coincident demand reductions

Size in $Btuh_{install}$ = equipment size of installed unit, measured in Btu/h

$SEER_{base}$ = seasonal energy efficiency ratio (SEER) of the existing or baseline air conditioning equipment. SEER is used when calculating savings for heat pumps and AC units that are smaller than 65,000 Btu/h.

$SEER_{install}$ = seasonal energy efficiency ratio (SEER) of the installed air conditioning equipment. SEER is used when calculating savings for heat pumps and AC units that are smaller than 65,000 Btu/h.

$IEER_{base}$ = integrated energy efficiency ratio (IEER) of the existing or baseline air conditioning equipment. SEER is used when calculating savings for heat pumps and AC units that are ≥ 65,000 Btu/h in size.

$IEER_{install}$ = integrated energy efficiency ratio (IEER) of the installed air conditioning equipment. SEER is used when calculating savings for heat pumps and AC units that are ≥ 65,000 Btu/h in size.

FLH_{cool} = annual full-load cooling hours

FLH_{heat} = annual full-load heating hours

EER_{base} = energy efficiency ratio (EER) of existing or baseline air conditioning equipment. EER is used to analyze demand performance of heat pumps and AC units.

$EER_{install}$ = energy efficiency ratio (EER) of installed air conditioning equipment. EER is used to analyze performance of heat pumps and AC units.

$HSPF_{base}$ = heating seasonal performance factor (HSPF) of existing or baseline heat pump. HSPF is used in heating savings for air source heat pumps.

$HSPF_{install}$ = heating seasonal performance factor (HSPF) of installed heat pump. HSPF is used in heating savings for air source heat pumps.

COP_{base} = coefficient of performance (COP) of existing or baseline heating equipment. Ground source heat pumps use COP to determine heating savings.

$COP_{install}$ = coefficient of performance (COP) of installed heating equipment. Ground source heat pumps use COP to determine heating savings.

CF = summer peak coincidence factor.

In the event of a missing efficiency metric from an application, the equations provided in Appendix E may be used to estimate it using another application-provided variable.

Input Variables

Table 36: Input Values for Non-Residential HVAC Equipment

Component	Type	Value	Units	Source(s)
Size in $Btuh_{install}$	Fixed	See customer application	Btu/hour	Customer application
FLH_{heat}	Variable	See Table 139	hours/year	Mid-Atlantic TRM 2017 p. 351-353
FLH_{cool}	Variable	See Table 138	hours/year	Mid-Atlantic TRM 2017 p. 351-353
HSPF/SEER/IEER/EER / COP_{base}	Variable	See Table 37 and Table 38	kBtu/kW-hour (except COP is dimensionless)	ASHRAE 90.1 2010 Table 6.8.1A and Table 6.8.1B
HSPF/SEER/IEER/EER / $COP_{install}$	Variable	See customer application 1. Where IEER is not available, IEER = SEER 2. See "Appendix E: General Equations" to convert the available efficiency data to the efficiency data required to calculate savings.	kBtu/kW-hour (except COP is dimensionless)	Customer application
CF	Variable	Where baseline and install system capacity vary, use install system capacity to assign CF. Otherwise, use baseline system capacity to assign CF: < 135 kBtu/h = 0.588 ≥ 135 kBtu/h = 0.874	-	Mid-Atlantic TRM 2017 p. 354

Table 37: Electrically Operated Unitary Air Conditioners and Condensing Units - Minimum Efficiency Requirement[143]

Equipment Type	Size Category (Btu/h)	Heating Section Type	Subcategory	Minimum Annual Efficiency	Minimum Demand Efficiency
Air conditioners, air cooled	< 65,000 Btu/h	All	Split system/ Single package	13.0 SEER	11.1 EER[144]
Through the wall (air cooled)	≤ 30,000 Btu/h	All	Split system/ Single package	12.0 SEER	10.5 EER[144]
Air conditioners, air cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric resistance (or none)	Split system/ Single package	11.4 IEER	11.2 EER
		All other	Split system/ Single package	11.2 IEER	11.0 EER
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric resistance (or none)	Split system/ Single package	11.2 IEER	11.0 EER
		All other	Split system/ Single package	11.0 IEER	10.8 EER
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric resistance (or none)	Split system/ Single package	10.1 IEER	10.0 EER
		All other	Split system/ Single package	9.9 IEER	9.8 EER
	≥ 760,000 Btu/h	Electric resistance (or none)	Split system/ Single package	9.8 IEER	9.7 EER
		All other	Split system/ Single package	9.6 IEER	9.5 EER
Air conditioners, water cooled	< 65,000 Btu/h	All	Split system/ Single package	12.3 IEER	12.1 EER
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric resistance (or none)	Split system/ Single package	12.3 IEER	12.1 EER
		All other	Split system/ Single package	12.1 IEER	11.9 EER

143 ASHRAE 90.1 2010, Table 6.8.1A - Electrically Operated Unitary Air Conditioners and Condensing Units - Minimum Efficiency Requirement.

144 This value was not provided in ASHRAE 90.1 2010, Table 6.8.1A, so Equation 3 in Appendix E was used to convert SEER to EER.

Equipment Type	Size Category (Btu/h)	Heating Section Type	Subcategory	Minimum Annual Efficiency	Minimum Demand Efficiency
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric resistance (or none)	Split system/ Single package	12.5 IEER	12.5 EER
		All other	Split system/ Single package	12.5 IEER	12.3 EER
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric resistance (or none)	Split system/ Single package	12.6 IEER	12.4 EER
		All other	Split system/ Single package	12.4 IEER	12.2 EER
	≥ 760,000 Btu/h	Electric resistance (or none)	Split system/ Single package	12.4 IEER	12.2 EER
		All other	Split system/ Single package	12.2 IEER	12.0 EER

Table 38. Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirement[145]

Equipment Type	Cooling Capacity/Size Category	Heating Section Type	Subcategory or Rating Conditions	Minimum Annual Efficiency	Minimum Demand Efficiency
Air Cooled (cooling mode)	< 65,000 Btu/h	All	Split System/ Single package	13.0 SEER	11.1 EER[146]
Through-the-wall (air-cooled cooling mode)	≤ 30,000 Btu/h	All	Split System/ Single package	12.0 SEER	10.5 EER[146]
Air Cooled (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric resistance (or none)	Split system/ Single package	11.2 IEER	11.0 EER
		All other	Split system/ Single package	11.0 IEER	10.8 EER
	≥ 135,000 Btu/h and	Electric resistance (or none)	Split system/	10.7 IEER	10.6 EER

[145] ASHRAE 90.1 2010, Table 6.8.1B - Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirement.

[146] This value was not provided in ASHRAE 90.1 2010, Table 6.8.1B, so Equation 3 in Appendix E was used to convert between SEER and EER.

Equipment Type	Cooling Capacity/Size Category	Heating Section Type	Subcategory or Rating Conditions	Minimum Annual Efficiency	Minimum Demand Efficiency
	< 240,000 Btu/h		Single package		
		All other	Split system/ Single package	10.5 IEER	10.4 EER
	≥ 240,000 Btu/h	Electric resistance (or none)	Split system/ Single package	9.6 IEER	9.5 EER
		All other	Split system/ Single package	9.4 IEER	9.3 EER
Water source[147] (Cooling mode)	< 17,000 Btu/h	All	86 °F entering water	13.1 SEER[146] (13.0 SEER for baseline)	11.2 EER (11.1 EER for baseline)
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86 °F entering water	14.5 SEER[146] (13.0 SEER for baseline)	12.0 EER (11.1 EER for baseline)
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86 °F entering water	13.4 IEER[148] (11.0 IEER for baseline)	12.0 EER (10.8 EER for baseline)
Ground source[147] (cooling mode)	< 65,000 Btu/h	All	77 °F entering water	17.4 SEER[146] (13.0 SEER for baseline)	13.4 EER (11.1 EER for baseline)
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	77 °F entering water	14.9 IEER[148] (11.0 IEER for baseline)	13.4 EER (10.8 EER for baseline)
Air cooled (heating mode)	< 65,000 Btu/h	-	Split system/ Single system	7.7 HSPF	N/A
Through-the-wall (air cooled heating mode)	≤ 30,000 Btu/h	- -	Split system/ Single system	7.4 HSPF	N/A

147 Although ASHRAE values reflect the Building Code minimum, savings are calculated using the efficiencies shown. This is due to the Mid-Atlantic TRM 2017 assumption that the baseline technology—for residential ground source heat pump applications—is an air-cooled heat pump. (There is no corresponding commercial measure in the Mid-Atlantic TRM 2017.)

148 This value was not provided in ASHRAE 90.1 2010, Table 6.8.1B, so Equation 4 in Appendix E was used to convert from EER to IEER.

Equipment Type	Cooling Capacity/Size Category	Heating Section Type	Subcategory or Rating Conditions	Minimum Annual Efficiency	Minimum Demand Efficiency
Air cooled (heating mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	-	47°F DBT/ 43°F WBT outdoor air	3.3 COP	N/A
	≥ 135,000 Btu/h (cooling capacity)	-	47°F DBT/ 43°F WBT outdoor air	3.2 COP	N/A
Water source (heating mode)	< 135,000 Btu/h (cooling capacity)	-	68°F entering water	4.2 COP	N/A
Ground source (heating mode)	< 135,000 Btu/h (cooling capacity)	-	32°F entering water	3.1 COP	N/A

Default Savings

No default savings will be awarded for this measure if the proper values are not provided in the customer application.

Source(s)

The primary sources for this deemed savings approach are the ENERGY STAR® Air Source Heat Pump Calculator (2002 EPA), Mid-Atlantic TRM 2017 p. 342 - 358 and ASHRAE 90.1 2010.

10.1.2 Variable Refrigerant Flow Systems and Mini-Split Systems

Measure Description

This measure relates to installation of new high efficiency variable refrigerant flow (VRF) and new mini-split systems in place of standard efficiency air conditioners or heat pumps. The baseline VRF air conditioner efficiencies are based on Table 6.8.1I of 2010 ASHRAE 90.1 and the baseline efficiencies of VRF heat pumps are based on Table 6.8.1J of ASHARE 90.1. The measure efficiency is based on the installed unit's efficiency. The measure approved savings applies only to the air cooled VRF air conditioners and air cooled VRF heat pumps and water source or ground source units are not included.

Minimum baseline requirements for VRF and mini-split systems are provided in this section. Since the baseline system could also be unitary/split HVAC and heat pumps, the minimum baseline efficiencies for those equipments should be referenced from Section 10.1.1.

These measures are offered in the Non-Residential Heating and Cooling Efficiency program; mini split systems are also offered in the Non-Residential Small Business Improvement program, described in Section 15.

Savings Estimation Approach

Algorithms and inputs to calculate heating, cooling, and gross coincident summer peak savings for variable refrigerant flow (VRF) systems and mini split systems are provided in this section.

Gross annual electric energy savings are calculated according to the following equations:

Cooling Energy Savings:

For VRF systems and mini-split systems <65 kBtu/h:

$$\Delta kWh/year_{cool,<65kBtuh} = \frac{Size\ in\ Btuh \times \left[\frac{1}{SEER_{base}} - \frac{1}{SEER_{install}}\right] \times FLH_{cool}}{1{,}000\ Btuh/kBtuh}$$

For VRF systems and mini split systems ≥65 kBtu/h:

$$\Delta kWh/year_{cool,\geq 65kBtuh} = \frac{Size\ in\ Btuh \times \left[\frac{1}{IEER_{base}} - \frac{1}{IEER_{install}}\right] \times FLH_{cool}}{1{,}000\ Btuh/kBtuh}$$

To convert between EER and SEER see Equation 3: Energy Efficiencies - EER to SEER, in Appendix E.

Heating Energy Savings:

For VRF and mini-split heat pump systems ≥65 kBtu/h:

$$\Delta kWh/year_{heat,\geq 65kBtuh} = \frac{Size\ in\ Btuh \times \left[\frac{1}{COP_{base}} - \frac{1}{COP_{install}}\right] \times FLH_{heat}}{1{,}000\ Btuh/kBtuh}$$

For VRF and mini-split heat pump systems <65 kBtu/h, use Equation 5, in Appendix E: General Equations, to convert from HSPF to COP.

Heating and cooling energy savings are added to calculate the total electricity impact:

$$\Delta kWh/year = \Delta kWh_{cool} + \Delta kWh_{heat}$$

Gross coincident summer peak demand reduction is calculated according to the following equation:

$$\Delta kW = \frac{Size\ in\ Btuh \times \left[\frac{1}{EER_{base}} - \frac{1}{EER_{install}}\right] \times CF}{1{,}000\ Btuh/kBtuh}$$

Where:

ΔkWh/year = gross annual electric energy savings

$\Delta kWh/year_{cool,<65kBtuh}$ = gross annual electric cooling energy savings for mini split heat pump systems that are less than 65 kBtu/h

$\Delta kWh/year_{cool,\geq 65kBtuh}$ = gross annual electric cooling energy savings for VRF systems that are greater than or equal to 65 kBtu/h

$\Delta kWh/year_{heat,<65kBtuh}$ = gross annual electric heating energy savings for mini split heat pump systems that are less than 65 kBtu/h

$\Delta kWh/year_{heat,\geq 65kBtuh}$ = gross annual electric heating energy savings for VRF systems that are greater than or equal to 65 kBtu/h

ΔkW = gross coincident summer peak demand savings

Size in Btuh = equipment cooling capacity, measured in Btu/h

$SEER_{base}$ = seasonal energy efficiency ratio (SEER) of the existing or baseline equipment. SEER is used when calculating savings for units that are < 65,000 Btu/h in size. See Equation 3: Energy Efficiencies - EER to SEER,, in Appendix E, to convert between EER and SEER.

$SEER_{install}$ = seasonal energy efficiency ratio (SEER) of the installed equipment. SEER is used when calculating savings for units that are < 65,000 Btu/h in size. See Equation 3, in Appendix E, to convert between EER and SEER.

$IEER_{base}$ = integrated energy efficiency ratio (IEER) of existing or baseline equipment. IEER is a weighted average of a unit's efficiency at four load points: 100%, 75%, 50%, and 25% of full cooling capacity. It is used to analyze performance of VRF units that are ≥ 65,000 Btu/h in size.

$IEER_{install}$ = integrated energy efficiency ratio (IEER) of installed equipment. IEER is a weighted average of a unit's efficiency at four load points: 100%, 75%, 50%, and 25% of full cooling capacity. It is used to analyze performance of VRF units that are ≥ 65,000 Btu/h in size.

FLH_{cool} = annual full load cooling hours

FLH_{heat} = annual full load heating hours

EER_{base} = energy efficiency ratio (EER) of existing or baseline equipment. EER is used to analyze performance of VRF units that are ≥ 65,000 Btu/h in size. See, in Appendix E, to convert between EER and SEER.

$EER_{install}$ = energy efficiency ratio (EER) of installed equipment. EER is used to analyze performance of VRF units that are ≥ 65,000 Btu/h in size. See, in Appendix E, to convert between EER and SEER.

$HSPF_{base}$ = heating seasonal performance factor (HSPF) of existing or baseline system. See Equation 7 in Appendix E, for the conversion between COP and HSPF.

$HSPF_{install}$ = heating seasonal performance factor (HSPF) of installed equipment.

See Equation 7 in Appendix E, for the conversion between COP and HSPF.
COP_{base} = coefficient of performance (COP) of existing or baseline heating equipment. See Equation 7 in Appendix E, for the conversion between COP and HSPF.
$COP_{install}$ = coefficient of performance (COP) of installed heating equipment. See Equation 7 in Appendix E, for the conversion between COP and HSPF.
CF = summer peak coincidence

Input Variables

Table 39: Input Values for VRF Systems and Mini Split Systems

Component	Type	Value	Units	Source(s)
FLH_{heat}	Fixed	See Table 139	hours/year	Mid-Atlantic TRM 2017 p. 351-353
FLH_{cool}	Fixed	See Table 138	hours/year	Mid-Atlantic TRM 2017
HSPF/SEER/EER/COP / $IEER_{base}$	Variable	See Table 40	kBtu/kW-hour (except COP is dimensionless)	ASHRAE 90.1 2010, Tables 6.8.1I and 6.8.1J
HSPF/SEER/EER/COP / $IEER_{install}$	Variable	See customer application 1. Where IEER is not available, IEER = SEER 2. See "Appendix E: General Equations" to convert the available efficiency data to the efficiency data required to calculate savings. 3.	kBtu/kW-hour (except COP is dimensionless)	Customer application
CF	Fixed	Where baseline and install system capacity vary, use install system capacity to assign CF. Otherwise, use baseline system capacity to assign CF. < 135 kBtu/h = 0.588 ≥ 135 kBtu/h = 0.874	-	Mid-Atlantic TRM 2017 p. 396

Table 40: Variable Refrigerant Flow Air Conditioners and Heat Pumps - Minimum Efficiency Requirements[149]

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Conditions	Minimum Annual Cooling Efficiency	Minimum Peak Cooling Efficiency	Minimum Heating Efficiency
VRF Air Conditioners, Air Cooled	< 65,000 Btu/h	All	VRF Multi-Split System	13.0 SEER	11.1 EER[150]	N/A
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split system	13.1 IEER	11.7 EER[151]	N/A
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split system	12.9 IEER	11.6 EER[151]	N/A
	≥ 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split system	11.6 IEER	10.4 EER[151]	N/A
VRF Heat Pumps, Air Cooled	< 65,000 Btu/h	All	VRF Multi-Split system	13.0 SEER	11.1 EER[150]	7.7 HSPF
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split system	12.9 IEER	11.6 EER[151]	3.3 COP
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split system	12.3 IEER	11.0 EER[151]	3.2 COP
	≥ 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split system	11.0 IEER	9.8 EER[151]	3.2 COP

[149] ASHRAE 90.1 2010, Tables 6.8.1I - Electrically Operated Variable Refrigerant Flow Air Conditioners- Minimum Efficiency Requirement and 6.8.1J - Electrically Operated Variable Refrigerant Flow Heat Pumps - Minimum Efficiency Requirement.

[150] This value was not provided in ASHRAE 90.1 2010, Table 6.8.1I and Table 6.8.1J, so Equation 3 in Appendix E was used to convert between SEER and EER.

[151] This value was not provided in ASHRAE 90.1 2010, Table 6.8. 1I and Table 6.8.1J, so Equation 4 in Appendix E was used to convert from EER to IEER.

Default Savings

No default savings will be awarded for this measure if the proper values are not provided in the customer application.

Source(s)

The primary sources for this deemed savings approach are the Maine Commercial TRM 2016 p. 47-48, the Mid-Atlantic TRM 2017 p. 396, and ASHRAE 90.1-2010, Table 6.8.1I and J – Electrically Operated Variable Refrigerant Flow Air Conditioners – Minimum Efficiency Requirement.

10.1.3 Electric Chillers

Measure Description

This measure relates to the installation of a new high-efficiency electric water chilling package (either water- or air-cooled types) in place of a standard efficiency electric water chilling package. For the baseline chiller efficiencies, refer to

Table 42 and Table 43 for the 2010 ASHRAE-90.1 specified minimum efficiencies. The installed chiller efficiency is taken from the customer application.

Savings Estimation Approach

Water-cooled Chillers

Gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh/year = Size\ in\ tons\ _{install} \times \left[\frac{kW}{ton_{base,IPLV}} - \frac{kW}{ton_{install,IPLV}}\right] \times FLH_{cool}$$

Gross coincident demand reductions are calculated according to the following equation:

$$\Delta kW = Size\ in\ tons_{install} \times \left[\frac{kW}{ton_{base,full\ load}} - \frac{kW}{ton_{install,full\ load}}\right] \times CF$$

Air-cooled Chillers

Gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh/year = Size\ in\ tons\ _{install} \times \left[\frac{12\ kBtuh/ton}{EER_{base,IPLV}} - \frac{12\ kBtuh/ton}{EER_{install,IPLV}}\right] \times FLH_{cool}$$

Gross coincident summer peak demand savings are calculated according to the following equation:

$$\Delta kW = Size\ in\ tons_{install} \times \left[\frac{12\ kBtuh/ton}{EER_{base,full\ load}} - \frac{12\ kBtuh/ton}{EER_{install,full\ load}}\right] \times CF$$

Where:

ΔkWh/year = gross annual electric energy savings

ΔkW = gross coincident demand reductions

Size in $tons_{install}$ = Cooling capacity of the installed chiller system, in tons

$EER_{base,IPLV}$, $kW/ton_{base,IPLV}$ = chiller system baseline efficiency at integrated part load value (IPLV), in kW/ton (for $kW/ton_{base,IPLV}$) assigned based on installed system capacity

$EER_{install,IPLV}$, $kW/ton_{install,IPLV}$ = chiller system installed efficiency at integrated part load value (IPLV), in kW/ton (for $kW/ton_{install,IPLV}$)

FLH_{cool} = annual cooling full load hours (FLH)

$EER_{basel,full\ load}$, $kW/ton_{base,full\ load}$ = chiller system baseline efficiency at full load, in kW/ton (for $kW/ton_{base,full\ load}$)

$EER_{installl,full\ load}$, $kW/ton_{install,full\ load}$ = chiller system installed efficiency at full load, in kW/ton (for $kW/ton_{install,full\ load}$)

CF = peak coincidence factor

Input Variables

Table 41: Input Values for Non-Residential Electric Chillers

Component	Type	Value	Unit	Source(s)
Size in $tons_{install}$	Variable	See customer application	ton	Customer application
$kW/ton_{base,full-load}$	Fixed	Use install system capacity to assign $kW/ton_{base,full-load}$ as per Table 43	kW/ton	ASHRAE 90.1 2010
$kW/ton_{base,IPLV}$	Fixed	Use install system capacity to assign $kW/ton_{base,IPLV}$ as per Table 43	kW/ton	ASHRAE 90.1 2010
$kW/ton_{install,full-load}$	Variable	See customer application.[152]	kW/ton	Variable
$kW/ton_{install,IPLV}$	Variable	See customer application.152	kW/ton	Variable
$EER_{base, full load}$	Variable	See customer application.[153] Default: Table 41	kBtu/kW	Customer Application; ASHRAE 90.1-2010
$EER_{Base, IPLV}$	Variable	See customer application.[153] Default: Table 41	kBtu/kW	Customer Application; ASHRAE 90.1-2010
$EER_{install, full load}$	Variable	See customer application.[153]	kBtu/kW	Customer application
$EER_{install, IPLV}$	Variable	See customer application.153	kBtu/kW	Customer application
FLH_{cool}	Variable	See Table 42	hours/year	Mid-Atlantic TRM 2017 p. 382, adjusted for Richmond, VA and Charlotte, NC based on TMY3 cooling degree days data. See adjustment in Table 130
CF	Fixed	0.923	-	Mid-Atlantic TRM 2017 p. 377

[152] When missing either the IPLV or the full load value, use the following efficiency relationship to replace the missing value: $kW/ton_{IPLV} = C \times kW/ton_{full\ load}$, where C=0.80 for water-cooled chillers <200 ton and C=0.95 for water-cooled chillers ≥200 ton.

[153] When missing either the IPLV or the full load value, use the following efficiency relationship to replace the missing value: $EER_{IPLV} = C \times EER_{full\ load}$, where C=0.76 for air-cooled chillers.

Table 42: Chiller Full Load Cooling Hours per Year[154]

Building Type	Baltimore, MD	Richmond, VA	Chorlette, NC
Education – Elementary and Middle School	743	873	963
Education – High School	369	433	478
Education – College and University[155]	780	916	1,010
Food Sales - Grocery	928	1,090	1,203
Food Sales – Convenience Store	928	1,090	1,203
Food Sales – Gas Station Convenience Store	928	1,090	1,203
Food Service - Full Service	928	1,090	1,203
Food Service - Fast Food	928	1,090	1,203
Health Care-inpatient	1,570	1,844	2,035
Health Care-outpatient	601	706	779
Lodging – (Hotel, Motel and Dormitory)	1,801	2,116	2,335
Mercantile (mall)	928	1,090	1,203
Mercantile (Retail, not mall)	928	1,090	1,203
Office – Small (<40,000 sq ft)	559	657	725
Office – Large (>= 40,000 sq ft)	603	708	782
Other	369	433	478
Public Assembly	369	433	478
Public Order and Safety (Police and Fire Station)	369	433	478
Religious Worship	369	433	478
Service (Beauty, Auto Repair Workshop)	928	1,090	1,203
Warehouse and Storage	810	952	1,050

[154] Baltimore, MD full load cooling hours taken from Mid-Atlantic TRM 2017 p.382 for different building types. Richmond VA and Charlotte NC hours are adjusted using cooling degree day estimates from TMY3 data from the weather stations Richmond International Airport, Charlotte Douglas International Airport. https://www.google.com/fusiontables/DataSource?docid=1EsB07O-9SiqyJDlzl69GO8jTHsomsNIpkA1SLL8#rows:id=1 , accessed June, 2017. See Appendix A for CDD and HDD.

[155] "Education – College and University" Baltimore, MD full load cooling hours is an average of the hours for "Education – Community College"(743 hours/year) and "Education – University" (816 hours/year) in the Mid-Atlantic TRM 2017, p. 382.

Table 43: Water Chilling Packages - Efficiency Requirement[156]

Equipment Type	Size Category	Units	Path A		Path B	
			Full Load	IPLV	Full Load	IPLV
Air Cooled Chillers	< 150 tons	EER	≥ 9.562	≥ 12.750	NA	NA
	≥ 150 tons	EER	≥ 9.562	≥ 12.750	NA	NA
Water-cooled, electrically operated, positive displacement	< 75 tons	kW/ton	≤ 0.780	≤ 0.630	≤ 0.800	≤ 0.600
	≥ 75 tons and < 150 tons	kW/ton	≤ 0.775	≤ 0.615	≤ 0.790	≤ 0.586
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.680	≤ 0.580	≤ 0.718	≤ 0.540
	≥ 300 tons	kW/ton	≤ 0.620	≤ 0.540	≤ 0.639	≤ 0.490
Water-cooled, electrically operated, centrifugal	≤ 150 tons	kW/ton	≥ 0.634	≤ 0.596	≤ 0.639	≤ 0.450
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.634	≤ 0.596	≤ 0.639	≤ 0.450
	≥ 300 tons and < 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.600	≤ 0.400
	≥ 600 tons	kW/ton	≤ 0.570	≤ 0.539	≤ 0.590	≤ 0.400
Water-cooled, unknown[157]	< 75 tons	kW/ton	≤ 0.780	≤ 0.630	≤ 0.800	≤ 0.600
	≥ 75 tons and < 150 tons	kW/ton	≤ 0.775	≤ 0.615	≤ 0.790	≤ 0.586
	≥ 150 tons and < 200 tons	kW/ton	≤ 0.680	≤ 0.580	≤ 0.718	≤ 0.540
	≥ 200 tons and < 300 tons	kW/ton	≤ 0.634	≤ 0.596	≤ 0.639	≤ 0.450
	≥ 300 tons and < 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.600	≤ 0.400
	≥ 600 tons	kW/ton	≤ 0.570	≤ 0.539	≤ 0.590	≤ 0.400

Note that some jurisdictions, such as New Jersey, provide a fixed estimate of full load cooling hours, while others provide several estimates of cooling hours based on factors such as facility

156 ASHRAE 90.1-2010, Table 6.8.1C - Water Chilling Packages - Efficiency Requirements. Consistent with International Energy Conservation Code 2009, Table 503.2.3(7) Water Chilling Packages, Efficiency Requirements, used in the 2017 Mid-Atlantic TRM. Compliance with this standard can be obtained by meeting the minimum requirements of Path A or Path B. However, both the full load and IPLV must be met to fulfill the requirements of Path A or Path B.

type, chiller type, chiller efficiency, or weather region. STEP follows a similar approach as used in Mid Atlantic TRM, i.e, assign the full load cooling hours of chiller by building type listed in Table 40.

In Table 43, the water chilling efficiency requirement from ASHRAE 90.1-2010, presents two paths of compliance for water-cooled chillers. Path A is intended for those project sites where the chiller application is primarily operating at full-load conditions during its annual operating period. Path B is intended for those project sites where the chiller application is primarily operating at part-load conditions during its annual operating period. Compliance with the code-specified minimum efficiency can be achieved by meeting the requirement of either Path A or Path B. However, both full-load and IPLV levels must be met to fulfill the requirements of Path A or Path B.

For application in Virginia and North Carolina region, chillers are expected to operate primarily at full-load conditions for a significant portion of their operating period. Therefore, the Path A efficiency is used for the baseline.

Default Savings

No default savings will be awarded for this measure if the proper values are not provided in the customer application.

Source(s)

The primary sources for this deemed savings approach are the Mid-Atlantic TRM 2017 p. 375-382, ASHRAE 90.1-2010, Table 6.8.1C - Water Chilling Packages - Efficiency Requirements.

10.1.4 Variable Frequency Drives

Measure Description

This measure defines savings that result from installing a variable frequency drive (VFD) control on a HVAC motor with application to: supply fans, return fans, exhaust fans, cooling tower fans, chilled water pumps, condenser water pumps, and hot water pumps. The HVAC application must also have a variable load and proper controls in place: feedback control loops to fan/pump motors and variable air volume (VAV) boxes on air-handlers. The algorithms and inputs to calculate energy and demand reductions for VFDs are provided below. The baseline equipment fan/pump type should be determined from the program application, if available. Otherwise, the minimum savings factors will be applied. For all known types, the energy savings calculations will include the following baseline applications:

Fans

- Constant Volume (CV)Fan
- Airfoil / Backward-Inclined (AF / BI) Fan
- Airfoil / Backward-Inclined w/Inlet Guide Vanes (AF / BI IGV) Fan
- Forward Curved (FC) Fan
- Forward Curved w/Inlet Guide Vanes (FC IGV) Fan
- Unknown (Default)

Pumps

- Chilled Water Pump (CHW-Pump)
- Condenser Water Pump (CW-Pump)
- Hot Water Pump (HW-Pump)
- Unknown (Default)

This measure is offered in both the Non-Residential Heating and Cooling Efficiency program as well as the Non-Residential Small Business Improvement program, described in Section 15.

Savings Estimation Approach

Gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh/year = \frac{HP \text{ x } 0.746 \text{ x LF}}{\eta} \times HOU \times ESF$$

Gross coincident demand reductions are calculated according to the following equation:

$$\Delta kW = \frac{HP \text{ x } 0.746 \text{ x LF}}{\eta} \times CF \times DSF$$

Where:

ΔkWh/year = gross annual electric energy savings
ΔkW = gross coincident demand reductions

HP = motor horse power
LF = motor load factor (%) at fan design CFM or pump design GPM
η = NEMA-rated efficiency of motor
HOU = annual hours of operation
ESF = energy savings factor (ESF)
CF = peak coincidence factor
DSF = demand savings factor (DSF)

Input Variables

Table 44: Input Values for Non-Residential Variable Frequency Drives

Component	Type	Value	Unit	Source(s)
HP	Variable	See customer application.	horsepower	Customer application
η	Variable	Default see Table 45.	-	NEMA Standards Publication Condensed MG 1-2007
ESF	Fixed	See Table 46.	-	Mid-Atlantic TRM 2015 p. 370; Mid-Atlantic TRM 2016 p. 414
DSF	Fixed	See Table 46.	-	Mid-Atlantic TRM 2015 p. 370; Mid-Atlantic TRM 2016 p. 414
HOU	Variable	Table 47. For condenser water pumps, use the same operating hours as chilled water pumps.	hours/year	Mid-Atlantic TRM 2016 p. 465-413
CF	Fixed	0.28 for fan applications 0.55 for pump applications	-	Mid-Atlantic TRM 2015 p. 370; Mid-Atlantic TRM 2016 p. 412
LF	Variable	If actual motor load factor unknown, use 0.65	-	Mid Atlantic TRM 2017, p. 367 and 369

Table 45: Baseline Motor Efficiency[158]

Horsepower (HP)	η
1	0.855
1.5	0.865
2	0.865
3	0.895
5	0.895
7.5	0.917
10	0.917
15	0.924
20	0.930
25	0.936
30	0.936
40	0.941

[158] NEMA Standards Publication Condensed MG 1-2007 - Information Guide for General Purpose Industrial AC Small and Medium Squirrel-Cage Induction Motor Standards. Assumed Totally Enclosed Fan-Cooled (TEFC), Premiums Efficiency, 1800 RPM (4 Pole).

Horsepower (HP)	η
50	0.945
60	0.950
75	0.954
100	0.954
125	0.954
150	0.958
200	0.962
250	0.962
300	0.962
350	0.962
400	0.962
450	0.962
500	0.962

Table 45 (above) is consistent with the minimum federal accepted motor efficiencies provided by the National Electrical Manufacturers Association (NEMA).[159]

Table 46: Savings Factors by Application

VFD Applications	ESF	DSF
Unknown VFD (Minimum)[160]	0.123	0.039
HVAC Fan VFD Savings Factors[161]		
Constant Volume	0.717	0.466
Airfoil / Backward Inclined (AF/BI-Fan)	0.475	0.349
Airfoil / Backward Inclined w/Inlet Guide Vanes (AF/BI IGV-Fan)	0.304	0.174
Forward Curved (FC-Fan)	0.240	0.182
Forward Curved w/Inlet Guide Vanes (FC IGV-Fan)	0.123	0.039
Unknown Fan (Average)	0.372	0.242
HVAC Pump VFD Savings Factors[162]		
Chilled Water Pump	0.633	0.460
Hot Water Pump	0.652	0.000
Unknown/Other Pump (Average)[163]	0.643	0.230

[159] Refer to NEMA Standards Publication Condensed MG 1-2007 - Information Guide for General Purpose Industrial AC Small and Medium Squirrel-Cage Induction Motor Standards and Table 52 'Full-Load Efficiencies for 60 Hz NEMA Premium Efficiency Electric Motors Rated 600 Volts or Less (Random Wound)' in the above mentioned NEMA Standard.

[160] Assigned for applications such as compressors, based on DNV GL research and judgement.

[161] Mid-Atlantic TRM 2015 p. 370

[162] Mid-Atlantic TRM 2017, p. 372.

[163] Assigned for pumps not specifically in this table, such as condenser water pump.

Table 47: Variable Frequency Drive Annual Operating Hours by Facility Type[164]

Building Type	Fan Motor Hours	Chilled Water Pumps	Heating Pumps
Education – Elementary and Middle School	2,187	1,205	3,229
Education – High School	2,187	1,205	3,229
Education – College and University	2,187	1,205	4,038
Food Sales - Grocery	4,055	1,877	5,376
Food Sales – Convenience Store	6,376	2,713	5,376
Food Sales – Gas Station Convenience Store	6,376	2,713	5,376
Food Service - Full Service	4,182	1,923	5,376
Food Service - Fast Food	6,376	2,713	5,376
Health Care - Inpatient	7,666	3,177	8,760
Health Care - Outpatient	3,748	1,767	5,376
Lodging – (Hotel, Motel and Dormitory)	3,064	1,521	5,376
Mercantile (Mall)	4,057	1,878	2,344
Mercantile (Retail, not Mall)	4,833	2,157	5,376
Office – Small (<40,000 sq ft)	3,748	1,767	3,038
Office – Large (≥ 40,000 sq ft)	3,748	1,767	3,038
Other	2,857	1,446	5,376
Public Assembly	1,952	1,120	5,376
Public Order and Safety (Police and Fire Station)	1,952	1,120	5,376
Religious Worship	1,955	1,121	5,376
Service (Beauty, Auto Repair Workshop)	1,949	1,119	5,376
Warehouse and Storage	2,602	1,354	-

Default Savings

No default savings will be awarded for this measure if the proper values are not provided in the customer application.

Source(s)

The primary sources for this deemed savings approach are Mid-Atlantic TRM 2015, p. 367-371 (for fans) and Mid-Atlantic TRM 2017, p. 366-373 (for pumps).

[164] Mid-Atlantic TRM 2017, p. 370-372. The facility hours have been mapped from a facility type list in the United Illuminating Company and Connecticut Light & Power Company. 2012. Connecticut Program Savings Document – 8th Edition for 2013 Program Year. Orange, CT.

10.1.5 Dual Enthalpy Air-side Economizers

This measure is offered under the Virginia Non-Residential Heating and Cooling Efficiency program as a new installation of an economizer or a retrofit add-on project, in the Non-Residential Energy Audit program as a retrofit of an existing economizer (Section 11.4.1), and in the Non-Residential Small Business Improvement program (Section 15) as either new installation or retrofit. They all use the same protocol provided below.

Measure Description

Non-Residential Heating and Cooling Efficiency Program

This measure involves the installation of a dual enthalpy economizer to provide free cooling during the appropriate ambient conditions. Dual enthalpy economizers are used to control a ventilation system's outside air intake in order to reduce a facility's total cooling load. The economizer operation controls the outside air and return air flow rate by monitoring the outside air temperature (sensible heat) and humidity (latent heat), and provides free cooling in place of mechanical cooling. This reduces the demand on the cooling system, lowering its usage hours, saving energy. This measure applies only to retrofits or newly installed cooling units with factory installed "dual-enthalpy" economizer controller.

The baseline condition is the existing HVAC system without economizer. The efficient condition is the HVAC system with functioning dual enthalpy economizer control.

Non-Residential Energy Audit Program

This measure realizes energy savings by repairing dual enthalpy economizers to provide free cooling during the appropriate ambient conditions. This measure applies only to retrofits. The baseline condition is the existing HVAC system with a malfunctioning dual enthalpy economizer control, that acts effectively as a system without an economizer. The efficient condition is the HVAC system with a properly functioning dual enthalpy economizer control.

Non-Residential Small Business Improvement Program

As mentioned in the program description section, this program allows for either the installation of a new dual enthalpy economizer as described in the Non-Residential Heating and Cooling Efficiency measure description or repairing an existing dual enthalpy economizer as described in the Non-Residential Energy Audit Program measure description section, above.

Savings Estimation Approach

Gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh/year = Tons \times SF$$

Gross coincident demand reductions are assigned as follows:

$\Delta kW^{165} = 0$

Where:

ΔkWh/year = gross annual electric energy savings
ΔkW = gross coincident demand reductions

Tons = HVAC system tonnage capacity

SF = savings factor for the installation of dual enthalpy economizer control [kWh/ton]

Demand savings are assumed to be zero because the economizer will typically not be operating during the peak period.

Input Variables

Table 48: Input Values for Economizer Repair Savings Calculations

Component	Type	Value	Unit	Source(s)
Tons	Variable	See customer application.	tons	Customer application
SF	Variable	See Table 49.	-	Mid-Atlantic TRM 2017, p. 393

Table 49. Economizer Energy Savings Factors (kWh/ton) for Virginia and North Carolina.[166]

Savings Factors (kWh/ton)	Baltimore, MD	Richmond, VA	Charlotte, NC
Education[167]	39	35	32
Education – College and University			
Education – High School			
Education – Elementary and Middle School			
Food Sales[168]	57	52	46
Food Sales – Convenience Store			
Food Sales – Gas Station Convenience Store			

165 Mid Atlantic TRM 2017, p. 391

166 Mid Atlantic TRM 2017, p. 393 lists savings factor for installation of dual enthalpy economizer. Mid Atlantic TRM does not have savings factor for VA or NC, therefore Baltimore,MD savings factors are used to calculate them.Richmond VA and Charlotte NC values are calculated from Baltimore,MD savings factors and degree days (DD-65°F = HDD + CDD) using TMY3 data for weather stations at Baltimore BLT-Washington International AP (Weather station number 724060; CDD = 1,233, HDD = 4,600), Richmond International AP (Weather station number 724010; CDD = 1,448, HDD = 3,849), and Charlotte Douglas International Airport (Weather station number 723140; CDD = 1,598, HDD = 3,140).

167 All education building types in the STEP Manual were mapped to savings factors for the "Primary School" building type listed in the Mid-Atlantic TRM 2017, p. 393.

168 All food sales, service (beauty, auto repair workshop) and mercantile (mall) building types in the STEP Manual were mapped to savings factors for the "Small Retail" building type listed in the Mid-Atlantic TRM 2017, p. 393.

Savings Factors (kWh/ton)	Baltimore, MD	Richmond , VA	Charlotte , NC
Service (Beauty, Auto Repair Workshop)			
Food Service[169]			
Food Service - Full Service	29	26	24
Food Service - Fast Food[170]	37	34	30
Food Sales - Grocery[171]	57	52	46
Mercantile (Retail, not mall)			
Mercantile (mall)	57	52	46
Office – Small (<40,000 sq ft)[172]	57	52	46
Office – Large (>= 40,000 sq ft)			
Public Assembly	25	23	20
Religious Worship	6	5	5
Warehouse and Storage	2	2	2
Other[173]	57	52	46
Lodging – (Hotel, Motel and Dormitory)			
Health Care - outpatient			
Health Care - inpatient			
Public Order and Safety (Police and Fire Station)			

Default Savings

If the proper values are not supplied, a default savings may be applied using conservative input values. Default hours of use will be taken from the above chart if the building type is available.

The default gross coincident demand reductions will be assigned as follows:

$$\Delta kW = 0$$

Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2017, p. 391-393.

[169] All general food service and food service-full service building types in the STEP Manual were mapped to savings factors for the "Full Service Restaurant" building type listed in the Mid-Atlantic TRM 2017, p. 393.

[170] Food service – fast food building types in the STEP Manual were mapped to savings factors for the "Fast Food" building type in the Mid-Atlantic TRM 2017, p. 393.

[171] Food-sales-grocery and mercantile (retail, not mall) building types in the STEP Manual were mapped to the "Big Box Retail" building type listed in the Mid-Atlantic TRM 2017, p. 393.

[172] Office – small (< 40,000 sq ft) and office – large (>= 40,000 sq ft) building types in the STEP Manual were mapped to savings factors for the "Small Office" building types in the Mid-Atlantic TRM 2017, p. 393.

[173] Other, lodging – (hotel, motel and dormitory), health care-outpatient, healthcare-inpatient, public order and safety (police and fire station) building types in the STEP Manual were mapped to the "Other" building type in the Mid-Atlantic TRM 2017, p. 393.

11 NON-RESIDENTIAL ENERGY AUDIT PROGRAM

Dominion's Non-Residential Energy Audit program provides incentives to building owners who work with a Dominion-approved energy auditor to identify potential electric energy savings and implement the incented measures. The incented measures include the following:

- Light Emitting Diode (LED) Case Lighting
- LED Exit Sign
- LED Reflector Lamp & A-line LED
- Occupancy Sensor
- Reach-In Unit Occupancy Sensor
- ENERGY STAR® Software
- Plug Load Occupancy Sensor
- Smart Strip
- Anti-Sweat Heat Control, Door Heater Control (Cooler and Freezer)
- Door Closer (Cooler and Freezer)
- Refrigeration Coil Cleaning
- Door Gasket (Cooler and Freezer)
- ECM Evaporator (Display Case and Walk-in)
- Evaporator Fan Control (Cooler and Freezer)
- Floating Head Pressure Control
- Refrigeration Night Cover
- Strip Curtain (Cooler and Freezer)
- Suction Pipe Insulation (Cooler and Freezer)
- Vending Machine Miser (Refrigerated, Non-Refrigerated and Glass Front Refrigerated)
- Zero-Heat Reach-In Glass Door
- Economizer Repair

At a higher level, all refrigeration measures that reference COP values, use COP efficiencies for low, medium and high temperature refrigeration systems taken from the Pennsylvania Technical Reference Manual (PA TRM), June 2016 version. Initially, when developing the savings equations for these measures, DNV GL evaluated COP values given in the Pennsylvania TRM (2014 version) and the Vermont TRM (2013 version), references used by measures in this version of the STEP Manual. It was determined that the COP values in the Pennsylvania TRM are representative of refrigeration system efficiencies that may be found in Dominion's service territory.