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

Case No. PUR-2020-00274 (Virginia)
Docket No. E-22 Sub 604 (North Carolina)

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Prepared by DNV Energy Insights USA Inc. (DNV)

Appendix F2 Technical Reference Manual (TRM) for Non-Residential Programs

Dominion Energy Virginia and North Carolina

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

Version 2021-Report

Prepared by DNV Energy Insights USA Inc.

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1 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 1-1.

Table 1-1. 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 1.1.1
		New Construction: none (new methodology for this program)	
	Occupancy Sensors & Controls	Non-Residential Lighting Systems and Controls, DSM III	Section 1.1.2
	Occupancy Sensors & Controls, Stairwell-integrated Occupancy Sensor	-	Section 1.1.3
	Reach-in Unit Occupancy Sensor	Non-Residential Lighting Systems and Controls, DSM III	Section 1.1.4

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 lighting that 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 reduction for delamping measures is included in PJM EE Resource nominations when reflectors or tombstones are installed since these are defined as persistent.

This measure is offered through various programs as listed in Table 1-2 and uses the impacts estimation approach described in this section. There are two methodologies described for this measure: 1) the retrofit/replace-on-

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burnout/exit signs/exterior methodology (applies to all programs); and 2) the new construction methodology only applies to one program (shown in the table that follows).

Table 1-2. Programs that Offer this Measure

Program Name	Applications	Section
Non-Residential Lighting Systems and Controls Program, DSM Phase VII	Retrofit, Replace-on-burnout, Exit signs, Exterior, and New Construction	Section 1.1.1
Non-Residential Small Business Improvement Program, DSM Phase V	Retrofit, Replace-on-burnout, Exit signs, and Exterior	Section 4.2.1 (points to Section 1.1.1)
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII		Section 9.4.1 (points to Section 1.1.1)
Non-Residential Multifamily Program, DSM Phase VIII		Section 11.4.1 (points to Section 1.1.1)

1.1.1.2 Impacts Estimation Approach

Each application of this measure uses its own impacts estimation approach as described in the sub-sections that follow.

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

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

$$\Delta kW_{summer} = \frac{(Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee}) \times CF_{summer} \times WHF_{d,summer} \times ISR}{1{,}000\, W/kW}$$

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

$$\Delta kW_{winter} = \frac{(Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee}) \times CF_{\ winter} \times WHF_{d,winter} \times ISR}{1{,}000\, W/kW}$$

New Construction Interior Lighting

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

$$\Delta kW_{summer} = \left(\frac{LPD_{base}}{LPD_{ee}} - 1\right) \times watts_{ee} \times Qty_{ee} \times WHF_{d,summer} \times ISR \times CF_{summer} \times \frac{1\ kW}{1{,}000\ W}$$

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

$$\Delta kW_{winter} = \left(\frac{LPD_{base}}{LPD_{ee}} - 1\right) \times watts_{ee} \times Qty_{ee} \times WHF_{d,winter} \times ISR \times CF_{winter} \times \frac{1\ kW}{1{,}000\ W}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak demand reduction
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
$WHF_{d,summer}$ = waste heat factor for summer peak demand to account for cooling savings from efficient lighting
$WHF_{d,winter}$ = waste heat factor for winter peak demand to account for heating penalty from efficient lighting
CF_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor
ISR = in-service rate

1.1.1.3 Input Variables

Table 1-3. 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

Component	Type	Value	Unit	Source(s)
LPD_{base}	Variable	See Table 1-4	watt/sq.ft.	2015 Virginia Energy Conservation Code/IECC 2015 Section C405.4.2, Table C405.4.2(1) and Maryland/Mid-Atlantic TRM v. 10, p. 229
		Default=Other building type	watt/sq.ft.	Maryland/Mid-Atlantic TRM v10, p. 217, per ENERGY STAR®[1]
LPD_{ee}	Variable	See customer application	watt/sq.ft.	Customer application
CF_{summer}	Variable	For measures where the location is "Exit sign," "Stairwell," "Exterior light except garage," or "Garage," use Table 13-14 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 - Parking garage." For measures where the locations is "Interior light except exit light" use Table 13-15 in Sub-Appendix F2-IV: Non-Residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors.	-	Maryland/Mid-Atlantic TRM v10, pp. 215, 243, 255, and 272[2]
CF_{winter}	Variable		-	Maryland/Mid-Atlantic TRM v10, pp. 215, 243, 255, and 272[3]
HOU	Variable		hours, annual	Maryland/Mid-Atlantic TRM v10, pp. 215, 242, 254, 272, and 415-416
WHF_e	Variable		-	Maryland/Mid-Atlantic TRM v10, pp. 419-420
$WHF_{d,summer}$	Variable		-	Maryland/Mid-Atlantic TRM v10, pp. 419-420
$WHF_{d,winter}$	Variable		-	Maryland/Mid-Atlantic TRM v10, pp. 419-420
ISR	Fixed	1.00	-	Maryland/Mid-Atlantic TRM v10, p. 218[4]

Table 1-4. Interior Lighting Power Allowances

Customer building type	LPD_{base}[5]
Education – Elementary and Middle School	0.87

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

[2] 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.

[3] 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.

[4] Maryland/Mid-Atlantic TRM v.9, 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.

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

Customer building type	LPD_{base}[5]
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

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 Effective Useful Life

The effective useful life of this measure is provided in Table 1-5.

Table 1-5. Effective Useful Life for Lifecycle Savings Calculations

<table>
<tr><th>DSM Phase</th><th>Program Name</th><th>Value</th><th>Units</th><th>Source(s)</th></tr>
<tr><td rowspan="2">VIII</td><td>Non-Residential Multifamily Program, DSM Phase VIII</td><td rowspan="2">15.00</td><td rowspan="2">years</td><td rowspan="2">Maryland/Mid-Atlantic TRM v10, p. 219</td></tr>
<tr><td>Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII</td></tr>
<tr><td>VII</td><td>Non-Residential Lighting Systems and Controls Program, DSM Phase VII</td><td>10.59</td><td>years</td><td rowspan="2">Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)</td></tr>
<tr><td>V</td><td>Non-Residential Small Business Improvement Program, DSM Phase V</td><td>14.00</td><td>years</td></tr>
</table>

1.1.1.6 Source(s)

The primary source for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 215–221, 241-243, 253-255, 271-272, 415-416, and 419-421, and the IECC 2015 Section C405.4.2.

1.1.1.7 Update Summary

Updates made to this section are described in Table 1-6. Summary of Update(s).

Table 1-6. Summary of Update(s)

<table>
<tr><th>Version</th><th>Update Type</th><th>Description</th></tr>
<tr><td rowspan="4">2021</td><td>Source</td><td>Updated page numbers / version of the Maryland/Mid-Atlantic TRM v10</td></tr>
<tr><td>Input Table</td><td>Updated CF, HOU values</td></tr>
<tr><td>Equation</td><td>Added coincident winter peak demand reduction equation</td></tr>
<tr><td>New table</td><td>Effective Useful Life (EUL) by program</td></tr>
<tr><td>2020</td><td>None</td><td>No change</td></tr>
<tr><td>v10</td><td>New Measure</td><td>New section</td></tr>
</table>

1.1.2 Occupancy Sensors and Daylight Controls

1.1.2.1 Measure Description

This measure defines the savings associated with installing at wall-, fixture-, or remote-mounted occupancy sensors that switch lights off or dim them after a brief delay when no occupants are detected or daylight conditions are sufficient. The baseline condition is lighting that is controlled with a manual switch.

This measure is offered through different programs listed in Table 1-7 and uses the impacts estimation approach described in this section.

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Table 1-7. Programs that Offer this Measure

Program Name	Section
Non-Residential Lighting Systems and Controls Program, DSM Phase VII	Section 1.1.2
Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.2.2 (points to Section 1.1.2)
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.4.2 (points to Section 1.1.2)
Non-Residential Multifamily Program, DSM Phase VIII	Section 11.4.3 (points to Section 1.1.2)

1.1.2.2 Impacts Estimation Approach

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

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

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

$$\Delta kW_{summer} = watts_{connected} \times \frac{1\ kW}{1{,}000\ W} \times ESF_d \times ISR \times WHF_{d,summer} \times CF_{summer}$$

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

$$\Delta kW_{winter} = watts_{connected} \times \frac{1\ kW}{1{,}000\ W} \times ESF_d \times ISR \times WHF_{d,winter} \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak demand reduction
$watts_{connected}$ = 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
$WHF_{d,summer}$ = waste heat factor for demand to account for cooling savings from efficient lighting
$WHF_{d,winter}$ = waste heat factor for demand to account for cooling savings from efficient lighting
CF_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor
ISR = in-service rate represents the proportion of rebated measures installed

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1.1.2.3 Input Variables

Table 1-8. Input Values for Occupancy Sensors and Controls Measure Savings

Component	Type	Value	Unit	Source(s)
$watts_{connected}$	Variable	See customer application	watt	Customer application
HOU	Variable	See Table 13-15 in Sub-Appendix F2-IV: Non-Residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	hours/ year	Maryland/Mid-Atlantic TRM v10, p. 222
ESF_e	Fixed	0.28	-	Maryland/Mid-Atlantic TRM v10, pp. 222 and 225
ESF_d	Variable	Occupancy sensor = 0.14 Daylight control = 0.28	-	Maryland/Mid-Atlantic TRM v10, pp. 223 and 225
CF_{summer}	Fixed	See Table 13-15 in Sub-Appendix F2-IV: Non-Residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Maryland/Mid-Atlantic TRM v10, p. 223
CF_{winter}	Fixed	See Table 13-15 in Sub-Appendix F2-IV: Non-Residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Maryland/Mid-Atlantic TRM v10, p. 223
WHF_e	Variable	See Table 13-15 in Sub-Appendix F2-IV: Non-Residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Maryland/Mid-Atlantic TRM v10, pp. 419-421
		Default: 0.94		Assumes "Small Office" building type
$WHF_{d,summer}$	Variable	See Table 13-15 in Sub-Appendix F2-IV: Non-Residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Maryland/Mid-Atlantic TRM v10, pp. 419-421
		Default: 1.35		Assumes "Other" building type
$WHF_{d,winter}$	Variable	See Table 13-15 in Sub-Appendix F2-IV: Non-Residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	-	Maryland/Mid-Atlantic TRM v10, pp. 419-421
		Default: 0.740		Assumes "Other" building type
ISR	Fixed	1.00	-	Maryland/Mid-Atlantic TRM v10, p. 223

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 Effective Useful Life

The effective useful life of this measure is provided in Table 1-9.

Table 1-9. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	10.00	years	Maryland/Mid-Atlantic TRM v10, p. 224
	Non-Residential Multifamily Program, DSM Phase VIII			
V	Non-Residential Small Business Improvement Program, DSM Phase V	14.00	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)
VII	Non-Residential Lighting Systems and Controls Program, DSM Phase VII	10.59		

1.1.2.6 Source(s)

The primary source for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 222-224, 225 – 227 and 419-421.

1.1.2.7 Update Summary

Updates made to this section are described in Table 1-10.

Table 1-10. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers/version of the Maryland/Mid-Atlantic TRM v10
	Inputs	Added daylight control inputs
	Equation	Added coincident winter peak demand reduction equation
	New table	Effective Useful Life (EUL) by program
2020	None	No change
v10	New Measure	New section

1.1.3 Occupancy Sensors and Controls – Stairwell Integrated

1.1.3.1 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 stairwells when unoccupied while also providing higher light levels when occupied. The baseline condition is interior-space lighting that provides continuous operation at high light levels, regardless of occupancy.

1.1.3.2 Impacts Estimation Approach

Gross annual electric energy savings are coincident demand reduction is calculated according to the following equation:

$$\Delta kWh = \left[\frac{Qty_{base} \times watts_{base}}{1{,}000\ W/kW} - \left(\frac{Qty_{ee} \times watts_{ee}}{1{,}000\ W/kW} \times (1 - ESF)\right)\right] \times HOU$$

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

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

$$\Delta kW_{summer} = \left(\frac{Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee}}{1{,}000\ W/kW}\right) \times CF_{summer}$$

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

$$\Delta kW_{winter} = \left(\frac{Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee}}{1{,}000\ W/kW}\right) \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak demand reduction
Qty_{base} = quantity of baseline fixtures
Qty_{ee} = quantity of installed fixtures 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} = proportion of annual operating time that fixture operates at low power
ESF = energy savings factor
HOU = hours of use per year
CF_{summer} = summer peak coincidence factor
CF_{winter} = winter peak coincidence factor

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1.1.3.3 Input Variables

Table 1-11. Input Values for Occupancy Sensors and Controls-Stairwell Integrated Measure

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
$watts_{ee,low}$	Variable	See customer application	watts	Customer application
$watts_{ee}$	Variable	See customer application	watts	Customer application
F_{low}	Fixed	0.73	-	New York TRM 2019, p. 445
HOU	Fixed	8,760	hours/year	New York TRM 2019, p. 444
CF_{summer}	Fixed	1.00	-	New York TRM 2019, p. 444
CF_{winter}	Fixed	1.00	-	New York TRM 2019, p. 444[6]

1.1.3.4 Default Savings

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

1.1.3.5 Effective Useful Life

The effective useful life of this measure is provided in Table 1-12.

Table 1-12. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VII	Non-Residential Lighting Systems and Controls Program, DSM Phase VII	10.59	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

1.1.3.6 Source(s)

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

1.1.3.7 Update Summary

Updates made to this section are described in Table 1-13.

[6] The source TRM doesn't differentiate between winter and summer peak periods. Therefore, the summer CF is also applied to winter peak periods.

Table 1-13. Summary of Update(s)

Version	Update Type	Description
2021	None	No change
	Equation	Added coincident winter peak demand reduction equation
	New table	Effective Useful Life (EUL) by program
2020	Equation	Modified the ΔkWh savings equation to incorporate the ESF and associated equation. This makes the calculation clearer and aligns with the reference TRM but does not change the result.
v10	New Measure	New section

1.1.4 Reach-In Unit Occupancy Sensor

1.1.4.1 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 reach-in refrigerated case lighting that is controlled with a manual switch.

1.1.4.2 Impacts Estimation Approach

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

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

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

$$\Delta kW_{summer} = Qty_{sensor} \times watts_{connected} \times \frac{1\ kW}{1{,}000\ W} \times ESF_d \times ISR \times WHF_{d,summer} \times CF_{summer}$$

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

$$\Delta kW_{winter} = Qty_{sensor} \times watts_{connected} \times \frac{1\ kW}{1{,}000\ W} \times ESF_d \times ISR \times WHF_{d,winter} \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross summer peak coincident demand reduction
ΔkW_{winter} = per measure gross winter peak coincident demand reduction

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Qty_{sensor} = number of occupancy sensors installed
$watts_{connected}$ = 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
$WHF_{d,summer}$ = Waste Heat Factor for Demand; represents the increased savings due to reduced waste heat from lights that must be rejected by the refrigeration equipment
$WHF_{d,winter}$ = 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_{summer} = summer peak coincidence factor
CF_{winter} = winter peak coincidence factor
ISR = in-service rate is the percentage of rebated measures actually installed

1.1.4.3 Input Variables

Table 1-14. 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[7], p. 173
ESF_d	Fixed	0.14	-	Maryland/Mid-Atlantic TRM v10, p. 223
HOU	Variable	See Table 13-15 in Sub-Appendix F2-IV: Non-Residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 222[8]
ISR	Fixed	1.00	-	Maryland/Mid-Atlantic TRM v10, p. 222
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	-	Maryland/Mid-Atlantic TRM v10, p. 269

[7] 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. It is assumed that this value accounts for both reduction in operating hours and incremental reduction in power.

[8] No default HOU was provided in the Maine TRM 2016.2. It refers to data collected from the application. Since this manual does not use customer application HOU data, a default was assigned using annual hours from the Maryland/Mid-Atlantic TRM v10.

Component	Type	Value	Unit	Source(s)
$WHF_{d,\ summer}$	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	-	Maryland/Mid-Atlantic TRM v10, p. 270
$WHF_{d,\ winter}$	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	-	Maryland/Mid-Atlantic TRM v10, p. 270[9]
CF_{summer}	Fixed	0.96	-	Maryland/Mid-Atlantic TRM v10, p. 270[10]
CF_{winter}	Fixed	0.96	-	Maryland/Mid-Atlantic TRM v10, p. 270[11]

1.1.4.4 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:

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

$$= 1 \times \frac{38\ W}{1{,}000\,\frac{W}{kW}} \times 7{,}272\ hours \times 0.31 \times 1.00 \times 1.41$$

$$= 121\ kWh$$

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

$$\Delta kW_{summer} = Qty_{sensor} \times \frac{watts}{1{,}000\,\frac{W}{kW}} \times ESF_d \times ISR \times WHF_{d,summer} \times CF_{summer}$$

[9] The source TRM doesn't differentiate between winter and summer WHFs. Therefore, the summer WHF is applied to the winter WHF.

[10] Value for "grocery" building type from Mid-Atlantic TRM v.9, p. 270 footnote 579 "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."

[11] The source TRM doesn't differentiate between winter and summer peak periods. Therefore, the summer CF is applied to the winter CF.

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$$= 1 \times \frac{38\ W}{1{,}000 \frac{W}{kW}} \times 0.14 \times 1.00 \times 1.40 \times 0.96$$

$$= 0.007\ kW$$

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

$$\Delta kW_{winter} = Qty_{sensor} \times \frac{watts}{1{,}000 \frac{W}{kW}} \times ESF_d \times ISR \times WHF_{d,winter} \times CF_{winter}$$

$$= 1 \times \frac{38\ W}{1{,}000 \frac{W}{kW}} \times 0.14 \times 1.00 \times 1.40 \times 0.96$$

$$= 0.007\ kW$$

1.1.4.5 Effective Useful Life

The effective useful life of this measure is provided in Table 1-15.

Table 1-15. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VII	Non-Residential Lighting Systems and Controls Program, DSM Phase VII	10.59	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

1.1.4.6 Source(s)

The primary sources for this deemed savings approach are the Efficiency Maine TRM 2019, p. 173, and Maryland/Mid-Atlantic TRM v10, pp. 222-224 and 269-270.

1.1.4.7 Update Summary

Updates made to this section are described in Table 1-16.

Table 1-16. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Maryland/Mid-Atlantic TRM v10

Version	Update Type	Description
	New table	Effective Useful Life (EUL) by program
	Equation	Added gross winter peak demand reduction equation
2020	None	No change
v10	New Measure	New section

2 NON-RESIDENTIAL HEATING AND COOLING EFFICIENCY PROGRAM, DSM PHASE VII

The Non-Residential Heating and Cooling Efficiency program is offered in Virginia beginning July 1, 2019 and approved in North Carolina on November 13, 2019. 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 2-1.

Table 2-1. Non-Residential Heating and Cooling Efficiency Program Measure List (DSM VII)

End Use	Measure	Manual Section
HVAC	Unitary/Split Air Conditioning (AC) & Heat Pump (HP) Systems	Section 2.1.1
	Variable Refrigerant Flow (VRF) & Mini-split Systems	Section 2.1.2
	Water- and Air-cooled Chillers	Section 2.1.3
	Variable Frequency Drive	Section 2.1.4
	Dual Enthalpy Air-side Economizer	Section 2.1.5

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

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

2.1.1 Unitary/Split Air Conditioning (AC) & Heat Pump (HP) Systems VAC Upgrade

2.1.1.1 Measure Description

This measure relates to the installation of new high-efficiency unitary/split HVAC units and heat pumps, variable-refrigerant flow (VRF), and mini-split units in place of standard efficiency unitary/split HVAC units. For the standard (baseline) efficiencies, refer to Table 13-8 and Table 13-9 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 through the various programs listed in Table 2-2 and uses the impacts estimation approach described in this section. (Not all programs offer all of the listed HVAC equipment types.)

Table 2-2. Programs that Offer this Measure

Program Name	Section
Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	Section 2.1.1
Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.1.4
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.3.4
Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	Section 10.2.1

Program Name	Section
Non-Residential Multifamily Program, DSM Phase VIII	Section 11.3.1

2.1.1.2 Impacts Estimation Approach

Algorithms and inputs to calculate heating, cooling savings, and demand reduction for unitary/split HVAC, package terminal AC, packaged terminal heat pump, variable refrigerant flow and mini-split 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:

$$\Delta kWh_{cool} = Size_{cool} \times \left[\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}}\right] \times EFLH_{cool} \times \frac{1\ kBtuh}{1{,}000\ Btuh}$$

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:

$$\Delta kWh_{cool} = Size_{cool} \times \left[\frac{1}{IEER_{base}} - \frac{1}{IEER_{ee}}\right] \times EFLH_{cool} \times \frac{1\ kBtuh}{1{,}000\ Btuh}$$

For package terminal AC and HP units of all sizes, per measure, gross annual electric cooling energy savings are calculated according to the following equation:

$$\Delta kWh_{cool} = Size_{cool} \times \left[\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right] \times EFLH_{cool} \times \frac{1\ kBtuh}{1{,}000\ Btuh}$$

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:

$$\Delta kWh_{heat} = Size_{heat} \times \left[\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right] \times EFLH_{heat} \times \frac{1\ kBtuh}{1{,}000\ Btuh}$$

For heat pumps ≥65,000 Btu/h, and water-source heat pumps of all sizes, and package terminal HP units of all sizes, per measure gross annual electric heating energy savings are calculated according to the following equation:

$$\Delta kWh_{heat} = Size_{heat} \times \left[\frac{1}{COP_{base}} - \frac{1}{COP_{ee}}\right] \times EFLH_{heat} \times \frac{1\ W}{3.412\ Btuh} \times \frac{1\ kBtuh}{1{,}000\ Btuh}$$

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

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

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

$$\Delta kW_{summer} \quad = Size_{cool} \times \left[\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right] \times CF_{summer} \times \frac{1\ kBtuh}{1{,}000\ Btuh}$$

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

$$\Delta kW_{winter} \quad = \frac{\Delta kWh_{heat}}{EFLH_{heat}} \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkWh_{cool} = per measure gross annual electric cooling energy savings
ΔkWh_{heat} = per measure gross annual electric heating energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak demand reduction
ΔkW_{winter} = per measure gross summer peak coincident demand reduction
$Size_{cool}$ = 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.

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COP_{ee} = coefficient of performance (COP) of installed heating equipment. Ground source heat pumps use COP to determine heating savings.
$\eta_{baseboard}$ = efficiency of existing or baseline electric-resistance heating baseboard equipment.
CF_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor

For ground-source heat pumps, the baseline efficiency is assumed to be that of an air-source heat pump.[12] See Equation 1 and Equation 2 in Sub-Appendix F2-VIII: General Equations to convert between tons and Btu/h or kBtu/h, or vice versa.

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

2.1.1.3 Input Variables

Table 2-3. 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[13] Default = $Size_{cool}$	Btu/h	Customer application
$EFLH_{heat}$	Variable	See Table 13-5 in Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 423
$EFLH_{cool}$	Variable	See Table 13-4 in Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 422
HSPF/SEER/ IEER/EER/ COP_{base}	Variable	See Table 13-8 and Table 13-9 in Sub-Appendix F2-III: Non-Residential HVAC Equipment Efficiency Ratings. If required efficiency value is not available, refer to Sub-Appendix F2-VIII: General Equations to convert the available efficiency value to the required efficiency value.	kBtu/kW-hour (except COP is dimension-less)	ASHRAE 90.1 2013, Table 6.8.1-1
HSPF/SEER/ IEER/EER/COP_{ee}	Variable	See customer application If required efficiency value is not available, refer to Sub-Appendix F2-VIII: General Equations to convert the available efficiency value to the required efficiency value.	kBtu/kW-hour (except COP is dimension-less)	Customer application

[12] 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 2020 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 2020.)

[13] When customer-provided heating system size is <80% or >156% of customer-provided cooling system size, a default value will be used, instead. In such instances, it is assumed that the heating system size was incorrectly documented. The acceptable range is based on a review of the AHRI database across numerous manufacturers and heat pump types.

Component	Type	Value	Units	Source(s)
CF_{summer}	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	-	Maryland/Mid-Atlantic TRM v10, p. 291
CF_{winter}	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	-	Maryland/Mid-Atlantic TRM v10, p. 291[14]

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 Effective Useful Life

The effective useful life of this measure is provided in Table 2-4.

Table 2-4. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	15.00	years	Maryland/Mid-Atlantic TRM v10, p. 291
	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII			
	Non-Residential Multifamily Program, DSM Phase VIII			
	Non-Residential Small Business Improvement Program, DSM Phase V			
VII	Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	15.00	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

[14] The source TRM does not provide a winter CF. Therefore, the summer CF is applied to the winter CF.

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2.1.1.6 Source(s)

The primary sources for this deemed savings approach are the ENERGY STAR® Air Source Heat Pump Calculator (2002 EPA), Maryland/Mid-Atlantic TRM v10, pp. 283-291 and 422-423, and ASHRAE 90.1 2013.

2.1.1.7 Update Summary

Updates made to this section are described in Table 2-5.

Table 2-5. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Maryland/Mid-Atlantic TRM v10
	Equation	• Added coincident winter peak demand reduction equation
	New table	Effective Useful Life (EUL) by program
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.
v10	Source	Updated page numbers / version of the Mid-Atlantic TRM v.9
	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

2.1.2 Variable Refrigerant Flow Systems and Mini-Split Systems

2.1.2.1 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 efficiencies refer to Table 13-10 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.

This measure is offered through different programs listed in Table 2-6, and uses the impacts estimation approach described in this section.

Table 2-6. Programs that Contain this Measure

Program Name	Section
Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	Section 2.1.2
Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.1.5

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2.1.2.2 Impacts 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:

$$\Delta kWh_{cool} = Size_{cool} \times \left[\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}}\right] \times EFLH_{cool} \times \frac{1\ kBtuh}{1{,}000\ Btuh}$$

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

$$\Delta kWh_{cool} = Size_{cool} \times \left[\frac{1}{IEER_{base}} - \frac{1}{IEER_{ee}}\right] \times EFLH_{cool} \times \frac{1\ kBtuh}{1{,}000\ Btuh}$$

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:

$$\Delta kWh_{heat} = Size_{heat} \times \left[\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right] \times EFLH_{heat} \times \frac{1\ kBtuh}{1{,}000\ Btuh}$$

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:

$$\Delta kWh_{heat} = Size_{heat} \times \left[\frac{1}{COP_{base}} - \frac{1}{COP_{ee}}\right] \times EFLH_{heat} \times \frac{1\ kW}{3{,}412\ Btuh}$$

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

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

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

$$\Delta kW_{summer} = Size_{cool} \times \left[\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right] \times CF_{summer} \times \frac{1\ kBtuh}{1{,}000\ Btuh}$$

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

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$$\Delta kW_{winter} = \frac{\Delta kWh_{heat}}{EFLH_{heat}} \times CF_{winter}$$

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_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak demand reduction
$Size_{cool}$ = 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 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_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor

To convert between EER, SEER, and IEER, see equations in Sub-Appendix F2-VIII: General Equations.

2.1.2.3 Input Variables

Table 2-7. Input Values for VRF Systems and Mini Split Systems

Component	Type	Value	Units	Source(s)
$Size_{cool}$	Variable	See customer application	Btu/h	Customer application
$Size_{heat}$	Variable	See customer application[15] Default = $Size_{cool}$	Btu/h	Customer application
$EFLH_{heat}$	Fixed	See Table 13-5 in Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 423

[15] When customer-provided heating system size is <80% or >156% of customer-provided cooling system size, a default value will be used, instead. In such instances, it is assumed that the heating system size was incorrectly documented. The acceptable range is based on a review of the AHRI database across numerous manufacturers and heat pump types.

Component	Type	Value	Units	Source(s)
$EFLH_{cool}$	Fixed	See Table 13-4 in Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 422
$HSPF/SEER/EER/COP/IEER_{base}$	Variable	See Table 13-10 in Sub-Appendix F2-III: Non-Residential HVAC Equipment Efficiency Ratings If required efficiency value is not available, refer to Sub-Appendix F2-VIII: General Equations to convert the available efficiency value to the required efficiency value.	kBtu/kW-hour (except COP is dimension-less)	ASHRAE 90.1 2013, Table 68.1-1
$HSPF/SEER/EER/COP/IEER_{ee}$	Variable	See customer application[16] If required efficiency value is not available, refer to Sub-Appendix F2-VIII: General Equations to convert the available efficiency value to the required efficiency value.	kBtu/kW-hour (except COP is dimension-less)	Customer application
CF_{summer}	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	-	Maryland/Mid-Atlantic TRM v10, p. 295
CF_{winter}	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	-	Maryland/Mid-Atlantic TRM v10, p. 295[17]

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 Effective Useful Life

The effective useful life of this measure is provided in Table 2-8.

Table 2-8. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VII	Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	15.00	years	Program design assumptions (weighted average of measure lives

[16] When missing either the IPLV or the full load value, use Equation 4 in Sub-Appendix F2-VIII: General Equations, as relevant.

[17] The source TRM does not provide a winter CF. Therefore, the summer CF is applied to the winter CF.

DSM Phase	Program Name	Value	Units	Source(s)
V	Non-Residential Small Business Improvement Program, DSM Phase V	14.00		of all measures offered by program and their planned uptake)

2.1.2.6 Source(s)

The primary sources for this deemed savings approach are the Maryland/Mid-Atlantic TRM v10, pp. 292-295 and 422-423, and ASHRAE 90.1-2013.

2.1.2.7 Update Summary

Updates made to this section are described in Table 2-9.

Table 2-9. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Maryland/Mid-Atlantic TRM
	Equation	Added coincident winter peak demand reduction equation
	New table	Effective Useful Life (EUL) by program
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.
V10	Source	Updated page numbers / version of the Maryland/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

2.1.3 Electric Chillers

2.1.3.1 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 13-11 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.

This measure is offered through different programs listed in Table 4-2 and uses the impacts estimation approach described in this section.

Table 2-10. Programs that Offer this Measure

Program Name	Section
Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	Section 2.1.3

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Program Name	Section
Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	Section 10.2.3

2.1.3.2 Impacts 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 summer peak demand reduction is calculated according to the following equation:

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

This measure does not have gross coincident winter peak demand reduction.

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:

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

This measure does not provide gross coincident winter peak demand reduction.

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident demand reduction
$Size_{ee}$ = 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_{summer} = summer peak coincidence factor

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2.1.3.3 Input Variables

Table 2-11. Input Values for Non-Residential Electric Chillers

Component	Type	Value	Unit	Source(s)
$Size_{ee}$	Variable	See customer application	ton	Customer application
$kW/ton_{base,full\text{-}load}$	Fixed	See Table 13-11 of Sub-Appendix F2-III: Non-Residential HVAC Equipment Efficiency Ratings	kW/ton	ASHRAE 90.1 2013, Table 6.8.1-3
$kW/ton_{base,IPLV}$	Fixed	See Table 13-11 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[18]	kW/ton	Customer application
$kW/ton_{ee,IPLV}$	Variable	See customer application[18]	kW/ton	Customer application
$EER_{base,\ full\ load}$	Variable	See customer application[19]	kBtu/kW	Customer Application
		Default: See Table 13-11 of Sub-Appendix F2-III: Non-Residential HVAC Equipment Efficiency Ratings		ASHRAE 90.1-2013, Table 6.8.1-3
$EER_{base,\ IPLV}$	Variable	See customer application[19]	kBtu/kW	Customer Application
		Default: See Table 13-11 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[19]	kBtu/kW	Customer application
$EER_{ee,\ IPLV}$	Variable	See customer application[19]	kBtu/kW	Customer application
$EFLH_{cool}$	Variable	See Table 13-4 in Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours	hours, annual	Maryland/Mid-Atlantic TRM v10, adjusted for ten locations in VA and NC, based on TMY3 cooling degree days data.
CF_{summer}	Fixed	0.923	-	Maryland/Mid-Atlantic TRM v10, p. 304

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. This TRM 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 13-11 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.

[18] When missing either the IPLV or the full load value, use Equation 8 in Sub-Appendix F2-VIII: General Equations, as relevant.

[19] When missing either the IPLV or the full load value, use Equation 4 in Sub-Appendix F2-VIII: General Equations, as relevant.

Compliance with the code-specified minimum efficiency can be achieved by meeting the requirement of either Path A or Path B. However, both full-load and IPLV levels must be met to fulfill the requirements of Path A or Path B.

For 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.

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 Effective Useful Life

The effective useful life of this measure is provided in Table 2-12.

Table 2-12. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	23.00	years	Maryland/Mid-Atlantic v10, p. 304
VII	Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	15.00	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

2.1.3.6 Source(s)

The primary sources for this deemed savings approach are the Maryland/Mid-Atlantic TRM v10, pp. 302-305 and 422 and ASHRAE 90.1-2013, Table 6.8.1-3 - Water Chilling Packages - Efficiency Requirements.

2.1.3.7 Update Summary

Updates made to this section are described in Table 2-13.

Table 2-13. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Maryland/Mid-Atlantic TRM
	New table	Effective Useful Life (EUL) by program
2020	None	No change
v10	Source	Updated page numbers / version of the Maryland/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

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2.1.4 Variable Frequency Drives

2.1.4.1 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 reduction 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:

HVAC 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)

HVAC Pumps

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

This measure is offered through different programs listed in Table 2-2, and uses the impacts estimation approach described in this section. However, the savings methodology is different for the Non-Residential Small Business Improvement program, described in Section 4.1.7.

Table 2-14: Programs that Offer this Measure

Program Name	Section
Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	Section 2.1.4
Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.1.7
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.3.4

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2.1.4.2 Impacts 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 summer peak demand reduction is calculated according to the following equation:

HVAC Fans:

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

HVAC Pumps:

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

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

HVAC Fans:

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

HVAC Pumps:

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

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak demand reduction
hp = motor horsepower
LF = motor load factor (%) at fan design airflow rate or pump design flowrate

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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
$PLR_{ee, peak}$ = summer peak efficient part-load ratio
ESF = energy savings factor
DSF = demand savings factor
CF_{summer} = summer peak coincidence factor
CF_{winter} = winter peak coincidence factor

2.1.4.3 Input Variables

Table 2-15. 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	-	Maryland/Mid-Atlantic TRM v10, p. 297
η	Variable	See customer application	-	Customer application
		Default see Table 2-16. Baseline Motor Efficiency		NEMA Standards Publication Condensed MG 1-2007
FF	Fixed	0.524 per Table 2-17	-	Maryland/Mid-Atlantic TRM v10, p. 297
PLR_{base}	Variable	See customer application	-	Maryland/Mid-Atlantic TRM v10, p. 298
		Default = 0.53 per Table 2-19. forward-curved fan with outlet dampers at FF=0.524		
$PLR_{base, peak}$	Fixed	1.00	-	DNV engineering judgement
PLR_{ee}	Fixed	See customer application	-	Customer application
		Default: 0.30[20] per Table 2-19. for VFD with duct Static Pressure Controls at FF=0.524		Maryland/Mid-Atlantic TRM v10, p. 299
$PLR_{ee, peak}$	Fixed	1.00	-	DNV engineering judgement
ESF	Variable	See Table 2-20	-	Maryland/Mid-Atlantic TRM v10, p. 301
DSF	Variable	See Table 2-20	-	Maryland/Mid-Atlantic TRM v10, p. 301
HOU	Variable	See Table 13-6 in Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours	hours, annual	Maryland/Mid-Atlantic TRM v10, pp. 299-301
CF_{summer}	Fixed	0.55 for pump applications	-	Maryland/Mid-Atlantic TRM v10, p. 299

[20] Corresponds to the approximate PLR for 'VFD with Duct Static Pressure Controls' from Table 2-18. at the average FF of 52.4% from Table 2-17.

Component	Type	Value	Unit	Source(s)
CF_{winter}	Fixed	0.78 for pump applications	-	Dominion Energy 2012 Commercial HVAC VSD Study[21]

Table 2-16 provides the baseline motor efficiencies that are consistent with the minimum federal accepted motor efficiencies provided by the National Electrical Manufacturers Association (NEMA).[22]

Table 2-16. Baseline Motor Efficiency[23]

Horsepower (hp)	η	Horsepower (hp)	η
1	0.855	**60**	0.950
1.5	0.865	**75**	0.954
2	0.865	**100**	0.954
3	0.895	**125**	0.954
5	0.895	**150**	0.958
7.5	0.917	**200**	0.962
10	0.917	**250**	0.962
15	0.924	**300**	0.962
20	0.930	**350**	0.962
25	0.936	**400**	0.962
30	0.936	**450**	0.962
40	0.941	**500**	0.962
50	0.945		

Table 2-17 provides the assumed proportion of time that fans operate within ten ranges of airflow rates, relative to the design airflow rate (cfm).

Table 2-17. Default Fan Duty Cycle

Airflow Range (% of design cfm)	Airflow Fraction (FF), Percent of Time in Flow Range	Average Flow Range (% of design cfm)
0% - 10%	0.0%	52.4%
10% - 20%	1.0%	
20% - 30%	5.5%	
30% - 40%	15.5%	
40% - 50%	22.0%	

21 The source TRM does not provide a winter CF. Therefore, the results from Dominion Energy's 2012 Commercial VSD Loadshape study to calculate winter CF.

22 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 standard.

23 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).

Airflow Range (% of design cfm)	Airflow Fraction (FF), Percent of Time in Flow Range	Average Flow Range (% of design cfm)
50% - 60%	25.0%	
60% - 70%	19.0%	
70% - 80%	8.5%	
80% - 90%	3.0%	
90% - 100%	0.5%	

Table 2-18. provides the part-load ratios (PLRs) that vary with fan control types and air flow range.

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Table 2-18. Part Load Ratios by Control Type, Fan Type, and Flow Range

Control Type	Fan Type(s)	Airflow Range (percent of design cfm)									
		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
Discharge Dampers	All	0.46	0.55	0.63	0.70	0.77	0.83	0.88	0.93	0.97	1.00
Outlet Damper	BI, AF	0.53	0.53	0.57	0.64	0.72	0.80	0.89	0.96	1.02	1.05
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	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
Outlet Damper	FC	0.22	0.26	0.30	0.37	0.45	0.54	0.65	0.77	0.91	1.06
Eddy Current Drives	All	0.17	0.20	0.25	0.32	0.41	0.51	0.63	0.76	0.90	1.04
Inlet Guide Vane	FC	0.21	0.22	0.23	0.26	0.31	0.39	0.49	0.63	0.81	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 2-19 displays the average part-load ratios calculated using the flow fractions from Table 2-17, and the part-load values across flow ranges from Table 2-18.

Table 2-19. Average Baseline 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 2-20. Energy and Demand Savings Factors by Application

VFD Applications[24]	ESF	DSF
Chilled Water Pump	0.633	0.460
Hot Water Pump	0.652	0.000
Unknown/Other Pump (Average)[25]	0.643	0.230

2.1.4.4 Default Savings

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

2.1.4.5 Effective Useful Life

The effective useful life of this measure is provided in Table 2-21.

[24] Mid-Atlantic TRM 2020, p. 301.
[25] Assigned for pumps not specifically in this table, such as condenser water pump.

Table 2-21. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	15.00	years	Maryland/Mid-Atlantic TRM v10, p. 301
	Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII			
VII	Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	15.00	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)
V	Non-Residential Small Business Improvement Program, DSM Phase V	14.00		

2.1.4.6 Source(s)

The primary sources for this deemed savings approach Maryland/Mid-Atlantic TRM v10, pp. 296-301.

2.1.4.7 Update Summary

Updates made to this section are described in Table 2-22.

Table 2-22. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Maryland/Mid-Atlantic TRM
	New table	Effective Useful Life (EUL) by program
	Equation	Added gross winter peak demand reduction equation
2020	None	Added efficient cases of control strategies to clarify assumptions. No change to resulting savings.
v10	Source	Updated page numbers / version of the Maryland/Mid-Atlantic TRM

2.1.5 Dual Enthalpy Air-side Economizers

2.1.5.1 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 rates by monitoring the outside air temperature (sensible heat) and humidity (latent heat) and provides free cooling in place of mechanical cooling. This reduces the load on the mechanical cooling system and lowers the operating hours. This measure applies only to retrofits or newly-installed cooling units with a 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. This measure is offered through the programs listed in Table 2-23 and uses the impacts estimation approach described in this section.

Table 2-23. Programs that Offer this Measure

Program Name	Section
Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	Section 2.1.5
Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.1.6
Non-Residential Office Program, DSM Phase VII	Section 8.3.7
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.3.5

2.1.5.2 Impacts 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 summer and winter coincident demand reduction is assumed to be zero because an economizer will typically not operate during the peak period.[26] Hence,

$$\Delta kW_{summer} = \Delta kW_{winter} = 0$$

Where:

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

2.1.5.3 Input Variables

Table 2-24. 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 2-25	kWh/ton	Maryland/Mid-Atlantic TRM v10, p. 314

[26] Maryland/Mid-Atlantic TRM v10, p. 313.

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Table 2-25. Economizer Energy Savings Factors by Building Type[27]

Building Type	Energy Savings Factors (kWh/ton)										
	Baltimore, MD	Richmond, VA	Norfolk, VA	Roanoke, VA	Sterling, VA	Arlington, VA	Charlottes-ville, VA	Farmville, VA	Fredericksburg, VA	Elizabeth City, NC	Rocky Mount, NC
Education:[28] **College and University, High School, – Elementary and Middle School**	39	46	51	35	35	48	34	41	43	56	43
Food Sales:[29] **Grocery,**[30] **Convenience Store, Gas Station Convenience Store**	57	67	75	51	51	70	50	59	63	82	63
Food Service:[31] **Full Service,**	29	34	38	26	26	36	26	30	32	41	32
Food Service: Fast Food[32]	37	43	49	33	33	46	33	39	41	53	41

[27] Maryland/Mid-Atlantic TRM v10, p. 314 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 CDD provided in Sub-Appendix F2-I: Cooling and Heating Degree Days and Hours. For example, VA and NC values are calculated from Baltimore, MD savings factors and degree days (DD-65°F = CDD) using TMY3 data.

[28] All education building types are mapped to savings factors for the “Primary School” building type listed in the Maryland/Mid-Atlantic TRM v10, p. 314.

[29] All food sales, and service (beauty, auto repair workshop) building types are mapped to savings factors for the “Small Retail” building type listed in the Maryland/Mid-Atlantic TRM v10, p. 314.

[30] Food-sales-grocery and mercantile (mall) building are mapped to the “Big Box Retail” building type listed in the Maryland/Mid-Atlantic TRM v10, p. 314.

[31] All general food service and food service-full service building types are mapped to savings factors for the “Full Service Restaurant” building type listed in the Maryland/Mid-Atlantic TRM v10, p. 314.

[32] Food service – fast food building types are mapped to savings factors for the “Fast Food” building type in the Maryland/Mid-Atlantic TRM v10, p. 314.

Building Type	Energy Savings Factors (kWh/ton)										
	Baltimore, MD	Richmond, VA	Norfolk, VA	Roanoke, VA	Sterling, VA	Arlington, VA	Charlottes-ville, VA	Farmville, VA	Fredericksburg, VA	Elizabeth City, NC	Rocky Mount, NC
Mercantile (Retail, not mall)[33]	57	67	75	51	51	70	50	59	63	82	63
Mercantile (mall)	57	67	75	51	51	70	50	59	63	82	63
Office: Small (<40,000 sq.ft.)[34] and Large (≥ 40,000 sq.ft.)	57	67	75	51	51	70	50	59	63	82	63
Public Assembly	25	29	33	23	22	31	22	26	28	36	28
Religious Worship	6	7	8	5	5	7	5	6	7	9	7
Other[35]: Lodging (Hotel, Motel and Dormitory), Health Care (Outpatient, Inpatient) Public Order and Safety (Police and Fire Station)	57	67	75	51	51	70	50	59	63	82	63
Service (Beauty, Auto Repair	57	67	75	51	51	70	50	59	63	82	63

33 Mercantile (retail, not mall) building types in are mapped to savings factors for the "Small Retail" building type in the Maryland/Mid-Atlantic TRM v10, p. 314.

34 Office – small (< 40,000 sqft) and office – large (>= 40,000 sqft) building types are mapped to savings factors for the "Small Office" building types in the Maryland/Mid-Atlantic TRM v10, p. 314.

35 Other, lodging – (hotel, motel and dormitory), health care-outpatient, healthcare-inpatient, public order and safety (police and fire station) building types are mapped to the "Other" building type in the Maryland/Mid-Atlantic TRM v10, p. 314.

Building Type	Energy Savings Factors (kWh/ton)										
	Baltimore, MD	Richmond, VA	Norfolk, VA	Roanoke, VA	Sterling, VA	Arlington, VA	Charlottes-ville, VA	Farmville, VA	Fredericksburg, VA	Elizabeth City, NC	Rocky Mount, NC
Workshop)											
Warehouse and Storage	2	2	3	2	2	2	2	2	2	3	2

2.1.5.4 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.

2.1.5.5 Effective Useful Life

The effective useful life of this measure is provided in Table 2-26.

Table 2-26. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	10.00	years	Mid-Atlantic TRM 2020, p. 313
VII	Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	15.00	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)
VII	Non-Residential Office Program, DSM Phase VII	7.00		
V	Non-Residential Small Business Improvement Program, DSM Phase V	14.00		

2.1.5.6 Source(s)

The primary source for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 313-314.

2.1.5.7 Update Summary

Updates made to this section are described in Table 2-27.

Table 2-27. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Maryland/Mid-Atlantic TRM
	Input Variable	Expanded weather stations
	New table	Effective Useful Life (EUL) by program
	Equation	Added gross winter peak demand reduction equation
2020	None	No change
v10	Source	Updated page numbers / version of the Maryland/Mid-Atlantic TRM
	Input Variable	Updated weather stations in North Carolina

3 NON-RESIDENTIAL WINDOW FILM PROGRAM, DSM PHASE VII

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.

3.1 Building Envelope End Use

3.1.1 Window Film

3.1.1.1 Measure Description

This measure applies to window film installed on existing windows to reduce the solar heat gain through the affected window. Because the window film reduces solar heat gain, cooling loads are often reduced leading to mechanical cooling savings. For the same reason, heating load may also increase leading to mechanical heating penalties.

Windows facing any orientation are eligible. The film must a SHGC equal to or less than 0.5.[36]

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.

This measure is offered through different programs listed in Table 3-1, and uses the impacts estimation approach described in this section.

Table 3-1. Programs that Offer this Measure

Program Name	Section
Non-Residential Window Film Program, DSM Phase VII	Section 3.1.1
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.1.1

3.1.1.2 Impacts Estimation Approach

The window film installation measure savings calculations utilize savings factors developed using OpenStudio™ and EnergyPlus™ software simulations of prototypical building models. The prototype building models were sourced from the DOE Commercial Reference Buildings within OpenStudio. Two building types, the public assembly and public safety and health buildings, were developed by DNV, as these building types were not included in the DOE Commercial Reference Buildings. The prototype models were modified for various heating equipment types. All models were based on ASHRAE 90.1-2004 building energy code and ASHRAE climate zone 4A.

Savings factors are calculated as the difference in simulated energy consumption between the baseline models and the efficient models. An efficient model is created for windows facing each orientation. This is done by changing the window properties to the efficient case in a given orientation, to isolate the effects of installing window film on each orientation, on the building energy consumption. DNV modeled an array of different building types, to represent the

[36] DSM Phase VII Non-Residential Window Film Program design assumptions.

varying types of customers who may participate in this program. DNV encountered three modeling scenarios, related to where windows are installed on the prototypical baseline models:

1. There are prototype models where there are windows on all four walls. In these cases, the efficient models are run with window film applied to each individual window orientation, to isolate its impact on energy consumption.
2. In some of the prototype models there are windows only on one orientation. In these cases, the model was rotated by 90 degrees for each orientation in the efficient model, to isolate the effects of the window film installation on that orientation.
3. Some prototype models did not have windows in the North orientation. In these cases, savings are set to zero as the savings are relatively small compared to the other orientations and the quantity of windows in these building types with north facing windows will likely be relatively small.

Table 3-2 provides building descriptions and the HVAC heating type assumptions depending on the heating fuel type.

Table 3-2. DOE and DNV Building Type Descriptions

Building Type	Total Floor Area (sq.ft.)	No. floors	Gas Heating HVAC system	Electric Heating HVAC system	Note
Quick service restaurant	2,500	1	Packaged AC w/ gas furnace	Packaged HP	No north-facing windows; north facing savings factors were not estimated
Full service restaurant	5,500	1	Packaged AC w/ gas furnace	Packaged HP	No north-facing windows; north facing savings factors were not estimated
Hospital	241,351	5	CHW/HW plant w/ VAV & HW reheat	PTHP & DOAS w/ HW coils	
Outpatient healthcare	40,946	3	Packaged VAV w/ HW & electric reheat	Packaged VAV w/ electric reheat	
Large Hotel	122,120	6	CHW/HW plant w/ 4-pipe FC	PTHP & Packaged HPs	
Small Office	5,500	1	Packaged AC w/ gas furnace	Packaged HP	
Large Office	498,588	12	CHW/HW plant w/ VAV & HW reheat	WSHP	
Primary School	73,960	1	Packaged VAV w/ HW reheat	Packaged VAV w/ electric reheat	
Secondary School	210,887	2	CHW/HW plant w/ VAV & HW reheat	WSHP	
Stand-alone retail	24,962	1	Packaged AC w/ gas furnace	Packaged HP	Original model has only east-facing windows. Models were rotated to estimate savings for all cardinal directions
Strip Mall	22,500	1	Packaged AC w/ gas furnace	Packaged HP	Original model has only east-facing windows. Models were rotated to estimate savings for all cardinal directions
Public Assembly	28,024	2	Packaged AC w/ HW coils	Packaged HP	Developed by DNV

Building Type	Total Floor Area (sq.ft.)	No. floors	Gas Heating HVAC system	Electric Heating HVAC system	Note
Public Order and Safety	8,734	2	Packaged AC w/ HW reheat	Packaged HP	Developed by DNV

Models are run for various locations throughout Dominion Energy's service territory using typical meteorological year 3 (TMY3) data—and modification of a few key window parameters.[37] The assumed values for key parameters affected by addition of window film to single and double pane windows are provided in Table 3-3.

Table 3-3. Key Building Energy Modelling Parameters

Window Variable	Window Type	Baseline Value	Source(s) [38]	Efficient Value	Source(s)[38]
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 13-25 to Table 13-33. Savings factors differ based on the number of panes within affected windows (single or double) and the heating fuel type of the building (electric or non-electric). Per measure, gross annual electric energy savings are calculated according to the following equation:

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

Per measure, gross coincident summer and winter peak demand reduction is negligible for this measure

Where:

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

3.1.1.3 Input Variables

Table 3-4. Input Values for Solar Window Film

Component	Type	Value	Unit	Source(s)
$SqFt_{orientation}$	Variable	See customer application	sq.ft.	Customer application

[37] See Sub-Appendix I: Cooling and Heating Degree Days and Hours for a description of the weather stations selected for this document.
[38] Building vintage ranges defined in DEER, www.deeresources.com.

Component	Type	Value	Unit	Source(s)
$ESF_{orientation}$	Variable	See Table 13-25 to Table 13-33 in Sub-Appendix F2-VII: Non-Residential Window Film Energy Saving Factors	kWh/sq.ft.	DOE 2.2 energy modeling software

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 Effective Useful Life

The effective useful life of this measure is provided in Table 3-5

Table 3-5. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	10.00	years	New York TRM 2019 v.7, p. 770[39]
VII	Non-Residential Window Film Program, DSM Phase VII	10.00		Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

3.1.1.6 Source(s)

The deemed savings for this measure are determined by using prototypical building energy models defined by California's 2008 Database for Energy Efficient Resources (DEER)[40] and modified to represent program-specific window characteristics for ten cities across Dominion Energy's service territory in Virginia and North Carolina (eight locations in Virginia and two in North Carolina).

3.1.1.7 Update Summary

Updates made to this section are described in Table 3-6

Table 3-6. Summary of Update(s)

Version	Update Type	Description
2021	New table	Effective Useful Life (EUL) by program
	Input Variable	Updated per-square-foot savings using new building models and revised weather stations

[39] California DEER 2014, GlazDaylt-WinFilm
[40] http://www.energy.ca.gov/deer/

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

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4 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 4-1.

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.[41]

Table 4-1. Non-Residential Small Business Improvement Program Measure List

End Use	Measure	Manual Section
HVAC	Duct Testing & Sealing	Section 4.1.1
	Unitary/Split AC, HP, and Chiller Tune-up	Section 4.1.2
	Refrigerant Charge Correction	Section 4.1.3
	Unitary/Split AC & HP Upgrade	Section 4.1.4
	Mini-split Heat Pump	Section 2.1.2
	Dual Enthalpy Air-side Economizer	Section 2.1.5
	Variable Frequency Drive	Section 4.1.7
	Programmable Thermostat	Section 4.1.8
Lighting	Lighting, Fixtures, Lamps, and Delamping	Section 1.1.1
	Sensors & Controls	Section 1.1.2
	LED Exit Signs	Section 4.2.3
Other	Compressed Air Leak Repair	Section 4.3.1

[41] 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.

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

4.1.1 Duct Testing and Sealing

4.1.1.1 Measure Description

This measure 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 through different programs listed in Table 4-2, and uses the impacts estimation approach described in this section.

Table 4-2. Programs that Offer this Measure

Program Name	Section
Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.1.1
Non-Residential Prescriptive Program, DSM Phase VI	Section 5.2.1
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.3.1
Non-Residential Multifamily Program, DSM Phase VIII	Section 11.3.3

4.1.1.2 Impacts Estimation Approach

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

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

Duct Testing and Sealing on 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.

For unitary-system heat pumps and AC units of $Size_{cool}$ < 65,000 Btu/h:

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

For unitary-system heat pumps of $Size_{heat}$ < 65,000 Btu/h:

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

For unitary-system heat pumps and AC units of $Size_{cool}$ ≥ 65,000 Btu/h,:

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

For unitary-system heat pumps of $Size_{heat}$ ≥ 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 summer peak demand reduction is calculated according to the following equation:

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

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

$$\Delta kW_{winter} = Size_{heat} \times \frac{1}{EER} \times \left(1 - \frac{n_{dist,pk,base}}{n_{dist,pk,ee}}\right) \times CF_{winter}$$

Duct Testing and Sealing on 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 systems with non-electric heating fuel will not have heating savings. For chiller systems with electric heating, savings are calculated as follows:

Chiller system with electric heating system < 65,000 Btu/h:

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

Chiller system with electric heating system ≥ 65,000 Btu/h:

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

The per measure gross coincident summer peak demand reduction is calculated according to the following equations:

Duct Testing and Sealing on Water-Cooled Chiller Systems:

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

Duct Testing and Sealing on Air-Cooled Chiller Systems:

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

Chiller systems with non-electric heating fuel will not have gross coincident winter peak demand reductions. For chiller systems with electric heating, savings are calculated as follows:

Air-cooled or water-cooled chiller system with electric resistance < 65,000 Btu/h:

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

Air-cooled or water-cooled chiller system with electric resistance ≥ 65,000 Btu/h:

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

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure summer peak gross coincident demand reduction
ΔkW_{winter} = per measure winter peak gross coincident demand reduction
$Size_{cool}$ = 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.

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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.
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 (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_{summer} = summer peak coincidence factor
CF_{winter} = winter peak coincidence factor
TRF = thermal regain factor

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

4.1.1.3 Input Variables

Table 4-3. 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[42]	kBtu/h (per unit)	Customer application
		Default = $Size_{cool}$ x 12 kBtu/ton		
SEER/IEER/EER /COP/HSPF	Variable	See customer application[43]	Btu/W-hr (COP is dimension -less)	Customer application
		Default: See Table 13-8, Table 13-9 and Table 13-12 in Sub-Appendix F2-III: Non-Residential HVAC Equipment Efficiency Ratings based on equipment type		ASHRAE 90.1-2013

[42] When customer-provided heating system size is <80% or >156% of customer-provided cooling system size, a default value will be used, instead. In such instances, it is assumed that the heating system size was incorrectly documented. The acceptable range is based on a review of the AHRI database across numerous manufacturers and heat pump types.
[43] The customer provided efficiency values are reviewed for reasonability. If the efficiency value is outside acceptable bounds the applicable default value is applied. The bounds were determined from a review of the AHRI database. Bounds are as follows: 9.90 < SEER < 46.2, 7.92 < EER < 22.11, 8.10 < IEER < 34.82, 8.82 < CEER < 16.50, 5.85 < HSPF < 15.07, 2.70 < COP < 15.01.

Component	Type	Value	Unit	Source(s)
$kW/ton_{full\ load}$	Variable	See customer application	kW/ton	Customer application
		Default: see Table 13-11 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 13-11 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[43]	Btu/W-h	Customer application
		Default: see Table 13-11 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[43]	kBtu/kW-h	Customer application
		Default: see Cooling Efficiencies of Water Chilling Packages Table 13-11 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	percent	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 4-4 and Table 4-5	percent	Customer application
		Default: No insulation, 30% leakage		New York TRM 2018, p. 242
$\bar{n}_{dist,ee,cool}$	Variable	See customer application along with Table 4-4 and Table 4-5	percent	Customer application
		Default: No insulation, 15% leakage		New York TRM 2018, p. 242
$\bar{n}_{dist,ee,heat}$	Variable	See customer application along with Table 4-4 and Table 4-5	percent	Customer application
		Default: No insulation, 15% leakage		New York TRM 2018, p. 242
$n_{dist,peak,base}$	Variable	See customer application along with Table 4-4 and Table 4-5	percent	Customer application
		Default: No insulation, 30% leakage		New York TRM 2018, p. 242
$n_{dist,peak,ee}$	Variable	See customer application along with Table 4-4 and Table 4-5	percent	Customer application
		Default: No insulation, 15% leakage		New York TRM 2018, p. 242
$EFLH_{heat}$	Fixed	See Table 13-5 in Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 423
$EFLH_{cool}$	Fixed	See Table 13-4 in Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 422

Component	Type	Value	Unit	Source(s)
CF_{summer}	Fixed	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	-	Maryland/Mid-Atlantic TRM v10, p. 291[44]
CF_{winter}		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	-	Maryland/Mid-Atlantic TRM v10, p. 291[45]

The New York TRM provides values for duct system efficiency for uninsulated ducts and ducts with R-6 insulation for four building types: assembly buildings, fast-food restaurants, full-service restaurant, and small retail. The average column in Table 4-4 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%.

[44] The New York TRM 2018 provides a CF with no specific source as a placeholder. Therefore, the same CFs are applied as used for other HVAC measure using the Maryland/Mid-Atlantic TRM v10.

[45] The Maryland/Mid-Atlantic TRM v10 does not provide a winter CF. Therefore, the summer CF is applied to the winter CF.

Table 4-4. Duct System Efficiency by Broad Building Type Categories[46]

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

46 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.

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Table 4-5. Duct System Efficiency Mapping to Building Type[47]

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

4.1.1.4 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.

4.1.1.5 Effective Useful Life

The effective useful life of this measure is provided in Table 4-6

Table 4-6. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	18.00	years	New York TRM 2019, p. 772
	Non-Residential Multifamily Program, DSM Phase VIII			

[47] 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 Maryland/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.

DSM Phase	Program Name	Value	Units	Source(s)
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)
V	Non-Residential Small Business Improvement Program, DSM Phase V	14.00	years	

4.1.1.6 Source(s)

The primary sources for this deemed savings approach is the New York TRM 2018, pp. 241-244, New York TRM 2019, pp. 681-686, Maryland/Mid-Atlantic TRM v10, pp. 422-423, and ASHRAE 90.1-2013.

4.1.1.7 Update Summary

Updates made to this section are described in Table 4-7.

Table 4-7. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Maryland/Mid-Atlantic TRM
	New table	Effective Useful Life (EUL) by program
	Equation	Added gross winter peak demand reduction equation
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 / 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

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

4.1.2.1 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.

This measure is offered through different programs listed in Table 4-8, and uses the impacts estimation approach described in this section.

Table 4-8. Programs that Offer this Measure

Program Name	Section
Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.1.2
Non-Residential Prescriptive Program, DSM Phase VI	Section 5.2.2
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.3.2
Non-Residential Multifamily Program, DSM Phase VIII	Section 11.3.2

4.1.2.2 Impacts Estimation Approach

Algorithms and inputs to calculate heating, cooling savings, and demand reduction 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.

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

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

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:

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

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

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

For air- and water-cooled chillers:

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

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:

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

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

$$\Delta kW_{summer} = Size_{cool} \times \frac{12\ kBtuh/ton}{EER} \times CF_{summer} \times TUF$$

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

$$\Delta kW_{winter} = \frac{\Delta kWh_{heat}}{EFLH_{heat}} \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross summer peak coincident demand reduction
ΔkW_{winter} = per measure gross winter peak coincident demand reduction
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

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$Size_{heat}$ = 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_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor

4.1.2.3 Input Variables

Table 4-9. 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[48]	kBtu/h	Customer application
		Default for HPs: 12 x $Size_{cool}$		
$EFLH_{cool}$	Variable	Refer to Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours ACs, HPs, & Chillers: Table 13-4	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 422
$EFLH_{heat}$	Variable	Refer to Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours HPs: Table 13-5	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 423

[48] When customer-provided heating system size is <80% or >156% of customer-provided cooling system size, a default value will be used, instead. In such instances, it is assumed that the heating system size was incorrectly documented. The acceptable range is based on a review of the AHRI database across numerous manufacturers and heat pump types.

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Component	Type	Value	Units	Source(s)
HSPF/SEER/IEER/ EER/COP	Variable	See customer application[49]	kBtu/kW-hour (except COP is dimensionless)	Customer application
		Refer to Sub-Appendix F2-III: Non-Residential HVAC Equipment Efficiency Ratings ACs & HPs: Table 13-9 Chillers: Table 13-11		ASHRAE 90.1-2013
IPLV	Variable	See customer application	Btu/W for air-cooled chillers; kW/ton for water-cooled chillers	Customer application
		Refer to Sub-Appendix F2-III: Non-Residential HVAC Equipment Efficiency Ratings Chillers: Table 13-11		ASHRAE 90.1-2013
RCA_Done[50]	Boolean	See customer application	True/False	Customer application
TUF	Variable	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	-	Maryland/Mid-Atlantic TRM v10, p. 316, California Impact Evaluation of 2013-14 Commercial Quality Maintenance Programs,[51] and Wisconsin Focus on Energy 2020 TRM, pp. 957-959.
CF_{summer}	Variable	Use system capacity to assign CF: < 11.5 tons = 0.588 ≥ 11.5 tons = 0.874	-	Maryland/Mid-Atlantic TRM v10, p. 316
CF_{winter}	Variable	Use system capacity to assign CF: < 11.5 tons = 0.588 ≥ 11.5 tons = 0.874	-	Maryland/Mid-Atlantic TRM v10, p. 316[52]

4.1.2.4 Default Savings

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

4.1.2.5 Effective Useful Life

The effective useful life of this measure is provided in Table 4-10

49 The customer provided efficiency values are reviewed for reasonability. If the efficiency value is outside acceptable bounds the applicable default value is applied. The bounds were determined from a review of the AHRI database. Bounds are as follows: 9.90 < SEER < 46.2, 7.92 < EER < 22.11, 8.10 < IEER < 34.82, 8.82 < CEER < 16.50, 5.85 < HSPF < 15.07, 2.70 < COP < 15.01.

50 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.

51 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.

52 The source TRM does not provide a winter CF. Therefore, the summer CF is applied to the winter CF.

Table 4-10. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	5.00	years	Maryland/Mid-Atlantic TRM v10, p. 316
	Non-Residential Multifamily Program, DSM Phase VIII			
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)
V	Non-Residential Small Business Improvement Program, DSM Phase V	14.00		

4.1.2.6 Source(s)

The primary sources for this deemed savings approach include the ASHRAE 90.1-2013, Maryland/Mid-Atlantic TRM v10, pp. 315-316, pp. 422-423, the California Impact Evaluation of 2013-14 Commercial Quality Maintenance Programs,[51] and the Wisconsin Focus on Energy TRM 2020, pp. 957-959.

4.1.2.7 Update Summary

Updates made to this section are described in Table 4-11.

Table 4-11. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers and versions of the Maryland/Mid-Atlantic TRM and Wisconsin TRM
	Equation	Added gross winter peak demand reduction equation
	New table	Effective Useful Life (EUL) by program
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: Maryland/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

4.1.3 Refrigerant Charge Adjustment

4.1.3.1 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.

This measure is offered through different programs listed in Table 4-12, and uses the impacts estimation approach described in this section.

Table 4-12. Programs that Offer this Measure

Program Name	Section
Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.1.3
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.3.3

4.1.3.2 Impacts Estimation Approach

Algorithms and inputs to calculate cooling, heating and demand reduction 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:

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

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:

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

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:

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

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

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$$\Delta kWh_{heat} = Size_{heat} \times \left(\frac{1}{COP \times 3.412\,Btuh/W}\right) \times EFLH_{heat} \times RCF$$

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

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

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

$$\Delta kW_{summer} = Size_{cool} \times \frac{12\,kBtuh/ton}{EER} \times RCF \times CF_{summer}$$

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

$$\Delta kW_{winter} = \frac{\Delta kWh_{heat}}{EFLH_{heat}} \times CF_{winter}$$

Where,

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

4.1.3.3 Input Variables

Table 4-13. Input Variables for Refrigerant Charge Adjustment

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

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Component	Type	Value	Units	Source(s)
$Size_{heat}$	Variable	See customer application[53]	kBtu/h	Customer application
		Default: = $Size_{cool}$ x 12 kBtu/h /ton		
$EFLH_{cool}$	Variable	See Table 13-4 in Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 422
$EFLH_{heat}$	Variable	See Table 13-5 in Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 423
EER/SEER	Variable	See customer application[54]	Btu/W-hr	Customer application
		See Table 13-8 and Table 13-9 in Sub-Appendix F2-III: Non-Residential HVAC Equipment Efficiency Ratings		ASHRAE 90.1 2013
HSPF/COP	Variable	See customer application[54]	Btu/W-hr (for HSPF); COP is -	Customer application
		See Table 13-9 in Sub-Appendix F2-III: Non-Residential HVAC Equipment Efficiency Ratings		ASHRAE 90.1 2013
RCF[55]	Variable	AC units: 0.027 HP units: 0.022	-	Maryland/Mid-Atlantic TRM v10, p. 315 and California 2013-2014 Evaluation Report[56]
CF_{summer}	Variable	Use system capacity to assign CF as follows: < 11.25 tons = 0.588 ≥ 11.25 tons = 0.874	-	Maryland/Mid-Atlantic TRM v10, p. 316
CF_{winter}	Variable	Use system capacity to assign CF as follows: < 11.25 tons = 0.588 ≥ 11.25 tons = 0.874	-	Maryland/Mid-Atlantic TRM v10, p. 316[57]

53 When customer-provided heating system size is <80% or >156% of customer-provided cooling system size, a default value will be used, instead. In such instances, it is assumed that the heating system size was incorrectly documented. The acceptable range is based on a review of the AHRI database across numerous manufacturers and heat pump types.

54 The customer provided efficiency values are reviewed for reasonability. If the efficiency value is outside acceptable bounds the applicable default value is applied. The bounds were determined from a review of the AHRI database. Bounds are as follows: 9.90 < SEER < 46.2, 7.92 < EER < 22.11, 8.10 < IEER < 34.82, 8.82 < CEER < 16.50, 5.85 < HSPF < 15.07, 2.70 < COP < 15.01.

55 RCF values were calculated utilizing the AC Tune-Up measure in the Maryland/Mid-Atlantic TRM v10 and electric savings due to coil cleaning and refrigerant charge adjustments found via extensive literature review.

56 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.

57 The source TRM does not provide a winter CF. Therefore, the summer CF is applied to the winter CF.

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4.1.3.4 Default Savings

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

4.1.3.5 Effective Useful Life

The effective useful life of this measure is provided in Table 4-14.

Table 4-14. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	5.00	years	Maryland/Mid-Atlantic TRM v10, p. 316
V	Non-Residential Small Business Improvement Program, DSM Phase V	14.00	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

4.1.3.6 Source(s)

The primary sources for this deemed savings approach include the ASHRAE 90.1-2013, Maryland/Mid-Atlantic TRM v10, pp. 315 - 316 and 422-423 as well as the California 2013-14 Impact Evaluation Report, pp. BB-2 to BB-3.

4.1.3.7 Update Summary

Updates made to this section are described in Table 4-15.

Table 4-15. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page number(s)/version of the Maryland/Mid-Atlantic TRM
	Equation	Added gross winter peak demand reduction equation
	New Table	Effective Useful Life (EUL) by program
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 Maryland/Mid-Atlantic TRM Clarified citation footnote of CPUC report
	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

4.1.4 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 2.1.1.

4.1.5 Mini-split Heat Pump

This measure is also offered through the Non-Residential Heating and Cooling Efficiency program. The savings approach is described in Section 2.1.2.

4.1.6 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 2.1.5.

4.1.7 Variable Frequency Drives

4.1.7.1 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 reduction 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 2.1.4. That program 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 through different programs listed in Table 4-16. The Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII, uses a different method than the impacts estimation approach described in this section.

Table 4-16. Programs that Offer this Measure

Program Name	Section
Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	Section 2.1.4
Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.1.7

Program Name	Section
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.2.1

4.1.7.2 Impacts 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, gross coincident summer peak demand reduction is calculated according to the following equation:

$$\Delta kW_{summer} = \frac{hp\ x\ 0.746\ x\ LF}{\eta} \times CF_{summer} \times DRF$$

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

$$\Delta kW_{winter} = \frac{hp\ x\ 0.746\ x\ LF}{\eta} \times CF_{winter} \times DRF$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak demand reduction
HP = motor rated horsepower
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_{summer} = summer peak coincidence factor
CF_{winter} = winter peak coincidence factor

4.1.7.3 Input Variables

Table 4-17. Input Values for Non-Residential Variable Frequency Drives

Component	Type	Value	Unit	Source(s)
HP	Variable	See customer application	horsepower	Customer application
LF	Fixed	0.65	-	Maryland/Mid-Atlantic TRM v10, p. 297
η	Variable	Default see Table 2-16. Baseline Motor Efficiency	-	NEMA Standards Publication Condensed MG 1-2007

Component	Type	Value	Unit	Source(s)
ESF	Variable	Default see Table 4-19	-	Mid-Atlantic TRM 2015 p. 370; Mid-Atlantic TRM v10, p. 301
DRF	Variable	Default see Table 4-19	-	Mid-Atlantic TRM 2015 p. 370; Mid-Atlantic TRM v10, p. 301
HOU	Variable	See Table 13-6 in Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours	hours, annual	Maryland/Mid-Atlantic TRM v10, pp. 299-301
CF_{summer}	Variable	0.28 for fan applications 0.55 for pump applications	-	Mid-Atlantic TRM 2015 p. 370; Maryland/Mid-Atlantic TRM v10, p. 299
CF_{winter}	Variable	0.28 for fan applications 0.55 for pump applications	-	Mid-Atlantic TRM 2015 p. 370; Maryland/Mid-Atlantic TRM v10, p. 299[58]

Table 4-18 provides the baseline motor efficiencies that are consistent with the minimum federal accepted motor efficiencies provided by the National Electrical Manufacturers Association (NEMA).[59]

Table 4-18. Baseline Motor Efficiency[60]

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

58 The source TRM does not provide a winter CF. Therefore, the summer CF is applied to the winter CF.

59 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.

60 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).

Table 4-19 provides the energy savings and demand reduction factors by the application and the baseline control types.

Table 4-19. Energy Savings and Demand Reduction Factors by Application

VFD Applications	ESF	DRF
Unknown VFD (Minimum)[61]	0.123	0.039
HVAC Fan VFD Savings Factors[62]		
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[63]		
Chilled Water Pump	0.633	0.460
Hot Water Pump	0.652	0.000
Unknown/Other Pump (Average)[64]	0.643	0.230

4.1.7.4 Default Savings

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

4.1.7.5 Effective Useful Life

The effective useful life of this measure is provided in Table 4-20.

Table 4-20. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	15.00	years	Maryland/Mid-Atlantic TRM v10, p. 301
VII	Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	15.00		Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)
V	Non-Residential Small Business Improvement Program, DSM Phase V	14.00		

61 Assigned for applications such as compressors, based on DNV research and judgement.
62 Mid-Atlantic TRM 2015, p. 370
63 Maryland/Mid-Atlantic TRM v10, p. 301.
64 Assigned for pumps not specifically listed in this table, such as condenser water pump.

4.1.7.6 Source(s)

The primary sources for this deemed savings approach are Mid-Atlantic TRM 2015, pp. 367-371 (for fans) and Maryland/Mid-Atlantic TRM v10, pp. 296-301 (for pumps).

4.1.7.7 Update Summary

Updates made to this section are described in Table 4-21.

Table 4-21. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Maryland/Mid-Atlantic TRM
	Equation	Added gross winter peak demand reduction equation
	New Table	Effective Useful Life (EUL) by program
2020	Section	Moved methodology from the retired Non-Residential Heating and Cooling Efficiency Program DSM III Section to this section.
v10	Source	Updated page numbers / version of the Mid-Atlantic TRM
	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

4.1.8 Programmable Thermostats

4.1.8.1 Measure Description

This measure involves the installation of programmable thermostats[65] for cooling and/or heating systems in spaces with no existing setback control. The programmable thermostat shall set back 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 is assumed to be in continuous ON mode during the unoccupied period with fans cycling to maintain the occupied-period temperature setpoints.

This measure is offered through different programs listed in Table 4-22 and uses the impacts estimation approach described in this section.

Table 4-22. Programs that Offer this Measure

Program Name	Section
Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.1.8
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.3.6

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

4.1.8.2 Impacts Estimation Approach

AC Units

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

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

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 summer peak demand reduction is considered to be zero since space conditioning equipment typically operates at maximum capacity during peak periods. There are no gross coincident winter peak demand reduction as AC units.

$$\Delta kW_{summer} = 0$$

$$\Delta kW_{winter} = 0$$

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:

$$\Delta kWh = \left[Size_{cool} \times \left(\frac{12}{IEER}\right) \times EFLH_{cool} \times ESF_{cool}\right] + \left[Size_{heat} \times EFLH_{heat} \times \left(\frac{1}{3.412 \times COP}\right) \times ESF_{heat}\right]$$

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

$$\Delta kW_{summer} = 0$$

$$\Delta kW_{winter} = 0$$

4.1.8.3 Input Variables

Table 4-23. 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
		Default[66] = $Size_{cool}$ x 12 kBtu/h / ton		
$EFLH_{heat}$	Variable	See Table 13-5 in Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 423
$EFLH_{cool}$	Variable	Refer to Table 13-4 in Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 422
SEER/IEER	Variable	See customer application[67]	kBtu/kW-hour	Customer application
		See Table 13-8 and Table 13-9 in Sub-Appendix F2-III: Non-Residential HVAC Equipment Efficiency Ratings		ASHRAE 90.1 2013, Table 6.8.1-1 and Table 6.8.1B
HSPF/COP	Variable	See customer application[67]	kBtu/kW-hour (except COP is dimensionless)	Customer application
		See Table 13-9 in Sub-Appendix F2-III: Non-Residential HVAC Equipment Efficiency Ratings		ASHRAE 90.1 2013, Table 6.8.1-1 and Table 6.8.1-2
ESF_{cool}	Fixed	0.090	-	NY TRM 2018, p. 263
ESF_{heat}	Fixed	0.068	-	NY TRM 2018, p. 263

4.1.8.4 Default Savings

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

4.1.8.5 Effective Useful Life

The effective useful life of this measure is provided in Table 4-24.

[66] When customer-provided heating system size is <80% or >156% of customer-provided cooling system size, a default value will be used, instead. In such instances, it is assumed that the heating system size was incorrectly documented. The acceptable range is based on a review of the AHRI database across numerous manufacturers and heat pump types.

[67] The customer provided efficiency values are reviewed for reasonability. If the efficiency value is outside acceptable bounds the applicable default value is applied. The bounds were determined from a review of the AHRI database. Bounds are as follows: 9.90 < SEER < 46.2, 7.92 < EER < 22.11, 8.10 < IEER < 34.82, 8.82 < CEER < 16.50, 5.85 < HSPF < 15.07, 2.70 < COP < 15.01.

Table 4-24. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	11.00	years	New York TRM 2018, p. 264
V	Non-Residential Small Business Improvement Program, DSM Phase V	14.00	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

4.1.8.6 Source(s)

The primary source for this deemed savings approach is the ASHRAE 90.1-2013, New York TRM 2018, pp. 262-264, and Maryland/Mid-Atlantic TRM v10, pp. 422-423.

4.1.8.7 Update Summary

Updates made to this section are described in Table 4-25.

Table 4-25. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Mid-Atlantic TRM
	New Table	Effective Useful Life (EUL) by program
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

4.2 Lighting End Use

4.2.1 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.

4.2.2 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.

4.2.3 LED Exit Signs

4.2.3.1 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.

This measure is offered through different programs listed in Table 4-26, and uses the impacts estimation approach described in this section.

Table 4-26. Programs that Offer this Measure

Program Name	Section
Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.2.3
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.4.3
Non-Residential Multifamily Program, DSM Phase VIII	Section 11.4.2

4.2.3.2 Impacts 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 summer peak demand reduction is calculated according to the following equation:

$$\Delta kW_{summer} = \frac{(Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee})}{1{,}000\,W/kW} \times WHF_{d,summer} \times CF_{summer} \times ISR$$

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

$$\Delta kW_{winter} = \frac{(Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee})}{1{,}000\,W/kW} \times WHF_{d,winter} \times CF_{winter} \times ISR$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak 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

$WHF_{d,summer}$ = waste heat factor for demand to account for cooling savings from efficient lighting
$WHF_{d,winter}$ = waste heat factor for demand to account for heating savings from efficient lighting
CF_{summer} = summer peak coincidence factor
CF_{winter} = winter peak coincidence factor
ISR = in-service rate, the percentage of rebated measures actually installed

4.2.3.3 Input Variables

Table 4-27. Input Values for LED Exit Sign Calculations

Component	Type	Value	Unit	Source(s)
Qty_{base}	Variable	See customer application	-	Customer application
Qty_{ee}	Variable	See customer application	-	Customer application
		Default: equal to Qty_{base}		
$watts_{base}$	Variable	See customer application	watts	Customer application
		Default: 16 W		Maryland/Mid-Atlantic TRM v10, p. 215, ENERGY STAR[68]
$watts_{ee}$	Variable	See customer application	watts	Customer application
		Default: 5 W LED		Maryland/Mid-Atlantic TRM v10, p. 314, ENERGY STAR
HOU	Fixed	8,760	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 215
WHF_e	Variable	See Table 13-15 in Sub-Appendix F2-IV: Non-Residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors Default savings assumed as lighting condition as Unconditioned space, WHFe=1.0	-	Maryland/Mid-Atlantic TRM v10, p. 215
$WHF_{d,summer}$	Variable	See Table 13-15 in Sub-Appendix F2-IV: Non-Residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors Default savings assumed as lighting condition as Unconditioned space, WHFe=1.0	-	Maryland/Mid-Atlantic TRM v10, p. 216

[68] 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).

Component	Type	Value	Unit	Source(s)
$WHF_{d,winter}$	Variable	See Table 13-15 in Sub-Appendix F2-IV: Non-Residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors Default savings assumed as lighting condition as Unconditioned space, WHFe=1.0	-	Maryland/Mid-Atlantic TRM v10, p. 216
CF_{summer}	Fixed	1.0	-	Maryland/Mid-Atlantic TRM v10, p. 216[69]
CF_{winter}	Fixed	1.0	-	Maryland/Mid-Atlantic TRM v10, p. 216[70]
ISR	Fixed	1.0	-	Maryland/Mid-Atlantic TRM v10, p. 215[71]

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.

4.2.3.4 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:

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

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

$$= 96.4\, kWh$$

The default per measure gross coincident summer peak demand reduction is calculated using the following calculation:

$$\Delta kW_{summer} = \frac{(Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee})}{1{,}000\, W/kW} \times WHF_{d,summer} \times CF_{summer} \times ISR$$

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

[69] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.
[70] Ibid.
[71] 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.

$$= 0.011\ kW$$

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

$$\Delta kW_{winter} = \frac{(Qty_{base} \times watts_{base} - Qty_{ee} \times watts_{ee})}{1{,}000\ W/kW} \times WHF_{d,winter} \times CF_{winter} \times ISR$$

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

$$= 0.011\ kW$$

4.2.3.5 Effective Useful Life

The effective useful life of this measure is provided in Table 4-28.

Table 4-28. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Multifamily Program, DSM Phase VIII	5.00	years	Maryland/Mid-Atlantic TRM v10, p. 216
	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII			
V	Non-Residential Small Business Improvement Program, DSM Phase V	14.00	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

4.2.3.6 Source(s)

The primary source for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 215-216.

4.2.3.7 Update Summary

Updates made to this section are described in Table 4-29.

Table 4-29. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Mid-Atlantic TRM
	Equation	Added gross winter peak demand reduction equation
	New Table	Effective Useful Life (EUL) by program

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

4.3 Compressed Air End Use

4.3.1 Air Compressor Leak Repair

4.3.1.1 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, DSM Phase VII in Section 7.1.2 but uses a different methodology. That program uses site-specific equipment and operating conditions for determining the system efficiency. The savings for this program uses deemed values for the system efficiency.

4.3.1.2 Impacts 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 summer peak demand reduction is calculated according to the following equation:

$$\Delta kW_{summer} = \frac{\Delta kWh \times CF_{summer}}{HOU}$$

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

$$\Delta kW_{winter} = \frac{\Delta kWh \times CF_{winter}}{HOU}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak 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_{summer} = summer coincidence factor of air compressor
CF_{winter} = winter coincidence factor of air compressor

4.3.1.3 Input Variables

Table 4-30. 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	-	Customer application
cfm/hp	Variable	See customer application	cfm/hp	Customer application
$Leak_{base}$	Variable	See customer application	-	Customer application
$Leak_{ee}$	Variable	See customer application	-	Customer application
kW/cfm	Fixed	0.17	kW/cfm	Michigan Energy Measure Database[72]
HOU	Fixed	6,240	hours, annual	Michigan Energy Measure Database 2018[73]
CF_{summer}	Fixed	0.865	-	Michigan Energy Measure Database 2018[74]
CF_{summer}	Fixed	0.865	-	Michigan Energy Measure Database 2018[75]

4.3.1.4 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.

4.3.1.5 Effective Useful Life

The effective useful life of this measure is provided in Table 4-31.

Table 4-31. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
V	Non-Residential Small Business Improvement Program, DSM Phase V	14.00	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

[72] Michigan Energy Measure Database 2018, at http://www.michigan.gov/mpsc, Document "FES-I20 Compressed Air Leak Survey and Repair Michigan 11282017.doc," August 317, p. 1.
[73] Ibid.
[74] Ibid.
[75] The source TRM does not provide a winter CF. Therefore, the summer CF is applied to the winter CF.

4.3.1.6 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," August 317.

4.3.1.7 Update Summary

Updates made to this section are described in Table 4-32.

Table 4-32. Summary of Update(s)

Version	Update Type	Description
2021	New Table	Effective Useful Life (EUL) by program
	Equation	Added gross winter peak demand reduction equation
2020	None	No Change
v10	None	No Change

5 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 5-1

Table 5-1. Non-Residential Prescriptive Program Measure List

End Use	Measure	Manual Section
Cooking	Commercial Convection Oven	Section 5.1.1
	Commercial Combination Oven	Section 5.1.2
	Commercial Fryer	Section 5.1.3
	Commercial Griddle	Section 5.1.4
	Commercial Hot Food Holding Cabinet	Section 5.1.5
	Commercial Steam Cooker	Section 5.1.6
HVAC	Duct Testing & Sealing	Section 4.1.1
	Unitary/Split AC/HP Tune-up	Section 4.1.2
	Variable Speed Drives on Kitchen Fan	Section 5.2.3
Plug Load	Smart Strip	Section 5.3.1
Refrigeration	Door Closer	Section 5.4.1
	Door Gasket	Section 5.4.2
	Commercial Freezers and Refrigerators – Solid Door	Section 5.4.3
	Commercial Ice Maker	Section 5.4.4
	Evaporator Fan ECM Retrofit	Section 5.4.5
	Evaporator Fan Control	Section 5.4.6
	Floating Head Pressure Control	Section 5.4.7
	Low/No-sweat Door Film	Section 5.4.8
	Refrigeration Night Cover	Section 5.4.9
	Refrigerator Coil Cleaning	Section 5.4.10
	Suction Pipe Insulation (Cooler & Freezer)	Section 5.4.11
	Strip Curtain (Cooler & Freezer)	Section 5.4.12
	Vending Machine Miser	Section 5.4.13

5.1 Cooking End Use

5.1.1 Commercial Convection Oven

5.1.1.1 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).

This measure is offered through different programs listed in Table 5-2, and uses the impacts estimation approach described in this section.

Table 5-2. Programs that Offer this Measure

Program Name	Section
Non-Residential Prescriptive Program, DSM Phase VI	Section 5.1.1
Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	Section 10.1.2

5.1.1.2 Impacts 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 summer peak demand reduction is calculated using the following equation:

$$\Delta kW_{summer} = \frac{\Delta kWh}{(Hours_{daily} \times Days)} \times CF_{summer}$$

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

$$\Delta kW_{winter} = \frac{\Delta kWh}{(Hours_{daily} \times Days)} \times CF_{winter}$$

where:

- ΔkWh = per measure gross annual electric energy savings
- ΔkW_{summer} = per measure gross coincident summer peak demand reduction
- ΔkW_{winter} = per measure gross coincident winter peak 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
- CF_{summer} = summer peak coincidence factor
- CF_{winter} = winter peak coincidence factor

5.1.1.3 Input Variables

Table 5-3. Input Parameters for Convection Oven

Component	Type	Value	Units	Source(s)
$Hours_{daily}$	Variable	See customer application	hours, daily	Customer application
		For defaults see Table 13-17 in Sub-Appendix F2-V: Non-Residential Commercial Kitchen Inputs		Maryland/Mid-Atlantic TRM v10, p. 383
Days	Variable	See customer application	days, annual	Customer application
		For defaults see Table 13-17 in Sub-Appendix F2-V: Non-Residential Commercial Kitchen Inputs		Maryland/Mid-Atlantic TRM v10, p. 383
lb_{daily}	Variable	See customer application	lb, daily	Customer application
		Default: 100		Maryland/Mid-Atlantic TRM v10, p. 383
E_{conv}	Fixed	0.0732	kWh/lb	Maryland/Mid-Atlantic TRM v10, p. 383
PC_{base}	Variable	Half Size: 45 Full Size: 90	lb/hour	Maryland/Mid-Atlantic TRM v10, p. 383
η_{base}	Variable	Half Size: 0.68 Full Size: 0.65	-	Maryland/Mid-Atlantic TRM v10, p. 383
$kW_{base,idle}$	Variable	Half Size:1.03 Full Size: 2.00	kW	Maryland/Mid-Atlantic TRM v10, p. 383

DNV

Component	Type	Value	Units	Source(s)
$kW_{ee,idle}$	Variable	Half Size: 1.00 Full Size: 1.60	kW	Maryland/Mid-Atlantic TRM v10, p. 382
PC_{ee}	Variable	Half Size: 50 Full Size: 90	lb/hour	Maryland/Mid-Atlantic TRM v10, p. 383
η_{ee}	Variable	Half Size: 0.71 Full Size: 0.71	-	Maryland/Mid-Atlantic TRM v10, p. 383
CF_{summer}	Fixed	1.0	-	Maryland/Mid-Atlantic TRM v10, p. 384[76]
CF_{winter}	Fixed	1.0	-	Maryland/Mid-Atlantic TRM v10, p. 384[76]

5.1.1.4 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 for a half size convection oven will be assigned as follows:

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

$$= \left[100\ lb\ \times \frac{0.0732\ kW/lb}{0.68} + 1.03\ kW \times \left(13.1\ hr - \frac{100\ \ lb/day}{45\ \ lb/hr}\right)\right] \times 307\ days$$

$$= 6{,}744\ kWh$$

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

$$= \left[100\ lb\ \times \frac{0.0732\ kW/lb}{0.71} + 1.00\ kW \times \left(13.1\ hr - \frac{100\ \ lb/day}{50\ \ lb/hr}\right)\right] \times 307\ days$$

$$= 6{,}572\ kWh$$

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

$$= 6{,}744\ kWh - 6{,}572\ kWh$$

$$= 172\ kWh$$

[76] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation and the coincidence factor is 1.0.

The default gross coincident summer peak demand reduction is calculated using the following calculation:

$$\Delta kW_{summer} = \frac{\Delta kWh}{(Hours_{daily} \times Days)} \times CF_{summer}$$

$$= \frac{172\ kWh}{(13.1\ hr \times 307\ day)} \times 1.0$$

$$= 0.043\ kW$$

The default gross coincident winter peak demand reduction is calculated using the following calculation:

$$\Delta kW_{winter} = \frac{\Delta kWh}{(Hours_{daily} \times Days)} \times CF_{winter}$$

$$= \frac{172\ kWh}{(13.1\ hr \times 307\ day)} \times 1.0$$

$$= 0.043\ kW$$

5.1.1.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-4.

Table 5-4. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	12.00	years	Maryland/Mid-Atlantic TRM v10, p. 385
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.1.1.6 Source(s)

The primary sources for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 382-385.

5.1.1.7 Update Summary

Updates made to this section are described in Table 5-5.

Table 5-5. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Mid-Atlantic TRM
	Input variable	Updated $Hour_{daily}$ and Days values and default customer building type
	Equation	Added equation for coincident winter peak demand reduction
	New Table	Effective Useful Life (EUL) by program
2020	None	No change
v10	Source	Updated page numbers / version of the Mid-Atlantic TRM
	Input variable	Clarified default assumption values

5.1.2 Commercial Combination Oven

5.1.2.1 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.

This measure is offered through different programs listed in Table 5-6, and uses the impacts estimation approach described in this section.

Table 5-6. Programs that Offer this Measure

Program Name	Section
Non-Residential Prescriptive Program, DSM Phase VI	Section 5.1.1
Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	Section 10.1.1

5.1.2.2 Impacts Estimation Approach

The baseline annual electric energy consumption is calculated as follows:

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

DNV

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

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

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 summer peak demand reduction is calculated using the following equation:

$$kW_{summer} = \frac{\Delta kWh}{(Hours_{daily} \times Days)} \times CF_{summer}$$

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

$$kW_{winter} = \frac{\Delta kWh}{(Hours_{daily} \times Days)} \times CF_{winter}$$

Per measure, gross annual water savings are calculated according to the following equation.

$$\Delta Water = (Water_{base} - Water_{ee}) \times Hours_{daily} \times PCT_{steam} \times Days$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak 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
$\Delta Water$ = per measure gross annual water savings$Hours_{daily}$ = 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
$Water_{base}$ = average water consumption rate of baseline combination ovens
$Water_{ee}$ = average water consumption rate of efficient combination ovens
CF_{summer} = summer peak coincidence factor
CF_{winter} = winter peak coincidence factor

5.1.2.3 Input Variables

Table 5-7. Input Parameters for Commercial Electric Combination Ovens

Component	Type	Value	Units	Source(s)
$Hours_{daily}$	Variable	See customer application	hours, daily	Customer application
		For defaults see Table 13-17 in Sub-Appendix F2-V: Non-Residential Commercial Kitchen Inputs		Maryland/Mid-Atlantic TRM v10, p. 387
Days	Variable	See customer application	days, annual	Customer application
		For defaults see Table 13-17 in Sub-Appendix F2-V: Non-Residential Commercial Kitchen Inputs		Maryland/Mid-Atlantic TRM v10, p. 387

Component	Type	Value	Units	Source(s)
lb_{daily}	Variable	See customer application Default: 200	pounds, daily	Customer application Maryland/Mid-Atlantic TRM v10, p. 387
PCT_{steam}	Variable	See customer application Default: 0.50	-	Customer application Maryland/Mid-Atlantic TRM v10, p. 387
PCT_{conv}	Variable	See customer application Default: 0.50	-	Maryland/Mid-Atlantic TRM v10, p. 387
E_{conv}	Fixed	0.0732	kWh/lb	Maryland/Mid-Atlantic TRM v10, p. 387
E_{steam}	Fixed	0.0308	kWh/lb	Maryland/Mid-Atlantic TRM v10, p. 387
$PC_{base,conv}$	Variable	<15 pans: 79 ≥15 pans: 166	lb/hr	Maryland/Mid-Atlantic TRM v10, p. 387
$PC_{base,steam}$	Variable	<15 pans: 126 ≥15 pans: 295	lb/hr	Maryland/Mid-Atlantic TRM v10, p. 387
$\eta_{base,conv}$	Fixed	0.72	-	Maryland/Mid-Atlantic TRM v10, p. 387
$\eta_{base,steam}$	Fixed	0.49	-	Maryland/Mid-Atlantic TRM v10, p. 387
$kW_{base,conv,idle}$	Variable	<15 pans: 1.320 ≥15 pans: 2.280	kW	Maryland/Mid-Atlantic TRM v10, p. 387
$kW_{base,steam,idle}$	Variable	<15 pans: 5.260 ≥15 pans: 8.710	kW	Maryland/Mid-Atlantic TRM v10, p. 387
$kW_{ee,conv,idle}$[77]	Variable	<15 pans: 1.299 ≥15 pans: 2.099	kW	Maryland/Mid-Atlantic TRM v10, p. 387
$kW_{ee,steam,idle}$[78]	Variable	<15 pans: 1.970 ≥15 pans: 3.300	kW	Maryland/Mid-Atlantic TRM v10, p. 387
$PC_{ee,conv}$	Variable	<15 pans: 119 ≥15 pans: 201	lb/hr	Maryland/Mid-Atlantic TRM v10, p. 387
$PC_{ee,steam}$	Variable	<15 pans: 177 ≥15 pans: 349	lb/hr	Maryland/Mid-Atlantic TRM v10, p. 387
$\eta_{ee,conv}$	Fixed	0.76	-	Maryland/Mid-Atlantic TRM v10, p. 387
$\eta_{ee,steam}$	Fixed	0.55	-	Maryland/Mid-Atlantic TRM v10, p. 387
$Water_{base}$	Fixed	40.0	gal/ hr	Ohio TRM 2010, p. 260[79]

77 Maryland/Mid-Atlantic TRM v10 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.

78 Maryland/Mid-Atlantic TRM v10 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, the list of qualifying ENERGY STAR® electric combination ovens was reviewed to determine t 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.

79 Ohio TRM Revised Edition, 2013. Food Service Technology Center (FSTC), based on assumption that baseline ovens use water at an average rate of 40 gal/hr while the efficient models use water at an average rate of 20 gal/hr.

DNV

Component	Type	Value	Units	Source(s)
$Water_{ee}$	Fixed	20.0	gal/ hr	Ohio TRM 2010, p. 260[80]
CF_{summer}	Fixed	1.0	-	Maryland/Mid-Atlantic TRM v10, p. 387[81]
CF_{winter}	Fixed	1.0	-	Maryland/Mid-Atlantic TRM v10, p. 387[81]

5.1.2.4 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:

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

$$= \left[200\ lb \times \frac{0.0732\ kWh/lb}{0.72} + 1.320\ kW \times \left(13.1\ hr - \frac{200\ lb}{79\ lb/hr}\right)\right] \times (1 - 0.50) \times 307\ days$$

$$= 5{,}263\ kWh$$

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

$$= \left[200\ lb \times \frac{0.0308\ kWh/lb}{0.49} + 5.260\ kW \times \left(13.1\ hr - \frac{200\ lb}{126\ lb/hr}\right)\right] \times 0.50 \times 307\ days$$

$$= 11{,}225\ kWh$$

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

[80] Ibid

[81] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation and the coincidence factor is 1.0.

$$= 5{,}263\ kWh + 11{,}225\ kWh$$

$$= 16{,}488\ kWh$$

The efficient annual electric energy consumption is calculated as follows:

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

$$= \left[200\ lb \times \frac{0.0732\ kWh/lb}{0.76} + 1.299\ kW \times \left(13.1\ hr - \frac{200\ lb}{119\ lb/hr}\right)\right] \times (1 - 0.50) \times 307\ days$$

$$= 5{,}234\ kWh$$

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

$$= \left[200\ lb \times \frac{0.0308\ kWh/lb}{0.55} + 1.970\ kW \times \left(13.1\ hr - \frac{200\ lb}{177\ lb/hr}\right)\right] \times 0.50 \times 307\ days$$

$$= 5{,}339\ kWh$$

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

$$= 5{,}234\ kWh + 5{,}339\ kWh$$

$$= 10{,}573\ kWh$$

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

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

$$= 16{,}488\ kWh - 10{,}573\ kWh$$

$$= 5{,}915\ kWh$$

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

$$\Delta kW_{summer} = \frac{\Delta kWh}{Hours_{daily} \times Days} \times CF_{summer}$$

$$= \frac{5{,}915\ kWh}{13.1\ hr \times 307\ days} \times 1.0$$

$$= 1.47\ kW$$

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

$$\Delta kW_{winter} = \frac{\Delta kWh}{Hours_{daily} \times Days} \times CF_{winter}$$

$$= \frac{5{,}915\ kWh}{13.1\ hr \times 307\ days} \times 1.0$$

$$= 1.47\ kW$$

Per measure, gross annual water savings are calculated according to the following equation.

$$\Delta Water = (Water_{base} - Water_{ee}) \times PCT_{steam} \times Hours_{daily} \times Days$$

$$= (40 - 20) gal/hr \times 0.5 \times 13.1\ hr \times 307 days$$

$$= 40{,}217 \text{ gallons}$$

5.1.2.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-8.

Table 5-8. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	12.00	years	Maryland/Mid-Atlantic TRM v10, p. 389

DNV

DSM Phase	Program Name	Value	Units	Source(s)
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.1.2.6 Source(s)

The primary sources for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, p. 383 and pp. 386-389.

5.1.2.7 Update Summary

Updates made to this section are described in Table 5-9.

Table 5-9. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Mid-Atlantic TRM
	Input Variable	• Updated $Hour_{daily}$ and Days values based on the customer building type • Added $Water_{base}$ and $Water_{ee}$ constants for water savings calculation
	Equation	• Added equation for coincident winter peak demand reduction • Added gross annual water savings equation
	Default Savings	Added default gross annual water savings value
	New Table	Effective Useful Life (EUL) by program
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

5.1.3 Commercial Fryer

5.1.3.1 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, fry-pot insulation reduces standby losses resulting in a lower idle energy rate. This measure applies to both standard-size and large-vat fryers.

DNV

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.[82]

This measure is offered through different programs listed in Table 5-10, and uses the impacts estimation approach described in this section.

Table 5-10. Programs that Offer this Measure

Program Name	Section
Non-Residential Prescriptive Program, DSM Phase VI	Section 5.1.3
Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	Section 10.1.4

5.1.3.2 Impacts 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 summer peak demand reduction is calculated using the following equation:

$$\Delta kW_{summer} = \frac{\Delta kWh}{(Hours_{daily} \times Days)} \times CF_{summer}$$

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

$$\Delta kW_{winter} = \frac{\Delta kWh}{(Hours_{daily} \times Days)} \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction

[82] 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.

DNV

ΔkW_{winter} = per measure gross coincident winter peak 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
CF_{summer} = summer peak coincidence factor
CF_{winter} = winter peak coincidence factor

5.1.3.3 Input Variables

Table 5-11. 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		Maryland/Mid-Atlantic TRM v10, p. 371
E_{fry}	Fixed	0.167	kWh/lb	Maryland/Mid-Atlantic TRM v10, p. 371
lb_{daily}	Variable	See customer application	lb, daily	Customer application
		Default: 150		Maryland/Mid-Atlantic TRM v10, p. 371
Days	Variable	See customer application	days, annual	Customer application
		Default: 365		Maryland/Mid-Atlantic TRM v10, p. 371
η_{base}	Variable	Standard fryer: 0.75 Large-vat fryer: 0.70	-	Maryland/Mid-Atlantic TRM v10, p. 371
$kW_{base,idle}$	Variable	Standard fryer: 1.05 Large-vat fryer: 1.35	kW	Maryland/Mid-Atlantic TRM v10, p. 371
PC_{base}	Variable	Standard fryer: 65 Large-vat fryer: 100	lb/hr	Maryland/Mid-Atlantic TRM v10, p. 371
η_{ee}	Variable	Standard fryer: 0.83 Large-vat fryer: 0.80	-	Maryland/Mid-Atlantic TRM v10, p. 371
$kW_{ee,idle}$	Variable	Standard fryer: 0.80 Large-vat fryer: 1.10	kW	Maryland/Mid-Atlantic TRM v10, p. 371
PC_{ee}	Variable	Standard fryer: 70 Large-vat fryer: 110	lb/hr	Maryland/Mid-Atlantic TRM v10, p. 371

Component	Type	Value	Units	Source(s)
CF_{summer}	Fixed	1.0	-	Maryland/Mid-Atlantic TRM v10, p. 371[83]
CF_{winter}	Fixed	1.0	-	Maryland/Mid-Atlantic TRM v10, p. 371[83]

5.1.3.4 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 summer peak demand reduction is calculated using the following calculation:

[83] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation and the coincidence factor is 1.0.

$$\Delta kW_{summer} = \frac{\Delta kWh}{(Hours_{daily} \times Days)} \times CF_{summer}$$

$$= \frac{2{,}377\ kWh}{(16\ hr \times 365\ days)} \times 1.0$$

$$= 0.407\ kW$$

The default per measure gross coincident winter peak demand reduction is calculated using the following calculation:

$$\Delta kW_{winter} = \frac{\Delta kWh}{(Hours_{daily} \times Days)} \times CF_{winter}$$

$$= \frac{2{,}377\ kWh}{(16\ hr \times 365\ days)} \times 1.0$$

$$= 0.407\ kW$$

5.1.3.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-12.

Table 5-12. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	12.00	years	Maryland/Mid-Atlantic TRM v10, p. 372
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.1.3.6 Source(s)

The primary sources for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 370-372.

5.1.3.7 Update Summary

Updates made to this section are described in Table 5-13.

Table 5-13. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Mid-Atlantic TRM
	Equation	Added equation for coincident winter peak demand reduction
	New Table	Effective Useful Life (EUL) by program
2020	None	No change
v10	Source	Updated page numbers / version of the Mid-Atlantic TRM

5.1.4 Commercial Griddle

5.1.4.1 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%.

This measure is offered through different programs listed in Table 5-14, and uses the impacts estimation approach described in this section.

Table 5-14. Programs that Offer this Measure

Program Name	Section
Non-Residential Prescriptive Program, DSM Phase VI	Section 5.1.4
Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	Section 10.1.3

5.1.4.2 Impacts 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 summer peak demand reduction is calculated using the following equation:

$$\Delta kW_{summer} = \frac{\Delta kWh}{(Hours_{daily} \times Days)} \times CF_{summer}$$

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

$$\Delta kW_{winter} = \frac{\Delta kWh}{(Hours_{daily} \times Days)} \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak 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
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
CF_{summer} = summer peak coincidence factor
CF_{winter} = winter peak coincidence factor

5.1.4.3 Input Variables

Table 5-15. Input Parameters for Commercial Griddle Measure

Component	Type	Value	Units	Source(s)
lb_{daily}	Variable	See customer application	lb, daily	Customer application
		Default: 100		Maryland/Mid-Atlantic TRM v10, p. 380
SqFt	Variable	See customer application	sq.ft.	Customer application

Component	Type	Value	Units	Source(s)
$Hours_{daily}$	Variable	See customer application	hours, daily	Customer application
		For defaults see Table 13-17 in Sub-Appendix F2-V: Non-Residential Commercial Kitchen Inputs		Maryland/Mid-Atlantic TRM v10, p. 380[84], for default the Dominion Energy 2020 Commercial Energy Survey Appendix B, p.3 weighted average of building types is used
Days	Variable	See customer application	days, annual	Customer application
		For defaults see Table 13-17 in Sub-Appendix F2-V: Non-Residential Commercial Kitchen Inputs		Maryland/Mid-Atlantic TRM v10, p. 38084, for default the Dominion Energy 2020 Commercial Energy Survey Appendix B, p.3 weighted average of building types is used
$E_{griddle}$	Fixed	0.139	kWh/lb	Maryland/Mid-Atlantic TRM v10, p. 380
PC_{base}	Fixed	5.83	lb/hr/sq.ft.	Maryland/Mid-Atlantic TRM v10, p. 380
η_{base}	Fixed	0.65	-	Maryland/Mid-Atlantic TRM v10, p. 380
$kW_{base,idle}$	Fixed	0.40	kW/sq.ft.	Maryland/Mid-Atlantic TRM v10, p. 380
$kW_{ee,idle}$	Fixed	0.32	kW/sq.ft.	Maryland/Mid-Atlantic TRM v10, p. 380
PC_{ee}	Fixed	6.67	lb/hr/sq.ft.	Maryland/Mid-Atlantic TRM v10, p. 380
η_{ee}	Fixed	0.70	-	Maryland/Mid-Atlantic TRM v10, p. 380
CF_{summer}	Fixed	1.0	-	Maryland/Mid-Atlantic TRM v10, p. 380[85]
CF_{winter}	Fixed	1.0	-	Maryland/Mid-Atlantic TRM v10, p. 380[85]

5.1.4.4 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.

5.1.4.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-16.

[84] Maryland/Mid-Atlantic TRM v. 10 uses customer application values for hours and days with a default provided. For consistency with commercial convection oven the same hours and days are used for his measure.

[85] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation and the coincidence factor is 1.0.

Table 5-16. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	12.00	years	Maryland/Mid-Atlantic TRM v10, p. 379
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.1.4.6 Source(s)

The primary source for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 379-381.

5.1.4.7 Update Summary

Updates made to this section are described in Table 5-11.

Table 5-11. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Mid-Atlantic TRM
	Equation	Added equation for coincident winter peak demand reduction
	New Table	Effective Useful Life (EUL) by program
2020	None	No change
v10	Source	Updated page numbers / version of the Mid-Atlantic TRM

5.1.5 Commercial Hot Food Holding Cabinet

5.1.5.1 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.

This measure is offered through different programs listed in Table 5-17, and uses the impacts estimation approach described in this section.

Table 5-17. Programs that Offer this Measure

Program Name	Section
Non-Residential Prescriptive Program, DSM Phase VI	Section 5.1.5
Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	Section 10.1.6

5.1.5.2 Impacts 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 summer peak demand reduction is calculated according to the following equation:

$$\Delta kW_{summer} = \frac{(watts_{base,idle} - watts_{ee,idle})}{1{,}000\ W/kW} \times CF_{summer}$$

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

$$\Delta kW_{winter} = \frac{(watts_{base,idle} - watts_{ee,idle})}{1{,}000\ W/kW} \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak 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
CF_{summer} = summer peak coincidence factor
CF_{winter} = winter peak coincidence factor

5.1.5.3 Input Variables

Table 5-18. Input Parameters for Hot Food Holding Cabinet

Component	Type	Value	Units	Source(s)
$watts_{base,idle}$	Variable	40 x Vol[86]	watts	Maryland/Mid-Atlantic TRM v10, p. 377

[86] Vol = the internal volume of the holding cabinet (ft^3) = volume of installed unit

Component	Type	Value	Units	Source(s)
$watts_{ee,idle}$	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	Maryland/Mid-Atlantic TRM v10, p. 377
Days	Variable	See customer application	days, annual	Customer application
		For defaults see Table 13-17 in Sub-Appendix F2-V: Non-Residential Commercial Kitchen Inputs		Maryland/Mid-Atlantic TRM v10, p. 380[87], for default the Dominion Energy 2020 Commercial Energy Survey Appendix B, p.3 weighted average of building types is used
$Hours_{daily}$	Variable	See customer application	hours, daily	Customer application
		For defaults see Table 13-17 in Sub-Appendix F2-V: Non-Residential Commercial Kitchen Inputs		Maryland/Mid-Atlantic TRM v10, p. 380[87], for default the Dominion Energy 2020 Commercial Energy Survey Appendix B, p.3 weighted average of building types is used
CFsummer	Fixed	1.0	-	Maryland/Mid-Atlantic TRM v10, p. 377[88]
CFwinter	Fixed	1.0	-	Maryland/Mid-Atlantic TRM v10, p. 377[88]

5.1.5.4 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.

5.1.5.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-19.

Table 5-19. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	12.00	years	Maryland/Mid-Atlantic TRM v10, p. 378
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

87 Maryland/Mid-Atlantic TRM v. 10 uses customer application values for hours and days with a default provided. For consistency with commercial convection oven the same hours and days for this measure.

88 No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation and the coincidence factor is 1.0.

5.1.5.6 Source(s)

The primary source for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 377-378.

5.1.5.7 Update Summary

Updates made to this section are described in Table 5-20.

Table 5-20. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Mid-Atlantic TRM
	Equation	Added equation for coincident winter peak demand reduction
	New Table	Effective Useful Life (EUL) by program
2020	None	No change
v10	Source	Updated page numbers / version of the Mid-Atlantic TRM

5.1.6 Commercial Steam Cooker

5.1.6.1 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.

This measure is offered through different programs listed in Table 5-21, and uses the impacts estimation approach described in this section.

Table 5-21. Programs that Offer this Measure

Program Name	Section
Non-Residential Prescriptive Program, DSM Phase VI	Section 5.1.6
Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	Section 10.1.5

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

$$\Delta kW_{summer} = \frac{\Delta kWh}{Hours_{daily} \times Days} \times CF_{summer}$$

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

$$\Delta kW_{winter} = \frac{\Delta kWh}{Hours_{daily} \times Days} \times CF_{winter}$$

Per measure, gross annual water savings is calculated according to the following equation:

$$\Delta Water = (GPH_{base} - GPH_{ee}) \times Hours_{daily} \times Days$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak 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
ΔWater = per measure gross annual water savings
$Hours_{daily}$ = 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
GPH_{base} = water consumption rate of baseline equipment
GPH_{ee} = water consumption rate of efficient equipment
CF_{summer} = summer peak coincidence factor
CF_{winter} = winter peak coincidence factor

5.1.6.3 Input Variables

Table 5-22. Input Parameters for Commercial Steam Cooker Measure

Component	Type	Value	Units	Source(s)
$Hours_{daily}$	Variable	See customer application	hours, daily	Customer application
		For defaults see Table 13-17 in Sub-Appendix F2-V: Non-Residential Commercial Kitchen Inputs		Maryland/Mid-Atlantic TRM v10, p. 380[89], for default the Dominion Energy 2020 Commercial Energy Survey Appendix B, p.3 weighted average of building types is used
Days	Variable	See customer application	days, annual	Customer application
		For defaults see Table 13-17 in Sub-Appendix F2-V: Non-Residential Commercial Kitchen Inputs		Maryland/Mid-Atlantic TRM v10, p. 380[90], for default the Dominion Energy 2020 Commercial Energy Survey Appendix B, p.3 weighted average of building types is used
lb_{daily}	Variable	See customer application	lb, daily	Customer application
		Default: 100		Maryland/Mid-Atlantic TRM v10, p. 374
Qty_{pans}	Variable	See customer application	pans	Customer application

[89] Maryland/Mid-Atlantic TRM v. 10 uses customer application values for hours and days with a default provided. For consistency with commercial convection oven the same hours and days for his measure.

[90] Maryland/Mid-Atlantic TRM v. 10 uses customer application values for hours and days with a default provided. For consistency with commercial convection oven the same hours and days for his measure.

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Component	Type	Value	Units	Source(s)
		Default: 3[91]		Maryland/Mid-Atlantic TRM v10, p. 374
E_{steam}	Fixed	0.0308	kWh/lb	Maryland/Mid-Atlantic TRM v10, p. 374
PC_{base}	Fixed	23.3	lb/hr, per pan	Maryland/Mid-Atlantic TRM v10, p. 375
η_{base}	Variable	Boilerless and Steam generator: 0.30 Boiler-based: 0.26 Default = Boiler-based: 0.26	-	Maryland/Mid-Atlantic TRM v10, p. 374[92]
$kW_{base,idle}$	Variable	Boilerless and Steam generator: 1.20 Boiler-based: 1.00 Default = Boiler-based: 1.00	kW	Maryland/Mid-Atlantic TRM v10, p. 375[92]
$kW_{ee,idle}$	Variable	3 pans: 0.40 4 pans: 0.53 5 pans: 0.67 6+ pans: 0.80 Default = 3 pans: 0.40	kW	Maryland/Mid-Atlantic TRM v10, p. 375
PC_{ee}	Fixed	16.7	lb/hr, per pan	Maryland/Mid-Atlantic TRM v10, p. 375
η_{ee}	Fixed	0.50	-	Maryland/Mid-Atlantic TRM v10, p. 374
PCT_{steam}	Fixed	0.40	-	Maryland/Mid-Atlantic TRM v10, p. 374
GPH_{base}	Variable	See Table 5-23	gal/hr	Maryland/Mid-Atlantic TRM v10, p. 376
GPH_{ee}	Variable	See Table 5-23	gal/hr	Maryland/Mid-Atlantic TRM v10, p. 376
CF_{summer}	Fixed	1.0	-	Maryland/Mid-Atlantic TRM v10, p. 374[93]
CF_{winter}	Fixed	1.0	-	Maryland/Mid-Atlantic TRM v10, p. 374[93]

Table 5-23. Water Consumption Rate for the Baseline and Energy Efficient Equipment

Parameter	No. of Pans	Baseline Model	Energy Efficient Model		
		All	Steam Generator	Boiler Based (default)	Boiler less
GPH	All	40	15	10	3

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

[92] For boilerless efficient units the steam generator baseline is applied. The source TRM doesn't include boilerless as an option for the base unit, however this type more closely matches the steam generator type.

[93] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation and the coincidence factor is 1.0.

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5.1.6.4 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:

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

$$= 100\ lb \times \frac{0.0308\ \ kWh/lb}{0.26} \times 307\ days$$

$$= 3{,}637\ kWh$$

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

$$= \left[(1 - 0.40) \times 1.20\ kW + 0.40 \times 23.3\ \frac{lb}{hr} \times 3\ pans \times \frac{0.0308\ \ kWh/lb}{0.26}\right] \times \left(13.1\ hr - \frac{100\ lb}{3\ pans\ \times\ 23.3\ \ lb/hr}\right) \times 307\ days$$

$$=\ 8{,}543\ kWh$$

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

$$= 100\ lb \times \frac{0.0308\ \ kWh/lb}{0.50} \times 307\ days$$

$$= 1{,}891\ kWh$$

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

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

$$\times\left(13.1\,hr - \frac{100\,lb}{3\,pans\ \times\ 16.7\ lb/hr}\right)\times 307\,days$$

$$= 1{,}010\,kWh$$

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

$$= (3{,}637\ \ kWh + 8{,}543\,kWh) - (1{,}891\,kWh + 1{,}010\,kWh)$$

$$= 9{,}279\,kWh$$

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

$$\Delta kW_{summer} \quad = \frac{\Delta kWh}{Hours_{daily}\times Days}\times CF_{summer}$$

$$= \frac{9{,}279\,kWh}{(13.1\ \ hr/day\ \times\ 307\ days)}\times 1.0$$

$$= 2.31\,kW$$

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

$$\Delta kW_{winter} \quad = \frac{\Delta kWh}{Hours_{daily}\times Days}\times CF_{summer}$$

$$= \frac{9{,}279\,kWh}{(13.1\ \ hr/day\ \times\ 307\ days)}\times 1.0$$

$$= 2.31\,kW$$

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

$$\Delta Water \quad = (GPH_{base} - GPG_{ee})\times Hours_{daily}\times Days$$

$$= (40-10)\times 13.1\times 307$$

$$= 120{,}651\ gallons$$

5.1.6.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-24.

Table 5-24. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	12.00	years	Maryland/Mid-Atlantic TRM v10, p. 376
VII	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.1.6.6 Source(s)

The primary source for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 373-376.

5.1.6.7 Update Summary

Updates made to this section are described in Table 5-25.

Table 5-25. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Mid-Atlantic TRM
	Equation	• Added equation for coincident winter peak demand reduction • Added gross annual water savings equation
	Input Variable	• Added GPHbase and GPHee for water savings calculation
	New Table	Effective Useful Life (EUL) by program
2020	None	No change
v10	Source	Updated page numbers / version of the Mid-Atlantic TRM
	Input Variable	Updated PC_{ee} value

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

5.2.1 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 4.1.1.

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5.2.2 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 4.1.2.

5.2.3 Variable Speed Drives on Kitchen Exhaust Fan

5.2.3.1 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.

5.2.3.2 Impacts 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.

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

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

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

There are no gross coincident summer and winter peak demand reduction:

$$\Delta kW_{summer} = 0\ kW$$

$$\Delta kW_{winter} = 0\ kW$$

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_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak 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

5.2.3.3 Input Variables

Table 5-26. 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	90%	-	New Jersey Clean Energy Program Protocols to Measure Resource Savings: Revisions to FY2020 Protocols, p. 117

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Component	Type	Value	Units	Source(s)
η_{EF}	Variable	See customer application	-	Customer application
		Default: See Table 2-16. Baseline Motor Efficiency based on hp_{EF}		See Table 2-16. Baseline Motor Efficiency in Section 2.1.4
HOU	Variable	See customer application	hours, annual	Customer application
		Default: See Table 5-27 that follows		New Jersey Clean Energy Program Protocols to Measure Resource Savings: Revisions to FY2020 Protocols, p. 118
$\Delta Power_{EF}$	Variable	See Table 5-27 that follows	-	New Jersey Clean Energy Program Protocols to Measure Resource Savings: Revisions to FY2020 Protocols, p. 118
$SqFt_{Kitchen}$	Variable	See customer application	sq.ft.	Customer application
$\frac{cfm}{SqFt}$	Fixed	0.7	cfm/sq.ft.	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 FY2020 Protocols, p. 117
Δcfm_{EF}	Variable	See Table 5-27 that follows	-	New Jersey Clean Energy Program Protocols to Measure Resource Savings: Revisions to FY2020 Protocols, p. 118
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 2020, p. 117
$MUA_{electricheat}$	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 2020, p. 117

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Table 5-27. Annual Hours of Use, Power, and Airflow Reductions due to VSD[94]

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

5.2.3.4 Default Savings

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

5.2.3.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-28.

Table 5-28. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.2.3.6 Source(s)

The primary source for this deemed savings approach include the New Jersey Clean Energy Program Protocols to Measure Resource Savings 2020, pp. 116-119.

5.2.3.7 Update Summary

Updates made to this section are described in Table 5-29.

Table 5-29. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the New Jersey Clean Energy Program Protocols to Measure Resource Savings
	Equation	Removed peak coincident demand reduction equation as the source TRM does not attribute peak savings to this measure.
	New Table	Effective Useful Life (EUL) by program

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

Version	Update Type	Description
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

5.3 Plug Load End Use

5.3.1 Smart Strip

5.3.1.1 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.

5.3.1.2 Impacts Estimation Approach

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

$$\Delta kWh = 26.9\ kWh$$ [95]

Per measure, gross coincident summer and winter peak demand reduction is assigned no reduction, as follows:

$$\Delta kW_{summer} = 0\ kW$$

$$\Delta kW_{winter} = 0\ kW$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak demand reduction

[95] 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.

5.3.1.3 Effective Useful Life

The effective useful life of this measure is provided in Table 5-30.

Table 5-30. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.3.1.4 Source(s)

The primary source for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 368-369.

5.3.1.5 Update Summary

Updates made to this section are described in Table 5-31.

Table 5-31. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Mid-Atlantic TRM
	New Table	Effective Useful Life (EUL) by program
2020	Source	Updated page numbers / version of the Mid-Atlantic TRM

5.4 Refrigeration End Use

5.4.1 Door Closer (Cooler and Freezer)

5.4.1.1 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.[96] 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.

[96] 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."

This measure is offered through different programs listed in Table 5-32, and uses the impacts estimation approach described in this section.

Table 5-32. Programs that Offer this Measure

Program Name	Section
Non-Residential Prescriptive Program, DSM Phase VI	Section 5.4.1
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.6.5

5.4.1.2 Impacts Estimation Approach

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

Cooler Doors:

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

Freezer Doors:

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

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

Cooler Doors:

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

Freezer Doors:

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

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

Cooler Doors:

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

Freezer Doors:

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

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction

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ΔkW_{winter} = per measure gross coincident winter peak 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

5.4.1.3 Input Variables

Table 5-33. Door Closer Gross Annual Electric Energy Savings and Gross Coincident Demand Reduction (per Closer)[97]

Refrigeration Unit Type	Location	Walk-In		Reach-In	
		ΔkWh	ΔkW[98]	ΔkWh	ΔkW[98]
Cooler (31°F to 55°F)	Richmond	43.9	0.0050	102	0.0116
	Norfolk	43.5	0.0050	101	0.0115
	Roanoke	42.4	0.0048	98	0.0112
	Sterling	42.3	0.0048	98	0.0112
	Arlington	42.3	0.0048	98	0.0112
	Charlottesville	42.7	0.0049	99	0.0113
	Farmville	44.8	0.0051	104	0.0119
	Fredericksburg	43.3	0.0049	101	0.0115
	Elizabeth City	43.1	0.0049	100	0.0114
	Rocky Mount	43.6	0.0050	101	0.0116
Freezer (-35°F to 30 °F)	Richmond	172.7	0.0197	439	0.0501
	Norfolk	170.2	0.0194	433	0.0494
	Roanoke	165.8	0.0189	422	0.0481
	Sterling	167.2	0.0191	425	0.0486
	Arlington	167.2	0.0191	425	0.0486
	Charlottesville	167.5	0.0191	426	0.0486
	Farmville	176.4	0.0201	449	0.0512
	Fredericksburg	171.8	0.0196	437	0.0499
	Elizabeth City	168.4	0.0192	428	0.0489
	Rocky Mount	171.4	0.0196	436	0.0498

5.4.1.4 Default Savings

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

[97] Methodology from Tennessee Valley Authority TRM 2018, pp. 127-129, was used. Savings were revised using the TMY3 weather data for Dominion Energy service territory locations.

[98] The source TRM calculates coincident kW as the kWh savings divided by 8,760 hours. This implies that the demand reduction is the same in all periods. This is the best information available. Therefore, the same coincident peak demand reduction for summer and winter periods.

- 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.

5.4.1.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-34.

Table 5-34. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	8.00	years	Tennessee Valley Authority TRM 2018, p. 128
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.4.1.6 Source(s)

The primary source for this deemed savings approach is the Tennessee Valley Authority TRM 2018, pp. 127-129.

5.4.1.7 Update Summary

Updates made to this section are described in Table 5-35.

Table 5-35. Summary of Update(s)

Version	Update Type	Description
2021	New Table	Effective Useful Life (EUL) by program
	Inputs	Added large office building type and expanded to 10 weather stations
	Equation	Added equation for coincident winter peak demand reduction
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)

5.4.2 Door Gasket (Cooler and Freezer)

5.4.2.1 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.

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5.4.2.2 Impacts Estimation Approach[99]

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

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

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

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

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak 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

5.4.2.3 Input Variables

Table 5-36. Input Values for Door Gasket Savings Calculations

Component	Type	Value	Unit	Source(s)
ΔkWh/ft	Variable	See Table 5-37	kWh/ft	Tennessee Valley Authority TRM 2018, p. 123.
ΔkW/ft	Variable	See Table 5-37	kW/ft	Tennessee Valley Authority TRM 2018, p. 123.[100]
L	Variable	See customer application	feet	Customer application
		Default = 15		DNV engineering judgment

[99] Electric energy and demand reduction 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.

[100] The source TRM calculates coincident kW as the kWh savings divided by 8,760 hours. This implies that the demand reduction is the same in all periods. This is the best information available. Therefore, the same coincident peak demand reduction for summer and winter periods.

Table 5-37. Door Gasket Gross Annual Electric Energy and Gross Coincident Demand Reduction (per Linear Foot) [101]

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

5.4.2.4 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 coincident summer peak demand savings per unit cooler/freezer will be assigned according to the following calculation:

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

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

101 Tennessee Valley Authority 2018, p. 123 – 124, methodology was used. TMY3 weather data was applied for Richmond, VA and Charlotte, NC. The difference between these locations was less than 1%. Richmond values are applied for all locations across Dominion Energy service territory as the variance is negligible across locations..

$$= 0.006\ kW$$

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

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

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

$$= 0.006\ kW$$

5.4.2.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-38.

Table 5-38. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.4.2.6 Source(s)

The primary source for this deemed savings approach is the Tennessee Valley Authority TRM 2018, pp. 123-124.

5.4.2.7 Update Summary

Updates made to this section are described in Table 5-39.

Table 5-39. Summary of Update(s)

Version	Update Type	Description
2021	New Table	Effective Useful Life (EUL) by program
	Equation	Added equation for coincident winter peak demand reduction
2020	Source	No Change
v10	Source	Updated page numbers / version of the Tennessee Valley Authority TRM

5.4.3 Commercial Freezers and Refrigerators

5.4.3.1 Measure Description

This measure involves the installation of an ENERGY STAR® qualified commercial freezer or refrigerator. These models are designed for warm commercial kitchen environments with frequent door opening. Qualifying equipment utilize a variety of energy-efficient components such as ECM fan motors, hot gas anti-sweat heaters, or high efficiency compressors. Qualifying equipment must not exceed the maximum daily kWh values determined by the volume, door type, and configuration specified by Version 4.0 specifications that went into effect March 2017.

This measure is offered through different programs listed in Table 5-40, and uses the impacts estimation approach described in this section.

Table 5-40. Programs that Offer this Measure

Program Name	Section
Non-Residential Prescriptive Program, DSM Phase VI	Section 5.4.3
Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	Section 10.3.1

5.4.3.2 Impacts Estimation Approach

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

$$\Delta kWh = (kWh_{base} - kWh_{ee}) \times Days$$

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

$$\Delta kW_{summer} = \left(\frac{\Delta kWh}{EFLH}\right) \times CF_{summer}$$

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

$$\Delta kW_{winter} = \left(\frac{\Delta kWh}{EFLH}\right) \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak 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_{summer} = summer peak coincidence factor
CF_{winter} = winter peak coincidence factor

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5.4.3.3 Input Variables

Table 5-41. Input Parameters for Commercial Freezers and Refrigerator Measure

Component	Type	Value	Units	Source(s)
kWh_{base}	Variable	See Table 5-42	kWh	Federal Standards, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2013)[102]
kWh_{ee}	Variable	See Table 5-43	kWh	ENERGY STAR® Certified-commercial-refrigerators-and-freezers[103]
Days	Fixed	365	days, annual	Constant
EFLH	Fixed	5,858	hours, annual	Maryland/Mid-Atlantic TRM v10, pp. 335 and 339[104]
CF_{summer}	Fixed	0.77	-	Maryland/Mid-Atlantic TRM v10, pp. 335 and 339[105]
CF_{winter}	Fixed	0.77	-	Maryland/Mid-Atlantic TRM v10, pp. 335 and 339[106]
Volume	Variable	See customer application	cubic feet	Customer application

Table 5-42. 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 5-43. Calculated Efficient Unit Daily Energy Consumption from Volume

Equipment Type and Volume (ft^3)	Refrigerator Energy, kWh	Freezer Energy, kWh
Vertical Closed		

[102] The Maryland/Mid-Atlantic TRM v10 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.

[103] 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

[104] 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.

[105] 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.

[106] The Maryland/Mid-Atlantic TRM v10 only provides summer peak CF. Without winter peak CF value available, the summer peak CF is applied.

Equipment Type and Volume (ft^3)	Refrigerator Energy, kWh	Freezer Energy, kWh
Solid Door		
$V < 15\ ft^3$	=0.022 x V + 0.970	=0.210 x V + 0.900
$15 \le V < 30\ ft^3$	=0.066 x V + 0.310	=0.120 x V + 2.248
$30 \le V < 50\ ft^3$	=0.040 x V + 1.090	=0.285 x V - 2.703
$V \ge 50\ ft^3$	=0.024 x V + 1.890	=0.142 x V + 4.445
Transparent Door		
$V < 15\ ft^3$	=0.095 x V + 0.445	=0.232 x V + 2.360
$15 \le V < 30\ ft^3$	=0.050 x V + 1.120	=0.232 x V + 2.360
$30 \le V < 50\ ft^3$	=0.076 x V + 0.340	=0.232 x V + 2.360
$V \ge 50\ ft^3$	=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

5.4.3.4 Default Savings

This measure does not have default savings.

5.4.3.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-44.

Table 5-44. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Midstream Energy Efficiency Products Program, DSM Phase VIII	12.00	years	Mid-Atlantic TRM 2020, p. 335
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.4.3.6 Source(s)

The primary source for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 334–341.

5.4.3.7 Update Summary

Updates made to this section are described in Table 5-45.

Table 5-45. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Mid-Atlantic TRM
	Equation	Added equation for coincident winter peak demand reduction
	New Table	Effective Useful Life (EUL) by program
2020	None	No change
v10	Source	Updated page numbers / version of the Mid-Atlantic TRM
	Input Variable	Updated CF value

5.4.4 Commercial Ice Maker

5.4.4.1 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.

5.4.4.2 Impacts Estimation Approach

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

$$\Delta kWh = \left(\frac{kWh_{base} - kWh_{ee}}{100\ lb}\right) \times H_{rated} \times DC \times Days$$

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

$$\Delta kW_{summer} = \frac{\Delta kWh}{8{,}760\ hours} \times CF_{summer}$$

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

$$\Delta kW_{winter} = \frac{\Delta kWh}{8{,}760\ hours} \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak demand reduction
kWh_{base} = energy consumption per 100 lb of ice produced by the baseline equipment

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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_{summer}	= summer peak coincidence factor
CF_{winter}	= winter peak coincidence factor

5.4.4.3 Input Variables

Table 5-46. Input Parameters for Commercial Ice Maker

Component	Type	Value	Units	Source(s)
kWh_{base}	Variable	Batch-type: See Table 5-47 Table 5-47. Batch-Type Ice Machine Baseline Efficiencies Continuous-type: see Table 5-48	kWh/ 100-lb of ice	Federal Standards 80 FR 4645[107]
kWh_{ee}	Variable	CEE Tier 2 Water-cooled: see Table 5-49 Air-cooled: ENERGY STAR® batch-type: see Table 5-50 ENERGY STAR® continuous-type: see Table 5-51	kWh/ 100-lb of ice	CEE Tier 2[108] and ENERGY STAR®[109] 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[110]: Default = CEE Tier 2 Water-cooled = cube or nugget		
H_{rated}	Variable	See customer application	pound, daily	From application
DC	Fixed	0.5	-	Arkansas TRM 2019 Volume 8.1 p. 498[111]
Days	Fixed	365	days, annual	Arkansas TRM 2019 Volume 8.1 p. 498
CF_{summer}	Fixed	1.0	-	Arkansas TRM 2019 Volume 8.1 p. 498[112]
CF_{winter}	Fixed	1.0	-	Arkansas TRM 2019 Volume 8.1 p. 498[112]

107 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.
108 Currently qualifying ice makers meet CEE requirements effective 7/01/2011. Qualifying equipment is updated quarterly, available here: https://library.cee1.org/content/commercial-kitchens-ice-machines-qualifying-product-list.
109 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.
110 ENERGY STAR® does not include water-cooled ice makers. If both of these are indicated to be true on the application, it is assumed the equipment type is CEE Tier-2 water-cooled.
111 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.
112 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. No winter CF is provided so summer CF is used.

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Table 5-47. Batch-Type Ice Machine Baseline Efficiencies[113]

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

Table 5-48. 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

[113] 10 CFR Part 431 Subpart H, Automatic Commercial Ice Makers. 77 FR 1591. January 11, 2012. New minimum requirements effective January 28, 2018.

Ice Machine Type	Type of Cooling	Harvest Rate (lb/day)	kWh_{base} (kWh/100-lb ice)
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 5-49. CEE Tier 2 Ice Machine Qualifying Efficiencies[114]

Ice Type[115]	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 Type	Water	< 1,000	4.8 – 0.0017 x H_{rated}
		≥ 1,000	3.2

Table 5-50. Batch-Type ENERGY STAR® Ice Machine Qualifying Efficiencies[116]

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}

114 CEE Requirements don't differentiate 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

115 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 differentiate 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.

116 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. The current requirements are found here: https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers/key_product_criteria

Ice Machine Type	Type of Cooling	Harvest Rate (lb/day)	kWh_{ee} (kWh/100-lb ice)
		≥ 110 and < 200	10.56 – 0.0215 x H_{rated}
		≥ 200 and ≤ 4,000	6.25

Table 5-51. Continuous-Type ENERGY STAR® Ice Machine Qualifying Efficiencies[117]

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

5.4.4.4 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.

5.4.4.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-52.

Table 5-52. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.4.4.6 Source(s)

The primary source for this deemed savings approach is the Arkansas TRM 2019 Version 8.1, pp. 495–498.

117 Ibid

5.4.4.7 Update Summary

Updates made to this section are described in Table 5-53.

Table 5-53. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Arkansas TRM
	Equation	Added equation for coincident winter peak demand reduction
	New Table	Effective Useful Life (EUL) by program
2020	Source	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 Prescriptive Program)
v10	Source	Updated page numbers of the Arkansas TRM
	Equation	Updated equation

5.4.5 Evaporator Fan Electronically Commutated Motor (ECM) Retrofit (Reach-In and Walk-in Coolers and Freezers)

5.4.5.1 Measure Description

The measure replaces the baseline shaded-pole (SP), evaporator-fan motors with electronically-commuted motors (ECMs). 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.

This measure is offered through different programs listed in Table 5-54, and uses the impacts estimation approach described in this section.

Table 5-54. Programs that Offer this Measure

Program Name	Section
Non-Residential Prescriptive Program, DSM Phase VI	Section 5.4.5
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.6.3

5.4.5.2 Impacts Estimation Approach

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

DNV

$$\Delta kWh = \frac{(watts_{base} - watts_{ee})}{1{,}000\ W/kW} \times \%\,ON \times HOU \times WHF_e$$

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

$$\Delta kW_{summer} = \frac{(watts_{base} - watts_{ee})}{1{,}000\ W/kW} \times WHF_d \times CF_{summer}$$

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

$$\Delta kW_{winter} = \frac{(watts_{base} - watts_{ee})}{1{,}000\ W/kW} \times WHF_d \times CF_{winter}$$

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 5-55—are to be used.

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident summer peak demand reduction
$watts_{base}$ = rated wattage of existing/baseline evaporator fan motor
$watts_{ee}$ = rated wattage of electronically commutated evaporator fan motor
%ON = duty cycle (effective run time) of controlled 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_{summer} = summer peak demand Coincidence Factor
CF_{winter} = winter peak demand Coincidence Factor

5.4.5.3 Input Variables

Table 5-55. Input Values for ECM Evaporator Savings Calculations

Component	Type	Value	Unit	Source(s)
$watts_{base}$	Variable	See customer application	watts	Customer application
		Defaults: See Table 5-56		Wisconsin TRM 2020, p. 795
$watts_{ee}$	Variable	See customer application	watts	Customer application
		Defaults: See Table 5-56		Wisconsin TRM 2020, p. 795
%ON	Variable	Uncontrolled: 0.978 ON/OFF Control: 0.636	-	Maryland/Mid-Atlantic TRM v10, p. 349

Component	Type	Value	Unit	Source(s)
		Multispeed Control/ Unknown (default): 0.692		
HOU	Fixed	8,760	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 346
WHF_e	Variable	Low Temp (-35˚F - -1˚F): 1.76 Med Temp (0˚F - 30˚F): 1.76 High Temp (31˚F - 55˚F): 1.38	-	Maryland/Mid-Atlantic TRM v10, p. 347
		Default: 1.38		
WHF_d	Variable	Low Temp (-35˚F - -1˚F): 1.76 Med Temp (0˚F - 30˚F): 1.76 High Temp (31˚F - 55˚F): 1.38	-	Maryland/Mid-Atlantic TRM v10, p. 347
		Default: 1.38		
CF_{summer}	Fixed	0.978	-	Maryland/Mid-Atlantic TRM v10, p. 349[118]
CF_{winter}	Fixed	0.978	-	Maryland/Mid-Atlantic TRM v10, p. 349[119]

Table 5-56. Total Deemed Savings for ECM Evaporator Fan Motor

System Type	Motor size	$watts_{base}$	$watts_{ee}$	Source
Walk-In Cooler	<1/20 hp	79.38	26.64	Wisconsin TRM 2020, pp. 795-796
Walk-In Cooler	1/20 - 1 hp	211.66	71.04	Wisconsin TRM 2020, pp. 795-796
Walk-In Cooler or unknown (default)	Unknown (default)[120]	151.19	50.74	Wisconsin TRM 2020, pp. 795-796
Walk-In Freezer	<1/20 hp	90.70	30.44	Wisconsin TRM 2020, pp. 795-796
Walk-In Freezer	1/20 - 1 hp	244.22	81.97	Wisconsin TRM 2020, pp. 795-796
Walk-In Freezer	Unknown (default)[121]	188.95	63.42	Wisconsin TRM 2020, pp. 795-796
Reach-In Cooler	<1/20 hp or 1/20 - 1 hp	31.00	12.00	Maryland/Mid-Atlantic TRM v10, p. 346
Reach-In Freezer	<1/20 hp or 1/20 - 1 hp	31.00	12.00	Maryland/Mid-Atlantic TRM v10, p. 346

5.4.5.4 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:

[118] Maryland/Mid-Atlantic TRM v10, p. 347. 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 (percent on), 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.

[119] Maryland/Mid-Atlantic TRM v10, p. 347. Winter coincidence factors were not provided in source TRM. Similar to summer CF, the Note: the CF referenced load shape study does not provide winter peak reduction relative to the change in baseline and ECM power. Instead, the reduction is provided in terms of the ECM wattage. There isn't enough information provided to determine the winter CF. Therefore, the percentage on is used as an approximation.

[120] Applied the Wisconsin TRM 2020 weighted average of all of the motors surveyed, 45.7% <1/20 hp and 54.3% 1/20 – 1 hp.

[121] Applied the Wisconsin TRM 2020 weighted average of all of the motors surveyed, 36.0% <1/20 hp and 64.0% 1/20 – 1 hp.

$$\Delta kWh = \frac{(watts_{base} - watts_{ee})}{1{,}000\, W/kW} \times \%ON \times HOU \times WHF_e$$

$$= \frac{(31\, W - 12\, W)}{1{,}000\, W/kW} \times 0.978 \times 8{,}760\, hours \times 1.38$$

$$= 225\, kWh$$

The default per measure, gross coincident summer peak demand reduction will be assigned according to the following calculation:

$$\Delta kW_{summer} = \frac{(watts_{base} - watts_{ee})}{1{,}000\, W/kW} \times WHF_d \times CF_{summer}$$

$$= \frac{(31\, W - 12\, W)}{1{,}000\, W/kW} \times 1.38 \times 0.978$$

$$= 0.026\, kW$$

The default per measure, gross coincident winter peak demand reduction will be assigned according to the following calculation:

$$\Delta kW_{winter} = \frac{(watts_{base} - watts_{ee})}{1{,}000\, W/kW} \times WHF_d \times CF_{winter}$$

$$= \frac{(31\, W - 12\, W)}{1{,}000\, W/kW} \times 1.38 \times 0.978$$

$$= 0.026\, kW$$

5.4.5.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-57.

Table 5-57. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	15.00	years	Maryland/Mid-Atlantic TRM v10, p. 347

DSM Phase	Program Name	Value	Units	Source(s)
VI	Non-Residential Prescriptive Program	6.30	years	Program design assumptions (weighted average of EULs across all measures offered by program and their planned uptake)

5.4.5.6 Source(s)

The primary source for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 346-347 and Wisconsin TRM 2020, pp. 394-397.

5.4.5.7 Update Summary

Updates made to this section are described in Table 5-58.

Table 5-58. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Mid-Atlantic TRM
	Input Variable	• Updated values of $watts_{base}$, $watts_{ee}$ • Added default values for Walk-in Coolers and Freezers with unknown motor size • Replaced DC_{evap} with %ON and updated values
	Equation	Added equation for coincident winter peak demand reduction
	New Table	Effective Useful Life (EUL) by program
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 and Wisconsin TRM

5.4.6 Evaporator Fan Control (Cooler and Freezer)

5.4.6.1 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 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.

This measure is offered through different programs listed in Table 5-59, and uses the impacts estimation approach described in this section.

Table 5-59. Programs that Offer this Measure

Program Name	Section
Non-Residential Prescriptive Program, DSM Phase VI	Section 5.4.6
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.6.4

5.4.6.2 Impacts Estimation Approach

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

$$\Delta kWh \quad = hp \times \frac{kW}{hp} \times (\%On_{base} - \%On_{ee}) \times HOU \times WHF_e$$

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

$$\Delta kW_{summer} \quad = hp \times \frac{kW}{hp} \times \; WHF_d \times CF_{summer}$$

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

$$\Delta kW_{winter} \quad = hp \times \frac{kW}{hp} \times \; WHF_d \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak 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_{summer} = summer peak demand Coincidence Factor
CF_{winter} = winter peak demand Coincidence Factor

DNV

5.4.6.3 Input Variables

Table 5-60. 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: If system is walk-in: 1/15 hp If system is reach-in: 1/62 hp		Maryland/Mid-Atlantic TRM v10, p. 348[122]
kW/hp	Variable	Single-speed: 2.088 kW/hp Multi-speed: 0.758 kW/hp	kW/hp	Maryland/Mid-Atlantic TRM v10, p. 348
		Default: 0.758 kW/hp		
$\%On_{base}$	Fixed	0.978	-	Maryland/Mid-Atlantic TRM v10, p. 348
$\%On_{ee}$	Variable	Single-speed (on/off controls): 0.636 Multi-speed: 0.692	-	Maryland/Mid-Atlantic TRM v10, p. 349
		Default: 0.692		
HOU	Fixed	8,760	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 349
WHFe	Variable	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	-	Maryland/Mid-Atlantic TRM v10, p.349
		Default: 1.38		
WHFd	Variable	Low Temp (-35˚F - -1˚F): 1.76 Med Temp (0˚F - 30˚F): 1.76 High Temp (31˚F - 55˚F): 1.38	-	Maryland/Mid-Atlantic TRM v10, p. 349
		Default: 1.38		
CF_{summer}	Fixed	Single-speed (on/off controls): 0.11 Multi-speed: 0.31	-	Maryland/Mid-Atlantic TRM v10, p. 349[123]
CF_{winter}	Fixed	Single-speed (on/off controls): 0.12 Multi-speed: 0.31	-	Maryland/Mid-Atlantic TRM v10, p. 349[124]

5.4.6.4 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 walk-in and reach-in coolers with a multi-speed evaporator motor will be assigned according to the following calculation, respectively:

[122] Default value not provided in Mid-Atlantic TRM, however the original source is the Commercial Refrigeration Loadshape Project NEEP 2015, p. 5, finds that the average new ECM motor is rated at 1/15 hp. This majority of motors studied were 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

[123] The Maryland/Mid-Atlantic TRM references the Commercial Refrigeration Loadshape Project NEEP 2015 for the summer CF. The CFs are calculated and separated out for single-speed and multispeed summer CFs.

[124] The Maryland/Mid-Atlantic TRM does not provide a winter CF. The referenced Commercial Refrigeration Loadshape Project NEEP 2015 is used to calculate winter CF.

DNV

Walk-in

$$\Delta kWh = hp \times \frac{kW}{hp} \times (\%On_{base} - \%On_{ee}) \times HOU \times WHF_e$$

$$= \frac{1}{15} hp \times 0.758 \frac{kW}{hp} \times (0.978 - 0.692) \times 8{,}760\ hours \times 1.38$$

$$= 175\ kWh$$

Reach-in

$$\Delta kWh = hp \times \frac{kW}{hp} \times (\%On_{base} - \%On_{ee}) \times HOU \times WHF_e$$

$$= \frac{1}{62} hp \times 0.758 \frac{kW}{hp} \times (0.978 - 0.692) \times 8{,}760\ hours \times 1.38$$

$$= 42\ kWh$$

The corresponding default per measure, gross coincident demand reduction for walk-in and reach-in coolers will be assigned according to the following calculation, respectively:

Walk-In

$$\Delta kW_{summer} = hp \times \frac{kW}{hp} \times WHF_d \times CF_{summer}$$

$$= \frac{1}{15} hp \times 0.758 \frac{kW}{hp} \times 1.38 \times 0.26$$

$$= 0.018\ kW$$

$$\Delta kW_{winter} = hp \times \frac{kW}{hp} \times WHF_d \times CF_{winter}$$

$$= \frac{1}{15} hp \times 0.758 \frac{kW}{hp} \times 1.38 \times 0.26$$

$$= 0.018\ kW$$

Reach-in

$$\Delta kW_{summer} = hp \times \frac{kW}{hp} \times WHF_d \times CF_{summer}$$

$$= \frac{1}{62} hp \times 0.758 \frac{kW}{hp} \times 1.38 \times 0.26$$

$$= 0.0042\ kW$$

$$\Delta kW_{winter} = hp \times \frac{kW}{hp} \times WHF_d \times CF_{winter}$$

$$= \frac{1}{62} hp \times 0.758 \frac{kW}{hp} \times 1.38 \times 0.26$$

$$= 0.0042\ kW$$

5.4.6.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-61.

Table 5-61. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	10.00	years	Maryland/Mid-Atlantic TRM v10, p. 349
VI	Non-Residential Prescriptive Program, DSM Phase VI)	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.4.6.6 Source(s)

The primary source for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 348-349.

5.4.6.7 Update Summary

Updates made to this section are described in Table 5-62

Table 5-62: Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Mid-Atlantic TRM
	Input variable	Updated hp values
	Default Calculation	Updated default calculation
	Equation	Added equation for coincident winter peak demand reduction
	New Table	Effective Useful Life (EUL) by program
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 hp, $\%On_{base}$ and $\%On_{ee}$ values

5.4.7 Floating Head Pressure Control

5.4.7.1 Measure Description

This measure realizes energy savings by adjusting the head-pressure setpoint in response to different outdoor temperatures. Without controls, the head-pressure setpoint is based on the design conditions regardless of the actual condenser operating conditions. 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.

5.4.7.2 Impacts Estimation Approach

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

$$\Delta kWh = \frac{kWh}{hp} \times hp_{comp}$$

Per measure, gross coincident summer peak and winter peak demand reduction is zero[125], as shown in the following equations:

$$\Delta kW_{summer} = 0$$

$$\Delta kW_{winter} = 0$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction

[125] Gross coincident demand savings are zero since savings are realized during off-peak periods. No demand reduction is expected from this measure.

ΔkW_{winter} = per measure gross coincident winter peak demand reduction
kWh/hp = floating head pressure control gross annual electric energy savings per compressor horsepower (hp)
hp_{comp} = compressor horsepower

5.4.7.3 Input Variables

Table 5-63. Input Values for Floating Head Pressure Control Savings Calculations

Component	Type	Value	Unit	Source(s)
kWh/hp	Variable	See Table 5-64	kWh/ horsepower/ year	Maine Commercial TRM v2020.4, p. 95
		Default = 509 (High Temperature, Scroll Compressor)		
hp_{comp}	Variable	See customer application.	horsepower	Customer application
		Default = 5		Vermont TRM 2015, p. 132[126]

Table 5-64. Floating-head Pressure Control Gross Annual Electric Energy Savings (per Horsepower)[127]

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

5.4.7.4 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:

$$\Delta kWh = \frac{kWh}{hp} \times hp_{comp}$$

$$= 509\ \frac{kWh}{hp} \times 5\ hp$$

$$= 2{,}545\ kWh$$

[126] Vermont TRM 2015, p. 132. Assumes “5 HP compressor data used, based on average compressor size.”
[127] Efficiency Maine Commercial TRM v2020.4, Table 16 – Floating Head Pressure Control kWh Savings per Horsepower, p. 95.

The default gross coincident summer peak demand reduction will be assigned according to the following calculation:

$$\Delta kW_{summer} = 0$$

The default gross coincident winter peak demand reduction will be assigned according to the following calculation:

$$\Delta kW_{winter} = 0$$

5.4.7.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-65.

Table 5-65. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.4.7.6 Source(s)

The primary source for this deemed savings approach is the Maine Commercial TRM v2020, pp. 94-95. Additionally, the Vermont TRM 2015, p. 132, was used to estimate the default compressor size.

5.4.7.7 Update Summary

Updates made to this section are described in Table 5-66.

Table 5-66. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page number / version of the Maine Commercial TRM
	New Table	Effective Useful Life (EUL) by program
2020	None	No change
v10	Source	Updated page numbers / version of the Maine Commercial TRM

5.4.8 Low/Anti-Sweat Door Film

5.4.8.1 Measure Description

This measure involves the installation of window film on the doors of refrigerated cooler and freezer cases. Anti-sweat film prevents condensation 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 eliminates the need for these heaters.[128] 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.

5.4.8.2 Impacts 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 summer peak demand reduction is assigned as follows:

$$\Delta kW_{summer} = kW_{ASDH} \times DC \times WHF_d \times CF_{summer}$$

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

$$\Delta kW_{winter} = kW_{ASDH} \times DC \times WHF_d \times CF_{winter}$$

Where:

ΔkWh = per measure, gross annual electric energy savings
ΔkW_{summer} = per measure, gross coincident summer peak demand reduction
ΔkW_{winter} = per measure, gross coincident winter peak 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} = summer peak Coincidence Factor
CF_{winter} = winter peak Coincidence Factor

5.4.8.3 Input Variables

Table 5-67. 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		Maryland/Mid-Atlantic TRM v10, p. 344[129]

[128] 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.

[129] Original source: Cadmus. 2015. Commercial Refrigeration Loadshape Project. Lexington, MA.

Component	Type	Value	Units	Source(s)
DC	Variable	No controls: 0.907 On/Off controls: 0.589 Micropulse controls: 0.428	-	Maryland/Mid-Atlantic TRM v10, p. 344
		Default: 0.428	-	Maryland/Mid-Atlantic TRM v10, p. 345
HOU	Fixed	8,760	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 345
WHF_e	Variable	Low Temp (-35˚F - -1˚F): 1.50 Med Temp (0˚F - 30˚F): 1.50 High Temp (31˚F - 55˚F): 1.25	-	Maryland/Mid-Atlantic TRM v10, p. 345
		Default: 1.25		
WHF_d	Variable	Low Temp (-35˚F - -1˚F): 1.50 Med Temp (0˚F - 30˚F): 1.50 High Temp (31˚F - 55˚F): 1.25	-	Maryland/Mid-Atlantic TRM v10, p. 345
		Default: 1.25		
CF_{summer}	Variable	Freezer (Low/Med Temp) case: On/Off controls: 0.21 Micropulse: 0.30 No controls: 1.00	-	Maryland/Mid-Atlantic TRM v10, pp. 345[130]. 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		
CF_{winter}	Variable	Freezer (Low/Med Temp) case: On/Off controls: 0.20 Micropulse: 0.29 No controls: 1.00		Maryland/Mid-Atlantic TRM v10, pp. 345[131]. Without heater controls, uniform load throughout year is assumed.
		Default for freezer case: 0.20		
		Refrigerated (High Temp) case: On/Off controls: 0.24 Micropulse: 0.35 No controls: 1.00		
		Default for refrigerated case: 0.24		

5.4.8.4 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:

130 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.
131 Applied the same methodology that Maryland/Mid-Atlantic TRM v10, p. 345 uses for summer CF and applied to the winter peak values provided by Cadmus. 2015. Commercial Refrigeration Loadshape Project

$$\Delta kWh = kW_{ASDH} \times DC \times HOU \times WHF_e$$

$$= 0.13\ kW \times 0.428 \times 8{,}760\ hours \times 1.25$$

$$= 609.3\ kWh$$

And the default per measure, gross coincident summer peak demand reduction is:

$$\Delta kW_{summer} = kW_{ASDH} \times DC \times WHF_d \times CF_{summer}$$

$$= 0.13\ kW \times 0.428 \times 1.25 \times 0.25$$

$$= 0.017\ kW$$

And the default per measure, gross coincident winter peak demand reduction is:

$$\Delta kW_{winter} = kW_{ASDH} \times DC \times WHF_d \times CF_{winter}$$

$$= 0.13\ kW \times 0.428 \times 1.25 \times 0.24$$

$$= 0.017\ kW$$

5.4.8.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-68.

Table 5-68. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.4.8.6 Source(s)

The primary source for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 344–345. The method was adapted from the ASDH controls methodology.

5.4.8.7 Update Summary

Updates made to this section are described in Table 5-69.

Table 5-69. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page number / version of the Mid-Atlantic TRM
	Equation	Added equation for coincident winter peak demand reduction
	New Table	Effective Useful Life (EUL) by program
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

5.4.9 Refrigeration Night Cover

5.4.9.1 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.

This measure is offered through different programs listed in Table 5-70, and uses the impacts estimation approach described in this section.

Table 5-70. Programs that Offer this Measure

Program Name	Section
Non-Residential Prescriptive Program, DSM Phase VI	Section 5.4.9
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.6.2

5.4.9.2 Impacts 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 measure, gross coincident summer and winter peak demand reduction is zero,[132] as shown in the following equations:

$$\Delta kW_{summer} = 0$$

[132] Mid-Atlantic TRM 2020, p. 343. Assumed that continuous covers are deployed at night; therefore, no demand savings occur during the peak period.

$$\Delta kW_{winter} = 0$$

Where:

ΔkWh	= per measure gross annual electric energy savings
ΔkW_{summer}	= per measure gross coincident demand reduction
ΔkW_{winter}	= 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

5.4.9.3 Input Variables

Table 5-71. 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		Maryland/Mid-Atlantic TRM v10, p. 342[133]
L	Variable	See customer application.	feet	Customer application
		Default = 6		DNV judgment
COP[134]	Fixed	2.20	-	Maryland/Mid-Atlantic TRM v10, p. 342
ESF[135]	Fixed	0.09	-	Maryland/Mid-Atlantic TRM v10, p. 342
HOU	Fixed	8,760	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 343

5.4.9.4 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:

$$\Delta kWh = \frac{load}{\frac{12{,}000\, Btu/hour}{ton}} \times L \times \frac{3.516\, kW/ton}{COP} \times ESF \times HOU$$

[133] Mid-Atlantic 2020, p. 342. 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.

[134] Kuiken et al, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, KEMA, March 22, 2010.

[135] Mid-Atlantic TRM 2020, p. 342. 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 summer and winter peak demand reduction will be assigned as follows:

$$\Delta kW_{summer} = 0$$

$$\Delta kW_{winter} = 0$$

5.4.9.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-72.

Table 5-72. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	5.00	years	Maryland/Mid-Atlantic TRM v10, p. 343
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.4.9.6 Source(s)

The primary source for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 342-343.

5.4.9.7 Update Summary

Updates made to this section are described in Table 5-73.

Table 5-73. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Maryland/Mid-Atlantic TRM v10
	New Table	Effective Useful Life (EUL) by program
2020	None	No change
v10	Source	Updated page numbers / version of the Mid-Atlantic TRM
	Default Savings	Corrected mistaken default annual energy savings

5.4.10 Refrigeration Coil Cleaning

5.4.10.1 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.

5.4.10.2 Impacts Estimation Approach

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

$$\Delta kWh = \frac{load}{12{,}000\,\frac{BTU/h}{ton}} \times \frac{3.156\,\frac{kW}{ton}}{COP} \times HOU \times ESF$$

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

$$\Delta kW_{summer} = \frac{load}{12{,}000\,\frac{BTU/h}{ton}} \times \frac{3.156\,\frac{kW}{ton}}{COP} \times DRF_{summer}$$

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

$$\Delta kW_{winter} = \frac{load}{12{,}000\,\frac{BTU/h}{ton}} \times \frac{3.156\,\frac{kW}{ton}}{COP} \times DRF_{winter}$$

Where:

ΔkWh = per measure gross annual energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{summer} = per measure gross coincident summer peak 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_{summer} = savings factor attributable to coil cleaning for summer peak demand reduction
DRF_{winter} = savings factor attributable to coil cleaning for winter peak demand reduction
HOU = annual hours of use

DNV

5.4.10.3 Input Variables

Table 5-74. Input Values for Refrigeration Coil Cleaning Savings Calculations

Component	Type	Value	Unit	Source(s)
load	Variable	See customer application	Btu/h	Customer application
COP	Variable	Low Temp (-35°F – -1°F): 1.30 Med Temp (0°F – 30°F): 1.30 High Temp (31°F – 55°F): 2.51	-	Pennsylvania TRM V3, 2019, p. 155
HOU	Variable	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[136]
ESF	Fixed	0.048	-	Qureshi and Zubair (2011)[137]
DRF_{summer}	Fixed	0.022	-	Qureshi and Zubair (2011)[138]
DRF_{winter}	Fixed	0.022	-	Qureshi and Zubair (2011)[139]

5.4.10.4 Default Savings

If the proper values are not supplied, no default savings will be awarded for this measure.

5.4.10.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-75.

Table 5-75. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.4.10.6 Source(s)

The primary sources for this deemed savings approach are the Pennsylvania TRM V3, 2019, p.155 and the technical paper titled, "Performance degradation of a vapor compression refrigeration system under fouled conditions."[137]

[136] 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.

[137] 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.

[138] Ibid.

[139] The source study for this measure does not provide a winter DRF. Therefore, the summer DRF is applied.

5.4.10.7 Update Summary

Updates made to this section are described in Table 5-76.

Table 5-76. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Pennsylvania TRM
	Input Value	Updated COP value
	Equation	Added equation for coincident winter peak demand reduction
	New Table	Effective Useful Life (EUL) by program
2020	None	No Change
V10	None	No Change

5.4.11 Suction Pipe Insulation (Cooler and Freezer)

5.4.11.1 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.

5.4.11.2 Impacts 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 summer and winter peak demand reduction are calculated according to the following equation:

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

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

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident demand reduction
ΔkW_{winter} = per measure gross coincident demand reduction
$\Delta kWh/ft$ = gross annual electric energy savings per linear foot
$\Delta kW/ft$ = gross coincident demand reduction per linear foot
L = length of insulation applied in linear feet

DNV

5.4.11.3 Input Variables

Table 5-77. Input Values for Suction Pipe Insulation Savings Calculations

Component	Type	Value	Unit	Source(s)
ΔkWh/ft	Variable	See Table 5-78	kWh/feet	Pennsylvania TRM V3, 2019, p. 178
ΔkW/ft	Variable	See Table 5-78	kW/feet	Pennsylvania TRM V3 2019, p. 178[140]
L	Variable	See customer application	feet	Customer application
		Default = 1		Per unit savings

Table 5-78. Suction Pipe Insulation Gross Annual Electric Energy Savings and Gross Coincident Demand Reduction (per Linear Foot)[141]

Refrigeration Type	ΔkWh/year·ft	ΔkW/ft
Low Temperature (-35°F - -1°F)	85.5	0.016
Medium Temperature (0°F - 30°F)	85.5	0.016
High Temperature (31°F - 55°F)	24.8	0.005

5.4.11.4 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:

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

$$= 0.005\, kW/ft \times 1 ft$$

140 The source TRM only provides summer peak demand reduction. Therefore, the summer CF is applied to the winter CF.
141 Pennsylvania TRM V3 2019, p. 178, original source: Southern California Edison Company, “Insulation of Bare Refrigeration Suction Lines”, Work Paper WPSCNRRN0003.

$$= 0.005\ kW$$

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

$$= 0.005\ kW/ft \times 1ft$$

$$= 0.005\ kW$$

5.4.11.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-79.

Table 5-79. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.4.11.6 Source(s)

The primary source for this deemed savings approach is the Pennsylvania TRM V3 2019, pp. 177–178.

5.4.11.7 Update Summary

Updates made to this section are described in Table 5-80.

Table 5-80. Summary of Update(s)

Version	Update Type	Description
2021	Source	• Updated page numbers / version of the Pennsylvania TRM • Updated footnote
	Input Values	Update annual electric energy savings per linear foot (ΔkWh/ft) and coincident demand reduction per linear foot (ΔkW/ft)
	Equation	Added equation for coincident winter peak demand reduction
	New Table	Effective Useful Life (EUL) by program
2020	None	No change
v10	Source	Updated footnote

DNV

5.4.12 Strip Curtain (Cooler and Freezer)

5.4.12.1 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.

This measure is offered through different programs listed in Table 5-81, and uses the impacts estimation approach described in this section.

Table 5-81. Programs that Offer this Measure

Program Name	Section
Non-Residential Prescriptive Program, DSM Phase VI	Section 5.4.12
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.6.7

5.4.12.2 Impacts 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 summer peak demand reductions are calculated according to the following equation:

$$\Delta kW_{summer} \quad = \frac{\Delta kWh}{HOU} \times CF_{summer}$$

Per measure, gross coincident winter peak demand reductions are calculated according to the following equation:

$$\Delta kW_{winter} \quad = \frac{\Delta kWh}{HOU} \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak demand reduction
kWh/sq.ft. = average annual kilowatt hour savings per square foot of infiltration barrier
Area = area of doorway where strip curtains are installed
CF_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor

5.4.12.3 Input Variables

Table 5-82. Input Values for Strip Curtain Savings Calculations

Component	Type	Value	Unit	Source(s)
ΔkWh/sq.ft.	Variable	See Table 5-83	kWh/sq.ft.	Pennsylvania TRM V3, 2019, p. 167
		Default = 19		Assume convenience store, Cooler
Area	Variable	See Table 5-84	sq.ft.	Pennsylvania TRM V3, 2019, p. 168
		Default = 21		Assume convenience store
HOU	Fixed	8,760	hours, annual	Wisconsin TRM 2019, p. 822
CF_{summer}	Fixed	1.0		Wisconsin TRM 2019, p. 822[142]
CF_{summer}	Fixed	1.0		Wisconsin TRM 2019, p. 822[142]

Table 5-83. Strip Curtain Gross Annual Electric Energy Savings (per sq.ft.)

Type		Annual Electric Energy Savings per Square Foot (ΔkWh/sq.ft.)
Grocery	Cooler	123
	Freezer	535
Convenience Store	Cooler	19
	Freezer	31
Restaurant	Cooler	24
	Freezer	129
Refrigerator	Cooler	410

Table 5-84. Doorway Area Assumptions (sq.ft.)

Type		Doorway Area (sq.ft.)
Grocery	Cooler	21
	Freezer	21
Convenience Store	Cooler	21
	Freezer	21
Restaurant	Cooler	21
	Freezer	21
Refrigerator	Cooler	120

142 The Wisconsin TRM 2019 does not provide summer or winter CFs. However, the equation for peak demand is kWh savings divided by annual hours implying a CF of 1.0.

5.4.12.4 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 for the baseline conditions—according to the following calculation:

$$\Delta kWh = kWh/ft^2 \times Area$$

$$=19\ kWh/ft^2 \times 21\ ft^2$$

$$= 399\ kWh$$

The default per measure, gross coincident summer peak demand reduction will be assigned according to the following calculation:

$$\Delta kW_{summer} = \frac{\Delta kWh}{HOU} \times CF_{summer}$$

$$= \frac{231\ kWh}{8{,}760\ hours} \times 1.0$$

$$= 0.046\ kW$$

The default per measure, gross coincident winter peak demand reduction will be assigned according to the following calculation:

$$\Delta kW_{winter} = \frac{\Delta kWh}{HOU} \times CF_{winter}$$

$$= \frac{231\ kWh}{8{,}760\ hours} \times 1.0$$

$$= 0.046\ kW$$

5.4.12.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-85.

Table 5-85. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	4.00	years	Wisconsin TRM 2020, p. 821

DSM Phase	Program Name	Value	Units	Source(s)
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.4.12.6 Source(s)

The primary source for this deemed savings approach is the Pennsylvania TRM V3, 2019, pp. 166-168 and Wisconsin TRM 2020, p. 822.

5.4.12.7 Update Summary

Updates made to this section are described in Table 5-86.

Table 5-86. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Pennsylvania TRM and Wisconsin TRM
	Input Value	Updated Area and ΔkWh/sq.ft.
	Equation	Added equation for coincident winter peak demand reduction
	Default Savings	Updated default savings
	New Table	Effective Useful Life (EUL) by program
2020	None	No change
v10	Source	Updated page numbers / version of the Pennsylvania TRM
	Equation	Updated equations

5.4.13 Vending Machine Miser

5.4.13.1 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.

This measure is offered through different programs listed in Table 5-87, and uses the impacts estimation approach described in this section.

Table 5-87. Programs that Offer this Measure

Program Name	Section
Non-Residential Prescriptive Program, DSM Phase VI	Section 5.4.13
Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	Section 9.5.1

5.4.13.2 Impacts 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 summer peak demand reductions are calculated according to the following equation:

$$\Delta kW_{summer} = \frac{\Delta kWh}{HOU} \times CF_{summer}$$

Per measure, gross coincident winter peak demand reductions are calculated according to the following equation:

$$\Delta kW_{winter} = \frac{\Delta kWh}{HOU} \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak demand reduction
kW_{rated} = rated kilowatts of connected equipment
HOU = annual hours of use
ESF = energy savings factor
CF_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor

5.4.13.3 Input Variables

Table 5-88. 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 5-89)		Massachusetts e-TRM 2019-2021, p. 595
ESF	Variable	See Table 5-89	-	Massachusetts e-TRM 2019-2021, p. 595
HOU	Fixed	8,760	hours, annual	Massachusetts e-TRM 2019-2021, p. 595

Component	Type	Value	Unit	Source(s)
CF_{summer}	Fixed	1.0		Massachusetts e-TRM 2019-2021, p. 595[143]
CF_{summer}	Fixed	1.0		Wisconsin TRM 2019, p. 822[143]

Table 5-89. Vending Miser Rated Kilowatts and Energy Savings Factors[144]

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

5.4.13.4 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 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 summer peak demand reduction will be applied according to the following calculation:

$$\Delta kW_{summer} = \frac{\Delta kWh}{HOU} \times CF_{summer}$$

$$= \frac{343\ kWh}{8{,}760\ hours} \times 1.0$$

$$= 0.039\ kW$$

The default, per measure, gross coincident winter peak demand reduction will be applied according to the following calculation:

[143] The Massachusetts TRM does not provide summer or winter CFs. However, the equation for peak demand is kWh savings divided by annual hours implying a CF of 1.0.

[144] Massachusetts TRM 2019-2021 Plan Version, p. 595-597; https://www.masssavedata.com/Public/TechnicalReferenceLibrary (accessed on April 18, 2012).

$$\Delta kW_{winter} = \frac{\Delta kWh}{HOU} \times CF_{winter}$$

$$= \frac{343\ kWh}{8{,}760\ hours} \times 1.0$$

$$= 0.039\ kW$$

5.4.13.5 Effective Useful Life

The effective useful life of this measure is provided in Table 5-90.

Table 5-90e. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	5.00	years	Massachusetts e-TRM 2019-2021, p. 596
VI	Non-Residential Prescriptive Program, DSM Phase VI	6.30	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

5.4.13.6 Source(s)

The primary source for this deemed savings approach is the Massachusetts e-TRM 2019-2021, pp. 595-597.

5.4.13.7 Update Summary

Updates made to this section are described in Table 5-91.

Table 5-91. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the Massachusetts TRM
	Equation	Added equation for coincident winter peak demand reduction
	New Table	Effective Useful Life (EUL) by program
2020	None	No change
v10	Source	Verified no changes to page numbers / version of the Massachusetts TRM

6 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.

6.1.1.1 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.

6.1.1.2 Impacts 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 6-1.

6.1.1.3 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.

6.1.1.4 Input Variables

Table 6-1. 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

6.1.1.5 Default Savings

Default savings will not be credited to a non-residential DG customer for unmeasured generation.

6.1.1.6 Effective Useful Life

The effective useful life of this measure is 1.00 years since demand reductions do not persist. The demand reductions are associated with the participation and events of each year.

6.1.1.7 Source(s)

DNV developed the non-residential DG evaluation methodology according to standard EM&V protocols.[145]

6.1.1.8 Update Summary

Updates made to this section are described in Table 6-2.

Table 6-2. Summary of Update(s)

Version	Update Type	Description
2021	None	No change
2020	None	No change
v10	None	No change

[145] 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.

7 NON-RESIDENTIAL SMALL MANUFACTURING PROGRAM, DSM PHASE VII

The Non-Residential Small Manufacturing Program provides qualifying business owners incentives to pursue one or more of the qualified energy efficiency measures through a local, participating contractor in Dominion Energy'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 7-1.

Table 7-1. Non-Residential Small Manufacturing Program Measure List

End Use	Measure	Legacy Program	Manual Section
Compressed Air	Compressed Air Nozzles	N/A	Section 7.1.1
	Leak Repair	Non-Residential Small Business Improvement Program	Section 7.1.2
	No Loss Drains	N/A	Section 7.1.3
	Add Storage (5 gal/cfm)		Section 7.1.4
	Heat of Compression Dryer		Section 7.1.5
	Low Pressure-drop Filter		Section 7.1.6
	VSD Air Compressor		Section 7.1.7
	Cycling Refrigerant Dryer		Section 7.1.8
	Dewpoint Controls		Section 7.1.9
	Pressure Reduction		Section 7.1.10
	Downsized VFD Compressor		Section 7.1.11

7.1 Compressed Air End Use

This section describe each measure and how energy and demand impacts are calculated. Due to the interactivity of the measures and the complexity of compressed air systems, savings are calculated in project-level spreadsheets.These spreadsheets are provided by the program implementer and reviewed by DNV. The in-depth reviews will verify that the appropriate baseline assumptions, operating hours, inputs and calculations are used. The savings calculations and inputs shown in this section are inline with the implementer calculations.

7.1.1 Compressed Air Nozzle

7.1.1.1 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 use 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 7-2.

Table 7-2. Compressed Air reduction for Engineered Nozzles

Nozzle Diameter (inch)	Flow Rate reduction at 80 psig (scfm)
1/8	11
1/4	29
5/16	56
1/2	140

7.1.1.2 Impacts Estimation Approach

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

$$\Delta kWh = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} - scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee} \right] \times Use \times HOU$$

The system air flow and loading values are calculated using the following equations:

$$scfm_{base} = scfm_{rated} \times Load_{base}$$

$$scfm_{ee} = scfm_{base} - \Delta scfm$$

$$Load_{ee} = \frac{scfm_{ee}}{scfm_{rated}}$$

If the system air flow and loading values are calculated using the following equations:

$$scfm_{ee} = scfm_{base} - \Delta scfm$$

$$Load_{ee} = \frac{scfm_{ee}}{scfm_{rated}}$$

To determine the reduction in flow rate from the standard to engineered nozzles, the following conditions and equations are used:

$$\Delta scfm = scfm_{80-psig,orifice} \times \left[\frac{p_{orifice} + 14.7}{(80 + 14.7)}\right]^n$$

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

$$\Delta kW_{summer} = \left[scfm_{base} \times \left(\frac{kW}{cfm}\right)_{base} - scfm_{ee} \times \left(\frac{kW}{cfm}\right)_{ee}\right] \times Use \times CF_{summer}$$

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

$$\Delta kW_{winter} = \left[scfm_{base} \times \left(\frac{kW}{cfm}\right)_{base} - scfm_{ee} \times \left(\frac{kW}{cfm}\right)_{ee}\right] \times Use \times CF_{winter}$$

Where:

ΔkWh	= per measure gross annual electric energy savings
ΔkW_{summer}	= per measure gross summer peak coincident demand reduction
ΔkW_{winter}	= per measure gross winter peak 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
Qty	= quantity of nozzles
$scfm_{80\text{-}psig,\ nozzle}$	= 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
$p_{orifice}$	= pressure at the nozzle
n	= flowrate pressure adjustment coefficient
Dia	= diameter of nozzle
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_{summer}	= summer coincidence factor
CF_{winter}	= winter coincidence factor

7.1.1.3 Input Variables

Table 7-3. 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 7-2	scfm	IL TRM V8.0 Vol. 2, 2020, p. 574
$Load_{base}$	Variable	See customer application	-	Customer application
		Default = 0.60		Engineering estimate
Qty	Variable	See customer application	-	Customer application
$P_{orifice}$	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 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Engineering estimate, only applicable if the control type is VFD
X_2	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
X_1	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
Use	Variable	See customer application	-	Customer application
		Default = 0.05		Minnesota TRM V3.1, 2020, pp. 451
HOU	Variable	See customer application	hours, annual	Customer application
		Default = 6,240		Minnesota TRM V3.1, 2020, pp. 451
CF_{summer}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Illinois TRM V8.0 Volume 2, 2020, pp. 575

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Component	Type	Value	Unit	Source(s)
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM V8.0 Volume 2, 2020, pp. 575
CF_{winter}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors		Illinois TRM V8.0 Volume 2, 2020, pp. 575[146]
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM V8.0 Volume 2, 2020, pp. 575

7.1.1.4 Default Savings

If the necessary values are not available, some values have defaults savings. However, there are no default savings for this measure as some values are essential to calculate savings.

7.1.1.5 Effective Useful Life

The effective useful life of this measure is provided in Table 7-4.

Table 7-4. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VII	Non-Residential Small Manufacturing Program, DSM Phase VII	12.24	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

7.1.1.6 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. Other sources include the IL TRM v.8.0 Vol.2 2020, pp. 573-575 and MN TRM v3.1 2020, pp. 450-452.

7.1.1.7 Update Summary

Updates made to this section are described in Table 7-5.

Table 7-5. Summary of Update(s)

Updates in Version	Update Type	Description
2021	Source	Updated page numbers / version of the IL TRM and MN TRM

[146] The source TRM does not differentiate between winter and summer peak periods. Therefore, DNV applied the same CF for summer and winter peak periods.

Updates in Version	Update Type	Description
	Table	Updated $scfm_{80\text{-}psig}$,values based on nozzle size
	Variable	• Added Nozzle Quantity • Added flowrate pressure adjustment coefficient • Added pressure at the nozzle $p_{orifice}$
	New Table	Effective Useful Life (EUL) by program
	Equation	• Added gross winter peak demand reduction equation • Added condition capping the maximum scfm reduction of nozzles to 50% of the total system baseline scfm. • Added clarification to Δscfm that the pressure is the pressure at the nozzle, not the system pressure
2020	None	No change
v10	New Measure	New section

7.1.2 Leak Repair

7.1.2.1 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 saves 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, DSM Phase V in Section 4.3.1 but uses a different methodology. That program uses a deemed value for system efficiency. This program uses site-specific equipment and operating conditions to determine the system efficiency.

7.1.2.2 Impacts Estimation Approach

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

$$\Delta kWh = \left(scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} - scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee} \right) \times HOU$$

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

$$\Delta kW_{summer} = \left(scfm_{base} \times \left(\frac{kW}{cfm}\right)_{base} - scfm_{ee} \times \left(\frac{kW}{cfm}\right)_{ee}\right) \times CF_{summer}$$

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

$$\Delta kW_{winter} = \left(scfm_{base} \times \left(\frac{kW}{cfm}\right)_{base} - scfm_{ee} \times \left(\frac{kW}{cfm}\right)_{ee}\right) \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross summer peak coincident demand reduction
ΔkW_{winter} = per measure gross winter peak 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
Δscfm = efficient trim compressor operating flow reduction
$Load_{base}$ = average percent of rated flow for base trim compressor
$Load_{ee}$ = average percent of system flow after leaks are repaired
kW/cfm_{base} = baseline system operating performance
kW/cfm_{ee} = efficient system operating performance
η_{VFD} = VFD efficiency
X_2 = coefficient
X_1 = coefficient
C = constant
HOU = annual hours of operation of compressor system
CF_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor

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7.1.2.3 Input Variables

Table 7-6. 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
ΔSCFM	Variable	See customer application	-	See customer application
η_{VFD}	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Engineering estimate; only applicable for VFD-controlled compressors
X_2	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
X_1	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
HOU	Variable	See customer application	hours, annual	See customer application
		Default=6,240		MN TRM V3.1, 2020, p. 451
CF_{summer}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	IL TRM V8.0 Volume 2, 2020, pp. 575
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM V8.0 Volume 2, 2020, p. 575
CF_{winter}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	IL TRM V8.0 Volume 2, 2020, p. 575[147]
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM V8.0 Volume 2, 2020, p. 575

[147] The source TRM doesn't differentiate between winter and summer peak periods. Therefore, the summer CF is applied to the winter CF.

7.1.2.4 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.

7.1.2.5 Effective Useful Life

The effective useful life of this measure is provided in Table 7-7.

Table 7-7. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VII	Non-Residential Small Manufacturing Program, DSM Phase VII	12.24	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

7.1.2.6 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. Other sources include the IL TRM V8.0 Vol. 2, 2020, pp. 573-575 and MN TRM V3.1, 2020, pp. 450-452.

7.1.2.7 Update Summary

Updates made to this section are described in Table 7-8.

Table 7-8. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the IL TRM and MN TRM
	Table	Updated $scfm_{80\text{-}psig}$,values based on nozzle size
	New Table	Effective Useful Life (EUL) by program
	Equation	Added gross winter peak demand reduction equation
2020	Input	Added default value for hours of use
v10	New Measure	New section

7.1.3 No-Loss Condensate Drain

7.1.3.1 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 eliminates 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.

7.1.3.2 Impacts 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 measure, gross summer peak coincident demand reduction is calculated according to the following equation:

$$\Delta kW_{summer} = \left(scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} - scfm_{ee} \times Qty \times \left(\frac{kW}{scfm}\right)_{ee} \right) \times CF_{summer}$$

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

$$\Delta kW_{winter} = \left(scfm_{base} \times \left(\frac{kW}{scfm} \right)_{base} - scfm_{ee} \times Qty \times \left(\frac{kW}{scfm} \right)_{ee} \right) \times CF_{winter}$$

Where:

ΔkWh = gross annual electric energy savings
ΔkW_{summer} = per measure gross summer peak coincident demand reduction
ΔkW_{winter} = per measure gross winter peak 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
Δscfm = efficient trim compressor operating flow
$scfm_{100\text{-}psig,\ drain}$ = reduction in flow rate at 100 psig
n = flowrate pressure 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
η_{VFD} = VFD efficiency
X_2 = coefficient
X_1 = coefficient
C = constant
HOU = annual hours of operation of compressor system
CF_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor

7.1.3.3 Input Variables

Table 7-9. 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	IL TRM v.8.0 Vol. 2 2020, p. 571
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
η_{VFD}	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Engineering estimate, only applicable for VFD-controlled compressors

Component	Type	Value	Units	Source
X2	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
X1	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	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 3.1 2020, p. 451
CF_{summer}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	IL TRM v 8.0 Volume 2 2020, p. 575
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575
CF_{winter}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors		IL TRM v 8.0 Volume 2 2020, p. 575[148]
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575

7.1.3.4 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.

7.1.3.5 Effective Useful Life

The effective useful life of this measure is provided in Table 7-10.

Table 7-10. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VII	Non-Residential Small Manufacturing Program, DSM Phase VII	12.24	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

148 The source TRM doesn't differentiate between winter and summer peak periods. Therefore, the summer CF is applied to the winter CF.

7.1.3.6 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.Other sources include the IL TRM V8.0 Vol.2, 2020, pp. 573-575 and MN TRM V3.1, 2020, pp. 450-452.

7.1.3.7 Update Summary

Updates made to this section are described in Table 7-11.

Table 7-11. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the IL TRM and MN TRM
	New Table	Effective Useful Life (EUL) by program
	Equation	Added gross winter peak demand reduction equation
2020	Equation	• Added η_{VFD} to the kW/scfm equations. • Removed quantity from the Δscfm equation
	Inputs	Added default operating hours
v10	New Measure	New section

7.1.4 Add Storage

7.1.4.1 Measure Description

This measure involves adding an air receiver 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 or 2 gallon/cfm.

Qualifying storage is at least 5 gallons of storage capacity per CFM capacity. This measure is eligible for load/no-load compressor systems.

7.1.4.2 Impacts Estimation Approach

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

$$\Delta kWh \quad = scfm \times \left[\left(\frac{kW}{scfm}\right)_{base} - \left(\frac{kW}{scfm}\right)_{ee}\right] \times HOU$$

The baseline system air flow and is calculated using the following equation:

$$scfm = scfm_{rated} \times Load$$

The baseline and efficient system operating performance values are calculated by the following equations:

$$\left(\frac{kW}{scfm}\right)_{base} = \frac{hp \times 1.1 \times 0.746}{0.945} \times \frac{\left(X_{2,base} \times Load^2 + X_{1,base} \times Load + C_{base}\right)}{scfm}$$

$$\left(\frac{kW}{scfm}\right)_{ee} = \frac{hp \times 1.1 \times 0.746}{0.945} \times \frac{\left(X_{2,ee} \times Load^2 + X_{1,ee} \times Load + C_{ee}\right)}{scfm}$$

Per measure, gross summer peak coincident demand reduction is calculated per compressed air system according to the following equation:

$$\Delta kW_{summer} = scfm_{base} \times \left[\left(\frac{kW}{scfm}\right)_{base} - \left(\frac{kW}{scfm}\right)_{ee}\right] \times CF_{summer}$$

Per measure, gross summer peak coincident demand reduction is calculated per compressed air system according to the following equation:

$$\Delta kW_{winter} = scfm_{base} \times \left[\left(\frac{kW}{scfm}\right)_{base} - \left(\frac{kW}{scfm}\right)_{ee}\right] \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross summer peak coincident demand reduction
ΔkW_{winter} = per measure gross winter peak 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
$scfm_{rated}$ = trim compressor rated flow rate
hp = compressor rated horsepower[149]
Load = average operating airflow rate percent of full load conditions of trim compressor
$X_{2,base}$ = coefficient
$X_{1,base}$ = coefficient
C_{base} = constant
$X_{2,ee}$ = coefficient
$X_{1,ee}$ = coefficient
C_{ee} = constant
HOU = annual hours of operation of compressor system
CF_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor

[149] 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.

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7.1.4.3 Input Variables

Table 7-12. 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 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
$X_{1,base}$	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C_{base}	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
$X_{2,ee}$	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
$X_{1,ee}$	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C_{ee}	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
HOU	Variable	See customer application	hours	See customer application
		Default=6,240		MN TRM v 3.1 2020, p. 451
CF_{summer}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	IL TRM v 8.0 Volume 2 2020, p. 575
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575

Component	Type	Value	Units	Source
CF_{winter}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors		IL TRM v 8.0 Volume 2 2020, p. 575[150]
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575

7.1.4.4 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.

7.1.4.5 Effective Useful Life

The effective useful life of this measure is provided in Table 7-13.

Table 7-13. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VII	Non-Residential Small Manufacturing Program, DSM Phase VII	12.24	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

7.1.4.6 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. Other sources include the IL TRM V8.0 Vol.2, 2020, pp. 573-575 and MN TRM V3.1, 2020, pp. 450-452.

7.1.4.7 Update Summary

Updates made to this section are described in Table 7-14.

Table 7-14. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the IL TRM and MN TRM
	New Table	Effective Useful Life (EUL) by program
	Equation	Added gross winter peak demand reduction equation
2020	Inputs	Added default operating hours and CF value

[150] The source TRM doesn't differentiate between winter and summer peak periods. Therefore, the summer CF is applied to the winter CF.

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Version	Update Type	Description
v10	New Measure	New section

7.1.5 Heat-of-compression Dryer

7.1.5.1 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.

7.1.5.2 Impacts 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 summer coincident demand reduction is calculated according to the following equation:

$$\Delta kW_{summer} = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} + kW_{heater,base} + kW_{blower,base} + kW_{refrig,base} - \left(1 + PSF \times (p_{base} - p_{ee})\right)\left((scfm_{ee}) \times \left(\frac{kW}{scfm}\right)_{ee}\right)\right] \times CF_{summer}$$

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

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$$\Delta kW_{winter} = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} + kW_{heater,base} + kW_{blower,base} + kW_{refrig,base} - (1 + PSF \times (p_{base} - p_{ee}))\left((scfm_{ee}) \times \left(\frac{kW}{scfm}\right)_{ee}\right)\right] \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross summer peak coincident demand reduction
ΔkW_{winter} = per measure gross winter peak 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
$scfm_{dryer, rated, ee}$ = 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
η_{VFD} = VFD efficiency
X_2 = coefficient
X_1 = coefficient
C = constant
HOU = annual hours of use
CF_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor

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7.1.5.3 Input Variables

Table 7-15. 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 13-23 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	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
$kW_{heater,base}$	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 13-22 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors for refrigerated dryers, only	-	Compressed Air Challenge, Cycling Refrigerated Air Dryers - Are Savings Significant
K	Variable	See Table 13-22 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors 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 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Engineering estimate; only applicable if the control type is a VFD

Component	Type	Value	Units	Sources
X_2	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
X_1	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	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 3.1 2020, p. 451
CF_{summer}	Fixed	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	IL TRM v 8.0 Volume 2 2020, p. 575
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575
CF_{winter}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors		IL TRM v 8.0 Volume 2 2020, p. 575[151]
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575

7.1.5.4 Default Savings

There are no default savings for this measure as site-specific values are required to calculate savings.

7.1.5.5 Effective Useful Life

The effective useful life of this measure is provided in Table 7-16.

Table 7-16. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VII	Non-Residential Small Manufacturing Program, DSM Phase VII	12.24	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

[151] The source TRM doesn't differentiate between winter and summer peak periods. Therefore, the summer CF is applied to the winter CF.

7.1.5.6 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.Other sources include the IL TRM v.8.0 Vol.2 2020, pp. 573-575, MN TRM v3.1 2020, pp. 450-452 and Dryer Selection for Compressed Air Systems, Compressed Air Challenge, 1999.

7.1.5.7 Update Summary

Updates made to this section are described in Table 7-17.

Table 7-17. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the IL TRM and MN TRM
	Equation	Added gross winter peak demand reduction equation
	New Table	Effective Useful Life (EUL) by program
2020	Input	• Changed CF from fixed value to allow for more than one production shift • Added default operating hours
v10	New Measure	New section

7.1.6 Low Pressure-Drop Filter

7.1.6.1 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 induce a static 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.[152] 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.

7.1.6.2 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:

[152] "Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004

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$$scfm_{base} = scfm_{rated} \times Load_{base}$$

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 summer peak demand reduction is calculated per filter according to the following equation:

$$\Delta kW_{summer} = scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} \times PSF \times \Delta p \times CF_{summer}$$

Per measure, gross coincident winter peak demand reduction is calculated per filter according to the following equation:

$$\Delta kW_{winter} = scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} \times PSF \times \Delta p \times CF_{winter}$$

Where:

ΔkWh = per measure, gross annual electric energy savings
ΔkW_{summer} = per measure, gross coincident summer peak demand reduction
ΔkW_{winter} = per measure, gross coincident winter peak 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
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
η_{VFD} = VFD efficiency
X_2 = coefficient
X_1 = coefficient
C = constant
HOU = annual hours of use
CF_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor

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7.1.6.3 Input Variables

Table 7-18. Input Parameters for Low Pressure Drop Filter Savings Calculations

Component	Type	Value	Units	Sources
p_{base}	Variable	See customer application	psig	Customer application
p_{ee}	Variable	See customer application	psig	Customer application
Δp_{max}	Fixed	5	psig	Assumed maximum amount of pressure reduction that can be attributed to measure (difference between base filter pressure reduction and low PD filter)
hp	Variable	See customer application	hp	See customer application
$scfm_{rated}$	Variable	See customer application	scfm	Customer application
$Load_{base}$	Variable	See customer application	-	Customer application
		Default = 0.60		Engineering estimate
PSF	Fixed	0.005	1/psig	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
η_{VFD}	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Engineering estimate, only applicable if the control type is VFD
X_2	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
X_1	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
HOU	Variable	See customer application	hours	See customer application
		Default=6,240		MN TRM v 3.1 2020, p. 451
CF_{summer}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	IL TRM v 8.0 Volume 2 2020, p.575
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575
CF_{winter}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors		IL TRM v 8.0 Volume 2 2020, p. 575[153]
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575

[153] The source TRM doesn't differentiate between winter and summer peak periods. Therefore, the summer CF is applied to the winter CF.

7.1.6.4 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.

7.1.6.5 Effective Useful Life

The effective useful life of this measure is provided in Table 7-19.

Table 7-19. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VII	Non-Residential Small Manufacturing Program, DSM Phase VII	12.24	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

7.1.6.6 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. The IL TRM v.8.0, Vol. 2. 2020, p. 575 and MN TRM v 3.1 2020, p. 451 is also referenced.

7.1.6.7 Update Summary

Updates made to this section are described in Table 7-20.

Table 7-20. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the IL TRM and MN TRM
	New Table	Effective Useful Life (EUL) by program
	Equation	Added winter peak coincident demand reduction equation
2020	Inputs	Added default operating hours
v10	New Measure	New section

7.1.7 VFD Air Compressor

7.1.7.1 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 conditions. Typical air compressors spend a small percent of the operation at or near full-load conditions.

The qualifying equipment is an air 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.

7.1.7.2 Impacts 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 bin flow rate is calculated using the following equation:

$$scfm_{bin} = scfm_{rated} \times Load_{bin}$$

The base and efficient system operating performance is calculated by the following equations:

$$\left(\frac{kW}{scfm}\right)_{base,bin} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_{2,base} \times Load_{bin}{}^{2} + X_{1,base} \times Load_{bin} + C_{base}\right)}{scfm_{bin}}$$

$$\left(\frac{kW}{scfm}\right)_{ee,bin} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_{2,ee} \times Load_{bin}{}^{2} + X_{1,ee} \times Load_{bin} + C_{ee}\right)}{scfm_{bin}}$$

Gross coincident summer peak demand reduction is calculated per VFD-controlled compressor according to the following equation:

$$\Delta kW_{summer} = \sum_{bin=1}^{7} scfm_{bin} \times \left[\left(\frac{kW}{scfm}\right)_{base,bin} - \left(\frac{kW}{scfm}\right)_{ee,bin}\right] \times HOU_{bin} \times CF_{summer}$$

Gross coincident winter peak demand reduction is calculated per VFD-controlled compressor according to the following equation:

$$\Delta kW_{winter} = \sum_{bin=1}^{7} scfm_{bin} \times \left[\left(\frac{kW}{scfm} \right)_{base,\,bin} - \left(\frac{kW}{scfm} \right)_{ee,\,bin} \right] \times HOU_{bin} \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure, gross coincident summer peak demand reduction
ΔkW_{winter} = per measure, gross coincident winter peak 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
C_{ee} = constant
$X_{2,ee}$ = coefficient
$X_{1,ee}$ = coefficient
HOU = annual hours of use
HOU_{bin} = percent of operating hours compressor operates at corresponding load
CF_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor

7.1.7.3 Input Variables

Table 7-21. 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
$load_{bin}$	Variable	For default see Table 13-19 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors.. The $Load_{bins}$ 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.	-	Average percent of bin definition, bins are 10% load ranges, from 100% to 40%, 30% assumed for <40% bin (bin 7)
η_{VFD}	Fixed	0.98	-	Engineering estimate
$X_{2,\,base}$	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
$X_{1,\,base}$	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004

Component	Type	Value	Units	Sources
C_{base}	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
$X_{2, ee}$	Fixed	VFD = 0	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
$X_{1, ee}$	Fixed	VFD = 0.95	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C_{ee}	Fixed	VFD = 0.05	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
HOU	Variable	See customer application	hour, annual	Customer application
		Default=6,240		MN TRM v 3.1 2020, p. 451
HOU_{bin}	Variable	See customer application	-	Customer application; sum of HOU_{bins} must equal 1.00
		For default see Table 13-19 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors. The $Load_{bins}$ 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.		Engineering judgement
CF_{summer}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	IL TRM v 8.0 Volume 2 2020, p. 575
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575
CF_{winter}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	IL TRM v 8.0 Volume 2 2020, p. 575[154]
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575

7.1.7.4 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.

7.1.7.5 Effective Useful Life

The effective useful life of this measure is provided in Table 7-22.

[154] The source TRM doesn't differentiate between winter and summer peak periods. Therefore, the summer CF is applied to the winter CF.

Table 7-22. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VII	Non-Residential Small Manufacturing Program, DSM Phase VII	12.24	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

7.1.7.6 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.Other sources include the IL TRM v.8.0, Vol. 2. 2020, p. 575 and MN TRM v 3.1 2020, p. 451.

7.1.7.7 Update Summary

Updates made to this section are described in Table 7-23.

Table 7-23. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the IL TRM and MN TRM
	Equation	Added gross winter peak demand reduction equation
	New Table	Effective Useful Life (EUL) by program
2020	Inputs	Added default operating hours
v10	New Measure	New section

7.1.8 Cycling Air Dryer

7.1.8.1 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 conditions are cooler and drier than the design conditions. 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.

7.1.8.2 Impacts Estimation Approach

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

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$$\Delta kWh = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} + kW_{heater} + kW_{blower} + kW_{refrig} - scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee} - kW_{dryer,\ ee}\right] \times HOU$$

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:

$$kW_{blower} = \frac{hp_{blower} \times 0.8 \times 0.746}{0.957}$$

$$kW_{heater} = kW_{heater,rated} \times Utilization_{heater}$$

$$kW_{refrig} = kW_{refrig.,rated} \times \left(R_{1,base} \times Load_{dryer,base} + K_{base}\right)$$

$$kW_{dryer,ee} = kW_{dryer,rated,ee} \times \left(R_{1,ee} \times Load_{dryer,ee} + K_{ee}\right)$$

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

$$\Delta kW_{summer} = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} + kW_{heater} + kW_{blower} + kW_{refrig} - scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee} - kW_{dryer,\ ee}\right] \times CF_{summer}$$

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

$$\Delta kW_{winter} = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} + kW_{heater} + kW_{blower} + kW_{refrig} - scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee} - kW_{dryer,\ ee}\right] \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure, gross coincident summer peak demand reduction
ΔkW_{winter} = per measure, gross coincident winter peak 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
$scfm_{ee}$ = EE trim compressor operating flow
$scfm_{reduced}$ = average reduction in flow resulting from replacing base dryer
$scfm_{base\ dryer\ rated}$ = base dryer rated flow
$scfm_{ee\ dryer\ rated}$ = EE 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
$kW_{rated\ refrig}$ = the rated kW of the base dryer
$kW_{rated\ dryer,ee}$ = the rated kW of the EE dryer
$R_{1,base}$ = 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_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor

7.1.8.3 Input Variables

Table 7-24. 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 13-23 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors		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 = 60%		Engineering estimate
hp_{blower}	Variable	See customer application, only applicable to blower purge and heated blower purge	hp	See customer application

Component	Type	Value	Units	Sources
$kW_{heater,rated}$	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 continuously, heated blower purge is based on engineering judgment
$kW_{refrig,rated}$	Variable	See customer application, only applicable to blower purge and heated blower purge dryer types	kW	See customer application
$kW_{ee,dryer,rated}$	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 13-22 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Compressed Air Challenge, Cycling Refrigerated Air Dryers - Are Savings Significant
K_{base}	Variable	See Table 13-22 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Compressed Air Challenge, Cycling Refrigerated Air Dryers - Are Savings Significant
$R_{1, ee}$	Variable	See Table 13-22 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Compressed Air Challenge, Cycling Refrigerated Air Dryers - Are Savings Significant
K_{ee}	Variable	See Table 13-22 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Compressed Air Challenge, Cycling Refrigerated Air Dryers - Are Savings Significant
X_2	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
X_1	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	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 3.1 2020, p. 451
CF_{summer}	Fixed	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	IL TRM v 8.0 Volume 2 2020, p. 575
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575

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Component	Type	Value	Units	Sources
CF_{winter}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	IL TRM v 8.0 Volume 2 2020, p. 575[155]
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575

7.1.8.4 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.

7.1.8.5 Effective Useful Life

The effective useful life of this measure is provided in Table 7-25.

Table 7-25. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VII	Non-Residential Small Manufacturing Program, DSM Phase VII	12.24	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

7.1.8.6 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, and Cycling Refrigerated Air Dryers - Are Savings Significant, Compressed Air Challenge. Other sources include the IL TRM v.8.0, Vol. 2. 2020, p 575 and MN TRM v 3.1 2020, p. 451

7.1.8.7 Update Summary

Updates made to this section are described in Table 7-26.

Table 7-26. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the IL TRM and MN TRM
	Equation	Added gross winter peak demand reduction equation
	New Table	Effective Useful Life (EUL) by program
2020	Inputs	Added default operating hours
v10	New Measure	New section

155 The source TRM doesn't differentiate between winter and summer peak periods. Therefore, the summer CF is applied to the winter CF.

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7.1.9 Dew Point Controls

7.1.9.1 Measure Description

Typical desiccant dryers use compressed air to purge moisture from the desiccant. 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 desiccant 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.

7.1.9.2 Impacts Estimation Approach

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

$$\Delta kWh = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} + kW_{heater} + kW_{blower} - scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee} - kW_{blower,\ ee} - kW_{heater,ee}\right] \times HOU$$

The reduction in airflow due to the new controls is calculated using the following equation:

$$scfm_{reduced} = scfm_{base\ dryer,rated} \times Purge_{base} - \left(scfm_{base,dryer,\ rated} \times Purge_{base} \times Load_{base,\ dryer}\right) \times (1 - Time)$$

The baseline air flow and loading are calculated using the following equations:

$$Load_{system,base} = \frac{scfm_{system,\ rated} - scfm_{rated} + scfm_{rated} \times Load_{base}}{scfm_{system,\ rated}}$$

$$scfm_{system,base} = scfm_{system,\ rated} \times Load_{system,\ base}$$

$$Load_{dryer,base} = \frac{scfm_{system,\ base}}{scfm_{dryer,rated}}$$

$$scfm_{base} \quad = scfm_{rated} \times Load_{base}$$

The efficient air flow and loading are calculated using the following equation:

$$scfm_{ee} \quad = scfm_{base} - scfm_{reduced}$$

$$Load_{ee} \quad = \frac{scfm_{ee}}{scfm_{rated}}$$

The base and efficient system operating performance is calculated by the following equations:

$$\left(\frac{kW}{scfm}\right)_{base} \quad = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_2 \times {Load_{base}}^2 + X_1 \times Load_{base} + C\right)}{scfm_{base}}$$

$$\left(\frac{kW}{scfm}\right)_{ee} \quad = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X_2 \times {Load_{ee}}^2 + X_1 \times Load_{ee} + C\right)}{scfm_{ee}}$$

Where the kW load due to each component is calculated using the following equations:

$$kW_{blower,ee} \quad = kW_{blower,base} \times Load_{ee}$$

$$kW_{blower,base} \quad = hp_{blower} \times 0.8 \times 0.746 \times 0.957 =$$

$$kW_{heater,base} \quad = kW_{heater,rated,base} \times Utilization_{heater} = \text{□□□□□□□□□□}$$

$$kW_{heater,ee} \quad = kW_{heater,base} \times Load_{ee}$$

Per measure, gross coincident summer peak demand reduction is calculated per dryer controlled according to the following equation:

$$\Delta kW_{summer} \quad = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} + kW_{heater} + kW_{blower} - scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee} - kW_{blower,\,ee} - kW_{heater,ee}\right] \times CF_{summer}$$

Per measure, gross coincident winter peak demand reduction is calculated per dryer controlled according to the

$$\Delta kW_{winter} = \left[scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} + kW_{heater} + kW_{blower} - scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee} - kW_{blower,\,ee} - kW_{heater,ee}\right] \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure, gross coincident summer peak demand reduction
ΔkW_{winter} = per measure, gross coincident winter peak demand reduction
hp = trim compressor rated horsepower
$scfm_{rated}$ = trim compressor rated flow
$scfm_{system,rated}$ = system rated flow
$scfm_{base}$ = baseline trim compressor operating flow
$scfm_{system,base}$ = baseline system operating flow
$scfm_{reduced}$ = average reduction in flow resulting from dewpoint controls
$scfm_{base\ dryer,rated}$ = baseline dryer rated flow
$scfm_{ee}$ = energy-efficient trim compressor operating flow
$Purge_{base}$ = purge percent of baseline dryer
$Load_{base}$ = average percentage of rated flow for trim compressor
$Load_{system,base}$ = average percentage of rated flow for baseline system
$Load_{dryer,base}$ = average operating percentage of base dryer rated flow
$Load_{ee}$ = average operating percentage 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 baseline heater
$kW_{blower,\ base}$ = average operating kW of the baseline blower
$kW_{heater,ee}$ = average operating kW of the energy-efficient heater
$kW_{blower,\ ee}$ = average operating kW of the energy-efficient blower
hp_{blower} = blower rated hp of baseline dryer
$kW_{rated\ heater}$ = heater rated kW of baseline dryer
$Utilization_{heater}$ = heater operation time
$kW/scfm_{base}$ = base system operating performance
$kW/scfm_{ee}$ = energy-efficient system operating performance
η_{VFD} = VFD efficiency
X2 = coefficient
X1 = coefficient
C = constant
HOU = annual hours of use
CF_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor

7.1.9.3 Input Variables

Table 7-27. 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

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Component	Type	Value	Units	Sources
$scfm_{base,dryer,rated}$	Variable	See customer application	scfm	See customer application
$Purge_{base}$	Variable	See Table 13-23 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	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 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 continuously, heated blower purge is based on engineering judgment
η_{VFD}	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	engineering estimate, only applicable if the control type is VFD
X2	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
X1	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Fundamentals of Compressed Air Systems, Compressed Air Challenge, 2004
C	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	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 3.1 2020, p. 451
CF_{summer}	Fixed	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	IL TRM v 8.0 Volume 2 2020, p. 575
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575

Component	Type	Value	Units	Sources
CF_{winter}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors		IL TRM v 8.0 Volume 2 2020, p. 575[156]
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575

7.1.9.4 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.

7.1.9.5 Effective Useful Life

The effective useful life of this measure is provided in Table 7-28.

Table 7-28. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VII	Non-Residential Small Manufacturing Program, DSM Phase VII	12.24	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

7.1.9.6 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. Other sources include the IL TRM v.78.0, Vol. 2. 2020, p 575, MN TRM v 3.1 2020, p. 451, Dryer Selection for Compressed Air Systems, Compressed Air Challenge, 1999.

7.1.9.7 Update Summary

Updates made to this section are described in Table 7-29.

Table 7-29. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the IL TRM and MN TRM
	Equation	Added gross winter peak demand reduction equation
	New Table	Effective Useful Life (EUL) by program
2020	Inputs	Added default operating hours

[156] The source TRM doesn't differentiate between winter and summer peak periods. Therefore, the summer CF is applied to the winter CF.

Version	Update Type	Description
v10	New Measure	New section

7.1.10 Pressure Reduction

7.1.10.1 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. Additionally, 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 rather than at a downstream pressure regulator. This measure is only applicable to positive displacement compressors (rotary screw and reciprocating compressors); centrifugal compressors are excluded, because they require compressor-specific performance curves to accurately calculate savings.

7.1.10.2 Impacts Estimation Approach

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

$$\Delta kWh = \Delta kWh_{artificial} + \Delta kWh_{pressure}$$

$$\Delta kWh_{artificial} = \left(scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} - (scfm_{ee}) \times \left(\frac{kW}{scfm}\right)_{ee} \right) \times HOU$$

$$\Delta kWh_{pressure} = \left(scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee} \times PSF \times \Delta p \right) \times HOU$$

To determine the reduction in flow rate from the change to the pressure set-point, the following equation is used:

$$scfm_{reduced} = (scfm_{base} \times scfm_{artificial}) - (scfm_{base} \times scfm_{artificial}) \times \left(\frac{(p_{ee} + 14.7)}{(p_{base} + 14.7)}\right)^n$$

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 equations:

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$$scfm_{ee} = scfm_{base} - scfm_{reduced}$$

$$Load_{ee} = \frac{scfm_{base} - scfm_{reduced}}{scfm_{rated}}$$

The baseline and efficient system operating performances are calculated using the following equations:

$$\left(\frac{kW}{scfm}\right)_{base} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X2 \times Load_{base}{}^{2} + X1 \times Load_{base} + C\right)}{scfm_{base}}$$

$$\left(\frac{kW}{scfm}\right)_{ee} = \frac{hp \times 1.1 \times 0.746}{0.945 \times \eta_{VFD}} \times \frac{\left(X2 \times Load_{ee}{}^{2} + X1 \times Load_{ee} + C\right)}{scfm_{ee}}$$

Per measure, gross coincident summer peak demand reduction is calculated per compressed air system according to the following equations:

$$\Delta kW_{summer} = \left(\Delta kW_{artificial} + \Delta kW_{pressure}\right) \times CF_{summer}$$

$$\Delta kW_{artificial} = \left(scfm_{base} \times \left(\frac{kW}{scfm}\right)_{base} - (scfm_{ee}) \times \left(\frac{kW}{scfm}\right)_{ee}\right)$$

$$\Delta kW_{pressure} = \left(scfm_{ee} \times \left(\frac{kW}{scfm}\right)_{ee} \times PSF \times \Delta p\right)$$

Per measure, gross coincident winter peak demand reduction is calculated per compressed air system according to the following equation:

$$\Delta kW_{winter} = \left(\Delta kW_{artificial} + \Delta kW_{pressure}\right) \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure, gross coincident summer peak demand reduction
ΔkW_{winter} = per measure, gross coincident winter peak demand reduction
$\Delta kWh_{artificial}$= gross annual electric energy savings resulting from artificial load reduction
$\Delta kWh_{pressure}$= gross annual electric energy savings resulting from pressure reduction
$\Delta kW_{artificial}$ = gross annual average demand reduction resulting from artificial load reduction
$\Delta kW_{pressure}$= gross annual average demand reduction s resulting from pressure reduction
Δp = the pressure reduction
p_{base} = base system operating pressure of base system
p_{ee} = efficient system operating pressure of efficient system
PSF = pressure savings factor

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n = flowrate pressure 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_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor

7.1.10.3 Input Variables

Table 7-30. Input Parameters for Pressure Reduction

Component	Type	Value	Units	Sources
p_{base}	Variable	See customer application	psig	Customer application
p_{ee}	Variable	See customer application	psig	Customer application
Δp	Variable	The lesser of the difference between customer application p_{base} and p_{ee} or 10	psig	Customer application values and capped at 10 psig reduction
PSF	Fixed	0.005	1/psig	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
n	Fixed	1.0	-	Engineering estimate
hp	Variable	See customer application	hp	Customer application
$scfm_{rated}$	Variable	See customer application	scfm	Customer application
$scfm_{artificial}$	Fixed	0.30	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
$Load_{base}$	Variable	See customer application	-	Customer application
		Default = 0.60		Engineering estimate
η_{VFD}	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	Engineering estimate, only applicable if the control type is VFD
X_2	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
X_1	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004

Component	Type	Value	Units	Sources
C	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
HOU	Variable	See customer application	hours, annual	Customer application
		Default=6,240		MN TRM v 3.1 2020, p. 451
CF_{summer}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	IL TRM v 8.0 Volume 2 2020, p. 575
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575
CF_{winter}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	IL TRM v 8.0 Volume 2 2020, p. 575[157]
		Default =0.59		Default based on single shift (8/5) operating schedule from IL TRM v 8.0 Volume 2 2020, p. 575

7.1.10.4 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.

7.1.10.5 Effective Useful Life

The effective useful life of this measure is provided in Table 7-31.

Table 7-31. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VII	Non-Residential Small Manufacturing Program, DSM Phase VII	12.24	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

7.1.10.6 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.Other sources include the IL TRM v78.0, Vol. 2. 2020, p. 575 and the MN TRM v3.1 2020, p. 451.

7.1.10.7 Update Summary

Updates made to this section are described in Table 7-32.

[157] The source TRM doesn't differentiate between winter and summer peak periods. Therefore, the summer CF is applied to the winter CF.

Table 7-32. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the IL TRM and MN TRM
	Equation	• Added gross winter peak demand and summer peak demand reduction equations • Modified ΔkWh equation to fix error in calculation by separating into separate terms of $\Delta kWh_{artificial}$ and $\Delta kWh_{pressure}$ for clarity
	Table	Effective Useful Life (EUL) by program
2020	Inputs	Added default operating hours
v10	New Measure	New section

7.1.11 Downsized VFD Compressor

7.1.11.1 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 conditions. 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.

7.1.11.2 Impacts 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:

$$scfm_{bin} = scfm_{rated,base} \times Load_{base,\,bin}$$

$$Load_{ee,\,bin} = \frac{scfm_{bin}}{scfm_{rated,\,ee}}$$

$$scfm_{bin} = scfm_{rated,base} \times Load_{base,bin}$$

$$Load_{ee,\,bin} = \frac{scfm_{bin}}{scfm_{rated,\ ee}}$$

The base and efficient system operating performance (of each bin) is calculated by the following equations:

$$\left(\frac{kW}{scfm}\right)_{base,\,bin} = \frac{hp_{base} \times 1.1 \times 0.746}{0.945} \times \frac{\left(X_{2,base} \times Load_{base,\ bin}{}^{2} + X_{1,base} \times Load_{base,\ \ bin} + C_{base}\right)}{scfm_{bin}}$$

$$\left(\frac{kW}{scfm}\right)_{ee,\,bin} = \frac{hp_{ee} \times 1.1 \times 0.746}{0.945 * \times \eta_{VFD}} \times \frac{\left(X_{2,ee} \times Load_{ee,\,bin}{}^{2} + X_{1,ee} \times Load_{ee,\,bin} + C_{ee}\right)}{scfm_{bin}}$$

Per measure, gross coincident summer peak demand reduction is calculated per VFD-controlled compressor according to the following equation:

$$\Delta kW_{summer} = \sum_{bin=1}^{7} scfm_{bin} \times \left[\left(\frac{kW}{cfm}\right)_{base,bin} - \left(\frac{kW}{cfm}\right)_{ee,bin}\right] \times HOU_{bin} \times CF_{summer}$$

Per measure, gross coincident winter peak demand reduction is calculated per VFD-controlled compressor according to the following equation:

$$\Delta kW_{winter} = \sum_{bin=1}^{7} scfm_{bin} \times \left[\left(\frac{kW}{cfm}\right)_{base,bin} - \left(\frac{kW}{cfm}\right)_{ee,bin}\right] \times HOU_{bin} \times CF_{winter}$$

Where:

ΔkWh = gross annual electric energy savings
ΔkW_{summer} = gross coincident summer peak demand reduction
ΔkW_{winter} = gross coincident winter peak 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
$kW/scfm_{basebin}$ = base trim compressor operating performance for each bin

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$kW/scfm_{eebin}$ = 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_{summer} = summer peak coincidence factor
CF_{winter} = winter peak coincidence factor

7.1.11.3 Input Variables

Table 7-33. Input Values Downsized VSD Air Compressor Savings Calculations

Component	Type	Value	Units	Sources
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	For default see Table 13-19 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors. The $Load_{bins}$ 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.	-	Average percent of bin definition, bins are 10% load ranges, from 100% to 40%, 30% assumed for <40% bin (bin 7)
$X_{2,base}$	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
$X_{1,base}$	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
C_{base}	Variable	See Table 13-20 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
η_{VFD}	Fixed	0.98	-	Engineering estimate
$X_{2,EE}$	Fixed	VFD = 0	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004
$X_{1,EE}$	Fixed	VFD = 0.95	-	"Fundamentals of Compressed Air Systems", Compressed Air Challenge, 2004

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Component	Type	Value	Units	Sources
C_{EE}	Fixed	VFD = 0.05	-	"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 3.1 2020, p. 451
HOU_{bin}	Variable	See customer application	-	Customer application
		For default see Table 13-19 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors. The $Load_{bins}$ 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.		Engineering assumption
CF_{summer}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors	-	IL TRM v 8.0 Volume 2 2020, p. 575
		Default =0.59		Default based on single shift operating schedule
CF_{winter}	Variable	See Table 13-21 in Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors		IL TRM v 8.0 Volume 2 2020, p. 575[158]
		Default =0.59		Default based on single shift (8/5) operating schedule[146]

7.1.11.4 Default Savings

This measure does not have default savings. The savings depend on the rated power. However, some variables have default values.

7.1.11.5 Effective Useful Life

The effective useful life of this measure is provided in Table 7-34.

Table 7-34. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VII	Non-Residential Small Manufacturing Program, DSM Phase VII	12.24	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

158 The source TRM doesn't differentiate between winter and summer peak periods. Therefore, the summer CF is applied to the winter CF.

7.1.11.6 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.Other sources include the IL TRM v.78.0, Vol. 2. 2020, p 575, MN TRM v 3.1 2020, p. 451.

7.1.11.7 Update Summary

Updates made to this section are described in Table 7-35.

Table 7-35. Summary of Update(s)

Version	Update Type	Description
2021	Source	Updated page numbers / version of the IL TRM and MN TRM
	Equation	Added gross winter peak demand reduction equation
	Table	Effective Useful Life (EUL) by program
2020	Inputs	Added default operating hours
v10	New Measure	New section

8 NON-RESIDENTIAL OFFICE PROGRAM, DSM PHASE VII

The Non-Residential Office Program (provides qualifying business owners incentives to pursue one or more of the qualified energy efficiency measures through a local, participating contractor in Dominion Energy'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 Office Program Measure List

End Use	Measure	Legacy Program	Manual Section
Lighting	Reduce Lighting Schedule by One Hour on Weekdays	N/A	Section 8.2.1
HVAC	HVAC Unit Scheduling	N/A	Section 8.3.1
	HVAC Temperature Setback		Section 8.3.2
	HVAC Condensing Water Temperature Reset		Section 8.3.3
	HVAC DAT Reset		Section 8.3.4
	HVAC Static Pressure Reset		Section 8.3.5
	HVAC VAV Minimum Flow Reduction		Section 8.3.6
	Dual Enthalpy Air-side Economizer	Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	Section 2.1.5

Except for the Dual Enthalpy Air-side Economizer measure (Section 8.3.7), analyses for all of the measure savings are based on building model simulations.

8.1.1 Building Model Simulation Description

Measures that utilize the building model simulation approach are described in this section. The U.S. Department of Energy (DOE) reference building "Large Office" with code vintage defined as ASHRAE 90.1-2004 is used as the basis for the baseline and installed case building models.[159] Current energy code in Virginia is 2015 IECC and ASHRAE 90.1-2013 with amendments.[160] It is DNV's expert engineering judgement that buildings and systems from the 2004 vintage would be appropriate candidates for the retro-commissioning measures in this program because the end-use systems being retro-commissioned in this program are generally assumed to be functioning properly but aged and should benefit from re-programming controls.

For smaller buildings the DOE Commercial Large Office Reference building was scaled down to a 4-story building.

There are baseline and efficient building models for each measure case. Energy savings are calculated using these models and simulated using TMY3 weather data for selected weather stations in Virginia and North Carolina.

[159] U.S. Department of Energy. Office of Energy Efficiency & Renewable Energy. Commercial Reference Buildings. https://www.energy.gov/eere/buildings/commercial-reference-buildings, accessed on 08/03/2021

[160] U.S. Department of Energy. Office of Energy Efficiency & Renewable Energy. Building Energy Codes Program. Virginia. https://www.energycodes.gov/status/states/virginia, accessed on 08/03/2021

8.1.1.1 Building Models

The baseline energy model is derived from DOE's Commercial Large Office Reference Building. That model assumes a baseline annual energy consumption of 24.35 kWh/sq.ft. and 0.08 therm/sq.ft. Electricity usage includes a data center that is typical of such buildings along with typical interior equipment load. The reference building is a large office (12-stories plus a basement totaling 498,600 sq.ft. or 38,350 sq.ft./floor).

For those program participant buildings 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 modelling. 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 modelled using the EnergyPlus™ engine—developed by DOE—with floors "multipliers" which means that the simulator itself was scaling results for the interior floors. The 4-story models were further modified by changing the said floors multipliers from ten to two. This 4-story model totaled 191,764 sq.ft. gross with about 150,000 sq.ft. in the above-ground floors subject to controls improvements.

There are three different models for HVAC system types representing the most likely HVAC systems to be encountered in small offices. The HVAC system types include: packaged VAV, chilled water VAV,and chilled water CV. Additionally, the heating fuel type is considered for each of these systems where the options are either electric or non-electric.

Scaling of results can be used to predict savings for medium to large multi-story office buildings. Loads on HVAC systems in offices tend to be dominated less by shell or envelop loads (e.g., passive stored heat) than internal loads such as occupants, lighting, and plug-load waste heat. Small buildings with relatively large exterior surface areas 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 (e.g., server rooms) and each floor includes its own small 390-sq.ft. data center (e.g., IT closet). The unoccupied basement areas (41,500 sq.ft.) are not included in the savings factors (i.e., kWh/sq.ft. and kW/sq.ft.) calculations provided in the sections that follow. Savings factors are normalized with a building area of 457,100 sq.ft. for the large office model and 153,400 sq.ft. for the 4-story models.

Each measure has an efficient model. The efficient building models were created by modifying the baseline energy models in ways that the measure is intended to operate. This is done by modifying the applicable setpoints and schedules for each measure, in just the end-use building systems that are affected by the energy efficient measure.

8.1.1.2 Impacts Estimation Approach

Modeled savings are calculated by subtracting the energy consumption of the efficient model from the baseline model, for each weather station. The savings are divided by the applicable model building floor area sq.ft. to produce the applicable energy savings factors used to calculate customer-specific gross savings. For each record, energy savings factors are multiplied against the customer-specific building floor area to calculate the customer-specific gross savings.

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

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$$\Delta kWh = ESF \times Area$$

Per measure, gross coincident summer and winter peak demand reduction is assigned as zero because these measures have a negligible demand reduction as shown below:

$$\Delta kW_{summer} = 0$$

$$\Delta kW_{winter} = 0$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW = per measure gross coincident demand reduction
Area = floor area of the building
ESF = annual energy savings factor per square foot based on measure, building type, weather station, and heating system type

8.1.1.3 Input Variables

Table 8-2. Input Values for Office Buildings with Electric and Non-Electric Heating Fuels

Component	Type	Value	Unit	Source(s)
Area	Variable	See customer application	sq.ft.	Customer application
ESF	Variable	See Table 8-3 through Table 8-6	kWh/sq.ft.	OpenStudio® energy modeling software outputs using EnergyPlus™ engine

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Table 8-3. Energy Saving Factor (ESF) for 4-Story Office (Chilled Water, VAV) Measures by Weather Station, and Heating System Type, kWh/sq.ft.

Annual Electric Energy Savings Factor (kWh/sq.ft.)	Weather Station	Heating System Fuel Type	ECM1: Schedule Lighting	ECM2: Schedule HVAC	ECM3: Temp. Setback	ECM4: Condenser Water Reset	ECM5: Discharge Air Temp. Reset	ECM6: Static Pressure Reset	ECM8: Reduced VAV Box Minimum Position
4-story Office, Chilled water, VAV	Charlottesville	Electric	0.9426	3.1111	2.0117	N/A	0.8754	0.7411	2.2962
		Non-Electric	1.2985	0.5137	0.5111	N/A	0.4375	1.2847	1.4020
	Farmville	Electric	0.9374	3.0802	1.9954	N/A	0.8772	0.7275	2.2654
		Non-Electric	1.3173	0.5242	0.5216	N/A	0.4222	1.2899	1.4288
	Fredericksburg	Electric	0.9326	3.0077	1.9602	N/A	0.8558	0.7017	2.1868
		Non-Electric	1.2900	0.5123	0.5099	N/A	0.4166	1.2631	1.3163
	Norfolk	Electric	0.9714	2.9175	1.8860	N/A	0.7872	0.7330	2.1416
		Non-Electric	1.2221	0.5143	0.5118	N/A	0.4190	1.2717	1.3415
	Washington DC Reagan Airport	Electric	0.9256	2.9889	1.9502	N/A	0.9327	0.7029	2.1954
		Non-Electric	1.2594	0.4967	0.4942	N/A	0.3989	1.2336	1.2886
	Roanoke	Electric	0.9359	3.0559	1.9782	N/A	0.9101	0.7454	2.2707
		Non-Electric	1.3204	0.5237	0.5214	N/A	0.4370	1.3083	1.3901
	Sterling	Electric	0.9201	3.0395	1.9803	N/A	0.9247	0.6814	2.2126
		Non-Electric	1.2920	0.4954	0.4933	N/A	0.3877	1.2306	1.2912
	Richmond	Electric	0.9542	2.9420	1.8979	N/A	0.7971	0.7312	2.1795
		Non-Electric	1.2701	0.5196	0.5174	N/A	0.4261	1.2871	1.3670
	Rocky Mount-Wilson	Electric	0.9808	3.0045	1.9271	N/A	0.7687	0.7650	2.2019
		Non-Electric	1.2628	0.5289	0.5266	N/A	0.4553	1.3161	1.4594
	Elizabeth City	Electric	0.9975	2.8411	1.8010	N/A	0.7457	0.7646	2.0871
		Non-Electric	1.2133	0.5322	0.5297	N/A	0.4650	1.3111	1.3470

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Table 8-4. Energy Saving Factor (ESF) for 4-Story Office (Chilled Water, CV) Measures by Weather Station, and Heating System Type, kWh/sq.ft.

Annual Electric Energy Savings Factor (kWh/sq.ft.)	Weather Station	Heating System Fuel Type	ECM1: Schedule Lighting	ECM2: Schedule HVAC	ECM3: Temp. Setback	ECM4: Condenser Water Reset	ECM5: Discharge Air Temp. Reset	ECM6: Static Pressure Reset	ECM8: Reduced VAV Box Minimum Position
4-story Office, Chilled water, CV	Charlottesville	Electric	1.3416	3.3268	2.4363	N/A	1.4414	N/A	N/A
		Non-Electric	1.0393	0.7804	0.3944	N/A	0.1661	N/A	N/A
	Farmville	Electric	1.3558	3.2949	2.4458	N/A	1.4728	N/A	N/A
		Non-Electric	1.0485	0.9491	0.4938	N/A	0.1621	N/A	N/A
	Fredericksburg	Electric	1.4063	3.2258	2.4680	N/A	1.5092	N/A	N/A
		Non-Electric	1.0754	0.6529	0.3119	N/A	0.1411	N/A	N/A
	Norfolk	Electric	1.3805	3.1348	2.3189	N/A	1.3526	N/A	N/A
		Non-Electric	1.0708	0.7712	0.4233	N/A	0.1514	N/A	N/A
	Washington DC Reagan Airport	Electric	1.3455	3.1841	2.4045	N/A	1.5359	N/A	N/A
		Non-Electric	1.1070	0.6295	0.3082	N/A	0.1643	N/A	N/A
	Roanoke	Electric	1.3248	3.2587	2.3994	N/A	1.4776	N/A	N/A
		Non-Electric	1.0557	0.6952	0.3276	N/A	0.1704	N/A	N/A
	Sterling	Electric	1.3240	3.2104	2.4217	N/A	1.5212	N/A	N/A
		Non-Electric	1.0771	0.5991	0.2576	N/A	0.1066	N/A	N/A
	Richmond	Electric	1.3777	3.1626	2.3513	N/A	1.3941	N/A	N/A
		Non-Electric	1.0487	0.8221	0.3989	N/A	0.1506	N/A	N/A
	Rocky Mount-Wilson	Electric	1.3904	3.2547	2.3587	N/A	1.3214	N/A	N/A
		Non-Electric	1.0849	0.9896	0.4759	N/A	0.1496	N/A	N/A
	Elizabeth City	Electric	1.4207	3.0960	2.2452	N/A	1.3070	N/A	N/A
		Non-Electric	1.0401	0.8332	0.4135	N/A	0.1409	N/A	N/A

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Table 8-5. Energy Saving Factor (ESF) for 4-StoryStory Office (Package, VAV) Measures by Weather Station, and Heating System Type, kWh/sq.ft.

Annual Electric Energy Savings Factor (kWh/sq.ft.)	Weather Station	Heating System Fuel Type	ECM1: Schedule Lighting	ECM2: Schedule HVAC	ECM3: Temp. Setback	ECM4: Condenser Water Reset	ECM5: Discharge Air Temp. Reset	ECM6: Static Pressure Reset	ECM8: Reduced VAV Box Minimum Position
4-story Office, Package system, VAV	Charlottesville	Electric	0.8665	0.0179	0.4843	N/A	0.2767	0.5718	0.7512
		Non-Electric	1.6465	0.4084	1.0399	N/A	0.2981	0.6456	0.3990
	Farmville	Electric	0.8591	0.0181	0.4890	N/A	0.2684	0.5647	0.7381
		Non-Electric	1.6544	0.4154	1.0506	N/A	0.2920	0.6449	0.3802
	Fredericksburg	Electric	0.8646	0.0173	0.4898	N/A	0.2444	0.5404	0.7099
		Non-Electric	1.6414	0.4057	1.0329	N/A	0.2702	0.6299	0.3506
	Norfolk	Electric	0.8802	0.0184	0.4973	N/A	0.2689	0.5782	0.7506
		Non-Electric	1.6635	0.4101	1.0419	N/A	0.2872	0.6413	0.3982
	Washington DC Reagan Airport	Electric	0.8648	0.0169	0.4683	N/A	0.2470	0.5337	0.6930
		Non-Electric	1.6150	0.3921	1.0149	N/A	0.2705	0.6158	0.3564
	Roanoke	Electric	0.8555	0.0181	0.4963	N/A	0.2689	0.5733	0.7452
		Non-Electric	1.6516	0.4167	1.0642	N/A	0.2931	0.6558	0.3893
	Sterling	Electric	0.8668	0.0165	0.4774	N/A	0.2347	0.5181	0.7108
		Non-Electric	1.6150	0.3919	1.0143	N/A	0.2622	0.6131	0.3685
	Richmond	Electric	0.8686	0.0183	0.5047	N/A	0.2666	0.5718	0.7381
		Non-Electric	1.6581	0.4134	1.0463	N/A	0.2884	0.6468	0.3782
	Rocky Mount-Wilson	Electric	0.8805	0.0194	0.5157	N/A	0.2958	0.6081	0.7836
		Non-Electric	1.6891	0.4248	1.0593	N/A	0.3130	0.6680	0.4190
	Elizabeth City	Electric	0.8801	0.0198	0.5155	N/A	0.3020	0.6228	0.7935
		Non-Electric	1.7020	0.4314	1.0683	N/A	0.3168	0.6737	0.4271

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Table 8-6. Energy Saving Factor (ESF) for Large Office (Package, VAV) Measures by Weather Station, and Heating System Type, kWh/sq.ft.

Annual Electric Energy Savings Factor (kWh/sq.ft.)	Weather Station	Heating System Fuel Type	ECM1: Schedule Lighting	ECM2: Schedule HVAC	ECM3: Temp. Setback	ECM4: Condenser Water Reset	ECM5: Discharge Air Temp. Reset	ECM6: Static Pressure Reset	ECM8: Reduced VAV Box Minimum Position
Large Office, Package System, VAV	Charlottesville	Electric	2.0217	1.4112	0.7956	0.0273	0.8362	1.6951	0.5503
		Non-Electric	3.3766	1.2276	1.1767	1.0830	1.0155	2.8377	0.7982
	Farmville	Electric	1.9986	1.5053	0.7938	0.0157	0.8732	1.6964	0.5154
		Non-Electric	3.3973	1.2665	1.1946	1.0977	1.0024	2.8763	0.7606
	Fredericksburg	Electric	1.9405	1.7095	0.9942	0.0383	0.9774	1.6466	0.4891
		Non-Electric	3.3851	1.2720	1.2118	1.1086	1.0033	2.8403	0.7014
	Norfolk	Electric	2.0279	1.8161	1.0828	0.0620	0.9664	1.7067	0.5310
		Non-Electric	3.4569	1.3200	1.2599	1.1416	1.0722	2.9044	0.7966
	Washington DC Reagan Airport	Electric	1.8660	2.1179	1.2639	0.0458	1.2708	1.6390	0.4729
		Non-Electric	3.3270	1.2816	1.2039	1.0710	1.0273	2.7847	0.7131
	Roanoke	Electric	1.9638	1.8206	1.0651	0.0156	1.0916	1.7180	0.5316
		Non-Electric	3.3839	1.2773	1.2142	1.1029	1.0575	2.8994	0.7789
	Sterling	Electric	1.8499	2.2055	1.3351	0.0215	1.2801	1.6029	0.5251
		Non-Electric	3.3106	1.2757	1.1976	1.0511	0.9811	2.7568	0.7372
	Richmond	Electric	1.9872	1.7821	1.0529	0.0397	1.0022	1.7140	0.5133
		Non-Electric	3.4078	1.2943	1.2317	1.1099	1.0565	2.8995	0.7567
	Rocky Mount-Wilson	Electric	2.1252	1.2633	0.7146	0.0282	0.6562	1.7743	0.5662
		Non-Electric	3.4438	1.2469	1.2034	1.1063	1.0509	2.9312	0.8383
	Elizabeth City	Electric	2.1446	1.2640	0.6784	0.0676	0.6212	1.8413	0.5608
		Non-Electric	3.5481	1.3243	1.2716	1.1893	1.1431	3.0749	0.8544

8.1.1.4 Default Savings

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

8.1.1.5 Effective Useful Life

The effective useful life of this measure is provided in Table 8-7.

Table 8-7. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VI	Non-Residential Office Program, DSM Phase VII	7.00	years	Program design assumptions (weighted average of measure lives of all measures offered by program and their planned uptake)

8.1.1.6 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 Dominion Energy's Virginia and North Carolina weather zones, using typical meteorological year 3 (TMY3) data along with various program-specific measures.

8.1.1.7 Update Summary

Updates made to this section are described in Table 8-8.

Table 8-8. Summary of Update(s)

Version	Update Type	Description
2021	Inputs	Added large office building type and expanded to 10 weather stations
2020	Inputs	Revised kWh/sq.ft. with results from updated building models
v10	New Measure	New section

8.2 Lighting End Use

8.2.1 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.

8.3 Heating, Ventilation, and Air Conditioning (HVAC) End Use

8.3.1 HVAC Unit Scheduling

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 outside air can be decreased by a half-hour in the morning and half-hour in the afternoon. In cases with greater reduction 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 reduction in free-cooling

8.3.2 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. Since the baseline HVAC schedules had already implemented temperature setback, this measure was “modeled in reverse” by eliminating the setback schedules in the reference energy model (which were set to nine degrees). Other schedule/setbacks can be scaled accordingly.

Code requires setback controls (but not setup) for ASHRAE Zone 4A, per ASHRAE 90.1-2004, sections 6.4.3.2(a) and 6.4.3.2.2. Implementing this measure involves restoring functionality that is intended by code.

- Setback temperature: 60.8 °F
- Occupied hours set point: 69.8 °F

8.3.3 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 to 70°F
- The measure accounts for the presence of two stages in the cooling tower that had not existed in the baseline case.

8.3.4 HVAC DAT Reset

The discharge air temperature from a variable air volume or constant volume re-heat air handling 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. Systems that are eligible for this measure include those with electric reheat coils or baseboard heaters. This is not required by ASHRAE 90.1-2004.

8.3.5 HVAC Static Pressure Reset

Supply fans controlled by variable-frequency drives (VFDs) must be converted from a fixed static-pressure supply setpoint to a control sequence that resets the static-pressure supply setpoint based on the 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 include functionality to 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 the National Renewable Energy Laboratory.

Fan curve coefficients used were as shown in Table 8-9.

Table 8-9. Fan Curve Coefficients

Coefficient	Fixed Static Pressure (baseline)	Reset Static Pressure (efficient)
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%

8.3.6 HVAC VAV Minimum Flow Reduction

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.

8.3.7 Dual Enthalpy Air-side Economizer

This measure does not use the building simulation approach that is applied to other measures in this program. Instead, it utilizes the Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII savings approach described in Section 2.1.5.

9 NON-RESIDENTIAL SMALL BUSINESS IMPROVEMENT ENHANCED PROGRAM, DSM PHASE VIII

The Non-Residential Small Business Improvement Enhanced Program provides mall businesses an energy use assessment and tune-up or re-commissioning of electric heating and cooling systems, along with financial incentives for the installation of specific energy efficiency measures. Participating small businesses would be required to meet certain size and connected load requirements. All non-residential customers who do not exceed the 100-kW demand threshold.

The measures offered through the program and the sections that contain the savings algorithms for each measure are presented in Table 9-1.

Table 9-1. Non-Residential Small Business Improvement Enhanced Program Measure List

End Use	Measure	Legacy Program	Manual Section
Building Envelope	Window Film Installation	Non-Residential Window Film Program, DSM Phase VII	Section 3.1.1
Domestic Hot Water	VFD on Hot Water Pump	Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.1.7
HVAC	Duct Testing & Sealing	Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.1.1
	Heat Pump Tune-up	Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.1.2
	Refrigerant Charge Correction	Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.1.3
	Heat Pump Upgrade	Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	Section 2.1.1
	Dual Enthalpy Air-side Economizer	Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	Section 2.1.5
	Programmable Thermostat	Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.1.8
Lighting	Lighting, Fixtures, Lamps, and Delamping	Non-Residential Lighting Systems and Controls Program, DSM Phase VII	Section 1.1.1
	Sensors and Controls	Non-Residential Lighting Systems and Controls Program, DSM Phase VII	Section 1.1.2
	LED Exit Signs	Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.2.3
Plug-load	Vending Machine Miser	Non-Residential Prescriptive Program, DSM Phase VI	Section 5.4.13
Refrigeration	Refrigeration Variable Frequency Drives	New Measure	Section 9.6.1
	Refrigeration Night Cover	Non-Residential Prescriptive Program, DSM Phase VI5.4.9	Section 5.4.9
	Evaporator Fan Electronically Commutated Motor (ECM) Retrofit	Non-Residential Prescriptive Program, DSM Phase VI	Section 5.4.5
	Evaporator Fan Motor Controls	Non-Residential Prescriptive Program, DSM Phase VI	Section 5.4.6
	Door Closer	Non-Residential Prescriptive Program, DSM Phase VI	Section 5.4.1
	Anti-Sweat Heater Controls	New Measure	Section 9.6.6
	Strip Curtain (Cooler and Freezer)	Non-Residential Prescriptive Program, DSM Phase VI	Section 5.4.12

9.1 Building Envelope End Use

9.1.1 Window Film Installation

This measure is also offered through the Non-Residential Window Film Program, DSM Phase VII. The savings approach is described in Section 3.1.1.

9.2 Domestic Hot Water End Use

9.2.1 VFD on Hot Water Pump

This measure is also offered through the Non-Residential Small Business Improvement Program, DSM Phase V. The savings approach is described in Section 4.1.7.

9.3 HVAC End Use

9.3.1 Duct Testing & Sealing

This measure is also offered through the Non-Residential Small Business Improvement Program, DSM Phase V. The savings approach is described in Section 4.1.1.

9.3.2 Heat Pump Tune-up

This measure is also offered through the Non-Residential Small Business Improvement Program, DSM Phase V. The savings approach is described in Section 4.1.2.

9.3.3 Refrigerant Charge Correction

This measure is also offered through the Non-Residential Small Business Improvement Program, DSM Phase V. The savings approach is described in Section 4.1.3.

9.3.4 Heat Pump Upgrade

This measure is also offered through the Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII . The savings approach is described in Section 2.1.1.

9.3.5 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 2.1.5.

9.3.6 Programmable Thermostat

This measure is also offered through the Non-Residential Small Business Improvement Program, DSM Phase V. The savings approach is described in Section 4.1.8.

9.4 Lighting End Use

9.4.1 Lighting, Fixtures, Lamps, and Delamping

This measure is also offered through the Non-Residential Lighting Systems and Controls Program, DSM Phase VII. The savings approach is described in Section 1.1.1.

9.4.2 Sensors and Controls

This measure is also offered through the Non-Residential Lighting Systems and Controls Program, DSM Phase VII. The savings approach is described in Section 1.1.2.

9.4.3 LED Exit Signs

This measure is also offered through the Non-Residential Small Business Improvement Program, DSM Phase V. The savings approach is described in Section 4.2.3.

9.5 Plug-Load End Use

9.5.1 Vending Machine Miser

This measure is also offered through the Non-Residential Prescriptive Program, DSM Phase VI. The savings approach is described in Section 5.4.13.

9.6 Refrigeration End Use

9.6.1 Refrigeration Variable Frequency Drives

Variable frequency drive (VFD) compressors are used to control and reduce the speed of the compressor during times when the refrigeration system does not require the motor to run at full capacity. VFD control is an economical and efficient retrofit option for existing compressor installations. The performance of variable speed compressors can more closely match the variable refrigeration load requirements thus minimizing energy consumption.

This measure, VFD control for refrigeration systems and its eligibility targets applies to retrofit construction in the commercial and industrial building sectors; it is most applicable to grocery stores or food processing applications with refrigeration systems. This protocol is for a VSD control system replacing a slide valve control system. The savings algorithms are shown below. There are two distinct sets of algorithms – one for if the refrigeration system is rated in tonnage, and another for if the refrigeration system is rated in horsepower.

9.6.1.1 Impacts Estimation Approach

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

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

If the refrigeration system is rated in horsepower:

$$tons_{cool} = 0.212 \times \frac{1}{COP} \times hp_{compressor}$$

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

$$\Delta kW_{summer} = tons_{cool} \times DSF_{summer}$$

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

$$\Delta kW_{winter} = tons_{cool} \times DSF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak demand reduction
$tons_{cool}$ = refrigeration cooling capacity of the system, in tons
ESF = energy saving factor in kWh per ton

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DSF_{summer} = summer demand saving factor, in kW per ton
DSF_{winter} = winter demand saving factor, in kW per ton
COP = coefficient of performance
$hp_{compressor}$ = rated horsepower of refrigeration compressor

9.6.1.2 Input Variable

Table 9-2. Input Variables for Refrigeration Variable Frequency Drives

Component	Type	Value	Unit	Source(s)
$hp_{compressor}$	Variable	See customer application	horsepower	Customer application
ESF	Fixed	1,696	kWh/ton	Pennsylvania TRM 2019 Vol.3, p. 164
DSF_{summer}	Fixed	0.22	kW/ton	Pennsylvania TRM 2019 Vol.3, p. 164
DSF_{winter}	Fixed	0.22	kW/ton	Pennsylvania TRM 2019 Vol.3, p. 164
COP	Variable	See customer application	-	Customer application
		Default: Reach-in Coolers = 2.04 Reach-in Freezers = 1.25 Reach-in Unknown = 1.80 Walk-in Coolers = 3.42 Walk-in Freezers = 1.00 Walk-in Unknown = 2.67		Pennsylvania TRM 2019 Vol. 3, p. 164

9.6.1.3 Default Savings

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

9.6.1.4 Effective Useful Life

The effective useful life of this measure is provided in Table 9-3.

Table 9-3. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	15.00	years	Pennsylvania TRM 2019, Vol. 3, p. 163

9.6.1.5 Source

The primary sources for this deemed savings approach Pennsylvania TRM 2019, Vol. 3, pp. 163-165.

9.6.1.6 Update Summary

Updates made to this section are described in Table 9-4.

Table 9-4. Summary of Update(s)

Version	Update Type	Description
2021	New Measure	New Section

9.6.2 Night Cover

This measure is also offered through the Non-Residential Prescriptive Program, DSM Phase VI. The savings approach is described in Section 5.4.9.

9.6.3 Evaporator Fan Electronically Commutated Motor (ECM) Retrofit

This measure is also offered through the Non-Residential Prescriptive program. The savings approach is described in Section 5.4.5.

9.6.4 Evaporator Fan Motor Controls

This measure is also offered through the Non-Residential Prescriptive program. The savings approach is described in Section 5.4.6.

9.6.5 Door Closer

This measure is also offered through the Non-Residential Prescriptive program. The savings approach is described in Section 5.4.1.

9.6.6 Anti-Sweat Heater Controls

Anti-sweat door heaters (ASDH) prevent condensation from forming on cooler and freezer doors. By installing a control device to turn off door heaters when there is little or no risk of condensation, significant energy savings can be realized. There are two commercially available control strategies—On/Off controls and micro-pulse controls—that respond to a call for heating. Heating is typically triggered based on a door-moisture sensor or an indoor-air temperature and humidity-sensor to calculate the dew point. In the first strategy, the On/Off controls turn the heaters on and off for minutes at a time, resulting in a reduction in run time. In the second strategy, the micro pulse controls turn on the door heaters for fractions of a second, in response to the call for heating. Either of these strategies result in annual energy and coincident peak demand reduction. Additional savings come from refrigeration interactive effects. When the heaters run less, they introduce less heat into the refrigerated spaces and reduce the cooling load.

The baseline condition is assumed to be a commercial glass door cooler or refrigerator with a standard heated door running 24 hours per day, seven days per week (24/7) with no controls installed. The efficient equipment is assumed to be a door heater control on a commercial glass door cooler or refrigerator utilizing either On/Off or micro-pulse controls.

9.6.6.1 Impacts Estimation Approach

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

$$\Delta kWh = kW_{load} \times (\%On_{base} - \%On_{ee}) \times HOU \times WHF_e$$

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

$$\Delta kW_{summer} = kW_{load} \times WHF_d \times CF_{summer}$$

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

$$\Delta kW_{winter} = kW_{load} \times WHF_d \times CF_{winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak demand reduction
kW_{load} = connected load kW per connected door
$\%On_{base}$ = effective run time of uncontrolled anti-sweat door heaters (ASDH)
$\%On_{ee}$ = effective run time of ASDH with controls
HOU = annual hours of operation
WHF_e = waste heat factor for energy
WHF_d = waste heat factor for demand
CF_{summer} = summer coincidence factor
CF_{winter} = winter coincidence factor

9.6.6.2 Input Variable

Table 9-5. Input Values for Anti-Sweat Heater Controls

Component	Type	Value	Units	Source(s)
kW_{load}	Variable	See customer application	kW	See customer application
		Default: 0.13		Maryland/Mid-Atlantic TRM v10, p. 344
$\%On_{base}$	Fixed	0.907	-	Maryland/Mid-Atlantic TRM v10, p. 344
$\%On_{ee}$	Fixed	Default: On/Off control=0.589 Micro-pulse control=0.428	-	Maryland/Mid-Atlantic TRM v10, p. 345
HOU	Fixed	8,760	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 345

Component	Type	Value	Units	Source(s)
CF_{summer}	Variable	Default: Refrigerator: ON/OFF controls: 0.25 Micro-pulse control: 0.36 Freezer: ON/OFF controls: 0.21 Micro-pulse control: 0.30	-	Maryland/Mid-Atlantic TRM v10, p. 345
CF_{winter}	Variable	Default: Refrigerator: On/Off controls: 0.24 Micro-pulse: 0.35 Freezer: On/Off controls: 0.20 Micro-pulse: 0.29	-	Maryland/Mid-Atlantic TRM v10, pp. 345[161].
WHF_e	Variable	High Temp (31˚F - 55˚F): 1.25 Med Temp (0˚F - 30˚F): 1.50 Low Temp (-35˚F - -1˚F): 1.50	-	Maryland/Mid-Atlantic TRM v10, p. 345
WHF_d	Variable	High Temp (31˚F - 55˚F): 1.25 Med Temp (0˚F - 30˚F): 1.50 Low Temp (-35˚F - -1˚F): 1.50	-	Maryland/Mid-Atlantic TRM v10, p. 345

9.6.6.3 Default Savings

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

9.6.6.4 Effective Useful Life

The effective useful life of this measure is provided in Table 9-6.

Table 9-6. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Small Business Improvement Enhanced Program, DSM Phase VIII	12.00	years	Maryland/Mid-Atlantic TRM v10, p. 345

9.6.6.5 Source

The primary sources for this deemed savings approach Maryland/Mid-Atlantic TRM v10, pp. 344-345.

9.6.6.6 Update Summary

Updates made to this section are described in Table 9-7.

[161] Applied the same methodology that Maryland/Mid-Atlantic TRM v10, pp. 345 uses for summer CF and applied to the winter peak values provided by Cadmus. 2015. Commercial Refrigeration Loadshape Project

Table 9-7. Summary of Update(s)

Version	Update Type	Description
2020	New Measure	• New Section

9.6.7 Strip Curtain (Cooler and Freezer)

This measure is also offered through the Non-Residential Prescriptive program. The savings approach is described in Section 5.4.12.

10 NON-RESIDENTIAL MIDSTREAM ENERGY EFFICIENCY PRODUCTS PROGRAM, DSM PHASE VIII

The Non-Residential Midstream Energy Efficiency Products Program consists of enrolling equipment distributors into the Program through an agreement to provide point-of-sales data in an agreed upon format each month. These monthly data sets will contain, at minimum, the data necessary to validate and quantify the eligible equipment that has been delivered for sale in the Company's service territory. In exchange for the data sets, the distributor will discount the rebate-eligible items sold to end customers. This Program aims to increase the availability and uptake of efficient equipment for the Company's non-residential customers.

The measures offered through the program and the sections that contain the savings algorithms for each measure are presented in Table 10-1.

Table 10-1. Non-Residential Midstream Energy Efficiency Products Improvement Enhanced Program Measure List

End Use	Measure	Legacy Program	Manual Section
Cooking	Commercial Combination Oven	Non-Residential Prescriptive Program, DSM Phase VI	Section 5.1.2
	Commercial Convection Oven	Non-Residential Prescriptive Program, DSM Phase VI	Section 5.1.1
	Commercial Griddle	Non-Residential Prescriptive Program, DSM Phase VI	Section 5.1.4
	Commercial Fryer	Non-Residential Prescriptive Program, DSM Phase VI	Section 5.1.3
	Commercial Steam Cooker	Non-Residential Prescriptive Program, DSM Phase VI	Section 5.1.6
	Commercial Hot Food holding Cabinet	Non-Residential Prescriptive Program, DSM Phase VI	Section 5.1.5
HVAC	Unitary/Split HVAC, Package Terminal Air conditioners and Heat Pumps	Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	Section 2.1.1
	Mini-split Systems	Non-Residential Lighting Systems and Controls Program, DSM Phase VII	Section 2.1.2
	Electric Chillers	Non-Residential Lighting Systems and Controls Program, DSM Phase VII	Section 2.1.3
Refrigeration	Commercial Freezers and Refrigerators	Non-Residential Prescriptive Program, DSM Phase VI	Section 5.4.3

10.1 Cooking End Use

10.1.1 Commercial Combination Oven

This measure is also offered through the Non-Residential Prescriptive program. The savings approach is described in Section 5.1.2.

10.1.2 Commercial Convection Oven

This measure is also offered through the Non-Residential Prescriptive program. The savings approach is described in Section 5.1.1.

10.1.3 Commercial Griddle

This measure is also offered through the Non-Residential Prescriptive program. The savings approach is described in Section 5.1.4.

10.1.4 Commercial Fryer

This measure is also offered through the Non-Residential Prescriptive program. The savings approach is described in Section 5.1.3.

10.1.5 Commercial Steam Cooker

This measure is also offered through the Non-Residential Prescriptive program. The savings approach is described in Section 5.1.6.

10.1.6 Commercial Hot Food Holding Cabinet

This measure is also offered through the Non-Residential Prescriptive program. The savings approach is described in Section 5.1.5.

10.2 HVAC End Use

10.2.1 Unitary/Split HVAC, Package Terminal Air conditioners and Heat Pumps

This measure is also offered through the Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII. The savings approach is described in Section 2.1.1.

10.2.2 Mini-split Systems

This measure is also offered through the Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII. The savings approach is described in Section 2.1.2.

10.2.3 Electric Chiller

This measure is also offered through the Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII. The savings approach is described in Section 2.1.3.

10.3 Refrigeration End Use

10.3.1 Commercial Freezers and Refrigerators

This measure is also offered through the Non-Residential Prescriptive program. The savings approach is described in Section5.4.3.

DNV

11 NON-RESIDENTIAL MULTIFAMILY PROGRAM, DSM PHASE VIII

The Multifamily Program is designed to encourage investment in both the residential and commercial areas of multifamily properties. The Program design is based on a whole-building approach where the implementation vendor will identify as many cost-effective measure opportunities as possible in the entire building (both residential and commercial metered) and encourage property owners to address the measures as a bundle. This approach provides "one-stop shop" programming for multifamily property owners with solutions to include direct-install measures and incentives for prescriptive efficiency improvements. The Program will identify, track, and report residential (in-unit) and commercial (common space) savings separately, according to the account type. The Program will be delivered through an expanded network of local trade allies that the implementation vendor will recruit and support while also establishing a robust relationship with property management companies—the gatekeepers for determining enrollment for their multifamily communities. Once a property management company has decided to enroll a property into the Program, the implementation vendor will send the tenants a letter that will provide information about Program benefits along with an opportunity to opt-out of participating within a defined period of time. If a tenant does not take action to notify the program implementation vendor that they are opting out of participation, their unit will be included in the enrolled locations to receive the installed measures during the delivery phase.

The implementation vendor intends to complete site assessments at the time of the enlistment visit—or within two weeks—to identify all eligible measures. Subsequently, the property owner or manager will receive an assessment report identifying and quantifying savings opportunities with estimated project costs and available incentives. The program implementation vendor or trade ally auditor will perform a walk-through audit covering the envelope and all energy systems in the buildings, paying particular attention to the condition of domestic hot water (DHW) and HVAC systems, building-envelope insulation, and lighting. After assessing the entire structure and living units, the auditor will use an assessment tool to perform appropriate calculations and generate a report showing projected energy and potential cost savings specific to each unit and/or common area. The auditor will review the findings and recommendations of the assessment with the property owner and assist them in making measure installation and investment decisions. Participation will require that all services or installations qualifying for an incentive be completed by a participating contractor or properly-credentialed building maintenance staff. The measures offered through the program and the sections that contain the savings algorithms for each measure are presented in Table 11-1.

Table 11-1. Residential / Non-Residential Multifamily Program Measure List

End Use	Measure	Legacy Program	Non-Residential Manual Section
Building Envelope	Air Sealing	Residential Manufactured Housing Program, DSM Phase VIII	Section 11.1.1
	Building Insulation/ Drill & Fill Wall Insulation	Residential Income and Age Qualifying Home Improvement Program, DSM Phase IV	Section 11.1.2
Domestic Hot Water	Domestic Hot Water Pipe Insulation	Residential Income and Age Qualifying Home Improvement Program, DSM Phase IV	Section 11.2.1
	Water Heater Temperature Setback/Turndown	Residential Home Energy Assessment Program, DSM Phase VII	Section 11.2.2

End Use	Measure	Legacy Program	Non-Residential Manual Section
HVAC	HVAC Upgrade/ Unitary AC	Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII	Section 2.1.1
	Heat Pump Tune-up	Non-Residential Small Business Improvement Program, DSM Phase V	in Section 4.1.2
	Duct Sealing	Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.1.1
	Energy Star® Room/Wall AC Units	Residential Home Energy Assessment Program, DSM Phase VII	Section 11.3.4
	Smart Thermostat Installation	New Measure	Section 11.3.5
Lighting	Lighting, Fixtures, Lamps, and Delamping	Non-Residential Lighting Systems and Controls Program, DSM Phase VII	Section 1.1.1
	LED Exit Signs	Non-Residential Small Business Improvement Program, DSM Phase V	Section 4.2.3
	Sensors and Controls	Non-Residential Lighting Systems and Controls Program, DSM Phase VI	Section 1.1.2
Plug-Load/ Appliances	ENERGY STAR® Clothes Dryer	Residential Efficient Products Marketplace Program, DSM Phase VII	Section 11.5.1
	ENERGY STAR® Clothes Washer		Section 11.5.2
Recreation	Two-speed & Variable Speed Pool Pump	New Measure	Section 11.6.1

11.1 Building Envelope End Use

11.1.1 Air Sealing

This measure is also offered through the Residential Manufactured Housing Program, DSM Phase VIII. The savings approach is described in Appendix F1: Technical Reference Manual for Residential Programs v.2021, Section 11.1.1.

11.1.2 Building Insulation/Drill & Fill Wall Insulation

This measure is also offered through the Residential Income and Age Qualifying Home Improvement Program, DSM Phase IV. The savings approach is described in Appendix F1: Technical Reference Manual for Residential Programs v.2021, Section 2.2.1.

11.2 Domestic Hot Water End Use

11.2.1 Domestic Hot Water Pipe Insulation

This measure is also offered through the Residential Income and Age Qualifying Home Improvement Program, DSM Phase IV. The savings approach is described in Appendix F1: Technical Reference Manual for Residential Programs v.2021, Section 2.1.1.

11.2.2 Water Heater Temperature Setback/Turndown

This measure is also offered through the Residential Home Energy Assessment Program, DSM Phase VII. The savings approach is described in Appendix F1: Technical Reference Manual for Residential Programs v.2021, Section 5.2.5.

11.3 Heating, Ventilation, and Air-Conditioning End Use

11.3.1 HVAC Upgrade/ Unitary AC

This measure is also offered through the Non-Residential Heating and Cooling Efficiency Program, DSM Phase VII. The savings approach is described in Section 2.1.1.

11.3.2 Heat Pump Tune-Up

This measure is also offered through the Non-Residential Small Business Improvement Program, DSM Phase V. The savings approach is described in Section 4.1.2.

11.3.3 Duct Sealing

This measure is also offered through the Non-Residential Small Business Improvement Program, DSM Phase V. The savings approach is described in Section 4.1.1.

11.3.4 ENERGY STAR® Room/Wall AC Units

This measure is also offered through the Residential Home Energy Assessment Program, DSM Phase VII. The savings approach is described in Appendix F1: Technical Reference Manual for Residential Programs v.2021, Section 5.3.1.

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11.3.5 Smart Thermostat Installation

11.3.5.1 Measure Description

The smart thermostat measure involves the replacement of a manually operated or conventional programmable thermostat with a smart thermostat that meets or exceeds the ENERGY STAR® requirements.[162] A "smart" or communicating thermostat allows remote set point adjustment and control via remote application. The system requires an outdoor-air-temperature algorithm in the control logic to operate heating and cooling systems.

The baseline is a mix of manual and programmable thermostats; the efficient condition is a smart thermostat that has earned ENERGY STAR® certification.

11.3.5.2 Impacts Estimation Approach

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

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

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:

$$\Delta kWh_{cool} = Size_{cool} \times \frac{1\ kBtuh}{1{,}000\ Btuh} \times \frac{EFLH_{cool}}{SEER} \times ESF_{cool}$$

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:

$$\Delta kWh_{cool} = Size_{cool} \times \frac{1\ kBtuh}{1{,}000\ Btuh} \times \frac{EFLH_{cool}}{IEER} \times ESF_{cool}$$

Heating savings are only applicable to spaced conditioned using heat pumps. For heat pumps <65,000 Btu/h, per measure gross annual electric heating energy savings are calculated according to the following equation

$$\Delta kWh_{heat} = Size_{heat} \times \frac{1\ kBtuh}{1{,}000\ Btuh} \times \frac{EFLH_{heat}}{HSPF} \times ESF_{heat}$$

For heat pumps ≥65,000 Btu/h, and water-source heat pumps of all sizes, and package terminal HP units of all sizes, per measure gross annual electric heating energy savings are calculated according to the following equation:

$$\Delta kWh_{heat} = Size_{heat} \times \frac{1\ W}{3.412\ Btuh} \times \frac{1\ kBtuh}{1{,}000\ Btuh} \times \frac{EFLH_{heat}}{COP} \times ESF_{heat}$$

This measure does not provide gross coincident summer or winter peak demand reductions.

[162] The key product criteria for Smart thermostats can be found at https://www.energystar.gov/products/heating_cooling/smart_thermostats/key_product_criteria;.

Where:

ΔkWh	= per measure gross annual electric energy savings
$Size_{cool}$	= cooling capacity of HVAC system
$Size_{heat}$	= heating capacity of heat pump
SEER	= seasonal energy efficiency ratio (SEER)
IEER	= integrated energy efficiency ratio (IEER)
HSPF	= heating seasonal performance factor (HSPF)
COP	= coefficient of performance (COP)
$EFLH_{cool}$	= equivalent cooling full load hours
$EFLH_{heat}$	= equivalent heating full load hours
ESF_{cool}	= cooling annual energy savings factor
ESF_{heat}	= heating annual energy savings factor

11.3.5.3 Input Variables

Table 11-2. Input Variables for Smart Thermostat Savings Calculations

Component	Type	Value	Units	Source(s)
$Size_{cool}$	Variable	See customer application	Btu/h	Customer application
$Size_{heat}$	Variable	See customer application[163]	Btu/h	Customer application
		Default = $Size_{cool}$		
$EFLH_{cool}$	Variable	See Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours, Table 13-4 and Table 13-5 use multifamily (common area)	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 423, scaled using CDD
$EFLH_{heat}$	Variable	See Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours, Table 13-5 use multifamily (common area)	hours, annual	Maryland/Mid-Atlantic TRM v10, p. 423, scaled using HDD
SEER/IEER/ HSPF/COP	Variable	See Sub-Appendix F2-III: Non-Residential HVAC Equipment Efficiency Ratings, Table 13-8 and Table 13-9	Btu/Wh (COP is unitless)	ASHRAE 90.1-2013
ESF_{cool}	Fixed	Manual thermostat existing: 0.050 Programmable thermostat existing: 0.020	-	Maryland/Mid-Atlantic TRM v10, p. 319
		Default = 0.030		DNV, Dominion Energy 2020 Commercial Energy Survey, Appendix B, p.60 (Q25)[164]
ESF_{heat}	Fixed	Manual thermostat existing: 0.040 Programmable thermostat existing: 0.020	-	Maryland/Mid-Atlantic TRM v10, p. 319
		Default = 0.027		DNV, Dominion Energy2020 Commercial Energy Survey, Appendix B, p. 60 (Q25)[164]

[163] When customer-provided heating system size is <80% or >156% of customer-provided cooling system size, a default value will be used, instead. In such instances, it is assumed that the heating system size was incorrectly documented. The acceptable range is based on a review of the AHRI database across numerous manufacturers and heat pump types.

[164] Used weighted average of programmable thermostat and manual thermostat responses to determine the ESF.

11.3.5.4 Default Savings

If the proper values are not available, zero savings will be given for gross annual electric energy savings.

11.3.5.5 Effective Useful Life

The effective useful life of this measure is provided in Table 11-3.

Table 11-3. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Multifamily Program, DSM Phase VIII	7.50	years	Maryland/Mid-Atlantic TRM v10, pp. 317-320

11.3.5.6 Source

The primary source for this deemed savings approach is the Maryland/Mid-Atlantic TRM v10, pp. 317-320.

11.3.5.7 Update Summary

Updates to this section are described in Table 11-8.

Table 11-4. Summary of Update(s)

Version	Update Type	Description
2021	New Measure	New section

11.4 Lighting End Use

11.4.1 LED Lamps, Advanced Lighting, and Delamping

This measure is also offered through the Non-Residential Lighting Systems and Controls Program, DSM Phase VII. The savings approach is described in Section 1.1.1.

11.4.2 LED Exit Signs

This measure is also offered through the Non-Residential Small Business Improvement Program, DSM Phase V. The savings approach is described in Section 4.2.3.

11.4.3 Sensors and Controls

This measure is also offered through the Non-Residential Lighting Systems and Controls Program, DSM Phase VII. The savings approach is described in Section 1.1.2.

11.5 Plug-Load End Use

11.5.1 Clothes Dryer

This measure is also provided by the Residential Efficient Products Marketplace Program, DSM Phase VII. The savings are determined using the methodology described in Section 6.2.3.

11.5.2 Clothes Washer

This measure is also provided by the Residential Efficient Products Marketplace Program, DSM Phase VII. The savings are determined using the methodology described in Section 6.2.2.

11.6 Recreation Use

11.6.1 Two-Speed & Variable-Speed Pool Pump

11.6.1.1 Measure Description

This measure replaces a single-speed pool filter pump with a variable-speed or dual-speed pump of equivalent horsepower. This measure is only applicable to self-priming pool filter pumps which are typically used with permanent, in-ground pools in multifamily and commercial buildings. Non-self-priming pool filter pumps, which are typically used with rigid, above-ground pools, are not eligible for this measure. The baseline efficiency equipment is a single-speed, self-priming pool filter pump. The efficient equipment is a variable-speed or dual-speed self-priming pool filter pump.

11.6.1.2 Impacts Estimation Approach

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

$$\Delta kWh = \left(kWh_{daily,base} - kWh_{daily,ee}\right) \times Days$$

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

$$\Delta kW_{summer} = \left[\left(\frac{kWh_{daily,base}}{Hours_{daily,base}}\right) \times CF_{base,summer}\right] - \left[\left(\frac{kWh_{daily,ee}}{Hours_{daily,ee}}\right) \times CF_{ee,summer}\right]$$

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

$$\Delta kW_{winter} = \left[\left(\frac{kWh_{daily,base}}{Hours_{daily,base}}\right) \times CF_{base,winter}\right] - \left[\left(\frac{kWh_{daily,ee}}{Hours_{daily,ee}}\right) \times CF_{ee,winter}\right]$$

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Where:

ΔkWh	= per measure gross annual electric energy savings
ΔkW_{summer}	= per measure gross coincident summer peak demand reduction
ΔkW_{winter}	= per measure gross coincident winter peak demand reduction
$kWh_{daily,base}$	= typical daily energy consumption of a single speed motor in a cool climate
$kWh_{daily,ee}$	= typical daily energy consumption for an efficient variable-speed or two-speed pump motor
Days	= number of days the pump operates in a year
$Hours_{dailybase}$	= daily runtime of baseline pump
$Hours_{daily\ ee}$	= daily runtime of dual speed or variable-speed pump
$CF_{base,summer}$	= summer coincidence factor of baseline pump
$CF_{ee,summer}$	= summer coincidence factor of dual speed or variable-speed pump
$CF_{base,winter}$	= winter coincidence factor of baseline pump
$CF_{ee,winter}$	= winter coincidence factor of dual speed or variable-speed pump

11.6.1.3 Input Variables

Table 11-5. Input Variables for Two speed & Variable Speed Pool Pump Savings Calculations

Component	Type	Value	Units	Source(s)
$Size_{base}$	Variable	See customer application	hp (pump motor)	Customer application
$Size_{ee}$	Variable	See customer application	hp (pump motor)	Customer application
$kWh_{daily,base}$	Variable	See Table 11-6 based on $Type_{base}$ and $Bin_{size,base}$	kWh, daily	Hawaii TRM 2019, p.172
$kWh_{daily,ee}$	Variable	See Table 11-6 based on $Type_{ee}$ and $Bin_{size,ee}$	kWh, daily	Hawaii TRM 2019, p.172
$Type_{base}$	Fixed	Default: Single-Speed Pump	-	Program requirement
$Type_{ee}$	Variable	Default: 1. Dual-Speed Pump 2. Variable Speed Pump	-	Customer application
Days	Variable	See customer application	Days, annual	Customer application
		Default: VA: 100 NC: 120		Hawaii TRM 2019, p.172
$Bin_{size,base}$	Variable	See Table 11-6	-	Hawaii TRM 2019, p.172
$Bin_{size,ee}$	Variable	See Table 11-6	-	Hawaii TRM 2019, p.172
$Hours_{daily,base}$	Variable	See Table 11-6 based on $Type_{base}$ and $Bin_{size,base}$	Hours, daily	Hawaii TRM 2019, p.172
$Hours_{daily,ee}$	Variable	See Table 11-6 based on $Type_{ee}$ and $Bin_{size,ee}$	hours, daily	Hawaii TRM 2019, p.172
$CF_{base,summer}$	Variable	See Table 11-6 based on $Type_{base}$ and $Bin_{size,base}$	-	Hawaii TRM 2019, p.172
$CF_{ee,summer}$	Variable	See Table 11-6 based on $Type_{ee}$ and $Bin_{size,ee}$	-	Hawaii TRM 2019, p.172

Component	Type	Value	Units	Source(s)
$CF_{base,winter}$	Variable	If Days < 365: 0.00 If Days = 365: See Table 11-6 based on $Type_{base}$ and $Bin_{size,base}$	-	Hawaii TRM 2019, p.172[165]
$CF_{ee,winter}$	Variable	If Days < 365: 0.00 If Days = 365: See Table 11-6 based on $Type_{ee}$ and $Bin_{size,ee}$	-	Hawaii TRM 2019, p.172[165]

Table 11-6. Typical Energy Consumption of Pumps, Operating Hours and Coincidence Factor for Various Pump Size Strategies and Pump Type

<table>
<tr><th rowspan="2">$Type_{pump}$</th><th rowspan="2">Metric</th><th colspan="4">Bin, based on pump size (hp)</th></tr>
<tr><th>> 0 and ≤ 1</th><th>> 1 and ≤ 2</th><th>> 2 and ≤ 3</th><th>> 3</th></tr>
<tr><td rowspan="4">Single-speed</td><td>$kWh_{daily,base}$ (kWh)</td><td>20.3</td><td>29.3</td><td>43.7</td><td>51.8</td></tr>
<tr><td>$Hours_{daily,base}$ (hr)</td><td>17.6</td><td>17.2</td><td>17.8</td><td>18.9</td></tr>
<tr><td>$CF_{base,summer}$</td><td rowspan="2">0.73</td><td rowspan="2">0.72</td><td rowspan="2">0.74</td><td rowspan="2">0.79</td></tr>
<tr><td>$CF_{base,winter}$</td></tr>
<tr><td rowspan="4">Two-speed</td><td>$kWh_{daily,ee}$ (kWh)</td><td>19.0</td><td>30.3</td><td>39.2</td><td>49.4</td></tr>
<tr><td>$Hours_{daily,ee}$ (hr)</td><td colspan="4">24.0</td></tr>
<tr><td>$CF_{ee,summer}$</td><td colspan="4" rowspan="2">1.00</td></tr>
<tr><td>$CF_{ee,winter}$</td></tr>
<tr><td rowspan="4">Variable-speed</td><td>$kWh_{daily,ee}$ (kWh)</td><td>9.2</td><td>13.9</td><td>21.6</td><td>27.0</td></tr>
<tr><td>$Hours_{daily,ee}$ (hr)</td><td colspan="4">22.7</td></tr>
<tr><td>$CF_{ee,summer}$</td><td colspan="4" rowspan="2">0.95</td></tr>
<tr><td>$CF_{ee,winter}$</td></tr>
</table>

11.6.1.4 Default Savings

If the proper values are not available, zero savings will be given for both gross annual electric energy savings and gross demand energy savings.

11.6.1.5 Effective Useful Life

The effective useful life of this measure is provided in Table 11-7.

[165] Source TRM does not have winter CF. If the pool is only used seasonally, it is assumed that it will not be used during the winter. Therefore, Winter CF is zero. However, the pool is used year-round (Days = 365), the summer CF to winter CF as an approximation.

Table 11-7. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Program Name	Value	Units	Source(s)
VIII	Non-Residential Multifamily Program, DSM Phase VIII	10.00	years	Hawaii TRM 2019, p. 173

11.6.1.6 Source

The primary source for this deemed savings approach is the Hawaii TRM 2019, pp. 171-174.

11.6.1.7 Update Summary

Updates to this section are described in Table 11-8.

Table 11-8. Summary of Update(s)

Version	Update Type	Description
2021	New Measure	New section

12 NON-RESIDENTIAL NEW CONSTRUCTION PROGRAM, DSM PHASE VIII

The Non-Residential New Construction Program provides incentives to non-residential customers to implement energy efficiency measures in their new construction project. Program engineers determine which energy efficiency upgrades are of interest to the owner and feasible within their budget. These measures—coupled with basic facility design data—are analyzed to determine the optimized building design. This in-depth analysis will be performed using building energy simulation models that will allow "bundles" of measures to be analyzed for energy savings while accounting for interactive effects between the measures within a given "bundle." The results are presented to the facility owner to facilitate their selection of the measures(s) to be installed. This program has been offered in Virginia and North Carolina beginning in March 2021.

To be eligible for a rebate, the new building must be eligible for a rate schedule that is not exempt by statute.

The measures offered through this program and the sections describing the measures are listed in Table 12-1. The energy savings methodology is provided in Section 12.5. The following sections include measure descriptions. Note that while some measures may be the same as those offered by other programs, the savings methodology will differ. That is because this program is designed to determine savings using building energy simulations. This approach accounts for measure interactivity across all measures to be implemented at a specific new building.

Table 12-1. Non-Residential Small Business Improvement Enhanced Program Measure List

End Use	Measure	Section
Building Envelope	Optimal Choice of Vertical Fenestration	Section 12.1.1
Heating, Ventilation, Air-conditioning	High Efficiency and Variable Speed Chillers (Air-Cooled)	Section 12.2.1
	High Efficiency DX Cooling Equipment	Section 12.2.2
	High Efficiency and Variable Speed Packaged DX Cooling Equipment	Section 12.2.3
	High Efficiency Packaged Air-Source Heat Pumps	Section 12.2.4
	Demand Controlled Ventilation/CO2 Controls	Section 12.2.5
	VAV Dual-Max Controls	Section 12.2.6
	VAV Supply Air Temperature Reset	Section 12.2.7
	Chiller Controls	Section 12.2.8
Plug Load	Supervisory Plug Load Management Systems	Section 12.3.1
Lighting	High Performance Interior Lighting	Section 12.4.1
	LED Exterior Lighting	Section 12.4.2

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12.1 Building Envelope

12.1.1 Optimal Choice of Vertical Fenestration

This measure upgrades the window assemblies relative to minimum building code requirements with assemblies having high insulative properties (low U-values), low Solar Heat Gain Coefficients (SHGC), and low visible sunlight transmittance (Tvis-glass).

12.2 Heating, Ventilation, Air Conditioning

12.2.1 High Efficiency and Variable Speed Chillers (Air-Cooled)

This measure upgrades a constant-speed, chilled-water system to one that includes variable-speed, air-cooled chillers and variable-speed chilled-water pumps. The baseline chiller performance and the VFD pump curves from ASHRAE 90.1-2013 are used.

12.2.2 High Efficiency DX Cooling Equipment

This measure upgrades from standard-efficiency DX cooling equipment to high-efficiency DX cooling equipment. The baseline equipment meets 90.1-2013 efficiency requirements.

12.2.3 High Efficiency and Variable Speed Packaged DX Cooling Equipment

This measure upgrades from a constant-speed rooftop unit (RTU) to a variable-speed RTU. This measure may utilize either a natural gas heating coil or a direct-expansion (DX) heating coil. The variable-speed RTU model stages the fan in response to the amount of heating/cooling required. The measure adjusts the fan flow according to the heating/cooling required at each stage.

12.2.4 High Efficiency Packaged Air-Source Heat Pumps

This measure upgrades from a standard efficiency air-source heat pump to a high efficiency air-source heat pump. The baseline equipment meets 90.1-2013 efficiency values.

12.2.5 Demand Controlled Ventilation/CO2 Controls

This measure varies the outside airflow based on the actual number of occupants in the space rather than the nominal number of occupants as required by building code. The baseline for this measure is a constant outside airflow based on the design conditions. This measure reduces the outside airflow and the amount of space conditioning needed for outside air.

12.2.6 VAV Dual-Max Controls (electric heat)

This measure modifies the control strategy for airflow of VAV boxes with electric reheat. In the efficient case, the minimum airflow is determined by the maximum of the lowest airflow setpoint allowed by the VAV box controls and the zone's minimum outdoor airflow rate. In the baseline case, the supply airflow rate operates at the maximum flow rate that meets the cooling load. The airflow is reset proportionally until the zone minimum when there is no cooling load. This minimum airflow setpoint is maintained throughout the heating periods and the deadband zone. This measure allows the minimum airflow to be lower during the deadband zone and resets proportional to the heating load. Energy is saved by reducing fan load, electric heating load, and electric reheat load.

12.2.7 VAV Supply Air Temperature Reset (electric heat)

This measure replaces a constant supply-air temperature setpoint with a temperature reset. A constant supply-air temperature provides more cooling than is required to meet cooling loads. By allowing the supply-air temperature setpoint to adjust to operating conditions, energy savings are achieved. There are energy savings by not cooling the supply air temperature more than is needed and minimizing reheating. Inputs to this control strategy can include the outside air temperature, the return air temperature, or the cooling demand across all zones.

12.2.8 Chiller Controls

This measure resets the chilled-water supply temperature or the condenser water temperature setpoint based on the chilled-water return temperature. The baseline maintains a constant condenser water temperature and chilled-water supply temperature setpoint. For condenser water reset, the condenser operates at a higher pressure than is needed when the building load is lower than the design conditions. By reducing the condenser-water temperature setpoint when feasible, the compressor lift, or the difference between condenser and evaporator saturation temperatures, energy consumption is reduced.

12.3 Plug Load

12.3.1 Supervisory Plug Load Management Systems

This measure reduces the Equipment Power Density (EPD) associated with select spaces. A supervisory plug load management system reduces plug-in and hardwired electrical loads in a building that are not associated with HVAC, lighting, or water heating. The system allows for review of plug load usage and identification of opportunities for reducing energy consumption and allows for scheduling of equipment. The baseline is no plug load management system present.

12.4 Lighting

12.4.1 High Performance Interior Lighting

This measure is for a reduction in lighting power density (LPD) relative to the code LPD for a given space type or building type. Lower LPD uses less energy while providing a comparable level of lighting. This measure is applicable only to interior lighting.

12.4.2 LED Exterior Lighting

This measure replaces baseline exterior lighting with LEDs. The efficient lighting provides similar lighting levels at a lower wattage than the baseline wattage, resulting in energy savings.

12.5 Building Simulation Description

Energy savings and demand reductions for this program are estimated using building energy simulations. The basic geometry and floor plan is created and imported into OpenStudio®, a front-end software platform for building models to analyze using DOE's EnergyPlus™ engine. OpenStudio is used to assign space types and apply thermal zones and develop the baseline building. Default construction, equipment, setpoints and building occupancy schedules are applied. The baseline building meets state and local building codes. The models are created to meet IECC 2015 and adjusted to meet local requirements. For other default inputs not determined by code, reasonable assumptions and standard practices are applied.

There are baseline and efficient building models for each measure case. Energy savings are calculated using these models and simulated using TMY3 weather data for selected weather stations in Virginia and North Carolina.

12.5.1 Model Review

To perform data validation and provide feedback to participating builders, DNV will request building models for a select sample of projects for review. The sample selection may consider the reported savings, building square footage, measures, and building type.

The models will be reviewed for relevant code compliance, default assumptions, equipment sizing, measure case assumptions, weather location, and savings results.

12.5.2 Impacts Estimation Approach

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

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

Per measure, gross coincident summer and winter peak demand reduction is calculated using the following equations:

$$\Delta kW_{summer} = kW_{base,summer} - kW_{ee,summer}$$

$$\Delta kW_{winter} = kW_{base,winter} - kW_{ee,winter}$$

Where:

ΔkWh = per measure gross annual electric energy savings
ΔkW_{summer} = per measure gross coincident summer peak demand reduction
ΔkW_{winter} = per measure gross coincident winter peak demand reduction
kWh_{base} = annual energy consumption of the baseline model
kWh_{ee} = annual energy consumption of the efficient model
$kW_{base,summer}$ = coincident summer peak demand of baseline model
$kW_{ee,summer}$ = coincident summer peak demand of efficient model
$kW_{base,winter}$ = coincident winter peak demand of baseline model
$kW_{ee,winter}$ = coincident winter peak demand of efficient model

12.5.2.1 Measure Sequence

All input variables used for calculating energy savings and demand reductions are generated by the building energy model runs. For each measure, there is a baseline model and an efficient model. For facilities with multiple measures, the measures are applied sequentially to account for measure interactivity. The sequence for applying measures is provided in Table 12-2. The first measure on the list that is implemented will have a baseline model and an efficient model. Each subsequent measure will use the preceding measure's efficient model as its baseline model. The sequence affects the way savings are attributed to each measure, but the total project impacts are not affected by the sequence.

Table 12-2. Non-Residential New Construction Measure Sequence for Modeling

Sequence	Measure
1	Optimal Choice of Vertical Fenestration
2	High Performance Interior Lighting
3	Supervisory Plug Load Management Systems
4	LED Exterior Lighting
5	High Efficiency and Variable Speed Chillers (Air-Cooled)
6	High Efficiency DX Cooling Equipment
7	High Efficiency and Variable Speed Packaged DX Cooling Equipment
8	High Efficiency Packaged Air-Source Heat Pumps
9	Demand Controlled Ventilation/CO2 Controls
10	VAV Supply Air Temperature Reset
11	VAV Dual-Max Controls
12	Chiller Controls

12.5.2.2 Default Savings

There are no default savings as model savings are required for each measure.

12.5.2.3 Effective Useful Life

The effective useful life of this measure is provided inTable 12-3.

Table 12-3. Effective Useful Life for Lifecycle Savings Calculations

DSM Phase	Measure	Value	Units	Source(s)
VIII	Optimal Choice of Vertical Fenestration	25.00	years	Ohio TRM 2010, p. 142[166]
	High Efficiency and Variable Speed Chillers (Air-Cooled)	23.00		Maryland/Mid-Atlantic TRM v10, p. 304
	High Efficiency DX Cooling Equipment	15.00		Maryland/Mid-Atlantic TRM v10, p. 291
	High Efficiency and Variable Speed Packaged DX Cooling Equipment	15.00		Maryland/Mid-Atlantic TRM v10, p. 291
	High Efficiency Packaged Air-Source Heat Pumps	15.00		Maryland/Mid-Atlantic TRM v10, p. 291
	Demand Controlled Ventilation/CO2 Controls	8.00		Illinois TRM commercial v.9 Volume 2, p. 258
	VAV Dual-Max Controls	10.00		Massachusetts TRM 2019-2021, p. 451[167]
	VAV Supply Air Temperature Reset	10.00		Massachusetts TRM 2019-2021, p. 451
	Chiller Controls	10.00		Massachusetts TRM 2019-2021, p. 451
	Supervisory Plug Load Management Systems	10.00		Massachusetts TRM 2019-2021, p. 451
	High Performance Interior Lighting	15.00		Maryland/Mid-Atlantic TRM v10, p. 219
	LED Exterior Lighting	15.00		Maryland/Mid-Atlantic TRM v10, p. 219

12.5.2.4 Source(s)

The primary source for this program is the building energy models.

12.5.2.5 Update Summary

Updates made to this section are described in Table 12-4.

[166] This reference is for residential new construction. Commercial new construction building design measures like this are not included in most TRMs. Therefore, the residential new construction measure life is applied as an approximation.

[167] Used Energy Management System (EMS) measure life for most HVAC controls measures.

Table 12-4. Summary of Update(s)

Version	Update Type	Description
2021	New Measure	New section

13 SUB-APPENDICES

13.1 Sub-Appendix F2-I: Cooling and Heating Degree Days and Hours

This section appears in Appendix F1 as Sub-Appendix F1-III: Cooling and Heating Degree Days and Hours (a.k.a. Section 19.3).

Table 13-1. Base Temperatures by Sector and End Use

This table appears in Appendix F1 as Sub-Appendix F1-III: Cooling and Heating Degree Days and Hours (a.k.a. Section 19.3).

Table 13-2. Reference Cooling and Heating Degree Days

This table appears in Appendix F1 as Sub-Appendix F1-III: Cooling and Heating Degree Days and Hours (a.k.a. Section 19.3).

Table 13-3. Reference Cooling and Heating Degree Hours

This table appears in Appendix F1 as Sub-Appendix F1-III: Cooling and Heating Degree Days and Hours (a.k.a. Section 19.3).

13.2 Sub-Appendix F2-II: Non-Residential HVAC Equivalent Full Load Hours

This sub-appendix provides the default heating and cooling the equivalent full load hours (EFLH)s for non-residential HVAC equipment and VFDs. Table 13-4 and Table 13-5 provide the EFLHs for HVAC equipment by facility type and location. Table 13-6 provides annual run hours for VFDs by facility type and VFD application.

The EFLH are determined using the methodology used in the Maryland/Mid-Atlantic TRM v10. The methodology adapts EFLH from the Pennsylvania TRM 2016 and adjusted for locally design temperatures and degree days from 2013 ASHREA Handbook Fundamentals[168]. DNV calculates EFLHs for various locations in Dominion Energy's service territory using the same adjustment method and TMY3 weather data. Baltimore is used as the reference location and EFLHs is scaled using local TMY3 weather data.

The scaling method is shown in the following example calculation, using Education – Elementary and Middle School for Richmond, VA:

$$\textit{Mid-Atlantic TRM Baltimore } EFLH_{cool} = 295\ hour/year$$

$$\textit{Baltimore CDD} = 1{,}222\ hour/year$$

$$\textit{Richmond CDD} = 1{,}448\ hour/year$$

$$\textit{Richmond } EFLH_{cool} = \textit{Richmond CDD} \times \frac{\textit{Baltimore } EFLH_{cool}}{\textit{Baltimore CDD}}$$

$$= 1{,}448\ hour/year \times \frac{295\ hour/year}{1{,}222\ hour/year}$$

$$= 349\ hour/year$$

[168] See pages 422 - 423, footnote 885 and 886 in the Maryland/Mid-Atlantic TRM v. 10

13.2.1 Annual Equivalent Full-Load Cooling Hours for Unitary Air Conditioners, Heat Pumps, Chiller, VRF, Room/Wall AC and Mini-split Systems

Table 13-4. Heat pump, Unitary AC, Chiller, VRF, Room/Wall AC, and Mini Split Equivalent Full-Load Cooling Hours for Non-Residential Buildings

Building Type by Weather Station	Maryland	North Carolina		Virginia							
	Baltimore	Elizabeth City	Rocky Mount	Char-lottesville	Sterling	Farmville	Norfolk	Arlington	Richmond	Roanoke	Fredericks-burg
Education – Elementary and Middle School	295	422	327	260	262	307	389	363	349	265	327
Education – High School	340	486	377	300	302	354	448	419	403	306	377
Education – College and University[169]	750	1,072	832	662	666	780	988	923	888	675	831
Food Sales - Grocery	678	969	752	598	602	705	893	835	803	610	751
Food Sales – Convenience Store	923	1,320	1,023	815	820	960	1,216	1,136	1,093	831	1,023
Food Sales – Gas Station Convenience Store	923	1,320	1,023	815	820	960	1,216	1,136	1,093	831	1,023
Food Service - Full Service	768	1,098	852	678	682	799	1,011	946	910	691	851

[169] "Education – College and University" Baltimore, MD full load cooling hours is an average of the hours for "Education – Community College"(713 hours/year) and "Education – University" (787 hours/year) in the Maryland/Mid-Atlantic TRM v10, p.422

Building Type by Weather Station	Maryland	North Carolina		Virginia							
	Baltimore	Elizabeth City	Rocky Mount	Char-lottesville	Sterling	Farmville	Norfolk	Arlington	Richmond	Roanoke	Fredericks-burg
Food Service - Fast Food	730	1,044	809	644	649	760	961	899	865	657	809
Health Care - Inpatient	1,223	1,748	1,356	1,079	1,086	1,273	1,611	1,506	1,449	1,100	1,355
Health Care - Outpatient	650	929	721	574	577	676	856	800	770	585	720
Lodging – (Hotel, Motel and Dormitory)	1,831	2,618	2,030	1,616	1,627	1,905	2,411	2,254	2,169	1,648	2,029
Mercantile (mall)	887	1,268	983	783	788	923	1,168	1,092	1,051	798	983
Mercantile (Retail, not mall)	911	1,302	1,010	804	809	948	1,200	1,122	1,079	820	1,009
Multifamily (Common Areas)	1,521	906	703	1,343	1,351	1,583	2,003	1,873	1,802	1,369	1,685
Office – Small (<40,000 sq ft)	634	1,048	813	560	563	660	835	781	751	570	702
Office – Large (≥40,000 sq ft)	733	350	272	647	651	763	965	902	868	660	812
Other[170]	245	1,351	1,048	216	218	255	323	302	290	220	271
Public Assembly	945	350	272	834	840	983	1,245	1,163	1,119	850	1,047
Public Order and Safety (Police and Fire Station)	245	350	272	216	218	255	323	302	290	220	271

170 "Other" building type is mapped to the building type with the most conservative full load cooling hours in the Mid-Atlantic TRM 2018, p.528 "Public Order and Safety."

Building Type by Weather Station	Maryland	North Carolina		Virginia							
	Baltimore	Elizabeth City	Rocky Mount	Char-lottesville	Sterling	Farmville	Norfolk	Arlington	Richmond	Roanoke	Fredericks-burg
Religious Worship	245	1,320	1,023	216	218	255	323	302	290	220	271
Service (Beauty, Auto Repair Workshop)	923	2,975	2,307	815	820	960	1,216	1,136	1,093	831	1,023
Warehouse and Storage[171]	2,081	2,175	1,686	1,837	1,849	2,165	2,741	2,562	2,465	1,873	2,306

13.2.2 Annual Equivalent Full-Load Heating Hours for Heat Pumps, VRFs, and Mini-split Systems

Table 13-5. Heat Pump, VRF, and Mini-split Equivalent Full Load Heating Hours for Non-Residential Buildings

Building Type by Weather Station	Maryland	North Carolina		Virginia							
	Baltimore	Elizabeth City	Rocky Mount	Char-lottesville	Sterling	Farmville	Norfolk	Arlington	Richmond	Roanoke	Fredericks-burg
Education – Elementary and Middle School	668	393	428	535	696	591	492	618	558	613	662
Education – High School	719	423	460	576	749	636	530	665	600	660	713
Education – College and University[172]	622	366	398	498	648	550	458	576	519	571	617
Food Sales - Grocery	980	576	627	785	1,021	867	722	907	818	899	972

[171] "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 Maryland/Mid-Atlantic TRM v10, p.423

[172] "Education – College and University" Baltimore, MD full load heating hours is an average of the hours for "Education – Community College" (713 hours/year) and "Education – University" (530 hours/year) in the Maryland/Mid-Atlantic TRM v10, p.423

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Building Type by Weather Station	Maryland	North Carolina		Virginia							
	Baltimore	Elizabeth City	Rocky Mount	Char-lottesville	Sterling	Farmville	Norfolk	Arlington	Richmond	Roanoke	Fredericks-burg
Food Sales – Convenience Store	623	366	399	499	649	551	459	577	520	572	618
Food Sales – Gas Station Convenience Store	623	366	399	499	649	551	459	577	520	572	618
Food Service - Full Service	1,131	665	724	906	1,179	1,001	833	1,047	944	1,038	1,122
Food Service - Fast Food	1,226	721	785	982	1,278	1,085	903	1,135	1,023	1,125	1,216
Health Care-inpatient	214	126	137	171	223	189	158	198	179	196	212
Health Care-outpatient	932	548	596	747	971	825	687	863	778	855	924
Lodging – (Hotel, Motel and Dormitory)	2,242	1,319	1,435	1,797	2,337	1,984	1,652	2,075	1,871	2,058	2,223
Mercantile (mall)	591	348	378	474	616	523	436	547	493	542	586
Mercantile (Retail, not mall)	739	435	473	592	770	654	545	684	617	678	733
Multifamily (Common Areas)	256	259	282	205	267	227	189	237	214	235	254
Office – Small (<40,000 sq ft)	440	130	141	353	459	389	324	407	367	404	436
Office – Large (≥40,000 sq ft)	221	86	93	177	230	196	163	205	184	203	219
Other	146	655	713	117	152	129	108	135	122	134	145

Building Type by Weather Station	Maryland	North Carolina		Virginia							
	Baltimore	Elizabeth City	Rocky Mount	Char-lottesville	Sterling	Farmville	Norfolk	Arlington	Richmond	Roanoke	Fredericks-burg
Public Assembly[173]	1,114	86	93	893	1,161	986	821	1,031	930	1,022	1,105
Public Order and Safety (Police and Fire Station)[174]	146	86	93	117	152	129	108	135	122	134	145
Religious Worship	146	366	399	117	152	129	108	135	122	134	145
Service (Beauty, Auto Repair Workshop)	623	352	383	499	649	551	459	577	520	572	618
Warehouse and Storage	598	151	164	479	623	529	441	553	499	549	593

173 "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 Maryland/Mid-Atlantic TRM v10, p.423, "Manufacturing – Bio Tech/High Tech."

174 "Religious Worship" building type is mapped to the building type with the most conservative full load heating hours in the Maryland/Mid-Atlantic TRM v10, p.423, p.529 "Manufacturing – Bio Tech/High Tech."

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13.2.3 Annual Hours of Use for Variable Frequency Drives

Table 13-6. Variable Frequency Drive Annual Hours of Use by Facility Type[175]

Building Type	Fan Motor Hours	Chilled Water Pumps[176]	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

[175] Maryland/Mid-Atlantic TRM v10, pp. 299 - 301. 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.
[176] For condenser water pumps, use the same operating hours as provided for chilled water pumps.

13.2.4 Update Summary

Updates made to this section are described in Table 13-7.

Table 13-7. Summary of Update(s)

Version	Update Type	Description
2021	New weather stations	To the single weather station in Richmond, VA, seven weather stations were added for Virginia: Charlottesville, Dulles International Airport, Farmville, Norfolk, Reagan International Airport, Roanoke, and Shannon Airport. Also, divided the previously shared column—that contained the average of the two NC weather stations—into two separate columns (Elizabeth City, NC and Rocky Mount-Wilson, NC).
	Table	Updated building type for the Unitary Air Conditioners, Heat Pumps, Chiller, VRF, and Mini-split Systems
	Table	Removed the separate table for Chiller system cooling hours
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.
	Updated EFLHs	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.

13.3 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:

1. Unitary air conditioners and condensing units, in Table 13-8
2. Unitary and applied heat pumps, in Table 13-9
3. Variable Refrigerant Flow (VRF) air conditioners and heat pumps, in Table 13-10
4. Water chilling packages (a.k.a. chillers), in Table 13-11

13.3.1 Cooling Efficiencies of Unitary Air Conditioners and Condensing Units

Table 13-8. Unitary Air Conditioners and Condensing Units - Minimum Efficiency[177]

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[178]
Through the wall, packaged terminal air conditioners (air cooled)	≤ 30,000 Btu/h	All	Split system/ Single package	12.0 SEER	10.5 EER[178]
Small-duct, high-velocity (air cooled)	< 65,000 Btu/h	All	Split system/ Single package	11.0 SEER	9.9 EER[178]

[177] ASHRAE 90.1 2013, Table 6.8.1-1 - Electrically Operated Unitary Air Conditioners and Condensing Units - Minimum Efficiency Requirement.

[178] This value was not provided in ASHRAE 90.1 2013, Table 6.8.1-1, so Equation 3 in Sub-Appendix F2-VIII: General Equations was used to convert between SEER and EER.

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Equipment Type	Size Category (Btu/h)	Heating System Type	Subcategory	Minimum Annual Efficiency	Minimum Demand Efficiency
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
	≥ 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

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Equipment Type	Size Category (Btu/h)	Heating System Type	Subcategory	Minimum Annual Efficiency	Minimum Demand Efficiency
Air conditioners, evaporatively cooled[179]	< 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
	≥ 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[179]	≥ 135,000 Btu/h	-	-	11.8 IEER	10.5 EER
Condensing units, water cooled[179]	≥ 135,000 Btu/h	-	-	14.0 IEER	13.5 EER
Condensing units, evaporatively cooled[179]	≥ 135,000 Btu/h	-	-	14.0 IEER	13.5 EER

13.3.2 Efficiencies of Unitary and Applied Heat Pumps

Table 13-9. Unitary and Applied Heat Pumps - Minimum Efficiency[180]

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[181]

[179] 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-Residential Heating and Cooling Efficiency Program offered under the DSM Phase VII program.

[180] ASHRAE 90.1 2013, Table 6.8.1-2 - Electrically Operated Unitary and Applied Heat Pumps - Minimum Efficiency Requirement.

[181] This value was not provided in ASHRAE 90.1 2013, Table 6.8.1-2, so Equation 3 in Sub-Appendix F2-VIII: General Equations was 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
Through-the-wall, packaged terminal heat pumps (air-cooled cooling mode)	≤ 30,000 Btu/h	All	Split System/ Single package	12.0 SEER	10.5 EER[181]
Single-duct	< 65,000 Btu/h	All	Split System/ Single package	11.0 SEER	9.9 EER[181]
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
Air Cooled (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	All other	Split system/ Single package	12.0 IEER	10.8 EER
Air Cooled (cooling mode)	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric resistance (or none)	Split system/ Single package	11.6 IEER	10.6 EER
Air Cooled (cooling mode)	≥ 135,000 Btu/h and < 240,000 Btu/h	All other	Split system/ Single package	11.4 IEER	10.4 EER
Air Cooled (cooling mode)	≥ 240,000 Btu/h	Electric resistance (or none)	Split system/ Single package	10.6 IEER	9.5 EER
Air Cooled (cooling mode)	≥ 240,000 Btu/h	All other	Split system/ Single package	10.4 IEER	9.3 EER
Water source[182] (Cooling mode)	< 17,000 Btu/h	All	86°F entering water	Retrofits: 14.0 SEER[182]	Retrofits: 11.7 EER[181]
Water source[182] (Cooling mode)	< 17,000 Btu/h	All	86°F entering water	RCx:[183] 13.1 $EER_{part\text{-}load}$	RCx: 11.2 EER
Water source[182] (Cooling mode)	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	Retrofits: 14.0 SEER[182]	Retrofits: 11.7 EER[181]
Water source[182] (Cooling mode)	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	RCx: 14.5 $EER_{part\text{-}load}$	RCx: 12.0 EER
Water source[182] (Cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	Retrofits: 12.2 IEER[182]	Retrofits: 10.9 EER[184]
Water source[182] (Cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	RCx: 13.4 $EER_{part\text{-}load}$	RCx: 12.0 EER
Ground source[182] (cooling mode)	< 65,000 Btu/h	All	77°F entering water	Retrofits: 14.0 SEER[182]	Retrofits: 11.7 EER[181]
Ground source[182] (cooling mode)	< 65,000 Btu/h	All	77°F entering water	RCx: 17.4 $EER_{part\text{-}load}$	RCx: 13.4 EER
Ground source[182] (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	All	77°F entering water	Retrofits: 12.2 IEER[182]	Retrofits: 10.9 EER[184]
Ground source[182] (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	All	77°F entering water	RCx: 14.9 $EER_{part\text{-}load}$	RCx: 13.4 EER

[182] 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.)

[183] Two types of measures are categorized as retro-commissioning (RCx) ones: Duct Testing & Sealing and AC/HP/Chiller Tune-ups.

[184] This value was not provided in ASHRAE 90.1 2013, Table 6.8.1-2, so Equation 4 in Sub-Appendix F2-VIII: General Equations was used to convert between IEER and EER.

DNV

Equipment Type	Cooling Capacity/ Size Category	Heating System Type	Subcategory or Rating Conditions	Minimum Annual Efficiency	Minimum Demand Efficiency
Air cooled (heating mode)	< 65,000 Btu/h	-	Split system/ Single system	7.7 HSPF	N/A
Through-the-wall, packaged terminal heat pump (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
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[185] (cooling capacity)	-	32°F entering water	3.2 COP	N/A

[185] ASHRAE 90.1-2013 values only apply to equipment <135 kBtu/h. However, this value is used across all sizes as there is limited guidance for systems 135 kBtu/h and larger.

DNV

13.3.3 Cooling Efficiencies of Variable Refrigerant Flow Air Conditioners and Heat Pumps

Table 13-10. Variable Refrigerant Flow Air Conditioners and Heat Pumps - Minimum Efficiency[186]

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[187]	N/A
	≥ 65,000 Btu/h and < 135,000 Btu/h	All[188]	VRF Multi-Split system	13.1 IEER	11.2 EER[187]	N/A
	≥ 135,000 Btu/h and < 240,000 Btu/h	All[188]	VRF Multi-Split system	12.9 IEER	11.0 EER[187]	N/A
	≥ 240,000 Btu/h	All[188]	VRF Multi-Split system	11.6 IEER	10.0 EER[187]	N/A
VRF Heat Pumps, Air Cooled	< 65,000 Btu/h	All	VRF Multi-Split system	13.0 SEER	11.1 EER[187]	7.7 HSPF
	≥ 65,000 Btu/h and < 135,000 Btu/h	All[188]	VRF Multi-Split system	12.9 IEER	11.0 EER[187]	3.3 COP
	≥ 135,000 Btu/h and < 240,000 Btu/h	All[188]	VRF Multi-Split system	12.3 IEER	10.6 EER[187]	3.2 COP
	≥ 240,000 Btu/h	All[188]	VRF Multi-Split system	11.0 IEER	9.5 EER[187]	3.2 COP

186 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.

187 This value was not provided in ASHRAE 90.1 2013, Table 6.8.1-9, so Equation 3 in Sub-Appendix F2-VIII: General Equations was used to convert between SEER and EER.

188 ASHRAE 90.1 2013, only provides Electric resistance or none for Heating Section Type. This is used for all Heating Section Types to allow for other heating system types.

DNV

13.3.4 Cooling Efficiencies of Water Chilling Packages

Table 13-11. Water Chilling Packages–Minimum Efficiency[189]

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

[189] 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 fulfil the requirements of Path A or Path B.

13.3.5 Heating Efficiencies of Systems with Central Chilled Water Plants

Table 13-12. Electric Heating Efficiency Associated with Central Chilled Water Cooling Systems[190]

Equipment Type	Size Category	HSPF (Btu/Wh)	COP
Air- or Water-Cooled Chillers with unknown electric heating	Any	3.4	1.0

13.3.6 Update Summary

Updates made to this section are described in Table 13-13

Table 13-13. Summary of Update(s)

Version	Update Type	Description
2021	Table	Added table for minimum COP for electric heating associated with central chilled water cooling systems.
2020	Standards Application	Revised the VRF heating section type categories to accommodate more than just the electric resistance
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.

[190] For some measures applications indicate electric heating associated with chilled water cooling systems. For these systems we assume either central electric boilers or other electric resistance type heating with an efficiency.

DNV

13.5 Sub-Appendix F2-IV: Non-Residential Lighting Factors: Annual Equivalent Hours, Coincidence Factors and Waste Heat Factors

For the purposes of this Technical Reference Manual, Table 13-15 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 13-14 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 manual, a separate mapping was conducted to arrive at the values. Under each building type in Table 13-15 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 13-14.

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 13-15.

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 13-14. Non-Residential Lighting Parameters by Exterior Lighting Type

Lighting Type	Annual Exterior Lighting Hours	CF_{summer}	CF_{winter}[191]	WHF_e[192]	$WHF_{d,summer}$	$WHF_{d,winter}$	Source
Pulse Start Metal Halide - exterior	3,604[193]	0.11[194]	0.50	1.00	1.00	1.00	Maryland/Mid-Atlantic TRM v10, p. 242
High Pressure Sodium	3,604[195]	0.11[196]	0.50	1.00	1.00	1.00	Maryland/Mid-Atlantic TRM v10, p. 242
LED Exit Sign and "24/7" lights[197]	8,760	1.00	1.00	1.00	1.00	1.00	Maryland/Mid-Atlantic TRM v10, p. 215; DNV judgement
LED Parking Garage	Canopy: 3,338 Parking garage: 8,678	Canopy: 0.00 Parking garage: 0.98	Canopy: 0.50 Parking garage: 0.98	1.00	1.00	1.00	Maryland/Mid-Atlantic TRM v10, p. 254
Outdoor LED and Roadway Lighting	3,604	0.11[198]	0.50	1.00	1.00	1.00	Maryland/Mid-Atlantic TRM v10, p. 242

The hours and coincident factors (CF) shown in Table 13-15 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).

[191] The source TRM does not provide winter CF. Therefore the winter CF is estimated based on sunrise and peak period. The winter peak period occurs for the hour ending at 8:00 A.M on non-holiday Mondays in January. The latest sunrise in the period is 7:17 A.M. Given the ambient light levels during the peak period, The winter CF is estimated to be 0.50. This estimate will be revised when better information becomes available.

[192] "If cooling and heating equipment types are unknown or the space is unconditioned, assume WHFd = WHFe = 1.0." Maryland/Mid-Atlantic TRM 2020, p. 215.

[193] Navigant Commercial and Industrial Long-Term Metering Study

[194] Ibid.

[195] Ibid.

[196] Ibid.

[197] 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.

[198] Navigant Commercial and Industrial Long-Term Metering Study

DNV

Table 13-15. Non-Residential Interior Lighting Parameters by Facility Type

Building Types	Interior Lighting Annual Hours[199]	CF_{summer}[200]	CF_{winter}[201]	$WHF_{d,summer}$[202]	$WHF_{d,winter}$[203]	WHF_e[204]
Education – College and University	2,233	0.360	0.330	1.44	0.710	0.960
Education – High School	2,233	0.360	0.330	1.44	0.710	0.960
Education – Elementary and Middle School	2,233	0.360	0.330	1.44	0.710	0.960
Food Sales – Convenience Store	7,272	0.970	0.930	1.35	0.740	0.930
Food Sales – Gas Station Convenience Store	7,272	0.970	0.930	1.35	0.740	0.930
Food Sales – Grocery	7,272	0.970	0.930	1.35	0.740	0.930
Food Service - Fast Food	4,696	0.830	0.930	1.27	0.740	0.950
Food Service - Full Service	4,696	0.830	0.930	1.27	0.740	0.950
Health Care – inpatient	3,817	0.680	0.510	1.35	0.740	0.930
Health Care – outpatient	3,817	0.680	0.510	1.35	0.740	0.930
Lodging – (Hotel, Motel and Dormitory)	4,058	0.610	0.460	1.35	0.740	0.930
Mercantile (Retail, Not Mall)	4,696	0.830	0.560	1.27	0.740	0.950
Mercantile (Mall)	4,696	0.830	0.560	1.27	0.740	0.950
Non-Residential Multifamily[205]	5,950	0.058	0.124	0.96	0.815	0.959
Office – Small (<40,000 sq ft)	3,044	0.690	0.490	1.36	0.750	0.940
Office – Large (>= 40,000 sq ft)	3,044	0.690	0.490	1.36	0.750	0.940
Other (default)	4,058	0.610	0.460	1.35	0.740	0.930
Public Assembly	4,058	0.610	0.460	1.35	0.740	0.930
Public Order and Safety (Police and Fire Station)	4,058	0.610	0.460	1.35	0.740	0.930

199 Maryland/Mid-Atlantic TRM v10, p. 418 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.

200 Ibid.

201 Ibid.

202 Maryland/Mid-Atlantic TRM v10, p. 419-421. 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."

203 Maryland/Mid-Atlantic TRM v10, p. 419-421. Selected waste heat factors from "Washington, D.C. All utilities", 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." Winter peak WHF_d is not provided, therefore, the WHFe is used for no AC with electric resistance heating. This will yield the most conservative winter peak demand reduction estimate.

204 Ibid.

205 Maryland/Mid-Atlantic TRM v10, p.44, common areas

DNV

Building Types	Interior Lighting Annual Hours[199]	CF_{summer}[200]	CF_{winter}[201]	$WHF_{d,summer}$[202]	$WHF_{d,winter}$[203]	WHF_{e}[204]
Religious Worship	4,058	0.610	0.460	1.350	0.740	0.930
Service (Beauty, Auto Repair Workshop)	4,696	0.830	0.460	1.270	0.560	0.950
Warehouse and Storage	4,361	0.800	0.460	1.230	0.500	0.890

13.5.1 Update Summary

Updates made to this section are described in Table 13-16

Table 13-16. Summary of Update(s)

Version	Update Type	Description
2021	Inputs	• Added winter CF_{winter} and $WHF_{d,winter}$
	Source	• Updated page numbers / version of the Maryland/Mid-Atlantic TRM v10
		• Updated Exterior Lighting Annual Hours and CF values • Added a new building type in the interior lighting parameter table
2020	None	• No change
v10	Source	• Updated page numbers / version of the Mid-Atlantic TRM v.9

13.6 Sub-Appendix F2-V: Non-Residential Commercial Kitchen Inputs

This sub-appendix contains the commercial kitchen inputs.

Table 13-17. Operational Hours by Building Type[206]

Facility Type	Hour/Day	Day/Year	Weight Applied for Unknown Facility Type[207]
Education - Elementary and Middle School	8.0	214	0.09
Education - High School			
Education - College and University			
Food Sales - Grocery	12.0	365	0.10
Food Sales - Convenience Store			
Food Sales - Gas Station Convenience Store			
Food Service - Full Service	13.0	342	0.17
Food Service - Fast Food			
Health Care - Inpatient	11.0	365	0.11
Health Care - Outpatient			
Lodging - Hotel, Motel and Dormitory	20.0	365	0.17
Mercantile - Mall	9.0	325	0.00
Mercantile - Retail, non-mall			
Office - Small (<40,000 sq.ft.)	12.0	250	0.36
Office - Large (≥40,000 sq.ft.)			
Other	9.0	325	0.00
Public Assembly			
Public Order and Safety (Police and Fire Station)			
Religious Worship			
Service (Beauty, Auto-repair, Workshop)			
Warehouse and Storage			
Unknown (default)[208]	13.1	307	0.00

206 Maryland/Mid-Atlantic TRM v10, p. 383, hours/day and days/year values are used for all facility types with the exception of Unknown, which uses Dominion Energy building weights. Maryland/Mid-Atlantic TRM v10 cites the original source as California Energy Commission, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, Appendix E.

207 Unknown facility type is based on a weighted average of building types from Dominion Energy 2020 Commercial Energy Survey Results Appendix B, p. 4. Question 3. Building types that are in the source TRM are used when calculating weights to avoid overweighting building types that aren't typically associated with cooking equipment. Those buildings use the Other/Miscellaneous building category from the source TRM for hours/day and days/year.

208 Unknown facility type is based on a weighted average of building types from DNV, Dominion Energy 2020 Commercial Energy Survey Results, Appendix B, p. 4, Question 3

13.6.1 Update Summary

Updates made to this section are described in Table 13-16

Table 13-18. Summary of Update(s)

Version	Update Type	Description
2021	New section	Moved tables shared by multiple measures from individual measure sections to this sub-appendix.

DNV

13.7 Sub-Appendix F2-VI: Non-Residential Compressed Air End Use Factors

This sub-appendix contains the compressed air end use factors of input variables based on type of control and coincidence factor based on operating schedule.

Table 13-19: 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
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

Table 13-20. 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 13-21. Coincidence Factor (CF) Based on Operating Schedule

Operating Schedule	CF_{summer}[209]	$CF_{swinter}$[210]
Single shift (8/5) (default)	0.59	0.59
2-shift (16/5)	0.95	0.95

[209] 2019 IL TRM v 7.0 Volume 2

[210] Source TRM does not provide a specific winter CF. Therefore, the summer CF is applied as the winter CF.

Operating Schedule	CF_{summer}[209]	$CF_{swinter}$[210]
3-shift (24/5)	0.95	0.95
4-shift (24/7)	0.95	0.95

Table 13-22. Dryer constant values, based on base dryer 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

Table 13-23. $Purge_{base}$, based on dryer type

Dryer Type	$Purge_{base}$
Non-cycling, Refrigerated	0.00
Cycling, Refrigerated	0.00
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

13.7.1 Update Summary

Updates made to this section are described in Table 13-16

Table 13-24. Summary of Update(s)

Version	Update Type	Description
2021	New section	Moved tables shared by multiple measures from individual measure sections to this sub-appendix.

DNV

13.8 Sub-Appendix F2-VII: Non-Residential Window Film Energy Saving Factors

This sub-appendix contains the Energy Saving Factor (ESF) per square foot of reflective window film by facility type, window pane type, heating system type, and window orientation. Each table is for a specific weather location in Dominion Energy's service territory.

Table 13-25. Energy Savings Factors for Reflective Window Film by Building Type and Window Orientation for Charlottesville, VA

Facility Type[211]	Window Type	Heating System Type[212]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[213] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Education – Elementary and Middle School	Single Pane	Electric	1.86	4.09	6.83	6.05
		Non-electric	2.12	5.76	7.93	10.03
	Double Pane	Electric	0.77	1.74	3.00	2.56
		Non-electric	0.89	2.45	3.62	4.48
Education – High School	Single Pane	Electric	3.93	6.88	16.77	11.43
		Non-electric	3.62	6.25	10.94	13.41
	Double Pane	Electric	1.73	2.77	6.62	4.59
		Non-electric	1.56	2.63	4.97	5.70
Education – College and University	Single Pane	Electric	3.93	6.88	16.77	11.43
		Non-electric	3.62	6.25	10.94	13.41
	Double Pane	Electric	1.73	2.77	6.62	4.59
		Non-electric	1.56	2.63	4.97	5.70
Food Sales - Grocery	Single Pane	Electric	2.58	7.21	6.47	10.99
		Non-electric	3.00	8.20	7.58	12.53
	Double Pane	Electric	13.06	4.66	5.03	3.03
		Non-electric	1.35	5.26	5.83	3.46
Food Sales – Convenience Store	Single Pane	Electric	2.58	7.21	6.47	10.99
		Non-electric	3.00	8.20	7.58	12.53
	Double Pane	Electric	13.06	4.66	5.03	3.03
		Non-electric	1.35	5.26	5.83	3.46
Food Sales – Non-electric Station Convenience Store	Single Pane	Electric	2.58	7.21	6.47	10.99
		Non-electric	3.00	8.20	7.58	12.53
	Double Pane	Electric	13.06	4.66	5.03	3.03
		Non-electric	1.35	5.26	5.83	3.46
Food Service - Full Service	Single Pane	Electric	0.00	6.56	8.37	11.69
		Non-electric	0.00	7.26	10.23	12.86
	Double Pane	Electric	0.00	0.00	4.05	5.28
		Non-electric	0.00	3.01	4.71	5.66
Food Service - Fast Food	Single Pane	Electric	0.00	3.72	4.68	6.57
		Non-electric	0.00	5.00	7.14	8.12
	Double Pane	Electric	0.00	1.60	2.38	3.00
		Non-electric	0.00	2.14	3.39	3.61

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

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

213 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 buildings leads to increased energy use due to increase heating load in the winter season.

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Facility Type[211]	Window Type	Heating System Type[212]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[213] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Health Care-inpatient	Single Pane	Electric	7.11	33.18	15.87	29.91
		Non-electric	4.60	18.31	11.15	17.66
	Double Pane	Electric	3.23	14.26	7.44	11.58
		Non-electric	2.03	7.66	4.91	6.68
Health Care-outpatient	Single Pane	Electric	1.25	39.48	17.60	23.83
		Non-electric	1.74	30.28	16.98	23.10
	Double Pane	Electric	0.55	16.95	7.12	9.45
		Non-electric	0.79	12.93	6.59	9.18
Lodging – (Hotel, Motel, and Dormitory)	Single Pane	Electric	3.69	11.43	13.40	10.31
		Non-electric	4.30	13.43	15.02	11.13
	Double Pane	Electric	1.52	4.70	5.62	4.10
		Non-electric	1.71	5.43	6.33	4.34
Mercantile (mall)	Single Pane	Electric	2.68	7.46	5.48	8.41
		Non-electric	2.93	8.24	6.85	9.00
	Double Pane	Electric	1.09	2.88	2.53	3.48
		Non-electric	1.22	3.21	3.10	3.72
Mercantile (Retail, not mall)	Single Pane	Electric	2.58	7.21	6.47	10.99
		Non-electric	3.00	8.20	7.58	12.53
	Double Pane	Electric	13.06	4.66	5.03	3.03
		Non-electric	1.35	5.26	5.83	3.46
Office – Small (<40,000 sq ft)	Single Pane	Electric	1.58	5.03	2.73	4.91
		Non-electric	1.76	5.54	3.19	5.66
	Double Pane	Electric	0.64	2.05	1.09	1.96
		Non-electric	0.72	2.22	1.25	2.21
Office –Large (≥ 40,000 sq ft)	Single Pane	Electric	5.30	17.19	15.82	17.79
		Non-electric	2.23	6.08	7.07	8.17
	Double Pane	Electric	2.15	6.83	6.06	6.70
		Non-electric	0.89	2.40	2.91	3.13
Other[214]	Single Pane	Electric	0.07	2.28	0.02	0.43
		Non-electric	0.09	2.39	0.04	0.52
	Double Pane	Electric	0.03	1.02	0.01	0.16
		Non-electric	0.03	1.06	0.02	0.20
Public Assembly	Single Pane	Electric	0.46	2.49	2.49	1.24
		Non-electric	0.75	2.38	2.83	1.74
	Double Pane	Electric	0.22	1.03	1.06	0.71
		Non-electric	0.36	0.98	1.18	0.92
Public Order and Safety (Police and Fire Station)	Single Pane	Electric	0.07	2.28	0.02	0.43
		Non-electric	0.09	2.39	0.04	0.52
	Double Pane	Electric	0.03	1.02	0.01	0.16
		Non-electric	0.03	1.06	0.02	0.20
Religious Worship	Single Pane	Electric	0.46	2.49	2.49	1.24
		Non-electric	0.75	2.38	2.83	1.74
	Double Pane	Electric	0.22	1.03	1.06	0.71
		Non-electric	0.36	0.98	1.18	0.92

214 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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Facility Type[211]	Window Type	Heating System Type[212]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[213] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Service (Beauty, Auto Repair Workshop)	Single Pane	Electric	2.68	7.46	5.48	8.41
		Non-electric	2.93	8.24	6.85	9.00
	Double Pane	Electric	1.09	2.88	2.53	3.48
		Non-electric	1.22	3.21	3.10	3.72

Table 13-26. Energy Savings Factors for Reflective Window Film by Facility Type and Window Orientation for Farmville, VA

Building Type[215]	Window Type	Heating System Type[216]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[217] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Education – Elementary and Middle School	Single Pane	Electric	2.00	4.83	7.76	7.02
		Non-electric	2.04	5.98	7.95	9.92
	Double Pane	Electric	0.91	1.85	3.41	3.11
		Non-electric	0.93	2.57	3.67	4.38
Education – High School	Single Pane	Electric	4.02	7.20	17.71	12.10
		Non-electric	3.35	6.32	11.26	13.78
	Double Pane	Electric	1.75	2.78	7.18	4.99
		Non-electric	1.47	2.73	5.24	5.89
Education – College and University	Single Pane	Electric	4.02	7.20	17.71	12.10
		Non-electric	3.35	6.32	11.26	13.78
	Double Pane	Electric	1.75	2.78	7.18	4.99
		Non-electric	1.47	2.73	5.24	5.89
Food Sales - Grocery	Single Pane	Electric	2.60	7.16	6.43	10.26
		Non-electric	3.08	8.29	7.57	11.70
	Double Pane	Electric	14.74	2.15	5.09	4.19
		Non-electric	1.28	2.56	5.93	4.92
Food Sales – Convenience Store	Single Pane	Electric	2.60	7.16	6.43	10.26
		Non-electric	3.08	8.29	7.57	11.70
	Double Pane	Electric	14.74	2.15	5.09	4.19
		Non-electric	1.28	2.56	5.93	4.92
Food Sales – Non-electric Station Convenience Store	Single Pane	Electric	2.60	7.16	6.43	10.26
		Non-electric	3.08	8.29	7.57	11.70
	Double Pane	Electric	14.74	2.15	5.09	4.19
		Non-electric	1.28	2.56	5.93	4.92
Food Service - Full Service	Single Pane	Electric	0.00	6.88	8.52	12.21
		Non-electric	0.00	7.51	10.09	13.04
	Double Pane	Electric	0.00	0.00	4.19	5.58
		Non-electric	0.00	3.23	4.82	5.93

[215] Warehouse and storage building type DEER models do not have windows. Tracking data with this building type will be flagged for on-site verification.
[216] Non-electric heating systems were represented by gas heating in building energy models.
[217] 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 buildings leads to increased energy use due to increase heating load in the winter season.

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Building Type[215]	Window Type	Heating System Type[216]	ESF$_{north}$ (kWh/sq.ft.)	ESF$_{east}$ (kWh/sq.ft.)	ESF$_{south}$[217] (kWh/sq.ft.)	ESF$_{west}$ (kWh/sq.ft.)
Food Service - Fast Food	Single Pane	Electric	0.00	3.93	4.80	6.76
		Non-electric	0.00	5.18	7.10	8.22
	Double Pane	Electric	0.00	1.68	2.41	2.98
		Non-electric	0.00	2.23	3.38	3.66
Health Care-inpatient	Single Pane	Electric	7.35	33.15	15.59	29.96
		Non-electric	4.68	18.31	10.88	17.71
	Double Pane	Electric	3.23	14.21	7.39	11.62
		Non-electric	2.02	7.66	4.85	6.73
Health Care-outpatient	Single Pane	Electric	1.32	38.88	16.62	23.90
		Non-electric	1.83	29.98	16.10	23.35
	Double Pane	Electric	0.59	16.91	6.75	9.48
		Non-electric	0.83	13.02	6.31	9.29
Lodging – (Hotel, Motel, and Dormitory)	Single Pane	Electric	3.62	11.58	12.80	10.34
		Non-electric	4.15	13.29	14.36	11.45
	Double Pane	Electric	1.53	4.65	5.43	4.17
		Non-electric	1.75	5.27	6.12	4.53
Mercantile (mall)	Single Pane	Electric	2.59	7.47	5.31	8.42
		Non-electric	2.90	8.38	6.75	9.11
	Double Pane	Electric	1.09	2.89	2.43	3.49
		Non-electric	1.21	3.27	3.04	3.78
Mercantile (Retail, not mall)	Single Pane	Electric	2.60	7.16	6.43	10.26
		Non-electric	3.08	8.29	7.57	11.70
	Double Pane	Electric	14.74	2.15	5.09	4.19
		Non-electric	1.28	2.56	5.93	4.92
Office – Small (<40,000 sq ft)	Single Pane	Electric	1.59	5.16	2.61	5.05
		Non-electric	1.74	5.81	3.00	5.83
	Double Pane	Electric	0.66	2.08	1.05	2.05
		Non-electric	0.75	2.33	1.24	2.32
Office – Large (≥ 40,000 sq ft)	Single Pane	Electric	5.34	17.71	15.70	18.27
		Non-electric	2.24	6.52	7.01	8.63
	Double Pane	Electric	2.17	6.97	6.11	6.92
		Non-electric	0.90	2.61	2.78	3.17
Other[214]	Single Pane	Electric	0.08	2.44	0.02	0.44
		Non-electric	0.10	2.55	0.04	0.54
	Double Pane	Electric	0.03	1.10	0.01	0.18
		Non-electric	0.04	1.15	0.02	0.22
Public Assembly	Single Pane	Electric	0.44	2.94	2.66	1.46
		Non-electric	0.74	2.72	2.92	1.88
	Double Pane	Electric	0.23	1.27	1.18	0.86
		Non-electric	0.37	1.13	1.29	1.03
Public Order and Safety (Police and Fire Station)	Single Pane	Electric	0.08	2.44	0.02	0.44
		Non-electric	0.10	2.55	0.04	0.54
	Double Pane	Electric	0.03	1.10	0.01	0.18
		Non-electric	0.04	1.15	0.02	0.22

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Building Type[215]	Window Type	Heating System Type[216]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[217] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Religious Worship	Single Pane	Electric	0.44	2.94	2.66	1.46
		Non-electric	0.74	2.72	2.92	1.88
	Double Pane	Electric	0.23	1.27	1.18	0.86
		Non-electric	0.37	1.13	1.29	1.03
Service (Beauty, Auto Repair Workshop)	Single Pane	Electric	2.59	7.47	5.31	8.42
		Non-electric	2.90	8.38	6.75	9.11
	Double Pane	Electric	1.09	2.89	2.43	3.49
		Non-electric	1.21	3.27	3.04	3.78

Table 13-27. Energy Savings Factors for Reflective Window Film by Facility Type and Window Orientation for Fredericksburg, VA

Facility Type[218]	Window Type	Heating System Type[219]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[220] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Education – Elementary and Middle School	Single Pane	Electric	1.96	4.67	8.26	7.09
		Non-electric	1.95	5.56	8.11	9.86
	Double Pane	Electric	0.89	1.79	3.60	3.09
		Non-electric	0.91	2.35	3.74	4.50
Education – High School	Single Pane	Electric	3.81	7.50	15.01	11.58
		Non-electric	3.52	6.47	11.47	14.11
	Double Pane	Electric	1.77	2.29	5.86	4.63
		Non-electric	1.42	2.75	5.29	5.63
Education – College and University	Single Pane	Electric	3.81	7.50	15.01	11.58
		Non-electric	3.52	6.47	11.47	14.11
	Double Pane	Electric	1.77	2.29	5.86	4.63
		Non-electric	1.42	2.75	5.29	5.63
Food Sales - Grocery	Single Pane	Electric	2.48	9.54	8.43	7.49
		Non-electric	3.01	11.17	10.14	8.64
	Double Pane	Electric	16.37	5.27	3.52	3.00
		Non-electric	1.29	6.08	4.26	3.52
Food Sales – Convenience Store	Single Pane	Electric	2.48	9.54	8.43	7.49
		Non-electric	3.01	11.17	10.14	8.64
	Double Pane	Electric	16.37	5.27	3.52	3.00
		Non-electric	1.29	6.08	4.26	3.52
Food Sales – Non-electric Station Convenience Store	Single Pane	Electric	2.48	9.54	8.43	7.49
		Non-electric	3.01	11.17	10.14	8.64
	Double Pane	Electric	16.37	5.27	3.52	3.00
		Non-electric	1.29	6.08	4.26	3.52

218 Warehouse and storage building type DEER models do not have windows. Tracking data with this building type will be flagged for on-site verification.
219 Non-electric heating systems were represented by gas heating in building energy models.
220 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 buildings leads to increased energy use due to increase heating load in the winter season.

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Facility Type[218]	Window Type	Heating System Type[219]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[220] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Food Service - Full Service	Single Pane	Electric	0.00	6.44	8.55	11.97
		Non-electric	0.00	7.38	10.18	12.87
	Double Pane	Electric	0.00	0.00	4.26	5.49
		Non-electric	0.00	3.11	4.77	5.71
Food Service - Fast Food	Single Pane	Electric	0.00	3.67	4.83	6.58
		Non-electric	0.00	4.98	7.14	8.04
	Double Pane	Electric	0.00	1.64	2.41	2.98
		Non-electric	0.00	2.17	3.38	3.56
Health Care-inpatient	Single Pane	Electric	6.66	32.82	15.88	29.55
		Non-electric	4.39	18.32	11.24	17.51
	Double Pane	Electric	3.34	13.91	7.30	11.47
		Non-electric	2.08	7.55	4.89	6.64
Health Care-outpatient	Single Pane	Electric	1.03	37.41	15.62	22.39
		Non-electric	1.61	29.19	15.53	22.23
	Double Pane	Electric	0.51	16.11	6.46	9.10
		Non-electric	0.77	12.50	6.13	9.02
Lodging – (Hotel, Motel, and Dormitory)	Single Pane	Electric	3.62	11.47	12.77	10.01
		Non-electric	3.97	12.71	14.23	10.46
	Double Pane	Electric	1.41	4.10	5.22	3.81
		Non-electric	1.66	5.16	5.99	4.15
Mercantile (mall)	Single Pane	Electric	2.54	5.78	5.37	8.12
		Non-electric	2.85	6.61	6.80	8.82
	Double Pane	Electric	1.10	3.07	2.46	3.44
		Non-electric	1.22	3.50	3.06	3.72
Mercantile (Retail, not mall)	Single Pane	Electric	2.48	9.54	8.43	7.49
		Non-electric	3.01	11.17	10.14	8.64
	Double Pane	Electric	16.37	5.27	3.52	3.00
		Non-electric	1.29	6.08	4.26	3.52
Office – Small (<40,000 sq ft)	Single Pane	Electric	1.54	4.88	2.39	4.74
		Non-electric	1.79	5.58	3.08	5.60
	Double Pane	Electric	0.59	1.97	0.96	1.93
		Non-electric	0.72	2.37	1.24	2.28
Office – Large (≥ 40,000 sq ft)	Single Pane	Electric	5.31	17.28	15.43	17.60
		Non-electric	2.19	6.61	7.45	8.35
	Double Pane	Electric	2.16	6.33	6.16	6.61
		Non-electric	0.96	2.64	3.03	3.19
Other[214]	Single Pane	Electric	0.06	2.37	0.02	0.42
		Non-electric	0.08	2.52	0.04	0.53
	Double Pane	Electric	0.03	1.10	0.01	0.17
		Non-electric	0.03	1.16	0.02	0.22
Public Assembly	Single Pane	Electric	0.43	2.91	2.55	1.57
		Non-electric	0.78	2.65	3.01	1.95
	Double Pane	Electric	0.23	1.25	1.14	0.80
		Non-electric	0.38	1.09	1.29	1.02

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Facility Type[218]	Window Type	Heating System Type[219]	ESF$_{north}$ (kWh/sq.ft.)	ESF$_{east}$ (kWh/sq.ft.)	ESF$_{south}$[220] (kWh/sq.ft.)	ESF$_{west}$ (kWh/sq.ft.)
Public Order and Safety (Police and Fire Station)	Single Pane	Electric	0.06	2.37	0.02	0.42
		Non-electric	0.08	2.52	0.04	0.53
	Double Pane	Electric	0.03	1.10	0.01	0.17
		Non-electric	0.03	1.16	0.02	0.22
Religious Worship	Single Pane	Electric	0.43	2.91	2.55	1.57
		Non-electric	0.78	2.65	3.01	1.95
	Double Pane	Electric	0.23	1.25	1.14	0.80
		Non-electric	0.38	1.09	1.29	1.02
Service (Beauty, Auto Repair Workshop)	Single Pane	Electric	2.54	5.78	5.37	8.12
		Non-electric	2.85	6.61	6.80	8.82
	Double Pane	Electric	1.10	3.07	2.46	3.44
		Non-electric	1.22	3.50	3.06	3.72

Table 13-28. Energy Savings Factors for Reflective Window Film by Facility Type and Window Orientation for Norfolk, VA

Facility Type[221]	Window Type	Heating System Type[222]	ESF$_{north}$ (kWh/sq.ft.)	ESF$_{east}$ (kWh/sq.ft.)	ESF$_{south}$[223] (kWh/sq.ft.)	ESF$_{west}$ (kWh/sq.ft.)
Education – Elementary and Middle School	Single Pane	Electric	2.00	4.60	7.20	6.75
		Non-electric	2.20	6.14	8.26	10.61
	Double Pane	Electric	0.82	1.67	3.15	2.69
		Non-electric	0.87	2.23	3.67	4.32
Education – High School	Single Pane	Electric	4.28	7.53	17.89	11.80
		Non-electric	3.92	6.53	11.41	15.09
	Double Pane	Electric	1.84	2.86	6.91	4.59
		Non-electric	1.75	2.48	5.52	6.07
Education – College and University	Single Pane	Electric	4.28	7.53	17.89	11.80
		Non-electric	3.92	6.53	11.41	15.09
	Double Pane	Electric	1.84	2.86	6.91	4.59
		Non-electric	1.75	2.48	5.52	6.07
Food Sales - Grocery	Single Pane	Electric	2.72	10.30	9.41	7.96
		Non-electric	3.23	11.58	10.99	8.88
	Double Pane	Electric	12.62	5.66	2.79	3.24
		Non-electric	1.39	6.32	3.23	3.64
Food Sales – Convenience Store	Single Pane	Electric	2.72	10.30	9.41	7.96
		Non-electric	3.23	11.58	10.99	8.88
	Double Pane	Electric	12.62	5.66	2.79	3.24
		Non-electric	1.39	6.32	3.23	3.64

221 Warehouse and storage building type DEER models do not have windows. Tracking data with this building type will be flagged for on-site verification.
222 Non-electric heating systems were represented by gas heating in building energy models.
223 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 buildings leads to increased energy use due to increase heating load in the winter season.

Facility Type[221]	Window Type	Heating System Type[222]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[223] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Food Sales – Non-electric Station Convenience Store	Single Pane	Electric	2.72	10.30	9.41	7.96
		Non-electric	3.23	11.58	10.99	8.88
	Double Pane	Electric	12.62	5.66	2.79	3.24
		Non-electric	1.39	6.32	3.23	3.64
Food Service - Full Service	Single Pane	Electric	0.00	6.76	7.96	12.00
		Non-electric	0.00	7.50	9.69	13.03
	Double Pane	Electric	0.00	0.00	3.89	5.51
		Non-electric	0.00	3.19	4.55	5.90
Food Service - Fast Food	Single Pane	Electric	0.00	4.07	4.67	6.76
		Non-electric	0.00	5.35	7.09	8.42
	Double Pane	Electric	0.00	1.78	2.29	3.07
		Non-electric	0.00	2.33	3.34	3.79
Health Care-inpatient	Single Pane	Electric	6.65	32.75	14.84	29.52
		Non-electric	4.42	18.30	10.69	17.53
	Double Pane	Electric	3.33	13.99	7.03	11.45
		Non-electric	2.10	7.64	4.78	6.67
Health Care-outpatient	Single Pane	Electric	1.24	38.50	14.45	23.37
		Non-electric	1.73	29.32	13.83	22.39
	Double Pane	Electric	0.58	16.83	6.44	9.40
		Non-electric	0.81	12.75	5.92	8.99
Lodging – (Hotel, Motel, and Dormitory)	Single Pane	Electric	4.01	12.26	13.03	10.62
		Non-electric	4.59	14.44	14.52	11.72
	Double Pane	Electric	1.63	4.67	5.49	4.02
		Non-electric	1.82	5.67	6.13	4.68
Mercantile (mall)	Single Pane	Electric	2.79	6.34	5.28	8.46
		Non-electric	3.09	7.09	6.77	9.12
	Double Pane	Electric	1.18	3.31	2.46	3.58
		Non-electric	1.31	3.66	3.09	3.83
Mercantile (Retail, not mall)	Single Pane	Electric	2.72	10.30	9.41	7.96
		Non-electric	3.23	11.58	10.99	8.88
	Double Pane	Electric	12.62	5.66	2.79	3.24
		Non-electric	1.39	6.32	3.23	3.64
Office – Small (<40,000 sq ft)	Single Pane	Electric	1.60	5.24	2.63	5.13
		Non-electric	1.78	5.69	3.05	5.71
	Double Pane	Electric	0.66	2.08	1.00	2.04
		Non-electric	0.74	2.32	1.20	2.34
Office – Large (≥ 40,000 sq ft)	Single Pane	Electric	5.49	16.69	14.64	17.03
		Non-electric	2.27	6.46	7.14	8.50
	Double Pane	Electric	2.22	6.39	5.89	6.37
		Non-electric	1.06	2.77	2.91	3.32
Other[214]	Single Pane	Electric	0.05	2.61	0.03	0.45
		Non-electric	0.07	2.72	0.03	0.55
	Double Pane	Electric	0.01	1.11	0.02	0.18
		Non-electric	0.02	1.15	0.02	0.21

Facility Type[221]	Window Type	Heating System Type[222]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[223] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Public Assembly	Single Pane	Electric	0.55	2.94	2.56	1.69
		Non-electric	0.85	2.69	2.83	2.21
	Double Pane	Electric	0.26	1.27	1.11	0.91
		Non-electric	0.38	1.05	1.16	1.07
Public Order and Safety (Police and Fire Station)	Single Pane	Electric	0.05	2.61	0.03	0.45
		Non-electric	0.07	2.72	0.03	0.55
	Double Pane	Electric	0.01	1.11	0.02	0.18
		Non-electric	0.02	1.15	0.02	0.21
Religious Worship	Single Pane	Electric	0.55	2.94	2.56	1.69
		Non-electric	0.85	2.69	2.83	2.21
	Double Pane	Electric	0.26	1.27	1.11	0.91
		Non-electric	0.38	1.05	1.16	1.07
Service (Beauty, Auto Repair Workshop)	Single Pane	Electric	2.79	6.34	5.28	8.46
		Non-electric	3.09	7.09	6.77	9.12
	Double Pane	Electric	1.18	3.31	2.46	3.58
		Non-electric	1.31	3.66	3.09	3.83

Table 13-29. Energy Savings Factors for Reflective Window Film by Facility Type and Window Orientation for Arlington, VA

Facility Type[224]	Window Type	Heating System Type[225]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[226] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Education – Elementary and Middle School	Single Pane	Electric	1.91	4.43	7.63	7.09
		Non-electric	1.99	5.79	8.00	9.99
	Double Pane	Electric	0.82	1.81	3.32	2.72
		Non-electric	0.86	2.09	3.58	4.00
Education – High School	Single Pane	Electric	3.97	6.74	15.27	11.23
		Non-electric	3.62	6.42	11.51	13.85
	Double Pane	Electric	1.70	2.40	6.09	4.40
		Non-electric	1.44	1.98	5.15	5.55
Education – College and University	Single Pane	Electric	3.97	6.74	15.27	11.23
		Non-electric	3.62	6.42	11.51	13.85
	Double Pane	Electric	1.70	2.40	6.09	4.40
		Non-electric	1.44	1.98	5.15	5.55
Food Sales - Grocery	Single Pane	Electric	2.46	9.86	8.82	7.40
		Non-electric	3.05	11.39	10.80	8.55
	Double Pane	Electric	16.05	5.49	2.48	2.88
		Non-electric	1.33	6.27	3.03	3.35

[224] Warehouse and storage building type DEER models do not have windows. Tracking data with this building type will be flagged for on-site verification.
[225] Non-electric heating systems were represented by gas heating in building energy models.
[226] 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 buildings leads to increased energy use due to increase heating load in the winter season.

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Facility Type[224]	Window Type	Heating System Type[225]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[226] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Food Sales – Convenience Store	Single Pane	Electric	2.46	9.86	8.82	7.40
		Non-electric	3.05	11.39	10.80	8.55
	Double Pane	Electric	16.05	5.49	2.48	2.88
		Non-electric	1.33	6.27	3.03	3.35
Food Sales – Non-electric Station Convenience Store	Single Pane	Electric	2.46	9.86	8.82	7.40
		Non-electric	3.05	11.39	10.80	8.55
	Double Pane	Electric	16.05	5.49	2.48	2.88
		Non-electric	1.33	6.27	3.03	3.35
Food Service - Full Service	Single Pane	Electric	0.00	6.20	8.10	11.37
		Non-electric	0.00	7.15	10.04	12.54
	Double Pane	Electric	0.00	0.00	3.90	5.15
		Non-electric	0.00	2.99	4.69	5.64
Food Service - Fast Food	Single Pane	Electric	0.00	3.35	4.27	6.14
		Non-electric	0.00	4.84	6.99	7.92
	Double Pane	Electric	0.00	1.55	2.23	2.85
		Non-electric	0.00	2.13	3.32	3.55
Health Care-inpatient	Single Pane	Electric	6.54	33.20	16.51	29.69
		Non-electric	4.33	18.36	11.38	17.54
	Double Pane	Electric	3.34	13.97	7.50	11.46
		Non-electric	2.08	7.56	4.94	6.64
Health Care-outpatient	Single Pane	Electric	1.21	38.50	16.83	23.07
		Non-electric	1.79	29.72	16.37	22.63
	Double Pane	Electric	0.45	16.60	6.86	9.08
		Non-electric	0.71	12.74	6.39	8.92
Lodging – (Hotel, Motel, and Dormitory)	Single Pane	Electric	3.51	11.22	12.71	9.41
		Non-electric	4.03	12.75	14.26	10.41
	Double Pane	Electric	1.43	4.37	5.31	3.81
		Non-electric	1.59	5.07	5.94	3.88
Mercantile (mall)	Single Pane	Electric	2.53	5.84	4.97	7.91
		Non-electric	2.92	6.71	6.75	8.74
	Double Pane	Electric	1.10	3.04	2.32	3.35
		Non-electric	1.25	3.56	3.04	3.72
Mercantile (Retail, not mall)	Single Pane	Electric	2.46	9.86	8.82	7.40
		Non-electric	3.05	11.39	10.80	8.55
	Double Pane	Electric	16.05	5.49	2.48	2.88
		Non-electric	1.33	6.27	3.03	3.35
Office – Small (<40,000 sq ft)	Single Pane	Electric	1.44	4.84	2.27	4.70
		Non-electric	1.80	5.69	3.09	5.68
	Double Pane	Electric	0.61	1.93	0.96	1.93
		Non-electric	0.71	2.28	1.24	2.24
Office – Large (≥ 40,000 sq ft)	Single Pane	Electric	5.45	16.35	15.31	17.15
		Non-electric	2.09	6.47	7.19	8.56
	Double Pane	Electric	2.19	6.14	6.07	6.43
		Non-electric	0.93	2.48	2.98	3.26

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Facility Type[224]	Window Type	Heating System Type[225]	ESF north (kWh/sq.ft.)	ESF east (kWh/sq.ft.)	ESF south[226] (kWh/sq.ft.)	ESF west (kWh/sq.ft.)
Other[214]	Single Pane	Electric	0.04	2.34	0.01	0.40
		Non-electric	0.06	2.49	0.04	0.52
	Double Pane	Electric	0.01	1.03	0.01	0.15
		Non-electric	0.02	1.08	0.02	0.20
Public Assembly	Single Pane	Electric	0.49	2.81	2.32	1.53
		Non-electric	0.81	2.54	2.77	1.85
	Double Pane	Electric	0.22	1.17	1.01	0.84
		Non-electric	0.37	1.03	1.15	0.90
Public Order and Safety (Police and Fire Station)	Single Pane	Electric	0.04	2.34	0.01	0.40
		Non-electric	0.06	2.49	0.04	0.52
	Double Pane	Electric	0.01	1.03	0.01	0.15
		Non-electric	0.02	1.08	0.02	0.20
Religious Worship	Single Pane	Electric	0.49	2.81	2.32	1.53
		Non-electric	0.81	2.54	2.77	1.85
	Double Pane	Electric	0.22	1.17	1.01	0.84
		Non-electric	0.37	1.03	1.15	0.90
Service (Beauty, Auto Repair Workshop)	Single Pane	Electric	2.53	5.84	4.97	7.91
		Non-electric	2.92	6.71	6.75	8.74
	Double Pane	Electric	1.10	3.04	2.32	3.35
		Non-electric	1.25	3.56	3.04	3.72

Table 13-30. Energy Savings Factors for Reflective Window Film by Facility Type and Window Orientation for Roanoke, VA

Facility Type[227]	Window Type	Heating System Type[228]	ESF north (kWh/sq.ft.)	ESF east (kWh/sq.ft.)	ESF south[229] (kWh/sq.ft.)	ESF west (kWh/sq.ft.)
Education – Elementary and Middle School	Single Pane	Electric	1.80	4.39	7.28	5.99
		Non-electric	1.90	5.83	7.76	9.74
	Double Pane	Electric	0.82	1.77	3.21	2.50
		Non-electric	0.82	2.24	3.47	3.86
Education – High School	Single Pane	Electric	3.91	7.10	14.39	10.93
		Non-electric	3.36	7.57	11.09	14.03
	Double Pane	Electric	1.66	2.85	6.35	4.32
		Non-electric	1.60	2.82	4.94	6.15
Education – College and University	Single Pane	Electric	3.91	7.10	14.39	10.93
		Non-electric	3.36	7.57	11.09	14.03
	Double Pane	Electric	1.66	2.85	6.35	4.32
		Non-electric	1.60	2.82	4.94	6.15

[227] Warehouse and storage building type DEER models do not have windows. Tracking data with this building type will be flagged for on-site verification.
[228] Non-electric heating systems were represented by gas heating in building energy models.
[229] 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 buildings leads to increased energy use due to increase heating load in the winter season.

Facility Type[227]	Window Type	Heating System Type[228]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[229] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Food Sales - Grocery	Single Pane	Electric	4.72	7.40	6.12	8.18
		Non-electric	5.67	8.55	7.50	9.28
	Double Pane	Electric	15.20	5.16	2.82	3.28
		Non-electric	1.30	5.86	3.41	3.76
Food Sales – Convenience Store	Single Pane	Electric	4.72	7.40	6.12	8.18
		Non-electric	5.67	8.55	7.50	9.28
	Double Pane	Electric	15.20	5.16	2.82	3.28
		Non-electric	1.30	5.86	3.41	3.76
Food Sales – Non-electric Station Convenience Store	Single Pane	Electric	4.72	7.40	6.12	8.18
		Non-electric	5.67	8.55	7.50	9.28
	Double Pane	Electric	15.20	5.16	2.82	3.28
		Non-electric	1.30	5.86	3.41	3.76
Food Service - Full Service	Single Pane	Electric	0.00	6.65	8.27	11.94
		Non-electric	0.00	7.47	10.04	13.01
	Double Pane	Electric	0.00	0.00	3.93	5.39
		Non-electric	0.00	3.15	4.67	5.86
Food Service - Fast Food	Single Pane	Electric	0.00	3.67	4.61	6.39
		Non-electric	0.00	5.12	7.10	8.04
	Double Pane	Electric	0.00	1.57	2.28	2.96
		Non-electric	0.00	2.19	3.35	3.63
Health Care-inpatient	Single Pane	Electric	7.47	33.28	15.45	29.99
		Non-electric	4.93	18.79	11.14	18.06
	Double Pane	Electric	3.08	14.18	7.16	11.60
		Non-electric	2.00	7.83	4.89	6.83
Health Care-outpatient	Single Pane	Electric	1.08	38.81	16.61	23.40
		Non-electric	1.68	30.34	16.53	23.14
	Double Pane	Electric	0.38	16.38	7.03	9.13
		Non-electric	0.66	12.63	6.73	9.02
Lodging – (Hotel, Motel, and Dormitory)	Single Pane	Electric	3.68	11.79	12.87	10.12
		Non-electric	4.25	13.72	14.48	11.12
	Double Pane	Electric	1.50	4.96	5.45	4.09
		Non-electric	1.67	5.42	6.13	4.17
Mercantile (mall)	Single Pane	Electric	2.55	7.21	5.28	8.45
		Non-electric	2.93	8.10	6.79	9.21
	Double Pane	Electric	1.13	5.04	2.48	3.52
		Non-electric	1.27	5.57	3.09	3.85
Mercantile (Retail, not mall)	Single Pane	Electric	4.72	7.40	6.12	8.18
		Non-electric	5.67	8.55	7.50	9.28
	Double Pane	Electric	15.20	5.16	2.82	3.28
		Non-electric	1.30	5.86	3.41	3.76
Office – Small (<40,000 sq ft)	Single Pane	Electric	1.55	5.26	2.32	5.04
		Non-electric	1.79	5.80	3.00	5.89
	Double Pane	Electric	0.67	2.13	0.93	2.04
		Non-electric	0.74	2.31	1.16	2.35

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Facility Type[227]	Window Type	Heating System Type[228]	ESF$_{north}$ (kWh/sq.ft.)	ESF$_{east}$ (kWh/sq.ft.)	ESF$_{south}$[229] (kWh/sq.ft.)	ESF$_{west}$ (kWh/sq.ft.)
Office – Large (≥ 40,000 sq ft)	Single Pane	Electric	5.65	17.39	15.96	17.77
		Non-electric	2.27	6.71	7.37	8.80
	Double Pane	Electric	2.25	6.81	6.16	6.67
		Non-electric	1.03	2.70	3.05	3.50
Other[214]	Single Pane	Electric	0.05	2.48	0.01	0.40
		Non-electric	0.08	2.62	0.04	0.52
	Double Pane	Electric	0.03	1.09	0.01	0.16
		Non-electric	0.04	1.15	0.02	0.21
Public Assembly	Single Pane	Electric	0.45	2.73	2.42	1.40
		Non-electric	0.80	2.63	2.85	1.84
	Double Pane	Electric	0.16	1.10	1.01	0.60
		Non-electric	0.37	1.07	1.18	0.94
Public Order and Safety (Police and Fire Station)	Single Pane	Electric	0.05	2.48	0.01	0.40
		Non-electric	0.08	2.62	0.04	0.52
	Double Pane	Electric	0.03	1.09	0.01	0.16
		Non-electric	0.04	1.15	0.02	0.21
Religious Worship	Single Pane	Electric	0.45	2.73	2.42	1.40
		Non-electric	0.80	2.63	2.85	1.84
	Double Pane	Electric	0.16	1.10	1.01	0.60
		Non-electric	0.37	1.07	1.18	0.94
Service (Beauty, Auto Repair Workshop)	Single Pane	Electric	2.55	7.21	5.28	8.45
		Non-electric	2.93	8.10	6.79	9.21
	Double Pane	Electric	1.13	5.04	2.48	3.52
		Non-electric	1.27	5.57	3.09	3.85

Table 13-31. Energy Savings Factors for Reflective Window Film by Facility Type and Window Orientation for Sterling, VA

Facility Type[230]	Window Type	Heating System Type[231]	ESF$_{north}$ (kWh/sq.ft.)	ESF$_{east}$ (kWh/sq.ft.)	ESF$_{south}$[232] (kWh/sq.ft.)	ESF$_{west}$ (kWh/sq.ft.)
Education – Elementary and Middle School	Single Pane	Electric	1.98	4.27	7.63	6.48
		Non-electric	2.01	5.59	7.64	9.59
	Double Pane	Electric	0.93	1.73	3.40	2.90
		Non-electric	0.91	2.15	3.35	4.18
Education – High School	Single Pane	Electric	3.86	6.56	13.59	10.24
		Non-electric	3.37	6.73	10.97	13.29
	Double Pane	Electric	1.64	2.37	6.34	4.24
		Non-electric	1.38	2.70	4.64	5.45

[230] Warehouse and storage building type DEER models do not have windows. Tracking data with this building type will be flagged for on-site verification.
[231] Non-electric heating systems were represented by gas heating in building energy models.
[232] 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 buildings leads to increased energy use due to increase heating load in the winter season.

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Facility Type[230]	Window Type	Heating System Type[231]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[232] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Education – College and University	Single Pane	Electric	3.86	6.56	13.59	10.24
		Non-electric	3.37	6.73	10.97	13.29
	Double Pane	Electric	1.64	2.37	6.34	4.24
		Non-electric	1.38	2.70	4.64	5.45
Food Sales - Grocery	Single Pane	Electric	2.39	9.43	8.46	7.22
		Non-electric	2.99	11.00	10.72	8.45
	Double Pane	Electric	17.37	5.32	2.36	2.87
		Non-electric	1.29	6.11	2.99	3.40
Food Sales – Convenience Store	Single Pane	Electric	2.39	9.43	8.46	7.22
		Non-electric	2.99	11.00	10.72	8.45
	Double Pane	Electric	17.37	5.32	2.36	2.87
		Non-electric	1.29	6.11	2.99	3.40
Food Sales – Non-electric Station Convenience Store	Single Pane	Electric	2.39	9.43	8.46	7.22
		Non-electric	2.99	11.00	10.72	8.45
	Double Pane	Electric	17.37	5.32	2.36	2.87
		Non-electric	1.29	6.11	2.99	3.40
Food Service - Full Service	Single Pane	Electric	0.00	6.35	8.25	11.54
		Non-electric	0.00	7.31	10.24	12.72
	Double Pane	Electric	0.00	0.00	4.06	5.23
		Non-electric	0.00	3.06	4.77	5.64
Food Service - Fast Food	Single Pane	Electric	0.00	3.43	4.31	6.22
		Non-electric	0.00	4.88	7.00	7.91
	Double Pane	Electric	0.00	1.45	2.21	2.73
		Non-electric	0.00	2.11	3.30	3.47
Health Care-inpatient	Single Pane	Electric	6.44	33.03	16.28	29.64
		Non-electric	4.34	18.41	11.38	17.56
	Double Pane	Electric	3.32	13.83	7.45	11.51
		Non-electric	2.08	7.52	4.90	6.66
Health Care-outpatient	Single Pane	Electric	1.04	37.91	16.28	22.83
		Non-electric	1.66	29.45	16.06	22.62
	Double Pane	Electric	0.37	16.33	6.66	8.89
		Non-electric	0.64	12.60	6.26	8.80
Lodging – (Hotel, Motel, and Dormitory)	Single Pane	Electric	3.43	10.46	12.34	9.39
		Non-electric	4.02	12.44	13.93	10.15
	Double Pane	Electric	1.40	4.14	5.09	3.48
		Non-electric	1.62	5.05	5.78	3.86
Mercantile (mall)	Single Pane	Electric	2.41	5.59	4.81	7.64
		Non-electric	2.86	6.62	6.69	8.63
	Double Pane	Electric	1.06	3.00	2.17	3.20
		Non-electric	1.23	3.52	2.95	3.60
Mercantile (Retail, not mall)	Single Pane	Electric	2.39	9.43	8.46	7.22
		Non-electric	2.99	11.00	10.72	8.45
	Double Pane	Electric	17.37	5.32	2.36	2.87
		Non-electric	1.29	6.11	2.99	3.40

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Facility Type[230]	Window Type	Heating System Type[231]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[232] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Office – Small (<40,000 sq ft)	Single Pane	Electric	1.54	4.85	2.11	4.50
		Non-electric	1.70	5.36	2.89	5.48
	Double Pane	Electric	0.65	1.96	0.83	1.78
		Non-electric	0.70	2.15	1.12	2.13
Office – Large (≥ 40,000 sq ft)	Single Pane	Electric	5.54	16.64	15.44	16.95
		Non-electric	2.07	6.66	7.45	8.65
	Double Pane	Electric	2.23	6.07	6.10	6.35
		Non-electric	0.97	2.76	3.10	3.44
Other[214]	Single Pane	Electric	0.08	2.35	0.02	0.38
		Non-electric	0.10	2.53	0.04	0.51
	Double Pane	Electric	0.03	1.02	0.01	0.13
		Non-electric	0.03	1.09	0.02	0.19
Public Assembly	Single Pane	Electric	0.33	2.63	2.07	1.38
		Non-electric	0.76	2.44	2.58	1.75
	Double Pane	Electric	0.15	1.07	0.85	0.70
		Non-electric	0.35	0.96	1.05	0.90
Public Order and Safety (Police and Fire Station)	Single Pane	Electric	0.08	2.35	0.02	0.38
		Non-electric	0.10	2.53	0.04	0.51
	Double Pane	Electric	0.03	1.02	0.01	0.13
		Non-electric	0.03	1.09	0.02	0.19
Religious Worship	Single Pane	Electric	0.33	2.63	2.07	1.38
		Non-electric	0.76	2.44	2.58	1.75
	Double Pane	Electric	0.15	1.07	0.85	0.70
		Non-electric	0.35	0.96	1.05	0.90
Service (Beauty, Auto Repair Workshop)	Single Pane	Electric	2.41	5.59	4.81	7.64
		Non-electric	2.86	6.62	6.69	8.63
	Double Pane	Electric	1.06	3.00	2.17	3.20
		Non-electric	1.23	3.52	2.95	3.60

Table 13-32. Energy Savings Factors for Reflective Window Film by Facility Type and Window Orientation for Richmond, VA

Facility Type[233]	Window Type	Heating System Type[234]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[235] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Education – Elementary and Middle School	Single Pane	Electric	1.90	4.53	7.56	6.30
		Non-electric	2.07	6.11	8.28	9.97
	Double Pane	Electric	0.85	1.82	3.26	2.73
		Non-electric	0.91	2.35	3.82	4.33

233 Warehouse and storage building type DEER models do not have windows. Tracking data with this building type will be flagged for on-site verification.
234 Non-electric heating systems were represented by gas heating in building energy models.
235 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 buildings leads to increased energy use due to increase heating load in the winter season.

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Facility Type[233]	Window Type	Heating System Type[234]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[235] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Education – High School	Single Pane	Electric	4.27	7.43	17.99	11.96
		Non-electric	3.76	7.72	11.71	14.84
	Double Pane	Electric	1.97	2.87	7.06	4.83
		Non-electric	1.67	2.70	5.17	5.94
Education – College and University	Single Pane	Electric	4.27	7.43	17.99	11.96
		Non-electric	3.76	7.72	11.71	14.84
	Double Pane	Electric	1.97	2.87	7.06	4.83
		Non-electric	1.67	2.70	5.17	5.94
Food Sales - Grocery	Single Pane	Electric	2.67	10.12	8.56	8.94
		Non-electric	3.16	11.47	10.14	10.16
	Double Pane	Electric	14.39	4.81	3.68	3.19
		Non-electric	1.38	5.41	4.39	3.63
Food Sales – Convenience Store	Single Pane	Electric	2.67	10.12	8.56	8.94
		Non-electric	3.16	11.47	10.14	10.16
	Double Pane	Electric	14.39	4.81	3.68	3.19
		Non-electric	1.38	5.41	4.39	3.63
Food Sales – Non-electric Station Convenience Store	Single Pane	Electric	2.67	10.12	8.56	8.94
		Non-electric	3.16	11.47	10.14	10.16
	Double Pane	Electric	14.39	4.81	3.68	3.19
		Non-electric	1.38	5.41	4.39	3.63
Food Service - Full Service	Single Pane	Electric	0.00	6.99	8.48	12.30
		Non-electric	0.00	7.64	10.09	13.05
	Double Pane	Electric	0.00	0.00	4.06	5.58
		Non-electric	0.00	3.24	4.73	5.92
Food Service - Fast Food	Single Pane	Electric	0.00	4.02	4.63	6.64
		Non-electric	0.00	5.32	7.16	8.31
	Double Pane	Electric	0.00	1.73	2.34	2.97
		Non-electric	0.00	2.27	3.39	3.65
Health Care-inpatient	Single Pane	Electric	6.70	33.01	15.30	29.63
		Non-electric	4.44	18.38	10.95	17.56
	Double Pane	Electric	3.33	13.92	7.09	11.48
		Non-electric	2.08	7.60	4.81	6.67
Health Care-outpatient	Single Pane	Electric	1.31	38.66	15.40	23.69
		Non-electric	1.82	29.61	14.79	22.83
	Double Pane	Electric	0.48	16.47	6.46	9.44
		Non-electric	0.72	12.44	5.93	9.04
Lodging – (Hotel, Motel, and Dormitory)	Single Pane	Electric	3.89	12.04	13.14	10.57
		Non-electric	4.44	13.90	14.71	11.55
	Double Pane	Electric	1.60	5.08	5.48	4.23
		Non-electric	1.84	5.55	6.18	4.34
Mercantile (mall)	Single Pane	Electric	2.70	6.08	5.22	8.25
		Non-electric	3.03	6.93	6.84	8.99
	Double Pane	Electric	1.14	3.24	2.42	3.48
		Non-electric	1.29	3.62	3.07	3.79

Facility Type[233]	Window Type	Heating System Type[234]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[235] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Mercantile (Retail, not mall)	Single Pane	Electric	2.67	10.12	8.56	8.94
		Non-electric	3.16	11.47	10.14	10.16
	Double Pane	Electric	14.39	4.81	3.68	3.19
		Non-electric	1.38	5.41	4.39	3.63
Office – Small (<40,000 sq ft)	Single Pane	Electric	1.58	5.22	2.62	5.11
		Non-electric	1.82	5.84	3.13	5.86
	Double Pane	Electric	0.69	2.15	1.06	2.07
		Non-electric	0.73	2.32	1.22	2.34
Office – Large (≥ 40,000 sq ft)	Single Pane	Electric	5.58	17.52	15.45	17.57
		Non-electric	2.28	6.37	7.24	8.60
	Double Pane	Electric	2.24	6.42	6.15	6.60
		Non-electric	1.04	2.59	2.97	3.12
Other[214]	Single Pane	Electric	0.07	2.58	0.03	0.46
		Non-electric	0.08	2.70	0.04	0.56
	Double Pane	Electric	0.03	1.12	0.01	0.17
		Non-electric	0.03	1.17	0.02	0.21
Public Assembly	Single Pane	Electric	0.58	3.12	2.70	1.43
		Non-electric	0.86	2.77	2.97	1.98
	Double Pane	Electric	0.28	1.21	1.16	0.83
		Non-electric	0.40	1.11	1.24	0.99
Public Order and Safety (Police and Fire Station)	Single Pane	Electric	0.07	2.58	0.03	0.46
		Non-electric	0.08	2.70	0.04	0.56
	Double Pane	Electric	0.03	1.12	0.01	0.17
		Non-electric	0.03	1.17	0.02	0.21
Religious Worship	Single Pane	Electric	0.58	3.12	2.70	1.43
		Non-electric	0.86	2.77	2.97	1.98
	Double Pane	Electric	0.28	1.21	1.16	0.83
		Non-electric	0.40	1.11	1.24	0.99
Service (Beauty, Auto Repair Workshop)	Single Pane	Electric	2.70	6.08	5.22	8.25
		Non-electric	3.03	6.93	6.84	8.99
	Double Pane	Electric	1.14	3.24	2.42	3.48
		Non-electric	1.29	3.62	3.07	3.79

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Table 13-33. Energy Savings Factors for Reflective Window Film by Facility Type and Window Orientation for Rocky Mount-Wilson, NC

Facility Type[236]	Window Type	Heating System Type[237]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[238] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Education – Elementary and Middle School	Single Pane	Electric	2.03	4.55	6.75	6.10
		Non-electric	2.27	6.24	8.35	10.70
	Double Pane	Electric	0.87	1.95	2.90	2.48
		Non-electric	1.00	2.59	3.76	4.55
Education – High School	Single Pane	Electric	4.47	8.10	20.13	12.97
		Non-electric	3.90	7.03	11.34	14.85
	Double Pane	Electric	1.91	3.15	7.81	5.23
		Non-electric	1.82	3.30	5.63	6.82
Education – College and University	Single Pane	Electric	4.47	8.10	20.13	12.97
		Non-electric	3.90	7.03	11.34	14.85
	Double Pane	Electric	1.91	3.15	7.81	5.23
		Non-electric	1.82	3.30	5.63	6.82
Food Sales - Grocery	Single Pane	Electric	3.64	7.79	6.90	10.81
		Non-electric	4.16	8.62	7.74	11.86
	Double Pane	Electric	10.34	2.28	5.32	3.53
		Non-electric	1.34	2.63	5.94	3.90
Food Sales – Convenience Store	Single Pane	Electric	3.64	7.79	6.90	10.81
		Non-electric	4.16	8.62	7.74	11.86
	Double Pane	Electric	10.34	2.28	5.32	3.53
		Non-electric	1.34	2.63	5.94	3.90
Food Sales – Non-electric Station Convenience Store	Single Pane	Electric	3.64	7.79	6.90	10.81
		Non-electric	4.16	8.62	7.74	11.86
	Double Pane	Electric	10.34	2.28	5.32	3.53
		Non-electric	1.34	2.63	5.94	3.90
Food Service - Full Service	Single Pane	Electric	0.00	7.00	8.51	12.74
		Non-electric	0.00	7.61	9.80	13.31
	Double Pane	Electric	0.00	0.00	3.93	5.83
		Non-electric	0.00	3.24	4.49	6.11
Food Service - Fast Food	Single Pane	Electric	0.00	4.00	4.83	6.96
		Non-electric	0.00	5.27	7.11	8.43
	Double Pane	Electric	0.00	1.70	2.37	3.16
		Non-electric	0.00	2.26	3.35	3.80
Health Care-inpatient	Single Pane	Electric	7.19	32.81	14.02	29.48
		Non-electric	4.67	18.14	10.38	17.45
	Double Pane	Electric	3.20	13.82	6.70	11.43
		Non-electric	2.02	7.51	4.64	6.62

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

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

238 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 buildings leads to increased energy use due to increase heating load in the winter season.

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Facility Type[236]	Window Type	Heating System Type[237]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[238] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Health Care-outpatient	Single Pane	Electric	1.16	38.33	13.54	23.36
		Non-electric	1.65	28.95	13.08	22.33
	Double Pane	Electric	0.40	16.43	6.00	9.16
		Non-electric	0.62	12.28	5.59	8.72
Lodging – (Hotel, Motel, and Dormitory)	Single Pane	Electric	4.29	13.30	13.93	12.22
		Non-electric	4.89	15.27	15.50	13.04
	Double Pane	Electric	1.79	5.71	5.97	4.97
		Non-electric	2.05	6.16	6.64	5.21
Mercantile (mall)	Single Pane	Electric	2.88	7.99	5.73	8.84
		Non-electric	3.05	8.60	6.79	9.15
	Double Pane	Electric	1.20	3.07	2.64	3.68
		Non-electric	1.27	3.32	3.10	3.84
Mercantile (Retail, not mall)	Single Pane	Electric	3.64	7.79	6.90	10.81
		Non-electric	4.16	8.62	7.74	11.86
	Double Pane	Electric	10.34	2.28	5.32	3.53
		Non-electric	1.34	2.63	5.94	3.90
Office – Small (<40,000 sq ft)	Single Pane	Electric	1.75	5.48	3.32	5.40
		Non-electric	1.86	5.70	3.49	5.91
	Double Pane	Electric	0.74	2.26	1.33	2.18
		Non-electric	0.75	2.29	1.36	2.29
Office – Large (≥ 40,000 sq ft)	Single Pane	Electric	5.44	17.77	15.93	18.02
		Non-electric	2.41	6.22	7.13	8.49
	Double Pane	Electric	2.21	7.05	6.45	6.77
		Non-electric	1.07	2.46	2.89	3.21
Other[214]	Single Pane	Electric	0.11	2.61	0.03	0.51
		Non-electric	0.11	2.69	0.04	0.58
	Double Pane	Electric	0.05	1.14	0.02	0.19
		Non-electric	0.05	1.17	0.03	0.21
Public Assembly	Single Pane	Electric	0.53	2.69	2.92	1.45
		Non-electric	0.85	2.63	3.27	1.90
	Double Pane	Electric	0.26	1.16	1.25	0.84
		Non-electric	0.40	1.13	1.38	1.00
Public Order and Safety (Police and Fire Station)	Single Pane	Electric	0.11	2.61	0.03	0.51
		Non-electric	0.11	2.69	0.04	0.58
	Double Pane	Electric	0.05	1.14	0.02	0.19
		Non-electric	0.05	1.17	0.03	0.21
Religious Worship	Single Pane	Electric	0.53	2.69	2.92	1.45
		Non-electric	0.85	2.63	3.27	1.90
	Double Pane	Electric	0.26	1.16	1.25	0.84
		Non-electric	0.40	1.13	1.38	1.00
Service (Beauty, Auto Repair Workshop)	Single Pane	Electric	2.88	7.99	5.73	8.84
		Non-electric	3.05	8.60	6.79	9.15
	Double Pane	Electric	1.20	3.07	2.64	3.68
		Non-electric	1.27	3.32	3.10	3.84

Table 13-34: Energy Savings Factors for Reflective Window Film by Facility Type and Window Orientation for Elizabeth City, NC

Facility Type[239]	Window Type	Heating System Type[240]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[241] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Education – Elementary and Middle School	Single Pane	Electric	1.97	5.26	7.38	6.86
		Non-electric	2.35	6.78	9.05	11.31
	Double Pane	Electric	0.87	1.98	3.24	3.04
		Non-electric	1.00	2.50	4.12	4.64
Education – High School	Single Pane	Electric	4.77	9.14	20.46	14.20
		Non-electric	4.50	8.42	12.67	17.47
	Double Pane	Electric	2.07	3.27	7.93	5.56
		Non-electric	1.98	3.03	5.78	7.32
Education – College and University	Single Pane	Electric	4.77	9.14	20.46	14.20
		Non-electric	4.50	8.42	12.67	17.47
	Double Pane	Electric	2.07	3.27	7.93	5.56
		Non-electric	1.98	3.03	5.78	7.32
Food Sales - Grocery	Single Pane	Electric	3.05	11.06	10.22	8.97
		Non-electric	3.44	11.99	11.43	9.66
	Double Pane	Electric	9.07	5.28	3.11	3.56
		Non-electric	1.39	5.72	3.45	3.86
Food Sales – Convenience Store	Single Pane	Electric	3.05	11.06	10.22	8.97
		Non-electric	3.44	11.99	11.43	9.66
	Double Pane	Electric	9.07	5.28	3.11	3.56
		Non-electric	1.39	5.72	3.45	3.86
Food Sales – Non-electric Station Convenience Store	Single Pane	Electric	3.05	11.06	10.22	8.97
		Non-electric	3.44	11.99	11.43	9.66
	Double Pane	Electric	9.07	5.28	3.11	3.56
		Non-electric	1.39	5.72	3.45	3.86
Food Service - Full Service	Single Pane	Electric	0.00	7.76	8.92	13.31
		Non-electric	0.00	8.23	10.24	13.96
	Double Pane	Electric	0.00	0.00	4.24	6.03
		Non-electric	0.00	3.50	4.77	6.31
Food Service - Fast Food	Single Pane	Electric	0.00	4.70	5.32	7.63
		Non-electric	0.00	5.84	7.52	9.14
	Double Pane	Electric	0.00	2.00	2.55	3.35
		Non-electric	0.00	2.50	3.52	4.03

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

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

[241] 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 buildings leads to increased energy use due to increase heating load in the winter season.

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Facility Type[239]	Window Type	Heating System Type[240]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[241] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Health Care-inpatient	Single Pane	Electric	6.84	32.68	14.58	29.43
		Non-electric	4.49	18.27	10.64	17.62
	Double Pane	Electric	3.34	13.81	6.87	11.41
		Non-electric	2.10	7.57	4.75	6.71
Health Care-outpatient	Single Pane	Electric	1.33	38.81	14.37	23.70
		Non-electric	1.79	29.62	13.78	22.67
	Double Pane	Electric	0.65	18.01	6.99	9.61
		Non-electric	0.87	12.69	5.89	9.17
Lodging – (Hotel, Motel, and Dormitory)	Single Pane	Electric	4.47	13.85	14.09	12.75
		Non-electric	5.03	15.70	15.59	13.63
	Double Pane	Electric	1.87	5.62	6.05	5.13
		Non-electric	2.06	6.11	6.63	5.34
Mercantile (mall)	Single Pane	Electric	3.12	7.06	6.21	9.43
		Non-electric	3.25	7.50	7.17	9.76
	Double Pane	Electric	1.31	3.58	2.88	3.97
		Non-electric	1.37	3.83	3.28	4.10
Mercantile (Retail, not mall)	Single Pane	Electric	3.05	11.06	10.22	8.97
		Non-electric	3.44	11.99	11.43	9.66
	Double Pane	Electric	9.07	5.28	3.11	3.56
		Non-electric	1.39	5.72	3.45	3.86
Office – Small (<40,000 sq ft)	Single Pane	Electric	1.81	5.82	3.27	5.74
		Non-electric	1.88	6.24	3.47	6.26
	Double Pane	Electric	0.74	2.37	1.30	2.30
		Non-electric	0.79	2.52	1.38	2.47
Office – Large (≥ 40,000 sq ft)	Single Pane	Electric	5.59	17.97	15.44	18.46
		Non-electric	2.37	6.58	7.21	8.91
	Double Pane	Electric	2.29	6.93	6.27	6.89
		Non-electric	1.03	2.58	2.92	3.16
Other[214]	Single Pane	Electric	0.06	2.83	0.03	0.56
		Non-electric	0.07	2.88	0.04	0.61
	Double Pane	Electric	0.02	1.23	0.02	0.21
		Non-electric	0.03	1.25	0.03	0.23
Public Assembly	Single Pane	Electric	0.73	3.44	3.56	1.75
		Non-electric	0.96	3.03	3.72	2.36
	Double Pane	Electric	0.35	1.47	1.55	1.01
		Non-electric	0.43	1.23	1.55	1.11
Public Order and Safety (Police and Fire Station)	Single Pane	Electric	0.06	2.83	0.03	0.56
		Non-electric	0.07	2.88	0.04	0.61
	Double Pane	Electric	0.02	1.23	0.02	0.21
		Non-electric	0.03	1.25	0.03	0.23
Religious Worship	Single Pane	Electric	0.73	3.44	3.56	1.75
		Non-electric	0.96	3.03	3.72	2.36
	Double Pane	Electric	0.35	1.47	1.55	1.01
		Non-electric	0.43	1.23	1.55	1.11

Facility Type[239]	Window Type	Heating System Type[240]	ESF_{north} (kWh/sq.ft.)	ESF_{east} (kWh/sq.ft.)	ESF_{south}[241] (kWh/sq.ft.)	ESF_{west} (kWh/sq.ft.)
Service (Beauty, Auto Repair Workshop)	Single Pane	Electric	3.12	7.06	6.21	9.43
		Non-electric	3.25	7.50	7.17	9.76
	Double Pane	Electric	1.31	3.58	2.88	3.97
		Non-electric	1.37	3.83	3.28	4.10

13.8.1 Update Summary

Updates made to this section are described in Table 13-16

Table 13-35. Summary of Update(s)

Version	Update Type	Description
2021	New section	Moved window film energy savings factors tables to this sub-appendix.

13.9 Sub-Appendix F2-VIII: General Equations

This section appears in Appendix F1 as Sub-Appendix F1-II: General Equations (a.k.a. Section 19.2).

Equation 1: Cooling Capacities – Btu/h to tons

This equation appears in Appendix F1 as Sub-Appendix F1-II: General Equations (a.k.a. Section 19.2).

Equation 2: Cooling Capacities – tons to Btu/h

This equation appears in Appendix F1 as Sub-Appendix F1-II: General Equations (a.k.a. Section 19.2).

Equation 3: Energy Efficiencies - SEER to EER, for systems < 65,000 Btu/h

This equation appears in Appendix F1 as Sub-Appendix F1-II: General Equations (a.k.a. Section 19.2).

Equation 4: Energy Efficiencies - EER to IEER, for systems ≥ 65,000 Btu/h

This equation appears in Appendix F1 as Sub-Appendix F1-II: General Equations (a.k.a. Section 19.2).

Equation 5: Energy Efficiencies - HSPF to COP

This equation appears in Appendix F1 as Sub-Appendix F1-II: General Equations (a.k.a. Section 19.2).

Equation 6: Energy Efficiencies - COP to HSPF

This equation appears in Appendix F1 as Sub-Appendix F1-II: General Equations (a.k.a. Section 19.2).

Equation 7: Energy Efficiencies - COP to EER

This equation appears in Appendix F1 as Sub-Appendix F1-II: General Equations (a.k.a. Section 19.2).

Equation 8: Energy Efficiencies – $kW/ton_{full\text{-}load}$ to kW/ton_{IPLV}

This equation appears in Appendix F1 as Sub-Appendix F1-II: General Equations (a.k.a. Section 19.2).

Equation 9: Energy Efficiencies – $EER_{full\text{-}load}$ to EER_{IPLV}

This equation appears in Appendix F1 as Sub-Appendix F1-II: General Equations (a.k.a. Section 19.2).

Equation 10: Heat to electric energy – Btu/h to kW

This equation appears in Appendix F1 as Sub-Appendix F1-II: General Equations (a.k.a. Section 19.2).

APPENDIX G RESIDENTIAL INCOME AND AGE QUALIFYING HOME IMPROVEMENT PROGRAM IMPACT ANALYSIS

INCOME AND AGE QUALIFYING (IAQ) HOME IMPROVEMENT PROGRAM

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

Appendix G
Impact Evaluation of Program Years 2015–2020

June 15, 2022

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1 EXECUTIVE SUMMARY

This report presents the results of the impact evaluation of the Residential Income and Age Qualifying (IAQ) Home Improvement program administered by the Virginia Electric and Power Company. The IAQ Home Improvement Program provided a home energy assessment and the direct installation of no-cost energy conservation measures to eligible IAQ households in Dominion's Virginia and North Carolina service territories. The program began in Virginia in May 2015 and in North Carolina in January 2016.

The Income and Age Qualifying Home Improvement program achieved a 105% realization rate for program years 2015–2020.

68,111 measures, installed across 24,420 accounts, contributed to program impacts.

The goal of the evaluation was to estimate net energy impacts (kWh/year) and the realization rate for the IAQ Home Improvement Program years 2015 through 2020.[1] Annual savings and realization rates by year were calculated for three measure groups: attic insulation, LED lighting, and water distribution measures. The impact evaluation calculated net energy savings using a statistically adjusted engineering (SAE) billing analysis. This analysis used future program participants as the comparison group for current-year participants.

The evaluated savings compared against tracked or deemed savings yielded a 105% realization rate over the program years 2015–2021. The average five-year per-participant savings was 400 kWh/year. While the deemed or tracked savings and evaluated savings may deviate more widely from each other, either by year or by measure group, taken at the program level, which is the goal of the evaluation, the deemed savings equations in the Dominion Energy Technical Reference Manual (DE TRM) were predictive of evaluated savings.

The program's first year (2015) had the lowest realization rate (52%) across all program years. This is not unusual for the first year of enrollment as the program ramps up. In comparison, the realization rates in 2019 and 2020 were higher than realization rates in previous program years.

Impacts were also calculated for three measure groups. Measure-level realization rates were 106% for attic insulation, 111% for LED lighting, and 88% for the water distribution measures. Similar to the program realization rates, the measure-level realization rates were strong, and information from this evaluation will be incorporated into the next annual update of the DE TRM. The average five-year per-participant measure-level savings ranges from 196 kWh/year for LED lighting to 206 kWh/year for water distribution measures.

Figure E-2. Program tracked savings, evaluated savings, and realization rate by year (2015–2020)

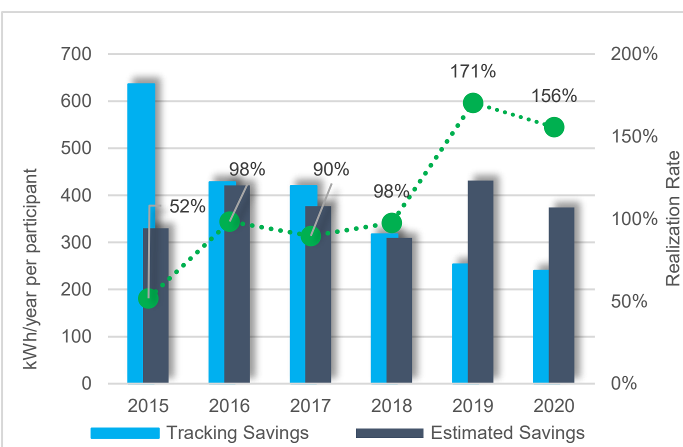
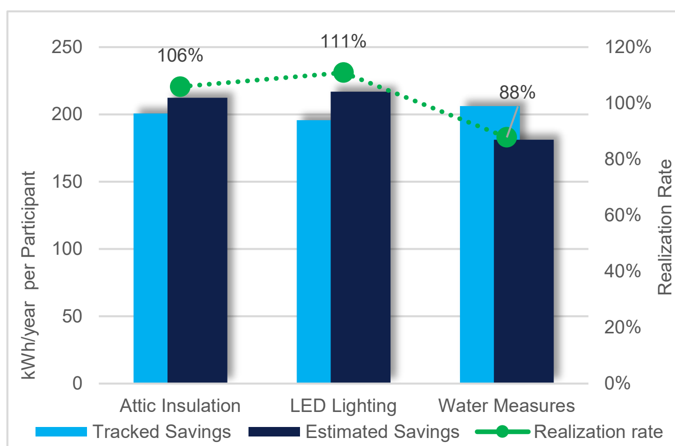


Figure E-2. Program tracked savings, evaluated savings, and realization rate by measure group



[1] The realization rate is the proportion of deemed or expected (i.e.tracking) energy and peak demand savings that have been verified for all customers or projects in an evaluation of a program. It is expressed as a percentage.

2 INTRODUCTION

This report presents the results of the impact evaluation of the Residential Income and Age Qualifying (IAQ) Home Improvement program administered by the Virginia Electric and Power Company. The IAQ Home Improvement Program is designed to provide a free service to IAQ customers who would not otherwise have the financial means to complete the work. This evaluation was conducted using the methods defined in the IAQ Home Improvement program EM&V plan across the program years 2015–2020.[2] The impact evaluation calculated ex post gross energy savings, which in the context of income-qualifying programs, are considered equal to net energy savings.[3]

2.1 Program background

The IAQ Home Improvement Program provides a home energy assessment and the direct installation of no-cost energy conservation measures (ECM) to eligible IAQ households in Dominion's Virginia and North Carolina service territories. The program began in Virginia in May 2015 and in North Carolina in January 2016. Home assessments and direct installation of ECMs did not begin until July of each state's respective start year due to program start-up and the natural lag between enrollment, qualification, and in-home treatments. The program was scheduled to expire (and in fact paused) in early 2018. However, both the Virginia and North Carolina Commissions granted a three-year program extension, and the program restarted mid-year 2018.[4] Program eligibility requirements are listed in Table 2-1.

Table 2-1. Residential IAQ Home Improvement Program eligibility requirements[5]

	Virginia	North Carolina
	Residential electric service for single, separately metered multi-family, and mobile homes. Renter-occupied households are also eligible with permission from the landlord.	
Income requirements	Total household income at or below 60% of the Virginia median income, or 80% of the local area median income, whichever is greater	Customers must have at or below a total household income of 200% of the federal poverty level
Age-qualifying income requirements	Customers 60 years or older with a total household income at or below 120% of the Virginia median income	Customers 60 years or older with a total income at or below 250% of the federal poverty level

2.2 Program services, delivery, and measures

Participation is initiated when a customer contacts a qualified Dominion Energy weatherization service provider (WSP). The WSPs also engage at the local level to spread awareness and promote the program. Once contact is initiated, the WSP determines income and/or age eligibility, performs the home assessment, and identifies qualifying measures. Not all households qualify for all measures. Applicability is determined based on the presence or absence of qualified measures and required pre-conditions such as the level of

2 Appendix H., Residential Income and Age Qualifying Home Improvement Program EM&V Plan. Evaluation, Measurement, and Verification Report for Virginia Electric and Power Company (Dominion Energy), Case No. PUR-2018-00168 (Virginia), Docket No. E-22 Sub 577 (North Carolina), Volume 1 of 4, May 15, 2021, Prepared by DNV Energy Insights USA Inc. (DNV).

3 Violette, Daniel M.; Rathbun, Pamela. (2017). Chapter 21: Estimating Net Savings – Common Practices: Methods for Determining Energy-Efficiency Savings for Specific Measures. Golden, CO; National Renewable Energy Laboratory. NREL/SR-7A40-68578, 45.; Synapse Energy Economics, Erin Malone, Wendy Ong, Max Chang. State Net-to-Gross Ratios, Research Results and Analysis for Average State Net-to-Gross Ratios Used in Energy Efficiency Savings Estimates. Prepared for the United States Environmental Protection Agency, January 23, 2015, 2.

4 The Program started in Virginia on May 1, 2015, and in North Carolina on January 1, 2016. On May 10, 2018. The respective state commissions approved three years extensions later that year; Virginia on May 10, 2018, Case No. PUR-2017-00129 and North Carolina on July 1, 2018 (Docket No. E-22, Sub 523).

5 State and local area median income for 2016–2020 (in 2020 USD) is available from the U.S. Census, Virginia Quick Facts, at https://www.census.gov/quickfacts/fact/table/VA/PST045221. North Carolina data can be accessed from the same page. 2017–2021 federal poverty guidelines are published by the U.S. Dept. Of Health and Human Services at https://aspe.hhs.gov/topics/poverty-economic-mobility/poverty-guidelines/prior-hhs-poverty-guidelines-federal-register-references/2021-poverty-guidelines

existing insulation, or existing lighting types. The contractor reviews the energy assessment with the customer, using it as a vehicle to provide energy education, and installs the measures. Table 2-2 contains the list of approved measures.

Table 2-2. Residential IAQ Home Improvement Program–eligible measures

End Use	Measures
Lighting	ENERGY STAR® LED A-Line lamps (up to 6 to replace existing 40- and 60-watt incandescent lamps.
Whole house	Attic insulation
Domestic Hot Water	Low-flow showerhead(s)
	Faucet aerators
	Hot water pipe wrap insulation

2.3 Evaluation objectives

The goal of the evaluation is to estimate energy impacts (kWh/year) and the realization rate for the IAQ Home Improvement Program years 2015–2020.[6] Annual savings and realization rates by year are calculated for three measure groups: attic insulation, LED lighting, and water distribution measures. Program impacts by year and measure are included in a secondary analysis. The evaluation uses a statistically adjusted engineering (SAE) billing analysis, with a representative comparison group.

2.4 Data sources

DNV used the following three primary data sources in this evaluation:

1. *Tracking data.* The tracking database contains all participant, measure, and program related information. The tracking data is used for program reporting and to calculate "tracked" savings estimates. Dominion Energy provides tracking data from their Business Intelligence (BI) system to DNV on a monthly basis.
2. *Billing data.* For each account, Dominion Energy provided all available monthly billing data (kWh) from January 2010 through December 2021. The billing data was merged with the tracking data to identify the pre- and post-program periods and to develop the comparison group pool.
3. *Weather data.* The temperature data used in the analysis was taken from the National Oceanic and Atmospheric Administration (NOAA).[7]

2.4.1 Tracking data

The Residential IAQ Home Improvement Program tracking database provides information about program activity. This included:

- Participant data such as contact information, building type and condition, end use information, and utility identifiers such as rate class
- Program data such as participation dates, vendor information, and pre-existing conditions
- Measure-level data such as measure type, quantity, and installation date
- Measure-level gross savings estimates that are calculated using the deemed methods defined in the DE TRM.[8]

For program years 2015–2020, 68,111 measures installed across 24,420 accounts contributed to program impacts. The tracked measure-level energy savings by year and number of accounts can be found in APPENDIX B, Tracked energy savings by measure and

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[6] The realization rate is the proportion of deemed or expected (i.e.tracking) energy and peak demand savings that have been verified for all customers or projects in an evaluation of a program. It is expressed as a percentage.

[7] NOAA, National Centers for Environmental Information, Climate Data Online, https://www.ncdc.noaa.gov/cdo-web/ (accessed Mar 29, 2022).

[8] Tracked (ex ante) savings are calculated using methods defined in the DE TRM. The DE TRM, updated annually, is included as an appendix to the annual EM&V report.

year. For each account, the period just on and after installation (the installation window) was established using the measure approval dates.

The tracking data was examined to identify inconsistencies or outliers. There were 314 participants with very low expected savings (i.e., total site savings of less than 30 kWh/year). This level of savings would be lost in the natural variability of a participant's electric consumption. Accordingly, these were eliminated from the analysis. There were also two customers with extremely large tracking savings (greater than 15,000 kWh/year). Since these participants were nearly three times larger than the next-largest participant, these were identified as outliers and were also eliminated from the analysis. This is a low data attrition rate for a typical income-qualified evaluation.

2.4.2 Billing data

This analysis was conducted using monthly customer billing data. Dominion Energy provided 1,455,197 monthly readings for 26,283 participant accounts for 2012–2021. Although the evaluation covered the 2015–2020 program years, the post-installation period for 2020 participants extended into 2021. Care was taken to include as much of the source billing data as possible. However, certain types of bills were identified as possible anomalies. The following bill types or participants were removed from the analysis set.

- Bills with less than or equal to zero energy consumption
- Bills with short or long monthly read cycles (less than 20 days or greater than 40 days)
- Bills that were obtained by postcard, estimated, rebilled, PC-read, or phoned in
- Duplicate records
- Participants who had fewer than 24 months of billing data[9]

The billing analysis requires that a participant (by premise and account number) have at least 10 months of billing data before and after the measure installation date. If a customer engages with the program fewer than 12 months after they have moved into the premise or moves out fewer than 12 months after project completion, there isn't enough billing data for that site to establish reliable models. Accordingly that account is excluded from the analysis. Between 2015 and 2020, 21,257, or 81%, of participants had enough billing data to be considered for the analysis.

2.4.3 Weather data

The billing analysis used weather data from the NOAA weather station closest to the customer service address. Temperature data from 27 NOAA weather stations for 296 participant zip codes was used in the analysis. The list of the weather stations used in the IAQ impact analysis is presented in APPENDIX C, Weather data.

Daily weather data were retained for each of the 27 stations from January 1, 2010, to December 1, 2021. The data set was checked for missing values. When there was missing data, it was filled using the relationship between the target weather station and the weather station in Richmond International Airport.

[9] This initial editing step is to eliminate participants that may not have the minimum bills that could provide 12 months of pre- and post- installation data.

3 METHODOLOGY

3.1 Research design

This impact evaluation used a time-series comparison/cross-sectional research design. This research design estimates the program impacts by examining the changes in a participant's electric usage patterns 10 months before (pre-treatment) and after (post-treatment) the measure installation date.

A representative comparison group is key to determining program attributable net energy savings. A comparison group is used to account for the energy usage changes of participants to the energy usage changes of a representative comparison group over the same period. The goal of a well-matched comparison group is to increase the likelihood that increases or decreases in participant energy consumption attributable to exogenous, or non-program factors such as changes in the economy, the price of energy, or trends in equipment efficiency, do not inflate or deflate program-related savings.

This analysis uses future program participants as the comparison group for current-year participants with the assumption that the participant mix has been stable over time and that future participants were similar to current participants, apart from participation. This research design also helps reduce concerns about self-selection bias and free-ridership, and improves the evaluation's internal and external validity.[10]

The analytical approach was an SAE model, which incorporated expected savings estimates from the tracking data into the analysis.

3.2 Analysis

The analysis was performed in six steps, with each step building on the one before it. Merge the tracking and billing data together

4. Create the comparison group pool
5. Temperature-normalize the annual consumption of the participant and comparison group using monthly billing data from both groups
6. Identify a representative and matched comparison group using the normalized annual consumption (NAC) estimated in step three
7. Estimate the annual and aggregate program level total energy savings
8. Estimate the measure group energy savings

Each step is described in the following sections.

3.2.1 Merging the tracking and billing data

The billing data was merged with the tracking data using matching electric account numbers. The participant data was split into pre-program and post-program data sets, based on the measure installation window. The billing data for each period was checked. Only bills within 2 years of participation were used. To be included in the analysis, a participant needed to have at least 8 bills in each period, and at least 3 winter bills (November through April) and 3 summer bills (May through October).[11] Data from the 15,199 participants who met these requirements were available for the analysis.

[10] Internal validity means the evaluation is conducted in a manner that allows the results to isolate the impact of the activity being studied. When other factors are not recognized, the changes attributed to the program may be the result of other phenomena. For example, if the experiment does not recognize the dynamic nature of a participant's characteristics, their change in usage could be explained by the impact of the implementation of the program or, alternatively, by the change in other participant characteristics. A research design can help achieve external validity by ensuring that the results are representative of a larger population of interest, allowing for the findings to be generalized. For example, for the selected program, the information determined by a sample of participants, and the corresponding comparison group, permits the evaluation to represent the total program impacts.

[11] The eight total bills and the three seasonal bill requirements were included to assure that the participant had enough degrees of freedom to estimate an adequate weather normalization model.

3.2.2 Creating the comparison group pool data

Although a comparison group is always required, the COVID-19 pandemic caused fundamental changes in energy consumption in 2020–2021 that must be recognized by the evaluation. These non-program effects can be mitigated by a well-matched comparison group. The analysis plan called for pre-treatment participants (participants who joined the program in later years) to be used to develop the comparison group. Accordingly, all participant bills before the measure installation window were considered in the initial comparison group pool, and only customers who maintained the same account in the analysis period were included. For example, a participant who joined the program in 2017 and had 3 years of account history was an ideal candidate for the comparison group of non-participants. Future participants are considered a good proxy for existing participants because they are apt to share similar characteristics to other program participants.

Every unique measure installation date window was identified from the tracking data. These dates were merged with each account in the comparison group pool. If an account had billing data within 9 months of an installation window (either before or after the installation), that customer/installation window combination was kept for consideration in the comparison group pool for participants with that installation window.

Each account/installation date combination was split into pre-program and post-program data sets. Each of these combinations was checked using the same criteria as the participant analysis data (i.e., only bills within 2 years of the installation window, minimum of 8 bills per period, etc.). After these edits, the comparison pool analysis data sets had 723,619 account/installation window combinations.

3.3 Temperature normalization

By controlling for other significant non-program influences, such as weather, the program's effects can be isolated and quantified. Accordingly, the first step in the analysis is to develop normalized annual consumption (NAC) during the pre-installation and the post-installation periods for each of the accounts in the participant group and for each of the account/installation window combinations for the comparison group. The temperature normalization procedure is taken from the U.S. Department of Energy's (DOE) Uniform Methods Project (UMP) and based on the Princeton Scorekeeping Method (PRISM®). The temperature normalization model isolates the relationship between temperature and energy consumption.[12] Models were developed to normalize each participant and comparison group pool member's energy consumption values and remove the effects of weather for both the pre-installation and the post-installation periods.

The model estimates the component of the energy usage attributed to baseload consumption (i.e., lighting, and hot water) and space conditioning (heating and cooling). The model isolates the baseload usage from the space conditioning usage and estimates the incremental rate of energy consumption per degree day for space conditioning, and the set point (or outdoor temperature) at which space conditioning occurs. This set point is influenced by the physical characteristic of the house and the thermostat behavior of its occupants and is unique to each site; therefore, heating degree days are not assumed to accumulate at or below 65ºF for every site under this model.

The site-level temperature normalization model recognizes that each customer has unique operating characteristics that influence the rate of energy consumption for space conditioning under given temperature conditions. These characteristics include structure type, appliance mix, space conditioning system(s) and how they are operated, and demographics. To capture these unique space

[12] Agnew, K.; Goldberg, M. (2017). "Chapter 8: Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol," The Uniform Methods Project: Methods for Determining Energy- Efficiency Savings for Specific Measures. Golden, CO; National Renewable Energy Laboratory. NREL/SR-7A40-68564. http://www.nrel.gov/docs/fy17osti/68564.pdf; Fels, Margaret F. 1986. "PRISM: An Introduction". *Energy and Buildings*. 9, 5-18.

conditioning characteristics, the normalization process compares multiple models across a range of heating and cooling reference, or set point, temperatures for each customer account. The model chosen to represent a customer's energy use is the one that best linearizes the relationship between usage and degree days, or the best-fit model. For each customer and site, the best fit model is identified based on their unique temperature reference or set point. A more detailed description of the model and the model results can be found in APPENDIX D. Detailed methodology.

3.4 Establishing a representative comparison group

The comparison group was built from the pre-program participants (the comparison group pool). The NAC and NDC of each member of the comparison group pool were estimated in the temperature normalization step. DNV matched each participant to each comparison group pool customer based on the participant's installation window. The root mean square error (RMSE)between the participant pre-installation NDC and the comparison pre-installation NDC was calculated. For each participant, the three comparison customers with the lowest RMSE were included in the final comparison group.

The comparison group was chosen *with replacement*. Selecting a sample *with replacement* allows a comparison group customer to have the potential to be designated a comparison group member for more than one participant. **Error! Reference source not found.** presents a comparison of the pre-installation NAC for the participants and the comparison groups. This table demonstrates that the comparison group was well-matched to the participants' NAC in the pre-program period. The comparison of the pre-installation NAC participants versus the comparison group can be found in APPENDIX D. Detailed Methodology.

3.5 Program impact analysis

The objectives of the impact analysis of the IAQ Home improvement program are to:

- Calculate the program impacts and the realization rate for program years 2015–2020
- Calculate the program impacts and realization rate by program years 2015–2020
- Calculate program impacts by measure and measure groups for program years 2015–2020
- Conduct the analysis according to protocols defined in the program EM&V plan[13]

DNV carried out a two-step process to meet these objectives. First, program impacts were calculated for each site; then, the site-level estimates were used to calculate the measure group impacts. Half of the participants had enough pre-installation and post-installation billing data to be included in the analysis. These participants are considered a representative sample of the population of participants.

3.5.1 Weighting the sample back to the population

To ensure that the results of the sample are an unbiased estimate of the population, the results of the analysis are weighted using case weights. A case weight is defined as the number of population participants represented by a sample participant. To determine the case weights, the population is stratified into homogeneous groups. For this analysis, we based the stratification groups on program year and a tracked savings category based on the quartiles of the distribution of the total tracking savings of all participants. The strata of tracked savings based on the distribution of the tracked savings for all participants can be found in APPENDIX D. Detailed methodology.

[13] Appendix H., Residential Income and Age Qualifying Home Improvement Program EM&V Plan. Evaluation, Measurement, and Verification Report for Virginia Electric and Power Company (Dominion Energy).

3.5.2 Total savings estimates

For the total program savings, we used an SAE regression model. In this model, the post-installation usage is a function of the pre-installation usage and the expected program savings (i.e., the tracked savings). These individual estimates are weighted using the case weights and summed by variables of interest (e.g., program year) to provide the estimated overall program savings. The basic form of this model is shown in APPENDIX D. Detailed methodology.

3.5.1 Estimates of measures and measure group savings

As a result of the nature of the natural variation of residential consumption, it is difficult to achieve statistically significant estimates associated with small (less than 5%) influences using billing analyses. Accordingly, the basic form of the individual measure regression model shown in APPENDIX D used the *total* tracked savings for a participant as an independent variable. While adding additional variables to define individual measures should provide the same estimate of total savings, the individual estimates of small measures could be misleading, collinear with other measures, or statistically insignificant.

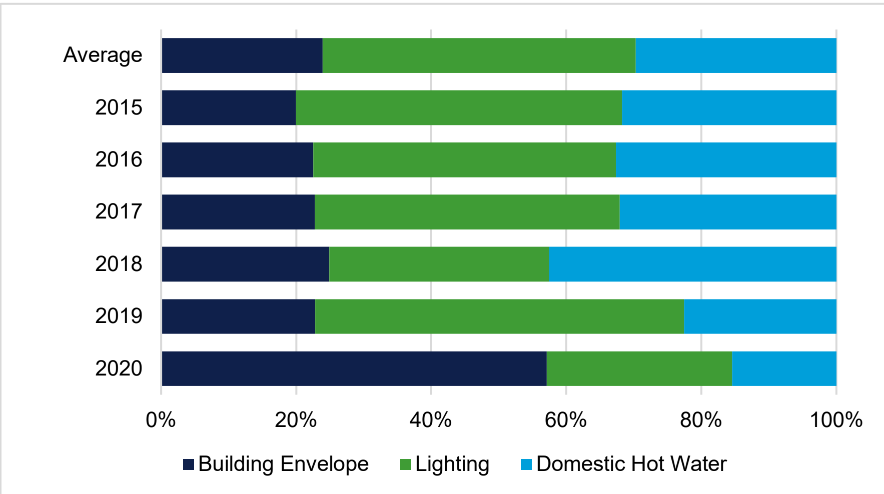
For the IAQ Home Improvement program, the disaggregation of the total savings into measure groups recognized that the measures are a function of the total participant savings. Accordingly, an initial estimate of total participant savings was incorporated into the individual measure regression model as the dependent variable, and the individual estimates of measure groupings were used as the independent variables.

Table 3-1 shows the number of participants for six program measures: one lighting (LEDs), one building envelope (attic insulation), and four water heating measures. Since the impact of the individual water heating measures is small and the impacts would be correlated (i.e., collinear), the water heating measures were grouped. Figure 3-1 shows the relative percent distribution of installed measure categories to all measures. This view shows the year over year change in measure mix. Although the relative distribution of installed measures differs slightly across program years, there was a substantial increase in building envelope measures in 2020, the first year of the Covid-19 pandemic.

Table 3-1. The number of participants for six program measures and the number of installed measures by participant

Year	Total	LED (N)	Attic Insulation (N)	Bathroom Aerators (N)	Kitchen Aerators (N)	Pipe Insulation (N)	Low Flow Showerhead (N)
2015	1,523	1,513	628	945	260	335	955
2016	8,560	8,199	4,121	4,460	4,286	3,355	4,486
2017	6,100	5,633	2,840	2,454	2,687	2,529	2,416
2018	1,142	726	557	474	601	436	430
2019	6,029	5,165	2,158	1,099	1,083	694	917
2020	1,066	420	875	106	81	59	128
Total	**24,420**	**21,656**	**11,179**	**9,538**	**8,998**	**7,408**	**9,332**

Figure 3-1. Relative percent distribution of installed measure categories to all measures



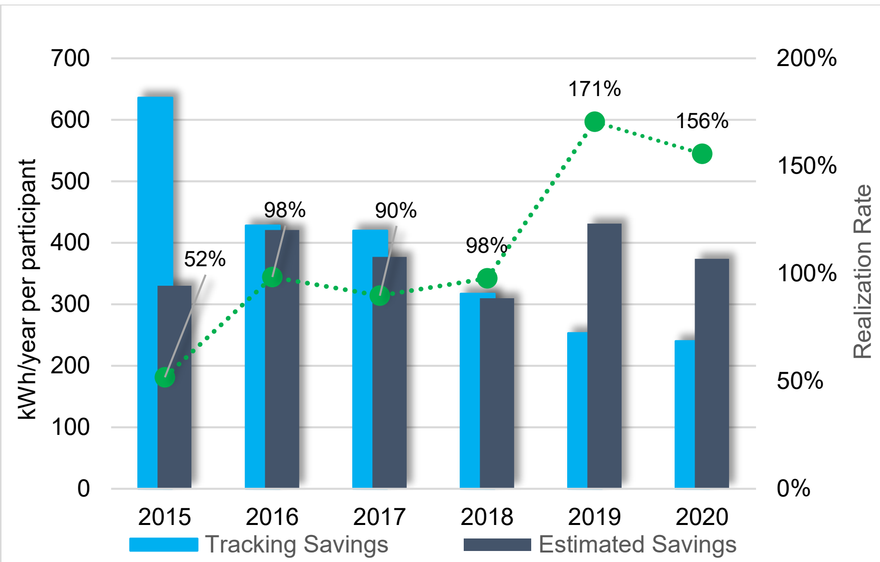
4 IMPACT ESTIMATES

The following sections describe the results of the impact analysis for the program and by measure.

4.1 Program Impacts

The evaluated savings compared against expected or tracked savings yielded a 105% realization rate. The overall per-participant evaluated savings was 400 kWh per participant/year. Tracked savings, evaluated savings, and realization rates by year are shown in Table 4-1. Tracked savings in 2015 is high relative to evaluated savings resulting in the lowest realization rate (52%) which is not unusual for the first year of a program. Measure-level realization rates were 88% for the water distribution measures, 106% for attic insulation, and 111% for LED lighting, as discussed in further detail in Section 4.2.

Figure 4-1 Program tracked savings, evaluated savings, and realization rate by year (2015–2020)



4.1.1 Number of participants, the analysis sample, NAC, savings, and confidence intervals

Table 4-1 shows the program impacts by year and for all years in aggregate combined. The first two columns in Table 4-1 show the number of participants in the program and the number of participants in the analysis sample by year, and for all years combined. Columns three and four show the pre-participation normalized annual consumption, which is followed by the tracked savings, and the realization rate per participant. Finally, the 90% confidence intervals and the relative confidence interval are shown.

A range of 38% to 64% of the participants were included in the analysis across all years. 2020 had the smallest relative sample size due to the timing of the evaluation and the availability of a minimum requirement for 12 months of post-participation billing data during the post-installation period. For 2015–2019, low relative participation occurred in 2015, the first year of the program, and in 2018, when the program paused before its reauthorization. Overall, nearly 60% of the participants were included in the analysis. This is considered a strong representative sample for age and income-qualified programs which typically have a higher number of renters and high data attrition rates due to move-in and moveouts. The high quality of billing and tracking data also contributed to the low data attrition rate.

The table shows that the average amount of the participants' average annual usage varied from year to year from 8,300 kWh/year to 10,500 kWh/year. Every year showed a decrease in NAC for the pre-installation to the post-installation period, with an overall average of 4.3% decrease between 2015 and 2020. The analysis showed that the average participant tracking savings varied substantially from year to year, from 240 kWh/year-participant in 2020 to 636 kWh/year-participant in 2015.

The overall participant savings of 400 kWh/year-participant has a ±2.8 kWh/year confidence interval (0.7% relative confidence interval). This level of savings yielded a 105% realization rate (i.e., the percentage of actual savings to tracking savings). Interestingly, the realization rate has increased over time. This may be due to the continuous improvement of program implementation and services and the refinement of the technical reference manual, or the DE TRM calculations used to calculate the tracked savings, which are updated annually.

Table 4-1. Participants, analysis sample, normalized annual consumption (NAC), savings, and confidence intervals

			NAC		Program Savings			Confidence Intervals	
Year	**Participants**	**Sample**	**Pre-Participation**	**Post-Participation**	**Tracking** (kWh/year-participants)	**Evaluated** (kWh/year-participants)	**Realization Rate** (%)	**90% Confidence Intervals**	**Relative Confidence Interval**
2015	1,522	874	10,245	9,796	636	330	52%	5.7	1.7%
2016	8,489	5,015	8,940	8,402	428	421	98%	3.7	0.9%
2017	5,993	3,821	8,484	8,139	420	377	90%	4.1	1.1%
2018	1,122	711	9,556	9,238	317	310	98%	14.7	4.7%
2019	5,947	3,279	8,360	8,166	253	431	171%	6.7	1.6%
2020	1,097	422	10,487	10,071	240	374	156%	33.9	9.1%
Total	**24,170**	**14,122**	**8,865**	**8,481**	**382**	**400**	**105%**	**2.8**	**0.7%**

4.2 Measure Impacts

Impacts were also calculated by measure. Interestingly, the tracking savings per measure group is consistent, ranging from 196 kWh/year for LED lighting to 206 kWh/year for water distribution measures. The realization rates range from 88% for water distribution measures to 111% for LED lighting. 90% of the participants had LED lighting measures installed. The combined measure savings are consistent with the aggregate tracked savings estimates shown in Figure 4-3 and Table 4-1, thus yielding a realization rate close to 103%.

Table 4-2 presents estimates based on all participants. Table 4-3 shows the estimates of savings based on the participants that received specific measure groups (attic insulation, LED lighting, and the water distribution measure group).

Figure 4-2 Tracked savings, evaluated savings, and realization rate by measure group

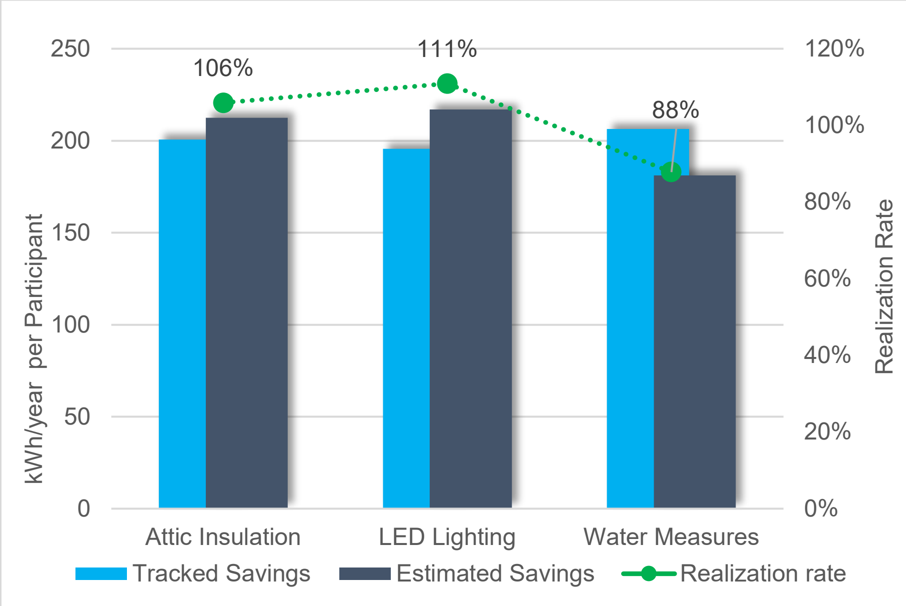


Figure 4-3. Percent of tracked measure savings to total savings for all measures

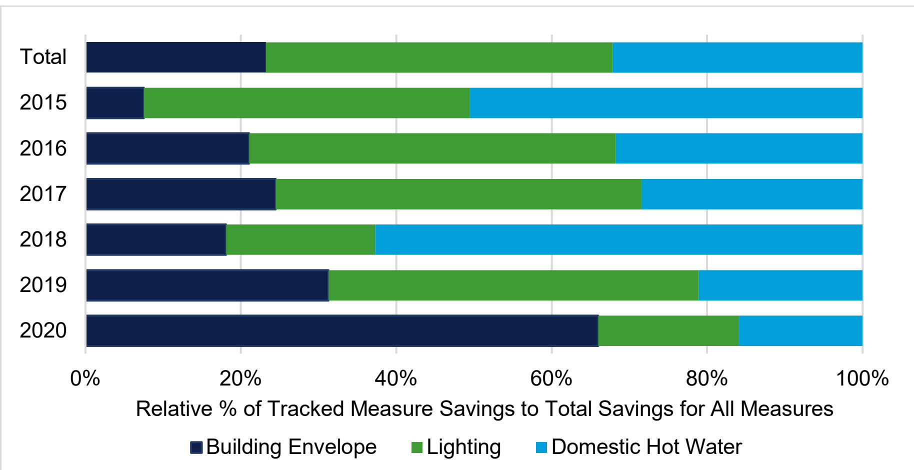


Table 4-2. Measure group savings per participant for all participants

	Measure savings			Confidence Intervals	
Measure	**Tracking** (kWh/year-participant)	**Evaluated** (kWh/year-participant)	**Realization rate** (%)	**90% confidence intervals**	**Relative confidence interval**
Attic Insulation	87	92	106%	2.59	2.8%
LED Lighting	175	194	111%	1.62	0.8%
Water Distribution Measures	121	106	88%	1.77	1.7%
Total	382	392	103%	2.47	0.6%

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Table 4-3. Measure group savings per participant/year (kWh) for participants with measures

		Measure savings		Evaluated savings		
Measure	**Participants with measure**	**Tracking** (kWh/year-participant)	**Evaluated** (kWh/year-participant)	**Realization rate** (%)	**90% confidence intervals**	**Relative confidence interval**
Attic Insulation	10,450	200.6	212	106%	3.03	1.4%
LED Lighting	21,596	195.6	217	111%	0.90	0.4%
Water Distribution Measures	14,162	206.3	181	88%	1.32	0.7%
Total	24,170	382.4	392	103%	1.5	0.6%

APPENDIX A. Residential IAQ Home Improvement tracking data elements

Table 4-4 is the list of Residential IAQ Home Improvement tracking data elements. The tracking data reports all participant, measure, and program related information. The tracking data is generated by Dominion Energy's Business Intelligence system and delivered to DNV on a monthly basis.

Table 4-4. Residential IAQ Home Improvement tracking data

Field	Description
ACTIVITY_DATE	Date record was last updated by Nexant
EXTRACTION_DATE	Date record was extracted by Nexant and sent to Dominion
RECORD_ID	Internal record key for BI data mart; Nexant = Unit ID
ELECTRIC_ACCOUNT_ID	Account Number from Dominion
ELECTRIC_PREMISE_ID	From Dominion
CUSTOMER_NAME	Customer Name on application; same as Dominion
ADDRESS_1	Service Address where work is performed; from Dominion
ADDRESS_2	Service Address where work is performed; from Dominion
CITY	Service City from Dominion
STATE	Service State from Dominion
ZIP	Service Zip from Dominion
MAILING_ADDRESS_1	Mailing address if Dominion has on record
MAILING_ADDRESS_2	Mailing address if Dominion has on record
MAILING_CITY	Mailing address if Dominion has on record
MAILING_STATE	Mailing address if Dominion has on record
MAILING_ZIP	Mailing address if Dominion has on record
CUSTOMER_RATE	Primary rate code in Dominion system
APP_CONTACT_PERSON	Contact name on application
APP_EMAIL_ADDRESS	Customer email address
APP_TELEPHONE_NO	Applicant primary telephone number
APP_VENDOR_NAME	Name of contractor that performed work
APP_VENDOR_ADDRESS1	Address of contractor (concatenated)
APP_VENDOR_ADDRESS2	Address of contractor
APP_VENDOR_CITY	Address of contractor
APP_VENDOR_STATE	Address of contractor
APP_VENDOR_ZIP_CODE	Address of contractor
APP_VENDOR_CONTACT_PERSON	Contact at Vendor's Company
APP_VENDOR_EMAIL	Vendor email address
APP_VENDOR_TELEPHONE	Vendor telephone number
OWNERSHIP_STATUS	Lease or Own
APPROVAL_YN	Was work authorized to be done?
AUDIT_DATE	Date audit was completed
DSM_PROGRAM_ID	Program ID from Dominion

Field	Description
WORK_ORDER_ID	Work order id assigned to rebate upon creation.
CUSTOMER_DWELLING_TYPE	
NO_OF_HOME_OCCUPANTS	
APPROXIMATE_HOME_SIZE	
APPROXIMATE_HOME_AGE	
APPROXIMATE_ATTIC_SIZE	Sq ft
EXISTING_ATTIC_INSULATION_TYPE	
EXISTING_ATTIC_INSULATION_QTY	In inches
EXISTING_ATTIC_INSULATION_RVAL	Existing insulation R value
ATTIC_INSULATION_TYPE	Type installed
INSTALLED_INSULATION_QUANTITY	In inches
PIPE_DIAMETER	inches
PIPE_INSULATION_LENGTH	inches
EXISTING_BULB_TYPE	
WATER_HEATER_TYPE	Type of water heater
WATER_HEATING_FUEL	
MEASURE_NAME	
REASON_CODE	Reason why measure wasn’t installed
REASON	Reason for replacement
COOLING_SYSTEM_TYPE	
HEATING_SYSTEM_TYPE	
HOW_HEAR	How did you hear about this program?
MARKETING_CODES	
SPACE_HEATING_FUEL	
BUDGET_RESOURCE	Provided by Nexant for accounting purposes
INSTALLD_ATTIC_INSULATION_RVAL	Installed insulation R value

APPENDIX B. Tracked energy savings by measure and year

The tracked measure-level energy savings by year and number of accounts includes 68,111 measures installed across 24,420 accounts (a single account can have multiple measures). The expected total by measure tracked savings are summarized in Table 4-5.

Table 4-5 Summary of tracked energy savings by year and measure

	Total		LED		Attic Insulation		Bathroom Aerators		Kitchen Aerators		Pipe Insulation		Low Flow Shower	
Year	# Accounts	kWh/year	# Accounts	kWh/year	# Accounts	kWh/year	# Accounts	kWh/year	# Accounts	kWh/year	# Accounts	kWh/year	# Accounts	kWh/year
2015	1,523	984,390	1,513	413,006	628	73,871	945	56,664	260	5,719	335	19,513	955	415,617
2016	8,560	3,681,827	8,199	1,738,156	4,121	775,253	4,460	103,631	4,286	84,992	3,355	278,803	4,486	700,992
2017	6,100	2,553,907	5,633	1,201,843	2,840	625,442	2,454	66,516	2,687	59,546	2,529	160,945	2,416	439,616
2018	1,142	449,359	726	86,376	557	81,258	474	18,701	601	36,290	436	120,195	430	106,539
2019	6,029	1,518,078	5,165	723,724	2,158	474,686	1,099	32,642	1,083	64,708	694	44,134	917	178,183
2020	1,066	231,558	420	41,972	875	152,769	106	3,748	81	4,854	59	3,330	128	24,884
Total	24,420	9,419,119	21,656	4,205,077	11,179	2,183,279	9,538	281,902	8,998	256,109	7,408	626,920	9,332	1,865,831

APPENDIX C. Weather data

The tracking data included the service address for each participant. The billing analysis used weather data from the station closest to the service address. Data from 27 NOAA weather stations for 296 valid participant zip codes was used in the analysis. Table 4-6 lists the NOAA station name and ID, the number of unique zip codes in the billing analysis for that zip code, and the number of participants within each zip code.

Table 4-6. Summary of weather stations used in the IAQ impact analysis

Station ID	Station Name	# Zip Codes	# Participants
723065	Pitt-Greenville Airport, NC	7	51
723068	Rocky Mount-Wilson Regional Airport, NC	8	373
723075	Oceana Naval Air Station, Va.	12	956
723080	Norfolk International Airport, Va.	6	1,746
723083	Franklin Municipal-John Beverly Rose Airport, Va.	22	438
723085	Norfolk Naval Station, Va.	14	2,513
723086	Newport News/Wimburg Intl Airport, Va.	30	3,302
724010	Richmond International Airport, Va.	37	5,627
724014	Dinwiddie County Airport, Va.	18	1,109
724016	Charlottesville Albemarle Airport, Va.	9	826
724017	Farmville Regional Airport, Va.	20	288
724030	Washington Dulles International Airport, Va.	8	1,363
724033	Shannon Airport, Va.	9	774
724035	Quantico MC Air Facility, Va.	5	508
724036	Manassas Regional/H P Davis Fd Airport, Va.	6	856
724037	Davison Army Airfield, Va.	11	1,457
724040	Naval Air Station, Md	7	209
724050	Ronald Reagan Washington Natl Airport, Va.	20	1,501
724053	Winchester Regional Airport, Va.	4	153
724055	Leesburg Executive Airport, Va.	5	296
724100	Lynchburg Regional/Preston Glenn Field Airport, Va.	3	111
724105	Shenandoah Valley Regional Art, Va.	14	776
724106	Danville Regional Airport, Va.	7	122
724115	Ingalls Field Airport, Va.	5	427
725064	Plymouth Municipal Airport, Ma	1	1
726050	Concord Municipal Airport, NH	1	1
745980	Langley AFB Airport, Va.	7	570
	Total	**296**	**26,354**

Daily weather data were retained for each of the stations from January 1, 2010, to December 1, 2021. The data set was checked for missing data. When there was missing data, it was filled using the relationship between the target weather station and the weather station in Richmond International Airport).

Normal temperatures were not available for the individual weather stations. Accordingly, normal temperatures were created for each of the stations. For each day of the year, the median temperature for the 11 historical years was determined and designated as the normal temperature for that month/day combination.

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APPENDIX D. Detailed Methodology

Temperature normalization

This appendix is a continuation of the summary description of temperature normalization in Section 3.3.

To capture a households unique space conditioning characteristics, the normalization process compares multiple models across a range of heating and cooling reference, or set point, temperatures for each customer account. The model chosen to represent a customer's energy use is the one that best linearizes the relationship between usage and degree days, or the best-fit model. For each customer and site, the best fit model is identified based on their unique temperature reference or set point. Equation 1 shows the temperature normalization model to consider heating and cooling loads.

Equation 1. The temperature normalization heating and cooling model

$$u_i = \beta_0 + \beta_1 * HDD_i(\tau_1) + \beta_2 * CDD_i(\tau_2) + e_i$$

Where:

U_i	=	Average daily usage during cycle i
$HDD_i(\tau_1)$	=	Average daily heating degree days during cycle i based on reference temperature τ_1
$CDD_i(\tau_2)$	=	Average daily cooling degree days during cycle i based on reference temperature τ_2
e_i	=	Error in predicting U_i

The optimal model for each account is determined using the regression models and assessing the model fit across a range of reference or set point values (τ_1 and τ_2). For this analysis, the heating degree set points considered ranged from 54ºF to 70ºF and the cooling degree set points considered ranged from 64ºF to 75ºF. Recognizing that homes may not have electric space heating or cooling loads, "heating and cooling," "heating only," "cooling only," and "base load only" models were considered. Accordingly, each customer had 204 models estimated for each period (pre- and post-installation.)

After the initial model estimates were established, the results were examined. Poorly modeled sites (e.g., negative heating or cooling coefficients) were eliminated from consideration. From the remaining models, the model that minimized the root mean squared error (RMSE) for each account for each period was identified as the initial model and reviewed. Poorly performing models (e.g., models with an R^2 less than .80) were identified, examined for anomalous data, and if found, re-estimated. The re-estimated models were compared to the initial models. The model with the lowest RMSE is considered the optimal, or final, model.

Once the optimal models were determined, normalized annual degree days are applied to the optimal model to calculate normalized annual consumption (NAC) and then the expected daily degree days are applied to the optimal model to calculate the normalized daily consumptions (NDC).

From Equation 1, the results of the model can be interpreted as:

- β_0 is an estimate of the average base load per day for a cycle.
- β_1 represents the heating slope, or the increase in electric usage for each incremental increase in heating degree days.
- β_2 represents the cooling slope, or the increase in electric usage for each incremental increase in cooling degree days.

The NACs were examined to identify anomalies. Participants or comparison pool members were eliminated from the analysis under the following model conditions:

- A large change in NAC from the pre- to the post-installation period (±7,000 kWh/year)
- A large relative change in NAC from the pre- to the post-installation period (<50% or >200%)
- Tracked savings were greater than 50% of the pre-NAC

Table 4-7 and Table 4-8 summarize the final models for the participants and comparison group, by program period. Table 4-7 describes the distribution of the temperature normalization model types for the participants and the comparison group pool. The three model types are *heating and cooling* (electric heating and cooling), *heating only* (electric heating, no cooling), *or cooling only* (no electric heating).

Table 4-8 shows the distribution of model R^2 for the same group.

Table 4-7. Model summary for the participants and the comparison group by program period

	Participants		Comparison pool	
Distribution of models				
Type	**Pre**	**Post**	**Pre**	**Post**
Heating and Cooling	70%	66%	71%	68%
Heating Only	9%	9%	8%	8%
Cooling Only	21%	25%	21%	24%

Table 4-8. Distribution of model R^2 for the participants and the comparison group by program period

	Participants		Comparison pool	
Distribution of Model R^2				
Percentile	**Pre**	**Post**	**Pre**	**Post**
Median	.86	.86	.87	.87
10^{th}	.55	.51	.60	.59
90^{th}	.96	.96	.96	.96

Establishing a representative comparison group

This section contains the detailed results of pre-installation NAC participants versus the comparison group analysis described in Section 3.4. Establishing a representative comparison group.

Table 4-9. Comparison of pre-installation NAC participants vs comparison group (unweighted)

	Average pre-installation NAC (kWh/year/participant)			
Year	**Participants**	**Comparison**	**Difference**	**Percentage**
2015	10,304	10,272	32	0.3%
2016	8,967	8,939	29	0.3%
2017	8,537	8,519	17	0.2%
2018	9,621	9,582	39	0.4%
2019	8,380	8,386	(7)	-0.1%
2020	10,427	10,262	165	1.6%
All Years	8,873	8,851	22	0.3%

Weighting the sample back to the population

A case weight is defined as the number of population participants represented by a sample participant. To determine the case weights, the population is stratified into homogeneous groups. For this analysis, we based the stratification groups on program year and a tracked savings category based on the quartiles of the distribution of the total tracking savings of all participants. Table 4-10 shows the strata of the distribution of tracked savings for all participants.

Table 4-10. The strata of tracked savings based on the distribution of the tracked savings for all participants

Stratum	Range of tracked savings (kWh/year/participant)
1	30 to 195
2	196 to 289
3	290 to 481
4	482 to 10,000

Once the strata were defined, the number of population and sample participants was determined for each stratum. The case weights (total population participants divided by the total analysis participants by stratum) were calculated and assigned to the sample participants.

The second data preparation step aggregated the comparison group by participants. As described above, 3 comparison customers were chosen for each participant. To give the comparison group equal weight in the analysis, we combined the matched comparison group NACs for their attendant participant account.

Total savings estimates

The section provides a more detailed description of the basic form of the SAE model summarized in Section 3.5.2.

For the total program savings, we used an SAE regression model. In this model, the post-installation usage is a function of the pre-installation usage and the expected program savings (i.e., the tracked savings). The basic form of this model is shown in Equation 2.

Equation 2. The statistically adjusted engineering regression model

$$NAC_{post,i} = \beta_0 + \beta_1 * NAC_{pre,i} + \beta_2 * TS_i + \varepsilon_i$$

Where:

$NAC_{post,I}$ =Post Installation Normalized Annual Consumption for customer (participant or comparison group member) i

$NAC_{pre,i}$ =Pre-Installation Normalized Annual Consumption for customer i

$TS_{,I}$ = Tracking estimate of total savings for participant i.

=Zero for comparison group member i

$\beta_0, \beta_1, \beta_2$ =Coefficients to be estimated to minimize the prediction error.

B_2 =The realization rate of tracking estimate savings

ε_i =Prediction error

Typically, in SAE models, the regression assumption most often violated is that the standard deviation of the error terms, or "residuals," is not constant across the range of predicted values. This is caused by the residual standard deviation being related to the size of the customer's electric usage or demand. When the standard deviation residuals are related to the predicted values, the model is said to be "heteroscedastic."

There are various ways to mitigate heteroscedasticity. One way is to segment the data into homogeneous groups. In setting the analysis, the customers were placed in strata based on the year of participation and their tracking savings. Since the tracking savings are highly correlated to the customer size, the development of independent models met the regression assumptions.

The models perform well. Table 4-11 summarizes a few of the performance statistics for the 24 models. The R^2 rate of the models for the individual stratum (year/savings) ranges from .87 to .95. All the models except four had significant β_2 coefficients.

Table 4-11. Total energy savings model statistics summary

	Percentile		
Statistic	**90^{th}**	**Median**	**10th**
β_2	1.93	1.18	0.67
R^2	.93	.92	.89
P-Value	24%	0%	0%

The models' estimate of the β_2 can be interpreted as the "realization rate" of the tracked savings, or the ratio of the tracked savings that is the "true" program savings. Accordingly, β_2 multiplied by the participants' individual tracked savings is their estimate of actual savings. These individual estimates are weighted using the case weights and summed by variables of interest (e.g., program year) to provide the estimated overall program savings.

The basic form of the individual savings model is shown in Equation 3.

Equation 3. The individual measure regression model

$$S_i = \beta_1 * TSLED_i + \beta_{2*} TSAI_i + \beta_{2*} TSWM_{i\ i} + \varepsilon_i$$

Where:

S_i =Estimated savings for all measures installed for participant I, $\beta_{2*} TS_i$ from Equation 2

$TSLED_{,i}$ = Tracking estimate of total savings of LEDs installed for participant i

$TSAI_i$ = Tracking estimate of total savings of attic insulation installed for participant i

$TSWM_i$ = sum of the tracking savings of the aerator, low flow showerhead, and pipe insulation measures

=Tracking estimate of total savings of water distribution measures installed for participant i

$TS_{,I}$ = Tracking estimate of total savings for customer i

$B_{1,}$ $\beta_{2,}$ β_3=Coefficients to be estimated to minimize the prediction error.

ε_i =Prediction error

Since the variables all are program savings, the models were based only on participant data. The estimation of the models was done by total savings stratum (4 total). Weighted least squares were used to mitigate the influence of the different annual sample sizes.

The models performed well. All of the coefficients were statistically significant. The R^2 statistics ranged from .88 to .99

APPENDIX E. EM&V Workplan

The IAQ Home Improvement Program Evaluation Workplan Plan is attached here as a pdf.

PROGRAM YEARS 2015—2020

Residential Income and Age Qualifying Home Improvement Program Impact Evaluation Work Plan

Dominion Energy

Date: November 3, 2021

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1 INTRODUCTION

This is the detailed work plan for impact evaluation of the Income and Age Qualifying Home Improvement program (EAL3) administered by the Virginia Electric and Power Company, hereafter Dominion. This impact evaluation will provide estimates of ex post gross energy savings which, in the context of income qualifying programs, are considered equal to net energy savings.[1] The design of these programs is to provide a free service to income eligible customer who would not otherwise have had the financial means to complete the work.

The evaluation will cover the program years 2015–2020. This evaluation will be conducted in accordance with the EAL3 EM&V Plan, calculate impacts, and inform future program design and implementation.[2]

1.1 Overview of Implemented Measures

The Dominion program offers qualifying low-income (60% or less of Virginia state median income) and elderly (60+ and household income up to 120% Virginia state median income) residential customers of the Company a free energy audit that identifies energy saving opportunities that can save money on their monthly electric bill. If homeowners (or authorized renters) approve, auditors may immediately make certain improvements while at the home. Table 1 lists all the energy-efficient measures implemented under this program.

Table 1: Program energy-efficient measures

End Use	Measure
Whole house	Attic insulation
Lighting	Replacing incandescent with LEDs (up to 6)
Domestic Hot Water	Low flow Showerhead (electric water heat) Kitchen and/or bathroom aerators Pipe wrap on exposed water supply pipes (electric water heat)

2 EVALUATION PLAN

This section provides an overview of the Income and Age Qualifying Home Improvement Program EM&V approach. The goal of the evaluation is to quantify the program impacts, by year. We will also use our best effort to quantify measure level impacts, but there is a risk that individual impact estimates of small measures will be statistically insignificant.

The evaluation approach will be a statistically adjusted engineering (SAE) billing analysis, with a well-matched representative comparison group. Table 2 summarizes the program participation and savings by year. This table shows that over half the participants and nearly two-thirds of the savings occurred in 2016 and 2017.

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1 Violette, Daniel M.; Rathbun, Pamela. (2017). Chapter 21: Estimating Net Savings – Common Practices: Methods for Determining Energy-Efficiency Savings for Specific Measures. Golden, CO; National Renewable Energy Laboratory. NREL/SR-7A40-68578, 45.; Synapse Energy Economics, Erin Malone, Wendy Ong, Max Chang. State Net-to-Gross Ratios, Research Results and Analysis for Average State Net-to-Gross Ratios Used in Energy Efficiency Savings Estimates. Prepared for the United States Environmental Protection Agency, January 23, 2015, 2.

2 Appendix H., Residential Income and Age Qualifying Home Improvement Program EM&V Plan. Evaluation, Measurement, and Verification Report for Virginia Electric and Power Company (Dominion Energy), Case No. PUR-2018-00168 (Virginia), Docket No. E-22 Sub 577 (North Carolina), VOLUME 1 OF 4, May 15, 2021, Prepared by DNV Energy Insights USA Inc. (DNV),

DNV

Table 2. Program participation by year

Year	Participant Premises	Savings (kWh/year)
2015	1,523	984,230
2016	8,561	3,681,872
2017	6,098	2,554,021
2018	1,142	448,498
2019	6,029	1,518,684
2020	1,066	231,558
2021	1,937	467,914
Total	**26,356**	**9,886,777**

2.1 Comparison Group

The program study period may present certain challenges for the evaluation. The first will be obtaining sufficient consumption data for the participants as consumption data from the early years of the program may be difficult to obtain if customers have moved within the pre-or post-analysis period.

During 2020 and 2021, the COVID-19 pandemic caused fundamental changes in energy consumption that must be recognized by the evaluation. These non-program effects can be mitigated by a well-matched comparison group. If possible, the comparison group will be developed from the participants who joined the program in later years, and were Dominion Energy customers under the same account in the study years. For example, a participant who joined the program in 2017 and had 3 years of account history is an ideal candidate for the comparison group of non-participants. Future participants are considered a good proxy for existing participants because they are apt to share similar characteristics to other program participants.

The success of this approach will depend account level attrition through the years and other factors. If the attrition rate is high and there are insufficient numbers of these “future participants” to make a valid comparison group, another approach for developing a comparison group will be required such as leveraging a large nonparticipant pool.[3] DNV’s initial data request will focus only on program participants. If necessary, additional billing data will be requested for non-participants.

2.2 Data Requirements

The billing analysis uses program tracking data (BI data), weather data, and monthly usage (billing data) shown in Table 3. The EAL3 monthly usage data will cover the period from 2014 (pre-installation for earliest program participants) through 2021 (post-installation of the program year 2020 participants). A more detailed data request has been submitted under separate cover and is attached as Appendix A.

Table 3. Billing data requirements for EAL3 impact evaluation

Electric account number
Electric premise number
Meter read date
Days in the billing cycle

[3] The comparison pool can be a large random sample of residential customers or the Dominion Energy residential population from 2014 to 2021.DNV would perform additional matching within the larger pool.

Billing code (i.e., estimated, or actual)
Consumption in kWh
Zip code
Office ID
Rate code
AMI Flag
Email address

3 IMPACT EVALUATION APPROACH

This impact evaluation approach will be a SAE model. This approach provides a method to incorporate engineering estimates of savings into the analysis.

3.1 Research Design

This analysis will use a two-stage billing analysis approach. This research design essentially determines the program impacts by examining the change in participant's usage and demand patterns over time. Comparing a representative comparison group's change in usage over a similar period further refines the impact estimate. This provides a robust experimental design allowing the change in usage to determine how energy consumption would have changed among program participants had the program not been offered.

The two-stage approach with prior and future participant comparison group offers the best feasible approach to consumption data analysis where a randomized experimental design is not put in place.

3.2 Establishment of a Representative Comparison Group

A comparison group for the analysis will be developed following steps:

Step 1: Establishing a comparison group Pool

When possible, a comparison group built with future/prior participants offers the highest quality results. Future participants' data from before their program participation, and prior participants from after, represent participants in steady-state situation year over year. They are uniquely qualified to provide the counterfactual to active participants because they have also made the decision to participate in the same program either before or after the current evaluation period. Not only does this match a key characteristic—interest in, able to, and qualified for participation in this specific program—it also indicates it is extremely unlikely that any similar measure installation activity is happening in comparison group households during the evaluation period.[4]

If a future/prior participant comparison group is not feasible due to limited span of available usage data, then we will request consumption information for a large random sample of all residential customers that are otherwise eligible for the program. In this case, each bill for the "comparison group pool" will be examined to form the optimal comparison group.

Step 2: Eliminating known participation periods or participants

If a future/prior participant comparison pool is used, data that crosses the participation data will be removed. That is, for a future participant, only data prior to their participation will be included. This makes it possible to use this almost-participant's

[4] Billing analysis results are generally considered not quite fully gross estimates of savings because there might be some naturally occurring similar measure activity occurring in the comparison group. This activity is expected to be low, in general, for a variety of reasons but should be effectively absent for comparison group members who either recently installed or shortly will install these exact measures as part of the same program.

data to track non-program change for active participants from a year or more before their future participation. Similarly, if prior participants are used, only data from after participation can be included.[5]

If a general population sample is used to construct the comparison group, then after the initial data cleaning, any known past participants will be eliminated from the comparison group pool. This will be done by matching the current participants and past participants against the available tracking data.

Step 3: Establishing the comparison group

During this step, each comparison group pool customer within a characteristic stratum will be compared to each participant in that stratum. Generally, either a minimum distance algorithm or a propensity score matching approach is used to match participants on multiple characteristics, such as consumption level and summer shoulder ratio. While both methods are appropriate, generally, we apply the minimum distance algorithm. The minimum distance algorithm effectively chooses the comparison group households closest to the participant in question across all dimensions. While we believe it is worth including more than one characteristic in the matching process, our experience has been that beyond two- or three-dimensions, improvements in the matching are minimal.

For each participant, up to two comparison group pool customers with the highest correlation in the annualized usage will be selected. These customers will be designated the comparison group.

The comparison group will be chosen *with replacement*. Selecting a sample with replacement allows a customer to have the potential of being designated a comparison Group member for more than one participant. This redundancy is addressed in the second stage regression with weighting to mitigate standard error estimates.

3.3 Temperature Normalization

One of the most important steps in the assessment of the program impacts is the pre-installation to the post-installation comparison of energy usage. By controlling for other non-program influences, such as weather, the programs effects can be isolated and quantified.

The temperature normalization procedure finds its fundamental basis derived from the *Princeton Scorekeeping Method* (PRISM®). The PRISM algorithm develops a mathematical model that represents the temperature to energy consumption relationship.[6]

The PRISM model reflects that a customer's energy usage is equal to some base level α, and a linear function between a reference temperature τ, and the outside temperature. The constant proportionality, β, represents a customer's effective heat-loss or heat-gain rate.

PRISM recognizes that each customer has unique space conditioning operating characteristics. To capture these unique space conditioning characteristics, PRISM examines a range of heating and cooling reference temperatures. The model chosen to represent a customer's energy use is the model that best linearizes the relationship between usage and degree days. For each customer, an optimal model based on a unique reference temperature (τ) is identified by the minimum mean

[5] Prior participants may be less intuitive than future participants for use in a comparison group. However, the approach is mathematically identical to using future participants in the comparison group. Both groups provide an estimate of year over year non-program-related change

[6] Fels, Margaret F. 1986. "PRISM: An introduction". *Energy & Buildings*. 9 (1): 5-18; Agnew, K.; Goldberg, M. 2017. Chapter 8: Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol, The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. Golden, CO; National Renewable Energy Laboratory. NREL/SR-7A40-68564.

squared error (MSE) of the regression. The PRISM approach to consider heating and cooling loads is calculated using Equation 3-1.

Equation 3-1. The PRISM Heating and Cooling Model

$$U_i = \beta_0 + \beta_1 * HDD_i(\tau_1) + \beta_2 * CDD_i(\tau_2) + e_i$$

Where:

U_i	=	The electric usage during cycle i.
$HDD_i(\tau_1)$	=	The heating degree days based on reference temperature τ_1, during cycle i.
$CDD_i(\tau_2)$	=	The cooling degree days based on reference temperature τ_2, during cycle i.
β_i	=	The coefficients to be estimated to minimize the error term.
e_i	=	The error in predicting U.

The optimal heating and cooling model is determined by calculating the regression models assuming various reference temperature values (τ_1 and τ_2). Expected annual degree days are applied to the optimal model to calculate a normalized annual consumption (NAC). The results of the model can be interpreted as:

- β_o is an estimate of the average base load for a cycle
- β_1 represents the heating slope, or the increase in electric usage for each incremental increase in heating degree days; and,
- β_2 represents the cooling slope, or the increase in electric usage for each incremental increase in cooling degree days.

Models are developed to allow for the temperature normalization of each individual participant and comparison group member for both the pre-installation and the post-installation periods.

Once the optimal parameters have been established, normalized annual consumption is estimated applying normal or historical degree-days to each model.

3.4 Regression Analysis Approach

An initial regression model is developed using ordinary least squares (OLS). This simple model determined the effect of *one* important change variable (i.e., participants engineering estimate of savings) on energy *while controlling for all other changes*. The basic form of this model is shown in Equation 3-2. Comparison group customers chosen multiple times in the matching process only enter the model once but with a weight associated with the number of times they were chosen. This addresses the potential for downwardly biasing the parameter standard errors.

Equation 3-2. The Statistically Adjusted Engineering Regression Model

$$NAC_{post,i} = \beta_0 + \beta_1 * NAC_{pre,i} + \beta_2 * P_i + \beta_3 * TS_i + \varepsilon_i$$

Where:

$NAC_{post,I}$	=Post Installation Normalized Annual Consumption for customer i
$NAC_{pre,i}$	=Pre-Installation Normalized Annual Consumption for customer i
P_i	= Dummy variable for participation
$TS_{,I}$	= Tracking estimate of total savings for customer i
$\beta_0, \beta_1, \beta_2, \beta_3$	=Coefficients to be estimated to minimize the prediction error.

B_2	=Realization rate of tracking estimate savings
ε_i	=Prediction error

As a result of the residual standard deviation being related to the size of the customer's electric usage or demand, one regression assumption most often violated is that the standard deviation of the error terms, (or "residuals") has a constant variance across the range of predicted values. When the standard deviation residuals are related to the predicted values, the model is said to be "heteroscedastic." Heteroscedasticity can often be detected in cross sectional models used to analyze program impact. During this step, a verification is performed to check that the regression assumptions are valid. If the initial regression model is found to be "heteroscedastic," it could result in the misspecification of mathematical relationships. Therefore, if the initial regression model is found to be heteroscedastic, further multivariate regression analysis are performed under a weighted least squares ("WLS") approach. As a result of the residual standard deviation being related to the size of the customer's electric usage or demand, heteroscedasticity is often detected in cross sectional models used to analyze DSM program impact.

3.5 Estimate of Total Savings

The final step in the analysis estimates the energy savings by using the resultant models.

Since there is seven implementation years, it may be worth producing annual savings estimates as well as an overall estimate. This will provide a time series of savings over the years, mitigate the effects of the availability of data by year, and mitigate outside influences (such as COVID). It will also reflect changing measure mixes over the years as well as lend insight into changes in program implementation. The yearly analysis can be treated as stratum, with the overall results being weighted by participation during the year.

3.6 Estimate of Measure Savings

As a result of the nature of the natural variation of residential consumption, it is difficult to get statistically significant estimates associated with small (less than 5%) influences. Accordingly, Equation 3-2 uses the *total* tracking savings as an independent variable. While adding additional variables to define individual measures should provide the same estimate of total savings, the individual estimates of small measures could be statistically insignificant. Accordingly, the estimate of individual measures would need to be *ex-post*. The analysis will attempt to disaggregate the savings using a number of techniques, including ratio allocation of savings and prediction models that would feature the total estimate of savings for a site as the dependent variable and the individual tracking estimates of savings as independent variables.

4 COMMUNCATION AND REPORTING

4.1 Project Schedule

Completing the evaluation on this accelerated schedule is dependent upon receiving usage data in a timely fashion. Delays in receiving complete data sets or collection efforts may cause disruption to the embedded milestone events. The evaluation schedule is presented below in Table 4.

Dates for each deliverable are listed in bold with 2 weeks for Dominion Energy to review and provide comments. DNV regularly allows for 4 weeks between draft report distribution and the final report deadline, allowing for 2 weeks of client review and 2 weeks to finalize the report.

About DNV

DNV is a global quality assurance and risk management company. Driven by our purpose of safeguarding life, property and the environment, we enable our customers 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, power and renewables industries. We also provide certification, supply chain and data management services to customers across a wide range of industries. Operating in more than 100 countries, our experts are dedicated to helping customers make the world safer, smarter and greener.

APPENDIX H RESIDENTIAL SMART COOLING REWARD PROGRAM IMPACT ANALYSIS

RESIDENTIAL AC CYCLING (SMART REWARDS) PROGRAM

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

Appendix H
Impact Evaluation of 2021 Dispatch Events

March 9, 2022

DNV

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EXECUTIVE SUMMARY

This report presents the load impacts of the 2021 Residential AC Cycling Program, marketed to customers as Smart Cooling Rewards and administered by Dominion Energy (the Company) in Virginia and North Carolina. The AC Cycling Program has been operating for 11 years as a supply resource to help the Company reduce summer peak demand. The results presented here represent the impacts realized from approximately 67,000 customers. Some customers from the 2020 analysis have transitioned to the demand response Smart Thermostat Rewards Program and this trend is expected to continue.[1]

When an AC Cycling event is called, a one-way radiofrequency (RF) paging signal is broadcast to load curtailment switches installed on central air conditioners (AC) and heat pumps of participating residential customers. The load curtailment switch reduces the duty cycle of the registered AC units up to 50% during an event. DNV evaluates the AC Cycling Program annually. The objectives of the evaluation are:

1. To estimate the average kW impacts of demand reduction for each event hour (ex post analysis)
2. To forecast the kW impacts by event-hour delivered by the AC Cycling resource in varying temperature and humidity conditions including the Company's summer peak planning conditions

In 2021, the AC Cycling Program called 25 events over 71 event hours that were distributed evenly over June, July, and August. This report summarizes the event history between 2018 and 2021, reviews the 2021 event impacts across the Company's service areas, and presents the results of the hourly ex post and ex ante impact analyses. It also presents sample event-day plots showing the hourly progression of events with high and low impacts and discusses the weighting strategy that allocates impacts over the advanced metering infrastructure (AMI) and non-AMI participants.

1.1 Key Findings

In 2021, the evaluated load impact for weather conditions observed during Dominion Energy's peak day conditions was 0.53 kW per participant.

- In 2021, the per-participant demand reduction is forecast to be 0.53 kW at the Company's peak planning conditions.
- Ex post impacts over the 71 event hours in 2021 ranged from 0.30 kW to 0.63 kW per participant. The lowest average event impact occurred on July 28 and the highest on June 29. Load profiles for a high- and low-case are shown in Figure 5-2 and Figure 5-3.
- In 2021, relative to prior years, the proportion of AMI to non-AMI participants increased from 10% to 27% due to the accelerated deployment of AMI meters in 2021. As a result, the number of accounts included in the regression analysis almost tripled. Until 2021, almost 90% of the accounts in the regression analysis came from the Northwest Division. In 2021, there was an even distribution of accounts across all divisions. To determine whether the increased number of AMI accounts impacted results, DNV calculated impacts for 2021 for the lower number (10%) of AMI accounts available in 2020. Impacts were similar regardless of the number of AMI accounts, indicating that the smaller, less geographically representative sample from prior years was similarly robust as the current larger and better geographically distributed sample.
- The effect of the COVID-19 pandemic on program impacts is unknown, but we assume that similar to 2020, more people were at home on weekdays in 2021 than in previous years. Qualitatively, the site-level customer load models were better behaved, which would be consistent with models dealing with fewer atypical periods such as vacations or family visits.

[1] Program website: Smart Cooling Rewards, Smart Thermostat Rewards program

2 INTRODUCTION

This report summarizes the event history between 2018 and 2021, reviews event participation in 2021, and presents the results of the ex post and ex ante impact analyses. It also presents sample event-day plots for events with high and low impacts, hourly impact estimates, and modeled impacts for varying weather conditions and time of day.

The AC Cycling event season spans June 1 through September 30 on non-holiday weekdays.[2] Events typically last between two and four hours. In 2021, the first event occurred on June 7 and the last on August 26. Under the program, when AC Cycling events are called, a one-way RF paging signal is broadcast throughout the Company's service area. The signal is received by load curtailment switches installed on central ACs and heat pumps of participating residential customers. The dispatch of the RF signal to the load curtailment switch reduces the duty cycle of the registered AC units up to 50%.

When the AC Cycling Program was launched in 2010, the estimated impacts were based on a statistical regression model of consumption data from other utilities in the region. Since 2011, the modeled impact estimates have used site-level interval data from AMI meters, AC switch control data from the implementer, and customer-specific weather data. In compliance with the order from the Virginia State Corporation Commission (the Commission), the sampling strategy transitioned from a random sample of participants with AMI meters to using consumption data from every AMI-enabled AC Cycling participant.[3]

In 2021, 20,557, or 27% of all participants were AMI-enabled and included in the analysis. This is a substantial increase over the 10% sample in 2019 and 2020. The effect of the larger analysis sample is discussed in more detail later in the report.

Figure 2-1. DR Potential (kW) for AC Cycling Participants in Virginia and North Carolina as of December 31, 2021

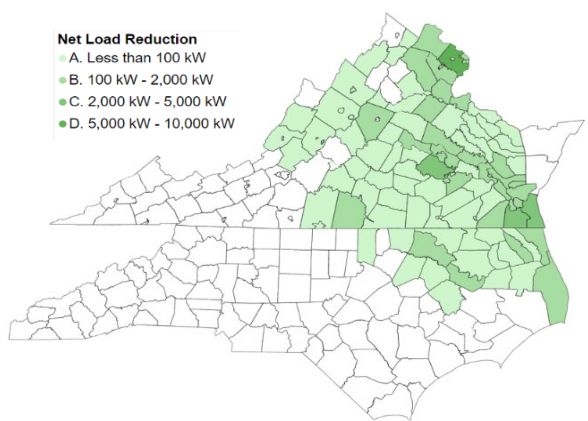

Figure 2-1 shows the amount of AC Cycling demand reduction potential as of December 31, 2021. As with the Company's energy efficiency programs, the Virginia regions with the highest demand reduction potential are Northern Virginia, Norfolk, and Richmond.

Understanding why results change from year to year is difficult without additional in-depth analysis because although the relationships between temperature, humidity, and demand reduction are strong, other factors drive demand reduction. Long hot periods and/or stretches of consecutive event days affect AC usage and the response to events. Conversely, a single hot day during an otherwise cool period also produces different demand reductions. Because demand reduction is a function of both the amount of cooling demanded at the time of an event (i.e., potential demand reduction) and the customer response (i.e., the customer turning on their AC equipment), the complex relationship between demand reduction, long-term temperature trends, and event call schedules is difficult to predict from event to event or season to season. To further complicate matters, there are unknown effects of the protracted Covid-19 pandemic.

[2] Events may be called after September 30 under extenuating circumstances.

[3] Required as part of the Final Order, State Corporation Commission of Virginia, Case #PUE-2015-00089, April 19, 2016.

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3 2021 AC CYCLING EVENTS AND PARTICIPATION

AC Cycling event seasons are distinguished from year to year by the number of events, the number of controlled hours, and the number of controlled participants. This section summarizes the 2021 events, including event hours (Table 3-1), and the number of controlled participants (Table 3-2). Data from prior years are provided for comparison.

Table 3-1. Summary of 2018–2021 Events

	2018	2019	2020	2021
Number of events	27	23	20	25
Controlled event hours	75	66	56	71

3.1 Frequency

There were 25 events spanning a total of 71 hours in the summer of 2021. This is a 20% increase over 2020, which had fewer events than any prior year. The 25 events were spread fairly evenly across June (7), July (8), and August (10).

3.2 Participation

Approximately 64,460 participants (accounts) and 70,600 AC and heat pump units were controlled in 2021. The number of participants and controlled units dropped approximately 6% from 2020 due to attrition. Table 3-2 shows the number of AMI-enabled and total participants by division. Approximately 100 customers have transitioned to the Smart Thermostat Rewards Program.

The relative proportion of AMI to non-AMI participants increased substantially in 2021. Over the last several years AMI data was available for approximately 10% of participants. In 2021, 27% of participants had AMI data, and the number of accounts included in the regression analysis almost tripled. Until 2021, almost 90% of all AMI data came from the Northwest Division, but as of 2021, it is evenly distributed across the Eastern, Northwest, and Central Divisions.

Table 3-2. 2021 Total and AMI Participants by Division[4]

Division	Total Participants by Division	AMI Participants by Division	Percentage AMI to Total AMI by Division
Eastern	27,052	6,248	34%
Northwest	21,555	6,284	35%
Central	15,954	5,581	31%
North Carolina	2,626	93	1%
Total	**67,187**	**18,206**	

4 The participation data was taken for the first event on June 7, 2021.

4 IMPACT ANALYSIS

The following sections describe the consumption, tracking, and weather data, the evaluation methodology, and the ex post and ex ante results. The ex post impact analysis describes what happened during the 2021 event season. The ex ante analysis predicts impacts under a variety of conditions.

The ex post analysis estimates per-participant kW impacts (demand reduction) realized at the end of each event hour for each event, and reports the time the event begins and ends, along with the length of each event (Section 5.2).

The ex ante analysis uses the kW impacts of the ex post analysis to forecast kW impacts by hour, temperature, and humidity conditions (Section 5.3). For example, 0.53 kW is the estimated impact from a demand response event for the Company's peak planning conditions, which are 95°F and 43% RH at 17:00.[5]

4.1 Data

Four sources of data are used in the impact analysis:

1. **AMI data**: Half-hourly whole-house consumption data collected from customer AMI meters
2. **Event control data**: A record of controlled participants for each event provided by the implementer, including opt-outs
3. **Tracking data**: Program tracking data is used to link the customer to their consumption data and to confirm that switch control records match the Company's list of active participants.
4. **Weather data**: Hourly temperature and humidity data collected at the weather station closest to the account address[6]

Descriptions and results of the data quality control (QC) procedures are provided in Appendix I.

4.2 Methodology

The following steps are used to calculate demand reduction impacts for the program:

1. DNV receives and performs QC on 30-minute interval data for each participant.
2. AMI data are merged with the event control data.
3. Using AMI data, event control data, and weather data, regression analysis is used to predict event-day baseline consumption for each controlled AMI-enabled account.
4. To ensure that the AMI population is representative of the program population, the AMI accounts are assigned weights based on state, connected load, and location. The weighting method and final weights are included in Appendix II.

[5] Dominions Energy's peak planning condition is hour-ending 17 at 95°F at 43% RH, or 83.4 THI. Temperature Humidity Index = THI = Td – (0.55 – 0.55*RH) * (Td – 58) where Td is dry bulb temperature and RH is relative humidity. Source: PJM Glossary: http://www.pjm.com/Glossary.aspx

[6] National Oceanic and Atmospheric Association (NOAA), National Centers for Environmental Information, Climate Data Online.

5. The predicted and actual consumption for AMI-enabled accounts is weighted to the full program population and the difference between baseline predicted consumption and actual consumption is the calculated ex post impact. The results of the ex post analysis are provided in Section 5.1.
6. Ex ante estimates are then calculated using a regression analysis of the ex post impacts for each event-hour as the dependent variable and temperature humidity index (THI) as the independent variable. Ex ante results are the predicted impacts for each event hour and THI and are used to estimate the program impacts at the Company's peak planning conditions. The ex ante results are provided in Section 5.3.

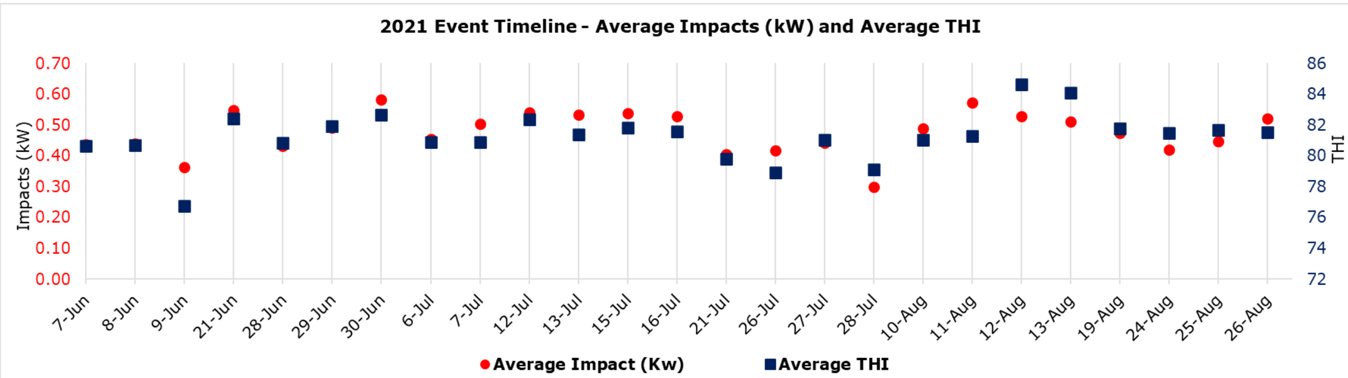
5 RESULTS

This section presents the results of the 2021 ex post and ex ante analyses. Figure 5-1 is a seasonal timeline showing the impacts and THI for each event. Figure 5-2 and Figure 5-3 show event-level plots illustrating the event days with the highest and lowest impacts. Table 5-1 and Table 5-2 show the ex post impacts calculated for each event hour.

5.1 Ex Post Impacts

The 2021 timeline in Figure 5-1 shows the average impact (in kW) and maximum THI for each event. In general, the magnitude of the impacts moves with temperature and humidity.

Figure 5-1. Timeline of 2021 Events by Average Impacts (Red) and Maximum Event-day THI (Blue)



5.1.1 Event-Day Plots

The ex post plots in Figure 5-2 and Figure 5-3 on the following pages illustrate events with relatively high and low impacts, respectively. The plots are described briefly below.

The ex post estimate, or what happened during the event, is the difference between the adjusted baseline during the event (solid red line) and the event load (purple line). Impacts are calculated at the end of each event hour and referred to as hour ending (HE). Impacts are determined by estimating the difference between the adjusted baseline load and the event load. The results are illustrated in time-series representations of:

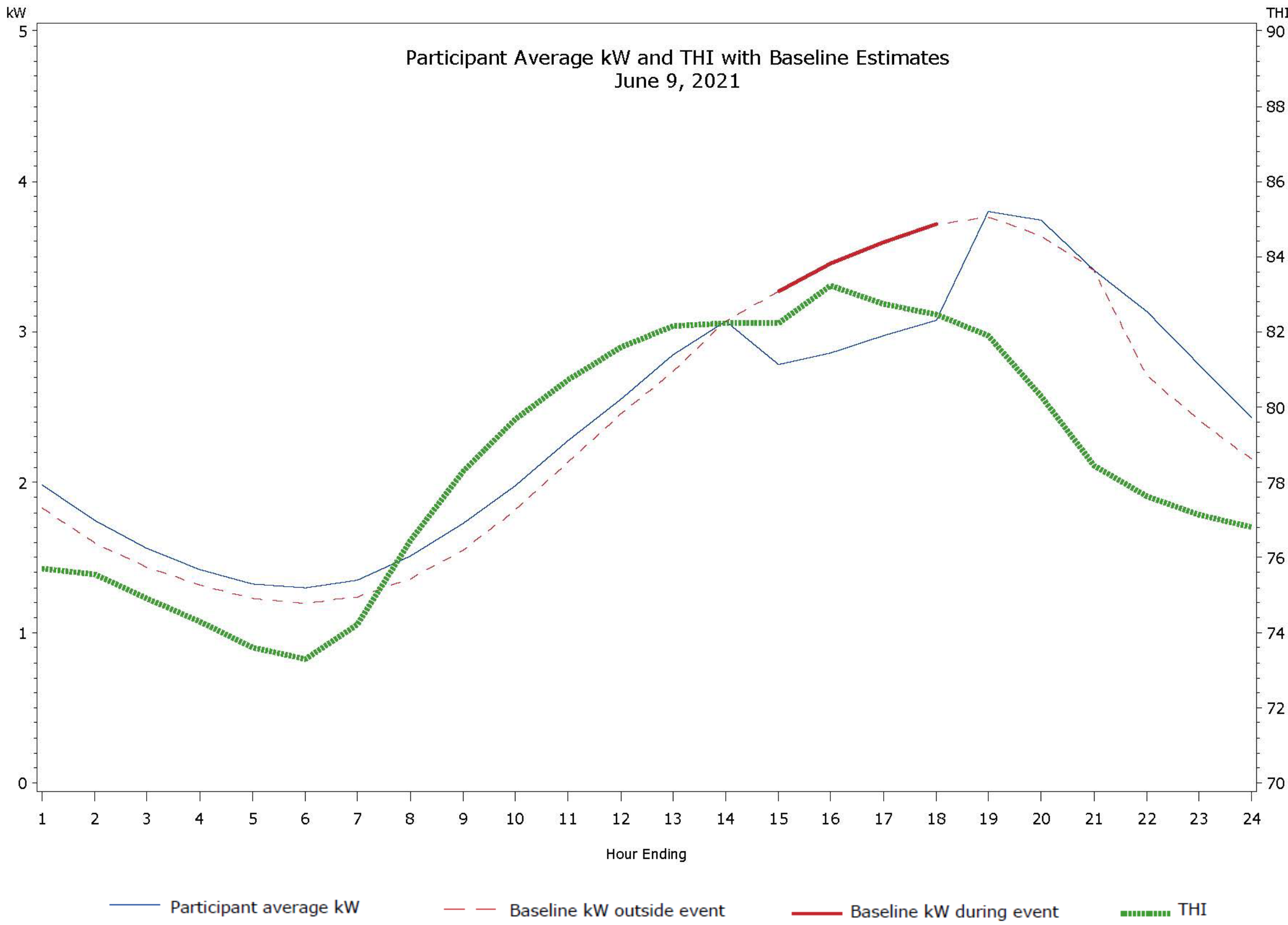
- ***Event-day load profile for the AC Cycling Program participant population (solid purple line).*** The beginning of the event is clearly visible and is typically followed by a post-event load spike (snapback or rebound) before the load resumes to non-event levels.
- ***Baseline during the event (solid red line)***. The solid red line plots the baseline for the event-day load curve during the event. The baseline is modeled from the non-event days and represents the estimated load for that day in the absence of an event.
- ***Reference load outside the event (dashed red line).*** This line plots the baseline load profile before and after the event taken from participant AMI data.
- ***Event-day THI* (green line)**. Hourly THIs are plotted to give context for the load curves and the relationship of load, temperature, and humidity.

Load Profile with High Impacts

The highest per-event impact occurred on June 30, 2021, on the day with the highest event-average THI (87). The June 30 event was the third day of 3 consecutive events and had the highest impact of the 3-day series.

The event was called at 14:00 with demand reduction clearly visible at hours ending 15, 16, and 17 (Figure 5-2). It was the only event in 2021 that was called at 14:00. The estimated average impact was 0.58 kW per participant. For a future comparison with the following low-impact event, the baseline consumption at the start of this high-impact event was approximately 3 kW.

Figure 5-2. Load Profile for the Event Day with the Highest Impacts (June 30, 2021)



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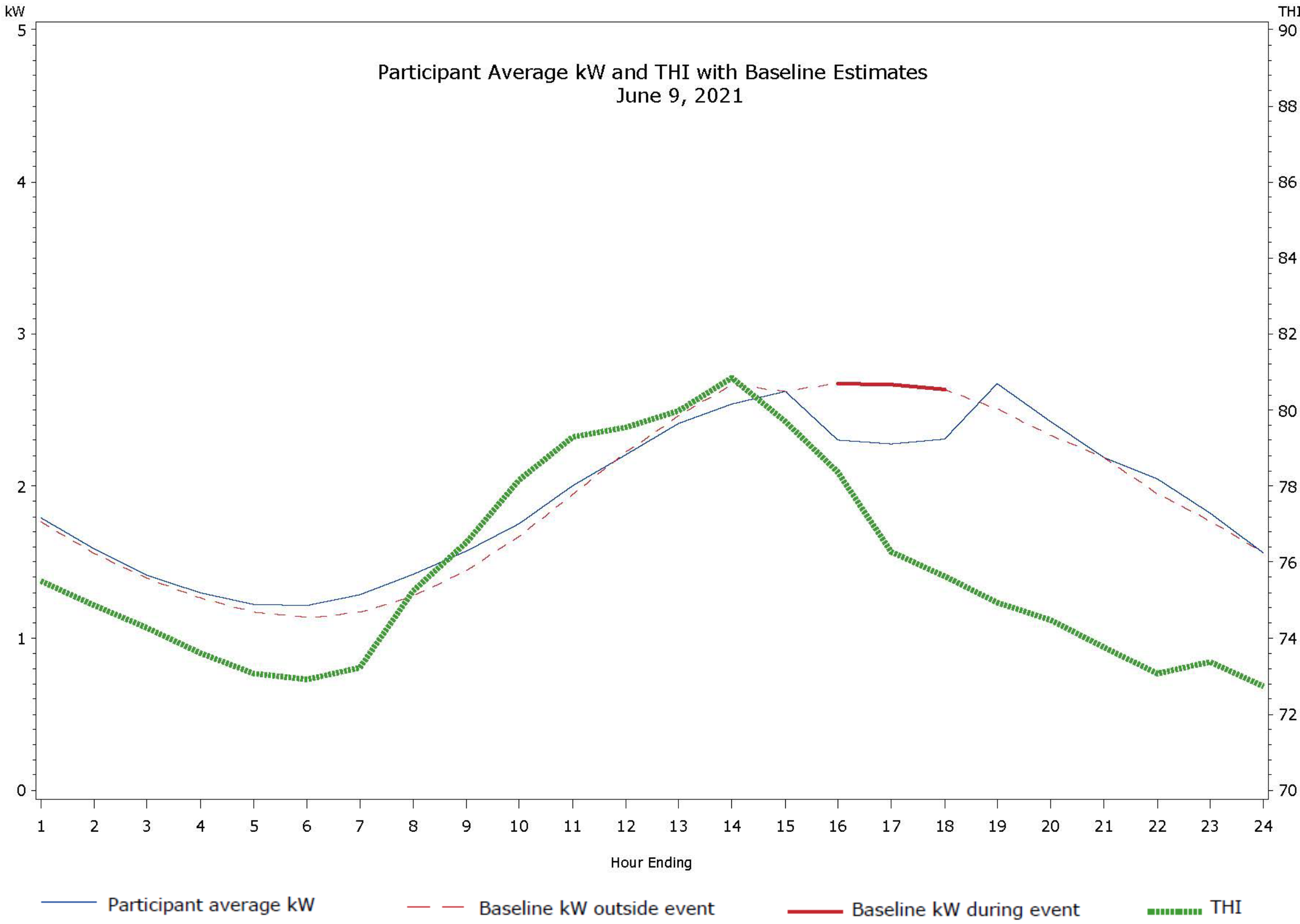
Load Profile with Low Impact

The second-lowest event impact for 2021 occurred on June 9, 2021, the event day with the second-lowest event-average THI (79). The event was called at 16:00 with demand reduction clearly visible at hours ending 16, 17, and 18. The estimated average impact was 0.36 kW per participant. Like the prior example, it was also the last consecutive event in a 3-day series, but the coolest, least humid day of the series because a cool front passed through parts of the state. In Richmond, for example, the temperature dropped 10 ºF between HE15 and HE16. The THI at HE16 was 79 (Figure 5-3), whereas the THI was 87 in the high-case in Figure 5-2. In this low case, the baseline consumption at the beginning of the event is just above 2.5 kW at HE15, whereas the high case is already 3 kW by HE14.

Figure 5-3. Load Profile for the Event Day with the Low Impacts (June 9, 2021)



The lowest average event impact occurred on July 28. Similar to the June 9 event, it was the third event day in a row but was an even cooler, less humid day, with a THI of 78. Despite the event beginning an hour later, in the last hour before the event (HE16), the average customer load was approximately 2.75 kW. This event further illustrates the influence of time, temperature, and humidity on the magnitude of impacts.

5.2 Ex Post Impacts

Ex post impacts by day and hour are presented in Table 5-1 and Table 5-2. Also shown are the maximum recorded event day THIs, Richmond daily high temperature in Fahrenheit, the opt-out percentage, and a day number indicating the event's order for consecutive event days.[7]

The highest average event impact (0.58 kW) occurred on June 30, and the lowest (0.30) on July 28. The maximum impact for a single interval in 2021 was 0.63 kW on June 30, the same event with the highest average impact that is plotted in Figure 5-2. The average opt-out percentage for 2021 was 0.01% and opt-outs for any given single event was 35 out of 70,433 switches.

Table 5-1. AC Cycling Impacts by Event-Day and Hour (June 7 through July 21, 2021)

Event Date	7-Jun	8-Jun	9-Jun	21-Jun	28-Jun	29-Jun	30-Jun	6-Jul	7-Jul	12-Jul	13-Jul	15-Jul	16-Jul	21-Jul
Consecutive Event-days		2	3			2	3		2		2		2	
Opt Out Percent	0.02%	0.04%	0.05%	0.01%	0.00%	0.00%	0.02%	0.01%	0.01%	0.02%	0.02%	0.01%	0.02%	0.01%
Weighted Average THI Across Event Hrs	80	80	79	82	81	82	82	81	81	82	82	82	82	80
Richmond Daily High Temp	89	90	89	95	90	92	95	92	94	91	91	92	94	92
HE15							0.48							
HE16	0.41	0.38	0.37	0.46		0.45	0.59		0.47	0.47	0.47	0.46	0.46	0.37
HE17	0.44	0.46	0.39	0.57	0.41	0.52	0.62	0.42	0.52	0.56	0.55	0.55	0.55	0.42
HE18	0.45	0.48	0.32	0.61	0.45	0.51	0.63	0.47	0.52	0.56	0.54	0.56	0.57	0.43
HE19								0.48		0.57	0.56	0.59		
Average Impact (Kw)	**0.44**	**0.44**	**0.36**	**0.55**	**0.43**	**0.49**	**0.58**	**0.45**	**0.50**	**0.54**	**0.53**	**0.54**	**0.53**	**0.41**

Table 5-2. AC Cycling Impacts by Event-Day and Hour (July 26 through August 26, 2021)

Event Date	26-Jul	27-Jul	28-Jul	10-Aug	11-Aug	12-Aug	13-Aug	19-Aug	24-Aug	25-Aug	26-Aug
Consecutive Event-days		2	3		2	3	4			2	3
Opt Out Percent	0.00%	0.01%	0.01%	0.00%	0.01%	0.01%	0.02%	0.01%	0.01%	0.00%	0.00%
Weighted Average THI Across Event Hrs	81	81	78	82	83	84	84	82	82	82	83
Richmond Daily High Temp	88	89	91	91	93	94	94	92	95	92	93
HE15											
HE16	0.40						0.47	0.42			
HE17	0.46	0.43	0.30	0.43	0.52	0.49	0.56	0.49	0.40	0.43	0.50
HE18	0.39	0.46	0.30	0.55	0.62	0.56		0.51	0.44	0.47	0.54
HE19		0.44			0.58						
Average Impact (Kw)	**0.42**	**0.44**	**0.30**	**0.49**	**0.57**	**0.53**	**0.51**	**0.47**	**0.42**	**0.45**	**0.52**

[7] The THI reported in Tables 5-1 and 5-2 is the AMI participant THI at the closest NOAA weather station, weighted to the population of AC Cycling participants.

5.3 Ex Ante Impacts

The primary metric of the impact analysis is the ex ante impact estimates for the program year for the company's peak planning conditions. The ex ante analysis models event impacts for a range of THI values and event hours. The ex ante impact for the Company's peak planning conditions (83.4 THI at 17:00) was 0.53 kW. A regression model was fit of the ex post impacts for each of the event hours ending 15, 16, 17, 18, and 19, with a weighted customer-specific THI as a predictor variable. Like prior years, the 2021 ex ante model was based solely on 2021 ex post impacts.

Table 5-3 shows the predicted kW per participant impacts from the regression models for event hours ending at 15, 16, 17, 18, and 19, across a range of THIs. The predicted impact of 0.53 kW at the Company's peak conditions of 83.4 THI falls within the thick bordered box at HE17.

Table 5-3. Ex Ante Per Participant Impacts by THI and Hour Ending (2021)

THI	HE15	HE16	HE17	HE18	HE19
76	0.48	0.29	0.33	0.32	0.41
77	0.48	0.32	0.36	0.35	0.44
78	0.48	0.35	0.39	0.39	0.47
79	0.48	0.37	0.41	0.43	0.49
80	0.48	0.40	0.44	0.47	0.52
81	0.48	0.42	0.47	0.50	0.55
82	0.48	0.45	0.50	0.54	0.57
83	0.48	0.48	0.52	0.58	0.60
84	0.48	0.50	0.55	0.62	0.63
85	0.48	0.53	0.58	0.65	0.65
86	0.48	0.56	0.60	0.69	0.68
87	0.48	0.58	0.63	0.73	0.71
88	0.48	0.61	0.66	0.77	0.73

APPENDIX I. AC CYCLING EVALUATION DATA

5.4 AMI Data – Quality Control

Four sources of data are used in the impact analysis:

1. Half-hourly AMI customer consumption data
2. A record of controlled participants for each event
3. Program tracking data
4. Regional weather data.

A series of QC procedures are performed on the AMI data and the event control logs. This section describes these QC procedures that include a review of the AMI data and a cross-reference between the account level AMI data, the implementers' event control logs, and Dominion Energy's business intelligence (BI) data.

The AMI data is reviewed to ensure that it spans the analysis period within a specified tolerance for missing data and a determination that the consumption is reasonable. The following specific conditions must be met for a participant to be included in the impact analysis:

- AMI accounts must include consumption data for the event season, June 7th through August 26th.
- An account must not be missing consumption for more than 48 intervals or have zero consumption for more than 400 intervals.
- An AMI account must be associated with a corresponding account in the event control log.
- An account in the event control log must be associated with an active participant in the BI data.

The event control log lists all dispatched accounts and the start and stop times of the event. Only dispatched participants are included in the event control log. A participant will not be included if they opted out of an event or were not dispatched during a partial-dispatch event. However, there were no partial-dispatch events in 2021.

5.4.1 QC Results

Table 5-4 summarizes QC results for the AMI data.

Table 5-4. Attrition of participant AMI data (2021)

Data Prep	Number of Accounts	Remaining Population
Participant AMI accounts	21,865	
Data out of range or missing intervals	-11	
Number of accounts that appeared in the AMI data before June 1, 2021, only, or after September 30, 2021, only	-1,262	
Accounts removed because the AMI and event data did not overlap (new AMI meters)	-35	
Accounts included in the analysis	20,557	

APPENDIX II. EXTRAPOLATING THE AMI-ENABLED ACCOUNT IMPACTS TO THE PROGRAM POPULATION

The distribution of the AMI participants (the sample for analysis) among divisions and connected loads is not a random sample of the participant population. However, in 2021, the AC Cycling AMI sample increased from 10% to 27% of all participants because of the accelerated deployment of AMI meters across Dominion's service territory.[8] To extrapolate the AMI account impacts to the participant population, the AMI-enabled accounts are assigned weights based on their division and connected load relative to all participants in the population. The distribution of AMI-enabled participants to all participants by division is shown in Table 5-5.

Table 5-5. Total and AMI Participants by Division[9]

Division	Total Participants by Division	Total AMI Participants by Division	Percentage AMI by Division
Eastern	27,052	6,248	34%
Northwest	21,555	6,284	35%
Central	15,954	5,581	31%
North Carolina	2,626	93	1%
Total	67,187	18,206	27%

The weights assigned to the AMI-enabled group for the June 23 event are listed in Table 5-6. The weights are unique to each event to reflect slight differences in participation levels. The weight can be understood as the number of program participants represented by each account in the AMI group. The following steps were taken to build the 2021 weights:

1. Construct a list of all event participants by division and connected load. The program tracking BI data is the source of the division and connected loads.
2. Stratify the participants based on state, division, and connected load.
3. Calculate weights based on the number of AMI participants for each event relative to all participants within each stratum.[10]

[8] Due to the non-random sample of AMI meters in the analysis, the Company commissioned a customer load modeling analysis, a new recruit trend study, and a non-AMI comparison. In turn, all were included in the Final Order of the State Corporation Commission on April 19, 2016. The results of these studies are found in the 2016 evaluation of dispatch events.

[9] The table shows total participants and AMI participants in the first event on June 7, 2021. Although 20,557 AMI accounts are included in the overall analysis only 18,206 participated on June 7, 2021.

[10] The weight within each stratum is the population divided by the total number of AMI meters in the study group.

Table 5-6. Weights by State, Division, and Connected Load for June 7, 2021

State	Division	Load (kW)	No. AMI meters	No. Participants	Weight
VA	Northwest	Not Available	1,079	5,807	5.38
VA	Northwest	< 4kW	3,085	8,826	2.86
VA	Northwest	≥4kW	2,120	6,922	3.27
VA	Eastern	Not Available	1,410	5,788	4.10
VA	Eastern	< 4 kW	3,179	13,618	4.28
VA	Eastern	>= 4 kW	1,659	7,646	4.61
VA	Central	Not Available	735	2,328	3.17
VA	Central	< 4kW	3,035	8,388	2.76
VA	Central	≥4kW	1,811	5,238	2.89
NC	NC	< 4kW	41	1,603	39.10
NC	NC	≥4kW	52	1,023	19.67
		Total	**18,206**	**67,187**	

About DNV

APPENDIX I NON-RESIDENTIAL DISTRIBUTED GENERATION PROGRAM IMPACT ANALYSIS

DNV

DISTRIBUTED GENERATION PROGRAM

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

Appendix I
Impact Evaluation of 2021 Dispatch Events

January 28, 2022

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EXECUTIVE SUMMARY

This report presents the results of the annual impact analysis of Dominion Energy Virginia's (the Company's) Non-residential Distributed Generation (DG) Program for 2021.

In 2021, the program achieved an overall realization rate of 111%, and for the second year in a row there were no winter call events.

The program began in June 2012 with the objective of curtailing peak load during periods of high demand. The Company calls upon participating large non-residential customers to provide it with a supply resource by operating backup power to curtail load on the grid. Customers must meet specific eligibility requirements to participate in the program and receive an incentive from the Company in exchange for their participation.

The three objectives of the impact analysis are to:

- Compute the aggregate and site-level curtailed load, in kilowatts (kW), for each event-hour and event day
- Compute program realization rates annually, seasonally, and for each event interval by comparing dispatched generation to measured generation
- Report monthly program performance and planned values

From January 1, 2021 to December 31, 2021, the program achieved an overall realization rate of 111%, exceeding its planned realization rate of 95%. Monthly realization rates ranged from 94% in May to 117% in August. There were no winter events in 2021; therefore, only summer events are included in the 2021 analysis.

Figure ES-1. Non-residential DG annual and seasonal realization rates, 2014–2021

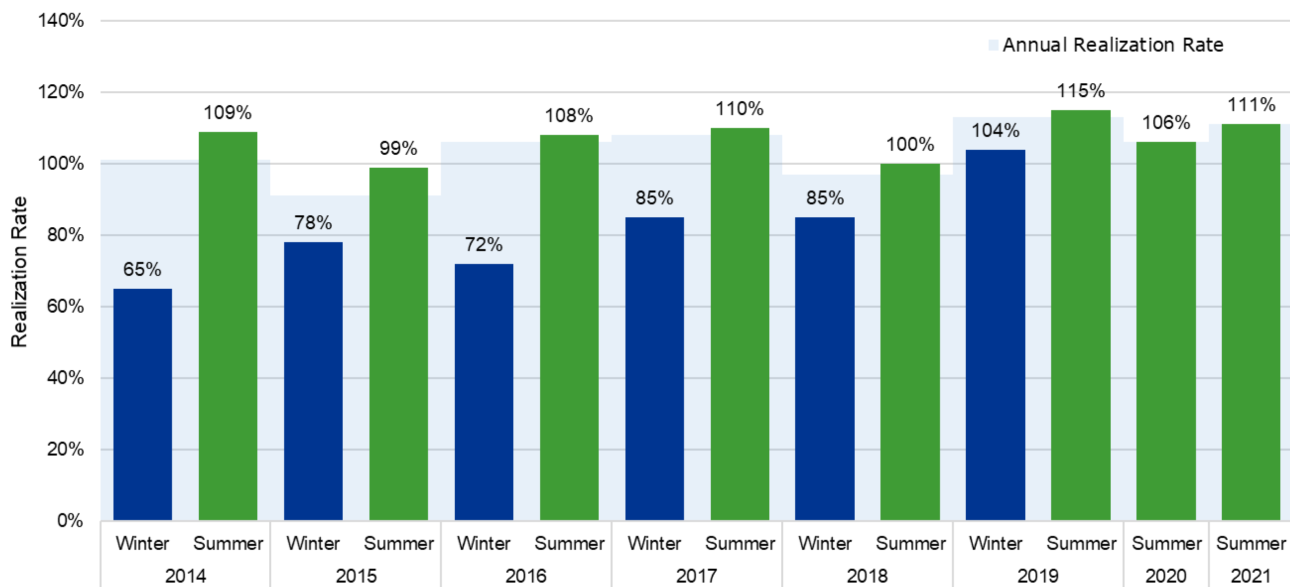


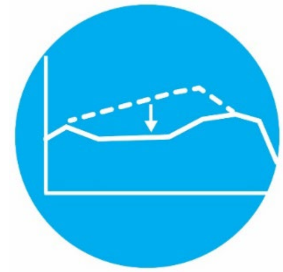
Table ES-1 shows DG Program performance and planned values for 2021. The table provides the planned and actual participants, in megawatts (MW), and the average dispatched and measured generation in kW.

Table ES-1. DG program performance for 2020 events

2021	Planned (MW)	Enrolled (MW)	Net kW planned	Net kW enrolled	Event days	Average dispatched (kW)	Average generation (kW)	Average realization rate
May	7.13	5.97	7,130	5,970	1	5,970	5,584	94%
June	7.13	5.97	7,130	5,970	7	5,601	6,050	108%
July	7.13	5.97	7,130	5,970	11	5,720	6,425	112%
August	7.13	5.97	7,130	5,970	8	5,782	6,783	117%

1 INTRODUCTION AND BACKGROUND

The Virginia State Corporation Commission approved the Non-residential Distributed Generation (DG) Pilot Program on January 17, 2008. The DG Pilot achieved program status on April 30, 2012. In September 2021, the DG program was extended for an additional two years through May 31, 2024.[1]



Large non-residential customers with at least 200 kW of demand are eligible to participate in the program. Dominion Energy may initiate a control event at any time during the year for any duration up to a total of 120 hours per calendar year subject to the physical constraints and environmental permitting requirements of the backup generation unit. The Company will pay an incentive payment each month based on the amount of load curtailment enrolled and actually delivered during control events. As of December 31, 2021, there were 21 enrolled sites, representing a resource potential of 5.97 MW to the Company.

Details of the DG program are as follows:

- A participant is defined by its enrolled capacity, and one participant equals 1,000 kW of enrolled generation. A customer with greater than 1,000 kW of enrolled capacity is counted as more than one participant.[2] The level of incentive corresponds with the kW of enrolled generation capacity.
- Participating customers are compensated if the average annual measured on-site generation is at least 95% of the dispatched target generation for each event day.
- The Company has the right to adjust the incentive paid to customers based on historical performance if the average annual realization rate falls below the 95% target.

1.1 Program terminology and metrics

Any day on which an event is called is considered an event day. A given event day may include multiple events. The length of each event varies by event and events are reported in one-hour intervals at the end of the hour. For example, the interval hour ending 17 corresponds to an event between 16:00 and 17:00. The number of dispatched sites during a given event day may vary.

For the non-residential DG program, total and average dispatched generation is the amount of load curtailment, in kW, requested by the Company, per event-hour, aggregated and reported at the daily, monthly, seasonal, and yearly levels. Total and average measured generation is metered on-site and is the amount of load curtailed by the participant per event-hour interval.

1.1.1 Realization rate

The program's key performance indicator is the realization rate. The realization rate is calculated by dividing the average monthly measured generation by the average monthly dispatched generation for participating sites, expressed as a percentage. The measured generation before or following an event is not attributed to the program.

From January 1 through December 31, 2021, the program achieved an overall realization rate of 111%, exceeding its planned realization rate of 95%. The 2021 monthly realization rates shown in Table 1-1 highlight the months with call events (May–August).

[1] . Case No. PUR-2020-00274, Commonwealth of Virginia, State Corporation Commission, Petition of Dominion Energy Virginia for approval of its 2020 DSM Update, Final Order September 2021.

[2] Customers who do not have exact multiples of 1,000 kW of on-site generation are credited with fractional levels of participation and incentive, e.g., 1,500 kW is considered 1.5 participants.

Table 1-1. DG program performance for 2021 events

2021	Planned (MW)	Enrolled (MW)	Net kW planned	Net kW enrolled	Event days	Average dispatched (kW)	Average generation (kW)	Average realization rate
May	7.13	5.97	7,130	5,970	1	5,970	5,584	94%
June	7.13	5.97	7,130	5,970	7	5,601	6,050	108%
July	7.13	5.97	7,130	5,970	11	5,720	6,425	112%
August	7.13	5.97	7,130	5,970	8	5,782	6,783	117%

Performance indicators for DG pilot participants were reported through the end of the pilot (2014). Therefore, results reported in 2015–2021 are not directly comparable to the results of the combined pilot and program reported in 2013 and 2014.

2 IMPACT ANALYSIS METHODOLOGY

For the non-residential DG program, dispatched generation is the amount of load curtailment, in kW, requested by the Company per event-hour interval, aggregated to the day, month, season, or year. Measured generation, which is site-metered generation, is the amount of load delivered to the Company per event-hour interval, aggregated to the day, month, season, or year. Both dispatched and measured generation is presented in total (cumulative) and average (mean) aggregates. The realization rate is calculated by dividing the measured generation by the dispatched generation for participating sites.

2.1 Data

The Company provides measured generation data to DNV every month. If a site is not dispatched for a given event, it is not recorded. Each record includes the enrolled (dispatchable) generation for every site called for the event, as well as the measured generation for each hour ending during the event duration (in kW). Observations are recorded at the event-hour level for each site called on a given event day for each event.

2.2 Evaluation metrics

The key performance indicator used to measure program performance is the realization rate. The site-level realization rate for a given event interval is the on-site measured generation during that interval divided by the dispatched generation for the interval. The program realization rate during an event interval is the total measured generation divided by the total dispatched generation for all sites. For participants indexed by *i*, and for an event interval *j*,

$$Realization\ Rate_j = \frac{\sum_i Measured\ Generation\ (kW_{i,j})}{\sum_i Dispatched\ Generation\ (kW_{i,j})}$$

The aggregate dispatched and measured generation across the program is calculated by event interval and day.

Results are reported seasonally for some parts of the analysis. The winter season spans October–May, and the summer season spans June–September.

3 RESULTS

This section summarizes program performance from 2013 to 2021 and presents a detailed impact analysis for the 2021 events.

A total of 27 events were called in 2021, with one event per event day. Eleven of the 27 events occurred in July. Table 3-1 presents an annual summary of the number of event days, average dispatched generation, average measured generation, and realization rates for event days through December 31, 2021.

Table 3-1. Program participant impacts and realization rates per year

Year	Number of event days	Average dispatched (kW)	Average measured generation (kW)	Realization rate
2013	12	6,239	6,306	102%
2014	23	5,862	5,978	101%
2015	26	5,899	5,457	93%
2016	37	5,215	5,524	106%
2017	27	5,603	6,054	108%
2018	31	5,296	5,140	97%
2019	25	5,619	6,368	113%
2020	29	5,932	6,293	106%
2021	27	5,695	6,314	111%

Table 3-2 presents an overview of yearly DG program impacts broken out by season. In 2021, summer's 111% realization rate exceeded the 95% target for 2021.

Table 3-2. DG performance indicators for winter and summer (2014–2021)

Year	Number of event days		Average dispatched (kW)		Average generation (kW)		Realization rate	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
2014	14	9	5,798	6,060	6,305	3,954	109%	65%
2015	20	6	5,958	5,846	5,903	4,515	99%	77%
2016	34	3	5,171	5,911	5,602	4,281	108%	72%
2017	24	3	5,564	6,130	6,114	5,234	110%	85%
2018	27	4	5,438	4,757	5,432	4,026	100%	85%
2019	23	2	5,565	6,085	6,376	6,302	115%	104%
2020	29	0	5,932	–	6,293	–	106%	–
2021	27	0	5,695	–	6,314	–	111%	–

Section 3.1 reports dispatched and measured generation by event-hour and day. Section 3.2 reports realization rates by event-hour and day. Section 3.3 provides site-level realization rate details by event day and month.

3.1 Program event impacts

Table 3-3 shows the total dispatched generation for all DG participants during the 2021 summer event intervals. The total and average dispatched generation is summarized by event day. The total hourly dispatched capacity ranged from 3,780 kW to 5,970 kW (27 events). The fully enrolled program capacity is 5,970 kW.

Dispatched kW is the amount of load curtailment requested (called) by the Company during an event. It is not a measure of participants' committed load and can vary by event.

Table 3-3. Dispatched generation by event day and hour ending–summer (kW)

Event day	Hour ending					Total	Average
	15	16	17	18	19		
23-May-21				5,970	5,970	11,940	5,970
7-Jun-21		5,730	5,730	5,730		17,190	5,730
8-Jun-21		5,970	5,970	5,970		17,910	5,970
9-Jun-21		5,970	5,970	5,970		17,910	5,970
21-Jun-21		5,820	5,820	5,820		17,460	5,820
28-Jun-21			5,970	5,970		11,940	5,970
29-Jun-21		3,780	3,780	3,780		11,340	3,780
30-Jun-21	5,970	5,970	5,970	5,970		23,880	5,970
6-Jul-21			5,970	5,970		11,940	5,970
7-Jul-21		5,970	5,970			11,940	5,970
12-Jul-21			5,970	5,970		11,940	5,970
13-Jul-21			5,730	5,730		11,460	5,730
15-Jul-21			5,510	5,510		11,020	5,510
16-Jul-21		5,730	5,730			11,460	5,730
21-Jul-21		5,730	5,730			11,460	5,730
26-Jul-21		5,730	5,730			11,460	5,730
27-Jul-21			5,490	5,490		10,980	5,490
28-Jul-21			5,490			5,490	5,490
29-Jul-21		5,490	5,490			10,980	5,490
10-Aug-21			5,470			5,470	5,470
11-Aug-21			5,510	5,510		11,020	5,510
12-Aug-21			5,510			5,510	5,510
13-Aug-21		5,970				5,970	5,970
19-Aug-21		5,970	5,970			11,940	5,970
24-Aug-21			5,970			5,970	5,970
25-Aug-21			5,970			5,970	5,970
26-Aug-21			5,970			5,970	5,970

Table 3-4 reports the program-level measured generation by event day and interval for summer events.

Total and average measured generation are given across all events during each event day. The average measured generation was 6,314 kW, which is consistent with program expectations.

Table 3-4. Measured generation by event day and hour ending–summer (kW)

Event day	Hour ending						
	15	16	17	18	19	Total	Average
23-May-21				5,640	5,529	11,169	5,584
7-Jun-21		5,960	6,056	6,053		18,069	6,023
8-Jun-21		6,401	6,363	6,355		19,120	6,373
9-Jun-21		6,166	6,001	5,525		17,693	5,898
21-Jun-21		6,220	6,219	6,241		18,679	6,226
28-Jun-21			6,298	6,413		12,712	6,356
29-Jun-21		4,687	4,706	4,717		14,111	4,704
30-Jun-21	6,656	6,674	6,679	6,666		26,675	6,669
6-Jul-21			6,666	6,592		13,258	6,629
7-Jul-21		6,417	6,392			12,810	6,405
12-Jul-21			6,766	6,769		13,534	6,767
13-Jul-21			6,484	6,437		12,921	6,460
15-Jul-21			6,402	6,341		12,743	6,372
16-Jul-21		6,722	6,684			13,406	6,703
21-Jul-21		6,345	6,352			12,697	6,348
26-Jul-21		6,413	6,197			12,610	6,305
27-Jul-21			6,278	6,276		12,554	6,277
28-Jul-21			5,798			5,798	5,798
29-Jul-21		6,307	6,280			12,587	6,294
10-Aug-21			6,228			6,228	6,228
11-Aug-21			6,573	6,487		13,060	6,530
12-Aug-21			6,610			6,610	6,610
13-Aug-21		7,034				7,034	7,034
19-Aug-21		6,993	6,968			13,961	6,980
24-Aug-21			6,750			6,750	6,750
25-Aug-21			7,095			7,095	7,095
26-Aug-21			7,093			7,093	7,093

3.2 Realization rates

The average realization rates for summer events are provided in Table 3-5, showing measured generation as a percentage of the dispatched generation for each event interval.

Twenty-six of 27 summer event days (96%) met or exceeded the 95% target average (Table 3-5). The May 23 event yielded a realization rate of 94%. The highest performing summer event day occurred June 29, generating 124% of the dispatched load on that day. Average realization rates that meet or exceed the 95% target are bolded in Table 3-5.

Table 3-5. Realization rates by event day and hour ending–summer

Event day	Hour ending					
	15	16	17	18	19	Average
23-May-21				94%	93%	94%
7-Jun-21		104%	106%	106%		**105%**
8-Jun-21		107%	107%	106%		**107%**
9-Jun-21		103%	101%	93%		**99%**
21-Jun-21		107%	107%	107%		**107%**
28-Jun-21			105%	107%		**106%**
29-Jun-21		124%	125%	125%		**124%**
30-Jun-21	111%	112%	112%	112%		**112%**
6-Jul-21			112%	110%		**111%**
7-Jul-21		107%	107%			**107%**
12-Jul-21			113%	113%		**113%**
13-Jul-21			113%	112%		**113%**
15-Jul-21			116%	115%		**116%**
16-Jul-21		117%	117%			**117%**
21-Jul-21		111%	111%			**111%**
26-Jul-21		112%	108%			**110%**
27-Jul-21			114%	114%		**114%**
28-Jul-21			106%			**106%**
29-Jul-21		115%	114%			**115%**
10-Aug-21			114%			**114%**
11-Aug-21			119%	118%		**119%**
12-Aug-21			120%			**120%**
13-Aug-21		118%				**118%**
19-Aug-21		117%	117%			**117%**
24-Aug-21			113%			**113%**
25-Aug-21			119%			**119%**
26-Aug-21			119%			**119%**

3.3 Site-level detail

Table 3-6 and Table 3-7 show the average realization rates by participant site for each event day. Each site is assigned a unique identifier. If a participant site was not dispatched during an event, the corresponding cell is blank. Realization rates greater than or equal to 95% are highlighted green, less than 95% and greater than or equal to 50% are lilac, and rates less than 50% are red. Site IDs 7, 9, 10, 11, 13, 14, 18, 19, and 20 met or exceeded the 95% target in every event. There was one enrolled customer site that was not included in any events.

Table 3-6. Average realization rates by site and event day (January 1–July 31, 2021)

Site ID	May	June							July										
	23	7	8	9	21	28	29	30	6	7	12	13	15	16	21	26	27	28	29
1	69%	91%	93%	86%	88%	85%		89%	90%	93%	97%	97%	97%	97%	92%	95%	96%	95%	95%
2	45%	45%	45%	45%	45%	45%		45%	45%	45%	45%	45%		104%	102%	104%	106%	11%	107%
3	58%	58%	58%	73%	106%	103%	102%	107%	98%	98%	95%	97%	94%	99%	94%	96%	92%	94%	99%
4	94%	107%	110%	49%	105%	100%	109%	109%	116%	0%	112%	111%	116%	120%	103%	34%			
5	79%	82%	84%	79%	87%	85%	87%	90%	84%	89%	86%	86%	88%	89%	87%	85%	84%	76%	87%
6	107%		114%	100%	119%	118%	118%	121%	109%	111%	113%								
7	97%	119%	120%	113%	123%	118%	118%	117%	124%	121%	124%	120%	119%	124%	113%	123%	120%	106%	125%
8	130%	132%	140%	118%		138%	140%	141%	134%	130%	136%	144%	134%	135%	129%	131%	136%	130%	125%
9	109%	111%	114%	106%	123%	118%	119%	123%	117%	117%	123%	115%	114%	120%	119%	113%	113%	115%	116%
10	145%	139%	147%	133%	146%	145%	143%	149%	146%	140%	147%	144%	146%	137%	129%	130%	143%	134%	133%
11	225%	222%	220%	214%	236%	231%	237%	242%	237%	230%	246%	246%	244%	245%	225%	224%	226%	214%	230%
12	80%	75%	78%	78%	95%	93%	89%	95%	97%	97%	98%	94%	98%	102%	84%	93%	95%	93%	93%
13	127%	133%	132%	128%	135%	131%	126%	137%	138%	137%	134%	139%	135%	137%	136%	125%	139%	125%	136%
14	108%	111%	111%	107%	116%	113%	114%	118%	114%	115%	114%	111%	111%	114%	108%	110%	114%	112%	109%
15	102%	112%	117%	116%	7%	123%	125%	128%	122%	128%	116%	109%	117%	124%	115%	128%	127%	125%	131%
16	86%	93%	92%	88%	98%	85%	93%	91%	109%	110%	105%	109%	109%	109%	111%	105%	107%	91%	111%
17	85%	101%	98%	100%	102%	101%	100%	103%	99%	100%	101%	100%	99%	104%	97%	100%	100%	85%	100%
18	117%	151%	147%	156%	171%	128%	171%	174%	165%	169%	160%	158%	153%	160%	158%	172%	165%	154%	170%
19	239%	246%	238%	230%	247%	243%	248%	249%	245%	246%	248%	245%	253%	255%	244%	248%	245%	226%	244%
20	157%	172%	169%	127%	176%	173%	173%	176%	176%	171%	179%	175%	184%	181%	175%	179%	177%	169%	179%

Legend > 95% | < 95% ≥50% | < 50% | No event called

Table 3-7. Average realization rates by site and event day (August 1–December 31, 2021)

Site ID	August							
	10	11	12	13	19	24	25	26
1	99%	100%	99%	107%	102%	94%	105%	104%
2	33%			0%	109%	107%	108%	108%
3		93%	111%	101%	99%	94%	97%	97%
4	112%	113%	0%	116%	114%	107%	112%	121%
5	83%	91%	96%	96%	89%	84%	89%	89%
6				112%	119%	111%	115%	115%
7	122%	128%	140%	131%	124%	122%	121%	120%
8	138%	135%	151%	142%	107%	139%	143%	141%
9	106%	107%	116%	118%	116%	95%	99%	113%
10	127%	143%	145%	142%	133%	136%	134%	142%
11	225%	242%	251%	243%	233%	236%	226%	228%
12	108%	102%	106%	107%	92%	98%	102%	103%
13	138%	134%	143%	141%	131%	113%	125%	132%
14	112%	113%	123%	114%	110%	113%	118%	106%
15	116%	119%	155%	118%	143%	133%	144%	119%
16	117%	114%	142%	118%	110%	109%	111%	114%
17	101%	106%	112%	104%	99%	101%	102%	99%
18	167%	171%	180%	166%	164%	169%	169%	173%
19	248%	259%	263%	262%	251%	255%	248%	255%
20	180%	186%	188%	183%	180%	183%	186%	182%

Legend	> 95%	< 95% ≥50%	< 50%	No event called

Table 3-8 shows the monthly average realization rate for each site. Twelve sites achieved or exceeded the program target of 95% every month.

Table 3-8. Average realization rates by site and event month (2021)

Site ID	May	June	July	Aug
1	69%	89%	95%	101%
2	45%	45%	75%	82%
3	58%	87%	96%	98%
4	94%	99%	89%	102%
5	79%	85%	86%	90%
6	107%	115%	111%	115%
7	97%	118%	121%	126%
8	130%	135%	133%	134%
9	109%	117%	117%	109%
10	145%	143%	139%	138%
11	225%	229%	234%	236%
12	80%	86%	95%	101%
13	127%	132%	135%	132%
14	108%	113%	112%	113%
15	102%	104%	122%	131%
16	86%	92%	108%	116%
17	85%	101%	99%	103%
18	117%	159%	163%	169%
19	239%	243%	246%	255%
20	157%	167%	177%	184%

Legend	> 95%	< 95% ≥50%	< 50%	No event called

4 CONCLUSIONS

The objective of each DG event is to provide the Company with a supply resource during periods of high demand. The performance goal of the DG program is that measured generation be at least 95% of the dispatched load. In 2021, the DG program exceeded 2021's program targets and achieved an annual realization rate of 111%, 16 percentage points higher than the program target of 95%. Similar to last year, there were no winter events in 2021. It is difficult to draw conclusions about the effect of the COVID-19 pandemic on program performance although impacts, if any, appear to be minimal.

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APPENDIX J RESIDENTIAL THERMOSTAT REWARD PROGRAM IMPACT ANALYSIS

DNV

SMART THERMOSTAT REWARDS DEMAND RESPONSE PROGRAM

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

Appendix I
Impact Evaluation of 2021 Dispatch Events

April 4, 2022

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1 EXECUTIVE SUMMARY

This is the first impact analysis of the Residential Smart Thermostat Rewards demand response program, which operated demand response events (events) for the first time in 2021. This report summarizes program participation in the 2021 events and reviews the 2021 program impacts. The program began enrolling participants in March 2021. From June through August, Dominion Energy called 25 events.

In 2021, the evaluated load impact for weather conditions observed during Dominion Energy's peak day conditions was 1.07 kW per participant.

The Smart Rewards Program leverages the demand response functionality of smart thermostats to provide residential load curtailment during periods of high demand on the Dominion grid. The smart thermostat functionality offers a pre-event cooling period that varies with the thermostat manufacturer. Following a pre-event cooling period, thermostat setpoints are increased from the cooler temperature achieved during pre-cooling, to a higher event-period setpoint, which also varies by customer and thermostat manufacturer.[1] Once the new setpoint is achieved, cooling action re-commences, but the air conditioner draws less power due to the higher setpoint. In addition to the pre-cooling functionality, smart thermostats allow the customer to override the event at the thermostat by simply changing the existing set point at any time during the event. While this functionality is an important customer selling point for smart thermostat demand response programs, it also has the potential to lower demand response impacts. In particular, override rates tend to vary with weather conditions, and can undermine load reduction on the hottest days.

Key Findings

- In 2021, the evaluated load impact was 1.07 kW per participant at Dominion's summer peak planning conditions of 95ºF and 43% relative humidity.
- By the first event, the program had 2,798 active participants and that number increased by 30% to 4,148 over the course of the summer.
- Average event-level ex post impacts range from 0.62 to 1.31 kW.
- First-hour load reduction is consistently higher than subsequent hours, with load reduction dropping with each additional hour. This pattern is present in all events and is explained by a combination of pre-cooling and the ease of override. Strategically leveraging this pattern to address system load reduction—through, for example, staggered starting hours—has the potential to increase the adaptability of the program impacts.
- Participating customers used smart thermostats from three manufacturers: Honeywell, Ecobee, and Emerson. During the first event on June 7, 47% of the thermostats were from Honeywell, 43% from Ecobee, and 10% from Emerson. By the end of August, Ecobee's share rose to 63%. In 2022, when the program is larger, DNV plans to analyze impacts by thermostat type.

[1] Not all thermostat manufacturers use the pre-cooling strategy.

2 INTRODUCTION

The smart thermostat is a measure in three Dominion Programs: Smart Thermostat Rewards Program, The Smart Thermostat Purchase Program, and the WeatherSmart℠ Program.[2] The Smart Thermostat Rewards Program began recruiting participants in March 2021. This report summarizes participation in the 2021 Smart Rewards events, reviews the 2021 event impacts, and presents the results of the ex post and ex ante impact analyses. It also presents event-hour and event-day results, sample plots showing the hourly progression of two events, and the weighting strategy that extrapolates impacts from the AMI participants to the full population.

2.1 Smart Thermostats

Smart Rewards leverages the demand response functionality of smart thermostats to provide residential load curtailment similar to the existing Residential AC Cycling Program. The smart thermostat functionality and operational strategy includes a pre-event cooling period followed an event-period increase in temperature setpoint, that varies by customer and thermostat manufacturer.

Smart thermostats are energy management tools that enable customers to regulate their HVAC energy consumption. Since these are programmable devices, customers can schedule the set points of their homes' cooling and heating systems, so they run during periods when customers need them. These devices can also sense occupancy and "learn" to adjust temperature settings of the home optimally in a way that may further reduce energy consumption. Because they are Wi-Fi-enabled, they allow customers to adjust settings from their smart devices for additional energy use control.

At the beginning of an event, the household temperature rises from the cooler temperature achieved during pre-cooling to the higher event-period setpoint before the air conditioner resumes operation. This can occur over a span of as much as 5 degrees. Once the new setpoint is achieved, cooling action re-commences, but the air conditioner draws less power due to the higher setpoint. In addition to the pre-cooling functionality, smart thermostats allow the customer to override the event at the thermostat by simply changing the existing set point at any time during the event. While this functionality is an important customer selling point for smart thermostat demand response programs, it also has the potential to lower demand response impacts. In particular, override rates tend to vary with weather conditions, and can undermine load reduction on the hottest days.

Dominion has been operating the residential AC Cycling demand response program since 2011. Although the two programs share a common objective, AC Cycling reduces demand by using a 50% adaptive cycling strategy with no pre-cooling. The 50% adaptive cycling strategy produces a different event-based indoor temperature response than the smart thermostat strategy described above and has a different load reduction pattern.

The two demand response programs operated on the same event schedule throughout the summer. Accordingly, DNV used the same analysis approach to calculate impacts for both programs, while accounting for differences in the two reduction strategies and technologies and taking advantage of the more detailed data available from the smart thermostats.

[2] Participants in the WeatherSmart Program allow the Company to make minor, short-term adjustments to the customer HVAC system via the smart thermostat.

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3 SMART THERMOSTAT REWARDS EVENTS AND CUSTOMER PARTICIPATION

3.1 Frequency

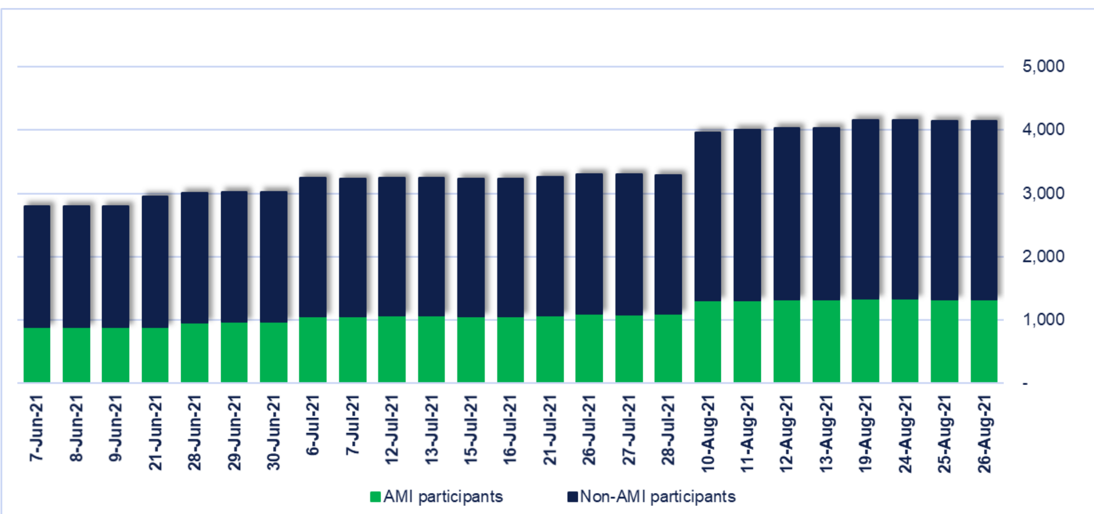
In 2021, there were 25 events spanning 71 event-hours. The 25 events were spread relatively evenly across June (7), July (8), and August (10). Dominion called 8 two-hour events, 13 three-hour events, and 4 four-hour events. The difference in load reduction as a function of consecutive event hours is discussed in Section 5.1, Ex Post Impacts.

3.2 Participation

Program enrollment began in March 2021. By the first event on June 7, there were 2,798 customers enrolled. By the end of the event season participation had increased by 30%, to 4,142. The savings estimated in this analysis reflect the mix of participants active on that event day. This could lead to change in load reduction estimates over time as the population changes. As the program grows, typical load reduction could increase; for example, if a higher proportion of participants are in high cooling load areas. More likely, the characteristics of participants will not change dramatically over time and any trends in load reduction estimates will be obscured by natural variation across events caused by weather and short-term customer behavior such as vacations.

The increase in participants over the event season and the proportion of participants with available AMI data are shown in Figure 3-1 The role of AMI data in the analysis is described in Section 4.1, AMI data, and Section 4.2, Methodology.

Figure 3-1. AMI and non-AMI participants by event



4 IMPACT ANALYSIS

4.1 Smart Thermostat Rewards Evaluation Data

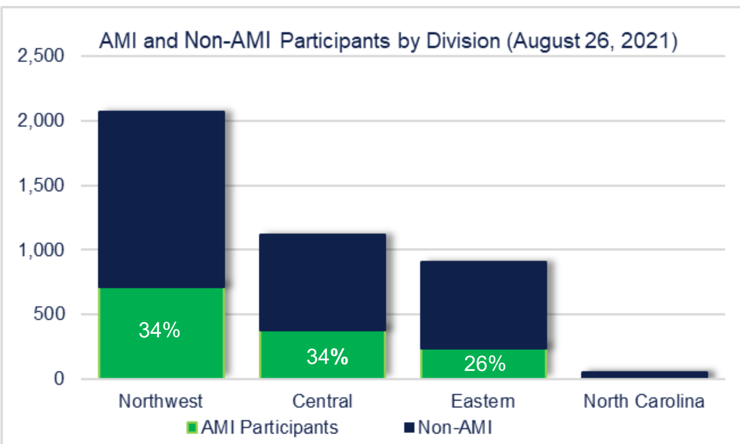
Four sources of data were used in the impact analysis: AMI whole-house energy consumption data, thermostat event control data, Smart Thermostat Rewards tracking data, and weather data. Each is described below. Descriptions and results of the data cleaning procedures are provided in Appendix A.

AMI Data

The analysis takes advantage of half-hourly whole-house consumption data collected from the AMI meters of all participating customers.

The distribution of AMI data across the Northwest, Central, and Eastern divisions, and in North Carolina is shown in Figure 4-1.[3] Roughly a third of participants have AMI data. AMI data coverage is important as it forms the basis of the impact estimates. AMI-based impact estimates are extrapolated to the division based on both weights developed from these participant counts as well as population-level knowledge of customer cooling consumption. This process is discussed further in Section 4.2, Methodology. The sample weights and weighting methodology is included in APPENDIX B.

Figure 4-1. AMI and non-AMI participants by division (August 21, 2021)



Thermostat Event Data

A record of controlled participants for each event provided by the implementer, including opt-outs.

Program Tracking Data

Program tracking data collected by the implementers is used to link the participant to their consumption data and division, to identify the participant's location (which is used to assign the appropriate weather station), and to confirm that thermostat control records match the Company's list of active participants.

3 Because there is only one North Carolina AMI participant and the total number of North Carolina program participants is so low, North Carolina observations are excluded from the analysis.

Weather Data

Hourly temperature and humidity data from NOAA is collected at the weather station associated with the Dominion office nearest to the household's service address.[4] Data from 7 weather stations was used in the analysis: Charlottesville-Albemarle Airport, Farmville Regional Airport, Norfolk International Airport, Richmond International Airport, Roanoke Regional Airport, Ronald Reagan Washington National Airport, and Washington Dulles International Airport.

4.2 Methodology

The following steps are used to calculate demand reduction impacts for the program:

1. For each account, hourly consumption on non-event days is modelled using AMI consumption data, temperature data, and humidity data. The regression specification estimates hourly consumption as a function of hour of the day, weekday/weekend and a five-hour, lagged average of THI for each hour. The estimated parameters from this regression analysis are used to predict a preliminary estimate of baseline consumption on event days for each AMI-enabled account.
2. Because regressions estimated on less extreme, non-event days tend to underestimate load on more extreme event days, a widely used pre-event adjustment is applied to estimated load at the customer/event level. The difference between actual consumption and the predicted baseline consumption during the third hourly interval prior to an event is added to the two-hour pre-event period and the event period. This adjusts the predicted baseline upward or downward to account for underestimation or overestimation of consumption on the afternoon of an event day. The difference during the third hour interval prior to an event was selected because it occurs prior to pre-cooling. If the adjustment were calculated using intervals during pre-cooling, load would be adjusted above the level that would have occurred in the absence of the program. Load reduction is calculated as the difference between the adjusted baseline consumption and actual consumption for each event hour for all AMI accounts.
3. The AMI sample used for this analysis is large but not selected at random. The geographic build-out of the AMI system determines which customers have hourly data. The sample is stratified at the division level to make sure each region gets proper representation regardless of the presence of AMI. As with the aggregation of any stratified sample, weights are required to reflect the presence of the population in the sample. Sample weights are calculated for each event by dividing the number of participants in the event logs by the number of participants with AMI consumption data for each division and event date. APPENDIX B. contains a description of the weighting method and final weights.
4. The load reduction for each AMI account is extrapolated to the full program population using the sample weights described above and a ratio estimation method that leverages the 2020 cooling consumption available for the full population of customers. Incorporating 2020 cooling consumption into the estimation method addresses possible differences in cooling system size between the sample and the population and decreases the standard errors of the load reduction estimate. The results are the calculated ex post impact for all event hours. The results of the ex post analysis are provided in Section 5.1 and APPENDIX C.

4 National Oceanic and Atmospheric Association (NOAA), National Centers for Environmental Information, Climate Data Online. Dominion Energy's peak planning condition is hour-ending 17 at 95°F at 43% RH, or 83.4 THI. Temperature Humidity Index = THI = Td – (0.55 – 0.55*RH) * (Td – 58) where Td is dry bulb temperature and RH is relative humidity. Source: PJM Glossary: http://www.pjm.com/Glossary.aspx

5. The ex post estimates are summarized in a linear regression model for each event-hour with the temperature humidity index (THI) as the independent variable. The predicted impact from these models for each event hour and THI are the basis of ex ante estimates that are used to estimate the program impacts at the Company's peak planning conditions. The ex ante results are provided in Section 5.3.

5 RESULTS

This section presents the results of the 2021 ex post and ex ante analyses.

5.1 Ex Post Impacts

Ex post impacts describe what actually happened during an event-hour and over each event. This is in contrast to the ex ante impacts which describe what is predicted to happen at the Company's peak load conditions.

The ex post per-participant kW impacts (demand reduction) are calculated for each event hour and for each event, on average across hours. The 2021 timeline in Figure 5-1 shows the average event-level impact (in kW) and maximum THI for each event. The red dashes are the event average THI and are plotted to provide the movement of this primary driver of load reduction. Average impacts for different event lengths are indicated by both color and shape. Light blue squares represent two-hour events, dark blue circles are for the three-hour events, and green triangles are for the four-hour events. In general, the magnitude of the impacts moves with THI, a combination of temperature and humidity. The length of an event is also quite important. While the impacts of the 3-hour events follow the general pattern set by the event THI values, seven of the eight 2-hour events fall above the THI trend, and all of the 4-hour events fall below the THI trend.

Figure 5-1. Timeline of 2021 events by average impacts and maximum event-day THI

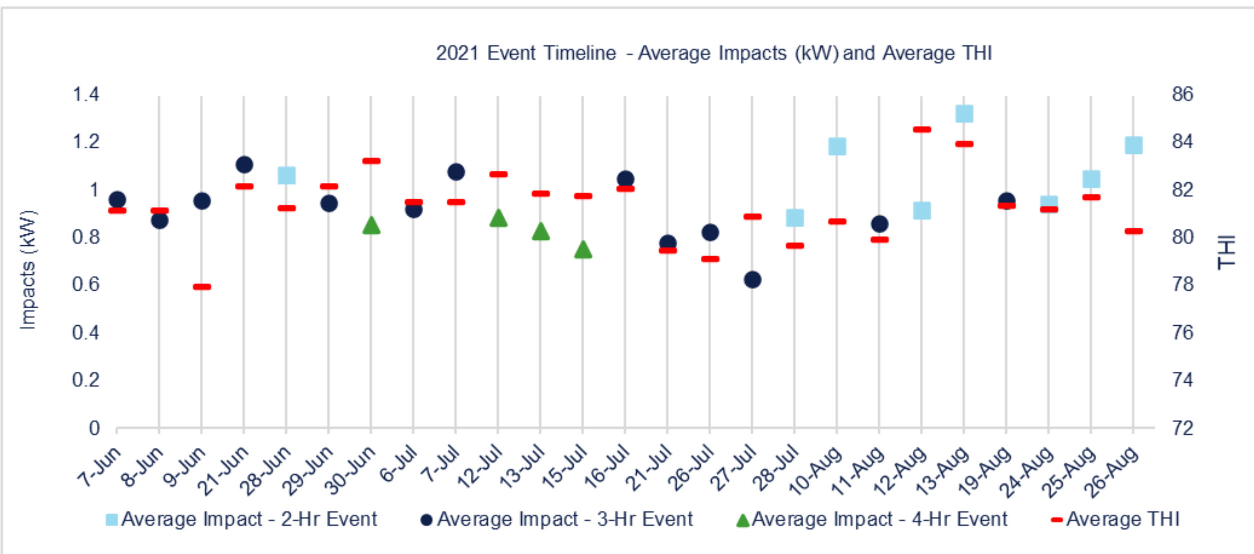
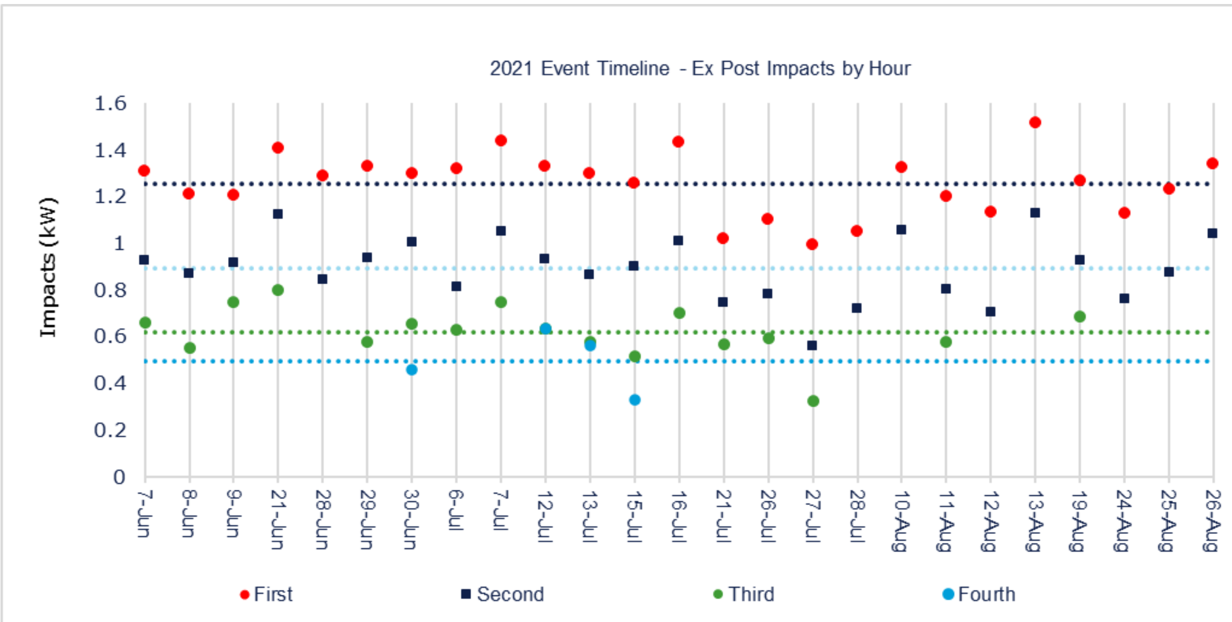


Figure 5-2 displays the estimated ex post load reduction by the event-hour for all events. The red circles represent load reduction during the first hour, dark blue squares are for the second hour, green circles are for the third hour, and light blue are for the fourth hour. The dotted lines represent the average load reduction for the first hour (red), second (dark blue), third (green), and fourth hours (light blue). The average first-hour load reduction across all events, regardless of start time, is 1.26 kW. On average across all events, load reduction in the second, third and fourth hours is 71%, 50%, and 38% of first hour load reduction, respectively.

Higher impacts are achieved in the first hour and drop as the event progresses because the pre-cooling produces the lowest internal temperature conditions of all event hours relative to subsequent event hours. During this initial period, the air conditioner system remains off and no cooling occurs. As the event progresses, the internal temperature of the house rises as much as 5 degrees until it reaches the higher event-period setpoint. The rate at which the house warms is a function of the physical characteristics of the house (insulation), occupancy, household activities, and shading effects. As the internal temperature of the household rises, cooling action will re-commence but the air conditioner will draw less power than during a non-event period due to the higher event-setpoint. Opt-out activity also increases as the temperature reaches and then stays at the higher temperature. Both processes contribute to the decrease in load reduction as the event proceeds, causing the dramatic and consistent pattern illustrated here.

Figure 5-2. Estimated load reduction by the order of event-hour for all events



Ex post impacts by day and hour are detailed in APPENDIX C., Table 5-4. Also shown are the number of participants, the opt out percent, the weighted average THI, the maximum daily temperature for Richmond, and a day number indicating the event's order for consecutive event days.

5.2 Event-Day Plots

The ex post plots in Figure 5-3 and Figure 5-4 on the following pages illustrate events with relatively high and low impacts, respectively. The plots are described briefly below.

The ex post estimate, or what happened during the event, is the difference between the adjusted baseline during the event (solid red line) and the event load (blue line). Impacts are calculated at the end of each event hour, referred to as hour-ending (HE). Impacts are determined by estimating the difference between the adjusted baseline load and the event load. The results are illustrated in time-series representations of:

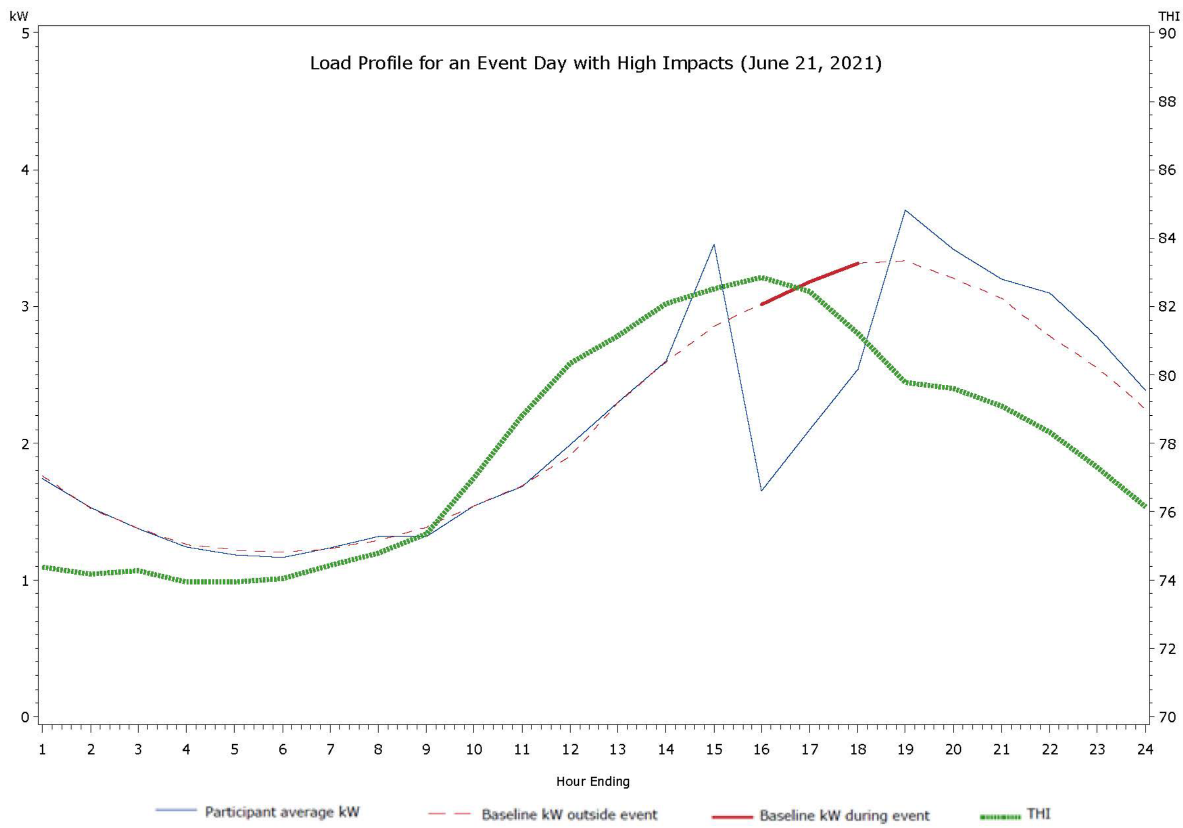
- ***Event-day load profile for the Smart Thermostat Rewards Program (blue line).*** The pre-cooling period immediately preceding the event is clearly visible at the first spike in kW load and is followed by a post-event load spike during snapback or rebound as the household returns to the non-event setpoint temperature.

- ***Baseline during the event (red line)***. The solid red line plots the baseline kW load for the event-day load curve during the event. The baseline is the modeled load for the specific event-day under similar weather conditions on non-event days.
- ***Reference load outside the event (red line).*** This line plots the baseline load profile before and after the event taken from participant AMI data.
- ***Event-day THI* (green line)**. Hourly THIs for the closest station to each AMI household are plotted to contextualize the relationship between load, temperature, and humidity.

5.2.1 Event load profile with a high impact

Figure 5-3 shows a high average impact event that occurred on June 21, 2021 (1.11 kW). is shown in. Pre-cooling begins at HE 14 and can be seen by the sharp increase in load for the following hour. The event begins at HE 15. Load reduction is taken as the difference between the adjusted baseline (red) and the actual power consumption (blue) at HE 16, 17, and 18. The baseline consumption prior to the event is slightly above 2.5 kW and the THI during the first event hour is 83. By contrast, THI is 79 for the low impact event shown in Figure 5-4. Load reduction in the first hour is 1.40 kW, and by the third hour has dropped to 0.80 kW.

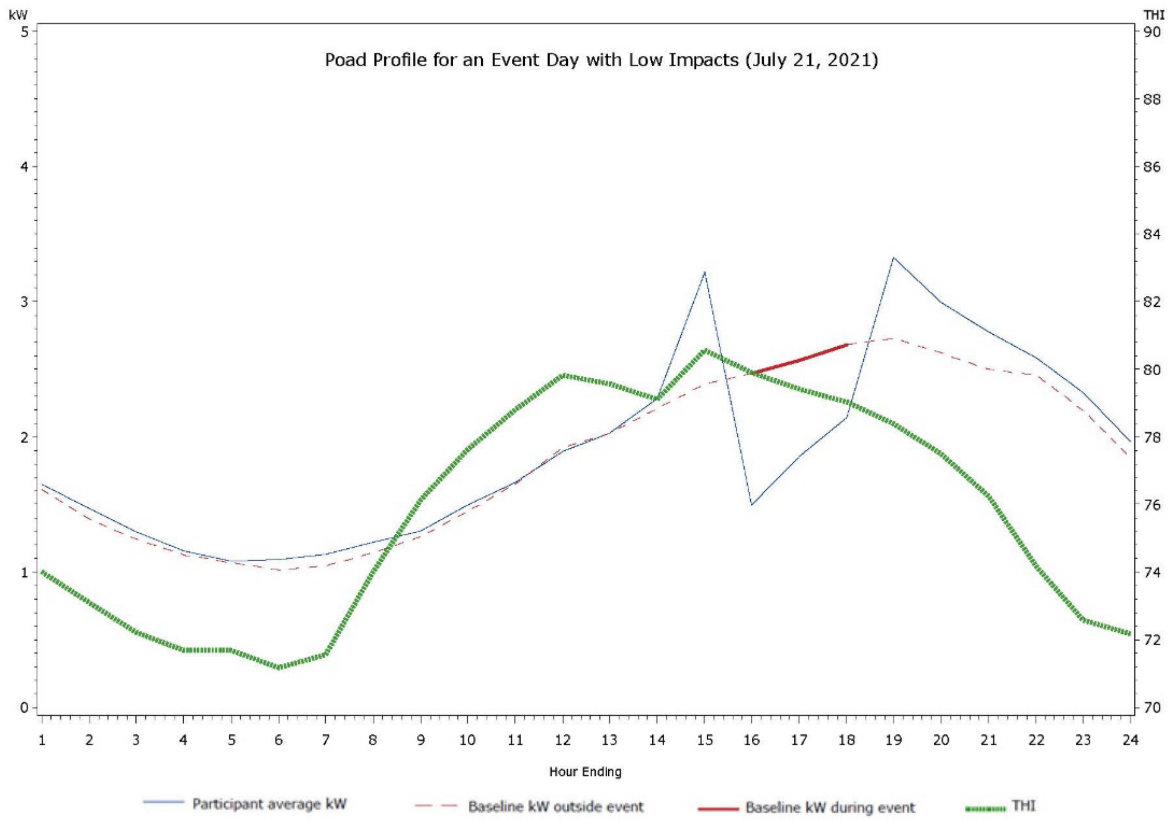
Figure 5-3. Load Profile for an event day with high impacts (June 21, 2021)



5.2.2 Event load profile with a low Impact

The second-lowest average impact (0.78 kW) occurred on July 21,2021 and is shown in Figure 5-4. This event had the second-lowest weighted THI during the first event hour (80) and the third-lowest average event THI (79). Similar to June 21, pre-cooling begins at HE 14 and can be seen by the sharp increase in load for the following hour. Baseline consumption prior to the event is approximately 1.75 kW (compared to 2.5 kW for the high-impact event shown above). The event begins at HE 15 and load reduction is visible for HE 16, 17, and 18. The baseline consumption prior to pre-cooling is slightly lower than the high-impact event. Load reduction in the first hour is 1.02 kW (vs 1.41 in the high-impact event), and by the third hour has dropped to 0.57 (vs. 0.80 kW).

Figure 5-4. Load Profile for an event day with low impacts (July 21, 2021)



5.3 Ex Ante Impacts

Ex ante impacts are the predicted load reduction for a range of weather conditions in kW at the company's peak planning conditions (83.4 THI during HE17). The predicted, or ex ante, impact of the Smart Thermostat Rewards Program for the Company's peak planning conditions was 1.07 kW. Figure 5-5 illustrates the relationship between hourly load estimates and THI for HE 15, 16, 17, 18, and 19. The ex ante estimates (dashed line) are plotted for each hour as a linear function of the ex post estimates (dots).

The diminishing impacts between the first hour (dark blue) and last hour (green) discussed previously for the ex post (what actually happened) and the ex ante (predicted) estimates are clearly illustrated. All but one event started in

HE 16 or later. As a result, 14 out of the 15 HE 16 load reduction estimates represent first-hour load reductions. Not surprisingly they are tightly clustered around the highest load reductions at any given THI. HE 17 is a mix of first and second hours, which explains the lower trend and the substantially greater variation of load reduction around the trend line. Similarly, HE 18 is a mix of second and third hours. The practical takeaway from this graph is that starting all events in HE 17 would maximize the ex ante estimate of load reduction.

Table 5-1 shows the predicted kW per participant impacts from the regression models across a range of THI values and event hours for the combined event day impacts, or event season. The predicted impact of 1.07 kW at the Company's peak conditions falls within the thick bordered boxes.

Figure 5-5. Ex post estimates (points) and predicted (ex ante) kW impacts for HE 16, 17, and 18

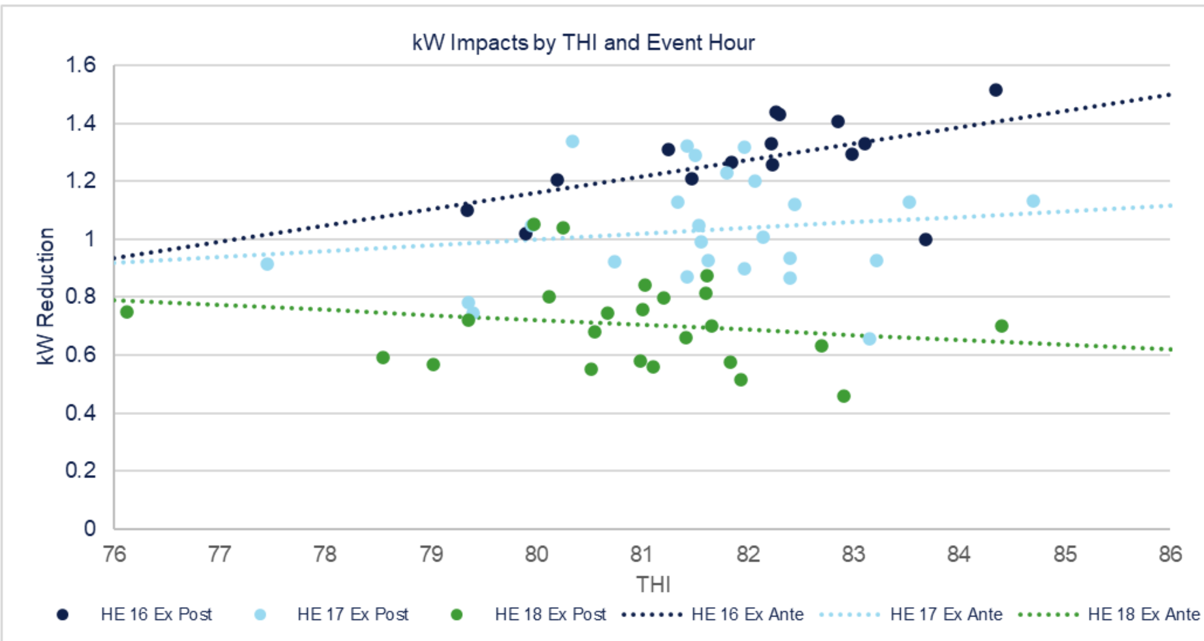


Table 5-1. 2021 Ex ante per participant impacts by THI and hour-ending

THI	HE15	HE16	HE17	HE18	HE19
76	1.30	0.94	0.92	0.79	0.48
77	1.30	0.99	0.94	0.77	0.49
78	1.30	1.05	0.96	0.76	0.49
79	1.30	1.10	0.98	0.74	0.50
80	1.30	1.16	1.00	0.72	0.51
81	1.30	1.22	1.02	0.70	0.51
82	1.30	1.27	1.04	0.69	0.52
83	1.30	1.33	1.06	0.67	0.52
84	1.30	1.39	1.08	0.65	0.53
85	1.30	1.44	1.10	0.64	0.54
86	1.30	1.50	1.12	0.62	0.54
87	1.30	1.56	1.14	0.60	0.55
88	1.30	1.61	1.16	0.58	0.55

APPENDIX A. AMI Data Cleaning and Attrition

5.4 AMI Data Cleaning

The analysis uses half-hourly AMI whole-house consumption data from all participants that have AMI meters. The AMI data is first subset to the accounts that appear in Smart Thermostat Rewards tracking data. Accounts that only appear in the AMI data before June 1, 2021, or only after September 30, 2021, and accounts which AMI observations did not overlap with the event data are removed.

5.5 AMI Data Attrition

Table 5-2 summarizes attrition for the AMI data.

Table 5-2. Attrition of participant AMI data (2021)

Data Prep	Number of Accounts	Remaining Population
Participant AMI accounts	1,599	
Number of accounts that appeared in the AMI data before June 1, 2021, only, or after September 30, 2021, only	-59	1,540
Accounts removed because the AMI and event data did not overlap (new AMI meters)	-15	
Accounts included in the analysis		1,525

APPENDIX B. EXTRAPOLATING THE AMI-ENABLED ACCOUNT IMPACTS TO THE PROGRAM POPULATION

5.6 Sample Weights

Sample weights are created to extrapolate the ami-enabled account impacts to the program population using the following method:

1. Construct a list of all event participants by division . The program tracking BI data is the source of the division.
2. Stratify the participants based on state and division.
3. Calculate weights based on the number of AMI participants for each event relative to all participants within each stratum.[5]

Table 5-3. Participants, AMI participants, and sample weights by division or State for August 26, 2021[6]

Division/State	Total Participants by Division	Total AMI Participants by Division	Percentage AMI by Division	Weight
Northwest	2,067	711	34%	2.91
Central	1,117	377	34%	2.96
Eastern	907	240	26%	3.78
North Carolina	51	1	2%	51.00
Total	4,142	1,329	32%	

[5] The weight within each stratum is the population divided by the total number of AMI meters in the study group.

[6] The table shows total participants and AMI participants in the last event on August 26, 2021.

APPENDIX C. Ex post Impact event data

Ex post impacts by day and hour are presented in . Also shown are the number of participants, the opt out percent, the weighted average THI, the maximum daily temperature for Richmond, and a day number indicating the event's order for consecutive event days.[7] The highest average event impact (1.32 kW) occurred on August 13, and the lowest (0.62) on July 27. The maximum impact for a single interval in 2021 was 1.51 kW on August 13. The greatest estimated impact is always during the first hour interval during the event and the impacts decrease during subsequent intervals.

Table 5-4. Smart Thermostat Rewards ex post impacts by event-day and hour (June 7–August 26, 2021)

Event Date	7-Jun	8-Jun	9-Jun	21-Jun	28-Jun	29-Jun	30-Jun	6-Jul	7-Jul	12-Jul	13-Jul	15-Jul	16-Jul	21-Jul
# of Participants	2,798	2,800	2,801	2,954	3,013	3,022	3,023	3,245	3,228	3,252	3,249	3,236	3,234	3,256
Consecutive Event-days		2	3			2	3		2		2		2	
Opt Out %	14%	15%	13%	18%	13%	17%	21%	20%	16%	20%	20%	20%	20%	15%
Weighted Avg THI	81	81	78	82	81	82	83	82	81	83	82	82	82	79
Richmond Max Temp	89	90	89	95	90	92	95	92	94	91	91	92	94	92
HE15							1.3							
HE16	1.31	1.21	1.2	1.41		1.33	1		1.44	1.33	1.29	1.26	1.43	1.02
HE17	0.92	0.87	0.91	1.12	1.29	0.93	0.65	1.32	1.05	0.93	0.86	0.9	1.01	0.74
HE18	0.66	0.55	0.75	0.8	0.84	0.58	0.46	0.81	0.75	0.63	0.58	0.52	0.7	0.57
HE19								0.63		0.63	0.56	0.33		
Average Impact (kW)	0.96	0.88	0.96	1.11	1.06	0.95	0.85	0.92	1.08	0.88	0.82	0.75	1.05	0.78

Event Date	26-Jul	27-Jul	28-Jul	10-Aug	11-Aug	12-Aug	13-Aug	19-Aug	24-Aug	25-Aug	26-Aug
# of Participants	3,306	3,306	3,295	3,970	4,000	4,031	4,029	4,160	4,156	4,145	4,142
Consecutive Event-days		2	3		2	3	4			2	3
Opt Out %	15%	17%	13%	12%	16%	12%	15%	17%	13%	13%	12%
Weighted Avg THI	79	81	80	81	80	85	84	81	81	82	80
Richmond Max Temp	88	89	91	91	93	94	94	92	95	92	93
HE15											
HE16	1.1						1.51	1.27			
HE17	0.78	0.99	1.05	1.32	1.2	1.13	1.13	0.93	1.13	1.23	1.34
HE18	0.59	0.56	0.72	1.05	0.8	0.7		0.68	0.76	0.87	1.04
HE19		0.32			0.57						
Average Impact (Kw)	0.82	0.62	0.88	1.19	0.86	0.92	1.32	0.96	0.94	1.05	1.19

7 The THI reported in Table 5-5 is the THI at the weather station designated by Dominion for each AMI participant weighted to the population of RT demand response participants.

About DNV

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