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Evaluation, Measurement, and Verification Report for Virginia Electric and Power Company (Dominion Energy)

Case No. PUR-2019-00201 (Virginia)
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Prepared by DNV Energy Insights USA Inc. (DNV)

Appendix F2 Standard Tracking and Engineering Protocols Manual for Non-residential Programs

Virginia and North Carolina

Protocols to Track Demand-Side Management Programs (DSM) Resource Savings

Version 2020 (Updated from STEP Version 10.0)

Prepared by DNV Energy Insights USA Inc.

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1 NON-RESIDENTIAL LIGHTING SYSTEMS AND CONTROLS PROGRAM, DSM PHASE III

The Non-Residential Lighting Systems and Controls Program is for DSM Phase III. It has been offered in Virginia since its inception in August 1, 2014 and in North Carolina since January 1, 2015. The program provides incentives to non-residential customers who install new lighting systems or retrofit existing lighting systems with more efficient systems, and/or install lighting sensors and controls.

Eligible measures defined under the Non-Residential Lighting Systems and Controls Program (DSM III) are shown in Table 1-1.

Table 1-1: Non-residential Lighting Systems and Controls Program DSM Phase III Measure List

End-Use	Measure	Manual Section
Lighting	Lighting, Fixtures, Lamps, and Delamping including T8s, T5s, LEDs, and CFLs	Section 1.1.1
	Occupancy Sensors & Controls	Section 1.1.2
	Reach-in Unit Occupancy Sensor	Section 1.1.3

1.1 Lighting End Use

1.1.1 Lighting Fixtures, Lamps, and Delamping

1.1.1.1 Measure Description

This measure realizes energy savings by installing reduced wattage lamp/ ballast systems that have higher lumens per watt than existing systems. The savings estimation method is applied to T8, T5, LED, or CFL lamps/ ballasts installations.

The measure also covers delamping of existing lighting systems. Delamping includes removal of one or more lamps in a fixture (e.g., removing two lamps out of four lamp fixtures), or removal of the entire fixture itself, so that there is no longer a connected load. Similarly to lamp and fixture retrofit calculations, changes in load due to delamping are tracked through the difference between baseline and installed wattage.

Gross coincident demand reductions for delamping measures are included in PJM EE Resource nominations when reflectors or tombstones are installed since these are defined as persistent.

This measure is offered in the Non-Residential Lighting Systems and Controls program, Non-Residential Lighting Systems and Controls Program, DSM Phase VII and the Non-Residential Small Business Improvement program (Section 5).

1.1.1.2 Savings Estimation Approach

Retrofit:

Per measure, gross annual electric energy savings are calculated according to the following equation:

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$$\Delta kWh = \frac{(Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee}) \times HOU \times WHF_e \times ISR}{1{,}000\, {}^{W}/_{kW}}$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \frac{(Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee}) \times CF \times WHF_d \times ISR}{1{,}000\, {}^{W}/_{kW}}$$

New construction:

When developing STEP Manual 9.0.0 (year-end 2018), DNV used existing program data from Virginia and North Carolina Non-Residential Lighting Systems and Controls program participants to generate a list of ratios for each eligible measure type that is used as a multiplier to be applied to the customer provided installed quantity times installed wattage to estimate a baseline default wattage times quantity for new construction measures, where no baseline information is available. The default ratios were generated using the following variables from available lighting retrofit measure records for all program particiapnts through the end of 2018.

- Installed energy-efficient (ee) wattage
- Installed energy-efficient (ee) quantity
- Baseline (base) wattage
- Baseline (base) quantity

DNV collaborates with the Company during program launch to specify the required data fields that implementers should collect for evaluation purposes. At the end of 2017, years after program launch, there were sufficient new construction records that it was necessary to identify a deemed savings method specific to those records. The Mid-Atlantic TRM deemed savings method for new construction projects could not be appropriately applied using the collected data (designed for retrofit projects). Therefore, DNV implemented the method described below.

$$\Delta kWh = \frac{Qty_{ee} \times watts_{ee} \times (Ratio - 1) \times HOU \times WHF_e \times ISR}{1{,}000\, {}^{W}/_{kW}}$$

$$\Delta kW = \frac{Qty_{ee} \times watts_{ee} \times (Ratio - 1) \times CF \times WHF_d \times ISR}{1{,}000\, {}^{W}/_{kW}}$$

$$Ratio = \frac{Qty_{base} \times watts_{base}}{Qty_{ee} \times watts_{ee}}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reductions
Qty_{base} = quantity of existing or baseline fixtures/lamps
Qty_{ee} = quantity of installed energy-efficient (ee) fixtures/lamps

$watts_{base}$ = load of the existing or baseline fixture/lamp on a per unit basis
$watts_{ee}$ = load of installed energy-efficient (ee) fixture/lamps on a per unit basis
Ratio = ratio of the installed condition to the baseline condition for new construction
HOU = annual operating hours of use for fixtures/lamps
WHF_e = waste heat factor for energy to account for cooling savings from efficient lighting
WHF_d = waste heat factor for demand to account for cooling savings from efficient lighting
CF = coincidence factor
ISR = in-service rate is the percentage of rebated measures actually installed

1.1.1.3 Input Variables

Table 1-2: Input Values for Lighting Fixtures, Lamps, and Delamping Savings Calculations

Component	Type	Value	Unit	Source(s)
Qty_{base}	Variable	See customer application	-	Customer application
Qty_{ee}	Variable	See customer application	-	Customer application
$watts_{base}$	Variable	See customer application	watts	Customer application
$watts_{ee}$	Variable	See customer application	watts	Customer application
Ratio	Variable	For default values, see Table 1-3:	-	Dominion Energy non-residential lighting systems and controls participant data through year-end 2019
CF	Variable	Measure with “24/7” or “exterior” in fixture name, treat as “LED Exit Sign“ in Table 10-14 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Mid-Atlantic 2019, pp. 315, 351, 369, and 391[1]
HOU	Variable		hours, annual	Mid-Atlantic 2019, pp. 315, 351, 369, 391
WHF_e	Variable	Measure without “exterior” or “24/7” in fixture name, treat as “interior” in Table 10-15 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Mid-Atlantic TRM 2019 pp. 587-588[2]
WHF_d	Variable		-	Mid-Atlantic TRM2019 pp. 587-588[3]
ISR	Fixed	1.00	-	Mid-Atlantic TRM 2019, p. 319[4]

1 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.
2 Waste heat factor used 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).
3 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).
4 Mid-Atlantic TRM 2019, p. 319 footnote 737 EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

Table 1-3: Default Ratio to be Multiplied with Baseline Quantity[5] to Calculate Baseline Lighting Wattage

Installed (ee) Fixture	Baseline (base) Fixture	Ratio
T8 - 2 - 2ft 17watt Lamps with Reflector & NB	62W – 420W T8 2 Bi-ax Lamps in 2x2, 2U-bends	2.3
T8 - 3 - 2ft 17watt Lamps with Reflector & NB	58W – 96W T8 2 Bi-ax Lamps in 2x2, 2U-bends	1.6
T8 Enclosed Fixture - 2 Lamp NB No Reflector 24/7	68W – 175W HID	2.6
T8 Enclosed Fixture - 3 Lamp NB No Reflector 24/7	23W – 308W HID	2.9
T8 Enclosed Fixture - 4 Lamp HB Miro Reflector[6]	T8 – 4ft 4 Lamp	N/A[7]
T8 High-Bay - 4ft 3 lamp	34W – 320W HID	2.4
T8 High-Bay - 4ft 4 lamp	117W – 456W HID	2.3
T8 High-Bay - 4ft 6 lamp	156W – 465W HID	2.2
T8 High-Bay - 4ft 8 lamp	400W – 465W HID	1.6
T8 High-Bay - Double Fixture 4ft 6 lamp	47W – 1,160W HID	2.8
T8 High-Bay - Double Fixture 4ft 8 lamp	1,060W HID	1.8
LW HPT8 4ft 1 lamp	30W – 135W T8	3.8
LW HPT8 4ft 2 lamp	30W – 218W T8	2.3
LW HPT8 4ft 3 lamp	32W – 190W T8	1.4
LW HPT8 4ft 4 lamp	32W – 226W T8	1.5
HPT8 T8 4ft 2 lamp	80W – 207W T12HO – 8ft 1 Lamp	2.0
HPT8 T8 4ft 4 lamp	30W – 516W T12HO – 8ft 2 Lamp	2.0
T5 HO Enclosed - 1 lamp 24/7	75W – 100W HID	N/A[7]
T5 HO Enclosed - 2 lamp 24/7	150W – 175W HID	N/A[7]
T5 HO Enclosed - 3 lamp 24/7	250W HID	N/A[7]
2 Lamp T5 28W 24/7	75W – 150W HID	N/A[7]
T5 HO Enclosed - 2 lamp Miro Reflector 24/7	250W HID	N/A[7]
T5 2 - 2ft lamps 24 watts	116W HID	2.1
T5 3 - 2ft lamps 24 watts	150W HID	N/A[7]
T5 4 - 2ft lamps 24 watts	175W HID	N/A[7]

5 Use the default New Fixture Type, if there is no ratio available for the specific new fixture type.
6 MIRO® is a registered trademark of Alanode. http://www.simkar.com/wp-content/uploads/2015/08/MIRO.pdf . Accessed 11/20/2018.
7 Use the default ratio for the "Default" Installed (ee) Fixture Type when there is no ratio available for the specific new fixture type.

Installed (ee) Fixture	Baseline (base) Fixture	Ratio
T5 3 - 4ft HO Lamps	250W – 296W HID	1.3
T5 HO - Highbay 2L	250WHID	2.2
T5 HO - Highbay 3L	295W HID	1.9
T5 HO - Highbay 4L	250W – 488W HID	2.2
T5 HO - Highbay 6L	324W - 508W HID	1.5
T5HO - Double fixture Highbay 5L	1,000W HID	N/A[7]
T5HO - Double Fixture Highbay 6L	1,000W HID	1.5
CFL - Screw In (bulb only) - <30W	65W – 100W Incandescent (EISA Standard)	3.6
CFL - Screw In (bulb only) - 30W or greater	40W – 75W Incandescent (EISA Standard)	4.0
CFL - Fixture/Wallpack	178W – 452W HID	5.1
CFL - Hardwired fixture	Incandescent (EISA Standard)	N/A[7]
LED Exit Signs	3W – 150W Incandescent Standard Exit Sign	9.5
LED Downlight Fixture >=31W	53W – 100W Incandescent	3.5
LED Downlight 13-30W (excludes screw-in lamps)	12W – 500W Incandescent Downlight(EISA Standard)	6.0
LED 2X4 FIXTURE (39-80W)	32W – 458W 2x4 T8 Fluorescent	3.1
LED Fixture (2x2 or 1x4)	28W – 456W 2 2x2 Bi-ax Lamps, 2U-bends, 2L 4ft T8	2.5
LED Lamps (<= 7W)	5W – 167W Halogen, 25W – 252W Incandescent	7.8
LED Lamps (>7W up to 12W) (excludes screw-in lamps)	14W – 240W Halogen	5.3
LED or Induction HE	32W – 1,408W HID	3.0
LED or Induction HE Exterior	30W – 1,610W HID	3.2
LED or Induction HE Garage	150W – 1,123W HID	4.1
T8 to HPT8 Conver, reduce bulbs, add reflector	28W – 458W T8	3.8
LED Exterior New Fixture	35W – 1,610 HID	4.2
LED Interior New Fixture	775W – 1,190W HID	4.0
LED Exterior	160W – 1,150W HID	3.7
LED 24/7	12W – 352W T5, 44W – 244W T8	1.9
LED	9W – 360W CFL, 63W – 464W HID, 16W – 150W Incandescent, 13W – 256W T8	4.2

Installed (ee) Fixture	Baseline (base) Fixture	Ratio
LED Highbay	196W – 456W T5, 107W – 363W T8	2.1
LED Panels	34W – 350W T8	2.1
LED Panels on Belly Pan	30W – 240W T8	2.2
LED Reach-in Refrigerated Case Lighting	15W – 565W T8	3.1
LED Screw In	30W – 300W Halogen, 14W – 400W Incandescent	5.9
LW HPT8 – 4ft 2 Lamp with Reflector and Delamp	59W – 190W T8	2.1
LW HPT8 – 4ft 3 Lamp with Reflector and Delamp	144W – 190W T8	3.1
LW HPT8 – 4ft 1 Lamp with Reflector and Delamp	48W – 80W T8	2.0
LED – 4 linear 4ft Tube/Bar	12W – 263W T8 – 4ft 4 Lamp	2.9
LED – 3 linear 4ft Tube/Bar	47W – 175W T8 – 4ft 3 Lamp	2.1
LED – 2 linear 4ft Tube/Bar	22W – 262W T8 – 4ft 2 Lamp	2.3
LED – 1 linear 4ft Tube/Bar	18W – 172W LED – 1 Linear 4ft Tube/Bar T8 – 4ft 1 Lamp	2.3
LED – 1 linear 4ft Tube/Bar – 1 T8 Delamp	30W – 150W LED – 1 Linear 4ft Tube/Bar T8 – 4ft 1 Lamp	3.2
LED – 2 linear 4ft Tube/Bar – 1 T8 Delamp	58W – 149W T8 – 4ft 2 Lamp	2.5
LED – 3 linear 4ft Tube/Bar – 1 T8 Delamp	93W – 172W T8 – 4ft 3 Lamp	2.6
LED – 2 linear 4ft Tube/Bar – 2 T8 Delamp	60W – 277W T8 – 4ft 4 Lamp	3.5
LED Linear/Bar	17W – 160W T8	2.2
Default[8]		3.1

1.1.1.4 Default Savings

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

1.1.1.5 Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2019, pp. 314-325, 351, 369, 391, and 587-588.

1.1.1.6 Update Summary

Changes to this section are described in Table 1-4.

[8] The default fixture type is based on a weighted average of the ratios for all fixture types in the table.

Table 1-4: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM
	Input Variable	• Established default ratios to be used to calculate baseline wattage for 2019 measures by using 2018 tracking data

1.1.2 Occupancy Sensors and Controls

1.1.2.1 Measure Description

This measure defines the savings associated with installing occupancy sensors at wall-, fixture-, or remote-mounted that 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 DSM Phase II as well as the Non-Residential Small Business Improvement program, described in Section5.

1.1.2.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = Qty_{sensors} \times \frac{watts_{connected}}{1{,}000 \, {}^{W}/_{kW}} \times HOU \times SVG_e \times ISR \times WHF_e$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = Qty_{sensors} \times \frac{watts_{connected}}{1{,}000 \, {}^{W}/_{kW}} \times SVG_d \times ISR \times WHF_d \times CF$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reductions
$Qty_{sensors}$ = number of occupancy sensors installed
watts = connected load on lighting sensor/control
HOU = hours of use per year
SVG_e = percentage of annual lighting energy saved by lighting control
SVG_d = percentage of lighting demand saved by lighting control
WHF_e = waste heat factor for energy to account for cooling savings from efficient lighting
WHF_d = waste heat factor for demand to account for cooling savings from efficient lighting
CF = coincidence factor
ISR = in-service rate is the percentage of rebated measures actually installed

1.1.2.3 Input Variables

Table 1-5: 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 10-14 or Table 10-15 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	hours/year	Mid-Atlantic TRM 2019, p. 582
$Qty_{sensors}$	Variable	See customer application	-	Customer application
SVG_e	Fixed	0.28	-	Mid-Atlantic TRM 2019, p. 326
SVG_d	Fixed	0.14	-	Mid-Atlantic TRM 2019, p. 327
CF	Variable	See Table 10-15 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Mid-Atlantic TRM 2019, p. 586
WHF_e[9]	Variable	See Table 10-15 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Mid-Atlantic TRM 2019, pp. 587-588
WHF_d[10]	Variable	See Table 10-15 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Mid-Atlantic TRM 2019, pp. 587-588
ISR	Fixed	1.00	-	Mid-Atlantic TRM 2019, p. 327

1.1.2.4 Default Savings

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

1.1.2.5 Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic 2019, pp. 326-329, 582, 586-588.

[9] 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).

[10] 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).

1.1.2.6 Update Summary

The changes to this section, compared with last year, are described in Table 1-6.

Table 1-6: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM

1.1.3 Reach-In Unit Occupancy Sensor

1.1.3.1 Measure Description

This measure realizes energy savings by adding occupancy sensors to reach-in refrigerated 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.

1.1.3.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = Qty_{sensors} \times \frac{watts}{1{,}000\frac{W}{kW}} \times OSS \times HOU \times WHF_e$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = Qty_{sensors} \times \frac{watts}{1{,}000\frac{W}{kW}} \times OSS \times WHF_d \times CF$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reductions
$Qty_{sensors}$ = number of occupancy sensors installed
watts = connected lighting load controlled by occupancy sensor
OSS = occupancy sensor savings, resulting from a reduction in operating hours
WHF_e = Waste Heat Factor for Energy; represents the increased savings due to reduced waste heat from lights that must be rejected by the refrigeration equipment
WHF_d = Waste Heat Factor for Demand; represents the increased savings due to reduced waste heat from lights that must be rejected by the refrigeration equipment
HOU = annual lighting hours of use
CF = peak coincidence factor

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1.1.3.3 Input Variables

Table 1-7: 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 for 5-foot lamp
$Qty_{sensors}$	Variable	See customer application	-	Customer application
OSS	Fixed	0.307	-	Efficiency Maine Commercial TRM 2019, p. 34[11]
HOU	Variable	See Table 10-15 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factorsfor grocery building type	hours (annual)	Mid-Atlantic TRM 2019, p. 525[12]
WHF_e	Fixed	Low Temp (-35˚F - -1˚F): 1.52 Med Temp (0˚F - 30˚F): 1.52 High Temp (31˚F - 55˚F): 1.41	-	Mid-Atlantic TRM 2019, p. 388
WHF_d	Fixed	Low Temp (-35˚F - -1˚F): 1.51 Med Temp (0˚F - 30˚F): 1.51 High Temp (31˚F - 55˚F): 1.40	-	Mid-Atlantic TRM 2019, p. 388
CF	Fixed	0.96	-	Mid-Atlantic TRM 2019, p. 389[13]

1.1.3.4 Default Savings

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

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

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

[11] 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.

[12] 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 2019.

[13] CF_{SSP} value for "grocery" building type.

$$= \frac{38\,watts}{1{,}000\,\frac{W}{kW}} \times 0.307 \times 7{,}272\,hours \times 1.41$$

$$= 120\,kWh$$

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

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

$$= \frac{38\,watts}{1{,}000\,\frac{W}{kW}} \times 0.307 \times 1.40 \times 0.96$$

$$= 0.016\,kW$$

1.1.3.5 Source(s)

The primary sources for this deemed savings approach are the Efficiency Maine Commercial TRM 2019, pp. 34-35, and Mid-Atlantic TRM 2019, pp. 387-389 and 525.

1.1.3.6 Update Summary

The changes to this section, compared with last year, are described in Table 1-8.

Table 1-8: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM and Maine Commercial TRM

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2 NON-RESIDENTIAL LIGHTING SYSTEMS AND CONTROLS PROGRAM, DSM PHASE VII

The Non-Residential Lighting Systems and Controls Program is for DSM Phase VII. It has been offered in Virginia since 2019; it is not yet offered in North Carolina. The program provides incentives to non-residential customers who install new or retrofit existing lighting systems with more efficient lighting systems and/or install lighting sensors and controls.

Eligible measures defined under the Non-Residential Lighting Systems and Controls Program DSM Phase VII are shown in Table 2-1.

Table 2-1: Non-residential Lighting Systems and Controls Program (DSM VII) Measure List

End-Use	Measure	Legacy Program	Manual Section
Lighting	Lighting, Fixtures, Lamps, and Delamping including T8s, T5s, LEDs, and CFLs	Retrofits & Delamping: Non-residential Lighting Systems and Controls, DSM III	Section 2.1.1
		New Construction: unrelated (uses new methodology)	
	Occupancy Sensors & Controls	Non-residential Lighting Systems and Controls, DSM III	Section 2.1.2
	Occupancy Sensors & Controls, Stairwell-integrated Occupancy Sensor	N/A	Section 2.1.3
	Reach-in Unit Occupancy Sensor	Non-residential Lighting Systems and Controls, DSM III	Section 2.1.4

2.1 Lighting End Use

2.1.1 Lighting Fixtures, Lamps, and Delamping

2.1.1.1 Measure Description

This measure realizes energy savings by installing reduced-wattage lamp/ ballast systems that have higher lumens per watt than existing systems. The savings estimation method is applied to lighting involving T8, T5, LED, or CFL lamps/ballasts. The baseline is assumed to be a Bulged Reflector (BR) lamp of a standard BR30-type.

The measure also covers delamping of existing lighting systems. Delamping includes removal of one or more lamps in a fixture (e.g., removing two lamps out of a four-lamp fixture) or removal of the entire fixture itself that results in either a reduced or eliminated connected load. Similar to lamp and fixture retrofit calculations, changes in load due to delamping are tracked through the difference between baseline and installed wattages. The baseline will vary with pre-existing characteristics.

Gross coincident demand reductions for delamping measures are included in PJM EE Resource nominations when reflectors or tombstones are installed since these are defined as persistent.

This measure is offered in the Non-Residential Lighting Systems and Controls program DSM Phase VII and the Non-residential Small Business Improvement program (Section 5).

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2.1.1.2 Savings Estimation Approach

Retrofit/Replace-on-burnout/Exit signs/Exterior:

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = \frac{(Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee}) \times HOU \times WHF_e \times ISR}{1{,}000 \, {}^{W}/_{kW}}$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \frac{(Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee}) \times CF \times WHF_d \times ISR}{1{,}000 \, {}^{W}/_{kW}}$$

New construction interior:

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = \left(\frac{LPD_{base}}{LPD_{ee}} - 1\right) \times watts_{ee} \times Qty_{ee} \times HOU \times WHF_e \times ISR \times \frac{1\ kW}{1{,}000\ W}$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \left(\frac{LPD_{base}}{LPD_{ee}} - 1\right) \times watts_{ee} \times Qty_{ee} \times WHF_d \times ISR \times CF \times \frac{1\ kW}{1{,}000\ W}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reductions
LPD_{base} = baseline lighting power density
LPD_{ee} = efficient lighting power density
Qty_{base} = quantity of existing or baseline fixtures/lamps
Qty_{ee} = quantity of installed energy-efficient (ee) fixtures/lamps
$watts_{base}$ = load of the existing or baseline fixture/lamp on a per unit basis
$watts_{ee}$ = load of installed energy-efficient (ee) fixture/lamps on a per unit basis
HOU = annual operating hours of use for fixtures/lamps
WHF_e = waste heat factor to account for annual cooling savings from efficient lighting
WHF_d = waste heat factor for demand to account for cooling savings from efficient lighting
CF = coincidence factor
ISR = in-service rate

2.1.1.3 Input Variables

Table 2-2: Input Values for Lighting Fixtures, Lamps, and Delamping Savings Calculations

Component	Type	Value	Unit	Source(s)
Qty_{base}	Variable	See customer application	-	Customer application

Component	Type	Value	Unit	Source(s)
$\mathbf{Qty_{ee}}$	Variable	See customer application	-	Customer application
$\mathbf{watts_{base}}$	Variable	See customer application[14]	watts	Customer application
$\mathbf{watts_{ee}}$	Variable	See customer application[14]	watts	Customer application
$\mathbf{LPD_{base}}$	Variable	See Table 2-3	watt/ft^2	2015 Virginia Energy Conservation Code / IECC 2015 Section C405.4.2, Table C405.4.2(1); Mid-Atlantic 2019, p. 335
		Default = Other building type	watts	Mid-Atlantic TRM 2019, p. 336, ENERGY STAR®[15]
$\mathbf{LPD_{ee}}$	Variable	See customer application	watt/ft^2	Customer application
CF	Variable	For measures where the location is “Exit sign,” “Stairwell,” “Exterior light except garage,” or “Garage,” use Table 10-14 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors. • Treat “Exit sign” and “Stairwell” as “LED Exit Sign and ‘24/7’ lights.” • Treat “Exterior light except garage” as “Outdoor LED and Roadway Lighting.” • Treat “Garage” as “LED “Parking Garage - Parkaging garage.” For measures where the location is “Interior light except exit light,” use Table 10-15 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Mid-Atlantic 2019, pp. 315, 351, 369, and 391[16]
HOU	Variable		hours, annual	Mid-Atlantic 2019, pp. 315, 351, 369, and 391
$\mathbf{WHF_e}$	Variable		-	Mid-Atlantic TRM 2019, pp. 587-588
$\mathbf{WHF_d}$	Variable		-	Mid-Atlantic TRM 2019, pp. 587-588
ISR	Fixed	1.00	-	Mid-Atlantic TRM 2019, p. 319[17]

[14] If the application wattage is greater than 10,000 watts the value will be considered incorrect. If a corrected application value is not provided the wattage will be set to zero and savings will not be calculated.

[15] LED exit sign default values come from an ENERGY STAR® report: Save Energy, Money and Prevent Pollution with Light-Emitting Diode (LED) Exit Signs:http://www.energystar.gov/ia/business/small_business/led_exitsigns_techsheet.pdf (accessed 7/13/2018).

[16] 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.

[17] Mid-Atlantic TRM 2019, p. 319 footnote 737 EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

Table 2-3: Interior Lighting Power Allowances

Customer building type	LPD_{base}[18]
Education – Elementary and Middle School	0.87
Education – High School	0.87
Education – College and University	0.87
Food Sales - Grocery	1.26
Food Sales – Convenience Store	1.26
Food Sales – Gas Station Convenience Store	1.26
Food Service - Full Service	1.01
Food Service - Fast Food	0.90
Health Care - Inpatient	1.05
Health Care - Outpatient	0.90
Lodging – (Hotel, Motel and Dormitory)	0.87
Mercantile (Mall)	1.26
Mercantile (Retail, not mall)	1.26
Office – Small (<40,000 sq ft)	0.82
Office – Large (≥ 40,000 sq ft)	0.82
Other	1.17
Public Assembly	1.01
Public Order and Safety (Police and Fire Station)	0.87
Religious Worship	1.00
Service (Beauty, Auto Repair Workshop)	1.19
Warehouse and Storage	0.66

2.1.1.4 Default Savings

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

2.1.1.5 Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2019, pp. 314–325, 351, 369, 391, and 587-588, and the IECC 2015 Section C405.4.2.

[18] DNV mapped the building types with the building area types contained in IECC 2015 Section C405.4.2, Table C405.4.2(1).

2.1.1.6 Update Summary

The changes to this section, compared with last year, are described in Table 2-4.

Table 2-4: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	New Measure	• New section

2.1.2 Occupancy Sensors and Controls

2.1.2.1 Measure Description

This measure defines the savings associated with installing at wall-, fixture-, or remote-mounted occupancy sensors that switch lights off after a brief delay when no occupants are detected.

This measure is offered in both the Non-Residential Lighting Systems and Controls program DSM Phase VII as well as the Non-Residential Small Business Improvement program, described in Section 5. The baseline condition is lighting that is controlled with a manual switch.

2.1.2.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh \quad = watts \times Qty \times \frac{1\ kW}{1{,}000\ W} \times HOU \times ESF_e \times ISR \times WHF_e$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW \quad = watts \times Qty \times \frac{1\ kW}{1{,}000\ W} \times ESF_d \times ISR \times WHF_d \times CF$$

Where:

ΔkWh	= per measure gross annual electric energy savings
ΔkW	= per measure gross coincident demand reductions
Qty	= number of occupancy sensors installed
watts	= connected load on lighting sensor/control
HOU	= hours of use per year
ESF_e	= percentage of annual lighting energy saved by lighting control
ESF_d	= percentage of lighting demand saved by lighting control
WHF_e	= waste heat factor for energy to account for cooling savings from efficient lighting
WHF_d	= waste heat factor for demand to account for cooling savings from efficient lighting
CF	= coincidence factor
ISR	= in-service rate is the percentage of rebated measures actually installed

DNV

2.1.2.3 Input Variables

Table 2-5: Input Values for Occupancy Sensors and Controls Measure Savings

Component	Type	Value	Unit	Source(s)
watts	Variable	See customer application[19]	watt	Customer application
HOU	Variable	See Table 10-14 or Table 10-15 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	hours/year	Mid-Atlantic TRM 2019, p. 582
Qty	Variable	See customer application	-	Customer application
ESF_e	Fixed	0.28	-	Mid-Atlantic TRM 2019, p. 326
ESF_d	Fixed	0.14	-	Mid-Atlantic TRM 2019, p. 327
CF	Fixed	See Table 10-15 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Mid-Atlantic TRM 2019, p. 586
WHF_e	Variable	See Table 10-15 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Mid-Atlantic TRM 2019, pp. 587-588
		Default: 0.94		Assumes small office building
WHF_d	Variable	See Table 10-15 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Mid-Atlantic TRM 2019, pp. 587-588
		Default: 1.36		Assumes small office building
ISR	Fixed	1.00	-	Mid-Atlantic TRM 2019, p. 327

2.1.2.4 Default Savings

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

2.1.2.5 Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic 2019, pp. 326-329 and pp. 586-588.

[19] If the application wattage is greater than 10,000 watts the value will be considered incorrect. If a corrected application value is not provided the wattage will be set to zero and savings will not be calculated.

2.1.2.6 Update Summary

The changes to this section, compared with last year, are described in Table 2-6.

Table 2-6: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	No change
v10	New Measure	New section

DNV

2.1.3 Occupancy Sensors and Controls – Stairwell Integrated

2.1.3.1 Measure Description

This measure defines the savings associated with installing controls on existing features or installation of luminaires with integrated bi-level occupancy control in stairwells. The bi-level occupancy control technology allows for continuous lighting that maintains the code-mandated minimum illumination levels in unoccupied spaces while also and providinghigher light levels in occupied spaces. The baseline condition is lighting within interior spaces required to be illuminated at all times, such as stairwells.

2.1.3.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are coincident demand reduction is calculated according to the following equation:

$$\Delta kWh = \left[\frac{Qty_{base} \times watts_{base}}{1000\frac{W}{kW}} - \left(\frac{Qty_{ee} \times watts_{ee}}{1000\frac{W}{kW}} \times (1 - ESF)\right)\right] \times HOU$$

$$ESF = F_{low} \times \left(1 - \frac{watts_{ee,low}}{watts_{ee}}\right)$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \left(\frac{Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee}}{1000\frac{W}{kW}}\right) \times CF$$

Where:

ΔkW	= per measure gross coincident demand reductions
ΔkWh	= per measure gross annual electric energy savings
Qty_{base}	= quantity of baseline fixtures
Qty_{ee}	= quanity of installed fixures equipped with bi-level occupancy control
$watts_{base}$	= baseline wattage per fixture
$watts_{ee,low}$	= installed wattage per fixture at low-power output
$watts_{ee}$	= installed wattage per fixture at full-power output (if bi-level occupancy controls are installed on existing fixtures, $watts_{ee}$ = $watts_{base}$)
F_{low}	= percentage of annual operating time that fixture operates at low-power
ESF	= energy savings factor
HOU	= hours of use per year
CF	= peak coincidence factor

2.1.3.3 Input Variables

Table 2-7: Input Values, Occupancy Sensors and Controls

Component	Type	Value	Unit	Source(s)
Qty_{base}	Variable	See customer application	-	Customer application

Component	Type	Value	Unit	Source(s)
Qty_{ee}	Variable	See customer application	-	Customer application
$watts_{base}$	Variable	See customer application[20]	watts	Customer application
$watts_{ee,low}$	Variable	See customer application	watts	Customer application
$watts_{ee}$	Variable	See customer application[20]	watts	Customer application
F_{low}	Fixed	0.73	-	New York TRM 2019, p. 445
HOU	Fixed	8,760	hours/year	New York TRM 2019, pp. 444-445
CF	Fixed	1.00	-	New York TRM 2019, p. 444

2.1.3.4 Default Savings

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

2.1.3.5 Source(s)

The primary source for this deemed savings approach is the New York TRM 7, 2019, pp. 443-445.

2.1.3.6 Update Summary

The changes to this section, compared with last year, are described in Table 2-8.

Table 2-8: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Equation	• Modified the ΔkWh savings equation to incorporate the ESF and associated equation. This makes the calculation clearer and alligns with the referenceTRM but does not change the result.
v10	New Measure	• New section

2.1.4 Reach-In Unit Occupancy Sensor

2.1.4.1 Measure Description

This measure realizes energy savings by adding occupancy sensors to reach-in refrigerated 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. The baseline condition is lighting that is controlled with a manual switch.

2.1.4.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

[20] If the application wattage is greater than 10,000 watts the value will be considered incorrect. If a corrected application value is not provided the wattage will be set to zero and savings will not be calculated.

$$\Delta kWh \quad = Qty_{sensor} \times watts \times \frac{1\ kW}{1{,}000\ W} \times HOU \times ESF_e \times ISR \times WHF_e$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW \quad = Qty_{sensor} \times watts \times \frac{1\ kW}{1{,}000\ W} \times ESF_d \times ISR \times WHF_d \times CF$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reductions
Qty = number of occupancy sensors installed
watts = connected lighting load controlled by occupancy sensor
ESF_e = percentage of annual lighting energy saved by lighting control
ESF_d = percentage of lighting demand saved by lighting control
WHF_e = Waste Heat Factor for Energy; represents the increased savings due to reduced waste heat from lights that must be rejected by the refrigeration equipment
WHF_d = Waste Heat Factor for Demand; represents the increased savings due to reduced waste heat from lights that must be rejected by the refrigeration equipment
HOU = hours of use per year
CF = peak coincidence factor
ISR = in-service rate is the percentage of rebated measures actually installed

2.1.4.3 Input Variables

Table 2-9: 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 for 5-foot lamp
$Qty_{sensors}$	Variable	See customer application	-	Customer application
ESF_e	Fixed	0.31	-	Efficiency Maine Commercial TRM 2019, Appendix D, Table 40[21], p. 173
ESF_d	Fixed	0.14	-	Mid-Atlantic TRM 2019, p. 327
HOU	Variable	See Table 10-15 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	hours, annual	Mid-Atlantic TRM 2019, p. 525[22]

[21] Maine TRM 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.

[22] No default HOU was provided in the Maine TRM 2016.2 since it uses data collected from the application. Instaed, a default value was assigned using the Mid-Atlantic TRM 2019.

Component	Type	Value	Unit	Source(s)
WHF_e	Fixed	Low Temp (-35˚F - -1˚F): 1.52 Med Temp (0˚F - 30˚F): 1.52 High Temp (31˚F - 55˚F): 1.41	-	Mid-Atlantic TRM 2019, p. 388
WHF_d	Fixed	Low Temp (-35˚F - -1˚F): 1.51 Med Temp (0˚F - 30˚F): 1.51 High Temp (31˚F - 55˚F): 1.40	-	Mid-Atlantic TRM 2019, p. 388
CF	Fixed	0.96	-	Mid-Atlantic TRM 2019, p. 389[23]

2.1.4.4 Default Savings

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

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

$$\Delta kWh = \frac{watts}{1{,}000\frac{W}{kW}} \times ESF_e \times HOU \times WHF_e$$

$$= \frac{38\text{ W}}{1{,}000\frac{W}{kW}} \times 0.31 \times 7{,}272\ hours \times 1.41$$

$$= 121\ kWh$$

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

$$\Delta kW = \frac{watts}{1{,}000\frac{W}{kW}} \times ESF_d \times WHF_d \times CF$$

$$= \frac{38\ W}{1{,}000\frac{W}{kW}} \times 0.14 \times 1.40 \times 0.96$$

$$= 0.007\ kW$$

2.1.4.5 Source(s)

The primary sources for this deemed savings approach are the Efficiency Maine TRM 2019, p. 173, and Mid-Atlantic TRM 2019, pp. 327, 387-389, and 525.

[23] Value for “grocery” building type from Mid-Atlantic TRM 2019, p. 389 footnote 873 “EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.”

2.1.4.6 Update Summary

The changes to this section, compared with last year, are described in Table 2-10.

Table 2-10: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No changes
v10	New Measure	• New section

3 NON-RESIDENTIAL HEATING AND COOLING EFFICIENCY PROGRAM, DSM PHASES III/VII

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 as shown in Table 3-1.

Table 3-1: Non-Residential Heating and Cooling Efficiency Program Measure List (DSM III/VII)

End-Use	Measure	Manual Section
HVAC	Unitary/Split Air Conditioning (AC) & Heat Pump (HP) Systems	Section 3.1.1
	Variable Refrigerant Flow (VRF) & Mini-split Systems	Section 3.1.2
	Water- and Air-cooled Chillers	Section 3.1.3
	Variable Frequency Drive	Section 3.1.4
	Dual Enthalpy Air-side Economizer	Section 3.1.5

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

3.1 Heating, Ventilation, and Air-Conditioning (HVAC) End Use

3.1.1 Unitary/Split HVAC and Heat Pumps

3.1.1.1 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 Table 10-9 and Table 10-10 in Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings. 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 5.

3.1.1.2 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 and gross coincident demand reduction are calculated according to the equations following this section.

Cooling Energy Savings:

For heat pumps and AC units <65,000 Btu/h, per measure, gross annual electric cooling energy savings are calculated according to the following equation:

$$\Delta kWh_{cool} = Size_{cool} \times \left[\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}}\right] \times EFLH_{cool} \times \frac{1\ kBtuh}{1000\ Btuh}$$

For pumps and AC units ≥65,000 Btu/h, per measure, gross annual electric cooling energy savings are calculated according to the following equation:

$$\Delta kWh_{cool} = Size_{cool} \times \left[\frac{1}{IEER_{base}} - \frac{1}{IEER_{ee}}\right] \times EFLH_{cool} \times \frac{1\ kBtuh}{1000\ Btuh}$$

For ground-source heat pumps, the baseline efficiency is assumed to be that of an air-source heat pump.[24] See Equation 1 and Equation 2 in Sub-appendix F2-V: General Equations to convert between tons and Btu/h or kBtu/h, or vice versa.

Heating Energy Savings:

For heat pumps <65,000 Btu/h, per measure gross annual electric heating energy savings are calculated according to the following equation:

$$\Delta kWh_{heat} = Size_{heat} \times \left[\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right] \times EFLH_{heat} \times \frac{1\ kBtuh}{1000\ Btuh}$$

For air-source heat pumps ≥65,000 Btu/h, per measure gross annual electric heating energy savings are calculated according to the following equation:

$$\Delta kWh_{heat} = Size_{heat} \times \left[\frac{1}{COP_{base}} - \frac{1}{COP_{ee}}\right] \times EFLH_{heat} \times \frac{1\ W}{3.412\ Btuh} \times \frac{1\ kBtuh}{1000\ Btuh}$$

Heating and cooling energy savings are added to calculate the per measure, gross annual electric energy savings are calculated according to the following equation:

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

The per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = Size_{cool} \times \left[\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right] \times CF \times \frac{1\ kBtuh}{1000\ Btuh}$$

If necessary, see Equation 3 to convert between SEER and EER or Equation 4 in Sub-appendix F2-V: General Equations to convert between IEER and EER.

Where:

ΔkWh = per measure gross annual electric energy savings

[24] Although ASHRAE values reflect the Building Code minimum, savings are calculated using the efficiencies provided in Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings. This is due to the Mid-Atlantic TRM 2019 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 2019.)

DNV

ΔkWh_{cool} = per measure gross annual electric cooling energy savings
ΔkWh_{heat} = per measure gross annual electric heating energy savings
ΔkW = per measure gross coincident demand reductions
$Size_{cool}$ = equipment cooling capacity of installed unit
$Size_{heat}$ = equipment heating capacity of installed unit
$SEER_{base}$ = seasonal energy efficiency ratio (SEER) of the existing or baseline air conditioning equipment. It is used for heat pumps and AC units that are smaller than 65,000 Btu/h.
$SEER_{ee}$ = seasonal energy efficiency ratio (SEER) of the installed air conditioning equipment. It is used 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. 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 for heat pumps and AC units that are 65,000 Btu/h or larger.
$IEER_{ee}$ = integrated energy efficiency ratio (IEER) of the installed air conditioning 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 for heat pumps and AC units that are 65,000 Btu/h or larger.
$EFLH_{cool}$ = equivalent full-load cooling hours
$EFLH_{heat}$ = equivalent 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_{ee} = 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.
$HSPF_{ee}$ = 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_{ee} = coefficient of performance (COP) of installed heating equipment. Ground source heat pumps use COP to determine heating savings.
CF = coincidence factor

In the event of a missing efficiency metric from an application, the equations provided in Sub-appendix F2-V: General Equations may be used to estimate the missing efficiency using another application-provided efficiency metric.

3.1.1.3 Input Variables

Table 3-2: Input Values for Non-Residential HVAC Equipment

Component	Type	Value	Units	Source(s)
$Size_{cool}$	Variable	See customer application	Btu/h	Customer application
$Size_{heat}$	Variable	See customer application	Btu/h	Customer application
$EFLH_{heat}$	Variable	See Table 10-5 in Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours	hours (annual)	Mid-Atlantic TRM 2019, p. 590
$EFLH_{cool}$	Variable	See Table 10-4 in Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours	hours (annual)	Mid-Atlantic TRM 2019, p. 589

Component	Type	Value	Units	Source(s)
HSPF/SEER/IEER/ EER/COP$_{base}$	Variable	See Table 10-9 and Table 10-10 in Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings[25].	kBtu/kW-hour (except COP is dimension-less)	ASHRAE 90.1 2013
HSPF/SEER/IEER/ EER/COP$_{ee}$	Variable	See customer application[25]	kBtu/kW-hour (except COP is dimension-less)	Customer application
CF	Variable	Where baseline and installed system capacities differ, use installed 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 2019, p. 415

3.1.1.4 Default Savings

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

3.1.1.5 Source(s)

The primary sources for this deemed savings approach are the ENERGY STAR® Air Source Heat Pump Calculator (2002 EPA), Mid-Atlantic TRM 2019 pp. 406-420 and 589-590, and ASHRAE 90.1 2013.

3.1.1.6 Update Summary

The changes to this section, compared with last year, are described in Table 3-3.

Table 3-3: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Input	• Added size condition of <65,000 Btu/h and ≥65,000 Btu/h for determining which equation to use for ground-source heat pumps. Previously all ground-source heat pumps used equations that used IEER and COP efficiency metrics.
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM
	Input	• Update to weather stations in North Carolina resulted in revised EFLHs for weather-sensitive measures • Baseline efficiency levels were revised per update to ASHRAE 2013 in VA and NC

3.1.2 Variable Refrigerant Flow Systems and Mini-Split Systems

3.1.2.1 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. For baseline VRF air conditioner, and heat pump

[25] If the value of the appropriate efficiency metric is unavailable, refer to Sub-appendix F2-V: General Equations to convert the provided value to that of the appropriate efficiency metric.

efficiencies refer to Table 10-11 in Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings The measure efficiency is based on the installed unit's efficiency. The measure approved savings applies only to the air cooled VRF AC, and air cooled VRF HP. Water source or ground source units are not included.

Mini split systems are also offered in the Non-Residential Small Business Improvement program, described in Section 5.

3.1.2.2 Savings Estimation Approach

Algorithms and inputs to calculate heating, cooling, and gross coincident savings for variable refrigerant flow (VRF) systems and mini split systems are provided in this section. Gross annual electric energy savings and gross coincident demand reduction are calculated according to the equations following this section.

Cooling Energy Savings:

For VRF systems and mini-split systems <65,000 Btu/h, per measure, gross annual electric cooling energy savings are calculated according to the following equation:

$$\Delta kWh_{cool} = Size_{cool,ee} \times \left[\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}}\right] \times EFLH_{cool} \times \frac{1\ kBtuh}{1000\ Btuh}$$

For VRF systems and mini split systems ≥65,000 Btu/h, per measure gross annual electric cooling energy savings are calculated according to the following equation:

$$\Delta kWh_{cool} = Size_{cool,ee} \times \left[\frac{1}{IEER_{base}} - \frac{1}{IEER_{ee}}\right] \times EFLH_{cool} \times \frac{1\ kBtuh}{1000\ Btuh}$$

To convert between EER and SEER see Equation 3 in Sub-appendix F2-V: General Equations.

Heating Energy Savings:

For VRF and mini-split heat pump systems <65,000 Btu/h, per measure gross annual electric heating energy savings are calculated according to the following equation:

$$\Delta kWh_{heat} = Size_{heat,ee} \times \left[\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right] \times EFLH_{heat} \times \frac{1\ kBtuh}{1000\ Btuh}$$

For VRF and mini-split heat pump systems ≥65,000 Btu/h, per measure gross annual electric heating energy savings are calculated according to the following equation:

$$\Delta kWh_{heat} = Size_{heat,ee} \times \left[\frac{1}{COP_{base}} - \frac{1}{COP_{ee}}\right] \times EFLH_{heat} \times \frac{1\ W}{3.412\ Btuh} \times \frac{1\ kBtuh}{1000\ Btuh}$$

Heating and cooling energy savings are added to calculate the per measure gross annual electric energy savings:

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

Per measure, gross coincident demand reduction is calculated according to the following equation:

DNV

$$\Delta kW \quad = Size_{cool,ee} \times \left[\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right] \times CF \times \frac{1\ kBtuh}{1000\ Btuh}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkWh_{cool} = per measure gross annual electric cooling energy savings for mini split heat pump systems
ΔkWh_{heat} = per measure gross annual electric heating energy savings for mini split heat pump systems
ΔkW = per measure gross coincident demand savings
$Size_{cool}$ = equipment cooling capacity
$Size_{heat}$ = equipment heating capacity
$SEER_{base}$ = seasonal energy efficiency ratio (SEER) of the existing or baseline equipment. SEER is used for units that are smaller than 65,000 Btu/h.
$SEER_{ee}$ = seasonal energy efficiency ratio (SEER) of the installed equipment. SEER is used for units that are smaller than 65,000 Btu/h.
$IEER_{base}$ = 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 for heat pumps and AC units that are 65,000 Btu/h or larger.
$IEER_{ee}$ = 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 for heat pumps and AC units that are 65,000 Btu/h or larger.
$EFLH_{cool}$ = equivalent full load cooling hours
$EFLH_{heat}$ = equivalent full load heating hours
EER_{base} = energy efficiency ratio (EER) of existing or baseline equipment
EER_{ee} = energy efficiency ratio (EER) of installed equipment
$HSPF_{base}$ = heating seasonal performance factor (HSPF) of existing or baseline system
$HSPF_{ee}$ = heating seasonal performance factor (HSPF) of installed equipment
COP_{base} = coefficient of performance (COP) of existing or baseline heating equipment
COP_{ee} = coefficient of performance (COP) of installed heating equipment
CF = coincidence

3.1.2.3 Input Variables

Table 3-4: Input Values for VRF Systems and Mini Split Systems

Component	Type	Value	Units	Source(s)
$Size_{cool}$	Fixed	See customer application	Btu/h	Customer application
$Size_{heat}$	Fixed	See customer application	Btu/h	Customer application
$EFLH_{heat}$	Fixed	See Table 10-5 in Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours	hours (annual)	Mid-Atlantic TRM 2019, pp. 423, 466, and 590
$EFLH_{cool}$	Fixed	See Table 10-4 in Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours	hours (annual)	Mid-Atlantic TRM 2019, pp. 423,465 & 589

Component	Type	Value	Units	Source(s)
HSPF/SEER/ EER/COP/ IEER$_{base}$	Variable	See Table 10-11 in Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings[26]	kBtu/kW-hour (except COP is dimensionless)	ASHRAE 90.1 2013
HSPF/SEER/ EER/COP/ IEER$_{ee}$	Variable	See customer application[26]	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 2019, pp. 424 and 466

3.1.2.4 Default Savings

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

3.1.2.5 Source(s)

The primary sources for this deemed savings approach are the Mid-Atlantic TRM 2019 pp. 421-425, 462-468, and 589-590, and ASHRAE 90.1-2013.

3.1.2.6 Update Summary

The changes to this section, compared with last year, are described in Table 3-5.

Table 3-5: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM
	Input Variable	• Update to weather stations in North Carolina resulted in revised EFLHs for weather-sensitive measures • Baseline efficiency levels were revised per update to ASHRAE 2013 in VA and NC

3.1.3 Electric Chillers

3.1.3.1 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 10-12 of Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings for the 2013 ASHRAE-90.1 specified minimum efficiencies. The installed chiller efficiency is taken from the customer application.

[26] If the value of the appropriate efficiency metric is unavailable, refer to Sub-appendix F2-V: General Equations to convert the provided value to that of the appropriate efficiency metric.

DNV

3.1.3.2 Savings Estimation Approach

Water-cooled Chillers

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = Size_{ee} \times \left[\frac{kW}{ton_{base,IPLV}} - \frac{kW}{ton_{ee,IPLV}}\right] \times EFLH_{cool}$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = Size_{ee} \times \left[\frac{kW}{ton_{base,full\ load}} - \frac{kW}{ton_{ee,full\ load}}\right] \times CF$$

Air-cooled Chillers

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = Size_{ee} \times \left[\frac{12\ {kBtuh}/{ton}}{EER_{base,IPLV}} - \frac{12\ {kBtuh}/{ton}}{EER_{ee,IPLV}}\right] \times EFLH_{cool}$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

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

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reductions
$Size_{ee}$ = cooling capacity of the installed chiller system
$EER_{base,IPLV}$, $kW/ton_{base,IPLV}$ = chiller system baseline efficiency at integrated part load value (IPLV), in kW/ton (for $kW/ton_{base,IPLV}$) assigned based on installed system capacity
$EER_{ee,IPLV}$, $kW/ton_{ee,IPLV}$ = chiller system installed efficiency at integrated part load value (IPLV)
$EFLH_{cool}$ = equivalent full load hours of cooling
$EER_{base,full\ load}$, $kW/ton_{base,full\ load}$ = chiller system baseline efficiency at full load
$EER_{ee,full\ load}$, $kW/ton_{ee,full\ load}$ = chiller system installed efficiency at full load
CF = peak coincident factor

3.1.3.3 Input Variables

Table 3-6: Input Values for Non-Residential Electric Chillers

Component	Type	Value	Unit	Source(s)
$Size_{ee}$	Variable	See customer application	ton, cooling capacity	Customer application
$kW/ton_{base,full-load}$	Fixed	See Table 10-12 of Sub-appendix F2-III: Non-residential	kW/ton	ASHRAE 90.1 2013, Table 6.8.1-3

Component	Type	Value	Unit	Source(s)
		HVAC Equipment Efficiency Ratings		
$kW/ton_{base,IPLV}$	Fixed	See Table 10-12 of Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings	kW/ton	ASHRAE 90.1 2013, Table 6.8.1-3
$kW/ton_{ee,full\text{-}load}$	Variable	See customer application[27]	kW/ton	Customer application
$kW/ton_{ee,IPLV}$	Variable	See customer application[27]	kW/ton	Customer application
$EER_{base,\ full\ load}$	Variable	See customer application[27]	kBtu/kW	Customer Application
		Default: See Table 10-12 of Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings[28]		ASHRAE 90.1-2013, Table 6.8.1-3
$EER_{base,\ IPLV}$	Variable	See customer application[27]	kBtu/kW	Customer Application
		Default: See Table 10-12 Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings		ASHRAE 90.1-2013, Table 6.8.1-3
$EER_{ee,\ full\ load}$	Variable	See customer application[28]	kBtu/kW	Customer application
$EER_{ee,\ IPLV}$	Variable	See customer application[28]	kBtu/kW	Customer application
$EFLH_{cool}$	Variable	See Table 10-6 of Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours	hours (annual)	Mid-Atlantic TRM 2019 p. 442, adjusted for Richmond, VA and Charlotte, NC based on TMY3 cooling degree days data.
CF	Fixed	0.923	-	Mid-Atlantic TRM 2019 p. 437

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 type, chiller type, chiller efficiency, or weather region. STEP follows a similar approach as used in Mid Atlantic TRM in that the full load cooling hours of chillers are assigned by building type. As per Table 10-12 of Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings, 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.

[27] When missing either the IPLV or the full load value, use Equation 8 in Sub-appendix F2-V: General Equations, as relevant.
[28] When missing either the IPLV or the full load value, use Equation 9 in Sub-appendix F2-V: General Equations, as relevant.

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For applications in the Virginia and North Carolina regions, 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.

3.1.3.4 Default Savings

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

3.1.3.5 Source(s)

The primary sources for this deemed savings approach are the Mid-Atlantic TRM 2019 pp. 435-442, ASHRAE 90.1-2013, Table 6.8.1-3 - Water Chilling Packages - Efficiency Requirements.

3.1.3.6 Update Summary

The changes to this section, compared with last year, are described in Table 3-7.

Table 3-7: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No Change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM
	Input Variable	• Update to weather stations in North Carolina resulted in revised EFLHs for weather-sensitive measures • Baseline efficiency levels were revised per update to ASHRAE 2013 in VA and NC

3.1.4 Variable Frequency Drives, DSM Phase VII

3.1.4.1 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

- 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 5. The methodology and assumptions differs between these two programs.

3.1.4.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equations:

HVAC Fans:

$$\Delta kWh_{fan} = \frac{hp\ x\ 0.746\ x\ LF}{\eta} \times HOU \times \Delta LR$$

$$\Delta LR = \sum_{0\%}^{100\%} FF \times (PLR_{base} - PLR_{ee})$$

HVAC Pumps:

$$\Delta kWh_{pump} = \frac{hp\ x\ 0.746\ x\ LF}{\eta} \times HOU \times ESF$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

HVAC Fans:

$$\Delta kW_{fan} = \frac{hp\ x\ 0.746\ x\ LF}{\eta} \times \left(PLR_{base,peak} - PLR_{ee,peak}\right) = 0$$

HVAC Pumps:

$$\Delta kW_{pump} = \frac{hp\ x\ 0.746\ x\ LF}{\eta} \times CF \times DSF$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reductions
hp = motor horse power
LF = motor load factor (%) at fan design airflow rate or pump design flowrate
η = NEMA-rated efficiency of motor
HOU = annual operating hours for fan motor based on building type
ΔLR = change in load ratio due to differences in part-load ratios
FF = flow fraction, percentage of run-time spent within a given range of flows
PLR_{base} = baseline part-load ratio
PLR_{ee} = efficient part-load ratio
$PLR_{base, peak}$ = summer peak baseline part-load ratio, default is 1.0

$PLR_{ee, peak}$ = summer peak efficient part-load ratio, default is 1.0
ESF = energy savings factor
DSF = demand savings factor
CF = peak coincidence factor

3.1.4.3 Input Variables

Table 3-8: Input Values for Non-Residential Variable Frequency Drives

Component	Type	Value	Unit	Source(s)
hp	Variable	See customer application	horsepower	Customer application
LF	Variable	See customer application	-	Customer application
		Default: 0.65	-	Mid Atlantic TRM 2019, p. 428
η	Variable	See customer application	-	Customer application
		Default see Table 3-9	-	NEMA Standards Publication Condensed MG 1-2007
FF	Fixed	0.524 per Table 3-10	-	Mid Atlantic TRM 2019, p. 428
PLR_{base}	Variable	See customer application	-	Customer application
		Default=0.53 per Table 3-11 for forward-curved fan with outlet dampers at FF=0.524		Mid Atlantic TRM 2019, p. 428
PLR_{ee}	Variable	See customer application	-	Customer application
		Default=0.30 per Table 3-11 for VFD with duct Static Pressure Controls at FF=0.524		Mid Atlantic TRM 2019, p. 428
$PLR_{base, peak}$	Fixed	1.00	-	DNV engineering judgement
$PLR_{ee, peak}$	Fixed	1.00	-	DNV engineering judgement
ESF	Variable	See Table 3-13	-	Mid-Atlantic TRM 2019, p. 433
DSF	Variable	See Table 3-13	-	Mid-Atlantic TRM 2019, p. 433
HOU	Variable	See Table 10-7 in Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours	hours (annual)	Mid-Atlantic TRM 2019, pp. 431-432
CF	Fixed	0.55 for pump applications	-	Mid-Atlantic TRM 2019, p. 431

Table 3-9 provides the baseline motor efficiencies that are consistent with the minimum federal accepted motor efficiencies provided by the National Electrical Manufacturers Association (NEMA).[29]

Table 3-9: Baseline Motor Efficiency[30]

Horsepower (hp)	η	Horsepower (hp)	η
1	0.855	60	0.950

[29] Refer to NEMA Standards Publication "Condensed MG 1-2011 - 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 said Sstandard.

[30] NEMA Standards Publication Condensed MG 1-2011 - 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
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
50	0.945

Horsepower (hp)	η
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 3-10 provides the assumed proportion of time that fans operate within ten ranges of airflow rates, relative to the design airflow rate (cfm).

Table 3-10: Default Fan Airflow as a Proportion of Design Airflow

Airflow Range (proportion of design cfm)	Airflow Fraction (FF), Proportion of Time in Range	Weighted Average of Airflow Range
0% - 10%	0.000	0.524
10% - 20%	0.010	
20% - 30%	0.055	
30% - 40%	0.155	
40% - 50%	0.220	
50% - 60%	0.250	
60% - 70%	0.190	
70% - 80%	0.085	
80% - 90%	0.030	
90% - 100%	0.005	

Table 3-11 provides the part-load ratios (PLRs) as they vary with fan control types, fan wheel types, and air flow ranges.

Table 3-11: Part-Load Ratios by Control Type, Fan Type, and Flow Range

Control Type	Fan Type(s)	Part-Load Ratio by Airflow Range (percent of design airflow rate)									
		0% - 10%	10% - 20%	20% - 30%	30% - 40%	40% - 50%	50% - 60%	60% - 70%	70% - 80%	80% - 90%	90% - 100%
No Control or Bypass Damper	All	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Outlet Damper	FC	0.22	0.26	0.30	0.37	0.45	0.54	0.65	0.77	0.91	1.06
	BI, AF	0.53	0.53	0.57	0.64	0.72	0.80	0.89	0.96	1.02	1.05
Discharge Damper	Unknown	0.46	0.55	0.63	0.70	0.77	0.83	0.88	0.93	0.97	1.00
Inlet Damper Box	All	0.56	0.60	0.62	0.64	0.66	0.69	0.74	0.81	0.92	1.07
Inlet Guide Vane	FC or Unknown	0.21	0.22	0.23	0.26	0.31	0.39	0.49	0.63	0.81	1.04
	BI, AF	0.53	0.56	0.57	0.59	0.60	0.62	0.67	0.74	0.85	1.00
Inlet Vane Dampers	All	0.38	0.40	0.42	0.44	0.48	0.53	0.60	0.70	0.83	0.99
Eddy Current Drives	All	0.17	0.20	0.25	0.32	0.41	0.51	0.63	0.76	0.90	1.04
VFD with Duct Static Pressure Controls	All	0.09	0.10	0.11	0.15	0.20	0.29	0.41	0.57	0.76	1.01
VFD with Low/No Duct Static Pressure Controls (<1" w.g.)	All	0.05	0.06	0.09	0.12	0.18	0.27	0.39	0.55	0.75	1.00

Fan types include: Bi=Backward Inclined fan; AF=Airfoil Fan; and FC=Forward-Curved fan.

Table 3-12 displays the weighted averages of the part-load ratios calculated using the flow fractions from Table 3-10 and the part-load values across flow ranges from Table 3-13.

Table 3-12: Average Part Load Ratios (PLRs) by Control Type and Fan Type

Case	Control Type	Fan Type(s)	Weighted Average PLR
Baseline	Outlet Damper	Airfoil (AF) or Backward Inclined (BI)	0.78
		Forward Curved (FC) or Unknown	0.53
	Discharge Damper	All	0.81
	Inlet Damper Box	All	0.70
	Inlet Guide Vane	Airfoil (AF) or Backward Inclined (BI)	0.64
		Forward Curved (FC) or Unknown	0.40
	Inlet Vane Damper	All	0.54
	Eddy Current Drive	All	0.50
	No Control or Bypass Damper	All	1.00
Efficient	VFD with Duct Static Pressure Controls	All	0.30
	VFD with Low/No Duct Static Pressure Controls (<1” w.g.)	All	0.28

Table 3-13: Energy Savings and Demand Reduction Factors by Application

VFD Applications[31]	ESF	DRF
Chilled Water Pump	0.633	0.460
Hot Water Pump	0.652	0.000
Unknown/Other Pump (Average)[32]	0.643	0.230

3.1.4.4 Default Savings

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

3.1.4.5 Source(s)

The primary sources for this deemed savings approach Mid-Atlantic TRM 2019, pp. 427-433.

3.1.4.6 Update Summary

The changes to this section, compared with last year, are described in Table 3-14.

Table 3-14: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Clarified Default Assumptions	• Added efficient cases of control strategie to Table 3-12 to clarify assumptions. No change to resulting savings.

[31] Mid-Atlantic TRM 2019, p. 433.

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

Version	Type of Change	Description of Change
v10	New Savings Methodology	• New section

3.1.5 Dual Enthalpy Air-side Economizers

This measure is offered under the Non-Residential Heating and Cooling Efficiency and Non-Residential Small Business Improvement (Section 5) programs as either a new installation of an economizer or a retrofit add-on project. Both programs use the protocol provided below.

3.1.5.1 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 mechanical 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(s).

Non-Residential Small Business Improvement Program

In addition to the measure scope description in Non-Residential Heating and Cooling Efficiency Program above, this program also includes repair of existing dual enthalpy economizer.

3.1.5.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = Size_{cool} \times ESF$$

Per measure, gross coincident demand reduction is assumed to be zero because an economizer will typically not operate during the peak period.[33] Hence,

$$\Delta kW = 0$$

Where:

ΔkWh	= per measure gross annual electric energy savings
ΔkW	= per measure gross coincident demand reductions
$Size_{cool}$	= HVAC system cooling capacity
ESF	= annual energy savings factor for the installation of dual enthalpy economizer control

[33] Mid Atlantic TRM 2019, p. 451.

3.1.5.3 Input Variables

Table 3-15: Input Values for Economizer Repair Savings Calculations

Component	Type	Value	Unit	Source(s)
$Size_{cool}$	Variable	See customer application	tons	Customer application
ESF	Variable	See Table 3-16	-	Mid-Atlantic TRM 2019, p. 453

Table 3-16: Economizer Energy Savings Factors by Building Type[34]

Building Type	Energy Savings Factors (kWh/ton)		
	Baltimore, MD	Richmond, VA	Rocky Mount/ Elizabeth City, NC
Education[35]	39	35	29
Education – College and University			
Education – High School			
Education – Elementary and Middle School			
Food Sales[36]	57	52	43
Food Sales - Grocery[37]			
Food Sales – Convenience Store			
Food Sales – Gas Station Convenience Store			
Food Service[38]	29	26	22
Food Service - Full Service	29	26	22
Food Service - Fast Food[39]	37	34	28
Mercantile (Retail, not mall)[40]	57	52	43
Mercantile (mall)	57	52	43
Office – Small (<40,000 sq. ft.)[41]	57	52	43
Office – Large (≥ 40,000 sq. ft.)			

[34] Mid Atlantic TRM 2019, p. 453 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 scaled to determine those for Richmond, VA and Rocky Mount-Wilson/Elizabeth City, NC values using the HDD and CDD provided in Sub-appendix F2-I: Cooling and Heating Degree Days and HoursFor example, VA and NC values are calculated from Baltimore,MD savings factors and degree days (DD-65°F = HDD + CDD) using TMY3 data.

[35] 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 2019, p. 453.

[36] All food sales, and service (beauty, auto repair workshop) building types in the STEP Manual were mapped to savings factors for the "Small Retail" building type listed in the Mid-Atlantic TRM 2019, p. 453.

[37] Food-sales-grocery and mercantile (mall) building types in the STEP Manual were mapped to the "Big Box Retail" building type listed in the Mid-Atlantic TRM 2019, p. 453.

[38] 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 2019, p. 453.

[39] 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 2019, p. 453.

[40] Mercantile (retail, not mall) building types in the STEP Manual were mapped to savings factors for the "Small Retail" building type in the Mid-Atlantic TRM 2019, p. 453.

[41] 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 2019, p. 447.

<table>
<tr><th rowspan="2">Building Type</th><th colspan="3">Energy Savings Factors (kWh/ton)</th></tr>
<tr><th>Baltimore, MD</th><th>Richmond, VA</th><th>Rocky Mount/ Elizabeth City, NC</th></tr>
<tr><td>Public Assembly</td><td>25</td><td>23</td><td>19</td></tr>
<tr><td>Religious Worship</td><td>6</td><td>5</td><td>5</td></tr>
<tr><td>Other[42]</td><td rowspan="5">57</td><td rowspan="5">52</td><td rowspan="5">43</td></tr>
<tr><td>Lodging – (Hotel, Motel and Dormitory)</td></tr>
<tr><td>Health Care - outpatient</td></tr>
<tr><td>Health Care - inpatient</td></tr>
<tr><td>Public Order and Safety (Police and Fire Station)</td></tr>
<tr><td>Service (Beauty, Auto Repair Workshop)</td><td>57</td><td>52</td><td>43</td></tr>
<tr><td>Warehouse and Storage</td><td>2</td><td>2</td><td>2</td></tr>
</table>

3.1.5.4 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 reduction is zero.

3.1.5.5 Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2019, pp. 451-453.

3.1.5.6 Update Summary

The changes to this section, compared with last year, are described in Table 3-17.

Table 3-17: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM
	Input Variable	• Updated weather stations in North Carolina

42 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 2019, p. 447.

4 NON-RESIDENTIAL WINDOW FILM PROGRAM, DSM PHASES III/VII

4.1 Building Envelope End Use

4.1.1 Window Film

The Non-Residential Window Film Program provides incentives to non-residential customers to install reflective window film on existing windows in order to reduce the solar heat gain through the affected windows. The program has been offered in Virginia beginning August 1, 2014 and in North Carolina beginning January 1, 2015.

This section is applicable to both DSM Phase III and Phase VII. However note that the Annual Energy Savings Factor and the Annual Demand Reduction Factors differ between Phase III and Phase IV Because the program eligibility requirements differ.

To be eligible for a rebate under the DSM Phase III version of the program, the final Solar Heat Gain Coefficient (SHGC) of the window after application of window film must be equal to or less than 0.4.[43] Under the DSM Phase VII program, the final SHGC must be equal to or less than 0.5.[44]

4.1.1.1 Measure Description

This measure applies to window film installed on the exterior side of existing non-residential single pane or double pane windows. Savings are calculated per square foot of north, south, east, and west facing windows.

4.1.1.2 Savings Estimation Approach

The window film installation measure savings calculations utilize savings factors developed using DOE-2.2 energy modelling software simulations of prototypical building eQUEST models. Building models are based on the Database for Energy Efficient Resources (DEER) building data—modified for Richmond, VA and a blend of Elizabeth City and Rocky Mount-Wilson, NC weather using typical meteorological year 3 (TMY3) data—and modification of a few key window parameters.[45] The assumed values for key parameters affected by addition of window film to single and double pane windows are provided in Table 4-1.

Table 4-1: Key Building Energy Modelling Parameters

Window Variable	Window Type	Baseline Value	Source(s) [46]	Efficient Value	Source(s)[46]
U-Factor	Single Pane	1.23	DEER (1978-2001)	1.23	DEER (1978-2001)
	Double Pane	0.77	DEER (1993-2001)	0.77	DEER (1993-2001)
SHGC	Single Pane	0.82	DEER (1978-2001)	0.40	Program requirement
	Double Pane	0.61	DEER (1993-2001)	0.40	Program requirement

The savings factors are listed per square foot of reflective window film area for each building type and window orientation in Table 4-5 and Table 4-4. Savings factors differ based on the number of panes within affected windows

[43] DSM Phase III Non-residential Window Film Program website. Dominion Energy. https://www.dominionenergy.com/large-business/energy-conservation-programs/window-film/non-residential-window-film-faqs. Accessed 10/10/2018.

[44] DSM Phase VII Non-residential Window Film Program design assumptions.

[45] See Sub-Appendix I: Cooling and Heating Degree Days and Hours for a description of the weather stations selected for this document.

[46] Building vintage ranges defined in DEER, www.deeresources.com.

(single or double) and the heating fuel type of the building (electric or non-electric). Similarly, gross coincident peak demand reduction factors are provided in Table 4-1.

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh \quad = SqFt_{orientation} \times ESF_{orientation}$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW \quad SqFt_{orientation} \times DRF_{orientation}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reductions
$SqFt_{orientation}$ = area of window film for each window orientation of a retrofitted building
$ESF_{orientation}$ = annual energy savings factor
$DRF_{orientation}$ = demand reduction factor

4.1.1.3 Input Variables

Table 4-2: Input Values for Solar Window Film

Component	Type	Value	Unit	Source(s)
$SqFt_{orientation}$	Variable	See customer application	sq.ft.	Customer application
$ESF_{orientation}$	Fixed	See Table 4-3 and Table 4-4	kWh/sq.ft.	DOE 2.2 energy modelling software
$DRF_{orientation}$	Fixed	See Table 4-5 and Table 4-6	kW/sq.ft.	DOE 2.2 energy modelling software

Table 4-3: Energy Savings Factors for Reflective Window Film by Building Type and Window Orientation for VA (DSM Phase III and VII)

Building Type[47]	Window Type	Heating System Type[48]	DSM Phase III				DSM Phase VII			
			ESF_{North} (kWh/ ft²)	ESF_{East} (kWh/ ft²)	ESF_{South}[49] (kWh/ ft²)	ESF_{West} (kWh/ ft²)	ESF_{North} (kWh/ ft²)	ESF_{East} (kWh/ ft²)	ESF_{South}[50] (kWh/ ft²)	ESF_{West} (kWh/ ft²)
Education – Elementary and Middle School	Single Pane	Electric	4.34	8.20	6.66	10.02	3.37	6.38	5.20	7.82
		Non-electric	4.20	9.07	9.51	9.31	3.28	6.67	7.39	7.15
	Double Pane	Electric	2.24	4.25	3.40	5.04	1.23	2.33	1.86	2.71
		Non-electric	2.09	4.58	4.56	4.70	1.16	2.52	2.51	2.56
Education – High School	Single Pane	Electric	3.39	7.37	13.00	5.14	2.62	5.71	12.10	3.35
		Non-electric	4.36	13.10	44.20	13.71	3.42	10.51	41.68	11.73
	Double Pane	Electric	1.74	3.70	2.76	3.92	0.94	2.06	1.59	2.18
		Non-electric	2.01	6.66	6.98	8.45	1.03	3.68	3.82	3.91
Education – College and University	Single Pane	Electric	1.67	11.99	16.83	13.29	1.34	9.35	14.83	10.64
		Non-electric	5.64	18.64	25.04	18.60	4.29	14.42	21.03	14.94
	Double Pane	Electric	1.62	7.99	12.97	8.84	1.01	4.49	4.39	4.95
		Non-electric	3.01	9.79	15.96	9.67	1.71	5.33	5.79	5.24
Food Sales - Grocery	Single Pane	Electric	3.06	5.20	-2.32	7.40	2.76	4.07	-2.74	5.80
		Non-electric	3.82	7.00	3.88	8.72	3.04	5.41	2.12	6.70
	Double Pane	Electric	1.63	2.79	-3.57	3.84	0.71	1.49	1.13	2.05
		Non-electric	1.84	3.55	-0.09	4.43	0.98	1.97	2.37	2.39

[47] Warehouse and storage building type DEER models do not have windows. Tracking data with this building type will be flagged for on-site verification.

[48] Non-electric heating systems were represented by gas heating in building energy models.

[49] Negative demand reduction is observed in some building types for south window orientation, implying that installation of window film on the south side of the these buildings leads to increased energy use due to increase heating load in the winter season.

[50] Negative demand reduction is observed in some building types for south window orientation, implying that installation of window film on the south side of the these buildings leads to increased energy use due to increase heating load in the winter season.

Building Type[47]	Window Type	Heating System Type[48]	DSM Phase III				DSM Phase VII			
			ESF_{North} (kWh/ ft²)	ESF_{East} (kWh/ ft²)	ESF_{South}[49] (kWh/ ft²)	ESF_{West} (kWh/ ft²)	ESF_{North} (kWh/ ft²)	ESF_{East} (kWh/ ft²)	ESF_{South}[50] (kWh/ ft²)	ESF_{West} (kWh/ ft²)
Food Sales – Convenience Store	Single Pane	Electric	1.50	4.24	-2.42	6.58	1.25	3.35	-2.52	5.13
		Non-electric	3.23	6.44	4.33	8.20	2.74	4.92	2.74	6.26
	Double Pane	Electric	0.78	2.29	-2.76	3.41	0.43	1.29	-3.65	2.85
		Non-electric	1.85	3.31	0.96	4.16	0.98	1.83	-1.11	2.27
Food Sales – Gas Station Convenience Store	Single Pane	Electric	1.50	4.24	-2.42	6.58	1.25	3.35	-2.52	5.13
		Non-electric	3.23	6.44	4.33	8.20	2.74	4.92	2.74	6.26
	Double Pane	Electric	0.78	2.29	-2.76	3.41	0.43	1.29	-3.65	2.85
		Non-electric	1.85	3.31	0.96	4.16	0.98	1.83	-1.11	2.27
Food Service - Full Service	Single Pane	Electric	5.03	9.59	6.29	9.57	3.63	7.23	4.79	7.39
		Non-electric	4.57	10.18	9.44	9.89	3.53	7.74	7.30	7.73
	Double Pane	Electric	2.45	4.94	3.24	4.70	1.30	2.85	1.99	2.52
		Non-electric	2.42	5.14	4.81	4.96	1.33	2.91	2.77	2.72
Food Service - Fast Food	Single Pane	Electric	3.48	8.64	5.72	7.09	2.68	6.35	4.97	5.55
		Non-electric	3.68	9.23	9.79	7.34	2.87	6.87	7.95	5.71
	Double Pane	Electric	1.78	4.18	4.49	3.60	1.03	2.40	2.52	2.05
		Non-electric	1.95	4.58	5.36	3.88	1.05	2.55	2.93	2.11
Health Care-inpatient	Single Pane	Electric	3.73	17.87	-59.89	3.88	2.87	13.91	-61.85	3.03
		Non-electric	4.84	23.16	-18.37	20.19	3.74	18.28	-59.88	4.18
	Double Pane	Electric	1.98	8.61	4.96	1.99	1.12	4.82	2.92	1.10
		Non-electric	3.13	11.92	6.47	10.16	1.87	6.35	3.97	1.55

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Building Type[47]	Window Type	Heating System Type[48]	DSM Phase III				DSM Phase VII			
			ESF_{North} (kWh/ ft²)	ESF_{East} (kWh/ ft²)	ESF_{South}[49] (kWh/ ft²)	ESF_{West} (kWh/ ft²)	ESF_{North} (kWh/ ft²)	ESF_{East} (kWh/ ft²)	ESF_{South}[50] (kWh/ ft²)	ESF_{West} (kWh/ ft²)
Health Care-outpatient	Single Pane	Electric	1.70	4.85	-3.63	4.62	1.35	3.77	2.18	3.59
		Non-electric	2.63	7.18	1.63	6.86	2.04	5.50	5.53	5.28
	Double Pane	Electric	1.06	2.54	-4.91	2.40	0.56	1.34	0.75	1.26
		Non-electric	1.50	3.60	-1.89	3.43	0.78	1.94	1.96	1.87
Lodging – (Hotel, Motel, and Dormitory)	Single Pane	Electric	2.81	5.57	-0.02	6.11	2.25	4.60	1.45	4.77
		Non-electric	5.04	11.31	9.21	9.28	3.89	9.00	8.73	7.17
	Double Pane	Electric	1.42	2.86	-1.27	2.78	0.75	1.77	-0.15	1.54
		Non-electric	2.58	5.89	3.02	4.24	1.40	3.34	2.55	2.31
Mercantile (mall)	Single Pane	Electric	2.97	5.11	1.17	6.06	2.34	3.98	1.07	4.76
		Non-electric	6.16	13.43	16.27	12.09	4.61	10.38	12.16	9.36
	Double Pane	Electric	1.85	3.24	2.11	3.96	1.01	1.98	1.34	2.22
		Non-electric	2.95	6.95	7.45	5.67	1.80	3.59	4.16	3.38
Mercantile (Retail, not mall)	Single Pane	Electric	3.26	8.75	11.28	11.55	2.07	6.08	8.16	8.33
		Non-electric	3.78	9.30	12.07	7.27	2.48	6.86	8.73	5.17
	Double Pane	Electric	1.34	4.10	5.18	5.55	0.79	2.27	2.75	2.91
		Non-electric	1.85	4.32	5.66	4.40	1.09	2.45	3.13	2.28
Office – Small (<40,000 sq ft)	Single Pane	Electric	0.52	6.05	3.22	5.52	0.43	5.11	4.50	4.65
		Non-electric	3.09	8.36	7.43	7.82	2.41	6.54	6.86	6.12
	Double Pane	Electric	0.36	3.25	2.86	2.99	0.24	1.80	1.71	1.73
		Non-electric	1.57	4.24	4.46	3.93	0.87	2.31	2.48	2.18

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Building Type[47]	Window Type	Heating System Type[48]	DSM Phase III				DSM Phase VII			
			ESF_{North} (kWh/ ft²)	ESF_{East} (kWh/ ft²)	ESF_{South}[49] (kWh/ ft²)	ESF_{West} (kWh/ ft²)	ESF_{North} (kWh/ ft²)	ESF_{East} (kWh/ ft²)	ESF_{South}[50] (kWh/ ft²)	ESF_{West} (kWh/ ft²)
Office – Large (≥40,000 sq ft)	Single Pane	Electric	5.93	30.29	41.28	29.71	4.65	23.92	32.84	23.37
		Non-electric	12.77	44.15	55.42	40.59	9.87	34.15	42.99	31.42
	Double Pane	Electric	3.45	16.38	22.04	15.91	1.89	9.15	12.26	8.74
		Non-electric	6.74	22.89	28.77	21.18	3.67	12.54	15.74	11.57
Other[51]	Single Pane	Electric	1.50	4.24	-2.42	6.58	1.25	3.35	-2.52	5.13
		Non-electric	3.23	6.44	4.33	8.20	2.74	4.92	2.74	6.26
	Double Pane	Electric	0.78	2.29	-2.76	3.41	0.43	1.29	-3.65	2.85
		Non-electric	1.85	3.31	0.96	4.16	0.98	1.83	-1.11	2.27
Public Assembly	Single Pane	Electric	3.02	5.52	3.05	15.47	10.99	13.00	2.54	14.05
		Non-electric	4.33	8.60	8.90	18.58	12.37	15.64	6.94	16.55
	Double Pane	Electric	1.52	2.97	1.73	12.01	0.85	1.65	0.99	2.01
		Non-electric	2.21	4.44	4.64	13.93	1.20	2.43	2.57	2.70
Public Order and Safety (Police and Fire Station)	Single Pane	Electric	1.04	7.64	-0.84	4.15	0.75	5.83	4.85	2.26
		Non-electric	2.17	11.12	6.85	8.75	1.70	8.57	9.02	6.11
	Double Pane	Electric	0.55	3.79	2.74	-0.07	0.32	2.10	1.59	-1.95
		Non-electric	1.12	5.60	5.60	2.95	0.68	3.03	3.05	0.26
Religious Worship	Single Pane	Electric	10.98	31.39	15.40	32.80	9.89	26.83	14.27	27.37
		Non-electric	9.08	22.89	10.84	23.59	2.97	6.97	3.23	7.00
	Double Pane	Electric	6.84	17.56	8.29	17.97	4.07	9.94	4.83	10.20
		Non-electric	5.35	12.68	5.87	12.76	2.97	6.97	3.23	7.00

51 ESF for the "Other" building type is taken from the Convenience store building energy model because it represents a conservative savings estimate and common building characteristics.

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Building Type[47]	Window Type	Heating System Type[48]	DSM Phase III				DSM Phase VII			
			ESF_{North} (kWh/ ft^2)	ESF_{East} (kWh/ ft^2)	ESF_{South}[49] (kWh/ ft^2)	ESF_{West} (kWh/ ft^2)	ESF_{North} (kWh/ ft^2)	ESF_{East} (kWh/ ft^2)	ESF_{South}[50] (kWh/ ft^2)	ESF_{West} (kWh/ ft^2)
Service (Beauty, Auto Repair Workshop)	Single Pane	Electric	5.26	1.78	0.00	1.65	21.22	5.67	2.86	5.78
		Non-electric	1.90	5.37	3.29	3.80	5.88	13.07	10.17	11.96
	Double Pane	Electric	0.20	0.79	0.42	0.99	0.73	1.66	0.90	2.37
		Non-electric	0.95	1.87	1.64	1.91	2.04	4.21	3.61	4.19

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Table 4-4: Energy Savings Factors for Reflective Window Film by Building Type and Window Orientation for NC (DSM Phase III and VII)

Building Type[52]	Window Type	Heating System Type[53]	DSM III				DSM VII			
			ESF_{North} (kWh/ ft^2)	ESF_{East} (kWh/ ft^2)	ESF_{South}[54] (kWh/ ft^2)	ESF_{West} (kWh/ ft^2)	ESF_{North} (kWh/ ft^2)	ESF_{East} (kWh/ ft^2)	ESF_{South}[55] (kWh/ ft^2)	ESF_{West} (kWh/ ft^2)
Education – Elementary and Middle School	Single Pane	Electric	5.39	10.33	10.29	12.53	3.94	7.57	3.27	8.96
Education – Elementary and Middle School	Single Pane	Non-electric	2.36	5.23	5.60	5.30	3.27	7.35	6.13	7.58
Education – Elementary and Middle School	Double Pane	Electric	2.74	5.33	5.41	6.32	1.47	2.78	2.90	3.23
Education – Elementary and Middle School	Double Pane	Non-electric	2.36	5.23	5.60	5.30	1.14	2.57	2.90	2.66
Education – High School	Single Pane	Electric	4.30	9.47	9.12	10.83	3.19	6.65	6.74	7.66
Education – High School	Single Pane	Non-electric	4.30	9.47	9.12	10.83	3.19	6.65	6.74	7.66
Education – High School	Double Pane	Electric	2.17	4.76	4.62	5.44	1.14	2.35	2.38	2.70
Education – High School	Double Pane	Non-electric	2.17	4.76	4.62	5.44	1.14	2.35	2.38	2.70
Education – College and University	Single Pane	Electric	2.61	25.42	27.91	16.32	2.19	16.49	12.11	12.47
Education – College and University	Single Pane	Non-electric	6.15	32.13	25.64	22.13	4.33	19.85	15.02	15.43
Education – College and University	Double Pane	Electric	1.55	8.25	9.95	-1.49	0.82	4.44	5.12	4.98
Education – College and University	Double Pane	Non-electric	2.75	10.04	11.97	-0.06	1.46	5.28	6.20	5.56
Food Sales - Grocery	Single Pane	Electric	4.14	7.39	-1.54	9.94	3.04	5.26	1.35	7.15
Food Sales - Grocery	Single Pane	Non-electric	4.11	7.88	2.79	10.10	3.10	5.92	4.04	7.33
Food Sales - Grocery	Double Pane	Electric	2.14	3.78	-3.75	5.09	1.09	1.93	2.07	2.59
Food Sales - Grocery	Double Pane	Non-electric	2.01	3.99	-1.34	5.08	1.09	2.11	2.73	2.58

Building Type[52]	Window Type	Heating System Type[53]	DSM III				DSM VII			
			ESF_{North} (kWh/ ft²)	ESF_{East} (kWh/ ft²)	ESF_{South}[54] (kWh/ ft²)	ESF_{West} (kWh/ ft²)	ESF_{North} (kWh/ ft²)	ESF_{East} (kWh/ ft²)	ESF_{South}[55] (kWh/ ft²)	ESF_{West} (kWh/ ft²)
Food Sales – Convenience Store	Single Pane	Electric	2.40	6.05	-1.68	8.75	1.76	4.23	0.72	6.27
		Non-electric	3.75	7.08	3.52	9.27	2.85	5.21	4.03	6.77
	Double Pane	Electric	1.22	3.04	-3.30	4.42	0.72	1.55	-1.43	2.24
		Non-electric	1.89	3.58	-0.19	4.67	1.05	1.84	0.04	2.39
Food Sales – Gas Station Convenience Store	Single Pane	Electric	2.40	6.05	-1.68	8.75	1.76	4.23	0.72	6.27
		Non-electric	3.75	7.08	3.52	9.27	2.85	5.21	4.03	6.77
	Double Pane	Electric	1.22	3.04	-3.30	4.42	0.72	1.55	-1.43	2.24
		Non-electric	1.89	3.58	-0.19	4.67	1.05	1.84	0.04	2.39
Food Service - Full Service	Single Pane	Electric	5.28	12.08	11.10	14.03	3.98	8.81	8.39	10.03
		Non-electric	4.93	11.26	11.75	12.72	3.80	8.52	9.03	9.25
	Double Pane	Electric	2.80	6.01	5.76	6.72	1.30	3.08	2.97	3.38
		Non-electric	2.59	5.75	6.01	6.16	1.43	2.95	3.18	3.13
Food Service - Fast Food	Single Pane	Electric	3.66	11.12	9.62	8.79	2.86	8.43	8.71	6.04
		Non-electric	3.62	10.63	10.22	8.37	2.76	8.11	8.85	5.85
	Double Pane	Electric	1.95	5.97	5.90	4.53	1.04	2.94	3.22	2.20
		Non-electric	1.89	5.68	5.93	4.30	1.03	2.87	3.24	2.13
Health Care-inpatient	Single Pane	Electric	4.54	21.98	14.75	-23.53	3.53	16.49	11.25	4.10
		Non-electric	6.29	26.17	15.16	24.57	5.17	19.17	13.12	5.50
	Double Pane	Electric	-12.17	11.23	7.49	-18.79	4.02	10.12	6.78	1.42
		Non-electric	6.29	26.17	15.16	24.57	4.47	11.03	7.34	1.81

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Building Type[52]	Window Type	Heating System Type[53]	DSM III ESF North (kWh/ ft²)	DSM III ESF East (kWh/ ft²)	DSM III ESF South[54] (kWh/ ft²)	DSM III ESF West (kWh/ ft²)	DSM VII ESF North (kWh/ ft²)	DSM VII ESF East (kWh/ ft²)	DSM VII ESF South[55] (kWh/ ft²)	DSM VII ESF West (kWh/ ft²)
Health Care-outpatient	Single Pane	Electric	2.77	6.02	3.33	2.04	2.15	4.44	2.91	2.43
		Non-electric	3.38	7.91	6.50	4.03	2.66	5.92	5.41	3.84
	Double Pane	Electric	1.39	3.07	2.69	3.16	0.78	1.61	1.45	1.67
		Non-electric	1.73	4.03	4.28	4.06	0.95	2.10	2.28	2.11
Lodging – (Hotel, Motel, and Dormitory)	Single Pane	Electric	3.77	10.11	3.68	8.87	2.89	7.68	3.24	6.83
		Non-electric	4.91	13.76	10.06	10.85	3.70	10.41	8.47	8.41
	Double Pane	Electric	1.85	5.02	-0.76	4.41	1.03	2.73	0.01	2.45
		Non-electric	2.50	7.10	2.00	5.48	1.35	3.77	1.74	3.04
Mercantile (mall)	Single Pane	Electric	4.11	8.85	7.00	9.50	3.17	5.87	4.82	6.81
		Non-electric	6.68	18.30	23.16	21.06	5.13	14.07	18.13	15.57
	Double Pane	Electric	2.04	3.95	3.18	4.43	1.09	2.07	1.93	2.25
		Non-electric	2.98	9.41	11.37	10.25	1.67	4.89	6.04	5.27
Mercantile (Retail, not mall)	Single Pane	Electric	3.38	9.45	13.99	14.03	2.37	7.21	10.78	10.26
		Non-electric	3.51	8.96	13.00	8.29	2.61	6.77	9.91	5.89
	Double Pane	Electric	1.83	4.81	6.47	6.91	1.02	2.66	3.78	3.65
		Non-electric	1.78	4.35	6.05	3.93	1.03	2.43	3.44	2.06
Office – Small (<40,000 sq ft)	Single Pane	Electric	1.40	7.28	8.01	7.82	1.29	5.29	6.20	5.60
		Non-electric	3.15	8.58	9.81	8.87	2.38	6.41	7.56	6.47
	Double Pane	Electric	0.97	3.62	4.05	3.97	0.59	1.87	2.24	2.02
		Non-electric	1.57	4.26	4.90	4.43	0.84	2.25	2.66	2.28

Building Type[52]	Window Type	Heating System Type[53]	DSM III				DSM VII			
			ESF_{North} (kWh/ ft^2)	ESF_{East} (kWh/ ft^2)	ESF_{South}[54] (kWh/ ft^2)	ESF_{West} (kWh/ ft^2)	ESF_{North} (kWh/ ft^2)	ESF_{East} (kWh/ ft^2)	ESF_{South}[55] (kWh/ ft^2)	ESF_{West} (kWh/ ft^2)
Office – Large (≥40,000 sq ft)	Single Pane	Electric	7.86	35.45	46.89	33.70	6.32	27.37	36.32	26.37
		Non-electric	13.23	44.49	56.89	41.44	10.18	34.09	43.61	32.16
	Double Pane	Electric	4.50	18.99	24.48	17.94	2.57	10.27	13.28	10.08
		Non-electric	6.77	22.83	29.08	21.31	3.79	12.22	15.63	11.82
Other[56]	Single Pane	Electric	2.40	6.05	-1.68	8.75	1.76	4.23	0.72	6.27
		Non-electric	3.75	7.08	3.52	9.27	2.85	5.21	4.03	6.77
	Double Pane	Electric	1.22	3.04	-3.30	4.42	0.72	1.55	-1.43	2.24
		Non-electric	1.89	3.58	-0.19	4.67	1.05	1.84	0.04	2.39
Public Assembly	Single Pane	Electric	3.71	7.46	5.46	12.53	2.71	5.44	4.34	7.62
		Non-electric	4.56	9.58	9.94	14.91	3.54	7.26	7.91	9.72
	Double Pane	Electric	1.88	3.85	2.91	7.77	0.99	1.98	1.69	2.52
		Non-electric	2.28	4.86	5.08	9.17	1.26	2.60	2.86	3.07
Public Order and Safety (Police and Fire Station)	Single Pane	Electric	3.59	9.59	9.65	8.83	2.78	6.85	7.26	5.56
		Non-electric	4.60	12.59	14.30	12.20	3.65	9.26	10.81	8.20
	Double Pane	Electric	3.59	9.59	9.65	8.83	0.98	2.35	2.49	1.77
		Non-electric	4.60	12.59	14.30	12.20	1.28	3.20	3.77	2.81
Religious Worship	Single Pane	Electric	19.30	44.39	20.46	43.22	14.81	33.95	17.30	33.86
		Non-electric	11.83	27.15	12.11	26.47	3.34	7.50	3.78	7.46
	Double Pane	Electric	10.46	20.33	12.52	22.13	5.50	12.29	6.61	12.17
		Non-electric	6.37	12.90	7.24	26.47	3.34	7.50	3.78	7.46

Building Type[52]	Window Type	Heating System Type[53]	DSM III				DSM VII			
			ESF_{North} (kWh/ ft^2)	ESF_{East} (kWh/ ft^2)	ESF_{South}[54] (kWh/ ft^2)	ESF_{West} (kWh/ ft^2)	ESF_{North} (kWh/ ft^2)	ESF_{East} (kWh/ ft^2)	ESF_{South}[55] (kWh/ ft^2)	ESF_{West} (kWh/ ft^2)
Service (Beauty, Auto Repair Workshop)	Single Pane	Electric	4.52	2.56	7.29	3.00	3.58	7.28	22.03	16.65
		Non-electric	2.04	4.25	7.57	4.35	6.50	12.65	22.50	19.25
	Double Pane	Electric	0.58	1.30	4.58	1.54	1.34	2.80	7.65	6.09
		Non-electric	1.02	2.10	4.51	1.42	2.25	4.46	8.05	6.80

Table 4-5: Demand Reduction Factors for Reflective Window Film by Building Type and Window Orientation for VA (DSM Phase III and VII)

Building Type[57]	Window Type	Heating System Type[58]	DSM III				DSM VII			
			DRF_{North} (kW/ft^2)	DRF_{East} (kW/ft^2)	DRF_{South}[59] (kW/ft^2)	DRF_{West} (kW/ft^2)	DRF_{North} (kW/ft^2)	DRF_{East} (kW/ft^2)	DRF_{South}[60] (kW/ft^2)	DRF_{West} (kW/ft^2)
Education – Elementary and Middle School	Single Pane	Electric	1.74E-03	2.52E-03	3.02E-03	3.83E-03	1.01E-03	1.61E-03	1.89E-03	3.28E-03
		Non-electric	1.72E-03	2.62E-03	2.90E-03	3.54E-03	2.61E-03	2.95E-03	3.12E-03	4.13E-03
	Double Pane	Electric	9.60E-04	1.33E-03	1.62E-03	2.01E-03	3.47E-04	5.27E-04	7.16E-04	1.10E-03
		Non-electric	8.47E-04	1.47E-03	1.41E-03	1.89E-03	7.21E-04	1.00E-03	9.66E-04	1.52E-03
Education – High School	Single Pane	Electric	1.18E-03	2.03E-03	4.89E-03	1.97E-03	1.49E-03	2.28E-03	7.66E-03	2.03E-03
		Non-electric	1.24E-03	2.42E-03	7.87E-03	3.10E-03	1.27E-03	2.36E-03	1.02E-02	3.11E-03
	Double Pane	Electric	6.16E-04	1.03E-03	1.18E-03	1.29E-03	5.38E-04	8.26E-04	8.58E-04	1.23E-03
		Non-electric	6.99E-04	1.22E-03	1.42E-03	1.88E-03	5.03E-04	6.89E-04	7.54E-04	9.62E-04

57 Warehouse and storage building type DEER models do not have windows. Tracking data with this building type will be flagged for on-site verification.

58 Non-electric heating systems were represented by gas heating in building energy models.

59 Negative demand reduction is observed in some building types for south window orientation, implying that installation of window film on the south side of the these buildings leads to increased energy use due to increase heating load in the winter season.

60 Negative demand reduction is observed in some building types for south window orientation, implying that installation of window film on the south side of the these buildings leads to increased energy use due to increase heating load in the winter season.

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Building Type[57]	Window Type	Heating System Type[58]	DSM III				DSM VII			
			DRF North (kW/ft²)	DRF East (kW/ft²)	DRF South[59] (kW/ft²)	DRF West (kW/ft²)	DRF North (kW/ft²)	DRF East (kW/ft²)	DRF South[60] (kW/ft²)	DRF West (kW/ft²)
Education – College and University	Single Pane	Electric	1.20E-03	2.67E-03	3.18E-03	3.21E-03	1.35E-03	2.73E-03	2.44E-03	3.20E-03
		Non-electric	1.26E-03	2.79E-03	3.24E-03	3.21E-03	1.36E-03	2.76E-03	2.47E-03	3.24E-03
	Double Pane	Electric	6.32E-04	1.30E-03	1.85E-03	1.58E-03	4.79E-04	5.43E-04	5.51E-05	1.21E-03
		Non-electric	6.61E-04	1.36E-03	1.95E-03	1.56E-03	4.79E-04	1.00E-03	9.30E-04	1.17E-03
Food Sales - Grocery	Single Pane	Electric	1.08E-03	1.68E-03	2.26E-04	2.57E-03	1.11E-03	1.61E-03	-2.50E-03	3.11E-03
		Non-electric	1.03E-03	1.47E-03	-2.55E-04	2.30E-03	9.22E-04	1.32E-03	-3.95E-03	2.57E-03
	Double Pane	Electric	5.45E-04	8.76E-04	-8.30E-04	1.33E-03	4.15E-04	5.90E-04	7.83E-04	1.12E-03
		Non-electric	4.73E-04	7.23E-04	-1.20E-03	1.14E-03	3.36E-04	4.80E-04	7.29E-04	9.24E-04
Food Sales – Convenience Store	Single Pane	Electric	8.76E-04	1.56E-03	7.02E-04	2.43E-03	8.92E-04	1.51E-03	-8.74E-04	2.98E-03
		Non-electric	8.34E-04	1.33E-03	2.23E-04	2.12E-03	9.54E-04	1.23E-03	-2.12E-03	2.46E-03
	Double Pane	Electric	4.25E-04	8.15E-04	-2.46E-04	1.25E-03	2.90E-04	5.21E-04	-2.24E-03	1.82E-03
		Non-electric	4.80E-04	6.75E-04	-6.07E-04	1.08E-03	3.59E-04	4.46E-04	-3.41E-03	8.83E-04
Food Sales – Gas Station Convenience Store	Single Pane	Electric	8.76E-04	1.56E-03	7.02E-04	2.43E-03	8.92E-04	1.51E-03	-8.74E-04	2.98E-03
		Non-electric	8.34E-04	1.33E-03	2.23E-04	2.12E-03	9.54E-04	1.23E-03	-2.12E-03	2.46E-03
	Double Pane	Electric	4.25E-04	8.15E-04	-2.46E-04	1.25E-03	2.90E-04	5.21E-04	-2.24E-03	1.82E-03
		Non-electric	4.80E-04	6.75E-04	-6.07E-04	1.08E-03	3.59E-04	4.46E-04	-3.41E-03	8.83E-04
Food Service - Full Service	Single Pane	Electric	1.16E-03	2.16E-03	2.18E-03	2.86E-03	1.18E-03	1.91E-03	1.78E-03	3.15E-03
		Non-electric	1.05E-03	1.91E-03	1.93E-03	2.55E-03	9.52E-04	1.75E-03	1.59E-03	2.68E-03
	Double Pane	Electric	5.84E-04	1.07E-03	1.09E-03	1.43E-03	3.56E-04	6.82E-04	6.13E-04	1.11E-03
		Non-electric	5.27E-04	9.64E-04	9.69E-04	1.27E-03	3.19E-04	6.16E-04	5.48E-04	9.44E-04
Food Service - Fast Food	Single Pane	Electric	1.01E-03	2.04E-03	1.29E-03	2.04E-03	1.02E-03	1.66E-03	1.08E-03	2.54E-03
		Non-electric	8.82E-04	1.80E-03	1.83E-03	1.79E-03	8.78E-04	1.46E-03	1.56E-03	2.18E-03
	Double Pane	Electric	5.29E-04	9.72E-04	1.13E-03	1.05E-03	3.73E-04	6.15E-04	6.27E-04	9.12E-04
		Non-electric	4.58E-04	8.46E-04	9.74E-04	9.19E-04	3.20E-04	5.47E-04	5.55E-04	7.83E-04

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Building Type[57]	Window Type	Heating System Type[58]	DSM III DRF North (kW/ft²)	DSM III DRF East (kW/ft²)	DSM III DRF South[59] (kW/ft²)	DSM III DRF West (kW/ft²)	DSM VII DRF North (kW/ft²)	DSM VII DRF East (kW/ft²)	DSM VII DRF South[60] (kW/ft²)	DSM VII DRF West (kW/ft²)
Health Care-inpatient	Single Pane	Electric	8.09E-04	3.14E-03	-9.03E-03	1.28E-03	7.83E-04	2.91E-03	-1.34E-02	1.52E-03
		Non-electric	7.17E-04	2.76E-03	-2.81E-03	3.22E-03	7.90E-04	2.96E-03	-1.34E-02	1.52E-03
	Double Pane	Electric	4.25E-04	1.18E-03	7.57E-04	6.41E-04	2.74E-04	1.03E-03	6.08E-04	5.37E-04
		Non-electric	5.55E-04	1.61E-03	9.14E-04	1.78E-03	3.73E-04	1.06E-03	6.23E-04	5.42E-04
Health Care-outpatient	Single Pane	Electric	8.09E-04	1.68E-03	-3.34E-05	1.81E-03	7.67E-04	1.60E-03	1.49E-03	2.02E-03
		Non-electric	8.06E-04	1.75E-03	-4.43E-07	1.87E-03	7.67E-04	1.66E-03	1.57E-03	2.07E-03
	Double Pane	Electric	4.33E-04	8.48E-04	-8.85E-04	9.14E-04	2.95E-04	5.75E-04	5.38E-04	7.17E-04
		Non-electric	4.38E-04	8.81E-04	-8.91E-04	9.45E-04	2.96E-04	5.96E-04	5.62E-04	7.36E-04
Lodging – (Hotel, Motel, and Dormitory)	Single Pane	Electric	1.08E-03	1.60E-03	1.61E-03	2.31E-03	1.12E-03	1.45E-03	1.53E-03	3.00E-03
		Non-electric	1.25E-03	2.14E-03	1.95E-03	2.57E-03	1.25E-03	1.93E-03	2.04E-03	3.19E-03
	Double Pane	Electric	5.56E-04	8.37E-04	6.35E-04	1.15E-03	3.82E-04	5.30E-04	4.86E-04	1.05E-03
		Non-electric	6.40E-04	1.11E-03	6.73E-04	1.28E-03	4.50E-04	7.16E-04	6.48E-04	1.14E-03
Mercantile (mall)	Single Pane	Electric	1.45E-03	2.49E-03	2.47E-03	3.01E-03	1.77E-03	2.72E-03	2.41E-03	4.04E-03
		Non-electric	1.27E-03	2.05E-03	2.12E-03	2.45E-03	1.53E-03	2.22E-03	2.01E-03	3.25E-03
	Double Pane	Electric	7.52E-04	1.21E-03	1.26E-03	1.52E-03	6.22E-04	9.59E-04	8.50E-04	1.43E-03
		Non-electric	6.33E-04	1.02E-03	1.06E-03	1.22E-03	4.94E-04	7.79E-04	6.66E-04	1.10E-03
Mercantile (Retail, not mall)	Single Pane	Electric	1.03E-03	1.96E-03	2.35E-03	2.79E-03	1.11E-03	1.72E-03	1.82E-03	3.60E-03
		Non-electric	1.01E-03	1.85E-03	2.01E-03	2.26E-03	8.12E-04	1.54E-03	1.57E-03	2.66E-03
	Double Pane	Electric	5.04E-04	9.78E-04	1.10E-03	1.64E-03	3.75E-04	6.06E-04	5.70E-04	1.26E-03
		Non-electric	4.93E-04	8.39E-04	9.26E-04	1.34E-03	3.00E-04	4.92E-04	4.63E-04	1.09E-03
Office – Small (<40,000 sq ft)	Single Pane	Electric	6.43E-04	1.75E-03	1.59E-03	2.35E-03	9.36E-04	2.11E-03	2.14E-03	2.62E-03
		Non-electric	8.41E-04	1.74E-03	1.47E-03	2.24E-03	1.15E-03	1.93E-03	2.00E-03	2.54E-03
	Double Pane	Electric	3.28E-04	9.10E-04	9.75E-04	1.18E-03	3.05E-04	8.13E-04	6.75E-04	9.36E-04
		Non-electric	4.31E-04	8.79E-04	9.45E-04	1.12E-03	4.29E-04	6.87E-04	6.91E-04	9.07E-04

Building Type[57]	Window Type	Heating System Type[58]	DSM III				DSM VII			
			DRF_{North} (kW/ft²)	DRF_{East} (kW/ft²)	DRF_{South}[59] (kW/ft²)	DRF_{West} (kW/ft²)	DRF_{North} (kW/ft²)	DRF_{East} (kW/ft²)	DRF_{South}[60] (kW/ft²)	DRF_{West} (kW/ft²)
Office – Large (≥40,000 sq ft)	Single Pane	Electric	3.10E-03	8.52E-03	9.84E-03	9.20E-03	4.21E-03	1.09E-02	1.21E-02	1.29E-02
		Non-electric	3.11E-03	8.62E-03	9.95E-03	9.28E-03	4.24E-03	1.11E-02	1.23E-02	1.30E-02
	Double Pane	Electric	1.58E-03	4.33E-03	5.04E-03	4.74E-03	1.57E-03	3.87E-03	4.28E-03	4.74E-03
		Non-electric	1.61E-03	4.42E-03	5.11E-03	4.79E-03	1.59E-03	3.95E-03	4.37E-03	4.82E-03
Other[61]	Single Pane	Electric	8.76E-04	1.56E-03	7.02E-04	2.43E-03	8.92E-04	1.51E-03	-8.74E-04	2.98E-03
		Non-electric	8.34E-04	1.33E-03	2.23E-04	2.12E-03	9.54E-04	1.23E-03	-2.12E-03	2.46E-03
	Double Pane	Electric	4.25E-04	8.15E-04	-2.46E-04	1.25E-03	2.90E-04	5.21E-04	-2.24E-03	1.82E-03
		Non-electric	4.80E-04	6.75E-04	-6.07E-04	1.08E-03	3.59E-04	4.46E-04	-3.41E-03	8.83E-04
Public Assembly	Single Pane	Electric	1.10E-03	1.82E-03	1.92E-03	5.63E-03	9.31E-03	9.94E-03	1.67E-03	1.11E-02
		Non-electric	1.21E-03	1.99E-03	2.07E-03	7.11E-03	1.40E-02	1.48E-02	1.82E-03	1.58E-02
	Double Pane	Electric	5.68E-04	9.40E-04	9.83E-04	4.42E-03	4.01E-04	6.20E-04	5.86E-04	1.02E-03
		Non-electric	6.17E-04	1.02E-03	1.05E-03	5.83E-03	4.20E-04	6.71E-04	6.42E-04	1.07E-03
Public Order and Safety (Police and Fire Station)	Single Pane	Electric	8.03E-04	1.95E-03	7.56E-04	1.64E-03	8.02E-04	1.67E-03	1.73E-03	1.54E-03
		Non-electric	7.68E-04	2.10E-03	8.88E-04	1.75E-03	7.92E-04	1.79E-03	1.87E-03	1.65E-03
	Double Pane	Electric	3.97E-04	9.84E-04	1.07E-03	3.42E-04	2.77E-04	5.97E-04	6.00E-04	-3.68E-04
		Non-electric	3.91E-04	1.06E-03	1.14E-03	4.04E-04	2.74E-04	6.39E-04	6.43E-04	-3.43E-04
Religious Worship	Single Pane	Electric	5.10E-03	1.20E-02	5.86E-03	1.26E-02	4.58E-03	1.12E-02	6.19E-03	1.19E-02
		Non-electric	2.80E-03	6.93E-03	3.27E-03	7.09E-03	9.05E-04	2.13E-03	9.59E-04	1.88E-03
	Double Pane	Electric	2.91E-03	6.49E-03	3.11E-03	6.73E-03	1.83E-03	4.16E-03	1.85E-03	4.38E-03
		Non-electric	1.63E-03	3.81E-03	1.77E-03	3.84E-03	9.05E-04	2.13E-03	9.59E-04	1.88E-03

[61] DRF for the “Other” building type is taken from the Convenience store building energy model because it represents a conservative savings estimate and common building characteristics.

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Building Type[57]	Window Type	Heating System Type[58]	DSM III				DSM VII			
			DRF_{North} (kW/ft^2)	DRF_{East} (kW/ft^2)	DRF_{South}[59] (kW/ft^2)	DRF_{West} (kW/ft^2)	DRF_{North} (kW/ft^2)	DRF_{East} (kW/ft^2)	DRF_{South}[60] (kW/ft^2)	DRF_{West} (kW/ft^2)
Service (Beauty, Auto Repair Workshop)	Single Pane	Electric	9.90E-04	1.02E-03	0.00E+00	1.37E-03	4.96E-03	4.39E-03	3.55E-03	8.00E-03
		Non-electric	6.19E-04	1.49E-03	1.07E-03	1.43E-03	2.81E-03	4.71E-03	3.77E-03	8.46E-03
	Double Pane	Electric	2.94E-04	4.34E-04	5.10E-04	6.89E-04	9.44E-04	1.18E-03	1.22E-03	2.82E-03
		Non-electric	3.08E-04	4.76E-04	5.34E-04	7.13E-04	9.85E-04	1.32E-03	1.33E-03	2.97E-03

DNV

Table 4-6: Demand Reduction Factors for Reflective Window Film by Building Type and Window Orientation for NC (DSM Phase III and VII)

Building Type[62]	Window Type	Heating System Type	DSM III				DSM VII			
			DRF_{North} (kW/ft²)	DRF_{East} (kW/ft²)	DRF_{South} (kW/ft²)	DRF_{West} (kW/ft²)	DRF_{North} (kW/ft²)	DRF_{East} (kW/ft²)	DRF_{South} (kW/ft²)	DRF_{West} (kW/ft²)
Education – Elementary and Middle School	Single Pane	Electric	1.84E-03	2.55E-03	3.09E-03	4.07E-03	1.71E-03	2.30E-03	1.45E-03	3.44E-03
		Non-electric	9.54E-04	1.41E-03	1.52E-03	2.02E-03	2.94E-03	3.37E-03	2.72E-03	4.93E-03
	Double Pane	Electric	9.97E-04	1.32E-03	1.58E-03	2.12E-03	7.14E-04	7.26E-04	8.49E-04	1.32E-03
		Non-electric	9.54E-04	1.41E-03	1.52E-03	2.02E-03	1.25E-03	1.47E-03	1.37E-03	1.78E-03
Education – High School	Single Pane	Electric	1.26E-03	2.09E-03	2.37E-03	3.30E-03	1.48E-03	2.09E-03	2.19E-03	3.48E-03
		Non-electric	1.26E-03	2.09E-03	2.37E-03	3.30E-03	1.48E-03	2.09E-03	2.19E-03	3.48E-03
	Double Pane	Electric	6.25E-04	1.04E-03	1.19E-03	1.62E-03	5.32E-04	7.51E-04	7.89E-04	1.24E-03
		Non-electric	6.25E-04	1.04E-03	1.19E-03	1.62E-03	5.32E-04	7.51E-04	7.89E-04	1.24E-03
Education – College and University	Single Pane	Electric	1.26E-03	4.43E-03	4.51E-03	3.99E-03	1.27E-03	3.45E-03	2.57E-03	3.32E-03
		Non-electric	1.49E-03	4.79E-03	3.42E-03	4.22E-03	1.27E-03	3.46E-03	2.43E-03	3.30E-03
	Double Pane	Electric	6.72E-04	1.46E-03	1.53E-03	5.12E-04	4.66E-04	9.09E-04	7.99E-04	1.16E-03
		Non-electric	6.39E-04	1.42E-03	1.48E-03	4.61E-04	4.67E-04	9.19E-04	8.10E-04	1.16E-03
Food Sales - Grocery	Single Pane	Electric	1.02E-03	1.65E-03	-6.42E-04	2.84E-03	1.08E-03	1.50E-03	-8.38E-04	3.10E-03
		Non-electric	8.59E-04	1.38E-03	-1.12E-03	2.46E-03	9.49E-04	1.26E-03	-1.68E-03	2.61E-03
	Double Pane	Electric	5.38E-04	8.52E-04	-1.48E-03	1.44E-03	3.84E-04	5.34E-04	6.29E-04	1.10E-03
		Non-electric	4.43E-04	7.00E-04	-1.86E-03	1.25E-03	3.46E-04	4.53E-04	6.04E-04	9.31E-04
Food Sales – Convenience Store	Single Pane	Electric	9.15E-04	1.54E-03	-5.66E-05	2.69E-03	9.12E-04	1.38E-03	-1.09E-04	2.97E-03
		Non-electric	9.24E-04	1.29E-03	-4.56E-04	2.33E-03	9.52E-04	1.17E-03	-7.69E-04	2.52E-03
	Double Pane	Electric	4.63E-04	8.00E-04	-8.48E-04	1.37E-03	3.21E-04	5.01E-04	-1.05E-03	1.06E-03
		Non-electric	4.74E-04	6.64E-04	-1.15E-03	1.18E-03	3.39E-04	4.23E-04	-1.62E-03	8.99E-04
Food Sales – Gas Station	Single Pane	Electric	9.15E-04	1.54E-03	-5.66E-05	2.69E-03	9.12E-04	1.38E-03	-1.09E-04	2.97E-03
		Non-electric	9.24E-04	1.29E-03	-4.56E-04	2.33E-03	9.52E-04	1.17E-03	-7.69E-04	2.52E-03

62 Warehouse and storage building type DEER models do not have windows. Tracking data with this building type will be flagged for on-site verification.

Building Type[62]	Window Type	Heating System Type	DSM III				DSM VII			
			DRF_{North} (kW/ft^2)	DRF_{East} (kW/ft^2)	DRF_{South} (kW/ft^2)	DRF_{West} (kW/ft^2)	DRF_{North} (kW/ft^2)	DRF_{East} (kW/ft^2)	DRF_{South} (kW/ft^2)	DRF_{West} (kW/ft^2)
Convenience Store	Double Pane	Electric	4.63E-04	8.00E-04	-8.48E-04	1.37E-03	3.21E-04	5.01E-04	-1.05E-03	1.06E-03
		Non-electric	4.74E-04	6.64E-04	-1.15E-03	1.18E-03	3.39E-04	4.23E-04	-1.62E-03	8.99E-04
Food Service - Full Service	Single Pane	Electric	1.18E-03	2.01E-03	2.19E-03	3.32E-03	1.13E-03	1.64E-03	1.61E-03	3.22E-03
		Non-electric	1.02E-03	1.76E-03	1.94E-03	2.94E-03	9.39E-04	1.43E-03	1.44E-03	2.81E-03
	Double Pane	Electric	5.93E-04	9.96E-04	1.10E-03	1.64E-03	4.01E-04	5.43E-04	5.34E-04	1.14E-03
		Non-electric	5.04E-04	8.88E-04	9.83E-04	1.45E-03	3.31E-04	4.69E-04	4.78E-04	9.74E-04
Food Service - Fast Food	Single Pane	Electric	9.86E-04	2.06E-03	1.83E-03	2.35E-03	9.33E-04	1.61E-03	1.55E-03	2.39E-03
		Non-electric	8.58E-04	1.80E-03	1.52E-03	2.07E-03	8.10E-04	1.42E-03	1.36E-03	2.10E-03
	Double Pane	Electric	5.13E-04	1.09E-03	1.11E-03	1.21E-03	3.35E-04	5.52E-04	5.58E-04	8.56E-04
		Non-electric	4.45E-04	9.56E-04	9.55E-04	1.06E-03	2.93E-04	4.83E-04	4.87E-04	7.52E-04
Health Care-inpatient	Single Pane	Electric	8.69E-04	3.44E-03	2.37E-03	-3.25E-03	8.06E-04	2.87E-03	1.86E-03	1.53E-03
		Non-electric	1.07E-03	3.52E-03	2.03E-03	4.36E-03	1.06E-03	2.90E-03	1.88E-03	1.53E-03
	Double Pane	Electric	-2.02E-03	1.83E-03	1.22E-03	-2.91E-03	8.42E-04	1.95E-03	1.27E-03	5.38E-04
		Non-electric	1.07E-03	3.52E-03	2.03E-03	4.36E-03	8.93E-04	1.95E-03	1.27E-03	5.37E-04
Health Care-outpatient	Single Pane	Electric	9.19E-04	1.75E-03	1.28E-03	9.88E-04	8.81E-04	1.42E-03	8.80E-04	1.16E-03
		Non-electric	9.37E-04	1.82E-03	1.36E-03	1.02E-03	8.97E-04	1.48E-03	9.54E-04	1.19E-03
	Double Pane	Electric	4.70E-04	8.82E-04	8.92E-04	1.01E-03	3.13E-04	5.03E-04	4.59E-04	7.03E-04
		Non-electric	4.79E-04	9.16E-04	9.39E-04	1.05E-03	3.19E-04	5.24E-04	4.88E-04	7.22E-04

Building Type[62]	Window Type	Heating System Type	DSM III				DSM VII			
			DRF_{North} (kW/ft^2)	DRF_{East} (kW/ft^2)	DRF_{South} (kW/ft^2)	DRF_{West} (kW/ft^2)	DRF_{North} (kW/ft^2)	DRF_{East} (kW/ft^2)	DRF_{South} (kW/ft^2)	DRF_{West} (kW/ft^2)
Lodging – (Hotel, Motel, and Dormitory)	Single Pane	Electric	1.05E-03	1.75E-03	1.17E-03	2.62E-03	1.02E-03	1.43E-03	7.56E-04	2.94E-03
		Non-electric	1.20E-03	2.40E-03	1.67E-03	2.97E-03	1.15E-03	1.95E-03	1.26E-03	3.22E-03
	Double Pane	Electric	5.33E-04	8.90E-04	9.50E-05	1.34E-03	3.66E-04	5.26E-04	-4.04E-05	1.05E-03
		Non-electric	6.12E-04	1.25E-03	1.70E-04	1.50E-03	4.17E-04	7.21E-04	7.31E-05	1.14E-03
Mercantile (mall)	Single Pane	Electric	1.55E-03	2.69E-03	2.53E-03	3.49E-03	1.71E-03	2.48E-03	2.18E-03	3.98E-03
		Non-electric	1.32E-03	2.93E-03	2.97E-03	4.13E-03	1.45E-03	2.56E-03	2.43E-03	4.12E-03
	Double Pane	Electric	7.74E-04	1.34E-03	1.27E-03	1.74E-03	5.98E-04	8.72E-04	7.63E-04	1.39E-03
		Non-electric	6.51E-04	1.44E-03	1.46E-03	2.04E-03	5.03E-04	8.98E-04	8.47E-04	1.43E-03
Mercantile (Retail, not mall)	Single Pane	Electric	1.12E-03	1.96E-03	2.41E-03	3.76E-03	9.77E-04	1.53E-03	1.81E-03	3.60E-03
		Non-electric	9.24E-04	1.60E-03	2.05E-03	2.58E-03	7.19E-04	1.22E-03	1.66E-03	2.52E-03
	Double Pane	Electric	6.28E-04	1.02E-03	1.15E-03	1.85E-03	3.75E-04	5.25E-04	4.98E-04	1.24E-03
		Non-electric	4.85E-04	8.46E-04	9.94E-04	1.27E-03	2.62E-04	4.01E-04	3.72E-04	8.46E-04
Office – Small (<40,000 sq ft)	Single Pane	Electric	6.82E-04	1.77E-03	1.90E-03	2.83E-03	7.77E-04	1.68E-03	1.56E-03	2.60E-03
		Non-electric	8.47E-04	1.71E-03	1.87E-03	2.64E-03	1.01E-03	1.61E-03	1.73E-03	2.49E-03
	Double Pane	Electric	3.70E-04	8.73E-04	9.07E-04	1.42E-03	2.91E-04	5.46E-04	5.44E-04	8.72E-04
		Non-electric	4.14E-04	8.43E-04	9.04E-04	1.33E-03	3.73E-04	5.86E-04	5.63E-04	8.86E-04
Office – Large (≥40,000 sq ft)	Single Pane	Electric	3.21E-03	8.24E-03	9.91E-03	9.71E-03	4.69E-03	9.88E-03	1.13E-02	1.41E-02
		Non-electric	3.20E-03	8.35E-03	1.00E-02	9.79E-03	4.72E-03	1.00E-02	1.14E-02	1.42E-02
	Double Pane	Electric	1.62E-03	4.20E-03	5.01E-03	4.99E-03	1.64E-03	3.52E-03	4.04E-03	5.12E-03
		Non-electric	1.62E-03	4.22E-03	5.05E-03	4.98E-03	1.65E-03	3.52E-03	4.06E-03	5.12E-03

Building Type[62]	Window Type	Heating System Type	DSM III				DSM VII			
			DRF_{North} (kW/ft^2)	DRF_{East} (kW/ft^2)	DRF_{South} (kW/ft^2)	DRF_{West} (kW/ft^2)	DRF_{North} (kW/ft^2)	DRF_{East} (kW/ft^2)	DRF_{South} (kW/ft^2)	DRF_{West} (kW/ft^2)
Other[63]	Single Pane	Electric	9.15E-04	1.54E-03	-5.66E-05	2.69E-03	9.12E-04	1.38E-03	-1.09E-04	2.97E-03
		Non-electric	9.24E-04	1.29E-03	-4.56E-04	2.33E-03	9.52E-04	1.17E-03	-7.69E-04	2.52E-03
	Double Pane	Electric	4.63E-04	8.00E-04	-8.48E-04	1.37E-03	3.21E-04	5.01E-04	-1.05E-03	1.06E-03
		Non-electric	4.74E-04	6.64E-04	-1.15E-03	1.18E-03	3.39E-04	4.23E-04	-1.62E-03	8.99E-04
Public Assembly	Single Pane	Electric	1.10E-03	1.84E-03	1.83E-03	3.88E-03	1.09E-03	1.57E-03	1.42E-03	3.83E-03
		Non-electric	1.21E-03	2.04E-03	1.97E-03	4.69E-03	1.19E-03	1.75E-03	1.54E-03	4.66E-03
	Double Pane	Electric	5.61E-04	9.44E-04	9.38E-04	2.48E-03	3.80E-04	5.61E-04	5.02E-04	1.04E-03
		Non-electric	6.10E-04	1.04E-03	1.01E-03	3.19E-03	4.19E-04	6.24E-04	5.53E-04	1.13E-03
Public Order and Safety (Police and Fire Station)	Single Pane	Electric	1.04E-03	2.03E-03	2.34E-03	2.36E-03	9.86E-04	1.55E-03	1.66E-03	2.25E-03
		Non-electric	1.07E-03	2.19E-03	2.54E-03	2.53E-03	1.02E-03	1.67E-03	1.82E-03	2.36E-03
	Double Pane	Electric	1.04E-03	2.03E-03	2.34E-03	2.36E-03	3.47E-04	5.40E-04	5.79E-04	7.80E-04
		Non-electric	1.07E-03	2.19E-03	2.54E-03	2.53E-03	3.59E-04	5.82E-04	6.34E-04	8.19E-04
Religious Worship	Single Pane	Electric	5.90E-03	1.32E-02	5.95E-03	1.32E-02	4.94E-03	1.13E-02	5.29E-03	1.19E-02
		Non-electric	3.38E-03	7.84E-03	3.33E-03	7.55E-03	1.03E-03	2.38E-03	1.22E-03	2.25E-03
	Double Pane	Electric	3.13E-03	6.11E-03	3.55E-03	6.75E-03	1.80E-03	4.04E-03	2.03E-03	4.21E-03
		Non-electric	1.81E-03	3.45E-03	2.14E-03	7.55E-03	1.03E-03	2.38E-03	1.22E-03	2.25E-03
Service (Beauty, Auto Repair Workshop)	Single Pane	Electric	9.37E-04	9.53E-04	1.88E-03	1.70E-03	2.39E-03	2.87E-03	5.40E-03	8.70E-03
		Non-electric	6.39E-04	1.07E-03	1.96E-03	1.69E-03	2.56E-03	3.16E-03	5.64E-03	9.17E-03
	Double Pane	Electric	2.99E-04	4.94E-04	1.10E-03	8.64E-04	8.42E-04	1.01E-03	1.94E-03	3.03E-03
		Non-electric	3.19E-04	1.15E-03	1.15E-03	5.78E-04	8.95E-04	1.11E-03	2.02E-03	3.19E-03

4.1.1.4 Default Savings

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

4.1.1.5 Source(s)

The primary source for this deemed savings approach uses the building energy model prototypes defined by the 2008 Database for Energy Efficient Resources (DEER)[64] and modified to represent Richmond, VA and a blend of Elizabeth City, NC and Rocky Mount-Wilson, NC weather along with program-specific window characteristics.

4.1.1.6 Update Summary

The changes to this section, compared with last year, are described in Table 4-7.

Table 4-7: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Input Variable	• Updated per-square-foot savings for buildings in North Carolina based on revised weather stations

[64] http://deeresources.com/index.php/deer-versions/archives/8-deer2008-exante-main-text

5 NON-RESIDENTIAL SMALL BUSINESS IMPROVEMENT PROGRAM, DSM PHASE V

Dominion's Non-Residential Small Business Improvement Program provides small business owners incentives to use Dominion-approved contractors to provide many of the measures already provided through existing legacy programs that typically target non-residential building owners: Non-Residential Heating and Cooling Efficiency program and the Non-residential Lighting Systems and Controls program. In addition, four retrocommissioning measures are provided. Program measures are summarized in Table 5-1.

According to the program terms and conditions, as of June 2017, to be eligible to participate in this program, Dominion Energy Virginia non-residential customers must be of a privately-owned business with five or fewer locations that has not exceeded monthly demand threshold of 100 kW three or more times in the past 12 months, has not opted out of participation, is responsible for the electric bill and is the owner of the facility or reasonably able to secure permission to complete measures. Once a customer participates in the program and receive a rebate, they cannot opt out for three years following the year of participation.

Prior to June 1, 2017, the Small Business Improvement Program delivered refrigeration measures to Virginia customers, but stopped per an SCC ruling.[65]

Table 5-1: Non-residential Small Business Improvement Program Measure List

End-Use	Measure	Manual Section
HVAC	Duct Testing & Sealing	Section 5.1.1
	Unitary/Split AC, HP, and Chiller Tune-up	Section 5.1.2
	Refrigerant Charge Correction	Section 5.1.3
	Unitary/Split AC & HP Upgrade	Section 5.1.4
	Mini-split Heat Pump	Section 3.1.2
	Dual Enthalpy Air-side Economizer	Section 3.1.5
	Variable Frequency Drive	Section 5.1.7
	Programmable Thermostat	Section 5.1.7
Lighting	Lighting, Fixtures, Lamps, and Delamping	Section 1.1.1
	Sensors & Controls	Section 1.1.2
	LED Exit Signs	Section 5.2.3
Other	Compressed Air Leak Repair	Section 5.3.1

[65] As of June 1, 2017, refrigeration measures ceased to be offered through this program as a result of the ruling in Virginia SCC Case No. PUE-2016-00111 issued and effective on the same date.

5.1 Heating, Ventilation, and Air-Conditioning (HVAC) End Use

5.1.1 Duct Testing and Sealing

5.1.1.1 Measure Description

This measures provides building owners incentives to use Dominion-approved, duct-sealing contractors to reduce conditioned-air leakage to unconditioned spaces by the following steps: 1) test non-residential duct systems for air leakage, 2) seal the ducts using an aerosol-based product, and then 3) test the sealed duct systems for air leakage to confirm that sealing the ducts reduced the air-leakage rate.

Eligible ductwork is connected to a unitary HVAC system or a heat pump and occurs within an unconditioned plenum space or between an insulated, finished ceiling and a roof surface. Based on DNV's judgment, this measure is applicable to ductwork at unitary and chiller-cooled systems.

This measure is offered in Non-Residential Prescriptive program DSM Phase VI, described in Section 1096.

5.1.1.2 Savings Estimation Approach

For all system types, per measure gross annual electric energy savings are calculated according to the following equation:

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

Unitary Systems, Air Source Heat Pumps, and AC Units

Per measure, gross annual electric cooling and heating energy savings are calculated according to the following equations.

Unitary systems, heat pumps and AC units, $Size_{cool}$ < 65,000 Btu/h:

$$\Delta kWh_{cool} = Size_{cool} \times \frac{12\frac{kBtuh}{ton}}{SEER} \times EFLH_{cool} \times \left(1 - \frac{\bar{n}_{dist,base}}{\bar{n}_{dist,ee}}\right)_{cool}$$

Unitary systems, heat pumps and AC units, $Size_{heat}$ < 65,000 Btu/h:

$$\Delta kWh_{heat} = Size_{heat} \times \frac{1}{HSPF} \times EFLH_{heat} \times \left(1 - \frac{\bar{n}_{dist,base}}{\bar{n}_{dist,ee}}\right)_{heat}$$

Unitary systems, heat pumps and AC units, $Size_{cool}$ ≥ 65,000Btu/h

$$\Delta kWh_{cool} = Size_{cool} \times \frac{12\frac{kBtuh}{ton}}{IEER} \times EFLH_{cool} \times \left(1 - \frac{\bar{n}_{dist,base}}{\bar{n}_{dist,ee}}\right)_{cool}$$

Unitary systems, for heat pumps and AC units, $Size_{heat} \geq$ 65,000 Btu/h:

$$\Delta kWh_{heat} = Size_{heat} \times \frac{1}{COP \times 3.412 \frac{Btuh}{W}} \times EFLH_{heat} \times \left(1 - \frac{\bar{n}_{dist,base}}{\bar{n}_{dist,ee}}\right)_{heat}$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = Size_{cool} \times \frac{12 \frac{kBtuh}{ton}}{EER} \times \left(1 - \frac{n_{dist,pk,base}}{n_{dist,pk,ee}}\right) \times CF$$

Chiller Systems

Water-cooled chiller systems, cooling savings:

$$\Delta kWh_{cool} = Size_{cool} \times \frac{kW}{ton_{IPLV}} \times EFLH_{cool} \times \left(1 - \frac{\bar{n}_{dist,base}}{\bar{n}_{dist,ee}}\right)_{cool}$$

Air-cooled chiller systems, cooling savings:

$$\Delta kWh_{cool} = Size_{cool} \times \frac{12 \frac{kBtuh}{ton}}{EER_{IPLV}} \times EFLH_{cool} \times \left(1 - \frac{\bar{n}_{dist,base}}{\bar{n}_{dist,ee}}\right)_{cool}$$

Chiller system heating savings for systems <65,000 Btu/h:

$$\Delta kWh_{heat} = Size_{heat} \times \frac{1}{HSPF} \times EFLH_{heat} \times \left(1 - \frac{\bar{n}_{dist,base}}{\bar{n}_{dist,ee}}\right)_{heat}$$

Chiller system heating savings for systems ≥65,000 Btu/h:

$$\Delta kWh_{heat} = Size_{heat} \times \frac{1}{COP \times 3.412 \frac{Btuh}{W}} \times EFLH_{heat} \times \left(1 - \frac{\bar{n}_{dist,base}}{\bar{n}_{dist,ee}}\right)_{heat}$$

For all system types, heating systems with non-electric primary heat will receive zero heating savings.

Per measure gross coincident demand reduction is calculated according to the following equations:

Water-cooled chiller systems:

$$\Delta kW = Size_{cool} \times \frac{kW}{ton_{full\ load}} \times \left(1 - \frac{\bar{n}_{dist,peak,base}}{\bar{n}_{dist,peak,ee}}\right) \times CF$$

Air-cooled chiller systems:

$$\Delta kW = Size_{cool} \times \frac{12\frac{kBtuh}{ton}}{EER_{full\ load}} \times \left(1 - \frac{\bar{n}_{dist,peak,base}}{\bar{n}_{dist,peak,ee}}\right) \times CF$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reductions
$Size_{cool}$ = system cooling capacity in tons, based on nameplate data
$Size_{heat}$ = system heating capacity in kBtu/h, based on nameplate data
SEER = seasonal energy efficiency ratio (SEER). It is used for heat pumps and AC units that are smaller than 65,000 Btu/h.
IEER = integrated energy efficiency ratio (IEER) of a unit's efficiency at four load points: 100%, 75%, 50%, and 25% of full cooling capacity. It is used for heat pumps and AC units that are 65,000 Btu/h or larger.
EER = energy efficiency ratio (EER) of heat pump and air-conditioning systems at full-load conditions. (See Equation 3 in Sub-appendix F2-V: General Equations to convert SEER to EER, if EER is not provided.)
HSPF = heating seasonal performance factor (HSPF). It is used for heat pumps. (See Equation 6 in Sub-appendix F2-V: General Equations to convert COP to HSPF, if HSPF is not provided.)
COP = coefficient of performance (heating)
$\bar{n}_{dist,base,cool}$ = duct system average seasonal efficiency of baseline (pre-sealing) cooling system
$\bar{n}_{dist,base,heat}$ = duct system average seasonal efficiency of baseline (pre-sealing) heating system
$\bar{n}_{dist,ee,cool}$ = duct system average seasonal efficiency of efficient (post-sealing) cooling system
$\bar{n}_{dist,ee,heat}$ = duct system average seasonal efficiency of efficient (post-sealing) heating system
$n_{dist,peak,base}$ = duct system efficiency of baseline system, under peak conditions (equal to $\bar{n}_{dist,base,cool}$)
$n_{dist,peak,ee}$ = duct system efficiency of efficient system, under peak conditions (equal to $\bar{n}_{dist,ee,cool}$)
$EER_{full\text{-}load}$ = energy efficiency ratio (EER) of air-cooled chillers at full-load conditions.
EER_{IPLV} = energy efficiency ratio (EER) of air-cooled chillers at integrated part load value (IPLV).
$\frac{kW}{ton}_{IPLV}$ = energy efficiency of water-cooled chiller system at integrated part load value (IPLV)
$\frac{kW}{ton}_{full\ load}$ = energy efficiency of water-cooled chiller system at full load
$EFLH_{cool}$ = cooling equivalent full load hours (EFLH)
$EFLH_{heat}$ = heating equivalent full load hours (EFLH)
CF = peak coincidence factor
TRF = Thermal regain factor

5.1.1.3 Input Variables

Table 5-2: Input Values for Duct Sealing Savings Calculations

Component	Type	Value	Unit	Source(s)
$Size_{cool}$	Variable	See customer application	tons of cooling capacity (per unit)	Customer application
$Size_{heat}$	Variable	See customer application	kBtu/h (per unit)	Customer application

Component	Type	Value	Unit	Source(s)
SEER/IEER/EER/COP/HSPF	Variable	See customer application	Btu/W-hr (COP is dimension-less)	Customer application
		Default: See Table 10-9 and Table 10-10 in Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings based on equipment type		ASHRAE 90.1-2013
$kW/ton_{full\ load}$	Variable	See customer application	kW/ton	Customer application
		Default: see Table 10-12 in Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings based on equipment type		ASHRAE 90.1-2013
kW/ton_{IPLV}	Variable	See customer application	kW/ton	Customer application
		Default: see Table 10-12 in Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings based on equipment type		ASHRAE 90.1-2013
$EER_{full\ load}$	Variable	See customer application	Btu/W-h	Customer application
		Default: see Table 10-12 in Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings based on equipment type		ASHRAE 90.1-2013
EER_{IPLV}	Variable	See customer application	kBtu/kW-h	Customer application
		Default: see Cooling Efficiencies of Water Chilling Packages Table 10-12 in Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings based on equipment type		ASHRAE 90.1-2013
$\bar{n}_{dist,base,cool}$	Variable	See customer application	-	Customer application
		Default: No insulation, 30% leakage.		New York TRM 2018, p. 242
$\bar{n}_{dist,base,heat}$	Variable	See customer application along with Table 5-3 and Table 5-4	-	Customer application
		Default: No insulation, 30% leakage		New York TRM 2018, p. 242

Component	Type	Value	Unit	Source(s)
$\overline{n}_{dist,ee,cool}$	Variable	See customer application along with Table 5-3 and Table 5-4	-	Customer application
		Default: No insulation, 15% leakage		New York TRM 2018, p. 242
$\overline{n}_{dist,ee,heat}$	Variable	See customer application along with Table 5-3 and Table 5-4	-	Customer application
		Default: No insulation, 15% leakage		New York TRM 2018, p. 242
$n_{dist,peak,base}$	Variable	See customer application along with Table 5-3 and Table 5-4	-	Customer application
		Default: No insulation, 30% leakage		New York TRM 2018, p. 242
$n_{dist,peak,ee}$	Variable	See customer application along with Table 5-3 and Table 5-4	-	Customer application
		Default: No insulation, 15% leakage		New York TRM 2018, p. 242
$EFLH_{heat}$	Fixed	See Table 10-5 in Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours	hours (annual)	Mid-Atlantic TRM 2019 p. 590
$EFLH_{cool}$	Fixed	For chiller systems, see Table 10-6; for all other system types, see Table 10-4 in Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours	hours (annual)	Mid-Atlantic TRM 2019 p. 442, p. 589
CF	Fixed	0.68	-	Calculated CF from Dominion's DSM Phase I program. April 1, 2012 EM&V Report, Sub-appendix C-1, p. F-166

The New York TRM provides values for duct system efficiency for uninsulated ducts and ducts with R-6 insulation for four building types: assembly building, fast food restaurant, full service restaurant, and small retail. The average column in Table 5-3 is a simple average of the four building types. The values for R-2, R-4 and R-8 insulation have been calculated by scaling the results using an engineering relationship of the effectiveness of increasing R-values (non-linear).

The manual provides efficiencies for only five leakage-rate bins: 8%, 15%, 20%, 25%, and 30%. In preparation for receiving duct leakage percentages that do not match these specific values, DNV used a linear regression to model duct system efficiency as a function of leakage proportion. The coefficients from this model were used to compute duct system efficiency for any leakage value between 0% and 50%.

[66] Appendix C-1, Commercial HVAC Program: Load Shape and Net Savings Analysis Evaluation Report; Evaluation, Measurement and Verification Report for Dominion Virginia Power, Case PUE-2010-00084, Apr. 1, 2012, p. F-1.

Table 5-3: Duct System Efficiency by Broad Building Type Categories[67]

Duct Total Leakage	Duct System R-Value	Assembly		Fast Food Restaurant		Full Service Restaurant		Small Retail		Average	
		Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling
8%	Uninsulated	0.857	0.922	0.766	0.866	0.797	0.854	0.614	0.838	0.759	0.870
15%	Uninsulated	0.829	0.908	0.734	0.853	0.765	0.845	0.581	0.827	0.727	0.858
20%	Uninsulated	0.810	0.897	0.714	0.844	0.743	0.837	0.559	0.818	0.707	0.849
25%	Uninsulated	0.793	0.886	0.693	0.834	0.721	0.829	0.538	0.809	0.686	0.840
30%	Uninsulated	0.776	0.873	0.675	0.823	0.701	0.820	0.520	0.799	0.668	0.829
8%	R-2	0.877	0.954	0.821	0.906	0.845	0.904	0.691	0.885	0.808	0.912
15%	R-2	0.846	0.938	0.780	0.889	0.807	0.893	0.648	0.871	0.770	0.898
20%	R-2	0.826	0.926	0.754	0.878	0.781	0.884	0.619	0.861	0.745	0.887
25%	R-2	0.807	0.913	0.729	0.865	0.755	0.874	0.593	0.850	0.721	0.875
30%	R-2	0.789	0.899	0.707	0.852	0.732	0.864	0.570	0.839	0.699	0.863
8%	R-4	0.886	0.970	0.848	0.925	0.869	0.929	0.729	0.908	0.833	0.933
15%	R-4	0.855	0.952	0.802	0.907	0.827	0.917	0.681	0.893	0.791	0.917
20%	R-4	0.833	0.940	0.774	0.894	0.799	0.908	0.649	0.883	0.764	0.906
25%	R-4	0.814	0.926	0.747	0.881	0.772	0.897	0.621	0.871	0.738	0.893
30%	R-4	0.795	0.911	0.723	0.867	0.748	0.885	0.594	0.859	0.715	0.881
8%	R-6	0.896	0.986	0.875	0.945	0.893	0.954	0.767	0.931	0.858	0.954
15%	R-6	0.863	0.967	0.825	0.925	0.848	0.941	0.714	0.915	0.813	0.937
20%	R-6	0.841	0.954	0.794	0.911	0.818	0.931	0.679	0.904	0.783	0.925
25%	R-6	0.821	0.939	0.765	0.896	0.789	0.919	0.648	0.891	0.756	0.911
30%	R-6	0.801	0.924	0.739	0.881	0.763	0.907	0.619	0.879	0.731	0.898
8%	R-8	0.901	0.994	0.889	0.955	0.905	0.967	0.786	0.943	0.870	0.965
15%	R-8	0.867	0.974	0.836	0.934	0.858	0.953	0.731	0.926	0.823	0.947
20%	R-8	0.845	0.961	0.804	0.919	0.827	0.943	0.694	0.915	0.793	0.935
25%	R-8	0.825	0.946	0.774	0.904	0.798	0.930	0.662	0.901	0.764	0.920
30%	R-8	0.804	0.930	0.747	0.888	0.771	0.918	0.631	0.889	0.738	0.906

67 NY TRM 2019, Appendix H. Distribution Efficiencies, pp. 681–686. New York City values are used for heating and cooling efficiencies for different building types. This table represent more R-Values and total duct leakage (%) than the reference table and for those cases, regression analysis was performed to obtain the respective heating and cooling duct system efficiencies.

Table 5-4: Duct System Efficiency Mapping to Building Type[68]

Building Type	Associated Duct System Efficiency Building Type
Education **Education – College and University** **Education – High School** **Education – Elementary and Middle School** **Health Care – inpatient** **Health Care – outpatient** **Lodging – (Hotel, Motel, and Dormitory)** **Office – Small (< 40,000 sq ft)** **Office – Large (≥ 40,000 sq ft)** **Other** **Warehouse and Storage**	Average
Food Sales **Food Sales – Gas Station Convenience Store** **Food Sales – Convenience Store** **Food Sales – Grocery** **Mercantile (Retail, not Mall)** **Mercantile (Mall)** **Service (Beauty, Auto Repair Workshop)**	Small Retail
Food Service **Food Service – Fast Food** **Food Service – Other**	Fast Food Restaurant
Food Service – Restaurant **Food Service – Full Service**	Full Service Restaurant
Public Assembly **Public Order and Safety (Police and Fire Station)** **Religious Worship**	Assembly Building

5.1.1.4 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.

5.1.1.5 Source(s)

The primary sources for this deemed savings approach is the New York TRM 2018, pp. 241-244, Mid-Atlantic TRM 2019, pp. 442 and 589-590, and ASHRAE 90.1-2013.

5.1.1.6 Update Summary

The changes to this section, compared with last year, are described in Table 5-5.

Table 5-5: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Equation	• Added size condition of <65,000 Btu/h and ≥65,000 Btu/h for determining which equation to use for ground-source heat pumps. Previously all ground-source heat pumps used equations with IEER and COP efficiency metrics.

[68] Where “Building Type” does not clearly map to “Associated Duct System Efficiency Building Type,” “Associated Duct System Efficiency Building Type is assigned to most conservative type.” Full building type list was consolidated to map directly to 2003 U.S. DOE CBECS building types. Full building type list from Mid-Atlantic TRM. Original sources: Connecticut Program Savings Document for 2012 Program Year (September, 2011), pp. 219-220. http://www.ctenergyinfo.com/2012%20CT%20Program%20Savings%20Documentation%20FINAL.pdf. 2003 US DOE CBECS building type definitions. http://www.eia.gov/emeu/cbecs/building_types.html.

Version	Type of Change	Description of Change
v10	Source	• Updated page numbers / version of the New York TRM
	Input Variable	• Update to weather stations in North Carolina resulted in revised EFLHs for weather-sensitive measures • Equipment efficiency levels were revised per update to ASHRAE 2013 in VA and NC
	Default Savings	• Default savings modified due to changes to Sub-appendix F2- III: Non-residential HVAC Equipment Efficiency Ratings

5.1.2 Unitary/Split Air Conditioning, Heat Pump, and Chiller Tune-up

5.1.2.1 Measure Description

This measure involves tuning up packaged air conditioning units, heat pump units (both air and ground source), and air- and water-cooled cooled chillers at small commercial and industrial sites. All HVAC applications other than space cooling and heating—such as process cooling—are ineligible for this measure.

For the Small Business Improvement Program, this measure is separated from the Refrigerant Charge Adjustment retrocommissioning measure. However, this measure is also offered by the Commercial Non-Residential Prescriptive Program in which case, the tune-up and the refrigerant charge adjustment steps are combined into a single measure.

5.1.2.2 Savings Estimation Approach

Algorithms and inputs to calculate heating, cooling savings, and demand reductions for unitary/split HVAC and package terminal AC system tune-ups are provided below. Gross annual electric energy savings and gross coincident demand reduction are calculated according to the equations following this section.

Cooling Energy Savings

For heat pumps and AC units <65,000 Btu/h, the per measure gross annual electric cooling energy savings are calculated as follows:

$$\Delta kWh_{cool} = Size_{cool} \times \frac{12\frac{kBtuh}{ton}}{SEER} \times EFLH_{cool} \times TUF$$

For heat pumps and AC units ≥65,000 Btu/h, the per measure gross annual electric cooling energy savings are calculated as follows:

$$\Delta kWh_{cool} = Size_{cool} \times \frac{12\frac{kBtuh}{ton}}{IEER} \times EFLH_{cool} \times TUF$$

For air- and water-cooled chillers:

$$\Delta kWh_{cool} = Size_{cool} \times IPLV \times EFLH_{cool} \times TUF$$

Per measure gross coincident demand reduction is calculated according to the following equation for air-conditioning and heat pump systems and chillers:

$$\Delta kW = Size_{cool} \times \frac{12\frac{kBtuh}{ton}}{EER} \times CF \times TUF$$

Heating Energy Savings

For heat pumps <65,000 Btu/h, the per measure gross annual electric heating energy savings are calculated as follows:

$$\Delta kWh_{heat} = Size_{heat} \times \frac{1}{HSPF} \times EFLH_{heat} \times TUF$$

For heat pumps ≥65,000 Btu/h, the per measure gross annual electric heating energy savings are calculated as follows:

$$\Delta kWh_{heat} = Size_{heat} \times \frac{1}{COP \times 3.412\frac{Btuh}{W}} \times EFLH_{heat} \times TUF$$

For AC units and air- and water-cooled chillers, there are no per measure gross annual electric heating energy savings:

$$\Delta kWh_{heat} = 0$$

Per measure gross annual electric energy savings are calculated by combining the cooling and heating energy savings according to the following equation:

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

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reductions
ΔkWh_{cool} = per measure gross annual electric cooling energy savings
ΔkWh_{heat} = per measure gross annual electric heating energy savings
$Size_{cool}$ = tons of cooling capacity of equipment
$Size_{heat}$ = heating capacity of equipment, if applicable.
SEER = seasonal energy efficiency ratio (SEER) of the installed air conditioning equipment. It is used for heat pumps and AC units that are smaller than 65,000 Btu/h.
IEER = integrated energy efficiency ratio (IEER) of the existing or baseline air conditioning 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 for heat pumps and AC units that are 65,000 Btu/h or larger.
$EFLH_{cool}$ = equivalent full load cooling hours
$EFLH_{heat}$ = equivalent full load heating hours

IPLV = energy efficiency at integrated part load value (IPLV) of chillers. For air-cooled chillers, this is typically shown as EER_{IPLV}; for water-cooled chillers, this is typically shown as kW/ton_{IPLV}.
TUF = rate of energy efficiency improvement due to tune-up
EER = energy efficiency ratio of air-conditioning and heat pump systems and air- and water-cooled chillers at full load conditions.
HSPF = heating seasonal performance factor (HSPF) of existing heat pump. HSPF is used in heating savings for air-source heat pumps.
COP = coefficient of performance of existing heating equipment. Ground source heat pumps use COP to determine heating savings.
CF = coincidence factor

5.1.2.3 Input Variables

Table 5-6: Input Variables for AC/HP/Chiller Tune-up Measure

Component	Type	Value	Units	Source(s)
$Size_{cool}$	Variable	See customer application	tons of cooling capacity	Customer application
$Size_{heat}$	Variable	See customer application Default for HPs: 12 x $Size_{cool}$	kBtu/h	Customer application
$EFLH_{cool}$	Fixed	Refer to Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours ACs & HPs: Table 10-4 Chillers: Table 10-6	hours (annual)	Mid-Atlantic TRM 2019, p. 589
$EFLH_{heat}$	Fixed	Refer to Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours HPs: Table 10-5	hours (annual)	Mid-Atlantic TRM 2019, p. 590
HSPF/SEER/IEER/ EER/COP	Variable	Refer to Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings ACs & HPs: Table 10-10 Chillers: Table 10-12	k/kW-hour (except COP is dimensionless)	ASHRAE 90.1-2013
IPLV	Variable	Refer to Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings Chillers: Table 10-12	Btu/W for air-cooled chillers; kW/ton for water-cooled chillers	ASHRAE 90.1-2013
RCA_Done[69]	Boolean	See customer application	True/False	Customer application

69 RCA_Done is only relevant to the Non-Residential Prescriptive Program; it is neither collected nor used for the Small Business Improvement Program because Refrigerant Charge Adjustment is a separate measure.

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Component	Type	Value	Units	Source(s)
TUF	Fixed	If RCA was not done: ACs: 0.023 HPs: 0.028 Chillers: 0.050 If RCA was also done (only for Commercial Non-Residential Prescriptive Program): ACs: 0.050 HPs: 0.050 Chillers: 0.050	-	Mid-Atlantic TRM 2019 p. 455, California Impact Evaluation of 2013-14 Commercial Quality Maintenance Programs,[70] and Wisconsin Focus on Energy 2019 TRM, pp. 285-288.
CF	Fixed	Use system capacity to assign CF: < 11.5 tons = 0.588 ≥ 11.5 tons = 0.874	-	Mid-Atlantic TRM 2019, p. 455

5.1.2.4 Default Savings

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

5.1.2.5 Source(s)

The primary sources for this deemed savings approach include the ASHRAE 90.1-2013, Mid-Atlantic TRM 2019, pp. 454-456, pp. 589-590, the California Impact Evaluation of 2013-14 Commercial Quality Maintenance Programs,[70] and the Wisconsin Focus on Energy TRM 2019, pp. 285-288.

5.1.2.6 Update Summary

The changes to this section, compared with last year, are described in Table 5-7.

Table 5-7: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Equation	• Added size condition of <65,000 Btu/h and ≥65,000 Btu/h for determining which equation to use for ground-source heat pumps. Previously all ground-source heat pumps used equations with IEER and COP efficiency metrics.
v10	Source	• Updated page numbers and versions of references to: ○ Mid-Atlantic TRM ○ Wisconsin Focus on Energy TRM • Clarified citation and footnote of CPUC's Impact Evaluation for 2013-14 (HVAC3)
	Input Variable	• For HPs at which RCA was not performed, revised Tune-up Factor (TUF) value from 0.027 to 0.028 • Update to weather stations in North Carolina resulted in revised EFLHs for weather-sensitive measures • Baseline efficiency levels were revised per update to ASHRAE 2013 in VA and NC

[70] California Public Utilities Commission (2016). Impact Evaluation of 2013-14 Commercial Quality Maintenance Programs (HVAC3), www.calmac.org/publications/HVAC3ImpactReport_0401.pdf. While these proportions were not provided in the report, DNV analyzed the same supporting data—though owned by the CPUC and not publicly available—used to produce the tables provided on pages BB-2 and BB-3 of Appendix BB of the report. Whereas the tables provided in Appendix BB were aggregated by program, DNV aggregated the raw data by HVAC-system type to determine appropriate TUF values. This analysis showed that for packaged air-conditioning systems, an average of 54.7% of the overall tune-up savings were attributable to the RCA treatment; for packaged heat pump systems, 44.7% of the overall tune-up savings were attributable to the RCA treatment.

5.1.3 Refrigerant Charge Adjustment

5.1.3.1 Measure Description

This measure involves adjusting the amount of refrigerant charge at air conditioners and heat pumps for packaged and split systems at small commercial and industrial sites. All HVAC applications other than space cooling and heating—such as process cooling—are ineligible for this measure.

5.1.3.2 Savings Estimation Approach

Algorithms and inputs to calculate cooling, heating and demand reductions for unitary/split air-conditioning and heating pump systems that receive refrigerant charge adjustments are provided below. Gross annual electric energy savings are calculated according to the equations that follow.

Cooling Energy Savings

For heat pumps and AC units <65,000 Btu/h, the per measure gross annual electric cooling energy savings are calculated according to the following equation:

$$\boldsymbol{\Delta kWh_{cool} = Size_{cool} \times \frac{12\,\frac{kBtuh}{ton}}{SEER} \times EFLH_{cool} \times RCF}$$

For heat pumps and AC units ≥65,000 Btu/h, the per measure gross annual electric cooling energy savings are calculated according to the following equation:

$$\Delta kWh_{cool} = Size_{cool} \times \frac{12\,\frac{kBtuh}{ton}}{IEER} \times EFLH_{cool} \times RCF$$

Heating Energy Savings

For heat pump units <65,000 Btu/h, the per measure gross annual electric heating energy savings are calculated according to the following equation:

$$\Delta kWh_{heat} = Size_{heat} \times \frac{12\,\frac{kBtuh}{ton}}{HSPF} \times EFLH_{heat} \times RCF$$

For heat pump units ≥65,000 Btu/h, the per measure gross annual electric heating energy savings are calculated according to the following equation:

$$\Delta kWh_{heat} = Size_{heat} \times \left(\frac{12\,\frac{kBtuh}{ton}}{COP \times 3.412\,{}^{Btuh}/_{W}} \right) \times EFLH_{heat} \times RCF$$

Cooling and heating savings are added to calculate the per measure gross annual electric energy savings as follows:

$$\Delta kWh \quad = \Delta kWh_{cool} + \Delta kWh_{heat}$$

Per measure, gross coincident demand reduction is calculated according to he following equation:

$$\Delta kW \quad = Size_{cool} \times \frac{12}{EER} \times RCF \times CF$$

Where,

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reductions
ΔkWh_{cool} = per measure gross annual electric cooling energy savings
ΔkWh_{heat} = per measure gross annual electric heating energy savings
$Size_{cool}$ = Unit capacity for cooling
$Size_{heat}$ = Unit capacity for heating
EER = Energy Efficiency Ratio (EER) at full load
SEER = seasonal energy efficiency ratio (SEER) of the installed air conditioning equipment. It is used for heat pumps and AC units that are smaller than 65,000 Btu/h.
IEER = integrated energy efficiency ratio (IEER) of the existing or baseline air conditioning 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 for heat pumps and AC units that are 65,000 Btu/h or larger.
HSPF = Heating Seasonal Performance Factor
COP = Coefficient of Performance (heating)
$EFLH_{cool}$ = Equivalent Full Load Hours for cooling
$EFLH_{heat}$ = Equivalent Full Load Hours for heating
RCF = Refrigerant Charge Factor
CF = Demand Coincidence Factor

5.1.3.3 Input Variables

Table 5-8: Input Variables for Refrigerant Charge Adjustment

Component	Type	Value	Units	Source(s)
$Size_{cool}$	Variable	See customer application	tons (cooling capacity)	Customer application
$Size_{heat}$	Variable	See customer application Default: = $Size_{cool}$	tons	Customer application
$EFLH_{cool}$	Fixed	See Table 10-4 in Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours	hours (annual)	Mid-Atlantic TRM 2019, p. 589
$EFLH_{heat}$	Fixed	See Table 10-5 in Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours	hours (annual)	Mid-Atlantic TRM 2019 p. 590

Component	Type	Value	Units	Source(s)
EER/SEER	Variable	See customer application	Btu/W-hr	Customer application
		See Table 10-9 and Table 10-10 in Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings		ASHRAE 90.1 2013
HSPF/COP	Variable	See customer application	Btu/W-hr (for HSPF); (except COP is dimensionless)	Customer application
		See Table 10-10 in Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings		ASHRAE 90.1 2013
RCF[71]	Fixed	AC units: 0.027 HP units: 0.022	-	Mid-Atlantic TRM 2019 p. 455 and California 2013-2014 Evaluation Report[72]
CF	Fixed	Use system capacity to assign CF as follows: < 11.25 tons = 0.588 ≥ 11.25 tons = 0.874	-	Mid-Atlantic TRM 2019 p. 455

5.1.3.4 Default Savings

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

5.1.3.5 Source(s)

The primary sources for this deemed savings approach include the ASHRAE 90.1-2013, Mid-Atlantic TRM 2019, pp. 454 - 456 and 589-590, and the California 2013-14 Impact Evaluation Report, pp. BB-2 to BB-3.

5.1.3.6 Update Summary

The changes to this section, compared with last year, are described in Table 5-9.

Table 5-9: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Equation	• Added size condition of <65,000 Btu/h and ≥65,000 Btu/h for determining which equation to use for ground-source heat pumps. Previously all ground-source heat pumps used equations with IEER and COP efficiency metrics.
v10	Source	• Updated page number(s)/version of Mid-Atlantic TRM • Clarified citation footnote of CPUC report

[71] RCF values were calculated utilizing the AC Tune-Up measure in the Mid-Atlantic TRM and electric savings due to coil cleaning and refrigerant charge adjustments found via extensive literature review.

[72] California Public Utilities Commission (2016). Impact Evaluation of 2013-14 Commercial Quality Maintenance Programs (HVAC3), www.calmac.org/publications/HVAC3ImpactReport_0401.pdf. While these proportions were not provided in the report, DNV analyzed the same supporting data—though owned by the CPUC and not publicly available—used to produce the tables provided on pages BB-2 and BB-3 of Appendix BB of the report. Whereas the tables provided in Appendix BB were aggregated by program, DNV aggregated the raw data by HVAC-system type to determine appropriate TUF values. This analysis showed that for packaged air-conditioning systems, an average of 54.7% of the overall tune-up savings were attributable to the RCA treatment; for packaged heat pump systems, 44.7% of the overall tune-up savings were attributable to the RCA treatment.

Version	Type of Change	Description of Change
	Input Variable	• Update to weather stations in North Carolina resulted in revised EFLHs for weather-sensitive measures • Equipment efficiency levels were revised per update to ASHRAE 2013 in VA and NC

5.1.4 Unitary/Split AC & HP Upgrade

This measure is also offered through the Non-Residential Heating and Cooling Efficiency program. The savings approach is described in Section 3.1.

5.1.5 Mini-split Heat Pump

This measure is also offered through the Non-Residential Heating and Cooling Efficiency program. The savings approach is described in 3.1.2.

5.1.6 Dual Enthalpy Air-side Economizer

This measure is also offered through the Non-Residential Heating and Cooling Efficiency program. The savings approach is described in Section 3.1.4.

5.1.7 Variable Frequency Drives

5.1.7.1 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. This measure is also delivered through the Non-Residential Heating and Cooling Efficiency program, DSM Phase VII as indicated in Section 3.1.4 . That program, however, uses a different savings methodology.

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 5.

5.1.7.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh \ = \frac{hp\ x\ 0.746\ x\ LF}{\eta} \times\ HOU\ \times\ ESF$$

Per measure, gGross coincident demand reduction is calculated according to the following equation:

$$\Delta kW \ = \frac{hp\ x\ 0.746\ x\ LF}{\eta} \times CF \times DRF$$

Where:

ΔkWh	= per measure gross annual electric energy savings
ΔkW	= per measure gross coincident demand reductions
HP	= motor horse power
LF	= motor load factor (%) at fan design airflow rate or pump design flowrate
η	= NEMA-rated efficiency of motor
HOU	= annual hours of use
ESF	= energy savings factor
DRF	= demand reduction factor
CF	= peak coincidence factor

5.1.7.3 Input Variables

Table 5-10: Input Values for Non-Residential Variable Frequency Drives

Component	Type	Value	Unit	Source(s)
HP	Variable	See customer application	horsepower	Customer application
LF	Fixed	Default: 0.65	-	Mid Atlantic TRM 2019, p. 428
η	Variable	Default see Table 5-11	-	NEMA Standards Publication Condensed MG 1-2007
ESF	Fixed	Default see Table 5-12	-	Mid-Atlantic TRM 2015, p. 370; Mid-Atlantic TRM 2019, p. 433
DRF	Fixed	Default see Table 5-12	-	Mid-Atlantic TRM 2015 p. 370; Mid-Atlantic TRM 2019, p. 433
HOU	Variable	See Table 10-7 in Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours	hours (annual)	Mid-Atlantic TRM 2019, pp. 431-432
CF	Fixed	0.28 for fan applications 0.55 for pump applications	-	Mid-Atlantic TRM 2015, p. 370; Mid-Atlantic TRM 2019, p. 431

Table 5-11 provides the baseline motor efficiencies that are consistent with the minimum federal accepted motor efficiencies provided by the National Electrical Manufacturers Association (NEMA).[73]

Table 5-11: Baseline Motor Efficiency[74]

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
50	0.945

Horsepower (hp)	η
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 5-12: Energy Savings and Demand Reduction Factors by Application

VFD Applications	ESF	DRF
Unknown VFD (Minimum)[75]	0.123	0.039
HVAC Fan VFD Savings Factors[76]		
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[77]		
Chilled Water Pump	0.633	0.460

[73] 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.

[74] 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).

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

[76] Mid-Atlantic TRM 2015, p. 370

[77] Mid-Atlantic TRM 2019, p. 433.

VFD Applications	ESF	DRF
Hot Water Pump	0.652	0.000
Unknown/Other Pump (Average)[78]	0.643	0.230

5.1.7.4 Default Savings

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

5.1.7.5 Source(s)

The primary sources for this deemed savings approach are Mid-Atlantic TRM 2015, pp. 367-371 (for fans) and Mid-Atlantic TRM 2019, pp. 427-433 (for pumps).

5.1.7.6 Update Summary

The changes to this section, compared with last year, are described in Table 5-13.

Table 5-13: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Section	• Moved methodology from the retired Non-Residential Heating and Cooling Efficiency Program DSM III Section to this section.
v10	HOU	• Update to weather stations in North Carolina resulted in revised HOUs for weather-sensitive measures
	Clarification	• Clarified that this methodology is only used for measures implemented during DSM Phase III

5.1.8 Programmable Thermostats

5.1.8.1 Measure Description

This measure involves the installation of programmable thermostats[79] for cooling and/or heating systems in spaces with no existing setback control. The programmable thermostat shall setback the temperature setpoint during unoccupied periods. The savings will be realized from reducing the system usage during unoccupied times. The baseline operation of the HVAC units are assumed to be in continuous ON mode during the unoccupied period with fans cycling to maintain the occupied period temperature setpoints.

5.1.8.2 Savings Estimation Approach

AC Units

Per measure, gross annual electric energy savings are calculated according to the following equation for units <65,000 Btu/h:

$$\Delta kWh = \left[Size_{cool} \times \left(\frac{12}{SEER}\right) \times EFLH_{cool} \times ESF_{cool}\right]$$

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

[79] Non-communicating thermostats are not eligible for the demand response programs.

Per measure, gross annual electric energy savings are calculated according to the following equation for units ≥65,000 Btu/h:

$$\Delta kWh = \left[Size_{cool} \times \left(\frac{12}{IEER}\right) \times EFLH_{cool} \times ESF_{cool}\right]$$

Per measure, gross coincident demand reduction is considered to be zero since space conditioning equipment typically operates at maximum capacity during peak periods.

$$\Delta kW = 0$$

Heat Pumps

Per measure, gross annual electric energy savings are calculated according to the following equation for units <65,000 Btu/h:

$$\Delta kWh = \left[Size_{cool} \times \left(\frac{12}{SEER}\right) \times EFLH_{cool} \times ESF_{cool}\right] + \left[Size_{heat} \times EFLH_{heat} \times \left(\frac{1}{HSPF}\right) \times ESF_{heat}\right]$$

Per measure, gross annual electric energy savings are calculated according to the following equation for units ≥65,000 Btu/h:

$$\Delta kWh = \left[Size_{cool} \times \left(\frac{12}{IEER}\right) \times EFLH_{cool} \times ESF_{cool}\right] + \left[Size_{heat} \times EFLH_{heat} \times \left(\frac{12}{3.412 \times COP}\right) \times ESF_{heat}\right]$$

Per measure, gross coincident demand reduction is considered to be zero since space conditioning equipment typically operates at maximum capacity during peak periods.

$$\Delta kW = 0$$

5.1.8.3 Input Variables

Table 5-14: Input Parameters for Programmable Thermostat Measure

Component	Type	Value	Units	Source(s)
$Size_{cool}$	Variable	See customer application	tons of cooling capacity	Customer application
$Size_{heat}$	Variable	See customer application	kBtu/h	Customer application

Component	Type	Value	Units	Source(s)
$EFLH_{heat}$	Fixed	See Table 10-5 in Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours	hours (annual)	Mid-Atlantic TRM 2019, p. 589
$EFLH_{cool}$	Fixed	Refer to Table 10-4 in Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours	hours (annual)	Mid-Atlantic TRM 2019, p. 590
SEER/IEER	Variable	See customer application	kBtu/kW-hour	Customer application
		See Table 10-9 and Table 10-10 in Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings		ASHRAE 90.1 2013, Table 6.8.1A and Table 6.8.1B
HSPF/COP	Variable	See customer application	kBtu/kW-hour (except COP is dimensionless)	Customer application
		See Table 10-10 in Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings		ASHRAE 90.1 2010 Table 6.8.1A and Table 6.8.1B
ESF_{cool}	Fixed	0.090	-	NY TRM 2018, p. 275
ESF_{heat}	Fixed	0.068	-	NY TRM 2018, p. 275

5.1.8.4 Default Savings

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

5.1.8.5 Source(s)

The primary source for this deemed savings approach is the ASHRAE 90.1-2010, New York TRM 2019, p. 275, and Mid-Atlantic TRM 2019, pp. 589-590.

5.1.8.6 Update Summary

The changes to this section, compared with last year, are described in Table 5-15.

Table 5-15: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the New York TRM
	Input Variable	• Update to weather stations in North Carolina resulted in revised EFLHs for weather-sensitive measures • Equipment efficiency levels were revised per update to ASHRAE 2013 in VA and NC

5.2 Lighting End Use

5.2.1 Lighting, Fixtures, Lamps, and Delamping

This measure is also offered through the Non-Residential Lighting Systems and Controls program. The savings approach is described in Section 1.1.1.

5.2.2 Sensors and Controls

This measure is also offered through the Non-Residential Lighting Systems and Controls program. The savings approach is described in Section 1.1.2.

5.2.3 LED Exit Signs

5.2.3.1 Measure Description

This measure realizes energy savings by installing an exit sign that is illuminated with light emitting diodes (LED). This measure should be limited to retrofit installations.

5.2.3.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = \frac{(Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee})}{1{,}000\, {}^{W}/_{kW}} \times HOU \times WHF_e \times ISR$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \frac{(Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee})}{1{,}000\, {}^{W}/_{kW}} \times WHF_d \times CF \times ISR$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
$watts_{base}$ = connected load of the baseline exit sign
$watts_{ee}$ = connected load of the efficient exit sign
Qty_{base} = number of baseline exit signs
Qty_{ee} = number of efficient exit signs
HOU = average hours of use per year
WHF_e = waste heat factor for energy to account for cooling savings from efficient lighting
WHF_d = waste heat factor for demand to account for cooling savings from efficient lighting
CF = coincidence factor
ISR = in-service rate, the percentage of rebated measures actually installed

5.2.3.3 Input Variables

Table 5-16: Input Values for LED Exit Sign Calculations

Component	Type	Value	Unit	Source(s)
Qty_{base}	Variable	See customer application	-	Customer application
Qty_{ee}	Variable	Default: equal to Qty_{base}	-	Customer application
$watts_{base}$	Variable	See customer application	watts	Customer application
		Default: 16 W CFL		Mid-Atlantic TRM 2019 p. 314, ENERGY STAR®[80]
$watts_{ee}$	Variable	See customer application Default: 5 W LED	watts	Mid-Atlantic TRM 2019 p. 314, ENERGY STAR®
HOU	Fixed	8,760	hours (annual)	Mid-Atlantic TRM 2019, p. 314
WHF_e	Variable	See Table 10-15 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Mid-Atlantic TRM 2019, p. 315
WHF_d	Variable	See Table 10-15 in Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Mid-Atlantic TRM 2019, p. 315
CF	Fixed	1.0	-	Mid-Atlantic TRM 2019, p. 314[81]
ISR	Fixed	1.0	-	Mid-Atlantic TRM 2019, p. 315[82]

Note that the coincidence factor (CF) is 1 for this measure since exit signs are on continuously, including during the entirety of the peak period.

5.2.3.4 Default Savings

If the proper values are not supplied, a default savings may be applied using conservative input values. The default per measure gross annual electric energy savings will be assigned according to the following calculation:

$$\Delta kWh = \frac{(Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee})}{1{,}000 \, {}^{W}/_{kW}} \times HOU \times WHF_e \times ISR$$

[80] LED exit sign default values come from an ENERGY STAR® report: Save Energy, Money and Prevent Pollution with Light-Emitting Diode (LED) Exit Signs:http://www.energystar.gov/ia/business/small_business/led_exitsigns_techsheet.pdf (accessed 7/13/2018).

[81] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

[82] EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

$$= \frac{(1 \times 16\,W - 1 \times 5\,W)}{1{,}000\,{}^{W}\!/_{kW}} \times 8{,}760\,hour \times 1.0 \times 1.0$$

$$= 96.4\,kWh$$

The default per measure gross coincident demand reduction are calculated using the following calculation:

$$\Delta kW = \frac{(Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee})}{1{,}000\,{}^{W}\!/_{kW}} \times WHF_d \times CF \times ISR$$

$$= \frac{(1 \times 16\,W - 1 \times 5\,W)}{1{,}000\,{}^{W}\!/_{kW}} \times 1.0 \times 1.0 \times 1.0$$

$$= 0.011\,kW$$

5.2.3.5 Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2019, pp. 314-317.

5.2.3.6 Update Summary

The changes to this section, compared with last year, are described in Table 5-17.

Table 5-17: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM

5.3 Other End Use

5.3.1 Air Compressor Leak Repair

5.3.1.1 Measure Description

This measure realizes energy savings by repairing compressed air leaks. Reducing the amount of air leaked in the compressed air system reduces the load on the compressors and, thereby saving energy.

This measure is offered in the Non-Residential Small Manufacturing Program in Section 8.1.2 but uses a different methodology. That program uses site-speific equipment and operating conditions for determining the system efficiecny. The savings for this program uses deemed values for the system efficecny.

5.3.1.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = hp \times LF \times \frac{cfm}{hp} \times (Leak_{base} - Leak_{ee}) \times \frac{kW}{cfm} \times HOU$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \frac{\Delta kWh \times CF}{HOU}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
hp = rated horsepower
LF = load factor of air compressor
cfm/hp = compressed airflow rate per air compressor motor horsepower
$Leak_{base}$ = baseline percentage of compressed air produced that is leaked
$Leak_{ee}$ = energy-efficient percentage of compressed air produced that is leaked
kW/cfm = energy consumed for each cubic foot of compressed air per minute produced
HOU = annual hours of operation
CF = coincidence factor of air compressor

5.3.1.3 Input Variables

Table 5-18: Input Variables for Air Compressor Leak Repair Measure

Component	Type	Value	Units	Source(s)
hp	Variable	See customer application	hp	Customer application
LF	Variable	See customer application	percent	Customer application
cfm/hp	Variable	See customer application	cfm/hp	Customer application
$Leak_{base}$	Variable	See customer application	percent	Customer application
$Leak_{ee}$	Variable	See customer application	percent	Customer application
kW/cfm	Fixed	0.17	kW/cfm	Michigan Energy Measure Database[83]
HOU	Fixed	6,240	hours (annual)	Michigan Energy Measure Database[84]
CF	Fixed	0.865	-	Michigan Energy Measure Database[85]

5.3.1.4 Default Savings

There are no default savings for this measure because the savings are dependent on the change in the percent air leaked, the system capacity and load factor.

[83] Michigan Energy Measure Database 2018, at http://www.michigan.gov/mpsc, Document "FES-I20 Compressed Air Leak Survey and Repair Michigan 11282017.doc," July 2017, p. 1.
[84] Ibid.
[85] Ibid.

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5.3.1.5 Source(s)

The primary source for this deemed savings approach is the Michigan Energy Measure Database 2018, at http://www.michigan.gov/mpsc, Document "FES-I20 Compressed Air Leak Survey and Repair Michigan 11282017.doc," July 2017.

5.3.1.6 Update Summary

The changes to this section, compared with last year, are described in Table 5-19.

Table 5-19: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	None	• No change

6 NON-RESIDENTIAL PRESCRIPTIVE PROGRAM, DSM PHASE VI

Dominion's Non-Residential Prescriptive Program provides qualifying business owners incentives to use pursue one or more of the qualified energy efficiency measures through a local, participating contractor in Dominion's contractor network. To qualify for this program, the customer must be responsible for the electric bill and must be the owner of the facility or reasonably able to secure permission to complete the measures. All program measures are summarized in Table 6-1.

Table 6-1: Non-residential Prescriptive Program Measure List

End-Use	Measure	Manual Section
Cooking	Commercial Convection Oven	Section 6.1.1
	Commercial Electric Combination Oven	Section 6.1.2
	Commercial Electric Fryer	Section 6.1.3
	Commercial Griddle	Section 6.1.4
	Commercial Hot Food Holding Cabinet	Section 6.1.5
	Commercial Steam Cooker	Section 6.1.6
HVAC	Duct Testing & Sealing	Section 5.1.1
	Unitary/Split AC/HP Tune-up	Section 5.1.2
	Variable Speed Drives on Kitchen Fan	Section 6.2.3
Plug Load	Smart Strip	Section 6.3.1
Refrigeration	Door Closer	Section 6.4.1
	Door Gasket	Section 6.4.2
	Commercial Freezers and Refrigerators – Solid Door	Section 6.4.3
	Commercial Ice Maker	Section 6.4.4
	Evaporator Fan ECM Retrofit	Section 6.4.5
	Evaporator Fan Control	Section 6.4.6
	Floating Head Pressure Control	Section 6.4.7
	Low/No-sweat Door Film	Section 6.4.8
	Refrigeration Night Cover	Section 6.4.9
	Refrigerator Coil Cleaning	Section 6.4.10
	Suction Pipe Insulation (Cooler & Freezer)	Section 6.4.11
	Strip Curtain (Cooler & Freezer)	Section 6.4.12
	Vending Machine Miser	Section 6.4.13

6.1 Cooking End Use

6.1.1 Commercial Convection Oven

6.1.1.1 Measure Description

This measure involves the installation of an ENERGY STAR® qualified commercial convection oven. Commercial convection ovens that are ENERGY STAR® certified have higher heavy load cooking efficiencies and lower idle energy rates making them more efficient than standard models.

The baseline equipment is assumed to be a standard efficiency convection oven with a heavy-load efficiency of 65% for full-size electric ovens (i.e., a convection oven that can accommodate full-size sheet pans measuring 18 x 26 x 1-inch) and 68% for half-size electric ovens (i.e., a convection oven that can accommodate half-size sheet pans measuring 18 x 13 x 1-inch).

6.1.1.2 Savings Estimation Approach

The baseline annual electric energy consumption is calculated as follows:

$$kWh_{base} = \left[lb_{daily} \times \frac{E_{conv}}{\eta_{base}} + kW_{base,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{base}} \right) \right] \times Days$$

The efficient annual electric energy consumption is calculated as follows:

$$kWh_{ee} = \left[lb_{daily} \times \frac{E_{conv}}{\eta_{ee}} + kW_{ee,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{ee}} \right) \right] \times Days$$

Per measure, gross annual electric energy savings are calculated using the following equations:

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

Per measure, gross coincident demand reduction is calculated using the following equation:

$$\Delta kW = \frac{\Delta kWh}{(Hours_{daily} \times Days)}$$

where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
$Hours_{daily}$ = average daily operating hours
$E_{conv.}$ = ASTM Energy to Food; the amount of energy absorbed by food during convection cooking
lb_{daily} = pounds of food cooked per day
Days = annual days of operation
η_{base} = baseline equipment cooking energy efficiency
η_{ee} = efficient equipment cooking energy efficiency
$kW_{base,idle}$ = baseline equipment idle energy rate
$kW_{ee,idle}$ = efficient equipment idle energy rate
PC_{base} = baseline equipment production capacity

PC_{ee} = efficient equipment production capacity

6.1.1.3 Input Variables

Table 6-2: Input Parameters for Convection Oven

Component	Type	Value	Units	Source(s)
$Hours_{daily}$	Variable	See customer application	hours, daily	Customer application
		Default: 5, per Table 6-3		Mid-Atlantic TRM 2019, p. 545
Days	Variable	See customer application	days, annual	Customer application
		Default: 180, per Table 6-3		Mid-Atlantic TRM 2019, p. 545
lb_{daily}	Variable	See customer application	lb, daily	Customer application
		Default: 100		Mid-Atlantic TRM 2019, p. 544
E_{conv}	Fixed	0.0732	kWh/lb	Mid-Atlantic TRM 2019, p. 544
PC_{base}	Fixed	Half Size: 45 Full Size: 90	lb/hour	Mid-Atlantic TRM 2019, p. 545
η_{base}	Fixed	Half Size: 0.68 Full Size: 0.65	-	Mid-Atlantic TRM 2019, p. 545
$kW_{base,idle}$	Fixed	Half Size:1.03 Full Size: 2.00	kW	Mid-Atlantic TRM 2019, p. 545
$kW_{ee,idle}$	Fixed	Half Size: 1.00 Full Size: 1.60	kW	Mid-Atlantic TRM 2019, p. 545
PC_{ee}	Fixed	Half Size: 50 Full Size: 90	lb/hour	Mid-Atlantic TRM 2019, p. 545
η_{ee}	Fixed	Half Size: 0.71 Full Size: 0.71	-	Mid-Atlantic TRM 2019, p. 545

Table 6-3: Operational Hours for Ovens by Building Type

Facility Type	Hour/Day	Day/Year
Community College	11	283
Fast Food Restaurant	14	363
Full Service Restaurant	12	321
Grocery	12	365
Hospital	11	365
Hotel	20	365
Miscellaneous	9	325
Motel	20	365
Primary School	5	180
Secondary School	8	180

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Facility Type	Hour/Day	Day/Year
Office	12	250
University	11	283

6.1.1.4 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 as follows:

$$kWh_{base} = \left[lb_{daily} \times \frac{E_{conv}}{\eta_{base}} + kW_{base,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{base}}\right)\right] \times Days$$

$$= \left[100\ lb \times \frac{0.0732\ {}^{kW}/_{lb}}{0.68} + 1.03\ kW \times \left(5\ hr - \frac{100\ {}^{lb}/_{day}}{45\ {}^{lb}/_{hr}}\right)\right] \times 180\ days$$

$$= 2{,}453\ kWh$$

$$kWh_{ee} = \left[lb_{daily} \times \frac{E_{conv}}{\eta_{ee}} + kW_{ee,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{ee}}\right)\right] \times Days$$

$$= \left[100\ lb \times \frac{0.0732\ {}^{kW}/_{lb}}{0.71} + 1.00\ kW \times \left(5\ hr - \frac{100\ {}^{lb}/_{day}}{50\ {}^{lb}/_{hr}}\right)\right] \times 180\ days$$

$$= 2{,}396\ kWh$$

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

$$= 2{,}453\ kWh - 2{,}396\ kWh$$

$$= 57\ kWh$$

The default gross coincident demand reduction are calculated using the following calculation:

$$\Delta kW = \frac{\Delta kWh}{(Hours_{daily} \times Days)}$$

$$= \frac{57\ kWh}{(5\ hr \times 180\ day)}$$

$$= 0.063\ kW$$

6.1.1.5 Source(s)

The primary sources for this deemed savings approach is the Mid-Atlantic TRM 2019, pp. 543-546.

6.1.1.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-4.

Table 6-4: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM
	Input variable	• Clarified default assumption values

6.1.2 Commercial Electric Combination Oven

6.1.2.1 Measure Description

This measure involves the installation of an ENERGY STAR® qualified combination oven. A combination oven is a convection oven that includes the added capability to inject steam into the oven cavity and typically offers at least three distinct cooking modes. This measure applies to time of sale opportunities.

The baseline equipment is assumed to be a typical standard efficiency electric combination oven.

6.1.2.2 Savings Estimation Approach

The baseline annual electric energy consumption is calculated as follows:

$$kWh_{base,conv} = \left[lb_{daily} \times \frac{E_{conv}}{\eta_{base,conv}} + kW_{base,conv,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{base,conv}}\right)\right] \times (1 - PCT_{steam}) \times Day$$

$$kWh_{base,steam} = \left[lb_{daily} \times \frac{E_{steam}}{\eta_{base,steam}} + kW_{base,steam,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{base,steam}}\right)\right] \times PCT_{steam} \times Days$$

$$kWh_{base} = kWh_{base,conv} + kWh_{base,steam}$$

The efficient annual electric energy consumption is calculated as follows:

$$kWh_{ee,conv} = \left[lb_{daily} \times \frac{E_{conv}}{\eta_{ee,conv}} + kW_{ee,conv,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{ee,conv}}\right)\right] \times (1 - PCT_{steam}) \times Days$$

$$kWh_{ee,steam} = \left[lb_{daily} \times \frac{E_{steam}}{\eta_{ee,steam}} + kW_{ee,steam,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{ee,steam}}\right)\right] \times PCT_{steam} \times Days$$

$$kWh_{ee} = kWh_{ee,conv} + kWh_{ee,steam}$$

Per measure, gross annual electric energy savings are calculated using the following equation:

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

Per measure, gross coincident demand reduction is calculated using the following equation:

$$\Delta kW = \frac{\Delta kWh}{Hours_{daily} \times Days}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
kWh_{base} = annual energy usage of the baseline equipment
kWh_{ee} = annual energy usage of the efficient equipment
$kWh_{base,conv}$ = baseline annual cooking energy consumption in convection mode
$kWh_{base,steam}$ = baseline annual steam energy consumption in steam mode
$kW_{base,conv,idle}$ = baseline idle energy rate in convection mode
$kW_{base,steam,idle}$ = baseline idle energy rate in steam mode
$kWh_{ee,conv}$ = efficient annual cooking energy consumption in convection mode
$kWh_{ee,steam}$ = efficient annual steam energy consumption in steam mode
$kW_{ee,conv,idle}$ = efficient idle energy rate in convection mode
$kW_{ee,steam,idle}$ = efficient idle energy rate in steam mode
$Hours_{daily}$ = average daily operating hours
$Days$ = annual days of operation
lb_{daily} = pounds of food cooked per day
E_{conv} = ASTM Energy to Food, the amount of energy absorbed by the food during convection mode cooking, per pound of food
E_{steam} = ASTM Energy to Food, the amount of energy absorbed by the food during steam cooking mode, per pound of food
$\eta_{base,conv}$ = baseline equipment cooking energy efficiency in convection mode

$\eta_{base,steam}$ = baseline equipment cooking energy efficiency in steam mode
$\eta_{ee,conv}$ = efficient equipment cooking energy efficiency in convection mode
$\eta_{ee,steam}$ = efficient equipment cooking energy efficiency in steam mode
PCT_{steam} = percent of food cooked in steam cooking mode
$PC_{base,conv}$ = baseline equipment production capacity in convection mode
$PC_{ee,conv}$ = efficient equipment production capacity in convection mode
$PC_{base,steam}$ = baseline equipment production capacity in steam mode
$PC_{ee,steam}$ = efficient equipment production capacity in steam mode

6.1.2.3 Input Variables

Table 6-5: Input Parameters for Commercial Electric Combination Ovens

Component	Type	Value	Units	Source(s)
$Hours_{daily}$	Variable	See customer application	hours, daily	Customer application
		Default: 5, per Table 6-3		Mid-Atlantic TRM 2019, p. 545
Days	Variable	See customer application	days, annual	Customer application
		Default: 180, per Table 6-3		Mid-Atlantic TRM 2019, p. 545
lb_{daily}	Variable	See customer application	pounds, daily	Customer application
		Default: 200		Mid-Atlantic TRM 2019, p. 549
PCT_{steam}	Variable	See customer application	-	Customer application
		Default: 0.50		Mid-Atlantic TRM 2019, p. 550
E_{conv}	Fixed	0.0732	kWh/lb	Mid-Atlantic TRM 2019, p. 549
E_{steam}	Fixed	0.0308	kWh/lb	Mid-Atlantic TRM 2019, p. 549
$PC_{base,conv}$	Fixed	<15 pans: 79 ≥15 pans: 166	lb/hr	Mid-Atlantic TRM 2019, p. 550
$PC_{base,steam}$	Fixed	<15 pans: 126 ≥15 pans: 295	lb/hr	Mid-Atlantic TRM 2019, p. 550
$\eta_{base,conv}$	Fixed	0.72	-	Mid-Atlantic TRM 2019, p. 550
$\eta_{base,steam}$	Fixed	0.49	-	Mid-Atlantic TRM 2019, p. 550
$kW_{base,conv,idle}$	Fixed	<15 pans: 1.320 ≥15 pans: 2.280	kW	Mid-Atlantic TRM 2019, p. 550
$kW_{base,steam,idle}$	Fixed	<15 pans: 5.260 ≥15 pans: 8.710	kW	Mid-Atlantic TRM 2019, p. 550
$kW_{ee,conv,idle}$[86]	Variable	<15 pans: 1.299 ≥15 pans: 2.099	kW	Mid-Atlantic TRM 2019, p. 550
$kW_{ee,steam,idle}$[87]	Variable	<15 pans: 1.970 ≥15 pans: 3.300	kW	Mid-Atlantic TRM 2019, p. 550

[86] Mid-Atlantic TRM 2019 provided an equation for calculating this value based on number of pans, as follows: =0.080 x Number of pans + 0.4989. To establish fixed kW values for efficient equipment, DNV reviewed the list of qualifying ENERGY STAR electric combination ovens and determined the mode for the number of pans: 10 pans is the mode for units having <15 pans (11 of 27 models or 41%); and 20 pans is the mode of capacity for units having ≥15 pans (5 of 7 models or 70%). These modes were used to calculate the kW values for <15 pans and ≥15 pans, respectively.

[87] Mid-Atlantic TRM 2019 provided an equation for calculating this value based on number of pans, as follows: = 0.133 x Number of pans + 0.64. To establish fixed kW values for efficient equipment, we reviewed the list of qualifying ENERGY STAR electric combination ovens and determined the mode for the

Component	Type	Value	Units	Source(s)
$PC_{ee,conv}$	Fixed	<15 pans: 119 ≥15 pans: 201	lb/hr	Mid-Atlantic TRM 2019, p. 550
$PC_{ee,steam}$	Fixed	<15 pans: 177 ≥15 pans: 349	lb/hr	Mid-Atlantic TRM 2019, p. 550
$\eta_{ee,conv}$	Fixed	0.76	-	Mid-Atlantic TRM 2019, p. 550
$\eta_{ee,steam}$	Fixed	0.55	-	Mid-Atlantic TRM 2019, p. 550

6.1.2.4 Default Savings

If the proper values are not supplied, a default savings may be applied using conservative input values. The default efficient annual electric energy consumption will be as follows for <15 pans:

$$kWh_{base,conv} = \left[lb_{daily} \times \frac{E_{conv}}{\eta_{base}} + kW_{base,conv,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{base,conv}}\right)\right] \times (1 - PCT_{steam}) \times Days$$

$$= \left[200\ lb \times \frac{0.0732\ ^{kWh}/_{lb}}{0.72} + 1.320\ kW \times \left(5\ hr - \frac{200\ lb}{79\ ^{lb}/_{hr}}\right)\right] \times (1 - 0.50) \times 180\ days$$

$$= 2{,}123\ kWh$$

$$kWh_{base,steam} = \left[lb_{daily} \times \frac{E_{steam}}{\eta_{base}} + kW_{base,steam,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{base,steam}}\right)\right] \times PCT_{steam} \times Days$$

$$= \left[200\ lb \times \frac{0.0308\ ^{kWh}/_{lb}}{0.49} + 5.260\ kW \times \left(5\ hr - \frac{200\ lb}{126\ ^{lb}/_{hr}}\right)\right] \times 0.50 \times 180\ days$$

$$= 2{,}747\ kWh$$

number of pans: 10 pans is the mode for units having <15 pans (11 of 27 models or 41%); and 20 pans is the mode of capacity for units having ≥15 pans (5 of 7 models or 70%). These modes were used to calculate the kW values for <15 pans and ≥15 pans, respectively.

$$kWh_{base} = kWh_{base,conv} + kWh_{base,steam}$$

$$= 2{,}123\ kWh + 2{,}747\ kWh$$

$$= 4{,}870\ kWh$$

The efficient annual electric energy consumption is calculated as follows:

$$kWh_{ee,conv} = \left[lb_{daily} \times \frac{E_{conv}}{\eta_{ee,conv}} + kW_{ee,conv,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{ee,conv}}\right)\right] \times (1 - PCT_{steam}) \times Days$$

$$= 1 \times \left[200\ lb \times \frac{0.0732\ {}^{kWh}/_{lb}}{0.76} + 1.299\ kW \times \left(5\ hr - \frac{200\ lb}{119\ {}^{lb}/_{hr}}\right)\right] \times (1 - 0.50) \times 180\ days$$

$$= 2{,}122\ kWh$$

$$kWh_{ee,steam} = \left[lb_{daily} \times \frac{E_{steam}}{\eta_{ee,steam}} + kW_{ee,steam,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{ee,steam}}\right)\right] \times PCT_{steam} \times Days$$

$$= \left[200\ lb \times \frac{0.0308\ {}^{kWh}/_{lb}}{0.55} + 1.970\ kW \times \left(5\ hr - \frac{200\ lb}{177\ {}^{lb}/_{hr}}\right)\right] \times 0.50 \times 180\ days$$

$$= 1{,}694\ kWh$$

$$kWh_{ee} = kWh_{ee,conv} + kWh_{ee,steam}$$

$$= 2{,}122\ kWh + 1{,}694\ kWh$$

$$= 3{,}816\ kWh$$

Gross annual electric energy savings are calculated using the following equation:

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

$$= 4{,}870\ kWh - 3{,}816\ kWh$$

$$= 1{,}054\ kWh$$

Gross coincident demand reduction is calculated using the following equation:

$$\Delta kW = \frac{\Delta kWh}{Hours_{daily} \times Days}$$

$$= \frac{1{,}054\ kWh}{5\ hr \times 180\ days}$$

$$= 1.171\ kW$$

6.1.2.5 Source(s)

The primary sources for this deemed savings approach is the Mid-Atlantic TRM 2019, pp. 445 and 548-550.

6.1.2.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-6.

Table 6-6: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM
	Equation	• Added Qty to savings equations
	Input Variable	• Updated $Hours_{daily}$, Days, $kW_{ee,conv,idle}$, and $kW_{ee,steam,idle}$ value

6.1.3 Commercial Electric Fryer

6.1.3.1 Measure Description

This measure involves the installation of an ENERGY STAR® qualified electric commercial fryer. Commercial fryers with the ENERGY STAR® designation offer shorter cook times and higher production rates through advanced burner and heat exchanger designs. Further, frypot insulation reduces standby losses resulting in a lower idle energy rate. This measure applies to both standard-size and large-vat fryers.

The baseline equipment is assumed to be a standard efficiency electric fryer with a heavy load efficiency of 75% for standard sized equipment and 70% for large vat equipment.[88]

6.1.3.2 Savings Estimation Approach

The baseline per measure gross annual electric energy usage is calculated using the following equation:

$$kWh_{base} = \left[lb_{daily} \times \frac{E_{fry}}{\eta_{base}} + kW_{base,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{base}}\right)\right] \times Days$$

Similarly, the efficient per measure gross annual electric energy usage is calculated using the following equation:

$$kWh_{ee} = \left[lb_{daily} \times \frac{E_{fry}}{\eta_{ee}} + kW_{ee,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{ee}}\right)\right] \times Days$$

Per measure, gross annual energy savings are calculated using the following equation:

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

Per measure, gross coincident demand reduction is calculated using the following equation:

$$\Delta kW = \frac{\Delta kWh}{(Hours_{daily} \times Days)}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
kWh_{base} = per measure annual energy usage of the baseline equipment
kWh_{ee} = per measure annual energy usage of the efficient equipment
$hours_{daily}$ = average daily operating hours
E_{fry} = ASTM Energy to Food ratio, the amount of energy absorbed by each pound of food during frying
lb_{daily} = pounds of food cooked per day
days = annual days of operation
η_{base} = baseline equipment cooking energy efficiency
η_{eff} = efficient equipment cooking energy efficiency
$kW_{base,idle}$ = baseline equipment idle energy rate
$kW_{ee,idle}$ = efficient equipment idle energy rate
PC_{base} = baseline equipment production capacity
PC_{ee} = efficient equipment production capacity

88 Standard fryers measure 12-18 in. wide and have a shortening capacity of 25-65 lb; large fryers measure 18-24-in. wide and have a shortening capacity greater than 50 lb.

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6.1.3.3 Input Variables

Table 6-7: Input Parameters for Electric Commercial Fryer Measure

Component	Type	Value	Units	Source(s)
$Hours_{daily}$	Variable	See customer application	hours, daily	Customer application
		Default: Standard fryer: 16 Large-vat fryer: 12		Mid-Atlantic TRM 2019, pp. 528-529
E_{fry}	Fixed	0.167	kWh/lb	Mid-Atlantic TRM 2019, pp. 528-529
lb_{daily}	Variable	See customer application	lb, daily	Customer application
		Default: 150		Mid-Atlantic TRM 2019, pp. 528-529
Days	Variable	See customer application	days, annual	Customer application
		Default: 365		Mid-Atlantic TRM 2019, pp. 528-529
η_{base}	Fixed	Standard fryer: 0.75 Large-vat fryer: 0.70	-	Mid-Atlantic TRM 2019, pp. 528-529
$kW_{base,idle}$	Fixed	Standard fryer: 1.05 Large-vat fryer: 1.35	kW	Mid-Atlantic TRM 2019, pp. 528-529
PC_{base}	Fixed	Standard fryer: 65 Large-vat fryer: 100	lb/hr	Mid-Atlantic TRM 2019, pp. 528-529
η_{ee}	Fixed	Standard fryer: 0.83 Large-vat fryer: 0.80	-	Mid-Atlantic TRM 2019, pp. 528-529
$kW_{ee,idle}$	Fixed	Standard fryer: 0.80 Large-vat fryer: 1.10	kW	Mid-Atlantic TRM 2019, pp. 528-529
PC_{ee}	Fixed	Standard fryer: 70 Large-vat fryer: 110	lb/hr	Mid-Atlantic TRM 2019, pp. 528-529

6.1.3.4 Default Savings

If the proper values are not supplied, a default savings may be applied using conservative input values. The default per measure gross annual electric energy savings will be assigned according to the following calculation (assuming for a standard fryer):

$$kWh_{base} = \left[lb_{daily} \times \frac{E_{fry}}{\eta_{base}} + kW_{base,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{base}}\right)\right] \times Days$$

$$= \left[150\ lb \times \frac{0.167\ {}^{kW}/_{lb}}{0.75} + 1.05\ kW \times \left(16\ hr - \frac{150\ {}^{lb}/_{day}}{65\ {}^{lb}/_{hr}}\right)\right] \times 365\ days$$

$$= 17{,}439\ kWh$$

$$kWh_{ee} = \left[lb_{daily} \times \frac{E_{fry}}{\eta_{ee}} + kW_{ee,idle} \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{base}}\right)\right] \times Days$$

$$= \left[150\ lb\ \times \frac{0.167\ {}^{kW}/_{lb}}{0.83} + 0.80\ kW \times \left(16\ hr - \frac{150\ {}^{lb}/_{day}}{70\ {}^{lb}/_{hr}}\right)\right] \times 365\ days$$

$$= 15{,}062\ kWh$$

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

$$= 17{,}439\ kWh - 15{,}062\ kWh$$

$$= 2{,}377\ kWh$$

The default per measure gross coincident demand reduction are calculated using the following calculation:

$$\Delta kW = \frac{\Delta kWh}{(Hours_{daily} \times Days)}$$

$$= \frac{2{,}377\ kWh}{(16\ hr \times 365\ days)}$$

$$= 0.407\ kW$$

6.1.3.5 Source(s)

The primary sources for this deemed savings approach is the Mid Atlantic TRM 2019, pp. 527-530.

6.1.3.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-8.

Table 6-8: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM

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6.1.4 Commercial Griddle

6.1.4.1 Measure Description

This measure involves the installation of an ENERGY STAR® qualified commercial griddle. ENERGY STAR® qualified commercial griddles have higher cooking energy efficiency and lower idle energy rates than standard equipment. The result is more energy being absorbed by the food compared with the total energy use, and less wasted energy when the griddle is in standby mode. This measure applies to only 10-sq.ft. commercial griddles due to Dominion Energy program requirements.

The baseline equipment is assumed to be a standard-efficiency electric griddle with a cooking-energy efficiency of 65%.

6.1.4.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated using the following equations:

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

where,

$$kWh_{base} = \left[lb_{daily} \times \frac{E_{griddle}}{\eta_{base}} + kW_{base,idle} \times SqFt \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{base} \times SqFt}\right)\right] \times Days$$

and

$$kWh_{ee} = \left[lb_{daily} \times \frac{E_{griddle}}{\eta_{ee}} + kW_{ee,idle} \times SqFt \times \left(Hours_{daily} - \frac{lb_{daily}}{PC_{ee} \times SqFt}\right)\right] \times Days$$

Per measure, gross coincident demand reduction is calculated using the following equation:

$$\Delta kW = \frac{\Delta kWh}{Hours_{daily} \times Days}$$

Where:

ΔkWh = per measure gross annual electric energy savings
Qty = quantity of griddles
ΔkW = per measure gross coincident demand reduction
kWh_{base} = per measure annual energy usage of the baseline equipment
kWh_{ee} = per measure annual energy usage of the efficient equipment
SqFt = surface area of griddle
$Hours_{daily}$ = average daily operating hours
$E_{griddle}$ = ASTM Energy to Food ratio, the amount of energy absorbed by each pound of food during griddling
lb_{daily} = pounds of food cooked per day
Days = annual days of operation

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η_{base} = baseline equipment cooking energy efficiency
η_{ee} = efficient equipment cooking energy efficiency
$kW_{base,idle}$ = baseline equipment idle energy rate
$kW_{ee,idle}$ = efficient equipment equipment idle energy rate
PC_{base} = baseline equipment production capacity
PC_{ee} = efficient equipment production capacity

6.1.4.3 Input Variables

Table 6-9: Input Parameters for Commercial Griddle Measure

Component	Type	Value	Units	Source(s)
lb_{daily}	Variable	See customer application	lb (daily)	Customer application
		Default: 100		Mid-Atlantic TRM 2019, p. 540
SqFt	Variable	See customer application	ft^2	Customer application
$Hours_{daily}$	Variable	See customer application	hours (daily)	Customer application
		Default: 12		Mid-Atlantic TRM 2019, p. 540
Days	Variable	See customer application	days (annual)	Customer application
		Default: 365		Mid-Atlantic TRM 2019, p. 540
$E_{griddle}$	Fixed	0.139	kWh/lb	Mid-Atlantic TRM 2019, p. 540
PC_{base}	Fixed	5.83	$lb/hr/ft^2$	Mid-Atlantic TRM 2019, p. 541
η_{base}	Fixed	0.65	-	Mid-Atlantic TRM 2019, p. 541
$kW_{base,idle}$	Fixed	0.40	kW/ft^2	Mid-Atlantic TRM 2019, p. 541
$kW_{ee,idle}$	Fixed	0.32	kW/ft^2	Mid-Atlantic TRM 2019, p. 541
PC_{ee}	Fixed	6.67	$lb/hr/ft^2$	Mid-Atlantic TRM 2019, p. 541
η_{ee}	Fixed	0.70	-	Mid-Atlantic TRM 2019, p. 541

6.1.4.4 Default Savings

There are no default savings for this measure. Applicant will need to provide the surface area of the griddle in square feet, for savings to be calculated. Default values are provided for most other input parameters.

6.1.4.5 Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2019, pp. 539-542.

6.1.4.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-10.

Table 6-10: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM

6.1.5 Commercial Hot Food Holding Cabinet

6.1.5.1 Measure Description

This measure involves installing an ENERGY STAR® qualified commercial hot food holding cabinet. The installed equipment will incorporate better insulation, reducing heat loss, and may also offer additional energy saving devices such as magnetic door gaskets, auto-door closures, or dutch doors. The insulation of the cabinet also offers better temperature uniformity within the cabinet from top to bottom. This means that qualified hot food holding cabinets are more efficient at maintaining food temperature while using less energy.

The baseline equipment is assumed to be a standard efficiency hot food holding cabinet.

6.1.5.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = \frac{(watts_{base,idle} - watts_{ee,idle})}{1{,}000 \, {}^{W}/_{kW}} \times Hours_{daily} \times Days$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \frac{(watts_{base,idle} - watts_{ee,idle})}{1{,}000 \, {}^{W}/_{kW}}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
$watts_{base,idle}$ = idle energy rate of the baseline equipment
$watts_{ee,idle}$ = idle energy rate of the efficient equipment
1,000 = conversion factor for W to kW
$Hours_{daily}$ = average daily operating hours
Days = annual days of operation

6.1.5.3 Input Variables

Table 6-11: Input Parameters for Hot Food Holding Cabinet

Component	Type	Value	Units	Source(s)
$watts_{base,idle}$	Variable	40 x Vol	watts	Mid-Atlantic TRM 2019, p. 537
$watts_{ee,idle}$	Variable	Vol < 13: 21.5 x Vol + 0.0 13 ≤ Vol < 28: 2.0 x Vol + 254.0 Vol ≥ 28: 3.8 x Vol + 203.5	watts	Mid-Atlantic TRM 2019, p. 537
Days	Variable	See customer application	days, annual	Customer application
		Default: 365		Mid-Atlantic TRM 2019, p. 537
$Hours_{daily}$	Variable	See customer application	hours, daily	Customer application
		Default: 15		Mid-Atlantic TRM 2019, p. 537

Note: Vol = the internal volume of the holding cabinet (ft^3) = actual volume of installed unit

6.1.5.4 Default Savings

There are no default savings for this measure. Applicant will need to provide the baseline and efficient idle wattage or the volume of the holding cabinet for savings to be calculated.

6.1.5.5 Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2019, pp. 536-538.

6.1.5.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-12.

Table 6-12: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-atlantic TRM

6.1.6 Commercial Steam Cooker

6.1.6.1 Measure Description

This measure involves an ENERGY STAR® qualified commercial steam cookers. Energy efficient steam cookers that have earned the ENERGY STAR® label offer shorter cook times, higher production rates, and reduced heat loss due to better insulation and a more efficient steam-delivery system.

The baseline condition assumes a standard efficiency, electric boiler-style steam cooker.

6.1.6.2 Savings Estimation

Per measure, gross annual electric energy savings are calculated using the following equations:

$$kWh_{base,steam} = lb_{daily} \times \frac{E_{steam}}{\eta_{base}} \times Days$$

$$kWh_{base,idle} = \left[(1 - PCT_{steam}) \times kW_{base,idle} + PCT_{steam} \times PC_{base} \times Qty_{pans} \times \frac{E_{steam}}{\eta_{base}}\right] \times \left(Hours_{daily} - \frac{lb_{daily}}{Qty_{pans} \times PC_{base}}\right) \times Days$$

$$kWh_{base} = kWh_{base,steam} + kWh_{base,idle}$$

$$kWh_{ee,steam} = lb_{daily} \times \frac{E_{steam}}{\eta_{ee}} \times Days$$

$$kWh_{ee,idle} = \left[(1 - PCT_{steam}) \times kW_{ee,idle} + PCT_{steam} \times PC_{ee} \times Qty_{pans} \times \frac{E_{steam}}{\eta_{ee}}\right] \times \left(Hours_{daily} - \frac{lb_{daily}}{Qty_{pans} \times PC_{ee}}\right) \times Days$$

$$kWh_{ee} = kWh_{ee,steam} + kWh_{ee,idle}$$

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \frac{\Delta kWh}{Hours_{daily} \times Days}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
kWh_{base} = the annual energy usage of the baseline equipment
kWh_{ee} = the annual energy usage of the efficient equipment
$kWh_{base,steam}$ = baseline daily cooking energy consumption
$kWh_{base,idle}$ = baseline daily idle energy consumption
$Hours_{daily}$ = average daily operating hours
E_{steam} = ASTM Energy to Food (kWh/lb); the amount of energy absorbed by each pound of food during steaming
lb_{daily} = pounds of food cooked per day
Days = annual days of operation
PCT_{steam} = percent of time in constant steam mode
Qty_{pans} = number of pans per unit
η_{base} = baseline equipment cooking energy efficiency
η_{ee} = efficient equipment cooking energy efficiency
$kW_{base,idle}$ = baseline equipment idle energy rate
$kW_{ee,idle}$ = efficient equipment idle energy rate
PC_{base} = baseline equipment production capacity
PC_{ee} = efficient equipment production capacity

DNV

6.1.6.3 Input Variables

Table 6-13: Input Parameters for Commercial Steam Cooker Measure

Component	Type	Value	Units	Source(s)
$Hours_{daily}$	Variable	See customer application	hours, daily	Customer application
		Default: 12		Mid-Atlantic TRM 2019, p. 532
Days	Variable	See customer application	days, annual	Customer application
		Default: 365		Mid-Atlantic TRM 2019, p. 532
lb_{daily}	Variable	See customer application	lb, daily	Customer application
		Default: 100		Mid-Atlantic TRM 2019, p. 532
Qty_{pans}	Variable	See customer application	pans	Customer application
		Default: 3[89]		Mid-Atlantic TRM 2019, p. 532
E_{steam}	Fixed	0.0308	kWh/lb	Mid-Atlantic TRM 2019, p. 532
PC_{base}	Fixed	23.3	lb/hr, per pan	Mid-Atlantic TRM 2019, p. 532
η_{base}	Fixed	Steam generator: 0.30 Boiler-based: 0.26	-	Mid-Atlantic TRM 201, p. 533
		Default = Boiler-based: 0.26		
$kW_{base,idle}$	Fixed	Steam generator: 1.20 Boiler-based: 1.00	kW	Mid-Atlantic TRM 2019, p. 533
		Default = Boiler-based: 1.00		
$kW_{ee,idle}$	Fixed	3 pans: 0.40 4 pans: 0.53 5 pans: 0.67 6+ pans: 0.80	kW	Mid-Atlantic TRM 2019, p. 533
		Default = 3 pans: 0.40		
PC_{ee}	Fixed	16.7	lb/hr, per pan	Mid-Atlantic TRM 2019, p. 532
η_{ee}	Fixed	0.50	-	Mid-Atlantic TRM 2019, p. 533
PCT_{steam}	Fixed	0.40	-	Mid-Atlantic TRM 2019, p. 532

6.1.6.4 Default Savings

If the proper values are not supplied, a default savings may be applied assuming boiler-based steam generation. The default per measure, gross annual electric energy savings will be assigned according to the following equations:

$$kWh_{base,steam} = lb_{daily} \times \frac{E_{steam}}{\eta_{base}} \times Days$$

[89] Assigned default of 3 pans based on the most conservative of the $kW_{ee,idle}$ options.

$$= 100\ lb \times \frac{0.0308\ {kWh}/{lb}}{0.26} \times 365\ days$$

$$= 4{,}324\ kWh$$

$$kWh_{base,idle} = \left[(1 - PCT_{steam}) \times kW_{base,idle} + PCT_{steam} \times PC_{base} \times Qty_{pans} \times \frac{E_{steam}}{\eta_{base}}\right] \times \left(Hours_{daily} - \frac{lb_{daily}}{Qty_{pans} \times PC_{base}}\right) \times Days$$

$$= \left[(1 - 0.40) \times 1.20\ kW + 0.40 \times 23.3 \frac{lb}{hr} \times 3\ pans \times \frac{0.0308\ {kWh}/{lb}}{0.26}\right] \times \left(12\ hr - \frac{100\ lb}{3\ pans \times 23.3\ {lb}/{hr}}\right) \times 365\ days$$

$$= 15{,}555\ kWh$$

$$kWh_{ee,steam} = lb_{daily} \times \frac{E_{steam}}{\eta_{ee}} \times Days$$

$$= 100\ lb \times \frac{0.0308\ {kWh}/{lb}}{0.50} \times 365\ days$$

$$= 2{,}248\ kWh$$

$$kWh_{ee,idle} = \left[(1 - PCT_{steam}) \times kW_{ee,idle} + PCT_{steam} \times PC_{ee} \times Qty_{pans} \times \frac{E_{steam}}{\eta_{ee}}\right] \times \left(Hours_{daily} - \frac{lb_{daily}}{Qty_{pans} \times PC_{ee}}\right) \times Days$$

$$= \left[(1 - 0.40) \times 0.4\ kW + 0.40 \times 16.7 \frac{lb}{hr} \times 3\ pans \times \frac{0.0308\ {kWh}/{lb}}{0.50}\right] \times \left(12\ hr - \frac{100\ lb}{3\ pans \times 16.7\ {lb}/{hr}}\right) \times 365\ days$$

$$= 5{,}384\ kWh$$

$$\Delta kWh = kWh_{base,steam} + kWh_{base,idle} - \left(kWh_{ee,steam} + kWh_{ee,idle}\right)$$

$$= 4{,}324\ kWh + 15{,}555\ kWh - (2{,}248\ kWh + 5{,}384\ kWh)$$

$$= 12{,}247\ kWh$$

The default per measure, gross coincident demand reduction is calculated using the following equation:

$$\Delta kW = \frac{\Delta kWh}{\left(Hours_{daily} \times Days\right)}$$

$$= \frac{12{,}247\ kWh}{\left(12\ ^{hr}/_{day} \times 365\ days\right)}$$

$$= 2.796\ kW$$

6.1.6.5 Source(s)

The primary source for this deemed savings approach is the 2019 Mid-Atlantic TRM, pp. 531-535.

6.1.6.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-14.

Table 6-14: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM
	Input Variable	• Updated PC_{ee} value

6.2 Heating, Ventilation, and Air-Conditioning (HVAC) End Use

6.2.1 Duct Testing and Sealing

This measure is also provided by the Non-Residential Small Business Improvement Program. The savings are determined using the methodology described in Section 5.1.1.

6.2.2 Unitary/Split Air Conditioning, Heat Pump, and Chiller Tune-up

This measure is also provided by the Non-Residential Small Business Improvement Program. The savings are determined using the methodology described in Section 5.1.2.

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6.2.3 Variable Speed Drives on Kitchen Exhaust Fan

6.2.3.1 Measure Description

This measure involves installing variable speed drives at commercial kitchen exhaust fans so that the fan motor speed matches the demand. The baseline condition is the manual on/off switch and magnetic relay or motor starter for commercial kitchen hoods. The baseline assumes that the fan operates at full speed while in operation.

This measure involves retrofitting a variable-speed drive (VSD) controller at an existing kitchen exhaust fan with a make-up-air fan. The measure includes optical and temperature sensors to detect the level of cooking activity and modulate the speed of the exhaust-air fan accordingly. The optical and temperature sensor(s) are typically located either in the collar of or the inlet to the exhaust-fan hood. The kitchen hood exhaust fans are modulated automatically to vary the exhaust airflow rate and make-up (ventilation) air by adjusting the exhaust and make-up air fan speeds.

The total measure energy savings includes the energy savings resulted from fan power reduction during part load operation as well as a decrease in heating and cooling requirement of make-up air. The measure also provides cooling and heating savings for the make-up air if the existing kitchen system(s) supplies conditioned make-up air through a dedicated make-up air unit. If the supplied make-up air is not conditioned, no heating and cooling savings are provided. Furthermore, the measure does not approve heating savings from gas-fired make-up-air units.

This measure is meant for the kitchen hood exhaust flow control only. The exhaust system from kitchen dishwashers is not included in this measure.

6.2.3.2 Savings Estimation Approach

Per measure, gross annual electric energy savings for the exhaust fan are calculated according to the following equation:

$$\Delta kWh_{EF} = hp_{EF} \times LF_{EF} \times \frac{0.746}{\eta_{EF}} \times HOU \times \Delta Power_{EF}$$

If the make-up air is conditioned, then the cooling and heating savings are calculated according to the following equations:

$$\Delta kWh_{cool} = SqFt_{Kitchen} \times \frac{cfm}{SqFt} \times OF_{EF} \times \Delta cfm_{EF} \times CDD \times \frac{24 \times 1.08}{3{,}412 \times COP_{MUA_{cool}}}$$

$$\Delta kWh_{heat} = SqFt_{Kitchen} \times \frac{cfm}{SqFt} \times OF_{EF} \times \Delta cfm_{EF} \times HDD \times \frac{24 \times 1.08}{3{,}412 \times COP_{MUA_{heat}}}$$

If make-up air is <u>not</u> conditioned, then the cooling and heating savings equal zero.

$$\Delta kWh_{cool} = \Delta kWh_{heat} = 0$$

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = \Delta kWh_{EF} + \Delta kWh_{cool} + \Delta kWh_{heat}$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \frac{\Delta kWh}{HOU}$$

Where:

ΔkWh_{EF} = per measure gross annual electric energy savings for the exhaust fan
ΔkWh_{cool} = per measure gross annual electric energy savings for cooling the make-up air
ΔkWh_{heat} = per measure gross annual electric energy savings for heating the make-up air
ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
hp_{EF} = total motor horsepower of exhaust fan(s)
LF_{EF} = load factor of exhaust fan motor(s)
η_{EF} = efficiency of exhaust fan motor(s)
HOU = annual run hours of use of exhaust fan(s)
$\Delta Power_{EF}$ = proportional exhaust fan power reduction due to VFD
$SqFt_{Kitchen}$ = floor area of kitchen
$\frac{cfm}{SqFt}$ = exhaust airflow rate per square foot of kitchen floor area
OF_{EF} = oversize ratio of exhaust fan system
Δcfm_{EF} = proportional exhaust fan airflow reduction due to VFD
CDD = cooling degree days
$COP_{MUA_{cool}}$ = coefficient of performance of cooling component of make-up air system
HDD = heating degree days
$COP_{MUA_{heat}}$ = coefficient of performance of heating component for make-up air system
0.746 = conversion factor for horsepower to kilowatt
3,412 = conversion factor for Btu/h to kilowatt-hour
24 = conversion factor for day to hour
1.08 = sensible heat factor for air, Btuh/cfm/°F

6.2.3.3 Input Variables

Table 6-15: Input Parameters for VSD on Kitchen Fan(s)

Component	Type	Value	Units	Source(s)
hp_{EF}	Variable	See customer application	hp	Customer application
LF_{EF}	Fixed	Default: 90%	-	New Jersey Clean Energy Program Protocols to Measure Resource Savings: Revisions to FY2019 Protocols, p. 105
η_{EF}	Variable	See customer application	-	Customer application
		Default: See Table 3-9 based on hp_{EF}		See Table 3-9 in Section 3.1.4
HOU	Variable	See customer application	hours (annual)	Customer application
		Default: See Table 6-16 that follows		New Jersey Clean Energy Program Protocols to Measure Resource Savings: Revisions to FY2019 Protocols, p. 106

Component	Type	Value	Units	Source(s)
$\Delta Power_{EF}$	Variable	See Table 6-16 that follows	-	New Jersey Clean Energy Program Protocols to Measure Resource Savings: Revisions to FY2019 Protocols, p. 106
$SqFt_{Kitchen}$	Variable	See customer application	ft^2	Customer application
$\frac{cfm}{SqFt}$	Fixed	0.7	cfm/ft^2	ASHRAE 62.1-2013, Table 6.5 – for Kitchen -Commercial
OF_{EF}	Fixed	1.4	-	New Jersey Clean Energy Program Protocols to Measure Resource Savings: Revisions to FY2019 Protocols, p. 105
Δcfm_{EF}	Variable	See Table 6-16 that follows	-	New Jersey Clean Energy Program Protocols to Measure Resource Savings: Revisions to FY2019 Protocols, p. 106
CDD	Variable	See Sub-appendix F2-I: Cooling and Heating Degree Days and Hours	Cooling Degree Days	
HDD	Variable	See Sub-appendix F2-I: Cooling and Heating Degree Days and Hours	Heating Degree Days	
MUA_{cool}	Boolean	See customer application	True/False	Customer application
$COP_{MUA_{cool}}$	Variable	See customer application	-	Customer application
		Default: 3.0		New Jersey Clean Energy Program Protocols to Measure Resource Savings 2019, p. 105
$MUA_{electric_{heat}}$	Boolean	See customer application	True/False	Customer application
$COP_{MUA_{heat}}$	Variable	See customer application	-	Customer application
		Default: 3.0		New Jersey Clean Energy Program Protocols to Measure Resource Savings 2019, p. 105

Table 6-16: Annual Hours of Use, Power, and Airflow Reductions due to VSD[90]

Facility Type	Annual Hours of Use (hours)	Proportion of Power Reduction ($\Delta Power_{EF}$)	Proportion of Airflow Reduction (Δcfm_{EF})
Campus	5,250	0.568	0.295
Lodging	8,736	0.618	0.330
Restaurant	5,824	0.552	0.295
Supermarket	5,824	0.597	0.320
Other	5,250	0.584	0.310

[90] New Jersey Clean Energy Program Protocols to Measure Resource Savings: Revisions to FY2019 Protocols, p. 106.

6.2.3.4 Default Savings

If the proper input variables are not supplied, no default savings will be given.

6.2.3.5 Source(s)

The primary source for this deemed savings approach include the New Jersey Clean Energy Program Protocols to Measure Resource Savings 2019, pp. 104-107.

6.2.3.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-17.

Table 6-17: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the New Jersey Clean Energy Program Protocols to Measure Resource Savings
	Input Variable	• Update to weather stations in North Carolina resulted in revised CDDs/HDDs for weather-sensitive measures

6.3 Plug Load End-Use

6.3.1 Smart Strip

6.3.1.1 Measure Description

This measure realizes energy savings by installing a “smart-strip” plug outlet in place of a standard “power strip.” Smart strip devices are designed to automatically turn-off connected loads when those devices are not in use, therefore minimizing energy losses caused by phantom loads.

The baseline condition is a standard “power strip.” This strip is simply a “plug multiplier” that allows the user to plug in multiple devices using a single wall outlet. Additionally, the baseline unit has no ability to control power flow to the connected devices.

6.3.1.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are assigned per unit as follows:

$$\Delta kWh = 26.9\ kWh$$ [91]

Per measure, gross coincident demand reduction is assigned as follows:

$$\Delta kW = 0\ kW$$

[91] Energy & Resource Solutions (ERS) 2013. Emerging Technologies Research Report; Advanced Power Strips for Office Environments prepared for the Regional Evaluation, Measurement, and Verification Forum facilitated by the Northeast Energy Efficiency Partnerships.” Assumes savings consistent with the 20W threshold setting for the field research site demonstrating higher energy savings (of two available sites). ERS noted that the 20 W threshold may be unreliable due to possible inaccuracy of the threshold setting in currently available units. It is assumed that future technology improvements will reduce the significance of this issue. Further, savings from the site with higher average savings was adopted (26.9 kWh versus 4.7 kWh) acknowledging that investigations of APS savings in other jurisdictions have found significantly higher savings. For example, Northwest Power and Conservation Council, Regional Technical Forum. 2011. “Smart Power Strip Energy Savings Evaluation” found average savings of 145 kWh.

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction

6.3.1.3 Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2019, pp. 525-526.

6.3.1.4 Update Summary

The changes to this section, compared with last year, are described in Table 6-18.

Table 6-18: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM

6.4 Refrigeration End Use

6.4.1 Door Closer (Cooler and Freezer)

6.4.1.1 Measure Description

This measure realizes energy savings by installing an auto-closer on main doors to walk-in coolers or freezers, or by installing an automatic, hydraulic-type door closer on glass-reach-in doors to coolers or freezers. This measure consists of installing a door closer where none existed before. Gross annual electric energy savings are gained when an auto-closer installation reduces the infiltration of warmer outside air into a cooler or freezer environment.

Savings assume that an auto-closer reduces warm air infiltration on average by 40% and the walk-in coolers and freezer doors have effective strip curtains.[92] To simulate the reduction, the main door open time is reduced by 40%. For walk-in coolers and freezers, savings are calculated with the assumption that strip curtains that are 100% effective are installed on the doorway.

6.4.1.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are assigned according to the refrigeration unit type and temperature setting:

Cooler Doors:

$$\Delta kWh = \Delta kWh_{cooler}$$

Freezer Doors:

$$\Delta kWh = \Delta kWh_{freezer}$$

[92] Tennessee Valley Authority TRM 2018, p. 127 -128. Original sources: California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008), and San Diego Gas & Electric work paper WPSDGENRRN0110 Rev 0, August, 17, 2012, “Auto-Closers for Main Cooler of Freezer Doors.”

Per measure, gross coincident demand reduction is assigned according to the refrigeration unit type and temperature setting:

Cooler Doors:

$$\Delta kW \quad = \Delta kW_{cooler}$$

Freezer Doors:

$$\Delta kW \quad = \Delta kW_{freezer}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
ΔkWh_{cooler} = annual electric energy savings for main cooler doors
ΔkW_{cooler} = coincident demand reduction for main cooler doors
$\Delta kWh_{freezer}$ = annual electric energy savings for main freezer doors
$\Delta kW_{freezer}$ = coincident demand reduction for main freezer doors

6.4.1.3 Input Variables

Table 6-19: Door Closer Gross Annual Electric Energy Savings and Gross Coincident Demand Reduction (per Closer)[93]

Refrigeration Unit Type	Location	Walk-In		Reach-In	
		ΔkWh	ΔkW	ΔkWh	ΔkW
Cooler (High Temperature, 31°F to 55°F)	Richmond, VA	44	0.0050	102	0.0116
	Average of Elizabeth City and Rocky Mount-Wilson, NC	42	0.0048	101	0.0115
Freezer (Medium Temperature, -35°F to 30 °F)	Richmond, VA	173	0.0196	439	0.0501
	Average of Elizabeth City and Rocky Mount-Wilson, NC	168	0.0192	432	0.0494

6.4.1.4 Default Savings

In the event of incomplete data, make the following conservative assumptions:

- If the door type is missing, assume it is a walk-in door type.
- If the refrigeration system type is missing, assume it is a high-temperature cooler.

6.4.1.5 Source(s)

The primary source for this deemed savings approach is the Tennessee Valley Authority TRM 2018, pp. 127-128.

6.4.1.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-20.

93 Methodology from Tennessee Valley Authority TRM 2018, pp. 127-128, was used. Savings were revised using the TMY3 weather data for Richmond, VA, Elizabeth City, NC, and Rocky Mount-Wilson, NC.

DNV

Table 6-20: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Tennessee Valley Authority TRM
	Default Savings	• Default savings were adjusted due to change of weather stations in North Carolina (from Charlotte to Elizabeth City and Rocky Mount-Wilson)

6.4.2 Door Gasket (Cooler and Freezer)

6.4.2.1 Measure Description

This measure realizes energy savings by replacing worn-out gaskets with new gaskets on refrigerator or freezer doors to reduce heat loss caused by air infiltration.

6.4.2.2 Savings Estimation Approach[94]

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = \frac{\Delta kWh}{ft} \times L$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \frac{\Delta kW}{ft} \times L$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
ΔkWh/ft = gross annual electric energy savings per linear foot
ΔkW/ft = gross coincident demand reduction per linear foot
L = length of gasket applied

6.4.2.3 Input Variables

Table 6-21: Input Values for Door Gasket Savings Calculations

Component	Type	Value	Unit	Source(s)
ΔkWh/ft	Variable	**See** Table 6-22	kWh/ft	Tennessee Valley Authority TRM 2018, p. 123

94 Electric energy and demand savings for this measure are based on modeled results found in the Tennessee Valley Authority TRM 2018, which based its model assumptions and equations on 3 sources: the California Database for Energy Efficiency Resources, www.deeresources.com (DEER 2008), the 2009 Southern California Edison Company- WPSCNRRN0004.1 - Door Gaskets for Glass Doors of Walk-In Coolers work paper, and the 2009 Southern California Edison Company- WPSCNRRN0001.1 - Door Gaskets for Main Door of Walk-in Coolers and Freezers work paper.

Component	Type	Value	Unit	Source(s)
ΔkW/ft	Variable	**See** Table 6-22	kW/ft	Tennessee Valley Authority TRM 2018, p. 123
L	Variable	See customer application	feet	Customer application
		Default = 15		DNV engineering judgment

Table 6-22: Door Gasket Gross Annual Electric Energy and Gross Coincident Demand Reduction (per Linear Foot) [95]

Refrigeration Type	ΔkWh/ ft	ΔkW/ft
Freezer (-35°F to 30°F)		
Walk-In Door	29.5	0.0036
Reach-In Glass Door	22.2	0.0025
Cooler (31°F to 55°F)		
Walk-In Door	9.3	0.0011
Reach-In Glass Door	3.4	0.0004

6.4.2.4 Default Savings

If the proper values are not supplied, a default savings may be applied using conservative input values assuming a reach-in, glass-door cooler.

The default per measure, gross annual electric energy savings per unit cooler/freezer will be assigned according to the following calculation:

$$\Delta kWh = \frac{\Delta kWh}{ft} \times L$$

$$= 3.4 \frac{kWh}{ft} \times 15\, ft$$

$$= 51.0\, kWh$$

The default per measure, gross demand energy savings per unit cooler/freezer will be assigned according to the following calculation:

$$\Delta kW = \frac{\Delta kW}{ft} \times L$$

$$= 0.0004 \frac{kW}{ft} \times 15\, ft$$

[95] Tennessee Valley Authority 2018, p. 123 - 124. Methodology was used. Weather data was applied for Richmond, VA and Charlotte, NC. The difference between these locations was less than 1%, so Richmond values are applied to both VA and NC installed measures.

$$= 0.006\ kW$$

6.4.2.5 Source(s)

The primary source for this deemed savings approach is the Tennessee Valley Authority TRM 2018, pp. 123-124.

6.4.2.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-23.

Table 6-23: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Tennessee Valley Authority TRM

6.4.3 Commercial Freezers and Refrigerators

6.4.3.1 Measure Description

This measure involves the installation of an ENERGY STAR® qualified commercial freezer or refrigerator. These models are designed for warm commercial kitchen enviornments with frequent door opening. Qualifying equipment utilize a varity of energy-efficiecnt components such as ECM fan motors, hot gas anti-sweat heaters, or high efficiency compressors. Qualifying equipment must not exceed the maxium daily kWh values determined by the volume, door type, and configuration specified by Version 4.0 specifications that went into effect March 2017.

6.4.3.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh \quad = (kWh_{base} - kWh_{ee}) \times Days$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW \quad = \left(\frac{\Delta kWh}{EFLH}\right) \times CF$$

Where:

ΔkWh	= per measure gross annual electric energy savings
ΔkW	= per measure gross coincident demand reduction
kWh_{base}	= daily energy consumption of the baseline equipment
kWh_{ee}	= daily energy consumption of the efficient equipment
Days	= days per year
EFLH	= equivalent full load hours of equipment
CF	= demand coincidence factor

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6.4.3.3 Input Variables

Table 6-24: Input Parameters for Commercial Freezers and Refrigerator Measure

Component	Type	Value	Units	Source(s)
kWh_{base}	Variable	See Table 6-25	kWh	Federal Standards, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2013)[96]
kWh_{ee}	Variable	See Table 6-26	kWh	ENERGY STAR® Certified-commercial-refrigerators-and-freezers[97]
Days	Fixed	365	days, annual	Constant
EFLH	Fixed	5,858	hours, annual	Mid-Atlantic TRM 2019, pp. 481 and 487[98]
CF	Fixed	0.77	-	Mid-Atlantic TRM 2019, pp. 481 and 488[99]
Volume	Variable	See customer application	cubic feet	Customer application

Table 6-25: Calculated Baseline Daily Energy Consumption from Volume, V

Equipment Type	Refrigerator Energy, kWh	Freezer Energy, kWh
Vertical Closed		
Solid Door	= 0.050 x V + 1.360	= 0.220 x V + 1.380
Transparent	= 0.100 x V + 0.860	= 0.290 x V + 2.950
Horizontal Closed		
Solid Door	= 0.050 x V + 0.910	= 0.060 x V + 1.120
Transparent	= 0.060 x V + 0.370	= 0.080 x V + 1.230

Table 6-26: Calculated Efficient Unit Daily Energy Consumption from Volume

Equipment Type and Volume (ft^3)	Refrigerator Energy, kWh	Freezer Energy, kWh
Vertical Closed		
Solid Door		
$V < 15\ ft^3$	=0.022 x V + 0.970	=0.210 x V + 0.900

[96] The Mid-Atlantic TRM 2019 references the federal standards, but the actual values used do not match. Since the baseline daily kWh is greater than required by code, it is assumed that they have been modified per program design.

[97] Values are provided in ENERGY STAR Certified Commercial Refrigerators and Freezers List as the “Energy Use (Daily Energy Consumption)(kWh/day)” downloadable list can be found here: https://www.energystar.gov/productfinder/product/certified-commercial-refrigerators-and-freezers/results

[98] Original source is cited as: Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013; Derived from Washington Electric Coop data by West Hill Energy Consultants.

[99] Derived from Itron eShapes, using 8,760 hourly data by end use for Upstate New York. This was combined with full load hour assumptions used for efficiency measures to account for diversity of equipment usage within the peak period hours.

Equipment Type and Volume (ft³)	Refrigerator Energy, kWh	Freezer Energy, kWh
$15 \le V < 30$ ft³	=0.066 x V + 0.310	=0.120 x V + 2.248
$30 \le V < 50$ ft³	=0.040 x V + 1.090	=0.285 x V - 2.703
$V \ge 50$ ft³	=0.024 x V + 1.890	=0.142 x V + 4.445
Transparent Door		
$V < 15$ ft³	=0.095 x V + 0.445	=0.232 x V + 2.360
$15 \le V < 30$ ft³	=0.050 x V + 1.120	=0.232 x V + 2.360
$30 \le V < 50$ ft³	=0.076 x V + 0.340	=0.232 x V + 2.360
$V \ge 50$ ft³	=0.105 x V - 1.111	=0.232 x V + 2.360
Horizontal Closed		
Solid or Transparent Door		
All Volumes	=0.050 x V + 0.280	=0.057 x V + 0.550

6.4.3.4 Default Savings

This measure does not have default savings.

6.4.3.5 Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2019, pp. 480–491.

6.4.3.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-27.

Table 6-27: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM
	Input Variable	• Updated CF value

6.4.4 Commercial Ice Maker

6.4.4.1 Measure Description

This measure involves high-efficiency ice makers meeting ENERGY STAR® or CEE Tier 2 ice maker requirements. The measure applies to batch type (also known as cube type) and continuous type (also known as flake or nugget type) equipment. The equipment includes ice-making head (without storage bin), self-contained, or remote-condensing units. ENERGY STAR® ice makers are limited to only air-cooled units while CEE Tier 2 standards address water-cooled units. The baseline for each type of ice maker is the corresponding Federal standard for the same technology.

6.4.4.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

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$$\Delta kWh = \left(\frac{kWh_{base} - kWh_{ee}}{100\ lb}\right) \times H_{rated} \times DC \times Days$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \frac{\Delta kWh}{8{,}760\ hours} \times CF$$

Where:

ΔkWh	= per measure gross annual electric energy savings
ΔkW	= per measure gross coincident demand reduction
kWh_{base}	= energy consumption per 100 lb of ice produced by the baseline equipment
kWh_{ee}	= energy consumption per 100 lb of ice produced by the new equipment
H_{rated}	= manufacturer-rated daily harvest rate of equipment
DC	= duty cycle of ice machine
Days	= number of days per year
CF	= demand coincidence factor

6.4.4.3 Input Variables

Table 6-28: Input Parameters for Commercial Ice Maker

Component	Type	Value	Units	Source(s)
kWh_{base}	Variable	Batch-type: see Table 6-29 Continuous-type: see Table 6-30	kWh/ 100-lb of ice	Federal Standards 80 FR 4645[100]
kWh_{ee}	Variable	ENERGY STAR[101]: ENERGY STAR batch-type: see Table 6-32 ENERGY STAR continuous-type: see Table 6-33 CEE Tier 2 Water-cooled: see Table 6-31	kWh/ 100-lb of ice	CEE Tier 2[102] and ENERGY STAR®[103] lists of qualifying equipment
		If ice machine type is unknown and water cooled: Default = cube or nugget If ice machine is ENERGY STAR and water-cooled[104]: Default = CEE Tier 2 Water-cooled = cube or nugget		
H_{rated}	Variable	See customer application	Lb/day	From application

[100] The standards are available here: https://www.regulations.gov/document?D=EERE-2010-BT-STD-0037-0137. Batch type ice maker efficiencies are on p. 5-4 and continuous type baseline efficiency levels are on p. 5-9.

[101] Use ENERGY STAR Tables for any ice maker that is ENERGY STAR certified (include CEE Tier 2 certified)

[102] Currently qualifying ice makers meet CEE requirements effective 7/01/2011. Qualifying equipment is updated quarterly, avialble here: https://library.cee1.org/content/commercial-kitchens-ice-machines-qualifying-product-list.

[103] Currently qualifying ice makers meet ENERGY STAR® Version 3.0 program requirements effective January 28, 2018. The list of qualifying equipment can be found here: https://www.energystar.gov/productfinder/product/certified-commercial-ice-machines/results.

[104] ENERGY STAR does not include water-cooled ice makers. If both of these are indicated to be true on the application, we assume the equipment type is CEE Tier-2 water-cooled.

Component	Type	Value	Units	Source(s)
DC	Fixed	0.5	-	Arkansas TRM 2018 Volume 8 p. 486[105]
Days	Fixed	365	Days/year	Arkansas TRM 2018 Volume 8 p. 486
CF	Fixed	1.0	-	Arkansas TRM 2018 Volume 8 p. 486[106]

Table 6-29: Batch-Type Ice Machine Baseline Efficiencies[107]

Ice Machine Type	Type of Cooling	Harvest Rate (lb/day)	kWh_{base} (kWh/100-lb ice)
Ice-Making Head	Water	< 300	6.880 – 0.00550 x H_{rated}
		≥ 300 and < 850	5.800 – 0.00191 x H_{rated}
		≥ 850 and < 1,500	4.420 – 0.00028 x H_{rated}
		≥ 1,500 and < 2,500	4.000
		≥ 2,500 and < 4,000	4.000
	Air	< 300	10.000 – 0.01233 x H_{rated}
		≥ 300 and < 800	7.055 – 0.00250 x H_{rated}
		≥ 800 and < 1,500	5.550 – 0.00063 x H_{rated}
		≥ 1,500 and < 4,000	4.610
Remote-Condensing w/o Remote Compressor	Air	≥ 50 and < 1,000	7.970 – 0.00342 x H_{rated}
		≥ 1,000 and < 4,000	4.590
Remote-Condensing w/ Remote Compressor	Air	< 942	7.970 – 0.00342 x H_{rated}
		≥ 942 and < 4,000	4.790
Self-Contained	Water	< 200	9.500 – 0.00342 x H_{rated}
		≥ 200 and < 2,500	5.700
		≥ 2500 and < 4,000	5.700
	Air	< 110	14.790 – 0.04690 x H_{rated}
		≥ 110 and < 200	12.420 – 0.02533 x H_{rated}
		≥ 200 and < 4,000	7.350

[105] Per Arkansas TRM, this value was selected based on the most conservative value from a collection of sources including TRMs in Vermont, Pennsylvania, Ohio, Wisconsin, and Missouri.
[106] Per Arkansas TRM, this value was selected based on building types and lighting CFs. There is limited information about the specific load profile of ice makers.
[107] 10 CFR Part 431 Subpart H, Automatic Commercial Ice Makers. 77 FR 1591. January 11, 2012. New minimum requirements effective January 28, 2018.

Table 6-30: Continuous-Type Ice Machine Baseline Efficiencies

Ice Machine Type	Type of Cooling	Harvest Rate (lb/day)	kWh_{base} (kWh/100-lb ice)
Ice-Making Head	Water	< 801	6.48 – 0.00267 x H_{rated}
		≥ 801 and < 2,500	4.34
		≥ 2,500 and < 4,000	4.34
	Air	< 310	9.19 – 0.00629 x H_{rated}
		≥ 310 and < 820	8.23 – 0.00320 x H_{rated}
		≥ 820 and < 4,000	5.61
Remote-Condensing w/o remote compressor	Air	< 800	9.70 – 0.00580 x H_{rated}
		≥ 800 and < 4,000	5.06
Remote-Condensing w/ remote compressor	Air	< 800	9.90 – 0.00580 x H_{rated}
		≥ 800 and < 4,000	5.26
Self-Contained	Water	< 900	7.60 – 0.00302 x H_{rated}
		≥ 900 and < 2,500	4.88
		≥ 2,500 and < 4,000	4.88
	Air	< 200	14.22 – 0.03000 x H_{rated}
		≥ 200 and < 700	9.47 – 0.00624 x H_{rated}
		≥ 700 and < 4,000	5.10

Table 6-31:CEE Tier 2 Ice Machine Qualifying Efficiencies[108]

Ice Machine Type[109]	Type of Cooling	Harvest Rate (lb/day)	kWh_{ee} (kWh/100-lb ice)
Cube or Nugget (default)	Water	< 175	10.6 – 0.0241 x H_{rated}
		≥ 175 and < 450	7.1 – 0.0062 x H_{rated}
		≥ 450 and < 1,000	4.7 – 0.0011 x H_{rated}
		≥ 1,000	3.7 – 0.0002 x H_{rated}
Flake	Water	< 1,000	4.8 – 0.0017 x H_{rated}
		≥ 1,000	3.2

108 CEE Requirments don't differentiat between continuous or batch type ice machines, requirements are found here: https://library.cee1.org/system/files/library/4280/CEE_Ice_Machines_Spec_Final_Effective_01Jul2011_-_updated_July_7_2015.pdf

109 CEE Ice machine types are cube (self-contained), Nugget (ice-making head) and flake (ice-making head). The application determines if the equipment is self-contained or ice-making head. However, the application does not differentiat between flake or nugget ice making head. Flake ice machine types make up a low percent of the CEE Tier 2 models and typically used for specific applications. Therefore cube or nugget ice machine type is used as the default for CEE Tier 2 water cooled ice makers.

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Table 6-32: Batch-Type ENERGY STAR® Ice Machine Qualifying Efficiencies[110]

Ice Machine Type	Type of Cooling	Harvest Rate (lb/day)	kWh_{ee} (kWh/100-lb ice)
Ice-Making Head	Air	< 300	9.20 – 0.01134 x H_{rated}
		≥ 300 and < 800	6.49 – 0.0023 x H_{rated}
		≥ 800 and < 1,500	5.11 – 0.00058 x H_{rated}
		≥ 1,500 and ≤ 4,000	4.24
Remote-Condensing (with and without Remote Compressor)	Air	< 988	7.17 – 0.00308 x H_{rated}
		≥ 988 and ≤ 4,000	4.13
Self-Contained	Air	< 110	12.57 – 0.0399 x H_{rated}
		≥ 110 and < 200	10.56 – 0.0215 x H_{rated}
		≥ 200 and ≤ 4,000	6.25

Table 6-33: Continuous-Type ENERGY STAR® Ice Machine Qualifying Efficiencies[111]

Ice Machine Type	Type of Cooling	Harvest Rate (lb/day)	kWh_{ee} (kWh/100-lb ice)
Ice-Making Head	Air	< 310	7.90 – 0.005409 x H_{rated}
		≥ 310 and < 820	7.08 – 0.002752 x H_{rated}
		≥ 820 and ≤ 4,000	4.82
Remote-Condensing (with and without Remote Compressor)	Air	< 800	7.76 – 0.00464 x H_{rated}
		≥ 800 and ≤ 4,000	4.05
Self-Contained	Air	< 200	12.37 – 0.0261 x H_{rated}
		≥ 200 and < 700	8.24 – 0.005429 x H_{rated}
		≥ 700 and ≤ 4,000	4.44

6.4.4.4 Default Savings

If the proper values are not available, some values have defaults savings. However, there are no default savings for this measure as some values are needed to calculate savings.

6.4.4.5 Source(s)

The primary source for this deemed savings approach is the Arkansas TRM 2018 Version 8.0, pp. 483–486.

[110] Currently qualifying ice makers meet ENERGY STAR® Version 3.0 program requirments effective January 28, 2018. The list of qualifying equipment can be found here: https://www.energystar.gov/productfinder/product/certified-commercial-ice-machines/results. The current requirements are found here: https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers/key_product_criteria

[111] Ibid

6.4.4.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-34.

Table 6-34: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Inputs	• Clarified which kWh_{ee} values to use for conflicts between CEE Tier 2, ENERGY STAR, for air-cooled and water-cooled units • Clarified CEE Tier 2 ice machine types and assigned default to cube or nugget ice machine types (not collected by the current Non-Residential Perscriptive Program)
v10	Source	• Updated page numbers of the Arkansas TRM
	Equation	• Updated equation

6.4.5 Evaporator Fan Electronically Commutated Motor (ECM) Retrofit (Reach-In and Walk-in Coolers and Freezers)

6.4.5.1 Measure Description

The measure replaces the baseline shaded-pole (SP), evaporator-fan motors with electronically-commuted motors. The baseline motors run 24 hour/day, seven day/week (24/7) and have no controls.

Evaporator fans circulate air in refrigerated spaces by drawing air across the evaporator coil and into the space. Fans are found in both reach-in and walk-in coolers and freezers. Energy and demand savings for this measure are achieved by reducing motor operating power. Additional savings come from refrigeration interactive effects. Because electronically-commutated motors (ECMs) are more efficient and use less power, they introduce less heat into the refrigerated space compared to the baseline motors and result in a reduction in cooling load on the refrigeration system.

6.4.5.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = \frac{(watts_{base} - watts_{ee})}{1{,}000\frac{W}{kW}} \times DC_{evap} \times HOU \times WHF_e$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \frac{(watts_{base} - watts_{ee})}{1{,}000\frac{W}{kW}} \times WHF_d \times CF$$

If the application shows that the rated wattage of existing/baseline evaporator fan motor, W_{base}, is less than rated wattage of electronically commutated evaporator fan motor, W_{ee}, then it is assumed that the baseline motor was replaced with a larger energy efficient motor. In such instances, the default values for these variables—provided in Table 6-35—are to be used.

Where:

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ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
$watts_{base}$ = rated wattage of existing/baseline evaporator fan motor
$watts_{ee}$ = rated wattage of electronically commutated evaporator fan motor
DC_{evap} = duty cycle (effective run time) of uncontrolled evaporator-fan motors
HOU = annual operating hours
WHF_e = Waste Heat Factor for Energy; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment,
WHF_d = Waste Heat Factor for Demand; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment
CF = peak demand Coincidence Factor

6.4.5.3 Input Variables

Table 6-35: Input Values for ECM Evaporator Savings Calculations

Component	Type	Value	Unit	Source(s)
$watts_{base}$	Variable	See customer application	watts	Customer application
		Defaults: Walk-in: 128 Reach-in: 31 Unknown: 31		Mid-Atlantic TRM 2019, p. 498[112]
$watts_{ee}$	Variable	See customer application	watts	Customer application
		Defaults: Walk-in: 50 Reach-in: 12 Unknown: 12		Commercial Refrigeration Loadshape Project 2015, NEEP, p. 5[113]
DC_{evap}	Fixed	0.978	-	Mid-Atlantic TRM 2019, p. 498
HOU	Variable	8,760	hours, annual	Mid-Atlantic TRM 2019, p. 498
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 2019, p. 498
		Default: 1.38		
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 2019, p. 498
		Default: 1.38		
CF	Fixed	0.978[114]	-	Mid-Atlantic TRM 2019, p. 498

6.4.5.4 Default Savings

If the proper values are not supplied, a default savings may be applied using conservative input values. Accordingly, the default per measure, gross annual electric energy savings will be assigned according to the following calculation:

[112] The Mid-Atlantic TRM approach states the default power reduction is 157%, The W_{base} are based on the default W_{ee} values and a 157% power reduction.

[113] The Commercial Refrigeration Loadshape Project NEEP 2015, p. 5, finds that the average new ECM motor is rated at 1/15 hp. This study had the majority of motors installed in walk-in cases. Therefore 1/15 hp or 50 W is the default for walk-in applications. Default size for reach-in cases is the smallest motor sizes identified in this study, 1/62 hp or 12 W.

[114] Mid-Atlantic TRM 2017, p. 411. Coincidence factors developed by dividing the PJM Peak Savings for EF Motors and Controls from Table 47 by the product of the average ECM wattage per rated horsepower (0.758 kW/hp) and the Waste Heat Factor for Demand. Note: the CF was adjusted to 0.978, for uncontrolled evaporator fan motors. The Mid-Atlantic TRM has a CF greater than one, because it is calculated relative to the wattage of the post-retrofit ECM motor as opposed to the existing SP motor.

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$$\Delta kWh = \frac{(watts_{base} - watts_{ee})}{1{,}000\, {}^{W}/_{kW}} \times DC_{evap} \times HOU \times WHF_e$$

$$= \frac{(31\, W - 12\, W)}{1{,}000\, {}^{W}/_{kW}} \times 0.978 \times 8{,}760\, hours \times 1.38$$

$$= 225\, kWh$$

The default per measure, gross coincident demand reduction will be assigned according to the following calculation:

$$\Delta kW = \frac{(watts_{base} - watts_{ee})}{1{,}000\, {}^{W}/_{kW}} \times WHF_d \times CF$$

$$= \frac{(31\, W - 12\, W)}{1{,}000\, {}^{W}/_{kW}} \times 1.38 \times 0.978$$

$$= 0.026\, kW$$

6.4.5.5 Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2019, pp. 497-499.

6.4.5.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-36.

Table 6-36: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Input variable	• Deleted a conversion factor, CW_{rated}, as it was not needed
	Source	• Updated page numbers / version of the Mid-Atlantic TRM

6.4.6 Evaporator Fan Control (Cooler and Freezer)

6.4.6.1 Measure Description

This measure realizes energy savings by installing evaporator controls for reach-in or walk-in coolers and freezers. Typically, evaporator fans run constantly (24 hours per day, 365 days per year) to provide cooling when the compressor is running, and to provide air circulation when the compressor is not running. This measure saves energy by cycling the fan off or reducing fan speed when the compressor is not running. This results in a reduction in fan energy usage and a reduction in the the refrigeration load resulting from the reduction in heat given off by the fan.

This approach applies to reach-in or walk-in freezers and refrigerator units; it is not applicable to refrigerated warehouses or other industrial refrigeration applications.

6.4.6.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated using the following equation:

$$\Delta kWh \ = hp \times \frac{kW}{hp} \times \left(\%On_{base} - \%On_{ee}\right) \times HOU \times WHF_e$$

Per measure, gross coincident demand reduction is calculated using the following equation:

$$\Delta kW \ = hp \times \frac{kW}{hp} \times WHF_d \times CF$$

Where:

ΔkWh	= per measure gross annual electric energy savings
ΔkW	= per measure gross coincident demand reduction
hp	= rated hp of evaporator fan motors connected to control
kW/hp	= evaporative fan connected load per rated horsepower
$\%On_{base}$	= duty cycle of the uncontrolled evaporator fan
$\%On_{ee}$	= duty cycle of the controlled evaporator fan
HOU	= annual hours of use
WHF_e	= Waste Heat Factor for Energy; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment
WHF_d	= Waste Heat Factor for Demand; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment
CF	= peak demand Coincidence Factor

6.4.6.3 Input Variables

Table 6-37: Input Values for Freezer and Cooler Evaporator Fan Controls Saving Calculations

Component	Type	Value	Unit	Source(s)
hp	Variable	See customer application	hp	Customer application
		Default: 1/15 hp		Mid-Atlantic TRM 2019, p. 501[115]
kW/hp	Fixed	Single-speed: 2.088 kW/hp Multi-speed: 0.758 kW/hp	kW/hp	Mid-Atlantic TRM 2019, p. 501
		Default: 0.758 kW/hp		
$\%On_{base}$	Fixed	0.978	-	Mid-Atlantic TRM 2019, p. 501
$\%On_{ee}$	Fixed	Single-speed: 0.636 Multi-speed: 0.692	-	Mid-Atlantic TRM 2019, p. 501
		Default: 0.692		

[115] Default value not provided in Mid-Atlantic TRM, however the original source for the Mid-Atlantic approach was used to select a default: Cadmus. 2015. *Commercial Refrigeration Loadshape Projects.* Lexington, MA.

Component	Type	Value	Unit	Source(s)
HOU	Fixed	8,760	hours (annual)	Mid-Atlantic TRM 2019, p. 501
WHFe	Fixed	Low Temp (-35˚F to -1˚F): 1.76 Med Temp (0˚F - 30˚F): 1.76 High Temp (31˚F - 55˚F): 1.38 Default: 1.38	-	Mid-Atlantic TRM 2019, p. 501
WHFd	Fixed	Low Temp (-35˚F to -1˚F): 1.76 Med Temp (0˚F - 30˚F): 1.76 High Temp (31˚F - 55˚F): 1.38 Default: 1.38	-	Mid-Atlantic TRM 2019, p. 501
CF	Fixed	0.26	-	Mid-Atlantic TRM 2019, p. 501

6.4.6.4 Default Savings

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

The default per measure, gross annual electric energy savings for a high-temperature cooler with a multi-speed evaporator motor will be assigned according to the following calculation:

$$\Delta kWh = hp \times \frac{kW}{hp} \times (\%On_{base} - \%On_{ee}) \times HOU \times WHF_e$$

$$= \frac{1}{15} hp \times 0.758 \frac{kW}{hp} \times (0.978 - 0.692) \times 8{,}760\ hours \times 1.38$$

$$= 175\ kWh$$

The corresponding default per measure, gross coincident demand reduction will be assigned according to the following calculation:

$$\Delta kW = hp \times \frac{kW}{hp} \times WHF_d \times CF$$

$$= \frac{1}{15} hp \times 0.758 \frac{kW}{hp} \times 1.38 \times 0.26$$

$$= 0.018\ kW$$

6.4.6.5 Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2019, pp. 500-502.

6.4.6.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-38.

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Table 6-38: **Summary of Update(s) from Previous Version**

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM
	Input variable	• Clarified kW/hp, WHF_e, and WHF_d default assumptions for values • Updated $\%On_{base}$ and $\%On_{ee}$ values

6.4.7 Floating Head Pressure Control

6.4.7.1 Measure Description

This measure realizes energy savings by adjusting the head-pressure setpoint in response to different outdoor temperatures. Without controls, the head-peasure setpoint is based on the design conditions regardless of the actual condenser operating conditons. By installing the floating-head pressure controller, the head-pressure setpoint is adjusted based on outside-air temperature. When conditions allow, the compressor operates at a lower discharge-head pressure, resulting in compressor energy savings.

6.4.7.2 Savings Estimation Approach

Per measue, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = \frac{kWh}{hp} \times hp_{comp}$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW^{116} = 0$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
kWh/hp = floating head pressure control gross annual electric energy savings per compressor horsepower (hp)
hp_{comp} = compressor horsepower

6.4.7.3 Input Variables

Table 6-39: Input Values for Floating Head Pressure Control Savings Calculations

Component	Type	Value	Unit	Source(s)
kWh/hp	Variable	See Table 6-40 Default = 509 (High Temperature, Scroll Compressor)	kWh/ horsepower/ year	Maine Commercial TRM 2019.5, p. 82

[116] Gross coincident demand savings are zero since savings are realized during off-peak periods. No demand reduction is expected from this measure.

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Component	Type	Value	Unit	Source(s)
hp_{comp}	Variable	See customer application.	horsepower	Customer application
		Default = 5		Vermont TRM 2015, p. 132[117]

Table 6-40: Floating-head Pressure Control Gross Annual Electric Energy Savings (per Horsepower)[118]

Compressor Type	Electric Savings (kWh/hp/year)		
	Low Temperature (-35°F to -1°F) ($Temp_{ref}$ -20°F SST)	Medium Temperature (0°F to 30°F) ($Temp_{ref}$ 20°F SST)	High Temperature (31°F to 55°F) ($Temp_{ref}$ 45°F SST)
Standard Reciprocating	695	727	657
Discus	607	598	694
Scroll	669	599	509

6.4.7.4 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 calculation:

$$\Delta kWh = \frac{kWh}{hp} \times hp_{comp}$$

$$= 509\ \frac{kWh}{hp} \times 5\ hp$$

$$= 2{,}545\ kWh$$

The default gross coincident demand reduction will be assigned according to the following calculation:

$$\Delta kW = 0$$

6.4.7.5 Source(s)

The primary source for this deemed savings approach is the Maine Commercial TRM 2019, pp. 82-83. Additonally, the Vermont TRM 2015, p. 132, was used to estimate the default compressor size.

6.4.7.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-41.

[117] Vermont TRM 2015, p. 132. Assumes “5 HP compressor data used, based on average compressor size.”
[118] Efficiency Maine Commercial TRM 2019.5, Table 12 – Floating Head Perssure Control kWh Savings per Horsepower, p. 83.

Table 6-41: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Maine Commercial TRM

6.4.8 Low/Anti-Sweat Door Film

6.4.8.1 Measure Description

This measure involves the installation of window film on the doors of refrigerated cooler and freezer cases. Anti-sweat film prevents consdesation from forming and collecting on refrigerated case doors. This measure saves energy by allowing anti-sweat heaters to be deactivated permanently. Typically, anti-sweat door heaters (ASDH) are installed on the glass itself to raise the surface temperature and prevent condensation from collecting on the glass. However, the low/anti-sweat door film elimates the need for these heaters.[119] Note that this measure does not affect frame heaters.

The savings methodology borrows from that of ASDH controls. The baseline condition for this measure is refrigerated case doors with operational ASDH, with or without controls. The measure case is door film with no ASDHs in use. Refrigerated case doors without ASDH are not allowed under this measure. Door size is assumed to be 12.5 sq.ft. based on program design assumptions.

6.4.8.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = kW_{ASDH} \times DC \times HOU \times WHF_e$$

Per measure, gross coincident demand reduction is assigned as follows:

$$\Delta kW = kW_{ASDH} \times DC \times WHF_d \times CF$$

Where:

ΔkWh	= per measure, gross annual electric energy savings
ΔkW	= per measure, gross coincident demand reduction
kW_{ASDH}	= rated power of the existing ASDH
DC	= duty cycle (effective run time) of the existing ASDH based on existing controls
HOU	= annual operating hours
WHF_e	= Waste Heat Factor represents the increased gross annual electric savings due to reduced heat from ASDH that must be rejected by the refrigeration equipment
WHF_d	= Waste Heat Factor represents the increased gross coincident demand reduction due to reduced heat from ASDH that must be rejected by the refrigeration equipment
CF	= summer peak Coincidence Factor

[119] In some cases ASDHs may not be deactivated altogether, but their controls are modified to drastically lower the dew-point setpoint thereby reducing the duration of heater operation. In these cases, it is assumed that the duration of heater operation is negligible.

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6.4.8.3 Input Variables

Table 6-42: Input Parameters for Low/No-Sweat Door Film

Component	Type	Value	Units	Source(s)
kW_{ASDH}	Variable	See customer application	kW	Customer application
		Default: 0.13		Mid-Atlantic TRM 2019, p. 495[120]
DC	Variable	No controls: 0.907 On/Off controls: 0.589 Micropulse controls: 0.428	-	Mid-Atlantic TRM 2019, p. 495
		Default: 0.428	-	Mid-Atlantic TRM 2019, p. 495
HOU	Fixed	8,760	hours, annual	Mid-Atlantic TRM 2019, p. 495
WHF_e	Fixed	Low Temp (-35˚F - -1˚F): 1.50 Med Temp (0˚F - 30˚F): 1.50 High Temp (31˚F - 55˚F): 1.25	-	Mid-Atlantic TRM 2019, p. 495
		Default: 1.25		
WHF_d	Fixed	Low Temp (-35˚F - -1˚F): 1.50 Med Temp (0˚F - 30˚F): 1.50 High Temp (31˚F - 55˚F): 1.25	-	Mid-Atlantic TRM 2019, p. 495
		Default: 1.25		
CF[121]	Variable	Freezer (Low/Med Temp) case: On/Off controls: 0.21 Micropulse: 0.30 No controls: 1.00	-	Mid-Atlantic TRM 2019, pp. 495–496. Without heater controls, uniform load throughout year is assumed.
		Default for freezer case: 0.21		
		Refrigerated (High Temp) case: On/Off controls: 0.25 Micropulse: 0.36 No controls: 1.00		
		Default for refrigerated case: 0.25		

6.4.8.4 Default Savings

When the application does not have information about the ASDH control type, it is assumed to have micropulse controls. When the temperature range and the case type are also unknown, the case is assumed to be a high-temperature, refrigerated case.

Accordingly, the default per measure gross annual energy savings are as follows:

$$\Delta kWh \quad = kW_{ASDH} \times DC \times HOU \times WHF_e$$

[120] Original source: Cadmus. 2015. Commercial Refrigeration Loadshape Project. Lexington, MA.

[121] Coincidence factors developed by dividing the PJM Summer Peak Savings for ASDH Controls from Table 52 of the original source by the product of the average wattage of ASDH per connected door (0.13 kW) and the Waste Heat Factor for Demand.

$$= 0.13\ kW \times 0.428 \times 8{,}760\ hours \times 1.25$$

$$= 609.3\ kWh$$

And the default per measure, gross demand reduction is:

$$\Delta kW = kW_{ASDH} \times DC \times WHF_d \times CF$$

$$= 0.13\ kW \times 0.428 \times 1.25 \times 0.25$$

$$= 0.017\ kW$$

6.4.8.5 Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2019 pp. 494–496. The method was adapted from the ASDH controls methodology.

6.4.8.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-43.

Table 6-43: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM
	Input variable	• Clarified WHF_e and WHF_d default assumption values

6.4.9 Refrigeration Night Cover

6.4.9.1 Measure Description

This measure realizes energy savings by installing a cover to minimize the energy losses associated with top open-case refrigeration units. Walk-in units are not included in this measure. The cover is used during hours which the business is closed. The baseline equipment is a refrigerated case without a night cover.

6.4.9.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = \frac{load}{\frac{12{,}000 Btuh}{ton}} \times \frac{3.516\ ^{kW}/_{ton}}{COP} \times L \times ESF \times HOU$$

Per measue, gross coincident demand reduction is assigned as follows:

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$$\Delta kW^{122} = 0$$

Where:

ΔkWh	= per measure gross annual electric energy savings
ΔkW	= per measure gross coincident demand reduction
load	= average refrigeration load per linear foot of refrigerated case without night covers deployed
L	= linear feet of covered refrigerated case
COP	= coefficient of performance of refrigerated case
ESF	= energy savings factor; reflects the percentage reduction in refrigeration load due to the deployment of night covers
HOU	= annual hours of use

6.4.9.3 Input Variables

Table 6-44: Input Values for Refrigeration Night Cover Savings Calculations

Component	Type	Value	Unit	Source(s)
load	Fixed	See customer application.	Btu/hour/ feet	Customer application
		Default = 1,500		Mid-Atlantic 2019, p. 492[123]
L	Variable	See customer application.	feet	Customer application
		Default = 6		DNV judgment
COP[124]	Fixed	2.2	-	Mid-Atlantic TRM 2019, p. 493
ESF[125]	Fixed	0.09	-	Mid-Atlantic TRM 2019, p. 493
HOU	Variable	8,760	hours (annual)	Mid-Atlantic TRM 2019, p. 493

6.4.9.4 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 calculation:

$$\Delta kWh = \frac{load}{\frac{12{,}000\ {Btu}/{hour}}{ton}} \times L \times \frac{3.516\ {kW}/{ton}}{COP} \times ESF \times HOU$$

122 Mid-Atlantic TRM 2019, p. 492. Assumed that continuous covers are deployed at night; therefore, no demand savings occur during the peak period.
123 Mid-Atlantic 2019, p. 492. Original source: Davis Energy Group, Analysis of Standard Options for Open Case Refrigerators and Freezers, May 11, 2004. (accessed on 7/7/2010.). http://www.energy.ca.gov/appliances/2003rulemaking/documents/case_studies/CASE_Open_Case_Refrig.pdf.
124 Kuiken et al, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, KEMA, March 22, 2010.
125 Mid-Atlantic TRM 2019, p. 493. Original source: Effects of the Low Emissivity Shields on Performance and Power Use of a Refrigerated Display Case, Southern California Edison, August 8, 1997. (accessed on July 7, 2010). http://www.sce.com/NR/rdonlyres/2AAEFF0B-4CE5-49A5-8E2C-3CE23B81F266/0/AluminumShield_Report.pdf. Characterization assumes covers are deployed for six hours per day.

$$= \frac{1{,}500 \, {}^{\frac{Btu}{hour}}\!/_{feet}}{12{,}000 \, {}^{\frac{Btu}{hour}}\!/_{ton}} \times \frac{3.516 \, {}^{kW}\!/_{ton}}{2.2} \times 6 \, feet \times 0.09 \times 8{,}760 \, hours$$

$$= 945.0 \, kWh$$

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

$$\Delta kW \quad = 0$$

6.4.9.5 Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2019, pp. 492-493.

6.4.9.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-45.

Table 6-45: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM
	Default Savings	• Corrected mistaken default annual energy savings

6.4.10 Refrigeration Coil Cleaning

6.4.10.1 Measure Description

This measure realizes energy savings by cleaning the condenser coils on reach-in and walk-in coolers and freezers. Eligible units will have 25% fouling or greater based on visual inspection. This measure may only receive energy savings and demand reduction when combined with the floating head pressure measure.

6.4.10.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh \quad = \frac{load}{12{,}000 \frac{\frac{BTU}{h}}{ton}} \times \frac{3.156 \frac{kW}{ton}}{COP} \times HOU \times ESF$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \frac{load}{12{,}000\frac{\frac{BTU}{h}}{ton}} \times \frac{3.156\frac{kW}{ton}}{COP} \times DRF$$

Where:

ΔkWh = per measure gross annual energy savings
ΔkW = per measure gross coincident demand reduction
load = total capacity of condensers (BTU per hour)
COP = coefficient of performance of refrigeration equipment
ESF = savings factor attributable to coil cleaning for annual energy
DRF = savings factor attributable to coil cleaning for demand reductions
HOU = annual hours of use

6.4.10.3 Input Variables

Table 6-46: Input Values for Refrigeration Coil Cleaning Savings Calculations

Component	Type	Value	Unit	Source(s)
load	Variable	See customer application	Btu/h	Customer application
COP	Fixed	Low Temp (-35°F – -1°F): 1.3 Med Temp (0°F – 30°F): 1.3 High Temp (31°F – 55°F): 2.5	-	Pennsylvania TRM 2016, p. 393
HOU	Fixed	Low Temp (-35°F - -1°F): 6,370 Med Temp (0°F - 30°F): 6,370 High Temp (31°F - 55°F): 6,173	hours, annual	Calculated duty cycle using weather factor, defrost factor, and capacity factor[126]
ESF[127]	Fixed	0.048	-	Qureshi and Zubair (2011)
DRF[128]	Fixed	0.022	-	Qureshi and Zubair (2011)

6.4.10.4 Default Savings

If the proper values are not supplied, no default savings will be awarded for this measure.

6.4.10.5 Source(s)

The primary sources for this deemed savings approach are the Pennsylvania TRM 2016 and "Performance degradation of a vapor compression refrigeration system under fouled conditions" by Qureshi and Zubair (2011), published in the *International Journal of Refrigeration*.

6.4.10.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-47.

126 The duty cycle is calculated using the same method as is used by TVA 2016 TRM for refrigeration measures. For coolers, a defrost factor of 0.995, a capacity factor of 0.87, and a weather factor of 0.84 is assumed. For freezers, a defrost factor of 0.90, a capacity factor of 0.87, a and weather factor of 0.90 is assumed.

127 Qureshi B.A. and Zubair S.M., "Performance degradation of a vapor compression refrigeration system under fouled conditions." International Journal of Refrigeration 24 (2011), p. 1016 – 1027. Figure 2-(a). Assumes a weighting of refrigerant types of 80% R-134 and 20% R-404.

128 Ibid.

Table 6-47: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	None	• No change

6.4.11 Suction Pipe Insulation (Cooler and Freezer)

6.4.11.1 Measure Description

This measure realizes energy savings by installing insulation on existing bare suction lines (lines that run from evaporator to compressor) that are located outside of the refrigerated space.

6.4.11.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = \frac{\Delta kWh}{ft} \times L$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \frac{\Delta kW}{ft} \times L$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
ΔkWh/ft = gross annual electric energy savings per linear foot
ΔkW/ft = gross coincident demand reduction per linear foot
L = length of insulation applied in linear feet

6.4.11.3 Input Variables

Table 6-48: Input Values for Suction Pipe Insulation Savings Calculations

Component	Type	Value	Unit	Source(s)
ΔkWh/ft	Variable	See Table 6-49	kWh/feet	Pennsylvania TRM 2016, p. 418
ΔkW/ft	Variable	See Table 6-49	kW/feet	Pennsylvania TRM 2016, p. 418
L	Variable	See customer application	feet	Customer application
		Default = 1		Per unit savings

Table 6-49: Suction Pipe Insulation Gross Annual Electric Energy Savings and Gross Coincident Demand Reduction (per Linear Foot)[129]

Refrigeration Type	ΔkWh/year·ft	ΔkW/ft
Low Temperature (-35°F - -1°F)	14.8	0.002726
Medium Temperature (0°F - 30°F)	14.8	0.002190
High Temperature (31°F - 55°F)	11.3	0.002190

6.4.11.4 Default Savings

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

The default per measure, gross annual electric energy savings will be assigned according to the following calculation:

$$\Delta kWh = \frac{\Delta kWh/year}{ft} \times L$$

$$= 24.8 \, {}^{kWh}/_{ft} \times 1\, foot$$

$$= 24.8\, kWh$$

The default per measure, gross coincident demand reduction will be assigned according to the following calculation:

$$\Delta kW = \frac{\Delta kW}{ft} \times L$$

$$= 0.005 \, {}^{kW}/_{ft} \times 1 ft$$

$$= 0.005\, kW$$

6.4.11.5 Source(s)

The primary source for this deemed savings approach is the Pennsylvania TRM 2016, pp. 417–418.

6.4.11.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-50.

Table 6-50: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated footnote

[129] Pennsylvania TRM 2016, p. 418, original source: Southern California Edison Company, "Insulation of Bare Refrigeration Suction Lines", Work Paper WPSCNRRN0003.

6.4.12 Strip Curtain (Cooler and Freezer)

6.4.12.1 Measure Description

The measure realizes energy savings by installing strip curtains on walk-in coolers and freezers. Strip curtains reduce the refrigeration load by minimizing infiltration of non-refrigerated air into the refrigerated space of walk-in coolers or freezers. Strip curtains are assumed to be operational only during building operating hours. When buildings are not operational, coolers and freezers doors will be closed.

6.4.12.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh \quad = {}^{kWh}/_{ft^2} \times Area$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW \quad = \frac{\Delta kWh}{HOU}$$

Where:

ΔkWh = per measure gross annual electric energy
ΔkW = per measure coincident demand reductions
kWh/ft^2 = average annual kilowatt hour savings per square foot of infiltration barrier
Area = area of doorway where strip curtains are installed

Table 6-51: Input Values for Strip Curtain Savings Calculations

Component	Type	Value	Unit	Source(s)
$\Delta kWh/ft^2$	Variable	See Table 6-52	kWh/ft^2	Pennsylvania TRM 2016, Table 3-107, p. 400
Area	Variable	Supermarkets: 35 Convenience Store: 21 Restaurant: 21 Refr. Warehouse: 80	ft^2	Supermarkets[130] Convenience Stores[131] Restaurant[132] Refr. Warehouse[133]
		Default = 21		Assume convenience store
HOU	Fixed	8,760	hours, annual	Pennsylvania TRM 2016, p. 398

[130] Pennsylvania TRM 2016, Table 3-108, p. 401, per data from California Public Utility Commission evaluation of 2006-2008 Investor-Owned Utility Energy Efficiency Programs, http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf.
[131] Ibid., p. 402.
[132] Ibid., p. 403.
[133] Ibid., p. 404.

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Table 6-52: Strip Curtain Gross Annual Electric Energy Savings (per sq.ft.)[134]

Type	Baseline Curtain	Annual Electric Energy Savings per Square Foot ($\Delta kWh/ft^2$)
Supermarket - Cooler	Yes	37
	No	108
	Unknown	108
Supermarket - Freezer	Yes	119
	No	349
	Unknown	349
Convenience Store - Cooler	Yes	5
	No	20
	Unknown	11
Convenience Store - Freezer	Yes	8
	No	27
	Unknown	17
Restaurant - Cooler	Yes	8
	No	30
	Unknown	18
Restaurant - Freezer	Yes	34
	No	119
	Unknown	81
Refrigerated Warehouse	Yes	254
	No	729
	Unknown	287
Other[135]	Yes	5
	No	20
	Unknown	11
Not applicable	Yes	0
	No	0
	Unknown	0

[134] Pennsylvania TRM 2016, p. 400. "The assumption is based on general observation that refrigeration is constant for food storage, even outside of normal conditions. The most conservative approach, in lieu of a more sophisticated model, is based on continuous operation [8,760 hours/year of operation]."

6.4.12.3 Default Savings

The default per measure, gross annual electric energy savings will be assigned—assuming the strip curtains were installed at a cooler within a convenience store of unknown baseline conditions—according to the following calculation:

$$\Delta kWh = {}^{kWh}/_{ft^2} \times Area$$

$$= 11\, {}^{kWh}/_{ft^2} \times 21\, ft^2$$

$$= 231\, kWh$$

The default per measure, gross coincident demand reduction will be assigned according to the following calculation:

$$\Delta kW = \frac{\Delta kWh}{HOU}$$

$$= \frac{231\, kWh}{8{,}760\, hours}$$

$$= 0.026\, kW$$

6.4.12.4 Source(s)

The primary source for this deemed savings approach is the Pennsylvania TRM 2016, p. 397 - 405.

6.4.12.5 Update Summary

The changes to this section, compared with last year, are described in Table 6-53.

Table 6-53: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Pennsylvania TRM
	Equation	• Updated equations

6.4.13 Vending Machine Miser

6.4.13.1 Measure Description

This measure realizes energy savings by installing vending misers that control the vending machine lighting and refrigeration systems power consumption of distributed closed-door cases. Miser controls power down these systems during periods of inactivity while ensuring that the product stays cold. Qualifying machines include glass front refrigerated coolers, non-refrigerated snack vending machines, and refrigerated beverage vending machines, but this measure does not apply to ENERGY STAR® vending machines that have built-in internal controls or distributed open door cases.

6.4.13.2 Savings Estimation Approach

Per measure gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = kW_{rated} \times HOU \times ESF$$

Per measure gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \frac{\Delta kWh}{HOU}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
kW_{rated} = rated kilowatts of connected equipment
HOU = annual hours of use
ESF = energy savings factor

6.4.13.3 Input Variables

Table 6-54: Input Values for Vending Miser Savings Calculations

Component	Type	Value	Unit	Source(s)
kW_{rated}	Variable	See customer application	kW	Customer application
		Default: Non-Refrigerated Snack Vending Machine (see Table 6-55)		Massachusetts TRM 2015, p. 268
ESF	Variable	See Table 6-55	-	Massachusetts TRM 2015, p. 268
HOU	Fixed	8,760	hours (annual)	Massachusetts TRM 2015, p. 268

Table 6-55: Vending Miser Rated Kilowatts and Energy Savings Factors[136]

Equipment Type	kW_{rated} (kW)	ESF
Refrigerated Beverage Vending Machine	0.400	0.46
Non-Refrigerated Snack Vending Machine	0.085	0.46
Glass Front Refrigerated Cooler	0.460	0.30

6.4.13.4 Default Savings

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

[136] Massachusetts TRM 2016-2018 Plan Version, p. 268-270; Original source is USA Technologies Energy Management Product Sheets (2006): https://www.usatech.com/energy_management/energy_productsheets.php (accessed on April 18, 2012).

The default, per measure gross annual electric energy savings will be applied according to the following calculation:

$$\Delta kWh = kW_{rated} \times HOU \times ESF$$

$$= 0.085\ kW \times 8{,}760\ hours \times 0.46$$

$$= 343 kWh$$

The default, per measure, gross coincident demand reduction will be applied according to the following calculation:

$$\Delta kW = \frac{\Delta kWh}{HOU}$$

$$= 343 \frac{kWh}{8{,}760} hours$$

$$= 0.039\ kW$$

6.4.13.5 Source(s)

The primary source for this deemed savings approach is the Massachusetts TRM 2015, pp. 268-270.

6.4.13.6 Update Summary

The changes to this section, compared with last year, are described in Table 6-56.

Table 6-56: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Verified no changes to page numbers / version of the Massachussetts TRM

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7 NON-RESIDENTIAL DISTRIBUTED GENERATION PROGRAM, DSM PHASE II

The Non-Residential Distributed Generation (NRDG) Program is designed to reduce peak demand for the Company. During a Distributed Generation Program dispatch event, large non-residential customers are incentivized to transfer their electrical demand from the grid to a distributed on-site resource. A third-party contractor installs, monitors and operates the distributed equipment controls.

Participants and the implementation contractor are notified 30 minutes in advance of an NRDG dispatch event by e-mail or telephone. The number of dispatched sites, and the beginning and ending event-hours varies by event. The program operates 12 months a year, but annual event-hours are limited per the terms of the program.

7.1.1.1 Measure Description

The impacts from the non-residential DG program are calculated by measuring the amount of aggregate and site-level kW generated by a distributed resource. The most important performance indicator is the program realization rate. The methodology for calculating the realization rate is presented below. A customer is compliant with the terms of the program if their average event-based generated kW, calculated monthly, is at least 95% of enrolled and committed kW.

7.1.1.2 Savings Estimation Approach

At the site and interval level, the ex-post impact is defined as the measured kW generated by the distributed resource. Dispatched generation is the amount of electricity requested by the company during a non-residential DG event. The sources of dispatched generation and enrolled dispatchable supply can be found in Table 7-1.

7.1.1.3 Realization Rate

The program realization rate for a given dispatch event (j) is the sum of measured generation (kW) from called participants (I) for the interval divided by the sum of dispatched generation for called participants.

$$Realization\ Rate_j = \frac{\sum_i Measured\ Generation\ (kW)}{\sum_i Dispatched\ Generation\ (kW)}$$

Program performance is tracked by aggregating measured generation and dispatched generation by event interval and day. Event-day plots facilitate the analysis of realization rate patterns for the entire program.

7.1.1.4 Input Variables

Table 7-1: Input Values for Non-Residential Distributed Generation Impact Analysis

Variable	Value	Unit	Source
Measured generation	Metered site data	kW	Dominion Energy
Dispatched generation	Event-based resource requested by Dominion Energy	kW	Dominion Energy
Enrolled dispatchable generation	Per program terms, fixed per site	kW	Dominion Energy

7.1.1.5 Default Savings

Default savings will not be credited to a non-residential DG customer for unmeasured generation.

7.1.1.6 Source(s)

DNV developed the non-residential DG evaluation methodology according to standard EM&V protocols.[137]

7.1.1.7 Update Summary

The changes to this section, compared with last year, are described in Table 7-2.

Table 7-2: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	None	• No change

[137] Miriam L. Goldberg & G. Kennedy Agnew. Measurement and Verification for Demand Response, National Forum on the National Action Plan on Demand Response, https://www.ferc.gov/industries/electric/indus-act/demand-response/dr-potential/napdr-mv.pdf.

8 NON-RESIDENTIAL SMALL MANUFACTURING PROGRAM, DSM PHASE VII

The Non-residential Small Manufacturing Program (CSTM) provides qualifying business owners incentives to use pursue one or more of the qualified energy efficiency measures through a local, participating contractor in Dominion's contractor network. To qualify for this program, the customer must be responsible for the electric bill and must be the owner of the facility or reasonably able to secure permission to complete the measures. All program measures are summarized in Table 8-1.

Table 8-1: Non-residential Targeted Small Manufacturing Program Measure List

End-Use	Measure	Legacy Program	Manual Section
Compressed Air	Compressed Air Nozzles	N/A	Section 8.1.1
	Leak Repairs	Non-residential Small Business Improvement Program	Section 5.3.1
	No-Loss Drains	N/A	Section 8.1.3
	Add Storage (5 gal/cfm)		Section 8.1.4
	Heat of Compression Dryer		Section 8.1.5
	Low Pressure-drop Filter		Section 8.1.6
	VSD Air Compressor		Section 8.1.7
	Cycling Refrigerant Dryer		Section 8.1.8
	Dewpoint Controls		Section 8.1.9
	Pressure Reduction		Section 8.1.10
	Downsized VFD Compressor		Section 8.1.11

8.1 Compressed Air End Use

8.1.1 Compressed Air Nozzle

8.1.1.1 Measure Description

This measure realizes energy savings by replacing standard air nozzles with engineered air nozzles. Nozzles are used in industrial processes to deliver jets of compressed air to remove debris or liquid, cool parts, eject parts from conveyors, or to perform other manufacturing functions. Standard nozzles use 100% compressed air to perform these tasks whereas engineered nozzles use compressed air to entrain ambient air, thereby halving the compressed-air usage. Engineered nozzles provide the same force and functionality as standard nozzles, but using less compressed air and, therefore, less energy.

Qualifying nozzles may use no more compressed air, at 80 psig, than the maximum flowrates shown in Table 8-2.

Table 8-2: Maximum Compressed Air Usage for Qualifying Nozzles

Nozzle Diameter (inch)	Maximum Flow Rate at 80 psig (scfm)
1/8	≤ 11
1/4	≤ 29
5/16	≤ 56
1/2	≤ 140

8.1.1.2 Savings Estimation Approach

Per measue, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = \left[scfm_{base} \times \left(\frac{kW}{scfm} \right)_{base} - scfm_{ee} \times \left(\frac{kW}{scfm} \right)_{ee} \right] \times Use \times HOU$$

To determine the reduction in flow rate from the standard to engineered nozzles, the following equation is used:

$$\Delta scfm = scfm_{80-psig,orifice} \times \left[\frac{P + 14.7}{(80 + 14.7)} \right]^{n}$$

The system air flow and loading values are calculated using the following equations:

$$scfm_{base} = scfm_{rated} \times Load_{base}$$

$$scfm_{ee} = scfm_{base} - \Delta scfm$$

DNV

$$Load_{ee} = \frac{scfm_{ee}}{scfm_{rated}}$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\left(\frac{kW}{scfm}\right)_{base} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_2 \times Load_{base}{}^2 + X_1 \times Load_{base} + C\right)}{scfm_{base}}$$

$$\left(\frac{kW}{scfm}\right)_{ee} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_2 \times Load_{ee}{}^2 + X_1 \times Load_{ee} + C\right)}{scfm_{ee}}$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} - scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee}\right] \times Use \times CF$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
hp = trim compressor rated horsepower
$scfm_{rated}$ = trim compressor rated flow rate
$scfm_{base}$ = base trim compressor operating flow
$scfm_{ee}$ = efficient trim compressor operating flow
Δscfm = reduction in trim compressor operating flow
$scfm_{80\text{-psig, nozzle}}$ = reduction in nozzle flow rate at 80 psig
$Load_{base}$ = average percent of rated flow for base trim compressor
$Load_{ee}$ = average percent of rated flow for base trim compressor with one engineered nozzle in operation
$kW/scfm_{base}$ = base trim compressor operating performance
$kW/scfm_{ee}$ = efficient trim compressor operating performance
P = system operating pressure
n = flowrate pressure adjustment coefficient
Dia = diameter of nozzle
$Type_{control}$ = control type adjustment factor
η_{VFD} = VFD efficiency
X_2 = coefficient
X_1 = coefficient
C = constant
Use = percent of annual operating hours (HOU) that nozzle is in use
HOU = annual hours of operation of compressor system
CF = demand coincidence factor

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8.1.1.3 Input Variables

Table 8-3: Input Values for Compressed Air Nozzles Savings Calculations

Component	Type	Value	Unit	Source(s)
$scfm_{rated}$	Variable	See customer application	scfm	Customer application
$scfm_{80\text{-}psig,\ nozzle}$	Variable	See Table 8-4	scfm	2019 IL TRM v.7.0 Vol. 2, Section 4.7.4
$Load_{base}$	Variable	See customer application	-	Customer application
		Default = 0.60		Engineering estimate
P	Variable	See customer application	psig	Customer application
n	fixed	1.0	-	Engineering estimate
Dia	Variable	See customer application	inches	Customer application
η_{VFD}	Variable	See Table 8-5	-	engineering estimate, only applicable if the control type is vfd
X_2	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
X_1	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
Use	Variable	See customer application	-	Customer application
		Default = 0.05		MN TRM v 3.0 2019, p. 449
HOU	Variable	See customer application	hours, annual	Customer application
		Default = 6,240		MN TRM v 3.0 2019, p. 450
CF	Fixed	See Table 8-6	-	2019 IL TRM v 7.0 Volume 2
		Default =0.59		Single shift (8/5) operating schedule

Table 8-4: $scfm_{80\text{-}psig,nozzle}$ Based on Nozzle Size

Nozzle Size, inches	scfm at 80 psig
1/2	140.0
5/16	56.5
1/4	29.0
1/8	10.5

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Table 8-5: Input Variables Based on Type of Control

Control Type	η_{VFD}	X_2	X_1	C
Inlet modulation	1.00	0.007900	0.297000	0.695800
Load/no-load, 1 gal/cfm	1.00	-0.901260	1.555462	0.320416
Load/no-load, 2 gal/cfm	1.00	-0.708400	1.429375	0.284163
Load/no-load, 3 gal/cfm	1.00	-0.479030	1.213741	0.267587
Load/no-load, 4 gal/cfm	1.00	-0.383750	1.127370	0.263671
Load/no-load, 5 gal/cfm	1.00	-0.193200	0.954629	0.255839
Reciprocating	1.00	-0.000610	0.833885	0.166648
Geometric	1.00	0.227656	0.324240	0.436002
VFD	0.98	3.09E-16	0.950000	0.050000

Table 8-6: Coincidence Factor (CF) Based on Operating Schdule

Operating Schedule	CF
Single shift (8/5)	0.59
2-shift (16/5)	0.95
3-shift (24/5)	0.95
4-shift (24/7)	0.95

8.1.1.4 Default Savings

If the proper values are not available, some values have defaults savings. However, there are no default savings for this measure as some values are needed to calculate savings.

8.1.1.5 Source(s)

The system performance (kW/scfm) relies on performance curves for various control types as provided by Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004.We also used the 2019 IL TRM v.7.0 Vol. 2, Section 4.7.4 and the MN TRM v 3.0 2019, pp. 449-450.

8.1.1.6 Update Summary

The changes to this section, compared with last year, are described in Table 8-7.

Table 8-7: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	New Measure	• New section

8.1.2 Leak Repair

8.1.2.1 Measure Description

This measure realizes energy savings by repairing compressed air leaks. Reducing the amount of air leaked in the compressed air system reduces the load on the compressors and, thereby saving energy.

Qualifying leaks must be identified, estimated, and tagged by a compressed-air professional.

This measure is offered in the Non-Residential Small Business Improvement Program in Section 5.3.1 but uses a different methodology. That program uses a deemed value for system efficiency. This program uses site-speific equipment and operating conditions for determining the system efficiecny.

8.1.2.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = \left(scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} - scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee} \right) \times HOU$$

To determine the reduction in flow rate from the leak repair, the following equation is used:

$$\Delta scfm = scfm_{80-psig,\ orifice} \times \left(\frac{P + 14.7}{(80 + 14.7)}\right)^{n}$$

The baseline system air flow is calculated using the following equation:

$$scfm_{base} = scfm_{rated} \times Load_{base}$$

The efficient system air flow and loading values are calculated using the following equations:

$$scfm_{ee} = scfm_{base} - \sum_{i=1}^{n} \Delta scfm_i$$

$$Load_{ee} = \frac{scfm_{ee}}{scfm_{rated}}$$

The baseline and efficient system operating performances are calculated using the following equations:

$$\left(\frac{kW}{scfm}\right)_{base} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_2 \times Load_{base}{}^2 + X_1 \times Load_{base} + C\right)}{scfm_{base}}$$

$$\left(\frac{kW}{scfm}\right)_{ee} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_2 \times Load_{ee}{}^2 + X_1 \times Load_{ee} + C\right)}{scfm_{ee}}$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \left(scfm_{base} \times \left(\frac{kW}{cfm}\right)_{base} - scfm_{ee} \times \left(\frac{kW}{cfm}\right)_{ee}\right) \times CF$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
hp = trim compressor rated horsepower
$scfm_{rated}$ = trim compressor rated flow rate
$scfm_{base}$ = baseline trim compressor operating flow
$scfm_{ee}$ = efficient trim compressor operating flow
$\Delta scfm$ = efficient trim compressor operating flow reduction
$scfm_{80\text{-psig, nozzle}}$ = reduction in flow rate at 80 psig
$Load_{base}$ = average percent of rated flow for base trim compressor
$Load_{ee}$ = average percent of system flow after leaks are repaired
$kW/scfm_{base}$ = baseline system operating performance
$kW/scfm_{ee}$ = efficient system operating performance
P = system operating pressure
n = flowrate preassure adjustment coefficient
Dia = diameter of orifice
$Type_{control}$ = control type adjustment factor
η_{VFD} = VFD efficiency
X_2 = coefficient
X_1 = coefficient
C = constant
HOU = annual hours of operation of compressor system
CF = demand coincidence factor

8.1.2.3 Input Variables

Table 8-8: Input Values for Leak Savings Calculations

Component	Type	Value	Units	Sources
hp	Variable	See customer application	hp	See customer application
$scfm_{rated}$	Variable	See customer application	scfm	See customer application
$scfm_{80\text{-psig, orifice}}$	Variable	Assigned by orifice size, see Table 8-9	scfm	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
$Load_{base}$	Variable	See customer application	-	See customer application
		Default = 0.60		Engineering estimate
P	Variable	See customer application	psig	See customer application
n	Fixed	1.0	-	Engineering estimate

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Component	Type	Value	Units	Sources
Dia	Variable	See customer application	inches	See customer application
η_{VFD}	Variable	See Table 8-5	-	Engineering estimate; only applicable for VFD-controlled compressors
X_2	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
X_1	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
HOU	Variable	See customer application	hours, annual	See customer application
		Default = 6,240		MN TRM v 3.0 2019, p. 450
CF	Fixed	See Table 8-6	-	2019 IL TRM v 7.0, Volume 2
		Default = 0.59		Assuming single shift

Table 8-9: $scfm_{80\text{-psig, orifice}}$ based on orifice size

Size, inch	$scfm_{80\text{-psig, orifice}}$
1/64	0.335
1/32	1.340
1/16	5.360
1/8	21.400
1/4	85.700
3/8	193.000

8.1.2.4 Default Savings

If the proper values are not available, some values have defaults savings. However, there are no default savings for this measure as some values are needed to calculate savings.

8.1.2.5 Source(s)

The system performance (kW/scfm) relies on performance curves for various control types as provided by Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004. We also used the 2019 IL TRM v.7.0, Vol. 2.

8.1.2.6 Update Summary

The changes to this section, compared with last year, are described in Table 8-10.

Table 8-10: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Input	• Added default value for hours of use

Version	Type of Change	Description of Change
v10	New Measure	• New section

8.1.3 No-Loss Condensate Drain

8.1.3.1 Measure Description

This measure involves the installation of a no-loss condensate drain on a compressed-air line. Timed drains open the drain at regular periods for a set amount of time. After timed drains open to drain the condensate, they allow compressed air to leak. Typically, these drains are set for the worst-case conditions resulting in a significant amount of wasted compressed air. No-loss drains use sensors to assess when the drain should open and for how long. This elimates the loss of compressed air when the drain purges. Energy is saved by reducing the load on the compressed-air system.

Qualifying drains are no-loss drains that do not vent compressed air when draining condensate.

8.1.3.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = \left(scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} - scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee}\right) \times HOU$$

To determine the reduction in flow rate from the leak repair, the following equation is used:

$$\Delta scfm = scfm_{100-psig,orifice} \times \left(\frac{p + 14.7}{(100 + 14.7)}\right)^{n}$$

The baseline system air flow is calculated using the following equation:

$$scfm_{base} = scfm_{rated} \times Load_{base}$$

The efficient system air flow and loading values are calculated using the following equations:

$$scfm_{ee} = scfm_{base} - \Delta scfm$$

$$Load_{ee} = \frac{scfm_{ee}}{scfm_{rated}}$$

The base and efficient system operating performances are calculated by the following equations:

$$\left(\frac{kW}{scfm}\right)_{base} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_2 \times {Load_{base}}^2 + X_1 \times Load_{base} + C\right)}{scfm_{base}}$$

$$\left(\frac{kW}{scfm}\right)_{ee} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_2 \times Load_{ee}{}^2 + X_1 \times Load_{ee} + C\right)}{scfm_{ee}}$$

Per measue, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \left(scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} - scfm_{ee} \times Qty \times \left(\frac{kW}{scfm}\right)_{ee}\right) \times CF$$

Where:

ΔkWh = gross annual electric energy savings
ΔkW = gross coincident demand reduction
hp = trim compressor rated horsepower
$scfm_{rated}$ = trim compressor rated flow rate
$scfm_{base}$ = baseline trim compressor operating flow
$scfm_{ee}$ = efficient trim compressor operating flow
$\Delta scfm$ = efficient trim compressor operating flow
$scfm_{100\text{-}psig,\ drain}$ = reduction in flow rate at 100 psig
n = flowrate preassure adjustment coefficient
$Load_{base}$ = percent of trim compressor load with standard drains
$Load_{ee}$ = percent of trim compressor load with no loss drains
$kW/scfm_{base}$ = baseline system operating performance
$kW/scfm_{EE}$ = efficient system operating performance
P = system operating pressure
$Type_{control}$ = control type adjustment factor
η_{VFD} = VFD efficiency
X_2 = coefficient
X_1 = coefficient
C = constant
HOU = annual hours of operation of compressor system
CF = demand coincidence factor

8.1.3.3 Input Variables

Table 8-11: Input Parameters for No-Loss Condensate Drain Savings Calculations

Component	Type	Value	Units	Source
Qty	Variable	See customer application	-	Customer application
hp	Variable	See customer application	hp	Customer application
$scfm_{rated}$	Variable	See customer application	scfm	Customer application
$scfm_{100\text{-}psig,drain}$	Fixed	3.0	scfm	2019 IL TRM v.7.0 Vol. 2, Section 4.7.3
n	Fixed	1.0	-	Engineering estimate
$Load_{base}$	Variable	See customer application; Default = 0.60	-	Customer application Engineering estimate
P	Variable	See customer application	psig	Customer application

Component	Type	Value	Units	Source
η_{VFD}	Variable	See Table 8-5	-	Engineering estimate, only applicable for VFD-controlled compressors
X_2	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
X_1	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
HOU	Variable	See customer application	hours, annual	See customer application
		Default = 6,240		MN TRM v 3.0 2019, p. 450
CF	Fixed	See Table 8-6	hours, annual	2019 IL TRM v 7.0 Volume 2
		Default=0.59		Default based on single shift

8.1.3.4 Default Savings

If the proper values are not available, some values have defaults savings. However, there are no default savings for this measure as some values are needed to calculate savings.

8.1.3.5 Source(s)

The system performance (kW/scfm) relies on performance curves for various control types as provided by Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004.We also used the 2019 IL TRM v.7.0 Vol. 2, Section 4.7.3.

8.1.3.6 Update Summary

The changes to this section, compared with last year, are described in Table 8-12.

Table 8-12: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Equation	• Added η_{VFD} to the kW/scfm equations. • Removed quantity from the $\Delta scfm$ equation
	Inputs	• Added default operating hours
v10	New Measure	• New section

8.1.4 Add Storage

8.1.4.1 Measure Description

This measure involves adding an air reciever with a flow controller on a load/no-load compressor system. Load/no-load compressors transition gradually from loaded to unloaded operation. Using storage and a flow controller the compressor has reduced cycling from loaded to unloaded operation. With fewer cycles the compressor spends less time transitioning, saving energy. The baseline case for savings is the existing storage capacity per cfm, which is expected to be 1 to 2 gallon/cfm.

Qualifying storage is at least 5 gallons of storage capacity per cfm of compressed airflow. This measure is available for load/no-load compressor systems.

8.1.4.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated per compressed air system according to the following equation:

$$\Delta kWh \quad = scfm_{base} \times \left[\left(\frac{kW}{scfm}\right)_{base} - \left(\frac{kW}{scfm}\right)_{ee}\right] \times HOU$$

The baseline system air flow and is calculated using the following equation:

$$scfm \quad = scfm_{rated} \times Load$$

The baseline and efficient system operating performance values are calculated by the following equations:

$$\left(\frac{kW}{scfm}\right)_{base} \quad = \frac{hp \times 1.1 \times 0.746}{0.945} \times \frac{\left(X_{2,base} \times Load^2 + X_{1,base} \times Load + C_{base}\right)}{scfm}$$

$$\left(\frac{kW}{scfm}\right)_{ee} \quad = \frac{hp \times 1.1 \times 0.746}{0.945} \times \frac{\left(X_{2,ee} \times Load^2 + X_{1,ee} \times Load + C_{ee}\right)}{scfm}$$

Per measure, gross coincident demand reduction is calculated per compressed air system according to the following equation:

$$\Delta kW \quad = scfm_{base} \times \left[\left(\frac{kW}{scfm}\right)_{base} - \left(\frac{kW}{scfm}\right)_{ee}\right] \times CF$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
scfm = trim compressor operating flow
$kW/scfm_{base}$ = base trim compressor operating performance
$kW/scfm_{ee}$ = efficient trim compressor operating performance
$scfm_{rated}$ = trim compressor rated flow rate
hp = compressor rated horsepower[138]
Load = average operating airflow rate percent of full load condtions of trim compressor
$X_{2,base}$ = coefficient
$X1_{base}$ = coefficient
C_{base} = constant
$X_{2,ee}$ = coefficient
$X_{1,ee}$ = coefficient

[138] With multiple fully loaded compressors, and only one part loaded unit, the horsepower and capacity (cfm) relate to the horsepower and capacity of the partly loaded compressor.

C_{ee} = constant
HOU = annual hours of operation of compressor system
CF = demand coincidence factor

8.1.4.3 Input Variables

Table 8-13: Input Parameters for Add Storage (5 gallon/cfm) Savings Calculations

Component	Type	Value	Units	Source
hp	Variable	See customer application	hp	Customer application
$scfm_{rated}$	Variable	See customer application	scfm	Customer application
Load	Variable	See customer application	-	Customer application
		Default = 0.60		Engineering estimate
$X_{2,base}$	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
$X_{1,base}$	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C_{base}	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
$X_{2,ee}$	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
$X_{1,ee}$	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C_{ee}	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
HOU	Variable	See customer application	hours	See customer application
		Default = 6,240		MN TRM v 3.0 2019, p. 450
CF	Fixed	See Table 8-6	-	2019 IL TRM v 7.0 Volume 2
		Default =0.59		Default based on single shift

8.1.4.4 Default Savings

If the proper values are not available, some values have defaults savings. However, there are no default savings for this measure as some values are needed to calculate savings.

8.1.4.5 Source(s)

The system performance (kW/scfm) relies on performance curves for various control types as provided by Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004. We also used the 2019 IL TRM v.7.0, Vol. 2.

8.1.4.6 Update Summary

The changes to this section, compared with last year, are described in Table 8-14.

Table 8-14: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Inputs	• Added default operating hours
v10	New Measure	• New section

8.1.5 Heat-of-compression Dryer

8.1.5.1 Measure Description

This measure replaces a standard purge-desiccant dryer with a heat-of-compression dryer. Standard desiccant dryers use compressed air to purge moisture from the desiccant. These dryers can use a significant amount of a system's rated compressed air capacity for drying. Heat-of-compression dryers, however, utilize the waste heat from the compressed air to recharge (dry) the desiccant. This saves energy by reducing the need to use compressed air for drying. The baseline is a standard purge desiccant dryer.

The installed equipment is a rotating drum or twin tower desiccant dryer that utilizes the heat of compression from the air compressor to regenerate the desiccant material.

8.1.5.2 Savings Estimation Approach

Per dryer, the gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} + kW_{heater,base} + kW_{blower,base} + kW_{refrig,base} - (1 + PSF \times (p_{base} - p_{ee}))\left(scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee}\right)\right] \times HOU$$

To determine the reduction in airflow rate due to the new dryer type, the following equation is used:

$$scfm_{reduced} = scfm_{dryer,rated,base} \times Purge_{base} - scfm_{dryer,rated,ee} \times Purge_{ee}$$

The baseline airflow rate and loading is calculated using the following equations:

$$scfm_{base} = scfm_{rated} \times Load_{base}$$

$$Load_{dryer,base} = \frac{scfm_{base}}{scfm_{dryer,rated,base}}$$

The efficient system air flow and loading is calculated using the following equations:

$$scfm_{ee} = scfm_{base} - scfm_{reduced}$$

$$Load_{ee} = \frac{scfm_{ee}}{scfm_{rated}}$$

The base and efficient system operating performance values are calculated by the following equations:

$$\left(\frac{kW}{scfm}\right)_{base} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_2 \times Load_{base}{}^2 + X_1 \times Load_{base} + C\right)}{scfm_{base}}$$

$$\left(\frac{kW}{scfm}\right)_{ee} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_2 \times Load_{ee}{}^2 + X_2 \times Load_{ee} + C\right)}{scfm_{ee}}$$

The load due to each component is calculated using the following equations:

$$kW_{blower,base} = \frac{hp_{blower,base} \times 0.8 \times 0.746}{0.957}$$

$$kW_{heater,base} = kW_{heater,base} \times Use_{heater,base}$$

$$kW_{refrig,base} = kW_{refrig,base,rated} \times \left(R_1 \times Load_{dryer,\ base} + K\right)$$

Per dryer, the gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} + kW_{heater,base} + kW_{blower,base} + kW_{refrig,base} - \left(1 + PSF \times (p_{base} - p_{ee})\right)\left((scfm_{ee}) \times \left(\frac{kW}{scfm}\right)_{ee}\right)\right] \times CF$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
hp = trim compressor rated horsepower
$scfm_{rated}$ = trim compressor rated flow
$scfm_{base}$ = base trim compressor operating flow
$scfm_{ee}$ = efficient trim compressor operating flow
$scfm_{reduced}$ = average reduction in flow resulting from replacing base dryer
$scfm_{dryer,\ rated,\ base}$ = base dryer rated flow

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$scfm_{dryer, rated, ee}$ = efficient cycling dryer rated flow
$Type_{dryer,base}$ = baseline dryer type
$Purge_{base}$ = purge percent of base dryer
$Purge_{ee}$ = purge percent of EE dryer
$Load_{base}$ = average percent of rated flow for trim compressor
$Load_{dryer\ base}$ = average operating proportion of baseline dryer rated airflow
$Load_{ee}$ = average operating percent of trim compressor rated flow with the heat of compression dryer
$kW_{heater,base}$ = average operating kW of the baseline heater
$kW_{blower,base}$ = average operating kW of the baseline blower
$kW_{refrig,base}$ = average operating kW of the baseline refrigerated dryer
$hp_{blower.base}$ = rated hp of blower in baseline dryer
$Use_{heater,base}$ = proportion of operating time that heater is in use
$kW_{refrig,base,rated}$ = the rated kW of the baseline dryer
R_1 = coefficient
K = coefficient
$kW/scfm_{base}$ = baseline system operating performance
$kW/scfm_{ee}$ = efficient system operating performance
p_{base} = system operating pressure of baseline system
p_{ee} = system operating pressure of efficient system
PSF = pressure savings factor
$Type_{control}$ = control type
η_{VFD} = VFD efficiency
X_2 = coefficient
X_1 = coefficient
C = constant
HOU = annual hours of use
CF = peak demand coincidence factor

8.1.5.3 Input Variables

Table 8-15: Input Parameters for Heat of Compression Dryer

Component	Type	Value	Units	Sources
hp	Variable	See customer application	hp	Customer application
$scfm_{rated}$	Variable	See customer application	scfm	Customer application
$scfm_{dryer, rated,base}$	Variable	see customer application	scfm	Customer application
$scfm_{dryer, rated\ ee}$	Variable	see customer application	scfm	Customer application
$Purge_{base}$	Variable	See Table 8-16	-	Desiccant purge rates are from: Dryer Selection for Compressed Air Systems, Compressed Air Challenge, 1999. no purge for other dryer types
$Purge_{ee}$	Fixed	0.02	-	Engineering estimate
$Load_{base}$	Variable	See customer application	-	Customer application
		Default = 0.60		Engineering estimate
$hp_{blower,base}$	Variable	See customer application, for blower purge and heated blower purge, only	hp	Customer application

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Component	Type	Value	Units	Sources
$kW_{heater,base}$	Variable	See customer application, for heated blower purge and heated desiccant dryer types, only	kW	Customer application
$Use_{heater,base}$	Variable	Assigned by baseline blower type: heated blower purge = 0.75 heated desiccant dryer = 1.00	-	Based on engineering judgment
$kW_{refrig,rated,base}$	Variable	See customer application, only applicable to: Non-cycling Refrigerated Cycling Refrigerated VFD Refrigerated Digital Scroll Refrigerated	kW	Customer application
R_1	Variable	See Table 8-17, for refrigerated dryers, only	-	Compressed Air Challenge, Cycling Refrigerated Air Dryers - Are Savings Significant
K	Variable	See Table 8-17, for refrigerated dryers, only	-	Compressed Air Challenge, Cycling Refrigerated Air Dryers - Are Savings Significant
p_{base}	Variable	See customer application	psig	Customer application
p_{ee}	Variable	See customer application	psig	Customer application
PSF	Fixed	0.005	1/psig	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
η_{VFD}	Variable	See Table 8-5	-	Engineering estimate; only applicable if the control type is a VFD
X_2	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
X_1	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
HOU	Variable	See customer application	hours, annual	See customer application
		Default = 6,240		MN TRM v 3.0 2019, p. 450
CF	Variable	See Table 8-6	-	2019 IL TRM v 7.0. Volume 2
		Default = 0.59		2019 IL TRM v 7.0. Volume 2

Table 8-16: $\%Purge_{base}$, based on dryer type

Dryer Type	$\%Purge_{base}$
Non-cycling, Refrigerated	0.00
Cycling, Refrigerated	0.00

Dryer Type	$\%Purge_{base}$
VFD, Refrigerated	0.00
Digital Scroll, Refrigerated	0.00
Desiccant	0.15
Heated Desiccant	0.70
Blower Purge	0.00
Heated Blower Purge	0.00

Table 8-17: Constant values, based on blower type and percent load

Dryer type	$Load_{dryer}$	R_1	K
Non-cycling, Refrigerated	0%	0.000	0.00
	> 0%	0.250	0.75
Cycling, Refrigerated	≤ 75%	1.133	0.10
	> 75%	0.200	0.80
VFD, Refrigerated	≤ 50%	0.100	0.45
	> 50%	1.000	0.00
Digital Scroll, Refrigerated	0%	0.000	0.00
	> 0%	0.900	0.10

8.1.5.4 Default Savings

If the proper values are not available, some values have defaults savings. However, there are no default savings for this measure as some values are needed to calculate savings.

8.1.5.5 Source(s)

The system performance (kW/scfm) relies on performance curves for various control types as provided by Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004.We also used the 2019 IL TRM v.7.0, Vol. 2 and Dryer Selection for Compressed Air Systems, Compressed Air Challenge, 1999.

8.1.5.6 Update Summary

The changes to this section, compared with last year, are described in Table 8-18.

Table 8-18: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Inputs	• Changed CF from fixed value to allow for more than one production shift • Added default operating hours
v10	New Measure	• New section

8.1.6 Low Pressure-Drop Filter

8.1.6.1 Measure Description

This measure involves replacing standard coalescing filters with low pressure-drop filters. Filters are used to remove contaminants from the compressed air system and protect equipment. Filters cause a pressure drop and require increased air pressure setpoints to overcome the pressure drop. By replacing standard filters with low pressure drop filters, the pressure setpoint can be reduced at the discharge to realize energy savings. Only positive-displacement compressors (rotary-screw and reciprocating) are eligible for this measure because lowering discharge pressure will result in approximately 0.5% drop in power for every 1-psig reduction of discharge pressure setpoint[139]. Furthermore, qualifying filters have a rated pressure drop of 1 psig or less. Centrifugal compressors are ineligible for this measure because they require compressor-specific performance curves to accurately calculate savings.

8.1.6.2 Savings Estimation

Per measure, gross annual electric energy savings are calculated per filter according to the following equation:

$$\Delta kWh = scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} \times PSF \times \Delta P \times HOU$$

The baseline airflow is calculated using the following equation:

$$scfm_{base} = scfm_{rated} \times Load_{base}$$

The base system operating performance is calculated using the following equation:

$$\left(\frac{kW}{scfm}\right)_{base} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_2 \times {Load_{base}}^2 + X_1 \times Load_{base} + C\right)}{scfm_{base}}$$

The change in pressure due to the new filter is calculated using the following equation:

$$\Delta p = MIN(p_{base} - p_{ee}, \Delta p_{max}))$$

Per measure, gross coincident demand reduction is calculated per filter according to the following equation:

$$\Delta kW = scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} \times PSF \times \Delta P \times CF$$

Where:

ΔkWh	= per measure, gross annual electric energy savings
ΔkW	= per measure, gross coincident demand reduction
hp	= compressor rated horsepower
P_{base}	= base pressure setpoint
P_{ee}	= system operating pressure after pressure reduction
ΔP	= the change in pressure setpoint

139 "Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004

ΔP_{max} = the maximum pressure reduction attributed to low pressure filter
$scfm_{rated}$ = trim compressor rated flow
$scfm_{base}$ = base trim compressor operating flow
$Load_{base}$ = average percent of rated flow for trim compressor
$kW/scfm_{base}$ = base system operating performance
PSF = pressure savings factor
Control_Type = control type
η_{VFD} = VFD efficiency
X_2 = coefficient
X_1 = coefficient
C = constant
HOU = annual hours of use
CF = peak coincidence factor

8.1.6.3 Input Variables

Table 8-19: Input Parameters for Low Pressure Drop Filter Savings Calculations

Component	Type	Value	Units	Sources
P_{base}	Variable	See customer application	psig	See customer application
P_{ee}	Variable	See customer application	psig	See customer application
ΔP_{max}	Fixed	5.0	psig	Engineering estimate
hp	Variable	See customer application	hp	See customer application
$scfm_{rated}$	Variable	See customer application	scfm	See customer application
$Load_{base}$	Variable	See customer application default = 0.60	-	See customer application Engineering estimate
PSF	Fixed	0.005	1/psig	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
η_{VFD}	Variable	See Table 8-5	-	Engineering estimate, only applicable if the control type is VFD
X_2	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
X_1	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
HOU	Variable	See customer application Default = 6,240	hours	See customer application MN TRM v 3.0 2019, p. 450
CF	Fixed	See Table 8-6 Default: 0.59	-	2019 IL TRM v 7.0 Volume 2 Assuming single production shift

8.1.6.4 Default Savings

If the proper values are not available, some values have defaults savings. However, there are no default savings for this measure as some values are needed to calculate savings.

8.1.6.5 Source

The system performance (kW/scfm) relies on performance curves for various control types as provided by Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004. We also referenced the 2019 IL TRM v.7.0, Vol. 2.

8.1.6.6 Update Summary

The changes to this section, compared with last year, are described in Table 8-20.

Table 8-20: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Inputs	• Added default operating hours
v10	New Measure	• New section

8.1.7 VFD Air Compressor

8.1.7.1 Measure Description

This measure installs an air compressor with variable frequency drive replacing an existing air compressor without a variable frequency drive. Variable frequency drives control the output airflow rate by varying the electrical frequency to the compressor motor. Inlet modulation with unloading, load/no-load, and centrifugal compressor systems vary the compressor capacity by physically changing the compressor operation. Variable frequency drive controls have much higher part-load efficiencies than the standard control types, thus saving energy under part-load conditons. Typical air compressors spend a small percent of the operation at or near full-load conditions.

The qualifying equipment is an air compressor compressor with a variable frequency drive. If this is installed as a replacement for an existing compressor, the compressor should be the same rated hp capacity as the existing compressor. Base-load units that serve multi-compressor systems do not qualify.

8.1.7.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated pVFD-controlled compressor according to the following equation:

$$\Delta kWh = \sum_{bin=1}^{7} scfm_{bin} \times \left(\left(\frac{kW}{scfm}\right)_{base,\ bin} - \left(\frac{kW}{scfm}\right)_{ee,\ bin}\right) \times HOU_{bin} \times HOU$$

The bin flow rate is calcaulated using the following equation:

$$scfm_{bin} = scfm_{rated} \times Load_{bin}$$

The base and efficient system operating performance is calculated by the following equations:

$$\left(\frac{kW}{scfm}\right)_{base,\,bin} = \frac{hp \times 1.1 \times 0.746}{0.945} \times \frac{\left(X_{2,base} \times Load_{bin}{}^{2} + X_{1,base} \times Load_{bin} + C_{base}\right)}{scfm_{bin}}$$

$$\left(\frac{kW}{scfm}\right)_{ee,\,bin} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_{2,ee} \times Load_{bin}{}^{2} + X_{1,ee,} \times Load_{bin} + C_{ee}\right)}{scfm_{bin}}$$

Gross coincident demand reduction is calculated per VFD-controlled compressor according to the following equation:

$$\Delta kW = \sum_{bin=1}^{7} scfm_{bin} \times \left(\left(\frac{kW}{scfm}\right)_{base,\ bin} - \left(\frac{kW}{scfm}\right)_{ee,\,bin}\right) \times HOU_{bin} \times CF$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
hp = trim compressor rated horsepower
$scfm_{rated}$ = trim compressor rated flow rate
$scfm_{bin}$ = flow rate of bin
$Load_{bin}$ = percent of rated flow of base trim compressor for each bin
$kW/scfm_{base,\ bin}$ = base trim compressor operating performance for each bin
$kW/scfm_{ee,\ bin}$ = ee trim compressor operating performance for each bin
η_{VFD} = VFD efficiency
$X_{2,\ base}$ = coefficient
$X_{1,\ base}$ = coefficient
C_{base} = constant
$X_{2,\ ee}$ = coefficient
$X_{1,\ ee}$ = coefficient
C_{ee} = constant
HOU = annual hours of use
HOU_{bin} = Percent of operating hours compressor operates at corisponding load
CF = peak coincidence factor

8.1.7.3 Input Variables

Table 8-21: Input Values VSD Air Compressor Savings Calculations

Component	Type	Value	Units	Sources
hp	Variable	See customer application	hp	Customer application
$scfm_{rated}$	Variable	See customer application	scfm	Customer application
$Load_{bin}$	Fixed	See Table 8-22	-	-
η_{VFD}	Fixed	0.98	-	Engineering estimate

Component	Type	Value	Units	Sources
$X_{2, base}$	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
$X_{1, base}$	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C_{base}	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
$X_{2, ee}$	Fixed	0.0	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
$X_{1, ee}$	Fixed	0.95	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C_{ee}	Fixed	0.05	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
HOU	Variable	See customer application	hours	Customer application
		Default = 6,240		MN TRM v 3.0 2019, p. 450
HOU_{bin}	Variable	See customer application	-	Customer application
		For default see Table 8-22 **provides the load bin definitions. These Loadsbins are the median load range of each bin. The HOUbin values are provided by the customer application and should total 1.00. If these values are unknown the defaults are used.** Table 8-22		Engineering assumption
CF	Fixed	See Table 8-6	-	2019 IL TRM v 7.0 Volume 2
		Default = 0.59		Single shift (8/5) operating schedule

Table 8-22 provides the load bin definitions. These $Loads_{bins}$ are the median load range of each bin. The HOU_{bin} values are provided by the customer application and should total 1.00. If these values are unknown the defaults are used.

Table 8-22: Load Proportion and HOU Proportion Defaults by Load Range Bins

Bin	Load Range	Default $Load_{bin}$ Proportion	Default HOU_{bin} Proportion
1	100% - 90%	0.95	0.00
2	90% - 80%	0.85	0.00
3	80% - 70%	0.75	0.00

Bin	Load Range	Default Load$_{bin}$ Proportion	Default HOU$_{bin}$ Proportion
4	70% - 60%	0.65	0.50
5	60% - 50%	0.55	0.50
6	50% - 40%	0.45	0.00
7	<40%	0.30	0.00

8.1.7.4 Default Savings

If the proper values are not available, some values have defaults savings. However, there are no default savings for this measure as some values are needed to calculate savings.

8.1.7.5 Source(s)

The system performance (kW/scfm) relies on performance curves for various control types as provided by Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004.We also used the 2019 IL TRM v.7.0 Vol. 2.

8.1.7.6 Update Summary

The changes to this section, compared with last year, are described in Table 8-23.

Table 8-23: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Inputs	• Added default operating hours
v10	New Measure	• New section

8.1.8 Cycling Air Dryer

8.1.8.1 Measure Description

This measure replaces an existing standard refrigerated air dryer with a new cycling air dryer. Standard non-cycling refrigerated air dryers run their refrigerant compressors continuously regardless of the need. This wastes energy by running when the compressed air does not need to be dried. This occurs when the ambient conditons are cooler and drier than the design conditons. Cycling dryers operate only when the compressed air needs to be dried.

The cycling dryer must either be a thermal-mass dryer, a VFD-controlled dryer, or a digital scroll-compressor dryer that modulates to match load.

8.1.8.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} + kW_{heater} + kW_{blower} + kW_{refrig}\right.$$

$$-scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee} - kW_{dryer,\ ee}\Bigg] \times HOU$$

To determine the reduction in flow rate due to the new dryer type, the following equation is used:

$$scfm_{reduced} = scfm_{base\ dryer,rated} \times Purge_{base}$$

The baseline air flow and loading is calculated using the following equations:

$$scfm_{system,\ base} = scfm_{system,\ rated} \times Load_{system,\ base}$$

$$scfm_{base} = scfm_{rated} \times Load_{base}$$

$$Load_{system,\ base} = \frac{scfm_{system,\ rated} - scfm_{rated} + scfm_{rated} \times Load_{base}}{scfm_{system,\ rated}}$$

$$Load_{dryer,\ base} = \frac{scfm_{system,\ base}}{scfm_{base\ dryer,\ rated}}$$

The efficient system air flow and loading is calculated using the following equations:

$$scfm_{ee} = scfm_{base} - scfm_{reduced}$$

$$Load_{ee} = \frac{scfm_{ee}}{scfm_{rated}}$$

$$Load_{dryer,\ ee} = \frac{scfm_{ee}}{scfm_{ee\ dryer,\ rated}}$$

The base and efficient system operating performance is calculated by the following equations:

$$\left(\frac{kW}{scfm}\right)_{base} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_2 \times {Load_{base}}^2 + X_1 \times Load_{base} + C\right)}{scfm_{base}}$$

$$\left(\frac{kW}{scfm}\right)_{ee} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_2 \times {Load_{ee}}^2 + X_1 \times Load_{ee} + C\right)}{scfm_{ee}}$$

The load due to each component is calculated using the following equations:

$$kW_{blower} = \frac{hp_{blower} \times 0.8 \times 0.746}{0.957}$$

$$kW_{heater} = kW_{rated,\ heater} \times Utilization_{heater}$$

$$kW_{refrig} = kW_{rated\,refrig} \times (R_{1,base} \times Load_{dryer,\,base} + K_{base})$$

$$kW_{dryer,\,ee} = kW_{rated\,dryer,\ ee} \times (R_{1,ee} \times Load_{dryer,\ ee} + K_{ee})$$

Per measure, gross coincident demand reduction is calculated according to the following equation:

$$\Delta kW = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} + kW_{heater} + kW_{blower} + kW_{refrig} - scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee} - kW_{dryer,\ ee}\right] \times CF$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
hp = trim compressor rated horsepower
$scfm_{rated}$ = trim compressor rated flow
$scfm_{system,\ rated}$ = system rated flow
$scfm_{base}$ = base trim compressor operating flow
$scfm_{system,\ base}$ = base system operating flow
$scfm_{ee}$ = efficient trim compressor operating flow
$scfm_{reduced}$ = average reduction in flow resulting from replacing base dryer
$scfm_{base\ dryer\ rated}$ = base dryer rated flow
$scfm_{ee\ dryer\ rated}$ = efficient cycling dryer rated flow
$Purge_{base}$ = purge percent of base dryer
$Load_{base}$ = average percent of rated flow for trim compressor
$Load_{system,\ base}$ = average percent of rated flow for system
$Load_{dryer\ base}$ = average operating percent of base dryer rated flow
$Load_{dryer\ ,ee}$ = average operating percent of EE dryer rated flow
$Load_{ee}$ = average operating percent of EE dryer rated flow
kW_{heater} = average operating kW of the base heater
kW_{blower} = average operating kW of the base blower
kW_{refrig} = average operating kW of the base refrigerated dryer
$kW_{dryer,\ ee}$ = average operating kW of the base refrigerated dryer
hp_{blower} = blower rated hp of base dryer
$kW_{rated\ heater}$ = heater rated kW of base dryer
$Utilization_{heater}$ = heater operation time
$kW_{rated\ refrig}$ = rated kW of the base dryer
$kW_{rated\ dryer,\ ee}$ = rated kW of the efficient dryer
$R1_{base}$ = coefficient
K_{base} = coefficient

$R_{1, ee}$ = coefficient
K_{ee} = coefficient
$kW/scfm_{base}$ = base system operating performance
$kW/scfm_{ee}$ = efficient system operating performance
η_{VFD} = VFD efficiency
X_2 = coefficient
X_1 = coefficient
C = constant
HOU = annual hours of use
CF = peak coincidence factor

8.1.8.3 Input Variables

Table 8-24: Input Parameters for Cycling Dryer

Component	Type	Value	Units	Sources
hp	Variable	See customer application	hp	See customer application
$scfm_{rated}$	Variable	See customer application	scfm	See customer application
$scfm_{system, rated}$	Variable	See customer application	scfm	See customer application
$scfm_{base\ dryer\ rated}$	Variable	See customer application	scfm	See customer application
$scfm_{ee\ dryer\ rated}$	Variable	See customer application	scfm	See customer application
$Purge_{base}$	Variable	See Table 8-16		Desicant purge rates are from: Dryer Selection for Compressed Air Systems, Compressed Air Challenge, 1999 No purge for other dryer types
$Load_{base}$	Variable	See customer application,	-	See customer application
		Default = 0.60		Engineering assumption
hp_{blower}	Variable	See customer application, only applicable to blower purge and heated blower purge	hp	See customer application
$kW_{rated\ heater}$	Variable	See customer application, only applicable to heated blower purge and heated desiccant dryer types	kW	See customer application
$Utilization_{heater}$	Variable	Assigned by base blower type: heated blower purge = 0.75 heated desiccant dryer = 1.0	-	Heated desiccant dryer operates continuiously, heated blower purge is based on engineering judgment
$kW_{rated\ refrig}$	Variable	See customer application, only applicable to blower purge and heated blower purge dryer types	kW	See customer application
$kW_{rated\ dryer,\ ee}$	Variable	See customer application, only applicable to blower purge and heated blower purge dryer types	kW	See customer application
$R_{1,\ base}$	Variable	See Table 8-17	-	Compressed Air Challenge, Cycling Refrigerated Air Dryers - Are Savings Significant

Component	Type	Value	Units	Sources
K_{base}	Variable	See Table 8-17	-	Compressed Air Challenge, Cycling Refrigerated Air Dryers - Are Savings Significant
$R_{1, ee}$	Variable	See Table 8-17	-	Compressed Air Challenge, Cycling Refrigerated Air Dryers - Are Savings Significant
K_{ee}	Variable	See Table 8-17	-	Compressed Air Challenge, Cycling Refrigerated Air Dryers - Are Savings Significant
X_2	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
X_1	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C	Variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
HOU	Variable	See customer application	hours	See customer application
		Default = 6,240		MN TRM v 3.0 2019, p. 450
CF	Fixed	See Table 8-6	-	2019 IL TRM v 7.0 Volume 2
		Default = 0.59		Assuming single shift

8.1.8.4 Default Savings

If the proper values are not available, some values have defaults savings. However, there are no default savings for this measure as some values are needed to calculate savings.

8.1.8.5 Source(s)

The system performance (kW/scfm) relies on performance curves for various control types as provided by Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004.We also used the 2019 IL TRM v.7.0 Vol. 2 and Cycling Refrigerated Air Dryers - Are Savings Significant, Compressed Air Challenge

8.1.8.6 Update Summary

The changes to this section, compared with last year, are described in Table 8-25.

Table 8-25: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Inputs	• Added default operating hours
v10	New Measure	• New section

DNV

8.1.9 Dew Point Controls

8.1.9.1 Measure Description

Typical desiccant dryers use compressed air to purge moisture from the desciant. Standard desiccant dryer purge rates are fixed. Timer controls rotate the chambers of desiccant for recharging at a fixed rate determined based on the design conditions of the compressed air system, i.e. full load airflow and humid ambient conditions. Most systems operate at loads near the design conditions for only short periods of time. This measure is to install dew point controls that recharge desciant only when the chamber is saturated. This is done by measuring the dew point of the dried air. This measure saves energy by limiting the compressed air purged to the amount needed to regenerate the desiccant.

Qualifying equipment must be installed on a twin tower desiccant dryer overriding fixed timer regeneration control and must use dew point based controls.

8.1.9.2 Savings Estimation Approach

Per measure, gross annual electric henergy savings are calculated per dryer controlled according to the following equation:

$$\Delta kWh = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} + kW_{heater} + kW_{blower} - scfm_{ee} \left(\frac{kW}{scfm}\right)_{ee} - kW_{blower,\ ee} - kW_{heater,ee} \right] \times HOU$$

The reduction in airflow due to the new controls is calculated using the following equation:

$$scfm_{reduced} = scfm_{base\,dryer,rated} \times Purge_{base} - \left(scfm_{base\,dryer,\ rated} \times Purge_{base} \times Load_{dryer,\,base}\right) \times (1 - Time)$$

The baseline air flow and loading are calculated using the following equations:

$$Load_{system,\,base} = \frac{scfm_{system,\ rated} - scfm_{rated} + scfm_{rated} \times Load_{base}}{scfm_{system,\ rated}}$$

$$scfm_{system,\,base} = scfm_{system,\ rated} \times Load_{system,\ base}$$

$$Load_{dryer,\,base} = \frac{scfm_{system,\ base}}{scfm_{dryer,rated}}$$

$$scfm_{base} = scfm_{rated} \times Load_{base}$$

The efficient air flow and loading are calculated using the following equation:

$$scfm_{ee} = scfm_{base} - scfm_{reduced}$$

$$Load_{ee} = \frac{scfm_{ee}}{scfm_{rated}}$$

The base and efficient system operating performance is calculated by the following equations:

$$\left(\frac{kW}{scfm}\right)_{base} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_2 \times Load_{base}{}^2 + X_1 \times Load_{base} + C\right)}{scfm_{base}}$$

$$\left(\frac{kW}{scfm}\right)_{ee} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_2 \times Load_{ee}{}^2 + X_1 \times Load_{ee} + C\right)}{scfm_{ee}}$$

The load due to each component is calculated using the following equations:

$$kW_{blower,\,ee} = kW_{blower,base} \times Load_{ee}$$

$$kW_{blower,base} = \frac{hp_{blower} \times 0.8 \times 0.746}{0.957}$$

$$kW_{heater,base} = kW_{rated,heater} \times Utilization_{heater}$$

$$kW_{heater,ee} = kW_{heater,base} \times Load_{ee}$$

Per measure, gross coincident demand reduction is calculated per dryer controlled according to the following equation:

$$\Delta kW = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} + kW_{heater} + kW_{blower} - scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee} - kW_{blower,\,ee} - kW_{heater,ee}\right] \times CF$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
hp = trim compressor rated horsepower
$scfm_{rated}$ = trim compressor rated flow
$scfm_{system,\ rated}$ = system rated flow
$scfm_{base}$ = base trim compressor operating flow
$scfm_{system,\ base}$ = base system operating flow

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$scfm_{reduced}$ = average reduction in flow resulting from dewpoint controls
$scfm_{base\ dryer,\ rate}$ = base dryer rated flow
$scfm_{ee}$ = efficient trim compressor operating flow
$Purge_{base}$ = purge percent of base dryer
$Load_{base}$ = average percent of rated flow for trim compressor
$Load_{system,\ base}$ = average percent of rated flow for base system
$Load_{dryer\ base}$ = average operating percent of base dryer rated flow
$Load_{ee}$ = average operating percent of trim compressor rated flow with dewpoint control dryer
Time = proportion of time reduction due to dew-point controls
$kW_{heater,\ base}$ = average operating kW of the base heater
$kW_{blower,\ base}$ = average operating kW of the base blower
$kW_{heater,\ ee}$ = average operating kW of the efficient heater
$kW_{blower,\ ee}$ = average operating kW of the efficient blower
hp_{blower} = blower rated hp of base dryer
$kW_{rated\ heater}$ = heater rated kW of base dryer
$Utilization_{heater}$ = heater operation time
$kW/scfm_{base}$ = base system operating performance
$kW/scfm_{ee}$ = efficient system operating performance
η_{VFD} = VFD efficiency
X_2 = coefficient
X_1 = coefficient
C = constant
HOU = annual hours of use
CF = peak coincidence factor

8.1.9.3 Input Variables

Table 8-26: Input Parameters for Heat of Compression Dryer

Component	Type	Value	Units	Sources
hp	variable	See customer application	hp	See customer application
$scfm_{rated}$	variable	See customer application	scfm	See customer application
$scfm_{system,\ rated}$	variable	See customer application	scfm	See customer application
$scfm_{base\ dryer\ rated}$	variable	See customer application	scfm	See customer application
$Purge_{base}$	variable	See Table 8-16	-	Desiccant purge rates are from: Dryer Selection for Compressed Air Systems, Compressed Air Challenge, 1999. no purge for other dryer types
$Load_{base}$	variable	See customer application	-	See customer application
		Default = 0.60		Engineering estimate
Time	fixed	0.25	-	Assumed, low RH during winter months
hp_{blower}	variable	See customer application, only applicable to blower purge and heated blower purge	hp	See customer application
$kW_{rated\ heater}$	variable	See customer application, only applicable to heated	kW	See customer application

Component	Type	Value	Units	Sources
		blower purge and heated desiccant dryer types		
$Utilization_{heater}$	variable	Assigned by base blower type: heated blower purge = 0.75 heated desiccant dryer = 1.0	-	Heated desiccant dryer operates continiuously, heated blower purge is based on engineering judgment
eff_{vfd}	variable	See Table 8-5	-	Engineering estimate, only applicable if the control type is VFD
X_2	variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
X_1	variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C	variable	See Table 8-5	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
HOU	variable	See customer application	hours	Customer application
		Default = 6,240		MN TRM v 3.0 2019, p. 450
CF	fixed	See Table 8-6	-	2019 IL TRM v 7.0 Volume 2
		Default = 0.59		Assuming single shift

8.1.9.4 Default Savings

If the proper values are not available, some values have defaults savings. However, there are no default savings for this measure as some values are needed to calculate savings.

8.1.9.5 Source(s)

The system performance (kW/scfm) relies on performance curves for various control types as provided by Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004.We also used the 2019 IL TRM v.7.0 Vol. 2, Dryer Selection for Compressed Air Systems, Compressed Air Challenge, 1999.

8.1.9.6 Update Summary

The changes to this section, compared with last year, are described in Table 8-27.

Table 8-27: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Inputs	• Added default hours
v10	New Measure	• New section

8.1.10 Pressure Reduction

8.1.10.1 Measure Description

This measure is for reducing the pressure setpoint of a compressed air system. Pressure setpoints are often set higher than is needed to ensure that serviced equipment is able to maintain the pressure requirements. Air compressors require more power to produce the same cfm at a higher pressure. Reducing this pressure setpoint saves energy. Additonally, there is a reduction in uncontrolled flow resulting from reducing the pressure setpoint.

This measure requires that the pressure reduction must take place at the compressor, not at a pressure regulator downstream. This measure is only applicable to positive displacement compressors (rotary scew and reciprocating compressors) centrifugal compressors are excluded, because they require compressor specific performance curves to accurately calculate savings.

8.1.10.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated per compressed air system according to the following equation:

$$\Delta kWh = \left(scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} \times \left(1 - PSF \times (P_{base} - P_{ee})\right) - (scfm_{base} - scfm_{reduced}) \times \left(\frac{kW}{scfm}\right)_{ee} \right) \times HOU$$

To determine the reduction in flow rate from the change is pressure set-point, the following equation is used:

$$scfm_{reduced} = \left(scfm_{base} \times \%scfm_{artificial}\right) - \left(scfm_{base} \times scfm_{artificial}\right) \times \left(\frac{(P_{ee} + 14.7)}{(P_{base} + 14.7)}\right)^{n}$$

The baseline system air flow is calculated using the following equation:

$$scfm_{base} = scfm_{rated} \times Load_{base}$$

The efficient system air flow and loading and is calculated using the following equation:

$$scfm_{ee} = scfm_{base} - scfm_{reduced}$$

$$Load_{ee} = \frac{scfm_{base} - scfm_{reduced}}{scfm_{rated}}$$

The base and efficient system operating performance is calculated by the following equations:

$$\left(\frac{kW}{scfm}\right)_{base} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X2 \times Load_{base}{}^{2} + X1 \times Load_{base} + C\right)}{scfm_{base}}$$

$$\left(\frac{kW}{scfm}\right)_{ee} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X2 \times Load_{ee}{}^{2} + X1 \times Load_{ee} + C\right)}{scfm_{ee}}$$

Per measure, gross coincident demand reduction is calculated per compressed air system according to the following equation:

$$\Delta kW = \left(scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} - (scfm_{base} - scfm_{reduced}) \times \left(\frac{kW}{scfm}\right)_{ee} + PSF \times (P_{base} - P_{ee})\right) \times CF$$

Where:

ΔkWh	= per measure gross annual electric energy savings
ΔkW	= per measure gross coincident demand reduction
P_{base}	= base system operating pressure of base system
P_{ee}	= efficient system operating pressure of efficient system
PSF	= pressure savings factor
n	= flowrate preassure adjustment coefficient
hp	= compressor system rated horsepower
$scfm_{rated}$	= compressor rated flow rate
$scfm_{base}$	= base compressor operating flow
$scfm_{ee}$	= efficient trim compressor operating flow
$scfm_{artificial}$	= percent compressed air artificial demand
$scfm_{reduced}$	= efficient compressor operating flow
$Load_{base}$	= average percent of rated flow for base system
$Load_{ee}$	= average percent of rated flow for efficient system
$kW/scfm_{base}$	= base system operating performance
$kW/scfm_{ee}$	= efficient system operating performance
η_{VFD}	= VFD efficiency
X2	= coefficient
X1	= coefficient
C	= constant
HOU	= annual hours of operation of compressor system
CF	= demand coincidence factor

8.1.10.3 Input Variables

Table 8-28: Input Parameters for Pressure Reduction

Component	Type	Value	Units	Sources
P_{ee}	Variable	See customer application	psig	See customer application
P_{ee}	Variable	See customer application	psig	See customer application
PSF	Fixed	0.05	1/psig	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004

Component	Type	Value	Units	Sources
n	Fixed	1.0	-	Engineering estimate
hp	Variable	See customer application	hp	customer application
$scfm_{rated}$	Variable	See customer application	scfm	customer application
$scfm_{artifictial}$	Fixed	0.30	-	compressed air challenge
$Load_{base}$	Variable	See customer application	-	See customer application
		Default = 0.60		Engineering estimate
η_{VFD}	Variable	See Table 8-5	-	engineering estimate, only applicable if the control type is vfd
X2	Variable	See Table 8-5	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
X1	Variable	See Table 8-5	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
C	Variable	See Table 8-5	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
HOU	Variable	See customer application	hours	See customer application
		Default = 6,240		MN TRM v 3.0 2019, p. 450
CF	Fixed	See Table 8-6	-	2019 IL TRM v 7.0 Volume 2
		Default = 0.59		Assuming single shift

8.1.10.4 Default Savings

This measure does not have default savings. The savings depend on the rated power and system pressures before and after implementing this measure. However, there are defaults for other variables.

8.1.10.5 Source(s)

The system performance (kW/scfm) relies on performance curves for various control types as provided by Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004.We also used the 2019 IL TRM v.7.0 Vol. 2.

8.1.10.6 Update Summary

The changes to this section, compared with last year, are described in Table 8-29.

Table 8-29: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Inputs	• Added default operating hours
v10	New Measure	• New section

8.1.11 Downsized VFD Compressor

8.1.11.1 Measure Description

This measure installs an air compressor with variable frequency drive (VFD) replacing a larger air compressor without VFD controls. Air compressors can be oversized and, hence, never operate near their rated capacity. Variable frequency drives control the output airflow rate by varying the electrical frequency to the compressor motor. Standard control types such as inlet valve modulation with unloading, load/unload, and centrifugal compressor systems vary the compressor capacity by physically changing the compressor operation. Variable frequency drive controls have much better part-load efficiencies than standard control types, thus saving energy under part load conditons. Additionally energy is saved by installing a smaller compressor that still meets system airflow requirements.

The qualifying equipment is an air compressor with a variable frequency drive and replaces an existing compressor of larger size without variable frequency drive controls. It is assumed that the typical size reduction is one standard size. Base load units that serve multi-compressor systems do not qualify.

8.1.11.2 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated per VFD-controlled compressor according to the following equation:

$$\Delta kWh = \sum_{bin=1}^{7} scfm_{bin} \times \left(\left(\frac{kW}{scfm}\right)_{base,\ bin} - \left(\frac{kW}{scfm}\right)_{ee,\ bin} \right) \times HOU_{bin} \times HOU$$

The airflow and load of each bin is calculated using the following equations:

$$scfm_{bin} = scfm_{rated,\ base} \times Load_{base,bin}$$

$$Load_{ee,bin} = \frac{scfm_{bin}}{scfm_{rated,ee}}$$

The base and efficient system operating performance (of each bin) is calculated by the following equations:

$$\left(\frac{kW}{scfm}\right)_{base,bin} = \frac{hp_{base} \times 1.1 \times 0.746}{0.945} \times \frac{\left(X_{2,base} \times Load_{base,\ bin}{}^{2} + X_{1,base} \times Load_{base,\ bin} + C_{base}\right)}{scfm_{bin}}$$

$$\left(\frac{kW}{scfm}\right)_{ee,bin} = \frac{hp_{ee} \times 1.1 \times 0.746}{0.945 * \times \eta_{VFD}}$$

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$$\times \frac{\left(X2_{ee} \times Load_{ee,\ bin}{}^{2} + X1_{ee} \times Load_{ee,\ bin} + C_{ee}\right)}{scfm_{bin}}$$

Per measure, gross coincident demand reduction is calculated per VFD-controlled compressor according to the following equation:

$$\Delta kW \ = \sum_{bin=1}^{7} scfm_{bin} \times \left(\left(\frac{kW}{cfm}\right)_{base,\ bin} - \left(\frac{kW}{cfm}\right)_{ee,\ bin}\right) \times HOU_{bin} \times CF$$

Where:

ΔkWh = gross annual electric energy savings
ΔkW = gross coincident demand reduction
Hp_{base} = base trim compressor rated horsepower
$scfm_{rated,\ base}$ = base trim compressor rated flow rate
hp_{ee} = efficient trim compressor rated horsepower
$scfm_{rated,\ ee}$ = efficient trim compressor rated flow rate
$scfm_{bin}$ = flow rate of bin
$Load_{base,\ bin}$ = percent of rated flow of base trim compressor for each bin
$Load_{ee,\ bin}$ = percent of rated flow of EE trim compressor for each bin
$kW/scfm_{base,\ bin}$ = base trim compressor operating performance for each bin
$kW/scfm_{ee,\ bin}$ = efficient trim compressor operating performance for each bin
η_{VFD} = VFD efficiency
$X_{2,\ base}$ = coefficient
$X_{1,\ base}$ = coefficient
C_{base} = constant
$X_{2,ee}$ = coefficient
$X_{1,ee}$ = coefficient
C_{ee} = constant
HOU = annual hours of use
HOU_{bin} = proportion of operating hours compressor at corresponding load
CF = peak coincidence factor

8.1.11.3 Input Variables

Table 8-30: Input Values Downsized VSD Air Compressor Savings Calculations

Component	Type	Value	Unit	Source(s)
hp_{base}	Variable	See customer application	hp	See customer application
$scfm_{rated,\ base}$	Variable	See customer application	scfm	See customer application
hp_{ee}	Variable	See customer application	hp	See customer application
$scfm_{rated,\ ee}$	Variable	See customer application	scfm	See customer application
$Load_{base,\ bin}$	Fixed	See Table 8-22	-	-
$X2_{base}$	Variable	See Table 8-5	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004

Component	Type	Value	Unit	Source(s)
$X1_{base}$	Variable	See Table 8-5	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
C_{base}	Variable	See Table 8-5	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
η_{VFD}	Fixed	0.98	-	Engineering estimate
$X2_{ee}$	Fixed	0.00	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
$X1_{ee}$	Fixed	0.95	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
C_{EE}	Fixed	0.05	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
HOU	Variable	See customer application	hours	Customer application
		Default = 6,240		MN TRM v 3.0 2019, p. 450
HOU_{bin}	Variable	See customer application	-	Customer application
		For default see Table 8-22 **provides the load bin definitions. These Loadsbins are the median load range of each bin. The HOUbin values are provided by the customer application and should total 1.00. If these values are unknown the defaults are used.** Table 8-22		Engineering assumption
CF	Fixed	See Table 8-6	-	2019 IL TRM v 7.0 Volume 2
		Default = 0.59		Single shift (8/5) operating schedule

8.1.11.4 Default Savings

This measure does not have default savings. The savings depend on the rated power. However, some variables have default values.

8.1.11.5 Source(s)

The system performance (kW/scfm) relies on performance curves for various control types as provided by Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004.We also used the 2019 IL TRM v.7.0 Vol. 2.

8.1.11.6 Update Summary

The changes to this section, compared with last year, are described in Table 8-31.

Table 8-31: **Summary of Update(s) from Previous Version**

Version	Type of Change	Description of Change
2020	Inputs	• Added default operating hours
v10	New Measure	• New section

9 NON-RESIDENTIAL OFFICE PROGRAM, DSM PHASE VII

The Non-residential Office Program (CTSO) provides qualifying business owners incentives to use pursue one or more of the qualified energy efficiency measures through a local, participating contractor in Dominion's contractor network. To qualify for this program, the customer must be responsible for the electric bill and must be the owner of the facility or reasonably able to secure permission to complete the measures. All program measures are summarized in Table 9-1.

Table 9-1: Non-residential Targeted Small Office Program Measure List

End-Use	Measure	Legacy Program	Manual Section
Lighting	Reduce Lighting Schedule by One Hour on Weekdays	N/A	Section 9.2.1
Space Conditioning	HVAC Unit Scheduling		Section 9.3.1
	Temperature Setback		Section 9.3.2
	Condensing Water Reset		Section 9.3.3
	DAT Reset (fuel and electric base)		Section 9.3.4
	Static Pressure Reset		Section 9.3.5
	VAV Minimum Flow Reduction		Section 9.3.6
	Enthalpy Economizer Control	Non-Residential Small Business Improvement Program	Section 3.1.4

Except for the Enthalpy Economizer Control measure (Section 3.1.4), analyses for all of the measures are based on DOE reference building "Large Office" with code vintage set to ASHRAE 90.1—2004 and the TMY weather file for either Richmond, VA, located in ASHRAE climate zone 4A, or Elizabeth City, NC, located in ASHRAE climate zone 3A. Current energy code in Virginia is described online as "Between 90.1-2007 and 90.1-2010." 2004 vintage buildings and systems would be good candidates for retrocommissioning measures such as these. Systems are generally assumed to be functioning properly, but can benefit from re-programming controls. The baseline system type (for occupied office spaces) is a central VAV system per floor with hot water reheat and chilled water.

The base building has other system types (CV, data center systems) in other parts of the building.

9.1.1.1 Measure Description

9.1.1.2 Baseline Building

The baseline energy model is derived from DOE's Commercial Large Office Reference Building. That model uses 24.35 kWh/sq.ft./year and 0.08 therm/sq.ft./year. Electricity usage includes a data cente that is typical of such buildings along with a corresponding interior equipment load. The reference building type is a large office (12-story plus basement totaling 498,600 sq.ft., or 38,350 sq.ft./floor) with one built-up VAV system per above-ground floor, hot water re-heats, and a single hot-water and water-cooled chiller plant for the building.

For those program participant buildings will be smaller than this, DOE's Commercial Large Office Reference Building was also scaled down to a 4-story building from simulations of the large building, as is standard practice in building energy simulation modeling. The reference 12-story building model was modified by removing eight of the interior floors—thereby reducing the building to four stories plus a basement data center. In fact, the interior floors of the 12-

story DOE reference model were modeled in EnergyPlus with "multipliers," which means that the simulator itself was scaling results for the interior floors. The 4-story models were further modified by changing said multipliers from ten to two. All but one of the load shapes were re-simulated using the resulting 4-story model (totaling 191,764 sq.ft. gross with about 150,000 sq.ft. in the above-ground floors subject to controls improvements).

9.1.1.3 Efficient Building

Savings estimates were updated based on the new simulations and/or de-rated simulations based on past engineering experience such that the savings results of measures involved those facilities with characteristics similar to the 4-story office.

Scaling of results can be used to predict savings for medium to large multi-story office buildings. Loads on HVAC equipment in such buildings tend to be dominated less by shell or envelop loads than internal loads such as people, lights, and equipment. Small buildings with relatively large exterior surface area compared to floor area (or larger sprawling buildings with only one or two floors) would not be modeled as well by scaling these results. On the other hand, small buildings would rarely be heated and cooled by VAV air-handlers with central hot water and chilled water plants.

The basement includes an 8,400 sq.ft. data center and each floor includes its own small 390 sq.ft. data center. Note: In general, the unoccupied basement areas (41,500 sq.ft.) are not included in the savings rate (i.e., kWh/sq.ft.) calculations provided in the sections that follow. Savings rates are normalized with a building area of 457,100 sq.ft. (or 153,400 sq.ft. for the 4-story models).

Existing systems are assumed to be ten years old with ten years of useful life remaining.

9.2 Lighting End Use

9.2.1 Reduce Lighting Schedule by One Hour on Weekdays

Lighting fixtures must be turned on and off by an automation system. The customer or controls vendor must provide documentation that lighting operating hours are reduced by at least 30 minutes per workday.

9.3 Heating, Ventilation, and Air Conditioning (HVAC) End Use

9.3.1 HVAC Unit Scheduling (Electric Heat, Gas Heat)

HVAC air handling equipment (air handling units, unitary HVAC, or split system HVAC) must be scheduled to an unoccupied mode by an automation system. The unoccupied mode must shut outdoor air dampers to remove ventilation loads. The customer or controls vendor must provide documentation that HVAC equipment operating hours are reduced by at least 30 minutes per workday. These measures are applicable to systems with gas heat.

These measures are based on the frequent observation during commercial facility audits that many facilities maintain comfort conditions, including ventilation, well beyond the occupied hours of the facility. The simulation of these measures assumes that scheduling of fans and OA can be decreased by a half-hour in the morning and half-hour in the afternoon. In cases with greater reductions in operating hours, savings can be scaled base on the number of hours of correction. The two measures and their savings differ in their heating type.

The following schedules were modified to determine the energy impact:

- VAV fan schedule for each of the 12 systems. This schedule essentially dictates when occupied hours occur, running the fan continuously and ensuring a constant supply of outside air (OA).
- Heating set point schedule for all zones served by VAV
- Cooling set points were not changed.

As with other measures that reduce OA, fan savings are limited due to reductions in free-cooling.

9.3.2 HVAC Temperature Setback

The unoccupied temperature must be set lower than it was previously in the baseline condition. The temperature must be reduced at least two degrees below the occupied set point. This measure is offered to buildings with either gas or electric heat. The customer or controls vendor must provide documentation of the existing and new unoccupied temperature set points and their schedules.

In the simulations, temperature setpoints during unoccupied hours are set back by nine degrees. Other spaces such as the data center are not modified. Baseline schedules had implemented setback so this was “modeled in reverse” by eliminating the setback schedules in the reference energy model (which were set to nine degrees.) Other setback schedules/temperatures can be scaled accordingly.

Code requires setback controls (but not setup) for zone 4A. See 90.1-2004, sections 6.4.3.2(a) and 6.4.3.2.2. Implementing this measure would be restoring function that is intended by code.

- Setback temperature: 60.8 °F
- Occupied hours set point: 69.8 °F

9.3.3 HVAC Condensing Water Temperature Reset

The condenser temperature on an air-cooled or water-cooled chiller system must be allowed to reset (lower) by at least five degrees from the summer design conditions during periods of partial load. The customer or controls vendor should provide documentation of implementation of the enhanced reset schedule compared to the baseline system control strategy.

Reset schedule as modeled for the efficient case reflects:

- For outside-air temperature of 60°F, the chilled water setpoint temperature is changed to 60°F.
- For outside air-temperature of 75°F, the chilled water setpoint temperature is changed to70°F

The measure accounts for the presence of two stages in the cooling tower that had not existed in the baseline case.

9.3.4 HVAC DAT Reset (fuel and electric base)

The discharge air temperature from a variable air volume or constant volume reheat air handler system must be allowed to reset (increase) at least two degrees from the summer design conditions during periods of partial load. The customer or controls vendor should provide documentation of implementation of the enhanced reset schedule compared to how the system was previously controlled. This measure is only eligible for systems with electric reheat coils or baseboard heaters.This is not required by 90.1-2004.

9.3.5 HVAC Static pressure Reset

Supply fans controlled by variable-frequency drives must be converted from a fixed static pressure supply set point to a control sequence that resets the static pressure supply set point based on variable air volume box position. The customer or controls vendor should provide documentation showing the existing set point and new static pressure reset control sequence.

See section 6.5.3.2.3 of ASHRAE 90.1-2004. This measure was required by code **for air systems with zone boxes integrated into DDC control system**. Implementing it would appear to restore the condition intended by code, though not all systems would have such controls. The base model did NOT have this control implemented. VAV fan curves in the base model correspond to fixed duct static pressure.

OpenStudio does not currently implement the more sophisticated “ComponentModel” fan present in EnergyPlus. Implementing the pressure reset strategy would require shifting the project entirely to raw EnergyPlus or modifying the VAV fan curve within OpenStudio in a way that would simulate static pressure reset. However, a fan curve for this purpose is available from NREL.[140]

Fan curve coefficients used were as shown in Table 9-2.

Table 9-2: Fan Curve Coefficients

Coefficient	Fixed SP (baseline)	Reset SP
Coefficient 1	0.00130	0.04076
Coefficient 2	0.14700	0.08810
Coefficient 3	0.95060	-0.07290
Coefficient 4	-0.09980	0.94370
Coefficient 5	0.00000	0.00000
Minimum percent power	20%	10%

9.3.6 HVAC VAV Minimum Flow Reduction (Fuel Heating & Electric Baselines)

VAV minimums were assumed to be set higher than necessary to meet winter heating loads. They were reduced by 10%. It is assumed that this measure can be implemented while continuing to provide code required ventilation levels and meeting winter heating set points in all zones (e.g., perhaps occupancy of the building has changed and not as much ventilation air is needed and/or insulation has been added so winter shell loads are smaller than before.). Verifying these conditions in an actual building would take a fair amount of analysis. This model run is based on a central plant with a hot-water boiler for re-heats. If re-heats were electric, then savings from this measure would be greater.

The presence of electric re-heats results in savings approximately double that for VAV with fossil fuel HW boilers.

9.3.6.1 Savings Estimation Approach

Per measure, gross annual electric energy savings are calculated according to the following equation:

$$\Delta kWh = ESF \times Area$$

[140] https://github.com/NREL/openstudio-standards/blob/master/lib/openstudio-standards/standards/Standards.FanVariableVolume.rb

Per measure, gross coincident demand reduction is assigned as zero because these measures have a negligible demand reduction as shown below:

$$\Delta kW \quad = 0$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reductions
Area = area of the building
ESF = annual energy savings factor per square foot based on building type, weather station and heating system type

9.3.6.2 Input Variables

Table 9-3: Input Values for HVAC VAV Minimum Flow Reduction Savings Calculations

Component	Type	Value	Unit	Source(s)
Area	Variable	See customer application	sq.ft.	Customer application
ESF	Variable	See Table 9-4, Table 9-5, and Table 9-6	kWh/sq.ft.	Open Studio energy modeling software outputs

Table 9-4: Energy Saving Factor (ESF) for 4-Story Office (Chilled Water, VAV) Various ECM Measures per by Building Type, Weather Station, and Heating System Type

Annual Electric Energy Saving Factor (kWh/sf)	Weather Station	Heating System Type	ECM1: Schedule Lighting	ECM2: Schedule HVAC	ECM3: Temp Setback	ECM4: Condenser Water Reset	ECM5: Discharge Air Temp Reset	ECM6: Static Pressure Reset	ECM8: VAV Box Minimum
4-story Office, Chilled water, VAV	Richmond	Electric	0.9547	2.9442	1.8980	N/A	0.7970	0.7323	3.3006
		Non-Electric	1.6832	0.5237	0.5214	N/A	0.4291	1.3122	1.3739
	Elizabeth City, NC & Rocky Mount-Wilson, NC, averaged	Electric	0.9897	2.9241	1.8639	N/A	0.7572	0.7660	3.3548
		Non-Electric	1.7030	0.5349	0.5325	N/A	0.4635	1.3401	1.4109

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Table 9-5: Energy Saving Factor (ESF) for 4-Story Office (Chilled Water, CV)0 Measures by Weather Station, and Heating System Type

Annual Electric Energy Saving Factor (kWh/sf)	Weather Station	Heating System Type	ECM1: Schedule Lighting	ECM2: Schedule HVAC	ECM3: Temp Setback	ECM4: Condenser Water Reset	ECM5: Discharge Air Temp Reset	ECM6: Static Pressure Reset	ECM8: VAV Box Minimum
4-story Office, Chilled water, CV	Richmond	Electric	0.9456	3.0007	1.9191	N/A	0.9617	N/AI	N/A
		Non-Electric	1.0482	0.8404	0.4128	N/A	0.1500	N/AI	N/A
	Elizabeth City, NC & Rocky Mount-Wilson, NC, averaged	Electric	0.9786	2.9660	1.8745	N/A	0.8867	N/A	N/A
		Non-Electric	1.0663	0.9172	0.4416	N/A	0.1697	N/A	N/A

Table 9-6: Energy Saving Factor (ESF) for 4-Story Office (Package, VAV) Measures by Weather Station, and Heating System Type

Annual Electric Energy Saving Factor (kWh/sf)	Weather Station	Heating System Type	ECM1: Schedule Lighting	ECM2: Schedule HVAC	ECM3: Temp Setback	ECM4: Condenser Water Reset	ECM5: Discharge Air Temp Reset	ECM6: Static Pressure Reset	ECM8: VAV Box Minimum
4-story Office, Package system, VAV	Richmond	Electric	0.8683	0.0180	0.5048	N/A	-0.6532	1.0514	0.5130
		Non-Electric	1.6582	0.4134	1.0463	N/A	0.3808	1.2939	0.7567
	Elizabeth City, NC & Rocky Mount-Wilson, NC, averaged	Electric	0.8803	0.0195	0.5156	N/A	-0.3890	1.1128	0.5634
		Non-Electric	1.6955	0.4281	1.0638	N/A	0.4180	1.3420	0.8463

9.3.6.3 Default Savings

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

9.3.6.4 Source(s)

The primary source for this deemed savings approach is prototypical building energy models derived from DOE's Commercial Large Office Reference Building and modified to represent Richmond, VA and a blend of Elizabeth City, NC and Rocky Mount-Wilson, NC weather using typical meteorological year 3 (TMY3) data along with various program-specific measures.

9.3.6.5 Update Summary

The changes to this section, compared with last year, are described in Table 9-7.

Table 9-7: **Summary of Update(s) from Previous Version**

Version	Type of Change	Description of Change
2020	Inputs	• Revised kWh/sq.ft. with results from updated building models
v10	New Measure	• New section

9.3.7 Dual Enthalpy Air-side Economizer

This measure is also offered through the Non-Residential Heating and Cooling Efficiency program. The savings approach is described in Section 3.1.5.

10 SUB-APPENDICES

10.1 Sub-appendix F2-I: Cooling and Heating Degree Days and Hours

This section appears in Appendix F1 as Sub-appendix F1-I: Cooling and Heating Degree Days and Hours (a.k.a. Section 10.1).

Table 10-1: Base Temperatures by Sector and End-use

This table appears in Appendix F1 as Sub-appendix F1-I: Cooling and Heating Degree Days and Hours (a.k.a. Section 10.1).

Table 10-2: Reference Cooling and Heating Degree Days

This table appears in Appendix F1 as Sub-appendix F1-I: Cooling and Heating Degree Days and Hours (a.k.a. Section 10.1).

Table 10-3: Reference Cooling and Heating Degree Hours

This table appears in Appendix F1 as Sub-appendix F1-I: Cooling and Heating Degree Days and Hours (a.k.a. Section 10.1).

10.2 Sub-appendix F2-II: Non-residential HVAC Equivalent Full Load Hours

Table 10-4, Table 10-5, and Table 10-6 provide the full load heating and cooling hours that are used as defaults for non-residential programs. The Richmond, VA and a blend of Elizabeth City and Rocky Mount-Wilson, NC full-load cooling and heating hours are determined by using ratios of the annual full load cooling and heating hours listed in the ENERGY STAR® heat pump and central AC savings calculators to the 2019 Mid-Atlantic TRM for Baltimore, MD.

The Mid-Atlantic TRM hours are based on an evaluation of the EmPOWER Maryland program of utilities in the state of Maryland. According to the Mid-Atlantic TRM, the values are "based on average 5 utilities in Maryland.[141] Since that evaluation only produced full load hours for Baltimore, DNV calculated full load hours for Richmond and blended Elizabeth City and Rocky Mount-Wilson using the same adjustment method used by the Mid-Atlantic TRM convert the Baltimore full load hours to Wilmington, DE and Washington, DC hours (see page 72, footnote 197 in the Mid-Atlantic TRM). It appears that the Mid-Atlantic TRM considers the ENERGY STAR® air source heat pump and central AC calculator full load hours to be different from "full load cooling" and "full load heating hours" that it imputed using the methods described in its footnote and also used here. DNV is using the methods and values from the Mid-Atlantic TRM for full-load cooling and heating hours in this document.

The conversion method uses the ratio of Baltimore full load cooling and heating hours in the Mid-Atlantic TRM to Baltimore full load cooling and heating hours in the ENERGY STAR® heat pump and central AC calculators. This ratio is then multiplied with the ENERGY STAR® hours for Richmond and blended Elizabeth City and Rocky Mount-Wilson to determine each city's respective full-load hours. Below is an example of the calculation of Richmond's full-load cooling hours for air-source heat pump systems:

$$\text{Mid-Atlantic TRM Baltimore EFLHcool} \quad = 744\ \text{hour/year}$$

[141] Navigant Consulting 'EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Residential HVAC Program.' April 4, 2014, table 30, page 48.

$$\textit{ENERGY STAR® Baltimore EFLHcool} = 1{,}050 \text{ hour/year}$$

$$\textit{ENERGY STAR® Richmond EFLHcool} = 1{,}188 \text{ hour/year}$$

$$\textit{STEP Richmond EFLHcool} = ENERGY\ STAR^{®}\ Richmond\ FLH_{cool} \times \frac{Mid-Atlantic\ TRM\ Baltimore\ FLH_{cool}}{ENERGY\ STAR^{®}\ Baltimore\ FLH_{cool}}$$

$$= 1{,}188\ {}^{hour}/_{year} \times \frac{774\ {}^{hour}/_{year}}{1{,}050\ {}^{hour}/_{year}}$$

$$= 842 \text{ hour/year}$$

In 2019, a similar method is used to adjust full-load hour for North Carolina. TMY data from Elizabeth City and Rocky Mount are used to determine North Carolina's CDD, HDD, and CDH (Average value taken between Elizabeth City and Rocky Mount-Wilson, see sub-appendix I). The ratio of Baltimore full-load hours to Baltimore CDD or HDD is multiplied by the North Carolina CDD or HDD to determine a full-load hour that is more location accurate.

Example calculation for air-source heat pump:

$$\textit{Mid-Atlantic TRM Baltimore CDD} = 1{,}233$$

$$\textit{STEP Baltimore EFLHcool} = 744 \text{ hour/year}$$

$$\textit{TMY Elizabeth City/RM CDD} = 1{,}552$$

$$\textit{STEP Elizabeth City/RM EFLHcool} = STEP\ Baltimore\ EFLH_{cool} \times \frac{TMY\ Rocky\ Mount - \frac{Wilson}{Elizabeth}\ City\ CDD}{Mid-Atlantic\ TRM\ Baltimore\ CDD}$$

$$= 744\ {}^{hour}/_{year} \times \frac{1{,}552}{1{,}233}$$

$$= 936\ {}^{hour}/_{year}$$

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10.2.1 Annual Cooling Hours for Unitary Air Conditioners, Heat Pumps, VRF, and Mini-split Systems

Table 10-4: Heat pump, Unitary AC, VRF, and Mini Split Equivalent Full-Load Cooling Hours for Non-residential Buildings[142]

Building Type	Baltimore, MD	Richmond, VA	Elizabeth City, NC & Rocky Mount-Wilson, NC, averaged
Education – Elementary and Middle School	295	347	375
Education – High School	340	400	432
Education – College and University[143]	756	888	960
Food Sales - Grocery	678	797	861
Food Sales – Convenience Store	923	1,085	1,172
Food Sales – Gas Station Convenience Store	923	1,085	1,172
Food Service - Full Service	768	902	975
Food Service - Fast Food	730	858	927
Health Care - Inpatient	1,223	1,437	1,553
Health Care - Outpatient	650	764	826
Lodging – (Hotel, Motel and Dormitory)	1,831	2,152	2,325
Mercantile (mall)	887	1,042	1,127
Mercantile (Retail, not mall)	911	1,071	1,157
Office – Small (<40,000 sq ft)	634	745	805
Office – Large (≥40,000 sq ft)	733	861	931
Other[144]	245	288	311
Public Assembly	945	1,110	1,200
Public Order and Safety (Police and Fire Station)	245	288	311
Religious Worship	245	288	311
Service (Beauty, Auto Repair Workshop)	923	1,085	1,172
Warehouse and Storage[145]	2,081	2,445	2,643

[142] Baltimore, MD full load cooling hours taken from Mid-Atlantic TRM 2019 p.583 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 (Weather station number 724010; CDD=1,448), Charlotte Douglas International Airport (Weather station number 723140; CDD=1,598), and Baltimore BLT – Washington International Airport (Weather station number 724060; CDD=1,233). See Sub-appendix F2-I: Cooling and Heating Degree Days and Hours for CDD and HDD.

[143] "Education – College and University" Baltimore, MD full load cooling hours is an average of the hours for "Education – Community College"(718 hours/year) and "Education – University" (793 hours/year) in the Mid-Atlantic TRM 2018, p.528

10.2.2 Annual Heating Hours for Heat Pumps, VRFs, and Mini-split Systems

Table 10-5: Heat Pump, VRF, and Mini-split Equivalent Full Load Heating Hours for Non-residential Buildings[146]

Building Type	Baltimore, MD	Richmond, VA	Elizabeth City, NC & Rocky Mount-Wilson, NC, averaged
Education – Elementary and Middle School	668	560	410
Education – High School	719	602	442
Education – College and University	622	521	382
Food Sales - Grocery	980	821	602
Food Sales – Convenience Store	623	522	383
Food Sales – Gas Station Convenience Store	623	522	383
Food Service - Full Service	1,131	948	695
Food Service - Fast Food	1,226	1,027	753
Health Care-inpatient	214	179	131
Health Care-outpatient	932	781	572
Lodging – (Hotel, Motel and Dormitory)	2,242	1,878	1,377
Mercantile (mall)	591	495	363
Mercantile (Retail, not mall)	739	619	454
Office – Small (<40,000 sq ft)	440	369	270
Office – Large (≥40,000 sq ft)	221	185	136
Other	146	122	90
Public Assembly[147]	1,114	933	684
Public Order and Safety (Police and Fire Station)[148]	146	122	90
Religious Worship	146	122	90
Service (Beauty, Auto Repair Workshop)	623	522	383
Warehouse and Storage	598	501	367

[144] "Other" building type is mapped to the building type with the most conservative full load heating hours in the Mid-Atlantic TRM 2018, p.528 "Manufacturing – Bio Tech/High Tech."

[145] "Warehouse and Storage" Baltimore, MD full load heating hours is an average of the hours for "Storage - Conditioned" (854 hours/year) and "Warehouse - Refrigerated" (342 hours/year) in the Mid-Atlantic TRM 2018, p.528

[146] Baltimore, MD full load cooling hours taken from Mid-Atlantic TRM 2018 p.529 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 (Weather station number 724010; HDD=3,849), Charlotte Douglas International Airport (Weather station number 723140; HDD=3,140), and Baltimore BLT – Washington International Airport (Weather station number 724060; HDD=4,600). See Sub-appendix F2-I: Cooling and Heating Degree Days and Hours for CDD and HDD.

[147] "Public Order and Safety (Police and Fire Station)" building type is mapped to the building type with the most conservative full load heating hours in the Mid-Atlantic TRM 2018, p.529 "Manufacturing – Bio Tech/High Tech."

[148] "Regligous Worship" building type is mapped to the building type with the most conservative full load heating hours in the Mid-Atlantic TRM 2018, p.529 "Manufacturing – Bio Tech/High Tech."

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10.2.3 Annual Cooling Hours for Chiller Systems

Table 10-6: Annual Chiller Full Load Cooling Hours at Non-Residential Buildings[149]

Building Type	Baltimore, MD	Richmond, VA	Elizabeth City, NC & Rocky Mount-Wilson, NC, averaged
Education – Elementary and Middle School	743	873	944
Education – High School	369	434	469
Education – College and University[150]	780	917	991
Food Sales - Grocery	928	1,091	1,179
Food Sales – Convenience Store	928	1,091	1,179
Food Sales – Gas Station Convenience Store	928	1,091	1,179
Food Service - Full Service	928	1,091	1,179
Food Service - Fast Food	928	1,091	1,179
Health Care-inpatient	1,570	1,845	1,994
Health Care-outpatient	601	706	763
Lodging – (Hotel, Motel and Dormitory)	1,801	2,116	2,287
Mercantile (mall)	928	1,091	1,179
Mercantile (Retail, not mall)	928	1,091	1,179
Office – Small (<40,000 sq.ft.)	559	657	710
Office – Large (≥ 40,000 sq.ft.)	603	709	766
Other	369	434	469
Public Assembly	369	434	469
Public Order and Safety (Police and Fire Station)	369	434	469
Religious Worship	369	434	469
Service (Beauty, Auto Repair Workshop)	928	1,091	1,179
Warehouse and Storage	810	952	1,029

149 Baltimore, MD full load cooling hours taken from Mid-Atlantic TRM 2018 p.437 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 July, 2018. See Sub-appendix F2-I: Cooling and Heating Degree Days and Hours for CDD and HDD.

150 “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 2018, p. 437.

10.2.4 Annual Hours for Variable Frequency Drives

Table 10-7: Variable Frequency Drive Annual Hours of Use by Facility Type[151]

Building Type	Fan Motor Hours	Chilled Water Pumps[152]	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	6,456	2,742	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	5,492
Mercantile (Mall)	4,833	2,157	5,376
Mercantile (Retail, not Mall)	4,057	1,878	2,344
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	1,955	1,121	5,376
Public Order and Safety (Police and Fire Station)	7,665	3,177	5,376
Religious Worship	1,955	1,121	5,376
Service (Beauty, Auto Repair Workshop)	3,750	1,768	5,376
Warehouse and Storage	2,602	1,354	5,376

10.2.5 Update Summary

The changes to this section, compared with last year, are described in Table 10-8.

Table 10-8: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	New Weather Stations	• Replaced the Charlotte, NC weather station with the average results from two weather stations located within the Company's service territory: Elizabeth City, NC and Rocky Mount-Wilson, NC.

[151] Mid-Atlantic TRM 2019, pp. 431-433. 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.
[152] For condenser water pumps, use the same operating hours as chilled water pumps

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Version	Type of Change	Description of Change
	Updated HOU	By-building hours of use values were updated and—in some cases, corrected—based upon revisions to HDD/CDD adjustments due to change of weather stations in NC.
	New Table	A table was added for the HOU values for VFDs.

10.3 Sub-appendix F2-III: Non-residential HVAC Equipment Efficiency Ratings

This sub-appendix contains the minimum efficiency metrics that are required by building codes for four categories of equipment:

- Unitary air conditioners and condensing units, in Table 10-9
- Unitary and applied heat pumps, in Table 10-10
- Variable Refrigerant Flow (VRF) air conditioners and heat pumps, in Table 10-11
- Water chilling packages (a.k.a. chillers), in Table 10-12

10.3.1 Cooling Efficiencies of Unitary Air Conditioners and Condensing Units

Table 10-9: Unitary Air Conditioners and Condensing Units - Minimum Efficiency[153]

Equipment Type	Size Category (Btu/h)	Heating System 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[154]
Through the wall (air cooled)	≤ 30,000 Btu/h	All	Split system/ Single package	12.0 SEER	10.5 EER[154]
Small-duct, high-velocity (air cooled)	< 65,000 Btu/h	All	Split system/ Single package	11.0 SEER	9.9 EER[154]
Air conditioners, air cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric resistance (or none)	Split system/ Single package	12.9 IEER	11.2 EER
		All other	Split system/ Single package	12.7 IEER	11.0 EER
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric resistance (or none)	Split system/ Single package	12.4 IEER	11.0 EER
		All other	Split system/ Single package	12.2 IEER	10.8 EER

[153] ASHRAE 90.1 2013, Table 6.8.1-1 - Electrically Operated Unitary Air Conditioners and Condensing Units - Minimum Efficiency Requirement.

[154] This value was not provided in ASHRAE 90.1 2013, Table 6.8.1-1, so Equation 3 in Sub-appendix F2-V: General Equations was used to convert SEER to EER.

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Equipment Type	Size Category (Btu/h)	Heating System Type	Subcategory	Minimum Annual Efficiency	Minimum Demand Efficiency
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric resistance (or none)	Split system/ Single package	11.6 IEER	10.0 EER
		All other	Split system/ Single package	11.4 IEER	9.8 EER
	≥ 760,000 Btu/h	Electric resistance (or none)	Split system/ Single package	11.2 IEER	9.7 EER
		All other	Split system/ Single package	11.0 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	13.9 IEER	12.1 EER
		All other	Split system/ Single package	13.7 IEER	11.9 EER
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric resistance (or none)	Split system/ Single package	13.9 IEER	12.5 EER
		All other	Split system/ Single package	13.7 IEER	12.3 EER
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric resistance (or none)	Split system/ Single package	13.6 IEER	12.4 EER
		All other	Split system/ Single package	13.4 IEER	12.2 EER
	≥ 760,000 Btu/h	Electric resistance (or none)	Split system/ Single package	13.5 IEER	12.2 EER
		All other	Split system/ Single package	13.3 IEER	12.0 EER
Air conditioners, evaporatively cooled[155]	< 65,000 Btu/h	All	Split system/ Single package	12.3 IEER	12.1 EER
	≥ 65,000 Btu/h and < 135,000 Btu/h	All other	Split system/ Single package	12.3 IEER	12.1 EER
		Electric resistance (or none)	Split system/ Single package	12.1 IEER	11.9 EER
	≥ 135,000 Btu/h and < 240,000 Btu/h	All other	Split system/ Single package	12.2 IEER	12.0 EER
		Electric resistance (or none)	Split system/ Single package	12.0 IEER	11.8 EER

[155] These systems types were added in ASHRAE 90.1-2013. Therefore, these systems are not retroactively used for the Non-residential Heating and Cooling Efficiency Program offered under the DSM Phase III program, due to data requirement constraints. However, these systems will be included in the DNV analysis for the Non-residneital Heating and Cooling Efficiency Program offered under the DSM Phase VII program.

Equipment Type	Size Category (Btu/h)	Heating System Type	Subcategory	Minimum Annual Efficiency	Minimum Demand Efficiency
	≥ 240,000 Btu/h and < 760,000 Btu/h	All other	Split system/ Single package	12.1 IEER	11.9 EER
		Electric resistance (or none)	Split system/ Single package	11.9 IEER	11.7 EER
	≥ 760,000 Btu/h	All other	Split system/ Single package	11.9 IEER	11.7 EER
		Electric resistance (or none)	Split system/ Single package	11.7 IEER	11.5 EER
Condensing units, air cooled[155]	≥ 135,000 Btu/h	-	-	11.8 IEER	10.5 EER
Condensing units, water cooled[155]	≥ 135,000 Btu/h	-	-	14.0 IEER	13.5 EER
Condensing units, evaporatively cooled[155]	≥ 135,000 Btu/h	-	-	14.0 IEER	13.5 EER

10.3.2 Heating Efficiencies of Unitary and Applied Heat Pumps

Table 10-10: Unitary and Applied Heat Pumps - Minimum Efficiency[156]

Equipment Type	Cooling Capacity/ Size Category	Heating System Type	Subcategory or Rating Conditions	Minimum Annual Efficiency	Minimum Demand Efficiency
Air Cooled (cooling mode)	< 65,000 Btu/h	All	Split System/ Single package	14.0 SEER	11.8 EER[157]
Through-the-wall (air-cooled cooling mode)	≤ 30,000 Btu/h	All	Split System/ Single package	12.0 SEER	10.5 EER[157]
Single-duct	< 65,000 Btu/h	All	Split System/ Single package	11.0 SEER	9.9 EER[157]
Air Cooled (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric resistance (or none)	Split system/ Single package	12.2 IEER	11.0 EER
		All other	Split system/ Single package	12.0 IEER	10.8 EER
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric resistance (or none)	Split system/ Single package	11.6 IEER	10.6 EER
		All other	Split system/ Single package	11.4 IEER	10.4 EER

[156] ASHRAE 90.1 2013, Table 6.8.1-2 - Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirement.

[157] This value was not provided in ASHRAE 90.1 2013, Table 6.8.1-2, so Equation 3 in Sub-appendix F2-V: General Equationswas used to convert between SEER and EER.

Equipment Type	Cooling Capacity/ Size Category	Heating System Type	Subcategory or Rating Conditions	Minimum Annual Efficiency	Minimum Demand Efficiency
	≥ 240,000 Btu/h	Electric resistance (or none)	Split system/ Single package	10.6 IEER	9.5 EER
		All other	Split system/ Single package	10.4 IEER	9.3 EER
Water source[158] (Cooling mode)	< 17,000 Btu/h	All	86°F entering water	Retrofits: 14.0 SEER[158]	Retrofits: 11.7 EER[157]
				RCx:[159] 13.1 IEER	RCx: 11.2 EER
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	Retrofits: 14.0 SEER[158]	Retrofits: 11.7 EER[157]
				RCx: 14.5 IEER	RCx: 12.0 EER
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	Retrofits: 12.2 IEER[158]	Retrofits: 10.9 EER[160]
				RCx: 13.4 IEER	RCx: 12.0 EER
Ground source[158] (cooling mode)	< 65,000 Btu/h	All	77°F entering water	Retrofits: 14.0 SEER[158]	Retrofits: 11.7 EER[157]
				RCx: 17.4 SEER	RCx: 13.4 EER
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	77°F entering water	Retrofits: 12.2 IEER[158]	Retrofits: 10.9 EER[160]
				RCx: 14.9 IEER	RCx: 13.4 EER
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
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

158 Although ASHRAE values reflect the Building Code minimum, savings are calculated using the efficiencies shown. This is due to the Mid-Atlantic TRM 2019 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 2019.)

159 Two types of measures are categorized as retro-commissioning (RCx): Duct Testing & Sealing and AC/HP/Chiller Tune-ups.

160 This value was not provided in ASHRAE 90.1 2013, Table 6.8.1-2, so Equation 4 in Sub-appendix F2-V: General Equations was used to convert between IEER and EER.

Equipment Type	Cooling Capacity/ Size Category	Heating System Type	Subcategory or Rating Conditions	Minimum Annual Efficiency	Minimum Demand Efficiency
Water source (heating mode)	< 135,000 Btu/h (cooling capacity)	-	68°F entering water	4.3 COP	N/A
Ground source (heating mode)	All Sizes[161] (cooling capacity)	-	32°F entering water	3.2 COP	N/A

[161] ASHRAE 90.1-2013 values only apply to equipment <135,Btu/h. However this value is used across all sizes as there is limited guidance for systems 135 Btu/hr and larger.

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10.3.3 Cooling Efficiencies of Variable Refrigerant Flow Air Conditioners and Heat Pumps

Table 10-11: Variable Refrigerant Flow Air Conditioners and Heat Pumps - Minimum Efficiency[162]

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[163]	N/A
	≥ 65,000 Btu/h and < 135,000 Btu/h	All[164]	VRF Multi-Split system	13.1 IEER	11.2 EER[163]	N/A
	≥ 135,000 Btu/h and < 240,000 Btu/h	All[164]	VRF Multi-Split system	12.9 IEER	11.0 EER[163]	N/A
	≥ 240,000 Btu/h	All[164]	VRF Multi-Split system	11.6 IEER	10.0 EER[163]	N/A
VRF Heat Pumps, Air Cooled	< 65,000 Btu/h	All	VRF Multi-Split system	13.0 SEER	11.1 EER[163]	7.7 HSPF
	≥ 65,000 Btu/h and < 135,000 Btu/h	All[164]	VRF Multi-Split system	12.9 IEER	11.0 EER[163]	3.3 COP
	≥ 135,000 Btu/h and < 240,000 Btu/h	All[164]	VRF Multi-Split system	12.3 IEER	10.6 EER[163]	3.2 COP
	≥ 240,000 Btu/h	All[164]	VRF Multi-Split system	11.0 IEER	9.5 EER[163]	3.2 COP

162 ASHRAE 90.1 2013, Tables 6.8.1-9 - Electrically Operated Variable Refrigerant Flow Air Conditioners- Minimum Efficiency Requirement and 6.8.1J - Electrically Operated Variable Refrigerant Flow Heat Pumps - Minimum Efficiency Requirement.

163 This value was not provided in ASHRAE 90.1 2013, Table 6.8.1-9, so Equation 3 in Sub-appendix F2-V: General Equations was used to convert between SEER and EER.

164 ASHRAE 90.1 2013, only provides Electtric resistance or none for Heating Section Type. We will use this value for all Heating Section Types to allow of other other heating section types.

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10.3.4 Cooling Efficiencies of Water Chilling Packages

Table 10-12: Water Chilling Packages–Minimum Efficiency[165]

Equipment Type	Size Category	Units	Path A		Path B	
			Full Load	IPLV	Full Load	IPLV
Air Cooled Chillers	< 150 tons	EER	≥ 10.100	≥ 13.700	≥ 9.700	≥ 15.800
	≥ 150 tons	EER	≥ 10.100	≥ 14.000	≥ 9.700	≥ 16.100
Water-cooled, electrically operated, positive displacement	< 75 tons	kW/ton	≤ 0.750	≤ 0.600	≤ 0.780	≤ 0.500
	≥ 75 tons and < 150 tons	kW/ton	≤ 0.720	≤ 0.560	≤ 0.750	≤ 0.490
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.660	≤ 0.540	≤ 0.680	≤ 0.440
	≥ 300 tons and < 600 tons	kW/ton	≤ 0.610	≤ 0.520	≤ 0.625	≤ 0.410
	≥ 600 tons	kW/ton	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380
Water-cooled, electrically operated, centrifugal	<150 tons	kW/ton	≥ 0.610	≤ 0.550	≤ 0.695	≤ 0.440
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.610	≤ 0.550	≤ 0.635	≤ 0.440
	≥ 300 tons and < 400 tons	kW/ton	≤ 0.560	≤ 0.520	≤ 0.595	≤ 0.390
	≥ 400 tons and < 600 tons	kW/ton	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380
	≥ 600 tons	kW/ton	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380
Water-cooled, unknown	< 75 tons	kW/ton	≤ 0.750	≤ 0.600	≤ 0.780	≤ 0.500
	≥ 75 tons and < 150 tons	kW/ton	≤ 0.720	≤ 0.560	≤ 0.750	≤ 0.490
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.660	≤ 0.540	≤ 0.680	≤ 0.440
	≥ 300 tons and < 600 tons	kW/ton	≤ 0.610	≤ 0.520	≤ 0.625	≤ 0.410
	≥ 600 tons	kW/ton	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380

10.3.5 Update Summary

The changes to this section, compared with last year, are described in Table 10-13.

Table 10-13: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	Standards Application	• Revised the VRF heating section type categories to accommodate more than just the electric resistance

[165] ASHRAE 90.1-2013, Table 6.8.1-3 - Water Chilling Packages - Efficiency Requirements. Consistent with International Energy Conservation Code 2015, Table C403.2.3(7) Water Chilling Packages, Efficiency Requirements, used in the 2019 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.

Version	Type of Change	Description of Change
v10	Standards Update	• Both VA and NC building codes were updated from ASHRAE 2010 to ASHRAE 2013 in 2019. This resulted in widespread increases to the minimum efficiency requirements of many equipment types.

10.4 Sub-appendix F2-IV: Non-residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors

For the purposes of this STEP Manual, Table 10-15 provides the annual lighting (interior CFL and non-CFL) hours of use, summer seasonal peak coincidence factors, and waste heat factors by building types for interior lighting fixtures that are designated for the Dominion territory. All of these are gathered from the Mid-Atlantic TRM, which pulls from a combinations of the Connecticut Program Savings Document (PSD) and the EmPOWER Maryland 2014 Evaluation Report. Table 10-14 provides the same variables for exterior lights and LED exit signs.

Since the building types in the Mid-Atlantic TRM do not map directly to those used in this STEP Manual, a separate mapping was conducted to arrive at the values. Under each STEP Manual building type in Table 10-15 are listings of the Mid-Atlantic TRM building types that were mapped to this document.

For all non-residential lighting measures, DNV assigns these variables based on the measure characteristics in this descending order:

1. Measure location (interior or exterior)
2. Fixture name
3. Building type

For example, when calculating savings for a specific non-residential lighting type (fixtures), variables (hours of use, coincidence factor, waste heat factors) are assigned based on if the fixture indicates it is for “exterior” use. All fixtures that contain the word “exterior” in the fixture name, from the tracking data provided to DNV, should assign parameters based on the lighting type in Table 10-14.

All fixtures that contain the phrase “24/7” in the fixture name, from the tracking data provided to DNV, shall be assigned variables appropriate for “LED Exit Sign”. All fixtures that do not specify “exterior” in the fixture name are assumed to be for interior use and should be assigned variables based on the building type as shown in Table 10-15.

Summary of terms used in this section:

- CF_{PJM} – PJM summer peak coincidence factor is from June to August, weekdays between 2 p.m. and 6 p.m. EDT.
- CF_{SSP} – Summer system peak coincidence factor refers to the hour ending 5 p.m. EDT on the hottest summer weekday.
- Interior CFL lighting refers to general-purpose CFL screw-based bulbs
- Interior Non-CFL lighting type includes:
    - T5 Lighting
    - Pulse-Start Metal Halide fixture – interior
    - Solid State Lighting (LED) Recessed Downlight Luminaire

- Delamping
- Occupancy Sensor - wall box

Table 10-14: Non-residential Lighting Parameters by Exterior Lighting Type

Lighting Type	Exterior Lighting Annual Hours (hour/year)	CF_{SSP}	Demand Waste Heat Factor and Annual Energy Waste Heat Factor[166]	Source
Pulse Start Metal Halide - exterior	3,338	0.0	1.0	Mid-Atlantic TRM 2019, p. 391
High Pressure Sodium	3,338	0.0	1.0	Mid-Atlantic TRM 2019, p. 391
LED Exit Sign and "24/7" lights[167]	8,760	1.0	1.0	Mid-Atlantic TRM 2019, p. 312; DNV judgement
LED Parking Garage	Canopy: 3,338 Parking garage: 8,760	Canopy: 0.0 Parking garage: 1.0	1.0	Mid-Atlantic TRM 2019, p. 391 and DNV engineering judgment
Outdoor LED and Roadway Lighting	3,338	0.0	1.0	Mid-Atlantic TRM 2019, p. 391

The hours and coincident factors (CF) shown in Table 10-15 apply only to the Non-Residential Lighting Systems and Controls Programs (DSM Phases III and VII) and Non-Residential Cooling and Heating Programs (DSM Phases III and VII).

Table 10-15: Non-Residential Lighting Parameters for Interior by Facility Type

Building Types	Interior Lighting Annual Hours (hours)[168]	CF_{SSP}[169]	Demand Waste Heat Factor[170]	Annual Energy Waste Heat Factor[171]
Education – College and University	2,233	0.36	1.44	0.96
Education – High School	2,233	0.36	1.44	0.96
Education – Elementary and Middle School	2,233	0.36	1.44	0.96

166 "If cooling and heating equipment types are unknown or the space is unconditioned, assume WHFd = WHFe = 1.0." Mid-Atlantic TRM 2019, p. 527.

167 DNV judgement that if non-residential lighting measure name contains "24/7" in the tracking data provided to DNV, treat it the same as "LED Exit Sign" when calculating savings.

168 Mid-Atlantic TRM 2019, p. 586 Table D-3: C&I Interior Midstream Lighting Parameters by Building Type. Midstream lighting tables are referenced because downstream table parameters require knowledge of the location of the product installation—information that is unavailable for midstream programs.

169 Ibid.

170 Mid-Atlantic TRM 2019, pp. 587-588. Selected waste heat factors from "Washington, D.C. All utilities", AC (utility) WHF_d and heat pump WHF_e. Waste heat factors were provided for only five building types (1. Office, 2. Retail, 3. School, 4. Warehouse, 5. Other), therefore they were mapped to the full list of building types as appropriate. Original source of waste heat factor values are from the "EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014. Values for Washington D.C. and Delaware assume values from Maryland, Pepco and Maryland, DPL, respectively."

171 Ibid.

Building Types	Interior Lighting Annual Hours (hours)[168]	CF_{SSP}[169]	Demand Waste Heat Factor[170]	Annual Energy Waste Heat Factor[171]
Food Sales – Convenience Store	7,272	0.97	1.35	0.93
Food Sales – Gas Station Convenience Store	7,272	0.97	1.35	0.93
Food Sales – Grocery	7,272	0.97	1.35	0.93
Food Service - Fast Food	4,696	0.83	1.27	0.95
Food Service - Full Service	4,696	0.83	1.27	0.95
Health Care – inpatient	3,817	0.68	1.35	0.93
Health Care – outpatient	3,817	0.68	1.35	0.93
Lodging – (Hotel, Motel and Dormitory)	4,058	0.61	1.35	0.93
Mercantile (Retail, Not Mall)	4,696	0.83	1.27	0.95
Mercantile (Mall)	4,696	0.83	1.27	0.95
Office – Small (<40,000 sq ft)	3,044	0.69	1.36	0.94
Office – Large (>= 40,000 sq ft)	3,044	0.69	1.36	0.94
Other	4,058	0.61	1.35	0.93
Public Assembly	4,058	0.61	1.35	0.93
Public Order and Safety (Police and Fire Station)	4,058	0.61	1.35	0.93
Religious Worship	4,058	0.61	1.35	0.93
Service (Beauty, Auto Repair Workshop)	4,696	0.83	1.27	0.95
Warehouse and Storage	4,361	0.80	1.23	0.89

10.4.1.1 Update Summary

The changes to this section, compared with last year, are described in Table 10-16.

Table 10-16: Summary of Update(s) from Previous Version

Version	Type of Change	Description of Change
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM

10.5 Sub-appendix F2-V: General Equations

This section appears in Appendix F1 as Sub-appendix F1-V: General Equations (a.k.a. Section 10.5).

Equation 1: Cooling Capacities – Btu/h to tons

This equation appears in Appendix F1 as Sub-appendix F1-V: General Equations (a.k.a. Section 10.5).

Equation 2: Cooling Capacities – tons to Btu/h

This equation appears in Appendix F1 as Sub-appendix F1-V: General Equations (a.k.a. Section 10.5).

Equation 3: Energy Efficiencies - SEER to EER, for systems < 65,000 Btu/h

This equation appears in Appendix F1 as Sub-appendix F1-V: General Equations (a.k.a. Section 10.5).

Equation 4: Energy Efficiencies - EER to IEER, for systems ≥ 65,000 Btu/h

This equation appears in Appendix F1 as Sub-appendix F1-V: General Equations (a.k.a. Section 10.5).

Equation 5: Energy Efficiencies - HSPF to COP

This equation appears in Appendix F1 as Sub-appendix F1-V: General Equations (a.k.a. Section 10.5).

Equation 6: Energy Efficiencies - COP to HSPF

This equation appears in Appendix F1 as Sub-appendix F1-V: General Equations (a.k.a. Section 10.5).

Equation 7: Energy Efficiencies - COP to EER

This equation appears in Appendix F1 as Sub-appendix F1-V: General Equations (a.k.a. Section 10.5).

Equation 8: Energy Efficiencies – $kW/ton_{full\text{-}load}$ to kW/ton_{IPLV}

This equation appears in Appendix F1 as Sub-appendix F1-V: General Equations (a.k.a. Section 10.5).

Equation 9: Energy Efficiencies – EERfull-load to EERIPLV

This equation appears in Appendix F1 as Sub-appendix F1-V: General Equations (a.k.a. Section 10.5).

Equation 10: Heat to electric energy – Btu/h to kW

This equation appears in Appendix F1 as Sub-appendix F1-V: General Equations (a.k.a. Section 10.5).

About DNV

Driven by our purpose of safeguarding life, property, and the environment, DNV enables organizations to advance the safety and sustainability of their business. We provide classification, technical assurance, software, and independent expert advisory services to the maritime, oil & gas, and energy industries. We also provide certification services to customers across a wide range of industries. Combining leading technical and operational expertise, risk methodology and in-depth industry knowledge, we empower our customers' decisions and actions with trust and confidence. We continuously invest in research and collaborative innovation to provide our customers and society with operational and technological foresight. Operating in more than 100 countries, we are dedicated to helping our customers make the world safer, smarter, and greener.

APPENDIX G. APPROACHES FOR MEETING VIRGINIA CLEAN ECONOMY ACT EM&V REQUIREMENTS

Dominion Energy North Carolina
Docket No. E-22, Sub 589

Appendix G
Approaches for Meeting Virginia Clean Economy Act EM&V Requirements

Dominion Energy

Date: May 14, 2021

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1 EXECUTIVE SUMMARY

Dominion Energy is required to utilize the services of a third party to perform evaluation, measurement, and verification services to review the utility's total customer bill savings that the programs and portfolios produce per the Virginia Clean Economy Act Code Section 56-596.2 C. This report details the process that DNV used to review Dominion Energy's total bill savings, non-energy impacts, avoided emissions, and avoided costs for their energy efficiency programs that were active in Virginia in 2020.

For total bill savings, DNV calculates the annual bill impacts by program and rate schedule for the programs that were active in Virginia in 2020. DNV used an algorithm that incorporated the participant population from program tracking data, pre-participation billing data, and the unitized rate class hourly load shapes from the Dominion Energy Load Research team matched with each of the participant customers based on rate schedule. The estimated post-participation load shape was calculated as the pre-participation load minus the savings for each hour with a savings shape and a pre-participation load shape for each customer. The difference between the pre-participation and post-participation billing parameters was the difference due to the program, and the bill impact is the rate components applied to those differences, across all billing parameters, with and without the program. The total bill savings was calculated at roughly $17 million per year resulting from the Company's programs in Virginia that were active in 2020.

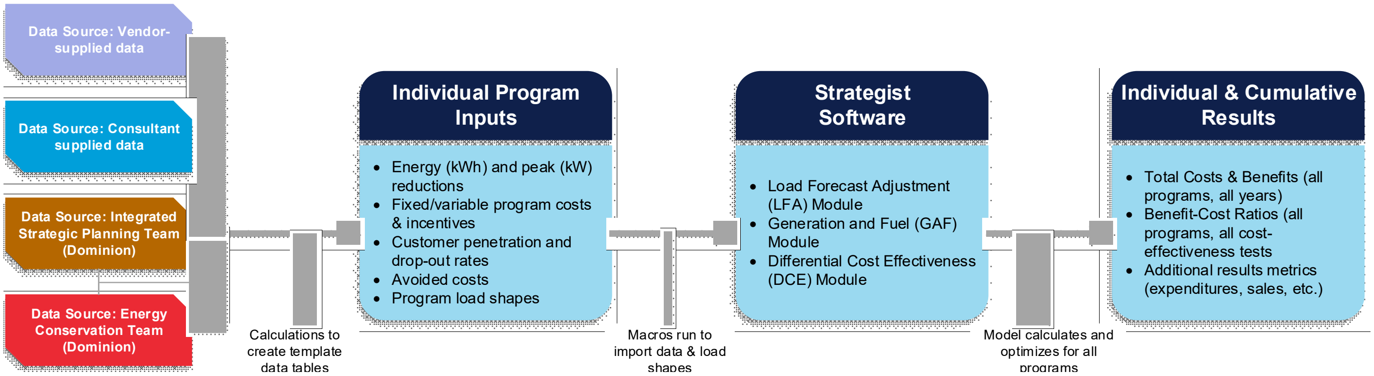
For non-energy impacts (NEIs), DNV calculates annual operations and maintenance (O&M) related non-energy impacts utilizing an engineering cost-estimating approach and DNV's proprietary 'Life Cycle Cost' tool. It relies upon an engineering lifecycle cost-based approach to inventory O&M cost data and to estimate the cost change impacts of Dominion Energy's select energy-efficiency measures and projects in Virginia for programs that were active in 2020. The total annualized net present value of the life cycle NEIs for upgraded lighting, HVAC, and drive/motor, from the programs that were available in Virginia in 2020, totaled an estimated $4.6 million per year.

For avoided emissions, DNV calculated impacts by applying the hourly emissions rates to the hourly demand side management (DSM) savings for each EE program that was active in Virginia in 2020, splitting the overall Dominion Energy emissions savings by state based on each state's annual 2020 usage savings percentage. The parameters included the 2020 emissions levels from the WattTime.org, using the PJM South historical emissions data, and the hourly 2020 DSM cumulative energy savings from load shapes already developed by program to determine the hourly DSM kWh energy savings to produce the emissions impacts, in 1000 lbs. of CO_2 units.

Overall, emissions impacts (in metric tons CO_2 Avoided) were a total of 185,551 metric tonsfrom the Virginia programs that were active in 2020 (inclusive of those participants from the program start through 2020). They contributed 96% of all Dominion Energy emissions impacts from the savings that persist in 2020. Impacts were distributed fairly evenly across the year, reflecting the combination of lighting (evenly distributed), some heating-oriented (winter seasonal, such as the Residential Income and Age Qualifying Home Improvement Program) and some cooling-oriented (summer-seasonal, such as from the Non-residential Prescriptive Program).

For the benefit-cost analyses, DNV reviewed the Strategist resource planning software system that models and calculates cost-effectiveness tests for Dominion Energy demand side management programs, per Figure 1-1.

Figure 1-1. Strategist Resource Planning Software System



For the avoided cost, DNV reviewed Dominion Energy's two main avoided costs that are the inputs for Strategist analyses. These costs include avoided transmission ($/kW) and avoided distribution ($/kW) that are summed to calculate the total transmission and distribution (T&D) demand credit (benefit), for each year in each program.

DNV's analyses showed that Dominion Energy's approach to benefit-cost testing and avoided costs follows standard practice. The Strategist model is a well-vetted and comprehensive tool that is appropriate for this use. Inputs to the modeling process are well-documented and appear appropriate to the programs.

These activities are meant to fulfill the requirements from the Virginia Clean Economy Act, Code Section 56-596.2 C, which states:

> "B. Utilities shall utilize the services of a third party to perform evaluation, measurement, and verification services to determine a utility's total annual savings as required by this subsection, as well as the annual and lifecycle net and gross energy and capacity savings, related emissions reductions, and other quantifiable benefits of each program; total customer bill savings that the programs and portfolios produce; and utility spending on each program, including any associated administrative costs. The third-party evaluator shall include and review each utility's avoided costs and cost-benefit analyses. The findings and reports of such third parties shall be concurrently provided to both the Commission and the utility, and the Commission shall make each such final annual report easily and publicly accessible online. Such stakeholder process shall include the participation of representatives from each utility, relevant directors, deputy directors, and staff members of the State Corporation Commission who participate in approval and oversight of utility efficiency programs, the office of Consumer Counsel of the Attorney General, the Department of Mines, Minerals and Energy, energy efficiency program implementers, energy efficiency providers, residential and small business customers, and any other interested stakeholder who the independent monitor deems appropriate for inclusion in such process. The independent monitor shall convene meetings of the participants in the stakeholder process not less frequently than twice in each calendar year during the period beginning July 1, 2019, and ending July 1, 2028. The independent monitor shall report on the status of the energy efficiency stakeholder process, including(i) (a) the objectives established by the stakeholder group during this process related to programs to be proposed, (ii) (b) recommendations related to programs to be proposed that result from the stakeholder process, and (iii) (c) the status of those recommendations, in addition to the petitions filed and the determination thereon, to the Governor, the State Corporation Commission, and the Chairmen of the House Committee on Labor and Commerce and Senate Committee on Commerce and Labor Committees on July 1, 2019, and annually thereafter through July 1, 2028."

2 LIST OF ACRONYMS

Dominion Energy Program Names:

CLT2 (Phase III) - Non-Residential Lighting Systems & Controls (not active in 2020)

EAL3 (Phase IV) – Residential Income and Age Qualifying

SBIP (Phase V) - Non-Residential Small Business Improvement

CNRP (Phase VI) – Non-residential Prescriptive

RAR2 (Phase VII) - Residential Appliance Recycling

REEC (Phase VII) - Residential Efficient Products Marketplace

RTHO (Phase VII) - Residential Home Energy Assessment

CHV3 (Phase VII) - Non-Residential Heating and Cooling Efficiency

CLT3 (Phase VII) - Non-Residential Lighting System & Controls

CSW2 (Phase VII) - Non-Residential Solar Window Film

CTSO (Phase VII) - Non-Residential Office

3 BILL SAVINGS

3.1 Introduction

Dominion Energy is required to utilize the services of a third party to perform evaluation, measurement, and verification services to review the utility's total customer bill savings that the programs and portfolios produce per the Virginia Clean Economy Act Code Section 56-596.2 C. The following sections highlight the process that DNV used to review Dominion Energy's total bill savings for their energy efficiency programs.

To meet the requirements described above related to customer bill savings (also referred to as bill impacts) resulting from Dominion Energy's programs, DNV used data from several sources to estimate each participating customer's pre-participation energy use and load shape, then applied the estimated energy savings from the Dominion Energy Business Intelligence tracking data (i.e., program tracking data) along with the savings load shape to estimate the post-participation energy use and load shapes. The difference between the pre-participation and post-participation billing parameters was calculated. Then rates and riders were applied to the differences in billing parameters and the results were reported as the bill impacts. This analysis was performed and reported by rate schedule and program, then aggregated across the rate schedules and programs to get the estimated total bill impacts for all program participants.

3.2 Methodology

DNV calculates the bill impacts by program and rate schedule per the algorithm as follows, and illustrated in Figure 3-1:

1. The participant population is defined by rate schedule and program using the program tracking data. This represents the total population of participating customers and is the starting point for the analysis. This database includes the account number, the premise ID, the rate schedule the customer is served under, the program in which the customer was a participant, and the estimated kWh/year savings that the customer achieved through participation in the program.
2. This participant population data is matched with the pre-participation billing data provided by Dominion Energy, using premise ID to match the physical location of each customer to maximize the number of customers with billing data.
3. Rate class hourly load shapes from the Dominion Energy Load Research team are unitized and then matched with each of the participant customers based on rate schedule. Since most of the participating customers do not have interval data available, we must use the average load shape for the rate class as their assumed load shape. This is done by distributing each customer's annual billing energy across the year based on the rate class unitized load shape.
4. The unitized measure-specific hourly savings shapes are calibrated to the savings for each measure installed for each customer. These calibrated hourly savings shapes are totalled for each customer, and that savings shape is then used to distribute the savings across the hours of the year.
5. With a savings shape and a pre-participation load shape for each customer, an estimated post-participation load shape can be calculated as the pre-participation load minus the savings for each hour. Using these load shapes, both the pre-participation and the post-participation billing parameters for each month can be calculated, based on the requirements of the rate schedule for which the customer is enrolled. The difference between the pre-participation and post-participation billing parameters is the difference due to the program, and the bill impact is the rate components applied to the difference in the calculated bills, across all billing parameters, with and without the program. The rates involve many different types of charges, but the billing parameters needed include:

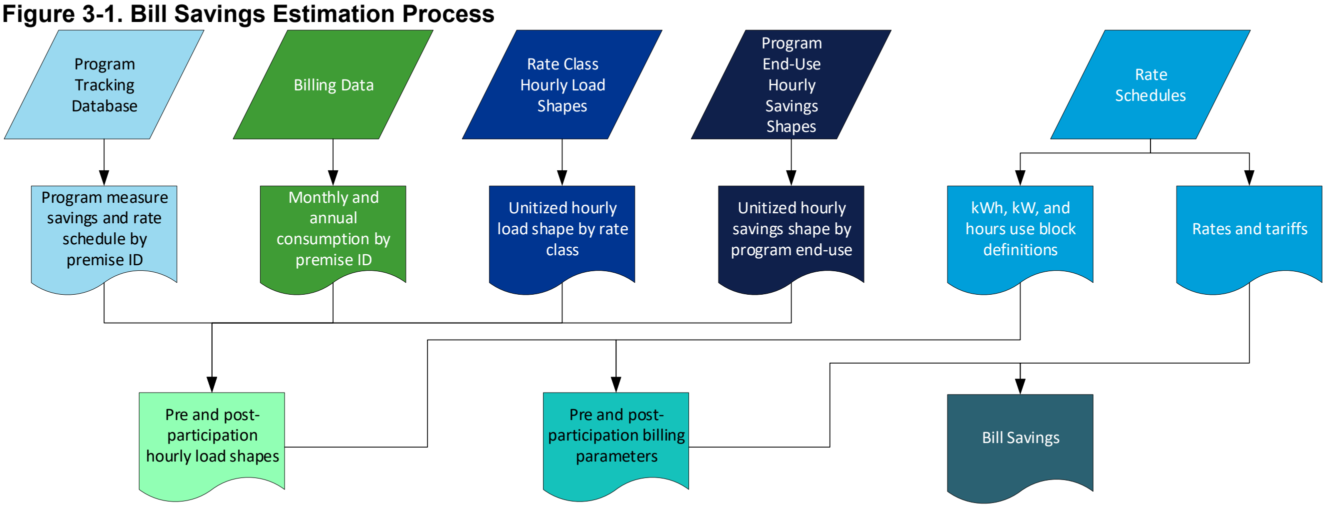
   a. Monthly kWh energy and peak kW demand, for all hours and for time-of-use (TOU) periods (e.g., on-peak, intermediate, and off-peak). Seasonal differences in rates are applied to the individual months based on seasonal definitions.

b. Monthly kWh consumption for each block, with the blocks defined in the rate schedule (e.g., Schedule 1), or defined based on hours use applied to peak kW (i.e., using kWh per kW to define the blocks). Seasonal differences in rates are applied based on seasonal definitions.
c. Monthly kW demand for each block for rate schedules with kW blocks (e.g., Schedule 6).
d. On-peak and off-peak kWh consumption based on the different day classifications (i.e., Day type A, B, or C) and seasons for experimental rate schedules (e.g., Schedule 10).
e. All fixed monthly charges are ignored since they will be assessed the same way before and after participation, so will not affect the calculation of bill impacts.

6. After the changes in all appropriate billing parameters are calculated, those billing parameters are summed across customers by program and rate schedule, and then rates and riders from the tariffs are applied to the totals of the billing parameters to get the bill impact by rate schedule and program.
7. Not all participants could be matched with billing data. The bill impacts for those that were not matched were estimated in one of two ways:

   a. For customers in the Residential Efficient Products Marketplace lighting program, the measures were not associated with individual customers since this is an upstream program. For this program only, the participants were all assumed to be on Schedule 1 (i.e., residential). Because Schedule 1 has a kWh block rate, the savings kWh was split between the two blocks based on the proportion of residential customers with billing data available that had consumption in the upper block versus only in the lower block. The two kWh block rates were applied to the estimated energy savings by block, and then summed to get the total bill impacts.
   b. For all other program and rate schedule combinations, an average bill impact per kWh of savings was calculated for those that did have billing data, and that was multiplied by the reported savings for those customers on that program and rate schedule that did not have billing data to get an estimated bill impact. The total bill impact for each program and rate schedule combination was then the sum of the bill impacts for those with and without billing data.

Figure 3-1. Bill Savings Estimation Process



Many assumptions had to be made to allow the estimation of load shapes, the calculation of billing parameters, and the application of rates and riders to those billing parameters. The following assumptions were made:

- The impacts are "first-year impacts" – they correspond to the first year of customer savings after measures have been installed, regardless of what the actual date of installation is. The savings estimates are based on a calendar year, using the calendar for 2020.
- The impacts are based on deemed savings, which represent weather normalized savings, not savings for a particular year with actual weather.
- The impacts use the modeled measure savings shapes created by DNV, which are intended to be based on normal weather.
- Because individual customer load shapes are not available, we used 2019 rate class average load shapes from the Company's Load research to estimate before-savings customer load shapes for calculating customer demands and TOU billing parameters. The 2019 load shapes were adjusted to reflect the 2020 calendar. These load shapes were then unitized and applied to each customer's annual consumption to provide an estimated customer load shape.
- Individual customer annual energy is allocated across months based on monthly customer billing data for calculating block energy rates.
- Customer billing energy is for the prior year, before the program year (i.e., 2019 billing consumption for 2020 participants), so appropriately reflects pre-participation consumption
- For the TOU rate, the calendar of day categories (e.g., A, B, and C) are from 2020, so that it matches the calendar for the adjusted load shapes.
- We made the simplifying assumption that each program's bill impact is the only impact for that customer and did not combine all savings for all programs for each customer. This only affects the bill impacts related to block rates for customers participating in multiple programs. This also allows the reporting of information by rate schedule and program.
- No participants are receiving power from an alternate supplier.
- All billing periods are assumed to match calendar months since billing cycle data is unavailable.
- Not all rate schedules were included in the analysis – those with very few customers were not calculated

Additional rate schedule-specific assumptions had to be made to allow the calculation of the impacts for certain rate schedules. These rate schedule-specific assumptions include:

- For Residential, Schedule 1, we assume that participants are not net-metered.
- For Schedule GS-3, no customers are Non-exempt (though there is no actual charge difference, as this rate is $0.000).
- For Schedule GS-3 and Schedule GS-4, rkVA did not change as a result of the program.
- For Schedule 10, we assumed the contract demand was the same as the measured demand.
- For Schedule GS-4, all participants are assumed to be receiving service at Primary voltage.
- For Schedule 5, the kWh blocks were based on the levels in the tariff, and not reset based on the customers' kW demands.

3.3 Results

The bill savings due to the program was calculated as the rate components for each rate applied to the difference between the pre-participation and post-participation billing parameters across all billing parameters, with and without the program. The total bill savings were calculated at $17,231,877.

DNV

Table 3-1: Bill Savings by Program and Rate Schedule

Program	Rate Schedule	Billing Data ($)	No Billing Data ($)	Total ($)
Non-residential Heating and Cooling Efficiency – DSM Phase VII	Schedule 5C	$2,753	$-	$2,753
	Schedule GS-1	$203	$8,993	$9,195
	Schedule GS-2 ND	$230,068	$-	$230,068
	Schedule GS-2T	$19,742	$-	$19,742
Non-residential Lighting Systems and Controls – DSM Phase VII	Schedule 5	$7,358	$-	$7,358
	Schedule 5C	$36,890	$-	$36,890
	Schedule 5P	$26,109	$-	$26,109
	Schedule GS-1	$373,516	$12,084	$385,600
	Schedule GS-2 ND	$1,733,321	$41,710	$1,775,031
	Schedule GS-2T	$649,527	$9,769	$659,296
	Schedule GS-3	$-	$3,910	$3,910
Non-residential Prescriptive – DSM Phase VI	Schedule 10 (Secondary)	$15,000	$-	$15,000
	Schedule 5	$333	$-	$333
	Schedule 5C	$651	$-	$651
	Schedule GS-1	$39,430	$6,084	$45,515
	Schedule GS-2 ND	$2,246,926	$2,349	$2,249,276
	Schedule GS-2T	$857,563	$5,831	$863,394
	Schedule GS-3	$341,022	$-	$341,022
	Schedule GS-4	$190,198	$-	$190,198
Non-residential Solar Window Film – DSM Phase VII	Schedule GS-1	$675	$51	$725
	Schedule GS-2 ND	$30,506	$-	$30,506
Non-residential Office – DSM Phase VII	Schedule GS-2 ND	$2,800	$-	$2,800
	Schedule GS-2T	$2,467	$-	$2,467
Residential Income and Age Qualifying Home Improvement – DSM Phase IV	Schedule 1	$23,264	$33	$23,297
Residential Appliance Recycling – DSM Phase VII	Schedule 1	$93,713	$-	$93,713
Residential Efficient Products Marketplace – DSM Phase VII	Schedule 1	$288,824	$16,160	$304,984
	Schedule 1 (Lighting)	$-	$8,534,791	$8,534,791

Program	Rate Schedule	Billing Data ($)	No Billing Data ($)	Total ($)
Residential Home Energy Assessment – DSM Phase VII	Schedule 1	$524,618	$1,083	$525,701
Non-residential Small Business Improvement – DSM Phase V	Schedule 5	$8,615	$-	$8,615
	Schedule 5C	$190,482	$1,804	$192,286
	Schedule 5P	$42,322	$-	$42,322
	Schedule GS-1	$262,763	$204	$262,967
	Schedule GS-2 ND	$333,825	$250	$334,075
	Schedule GS-2T	$11,288	$-	$11,288
Total		**$8,586,772**	**$8,645,105**	**$17,231,877**

4 NON-ENERGY IMPACTS

4.1 Introduction

Dominion Energy is required to utilize the services of a third party to perform evaluation, measurement, and verification services to review the other quantifiable benefits of the program (i.e., non-energy impacts) per the Virginia Clean Economy Act Code Section 56-596.2 C. The following sections highlight the process that DNV used to review Dominion Energy's NEIs for their energy efficiency programs.

As this was the first year for DNV to conduct this analysis for the portfolio, we started by targeting three end-use categories: lighting upgrades, HVAC upgrades, and variable-frequency/variable-speed drives (VFD/VSD) at motors. The targeted categories are limited to upgrades where high-efficiency equipment replaced existing equipment or was added to existing equipment.

Table 4-1 lists the programs, end-use categories, and measures included in this analysis along with a count of the 2020 records included. Measures included those delivered by programs active in 2020 that yielded annual gross deemed electric savings greater than zero kWh/year using the methodology established in the Standard Tracking and Engineering Protocol Manual Version 2020 (STEP Manual).

Table 4-1. Included Programs and Measures and Records Analyzed

Program – DSM Phase	End Use	Measure	Records, n
Residential Programs			
Income and Age Qualifying Home Improvement – DSM Phase IV	Lighting	40W-equivalent LED	496
		60W-equivalent LED	
Efficient Products Marketplace – DSM Phase VII	Lighting	LED A-Line	134,363
		Fixture and Retrofit Kit	
		LED Reflector	
		LED Specialty	
Home Energy Assessment – DSM Phase VII	HVAC	Heat Pump Upgrade	22,718
	Lighting	LED	
Non-residential Programs			
Lighting Systems and Controls – DSM Phase VII	Lighting	LED Lamp	1,340
		T8/T5 Lamp	
Heating and Cooling Efficiency – DSM Phase VII	HVAC	Heat Pump Upgrade	219
		Unitary AC Upgrade	
	Drive/Motor	VFD at space-conditioning motor	
Small Business Improvement – DSM Phase V	Lighting	LED Lamp	916
Prescriptive – DSM Phase VI	Drive/Motor	VSD at Kitchen Exhaust Fan	8
Total			**160,060**

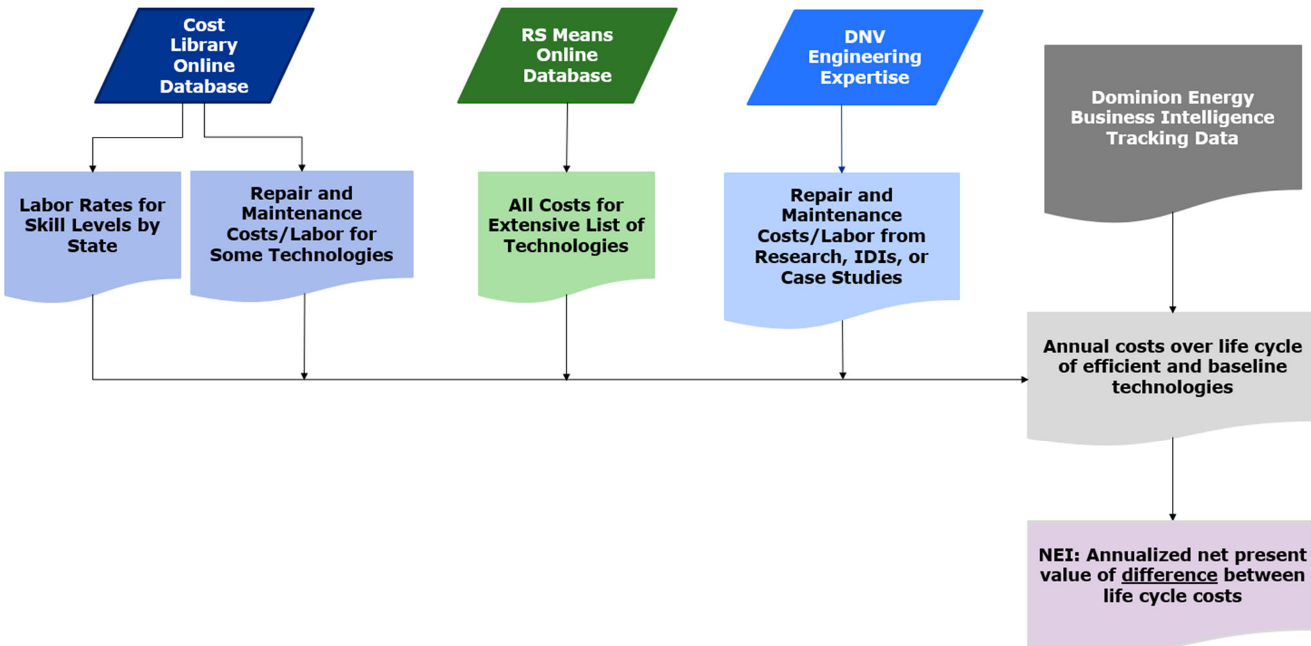
To determine non-energy impacts, the annualized net present value ($/kWh) of the operations and maintenance costs (O&M) of specific measures were analyzed by program and end use. As this program year was the first to analyze such impacts, the assumptions and limitations of the analysis are detailed in the following sections.

DNV

4.2 Methodology

DNV calculates non-energy impacts utilizing our Life Cycle Cost (LCC) tool that leverages data gathered from two third-party sources—Cost Library by CBRE Whitestone and RS Means by Gordian—and, in some cases, primary research conducted by DNV. Both sources are commonly used by cost estimators for new construction. We have fine-tuned this method through lessons learned on previous projects and via institutional knowledge and expertise. Our data sources are shown in Figure 4-1.

Figure 4-1. Data Sources Utilized by LCC Tool to Estimate Measure NEIs



Using the LCC tool requires employing the steps described as follows:

- Identify measure description from tracking data including detailed measure description, program-level expected useful life (EUL), equipment size, and annual electric savings, etc.
- Identify measures from the existing LCC data sources that match most closely to each tracking data record.
  - This step requires an engineering review of all measures in the tracking data alongside each of the available data sources contained in the LCC tool. Each data source contains replacement, repair, and maintenance cycles and costs for a finite set of measures. The engineering review identifies measures contained in the published data that most closely align with the tracked measures. Once the closest measure is identified, the source for the data (Cost Library, RS Means, or DNV research) is identified.
- Auto-populate replacement, repair, and maintenance costs from the relevant existing data source for the best match to an identified published measure.

Assumptions used for the NEI analyses:

- **Labor rate**: The labor rate tells the LCC Tool whether to select union or non-union labor rates from the existing data source. For this analysis, union labor rates were used.

- **Measure life**: While each of the published data sources contains information regarding the "Replacement Years," to identify the expected life of the measure as documented by the published life-cycle data, these values are not used for this analysis. Instead, the program-specific planned savings-weighted measure lives were used. This assumption has a substantial impact on the annualized net present value of the life cycle costs—the shorter the assumed equipment life the higher the annualized net present value of the life cycle costs. Alternative approaches include using either the measure lives in the published data source leveraged or those established in the related Technical Resource Manual (TRM) referenced by the STEP Manual for each given measure. Where a partial year was assumed for the final year of the program's EUL, we rounded to the nearest whole year.
- **First Costs**: The costs of purchasing and installing—including any heavy equipment rental rates—the upgraded equipment are included in the analysis results.
- **Incentives:** The first costs are not offset by the amount of the incentive offered by the program.
- **Repair Costs:** The costs of materials and labor to perform periodic repairs are included in the analysis.
- **Maintenance Costs:** The costs of materials and labor to perform periodic maintenance are included in the analysis.
- **Discount Rate:** We assume a discount rate of 7.83% to determine the annualized net present value of the life cycle costs for each efficient and baseline technology. The discount rate applied was provided by the Company's Integrated Strategic Planning Team and represents the customer discount rate.
- **Timing of Costs Incurred:** Costs are assumed to be incurred at the beginning of each year within the lifetime of the equipment.
- **Records Excluded:** A record was excluded whenever one or more of the following conditions were met:
  - A measure record yielded zero annual gross deemed savings (kWh/year) per the STEP Manual methodology
  - If only one of two equipment types—efficiency or baseline—could be matched to the data in the LCC tool
  - If a given record was missing a value for quantity (i.e., number of units installed, number of existing lamps, number of new lamps)
- **End Use Category:** There were specific assumptions established that varied by end use as listed.
  - For measures classified as HVAC or Drive/Motor, the size or capacity of the new equipment provided in the Dominion Energy Business Intelligence tracking data is assumed to be the size or capacity of the old unit that was replaced (a one-to-one replacement). This is aligned with the methodology established in the STEP Manual for estimating gross annual electric savings.
  - On the other hand, lighting measure analyses accommodated differing efficient- and baseline-case wattages and quantities for this analysis.
  - For variable-frequency/variable-speed drive (VFD/VSD) installed at a motor, the baseline is assumed to be the same motor without a VFD/VSD.

A known limitation of the secondary data sources:

- **Efficient Equipment:** Neither Cost Library nor RS Means provide cost differences between standard and high-efficiency equipment for many types of equipment. In those cases where the same cost data were used for both the efficient and baseline cases, the resulting NEI was always zero.

4.3 Results

The combined annualized net present value of the non-energy impacts provided by active 2020 programs totaled approximately $4.5 million for the lighting, HVAC, and VFD upgrades, combined. These include the first costs of purchasing and installing the equipment, repair costs, and maintenance costs over the life of each program. The NEIs by program and end use are shown in Table 4-2.

Table 4-2. Annualized Net Present Value NEI by Program and End Use from Programs that were Active in Virginia in 2020

Program – DSM Phase	End Use	Annual $NEI	Annual $NEI/kWh
Residential Programs			
Income and Age Qualifying Home Improvement – DSM Phase IV	Lighting	2,257	0.0556
Efficient Products Marketplace – DSM Phase VII	Lighting	2,473,230	0.0493
Home Energy Assessment – DSM Phase VII	HVAC	0	0.0000
	Lighting	1,700,398	0.3807
Non-residential Programs			
Lighting Systems and Controls – DSM Phase VII	Lighting	380,790	0.0133
Heating and Cooling Efficiency – DSM Phase VII	HVAC	-42,964	-0.0626
	Drive/Motor	-105,020	-0.0902
Small Business Improvement – DSM Phase V	Lighting	135,790	0.0176
Prescriptive – DSM Phase VI	Drive/Motor	-22,074	-0.2207
Total		**4,522,406**	**0.0486**

The program-level NEIs are summarized in Table 4-3.

Table 4-3. Annualized Net Present O&M Value per Annual Electric Savings by Program, for Programs that were Active in Virginia in 2020

Program – DSM Phase	Annual $NEI	Annual $NEI/kWh
Residential Programs		
Income and Age Qualifying Home Improvement – DSM Phase IV	2,257	0.0556
Efficient Products Marketplace – DSM Phase VII	2,473,230	0.0493
Home Energy Assessment – DSM Phase VII	1,700,398	0.3796
Non-residential Programs		
Lighting Systems and Controls – DSM Phase VII	380,790	0.0133
Heating and Cooling Efficiency – DSM Phase VII	-147,984	-0.0800
Small Business Improvement – DSM Phase V	135,790	0.0176
Prescriptive – DSM Phase VI	-22,074	-0.2207
Total	**4,522,406**	**0.0486**

Finally, the end-use-specific NEIs are summarized in Table 4-4.

Table 4-4. Overall Annualized Net Present Value NEI by End Use

End Use	Annual $NEI	Annual $NEI/kWh
Drive/Motor	-127,095	-0.1005
HVAC	-42,964	-0.0615
Lighting	4,692,465	0.0515
Total	**4,522,406**	**0.0486**

5 EMISSIONS AVOIDED

5.1 Introduction

Dominion Energy is required to utilize the services of a third party to perform evaluation, measurement, and verification services to determine the utility's related emissions reductions per the Virginia Clean Economy Act Code Section 56-596.2 C. The following sections highlight the process that DNV used to review Dominion Energy's emission reductions for their energy efficiency programs. The objective of this activity was to estimate the emissions effects of program activities affecting the 2020 calendar year because of program participants for years up to and including 2020 that would impact 2020 emissions levels.

The level of accuracy of these estimates is subject to the level of accuracy of the source data on hourly emissions, which was obtained from WattTime.org, an independent private non-profit company.[1] WattTime's marginal emissions rate data is proprietary, available via subscription. WattTime does not rely upon any data from utilities to model the emissions.

The accuracy of the load shapes applied to the emissions levels is based on the Dominion Energy deemed savings developed by DNV based on the engineering models from the Standard Tracking and Engineering Protocol Manual Version 2020 (STEP Manual). Full hourly load shapes per year are developed by DNV based on best available data from (in decreasing priority order):

1. Metered program data on samples of program-specific participants and non-participants
2. Comparable end use profiles from other programs
3. Load shape library of public end use load studies compiled by DNV

All load shapes are calibrated to the total annualized (or the first year) energy savings by end use measure to ensure that the ratio of energy to demand match as closely as possible to the deemed energy savings and demand reductions to produce the same annual usage impacts and match the peak demand impacts as closely as possible.

Some key assumptions in the analysis are:

- Emissions data from the WattTime.org site, using the PJM South Historical emissions factors for 2020, was considered most applicable to the Dominion Energy service territory.
- Emissions rates for Virginia and North Carolina are considered to be the same, although energy savings for the Virginia jurisdiction are over 95% of the total for Dominion Energy.
- Emissions data for 2020 would apply to all savings measures contributing to in 2020.
- The split between Virginia and North Carolina jurisdiction emissions savings was based on the split in 2020 annual cumulative kWh savings by state.

[1] WattTime is a nonprofit company that offers technology solutions that make it easy for anyone to achieve emissions reductions without compromising cost, comfort, or function.

DNV

5.2 Methodology

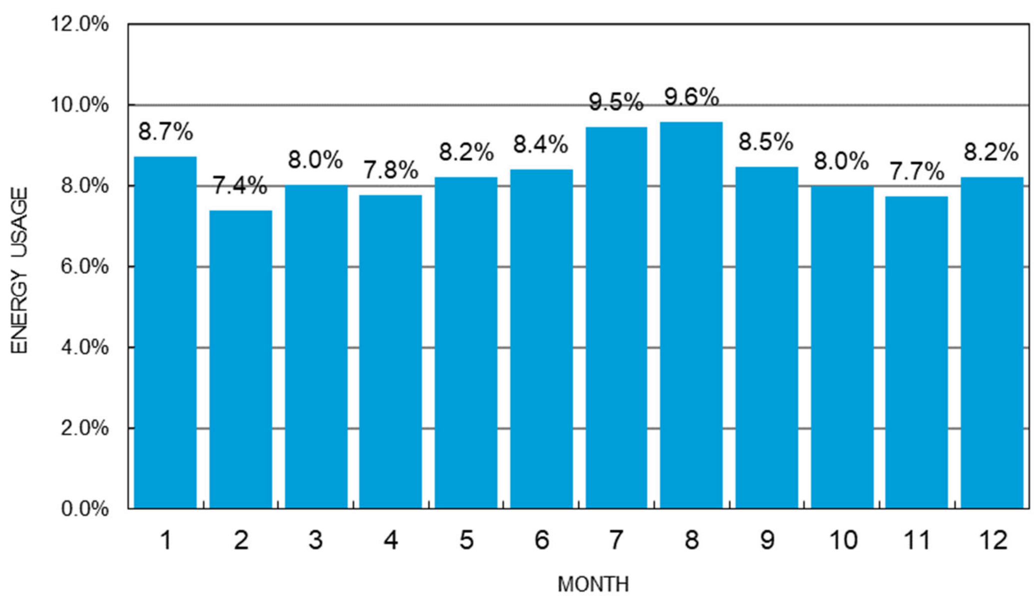
DNV calculates emissions impacts by applying the hourly emissions rates to the hourly DSM program savings for each program, splitting the overall Dominion Energy emissions savings by state based on each state's annual 2020 usage savings percentage. The steps involved were the following:

1. Obtained the 2020 emissions levels from the WattTime.org, using the PJM South Historical emissions data.
2. Used the hourly 2020 DSM cumulative energy savings from load shapes already developed by program
3. Multiplied the 2020 hourly emissions rates (lbs. CO2 per MWh) by the hourly DSM kWh/year energy savings to produce the emissions impacts, in 1000 lbs. of CO2 units.
4. Calculated the percentage split between Virginia and North Carolina State energy impacts for 2020.
5. Applied State percentages to overall Dominion Energy emissions factors to calculate state-specific emissions.

Emissions data was obtained from Watttime.org, which consists of Marginal Operating Emissions Rate (MOER), measured in lbs. CO_2/MWh. Data was obtained for 2018 through 2020 and compared, to identify any trends in the pattern.

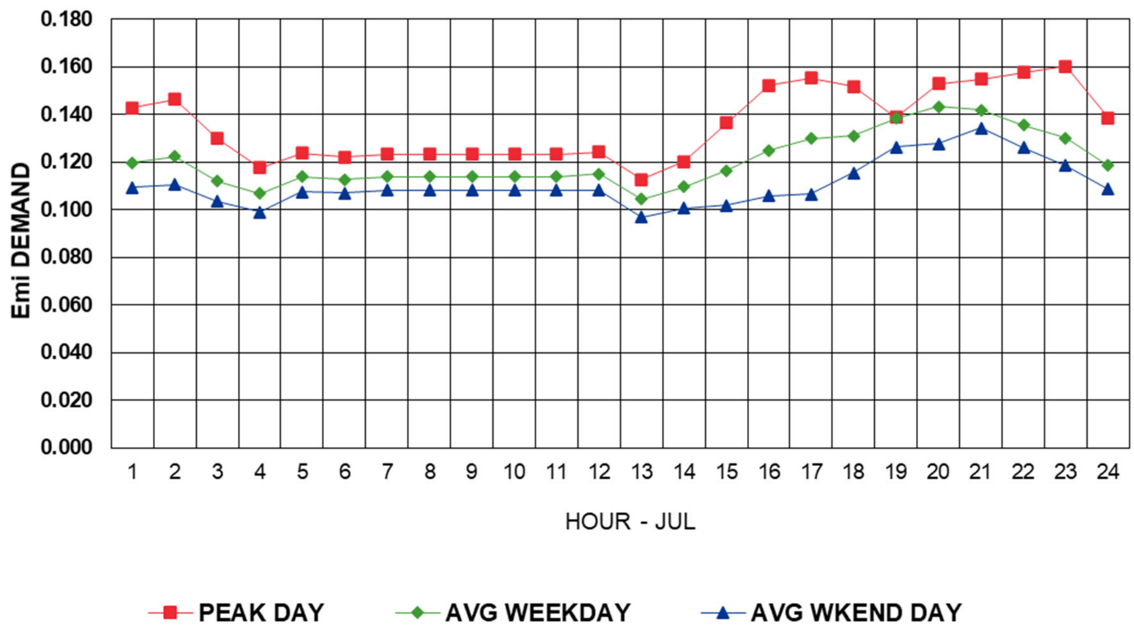
For the monthly pattern, the 2020 emissions for the PJM Southern Area showed only a slight summer-seasonal pattern, shown in Figure 5-1.

Figure 5-1. PJM South 2020 Monthly Marginal Operating Emissions Rate



For the peak month (July), the day type hourly pattern showed slightly higher evening emissions rates, as demonstrated in Figure 5-2.

Figure 5-2. PJM South July 2020 Hourly Marginal Operating Emissions Rate



Comparing winter vs. summer showed no comparable evening peak for winter, but slightly lower evening emission rates instead for average weekdays as shown in Figure 5-3.

Figure 5-3. PJM January vs. July 2020 Weekday Hourly Marginal Operating Emissions Rate

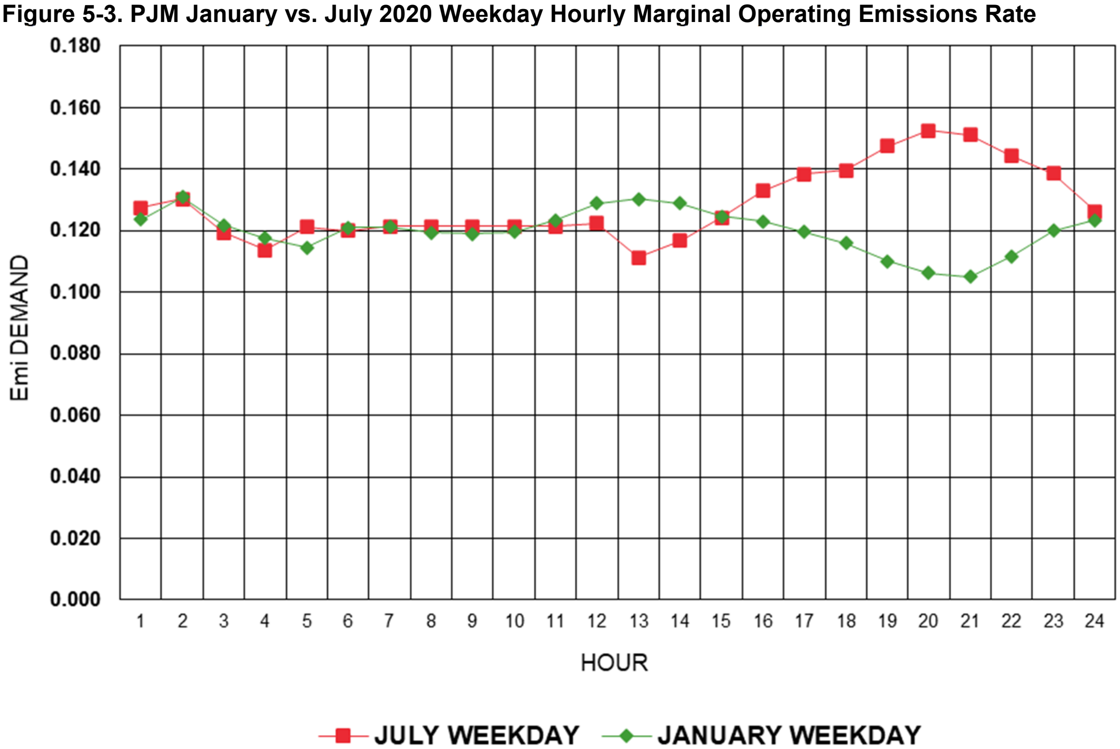
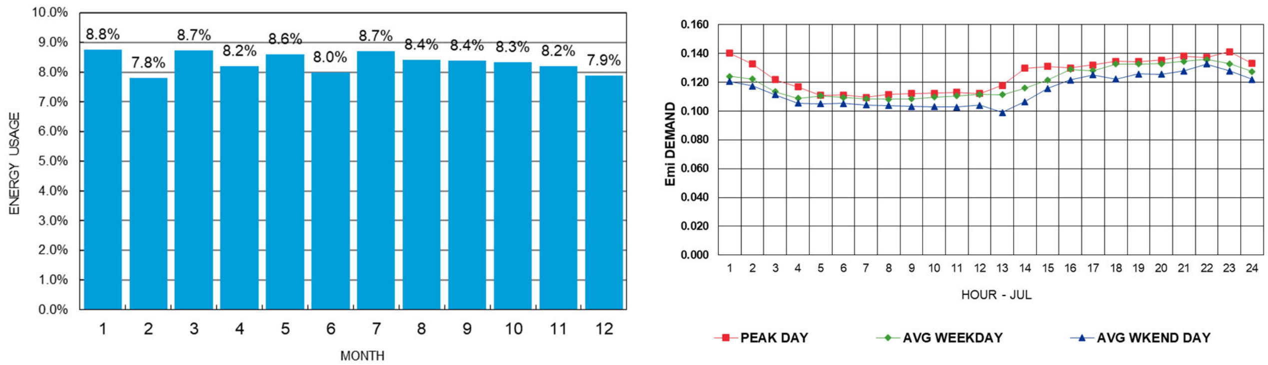


Figure 5-4. PJM 2019 Monthly and Hourly Marginal Operating Emissions Rate



Comparing 2018 and 2019 (which were both very similar) to 2020 showed slightly less summer seasonality and less of an evening peak for 2018 and 2019 (2019 results displayed) than for 2020. The summer vs. winter differences, however, were similar to 2020.

As a result, the 2020 emissions rates were considered sufficient for evaluating the overall emissions impacts.

Table 5-1 below indicates the CO2 Avoided Rates from the Southern MOER for the first 4 days of 2020. Units are lbs. CO2 per MWh, and have been converted to metric tons CO2. The data is in EEI format, which consists of 2 lines per day, 12 hours each, the same as the load shape impacts data that has been used for the past five years for reporting hourly load savings per program.

Table 5-1. Hourly Emission Rates

Emission Rates		2020	1	2	3	4	5	6	7	8	9	10	11	12
Day	Date	AM/PM Block	lbs CO2/MWH											
1	1/1/2020	1	1,418	1,396	1,383	1,281	1,258	1,294	1,363	1,359	1,304	1,322	1,305	1,346
1	1/1/2020	2	1,338	1,313	1,245	1,248	1,273	1,240	1,240	1,253	1,154	1,221	1,319	1,313
2	1/2/2020	1	1,417	1,402	1,399	1,325	1,251	1,278	1,343	1,319	1,268	1,197	1,294	1,379
2	1/2/2020	2	1,386	1,407	1,449	1,433	1,404	1,384	1,385	1,367	1,381	1,380	1,401	1,376
3	1/3/2020	1	1,428	1,420	1,388	1,329	1,287	1,398	1,389	1,367	1,316	1,290	1,300	1,319
3	1/3/2020	2	1,366	1,363	1,345	1,289	1,303	1,311	1,354	1,384	1,384	1,364	1,397	1,314
4	1/4/2020	1	1,374	1,305	1,340	1,335	1,318	1,379	1,404	1,367	1,289	1,304	1,282	1,245
4	1/4/2020	2	1,305	1,340	1,361	1,300	1,321	1,348	1,340	1,339	1,320	1,357	1,372	1,283

Hourly load shapes by DSM program previously developed were used, having already been calibrated to the annualized or first-year deemed savings developed through the STEP Manual. Percentage split between Virginia and North Carolina were calculated based on annual usage by state.

5.2.1 Calculation approach

Hourly emissions rates (MOER) were applied to hourly estimates of program-level kWh so the resulting units are in metric tons of CO2. Each hour of 2020 emissions was multiplied by the same hour of the 2020 usage impacts. Percentages by state were then applied to produce separate emissions impacts for Virginia and North Carolina.

It should be noted that separate load shapes are not typically produced by state; therefore, any differences in program participation mix, in terms of types of customer and measures implemented by state, will not be reflected. However, given the dominance of Virginia participation (over 95%) in program impacts, and fairly consistent pattern of emissions across months and hours, it was not considered worthwhile to develop state-specific hourly load impacts and resulting emissions impacts.

DNV

5.3 Results

Overall, avoided emissions impacts (in metric tons CO2 Avoided) totalled 185,551 metric tons CO_2 avoided per year for the programs that were active in Virginia in 2020 (see Table 5-2 and Figure 5-5). Overall, monthly program impacts (as shown in Figure 5-6) were distributed fairly evenly across the year, reflecting the combination of lighting (evenly distributed), some heating-oriented (winter seasonal, such as the DSM Phase IV Residential Income and Age Qualifying Home Improvement program) and some cooling-oriented (summer-seasonal, such as the DSM Phase VI Non-residential Prescriptive program).

Table 5-2. Virginia Monthly Emissions by Active 2020 Programs

Program	EAL3-20	SBIP-20	CNRP-20	RAR2-20	REEC-20	RTHO-20	CHV3-20	CLT3-20	CSW2-20	CTSO-20	All Programs	Month %
Total Annual kWh /Unit	385.19	21,943.36	26,808.79	832.46	31.81	1,807.65	78,415.82	70,604.97	11,643.77	21,902.80	**234,377**	
1 Virginia	96.9%	95.8%	96.4%	100.0%	98.3%	99.6%	100.0%	99.6%	93.5%	100.0%		
CO_2 Avoided (Metric Tons)	EAL3-20	SBIP-20	CNRP-20	RAR2-20	REEC-20	RTHO-20	CHV3-20	CLT3-20	CSW2-20	CTSO-20	**All Programs**	
1 Jan	671	2,575	2,403	92	9,074	265	283	1,518	11.48	2.25	**16,894**	**9.1%**
2 Feb	612	2,470	2,257	87	8,547	244	241	1,423	10.14	2.19	**15,894**	**8.6%**
3 Mar	509	2,561	2,330	94	7,788	243	145	1,442	12.21	2.80	**15,126**	**8.2%**
4 Apr	381	2,488	2,431	98	6,846	233	60	1,399	12.50	3.92	**13,953**	**7.5%**
5 May	334	2,351	2,828	104	6,924	243	40	1,385	11.74	6.62	**14,227**	**7.7%**
6 Jun	339	2,554	3,423	119	7,040	259	61	1,405	13.05	11.34	**15,225**	**8.2%**
7 Jul	406	2,929	4,228	145	7,850	290	83	1,617	14.79	17.39	**17,579**	**9.5%**
8 Aug	380	2,770	3,919	132	7,650	279	74	1,531	14.06	14.74	**16,763**	**9.0%**
9 Sept	324	2,376	2,930	112	6,784	237	43	1,340	12.06	10.84	**14,169**	**7.6%**
10 Oct	430	2,453	2,441	105	7,245	238	55	1,419	12.47	4.32	**14,403**	**7.8%**
11 Nov	458	2,214	2,198	92	7,738	232	110	1,356	11.17	3.15	**14,411**	**7.8%**
12 Dec	602	2,559	2,350	91	9,308	254	214	1,515	11.19	2.83	**16,907**	**9.1%**
Annual CO2 Avoided Totals	**5,446**	**30,300**	**33,736**	**1,273**	**92,794**	**3,016**	**1,409**	**17,347**	**146.88**	**82.39**	**185,551**	
Percent All Programs	2.9%	16.3%	18.2%	0.7%	50.0%	1.6%	0.8%	9.3%	0.1%	0.0%		

Figure 5-5. Dominion Energy 2020 Virginia Emissions by Active Programs

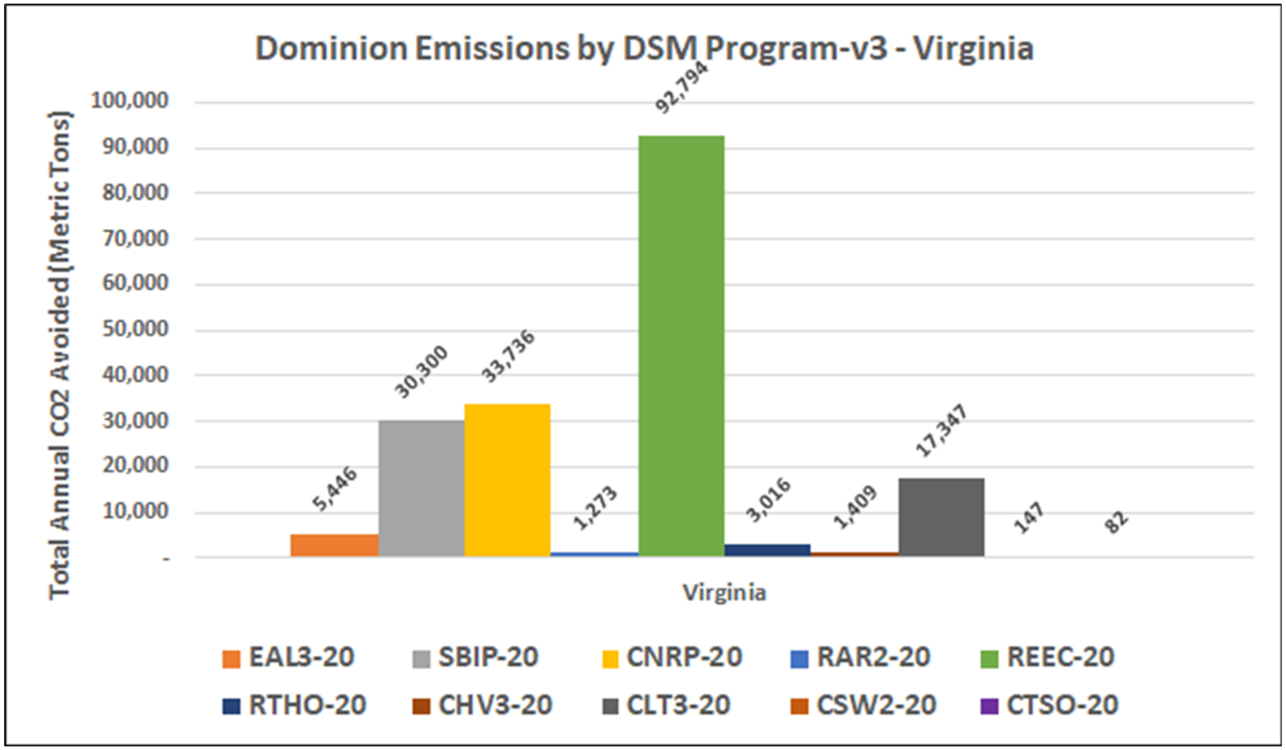
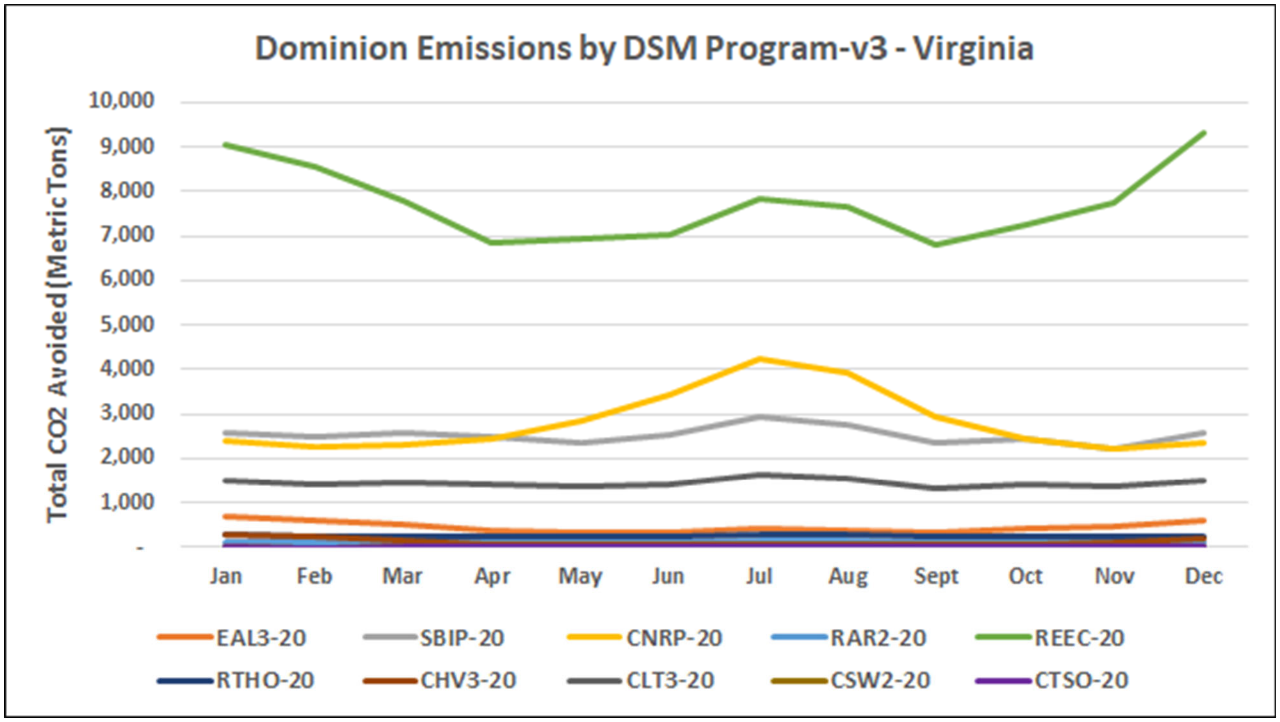


Figure 5-6. Dominion Energy 2020 Virginia Emissions by Program



6 BENEFIT/COST AND AVOIDED COST METHODOLOGY REVIEW

Dominion Energy is required to "utilize the services of a third party to perform evaluation, measurement, and verification services to review the utility's avoided costs and cost-benefit analyses" per the Virginia Clean Economy Act Code Section 56-596.2 C. The following sections highlight the process that DNV used to review Dominion Energy's avoided costs and cost-benefit analyses for their energy efficiency programs, specifically focusing on the Strategist modeling software, development of model inputs, and internal modeling processes and concepts.

DNV interviewed Dominion Energy staff on their benefit-cost modeling. We walked through Strategist with their modeling team and reviewed internal documentation of the model. Dominion Energy also provided, and DNV reviewed in detail, the Strategist inputs for the DSM IX programs.

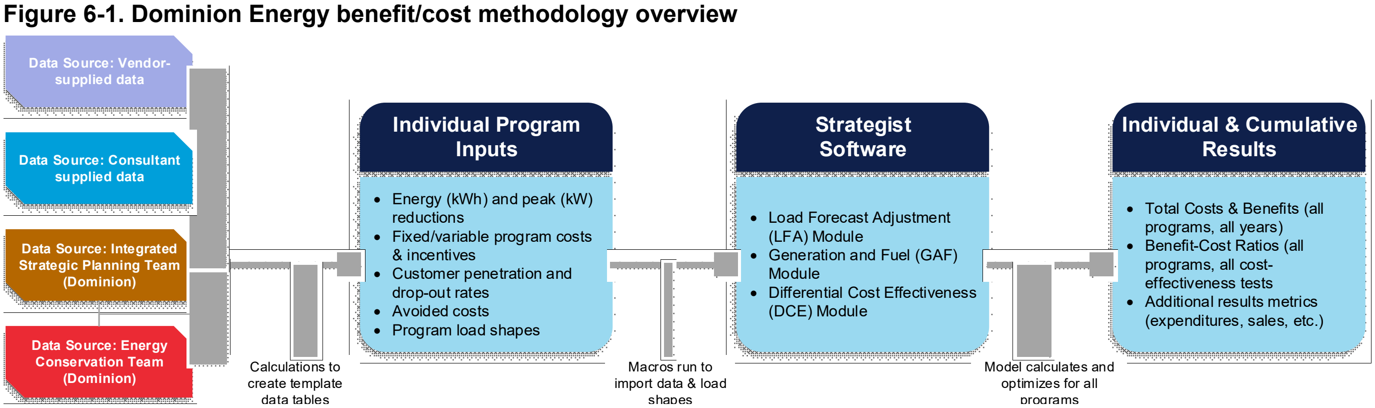
6.1 Benefit/cost review

6.1.1 Overview of Dominion Energy's benefit-cost modeling approach

Dominion Energy uses the Strategist resource planning software to model and calculate cost-effectiveness tests for their demand side management (DSM) programs.

The first step in the overall modeling process is to gather all necessary data from external and internal sources and perform basic calculations that consolidate the data into template tables. These template tables contain all the necessary inputs that Strategist uses to perform load shape calculations, determine production cost estimates, and calculate final benefit/cost results for all programs. An overview of the entire process is shown below in Figure 6-1, starting with individual data sources and continuing through program input templates, modeling in Strategist, and finally the development of results for all programs.

Figure 6-1. Dominion Energy benefit/cost methodology overview



6.1.2 Model inputs overview

Dominion Energy uses the same process to gather and consolidate inputs for each new DSM program included in the cost-effectiveness modeling in Strategist. Dominion Energy collects model inputs from various internal Dominion Energy teams and external consultants and vendors and compiles them in Excel workbooks that are called upon by Strategist macros to import the data with minimal user effort. Load shape inputs will be described in the load forecast adjustment (LFA) section further below, but all cost/benefit inputs required for Strategist are shown in Table 6-1 (next page). This table provides a relevant description of each model input and provides detail on the source (Dominion Energy, vendor, consultant, etc.). Not all model inputs shown are used directly in Strategist calculations but may be required for the import process.

Table 6-1. Cost-effectiveness calculation inputs for Strategist

Strategist input	Units (/year)	Description	Source
Dropout Rate	Number of Customers	Replacement in kind–driven by program life and equipment life	Calculated from annual new participants, program life, and equipment life
Elasticity at Peak	%/%	The percent change in demand due to a percent change in price; used to alter load shapes	Strategist default
Energy Sales	kWh/unit	Annual kWh reduction per installed unit	Vendor
Fixed Customer Cost	$	Set to 0 for all years (not used)	N/A
Fixed Marketing Expense	$	Program marketing expenses (fixed marketing, program design, etc.), calculated w/ROE; input is also used to capture miscellaneous utility-fixed expenses not captured elsewhere	Vendor ROE obtained from IRP
Fixed Evaluation Expense	$	Program evaluation expenses (vendor M&V, support, etc.), calculated w/ROE	Vendor ROE obtained from IRP
Free Drivers Percentage	%	Set to 0 for all years (not used)	N/A
Free Riders Percentage	%	Percentage of free riders based on vendor assumptions and the in-service rate (100% for most measures)	From net-to-gross ratio, provided by vendor
Load Shape Pointer	index	Index lookup for the associated program load shape	Dominion Energy Conservation
Lost Revenue Override	$	Strategist-defined metric, set to -99999000000 for all years	Strategist default
New Participant Customer Benefit	$/unit	Benefits other than those from energy and demand savings	Provided by vendor
New Participant Customer Cost	$/unit	Average incremental measure cost for each new participant	Provided by vendor
New Participant Marketing Expense	$/unit	Average incremental marketing cost for each new participant	Provided by vendor
New Participant Evaluation Expense	$/unit	Set to 0 for all programs (not used)	N/A
New Participant External Cost	$/unit	Set to 0 for all programs (not used)	N/A
New Participant Incentives	$/unit	One-time incentive paid by utility, adjusted for ROE	Vendor
Number of Customers	Number of Customers	Set to 0 – captured in other metrics (penetration, drop out)	N/A
Other Variable Customer Benefits	$/unit	Average maintenance savings per unit, adjusted for inflation; set to 0 for all reviewed programs	Provided by vendor, if applicable
Peak	kW/unit	Non-coincident peak energy savings per unit	Vendor
Penetration Factor	Number of Customers	Total new participation per year	Vendor
Percent Firm	%	Set to 100% for all programs	Strategist default
Persistence	%	Set to 1 for all programs	Strategist default

Strategist input	Units (/year)	Description	Source
Price Elasticity	%/%	Percent change in energy use for a percent change in price. Set to 0 for all programs.	Strategist default
Program Starts	index	Index lookup when only running certain modules	User toggle
Retail Fuel Switch Savings	$/unit	Set to 0 – mandated that fuel-switching savings should not be counted	N/A
Shareholder Saving Override	$/unit	Strategist-defined metric, set to -99999000000 for all years	Strategist default
T and D Demand Credit	$/kW	Avoided T&D costs (only EE programs receive distribution benefit)	Conservation & Load Management Team (Dom)
T and D Energy Credit	$/MWh	Set to 0 for all programs	Strategist default
Variable Customer Cost	$/unit	Set to 0 for all programs	Strategist default
Variable Marketing Expense	$/unit	Set to 0 for all programs	Strategist default
Variable Evaluation Expense	$/unit	Set to 0 for all programs	Strategist default
Variable External Cost	$/unit	Set to 0 for all programs	Strategist default
Variable Incentives	$/unit	Set to 0 for all programs reviewed	Vendor
Wholesale Fuel Switch Savings	$/unit	Set to 0 – mandated that fuel-switching savings should not be counted	N/A

6.1.3 Avoided costs overview

Dominion Energy includes two main avoided costs in their inputs for Strategist. These include avoided transmission ($/kW) and avoided distribution ($/kW) costs that are summed to calculate the total T&D demand credit (benefit) for each year in each program. The avoided costs, obtained from the Integrated Strategic Planning Team, consist of both forecasted locational marginal prices (LMP, $/kWh) and capacity prices ($/kW) provided by an external consultant for all generators in the PJM DOM zone. These costs are also verified internally by Dominion Energy using PLEXOS.

This discussion continues in more detail in the avoided costs section that follows.

6.1.3.1 Load shape development

Dominion Energy develops load shapes internally for each DSM program evaluated for cost-effectiveness tests in Strategist. The team obtains program-specific information such as cost assumptions, forecasted installations, energy savings, participants, and other metrics from vendors specific to each program. Dominion Energy uses this information to calculate hourly annual load shapes and imports them into Strategist. Dominion Energy then uses template Excel tables to calculate weekly load profiles for each program, aggregating hourly demand across each day of the week for each hour of the entire year.

6.1.3.2 Strategist overview

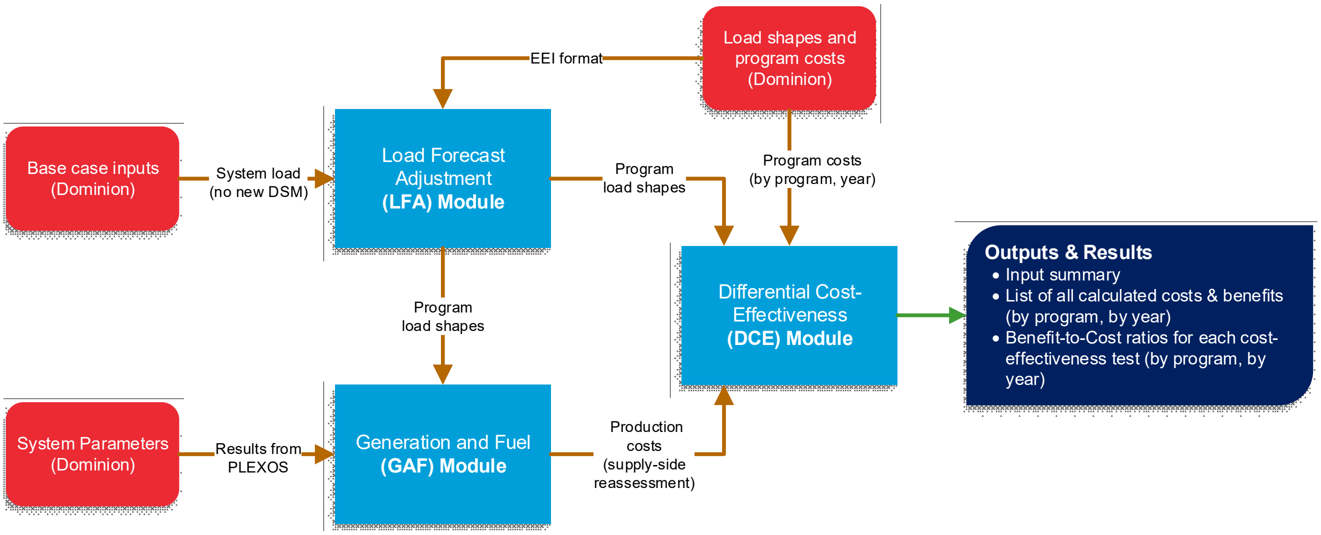
Once Dominion Energy has gathered and confirmed all inputs for each program into the Strategist import templates, they proceed to use Strategist to calculate cost-effectiveness tests for each program. Strategist is a computer software system developed by Ventyx that is used for resource and strategic planning initiatives at electric utility companies. The system has multiple functions that help utilities model their system costs and load over long planning horizons, optimize for future resource additions, and find optimal solutions for potential policy and program updates. Strategist has nine different application modules that are used for a variety of different functions, detailed below:

1. **Load forecast adjustment (LFA):** The LFA module is used to create and modify load forecasts, and to evaluate seasonal loads and hourly impacts of marketing programs. It is also used in conjunction with the DCE and GAF modules to provide detailed analyses of marketing programs.
2. **Differential cost-effectiveness cost (DCE):** The DCE module develops detailed estimates of benefit-cost analysis (BCA) ratios from defined marketing initiatives in conjunction with the LFA module.
3. **Generation and fuel (GAF):** The GAF module provides a production cost simulation of the utility power system and details production costs and generation reliability.
4. **Dynamic marketing program design (DPD):** The DPD module designs marketing programs and examines the impacts of certain metrics on program effectiveness.
5. **Capital expenditure and recovery (CER):** The CER module allows users to compare the economics of generation alternatives.
6. **Class revenue (CRM):** The CRM module analyzes corporate rate strategy over time and the impacts on utility planning and customer classes.
7. **Holding company (HCM):** The HCM module provides financial modeling and reporting features for analysis of utility holding companies and acquisition strategies.
8. **Financial reporting and analysis (FIR):** The FIR module produces a series of financial statements and other select information from the LFA, GAF, and CER modules.
9. **PROVIEW (PRV):** The PRV module is a resource planning model that optimizes the least-cost supply and demand for utility system planning.

While all the above modules are important to overall utility planning objectives and analyses, Dominion Energy only uses the LFA, DCE, and GAF modules in its cost-effectiveness calculations for DSM programs.

The LFA module is used first to import existing and updated program load shapes. The GAF module uses LFA-generated program load shapes to calculate system production costs. The DCE module then uses the load shapes generated from the LFA and production costs from the GAF module to calculate BCA ratios for each identified program. Figure 6-2 shows a basic framework of the Strategist process using the three main modules to calculate BCA ratios.

Figure 6-2. Strategist module framework for Dominion Energy BCA calculations



The following sections provide additional detail on the three modules described, including individual module methodology and how the inputs in the previous section are used within the overall Strategist process and within each module.

6.1.3.3 Strategist – base case development

Before individual modules can be run in Strategist, the first step in setting up the modeling environment to evaluate DSM cost-effectiveness is to load a base case to establish current system parameters. Dominion Energy identifies the base case as their current system load and related metrics without any new marketing programs included. The base case includes all DSM programs up to the new analysis timeframe and assumes no new penetration from current programs. This is defined as the “no-new-DSM” case in Strategist and is used to compare approved DSM programs and model the incremental effects in relation to the base case.

The base case assumptions and system load data are obtained from Dominion Energy’s Integrated Resource Planning (IRP)–Conservation & Load Management team, which regularly calculates system load with current DSM programs and related parameters for a variety of strategy and planning assessments.

6.1.3.4 Strategist input data

After the base case is loaded into Strategist, Dominion Energy uses pre-defined macros within Strategist to load all the required data that will be used in the modeling process. Cost data for each program is loaded individually from two separate tables. The first table is used to identify high-level program characteristics and options in Strategist (see Table 6-2). For example, this table identified the individual program name, program start year, and other factors that Strategist uses to select internal factors and to differentiate it from other programs.

Table 6-2. Strategist input metrics

Description	Input
Air Basin Pointer	1
Class Number	11
Class Profile Reference	N/A
Data Start Year	2020
DLC Data Set Reference	N/A
Load Basis	1
Escalation Option	1
Escalation Reference	N/A
Name	CNR2
Penetration Option	I
Print Diagnostic 15	0
Program Type	N/A
Ramp Up Profile Reference	PROPOSED
Type Switch	3
Unit Size	SMALL

The second table contains all program inputs used in Strategist calculations (see Table 6-1 from the previous section). It is used to identify individual program costs for each year of the analysis timeframe and specific scaling factors used in the calculations. Dominion Energy identifies the analysis timeframe as 25 years to align with the integrated resource planning (IRP) process.

6.1.3.5 Load forecast adjustment (LFA) module

After the base case data is loaded into Strategist, Dominion Energy uses predefined macros for each program within Strategist to import all the required load and cost data that will be used in the modeling process. Strategist defines individual programs as load groups. Once all the required program data is imported, load groups are then selected individually to be included in the analysis. A single individual load shape is then also defined for each load group (program). The LFA module does not forecast load shapes but simply stores the load data and applies demand changes calculated from each DSM program.

Load shapes for each program are provided by vendors in 8760 EEI format based on individual program characteristics (as defined in the load shape development section above). Dominion Energy then converts these load shapes into a typical weekly load profile format (chronological 168-hour load profile) to determine the load impacts for each DSM program. Dominion Energy also calculates monthly load metrics for each program that are incorporated as Strategist inputs, as shown below:

- *Seasonal energy sales (ratio of annual)*: total kWh (typical week) / total kWh (annual)
- *Seasonal peak at meter (ratio of annual peak)*: peak kW (month) / max peak kW (annual)

The LFA module first develops energy sales and peak demand for each load group by multiplying the inputs by a user-defined penetration factor and adjusting for price elasticity. Energy sales are assumed to be price-inelastic for the cost-effectiveness calculations. The LFA module then develops the group requirements shape by scaling the sales shape by the group loss factor for the season. Once each group has been processed, the hourly profiles are summed to produce total company loads, which are transferred to the GAF module. The processed load profiles for each group are also used directly in the DCE module for cost-effectiveness testing.

An additional feature of the LFA module is the direct load control (DLC) adjustment. DLC is applied to marketing programs within Strategist. Its algorithm works to link the LFA and GAF modules to allow dispatch decisions to benefit from the commitment, outage, and cost information available in generating unit logic within GAF.

6.1.3.6 Generation and fuel (GAF) module

The GAF module uses the load data outputs from the LFA module combined with defined electric system parameters, unit characteristics, transaction data, and fuel data to produce total system production costs, fuel usage, and reliability statistics. This module uses an hourly dispatch simulation to estimate how demand will be met in accordance with each DSM program and the associated costs.

The load data provided by the LFA module has three primary components that are necessary for the GAF module to run for each DSM program: annual energy, annual peak, and the load shape. System parameters modeled by Dominion Energy internally in PLEXOS are also used as inputs to the GAF module and are shown in Table 6-3 below.

Table 6-3. GAF module inputs

Type	Description
Company data	Capability & Peak Adjustment, Emergency Energy Costs, Commitment, and Spinning Reserve Level
Transaction data	Seasonal Capacity & Energy, Seasonal Capacity & Energy Costs, Hourly Profile, Emissions Data
Thermal units	Maximum and Minimum Capacity, Segment Capacity, Segment Heat Rate, Heat Rate Method, Spinning Reserve Percent, Forced Outage Rates, Annual or Seasonal Maintenance Requirement, Unit Fuel Type, Fixed and Variable O&M, Must Run Status, Emissions Data
Fuel class and fuel type data	Fuel Heat Content, Fuel Cost and Fuel Replacement Cost, Fuel Auxiliary Cost Annual or Seasonal Fuel Limits, Fuel Inventory, Emissions Data
Parameters	Maintenance Treatment Option, Interchange Method, Emergency Energy Cost, Diagnostic Flags, Emergency Use of Hydro and Storage, Fuel Limit and Switching Options, Non-thermal Dispatch Order, Probability Methods
Interchange	Marginal Cost and Load Curves, Bi-directional Tie Capacity, Transmission Losses, Connection Charges, Ownership Ratio for Ties, Third Party Method

The GAF module is used sequentially after each program is run in the DCE module. It performs a reassessment of the supply-side stack for each program being evaluated, using the load shapes from the LFA module to simulate system demand and associated costs based on individual program metrics.

6.1.3.7 Differential cost-effectiveness cost (DCE) module

The data required to analyze DSM program alternatives in the DCE module is composed of load shape impacts and program costs. Load shape demand conditions modeled in the LFA module are used within the DCE module to evaluate individual program impacts in relation to the base case. Program cost inputs calculated by Dominion Energy are also incorporated into the DCE methodology on an annual basis, as defined in the model inputs section and shown in Table 6-1.

A full production cost simulation using the GAF module is run with each program added to the base case. Results from the GAF module and load shape impacts are incorporated into the cost-effectiveness tests run in the DCE module to obtain final BCA ratios and total costs and benefits. Cost-effectiveness measures are calculated based on costs and benefits of the individual program compared to the base case.

The hourly load impacts and program costs are used to calculate differentials from the base case for class sales, revenues, customer costs, and utility costs for each year of the analysis timeframe. An "end-effects" analysis is also performed to account for costs and benefits of DSM programs that may occur after the analysis timeframe. Once all benefits and costs are calculated for each year in the analysis timeframe, the net present value (NPV) of each is also calculated to develop benefit-cost ratios.

Table 6-4 and Table 6-5, below, show the individual costs and benefits calculated for each program (by year) along with the cost-effectiveness tests for which they are included. These tables also describe the general methodology used to calculate each cost or benefit.

Table 6-4. Strategist benefit outputs by cost-effectiveness measure

Benefit category	Participant (P)	Utility (U)	RIM (R)	TRC (T)	Societal (S)	Methodology description
Customer Bill Savings	P			T▪	S▪	NPV annual bill savings; annual bill savings equals # of participants × kWh savings per participant × rate per kWh
Other Customer Benefits	P			T	S	NPV other variable customer benefits (# of participants × variable customer benefits)
Production Cost Savings		U	R	T	S	NPV of avoided energy costs Avoided energy costs = per kWh avoided cost × kWh savings × (1+ line loss %)
Deferred T&D Capacity Costs		U	R	T	S	NPV T&D capacity cost change; equals T&D demand credit × kW reduction × (1+ line loss %)
Deferred Generation Capacity Costs		U	R	T	S	NPV of avoided capacity costs Avoided capacity costs = per kW avoided cost × kW reduction × (1+ line loss %)
Retail Fuel Switch Savings	P					NPV customer fuel switching savings
Wholesale Fuel Switch Benefit				T	S	N/A in Virginia
Utility Revenue Increase			R	T▪	S▪	NPV any positive change to utility revenue
External Benefits					S	NPV cost of societal externalities (notably, societal cost of emissions)
Incentive Payments	P			T▪	S▪	Incentive payments are a benefit to participants. In the TRC and SCT, they also count as a cost for the utility NPV incentive payments; equal to annual new participation × per unit one-time incentive × (1 + ROE)

▪ Transfer payment; value appears as a cost to one party but a benefit to another (for example, an incentive is a cost to the utility, but a benefit to the participant). Transfer payments are often omitted from the TRC and societal cost test calculation.

Table 6-5. Strategist cost outputs by cost-effectiveness measure

Direct customer costs	Participant (P)	Utility (U)	RIM (R)	TRC (T)	Societal (S)	Methodology description
Direct Customer Costs	P			T	S	NPV incremental measure cost, net of free riders
Production Cost Increase		U	R	T	S	Offsets to production cost savings (see Table 4)
T&D Capacity Cost Increase		U	R	T	S	Offsets to deferred T&D capacity costs (see Table 4)
Generation Capacity Cost Increase		U	R	T	S	Offsets to deferred generation capacity costs (see Table 4)
DSM Expenses		U	R	T	S	NPV of utility program marketing and admin expenses with ROE
Evaluation Expenses		U	R	T	S	NPV program evaluation costs
Incentive Payment		U	R	T[1]	S[1]	Incentive payments are a cost for the UC and RIM test. In the TRC and SCT, they are a transfer that counts as a cost for the utility but a benefit to the participant NPV incentive payments; equal to annual new participation × per unit one-time incentive × (1 + ROE)
External Cost Increase					S	NPV of any negative societal externalities
Customer Interrupt Costs	P					NPV customer interruption costs
Utility Revenue Decrease			R	T[1]	S[1]	NPV reduction in utility revenue, especially due to customer bill savings (a transfer for the TRC and SCT)
Customer Bill Increase	P			T[1]	S[1]	NPV any offsets to customer bill savings
Retail Fuel Switch Costs	P					NPV customer fuel switching costs
Wholesale Fuel Switch Costs				T	S	N/A in Virginia

[1] Transfer payment; value appears as a cost to one party but a benefit to another (for example, an incentive is a cost to the utility, but a benefit to the participant). Transfer payments are often omitted from the TRC and societal cost test calculation.

Using the calculated costs and benefits highlighted in the above tables, Strategist then calculates individual benefit-cost ratios for each cost-effectiveness measure for each program. Benefit-cost ratios are calculated based on the five industry-standard cost-effectiveness measures using internal Strategist algorithms. These standard cost-effectiveness measures are as follows:

- *Participant test*: Cost/benefit comparison from an individual customer perspective after program measures have been installed
- *Utility test:* Cost/benefit comparison of program administrator costs to supply-side resource costs
- *Ratepayer impact measure test:* Cost/benefit comparison of program administrator costs to utility savings and supply-side resource costs
- *Total resource cost test:* Cost/benefit comparison of customer and program administrator costs to utility savings
- *Societal test:* Cost/benefit comparison of the societal program impacts to utility savings and other non-monetary costs/benefits

Strategist also performs a sequential reassessment of the supply-side stack for each program being evaluated. This is completed in the GAF module before the next DSM program can be run for cost-effectiveness tests in the DCE module.

6.1.3.8 Strategist outputs

Once Strategist completes its sequential cost-effectiveness calculations and optimization for each program, it produces a variety of inputs/results summaries and reports. The following input parameters and results are produced and summarized from either the DCE or GAF module for each program for each year in the analysis. They are then exported to Excel workbooks for further analysis.

- **Peaks:** Coincident Peak, Noncoincident Peak
- **Energy & Sales:** Energy (GWh), DLC Control Energy, DLC Payback Energy, Energy Sales
- **Participation:** Total Participation, Non-Free Rider Participation, Free Rider Percent
- **Expenses:** Market Expenses, EM&V Expenses, Incentive Expenses, Customer Expenses
- **Cost-Effectiveness:** DCE Benefits, DCE Costs, BCA Ratio

6.2 Avoided costs review

Dominion Energy's Integrated Strategic Planning Team produces the avoided costs used in the benefit/cost analysis. An external consultant provides a forecast of LMP ($/kWh) and capacity prices ($/kW) for all generators in the PJM DOM zone. PLEXOS market simulation software is used to optimize the mix of resources at any particular hour to find the least-cost option.

Avoided capacity costs measure the value in avoiding or delaying the construction of new generation capacity. The avoided-cost estimate factors in both the type of generation and the timing of when the additional capacity would be needed. Avoided costs used in Dominion Energy's benefit-cost calculations are shown in Table 6-6.

Because Virginia participates in the Regional Greenhouse Gas Initiative (RGGI), a carbon cap-and-trade program, the purchase of carbon allowances is an explicit cost to Dominion Energy and is embedded in their avoided cost. Dominion Energy's avoided-cost forecast assumes that there will be a federal cap-and-trade program beginning in 2026.

Table 6-6. Avoided costs for transmission and distribution

						T&D demand benefit		
Year	On-peak ($/MWh)	Off-peak ($/MWh)	Average ($/MWh)	Capacity ($/kW-month)	Capacity ($/kW-yr)	Avoided trans-mission ($/kW)	Avoided distribution ($/kW)	Total T&D demand credit ($/kW)
2020	$32.49	$24.01	$28.05	$2.63	$31.50	$34.40	$19.71	$54.11
2021	$34.55	$26.05	$30.10	$3.45	$41.45	$35.11	$20.12	$55.23
2022	$37.65	$28.96	$33.10	$4.28	$51.31	$35.84	$20.54	$56.38
2023	$38.68	$29.75	$34.00	$4.37	$52.48	$36.59	$20.96	$57.55
2024	$38.35	$29.65	$33.79	$4.46	$53.50	$37.25	$21.35	$58.60
2025	$40.49	$31.38	$35.72	$4.54	$54.52	$37.93	$21.74	$59.67
2026	$43.09	$33.45	$38.04	$4.63	$55.56	$38.63	$22.13	$60.76
2027	$43.67	$34.04	$38.63	$4.72	$56.64	$39.33	$22.54	$61.87
2028	$44.66	$34.93	$39.56	$4.81	$57.74	$40.05	$22.95	$63.00
2029	$46.30	$36.32	$41.07	$4.91	$58.88	$40.78	$23.37	$64.15
2030	$48.58	$38.24	$43.16	$5.00	$60.04	$41.53	$23.80	$65.33
2031	$48.44	$38.19	$43.07	$5.10	$61.21	$42.29	$24.23	$66.52
2032	$48.73	$38.43	$43.33	$5.20	$62.39	$43.06	$24.67	$67.73
2033	$50.93	$40.09	$45.25	$5.30	$63.59	$43.85	$25.12	$68.97
2034	$52.78	$41.50	$46.87	$5.40	$64.81	$44.65	$25.58	$70.23
2035	$51.73	$40.80	$46.00	$5.50	$66.05	$45.47	$26.05	$71.52
2036	$53.96	$42.58	$48.00	$5.82	$69.85	$46.30	$26.53	$72.82
2037	$56.62	$44.67	$50.36	$6.30	$75.62	$47.14	$27.01	$74.15
2038	$56.72	$44.92	$50.54	$6.80	$81.56	$48.00	$27.50	$75.51
2039	$63.54	$50.23	$56.57	$7.31	$87.67	$48.88	$28.01	$76.89
2040	$64.28	$50.95	$57.30	$7.83	$93.94	$49.77	$28.52	$78.29
2041	$65.03	$51.58	$57.99	$8.09	$97.13	$50.68	$29.04	$79.72
2042	$65.31	$51.87	$58.27	$8.17	$98.01	$51.61	$29.57	$81.18
2043	$68.18	$54.07	$60.78	$8.24	$98.85	$52.55	$30.11	$82.66
2044	$67.98	$53.98	$60.65	$8.30	$99.65	$53.51	$30.66	$84.18
2045	$68.58	$54.49	$61.20	$8.37	$100.43	$54.49	$31.22	$85.71
2046	$69.83	$55.48	$62.31	$8.52	$102.26	$55.49	$31.79	$87.28
2047	$71.11	$56.49	$63.45	$8.68	$104.13	$56.50	$32.37	$88.87
2048	$72.40	$57.53	$64.61	$8.84	$106.03	$57.53	$32.96	$90.50
2049	$73.73	$58.58	$65.79	$9.00	$107.97	$58.59	$33.57	$92.15
2050	$75.08	$59.65	$66.99	$9.16	$109.94	$59.66	$34.18	$93.84
2051	$76.45	$60.74	$68.22	$9.33	$111.95	$60.75	$34.81	$95.55
2052	$77.84	$61.85	$69.47	$9.50	$114.00	$61.86	$35.44	$97.30
2053	$79.27	$62.98	$70.73	$9.67	$116.08	$62.99	$36.09	$99.08

						T&D demand benefit		
Year	On-peak ($/MWh)	Off-peak ($/MWh)	Average ($/MWh)	Capacity ($/kW-month)	Capacity ($/kW-yr)	Avoided trans-mission ($/kW)	Avoided distribution ($/kW)	Total T&D demand credit ($/kW)
2054	$80.71	$64.13	$72.03	$9.85	$118.20	$64.14	$36.75	$100.89
2055	$82.19	$65.30	$73.34	$10.03	$120.36	$65.31	$37.42	$102.73
2056	$83.69	$66.49	$74.68	$10.21	$122.56	$66.50	$38.10	$104.61
2057	$85.22	$67.71	$76.05	$10.40	$124.80	$67.72	$38.80	$106.52
2058	$86.78	$68.95	$77.44	$10.59	$127.08	$68.96	$39.51	$108.46
2059	$88.36	$70.21	$78.85	$10.78	$129.41	$70.22	$40.23	$110.45
2060	$89.98	$71.49	$80.29	$10.98	$131.77	$71.50	$40.97	$112.46
2061	$91.62	$72.80	$81.76	$11.18	$134.18	$72.81	$41.71	$114.52
2062	$93.30	$74.13	$83.26	$11.39	$136.63	$74.14	$42.48	$116.61
2063	$95.00	$75.48	$84.78	$11.59	$139.13	$75.49	$43.25	$118.74
2064	$96.74	$76.86	$86.33	$11.81	$141.67	$76.87	$44.04	$120.91
2065	$98.51	$78.27	$87.90	$12.02	$144.26	$78.27	$44.85	$123.12
2066	$100.31	$79.70	$89.51	$12.24	$146.89	$79.70	$45.67	$125.37
2067	$102.14	$81.15	$91.15	$12.46	$149.58	$81.16	$46.50	$127.66

6.2.1 Review summary

Dominion Energy's approach to benefit-cost testing and avoided costs follows standard practice. The Strategist model is a well-vetted and comprehensive tool that is appropriate for this use. Inputs to the modeling process are well-documented and appear appropriate to the programs.

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