2.4 Plug Load End Use

2.4.1 Smart Strip Plug

Measure Description

This measure realizes energy savings by replacing an existing power strip with a current-sensing master/controlled advanced power strip (or smart strip). These multi-plug power strips have the ability to automatically disconnect specific connected loads depending upon the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. By disconnecting, the standby load of the controlled devices, the overall load of a centralized group of equipment (i.e. entertainment centers and home office) can be reduced.

This measure characterization provides a single prescriptive savings assumption based on office and entertainment savings from a 2011 NYSERDA Advanced Power Strip Research Report and weightings and in service rates based on EmPower evaluations.

Savings Estimation Approach

Gross annual electric energy savings are assigned per unit as follows:

$$\Delta kWh/year = \left(kWh/year_{office} \times Weighting_{office} + kWh/year_{ent} \times Weighting_{ent}\right) \times ISR$$

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

$$\Delta kW = \frac{\Delta kWh/year}{hours_{off}} \times CF$$

Where:

ΔkWh/year = gross annual electric energy savings
ΔkW = gross coincident demand reductions
kWh_{office} = estimated energy savings from using an advance power strip (APS) in a home office
$Weighting_{office}$ = relative penetration of computers
kWh_{ent} = estimated energy savings from using an APS in a home entertainment system
$Weighting_{ent}$ = relative penetration of televisions
ISR = in-service rate
$hours_{off}$ = annual hours when controlled standby loads are turned off
CF = peak coincidence factor

Input Variables

Table 15: Input Values for Smart Strips Savings Calculations

Component	Type	Value	Unit	Source(s)
kWh_{office}	Fixed	31.0	kWh/year	Mid-Atlantic TRM 2016, p. 279[54]
$Weighting_{office}$	Fixed	0.41	-	Mid-Atlantic TRM 2016, p. 279
kWh_{ent}	Fixed	75.1	kWh/year	Mid-Atlantic TRM 2016, p. 279
$Weighting_{ent}$	Fixed	0.59	-	Mid-Atlantic TRM 2016, p. 279
ISR	Fixed	0.89	-	Mid-Atlantic TRM 2016, p. 279
$hours_{off}$[55]	Fixed	6,351	hours/year	Mid-Atlantic TRM 2016, p. 280
CF[56]	Fixed	0.80	-	Mid-Atlantic TRM 2016, p. 280

Default Savings

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

The default gross annual electric energy savings will be assigned as follows:

$$\Delta kWh/year = \left(kWh/year_{office} \times Weighting_{office} + kWh/year_{ent} \times Weighting_{ent}\right) \times ISR$$

$$= (31.0\ kWh/year \times 0.41 + 75.1\ kWh/year \times 0.59) \times 0.89 = 50.8\ kWh/year$$

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

$$\Delta kW = \frac{\Delta kWh/year}{hours_{off}} \times CF$$

$$= \frac{50.8\ kWh/year}{6{,}351\ hours/year} \times 0.80$$

$$= 0.0064\ kW$$

[54] Advanced Power Strip Research Report, 2011. NYSERDA. https://www.nyserda.ny.gov/-/media/Files/EERP/Residential/Power-Management-Research-Report.pdf. Note that estimates are not based on pre/post metering but on analysis based on frequency and consumption of likely products in active, standby and off modes. This measure should be reviewed frequently to ensure that assumptions continue to be appropriate.

[55] Mid-Atlantic TRM 2016, p. 280. EmPower 2012 Residential Retrofit evaluation.

[56] Ibid.

Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2016, p. 278-280.

3 RESIDENTIAL HEAT PUMP UPGRADE PROGRAM

Dominion's Residential Heat Pump Upgrade program offers incentives to residential homeowners to install a new, higher efficiency (ENERGY STAR® rated) heat pump unit. Both air sourced and geothermal heat pumps are eligible. The measure could be installed in either an existing or new home. The installation is assumed to occur during a natural time of sale of the heat pumps. Program requirements state that homes with non-electric heating systems are not eligible for this program.[57] Therefore, homes with central air conditioning as the baseline cooling system are assumed to have electrical resistance heat as their baseline heating systems.

The baseline efficiencies used in this program are based on federal minimum values provided in 2012 International Energy Conservation Code® (IECC). The existing heat pump or air conditioner efficiencies will not be used as baseline efficiencies in all categories of measure classifications: early replacement, normal replacement, replacement on burn-out.

3.1 Heating Ventilation and Air Conditioning (HVAC) End Use

3.1.1 Heat Pump Upgrade – Air Source

Measure Description

This measure realizes energy savings by installing a new air source heat pump meeting the efficiency standards presented in Table 16. Heat pumps with SEER ratings of 14.5 or greater and HSPF ratings of 8.2 or greater qualify in existing houses. Heat pumps with SEER ratings of 15 or greater and HSPF ratings of 8.2 or greater qualify in new homes.[58]

Savings Estimation Approach

Gross annual electric energy savings for time of sale and early replacement units are calculated according to the following equation. The calculation for early replacement units in this manual deviates from that in the Mid-Atlantic TRM 2016, which has two separate approaches to calculate the initial phase savings (existing to efficient savings) and remain phase savings (new baseline to efficient savings). DNV GL conducts a single calculation at the time of the measure installation to determine the measure's annualized savings. That savings is then aggregated with other measure savings and the aggregated value is tracked over time. We do not keep records of that individual participant's savings over time, to discount it at the appropriate time for the new baseline. In the case of early replacement units, DNV GL assumes the baseline to be at the new Federal minimum requirement to be conservative with the savings that are reported.

$$\Delta kWh/year = \frac{FLH_{cool} \times BtuH \times \left(\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}}\right)}{1{,}000\ W/kW} + \frac{FLH_{heat} \times BtuH \times \left(\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right)}{1{,}000\ W/kW}$$

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[57] Residential Heat Pump Upgrade Program website. https://www.dom.com/library/domcom/pdfs/virginia-power/ways-to-save/residential-heat-pump-upgrade-rebate-form.pdf. Accessed 7/14/2016

[58] Ibid

Gross coincident demand reductions savings for **time of sale** and **early replacement** units are calculated according to the following equation:

$$\Delta kW = \frac{BtuH \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF}{1{,}000\, W/kW}$$

Where:

ΔkWh/year = gross annual electric energy savings

ΔkW = gross coincident demand reductions. The above equation is for estimating the summer peak demand reduction. At present, both VA and NC do not consider the winter peak demand in their utility tariff structure. However, when needed, this reference manual can be updated with algorithm on winter peak demand reduction calculation.

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

FLH_{heat} = annual heating FLH

Btu/h = capacity of air source heat pump (1 ton = 12,000 Btu/h). Btu/h appearing in energy savings and peak demand reduction equations above refers to the cooling nameplate rated capacity, converted to Btu/h.

$SEER_{base}$ = seasonal energy efficiency ratio (SEER) of baseline (pre-retrofit) air source heat pump

$SEER_{ee}$ = SEER of efficient (post-retrofit) air source heat pump

$HSPF_{base}$ = heating seasonal performance factor (HSPF) of baseline air source heat pump

$HSPF_{ee}$ = HSPF of efficient air source heat pump

EER_{base} = energy efficiency ratio (EER) of baseline unit

EER_{ee} = EER of efficient unit

CF = summer peak coincidence factor

For heat pumps less than 65,000 Btu/h capacity, there are no documented values available for EER_{base} and EER_{ee}. However, they can be estimated using Equation 3 in Appendix E.

The above equation for energy savings estimation (ΔkWh) is applicable for heat pump units less than 65,000 Btu/h. According to the program application, the program rebated system size ranges from 1.5 tons (18,000 Btu/h) to 5 tons (60,000 Btu/h), therefore we do not expect to encounter systems outside of this range. If the program encounters higher capacity units (greater than 65,000 Btu/h), then the said equation can be modified with EER values in place of SEER (for cooling energy savings part) and COP values in place of HSPF (for heating energy savings part). The appropriate values for EER and COP are provided in either the customer application or Table 86. For estimating the heating energy savings portion, COP values will be selected at '47°F db/43°F wb outdoor air' (refer to Column Sub-category or Rating Condition).

Input Variables

Table 16: Input Values for Air Source Heat Pump Upgrade Savings Calculations

Component	Type	Value	Unit	Source(s)
FLH_{cool}	Fixed	Richmond, VA = 842; Charlotte, NC = 939; See Table 131	hours/year	Mid-Atlantic TRM 2016, p. 104; ENERGY STAR® calculator[59]
FLH_{heat}	Fixed	Richmond, VA = 789; Charlotte, NC = 744; See Table 131	hours/year	Mid-Atlantic TRM 2016, p. 106
Btuh	Variable	See customer application	Btu/h	Customer application
		Richmond, VA default = 28,720 Charlotte, NC default = 30,889		Dominion's portfolio of residential energy efficiency programs program[60]
$SEER_{base}$	Fixed	See Table 132 for federal minimum baseline	Btu/watt-hour	Mid-Atlantic TRM 2016, p. 105[61]
$SEER_{ee}$	Variable	See customer application	Btu/watt-hour	Customer application
		Default = 14.5		Dominion program requirements[62]
$HSPF_{base}$	Fixed	See Table 132 for federal minimum baseline	Btu/watt-hour	Mid-Atlantic TRM 2016, p. 106[63]
$HSPF_{ee}$	Variable	See customer application	Btu/watt-hour	Customer application
		Default = 8.2		Dominion program requirements[64]
EER_{base}	Variable	See Table 132 for federal minimum baseline	Btu/watt-hour	Mid-Atlantic TRM 2016, p. 108[65]
EER_{ee}	Variable	See customer application	Btu/watt-hour	Customer application
		Default value 12.0.		Dominion program requirements[66]
CF	Fixed	0.69	-	Mid-Atlantic TRM 2016, p.108[67]

[59] ENERGY STAR®. Heat Pumps "Savings Calculator," Heating Usage, http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=EP. Accessed 7/14/2016.

[60] DNV GL reviewed the customer application data on heat pump size of participants in the Residential AC Cycling Program, Residential Duct Testing Program, Residential Heat Pump Upgrade Program and Residential Heat Pump Tune-Up Programs from program start dates through the end of 2015 (12/31/2015). The average heat pump capacity in VA (2.39 ton or 28,720 Btu/h) was calculated using data from 85,412 air source heat pump units enrolled in these programs in Virginia. The average capacity in NC (2.57 tons or 30,889 Btu/h) was calculated

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 projects will be assigned according to the following calculation:

Richmond, VA:

$$\Delta kWh/year = \frac{FLH_{cool} \times Btuh \times \left(\frac{1}{SEER_{base}} - \frac{1}{SEER_{ee}}\right)}{1{,}000\ W/kW} + \frac{FLH_{heat} \times Btuh \times \left(\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right)}{1{,}000\ W/kW}$$

$$\Delta kWh/year_{VA} = \frac{842\ hours/year \times 28{,}720\ Btu/h \times \left(\frac{1}{13.0} - \frac{1}{14.5}\right)}{1{,}000\ W/kW} + \frac{789\ hours/year \times 28{,}720\ Btu/h \times \left(\frac{1}{7.7} - \frac{1}{8.2}\right)}{1{,}000\ W/kW}$$

$$= 372\ kWh/year$$

Charlotte, NC:

$$\Delta kWh/year_{NC} = \frac{939\frac{hours}{year} \times 30{,}889\ Btu/h \times \left(\frac{1}{13.0} - \frac{1}{14.5}\right)}{1{,}000\ W/kW} + \frac{744\frac{hours}{year} \times 30{,}889\ Btu/h \times \left(\frac{1}{7.7} - \frac{1}{8.2}\right)}{1{,}000\ W/kW}$$

$$= 413\ kWh/year$$

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

$$\Delta kW = \frac{Btuh \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right) \times CF}{1{,}000\ W/kW}$$

Richmond, VA:

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using data from 5,292 air source heat pump units enrolled in these programs in North Carolina. The average capacity was converted to Btu/h using the conversion factor of 12,000 Btu/h per ton. These values were not updated for 2016 as average heat pump capacity varied little beween 2014 and 2015.

[61] Mid-Atlantic TRM 2016, p. 105. Minimum Federal Standard

[62] Dominion Heat Pump Updgrade program description. https://www.dom.com/heatpumpupgrade. Accessed 7/14/2016.

[63] Mid-Atlantic TRM 2016, p. 106. Minimum Federal Standard

[64] Dominion Heat Pump Updgrade program description. https://www.dom.com/heatpumpupgrade. Accessed 7/14/2016.

[65] The federal Standard does not currently include an EER component. The value is approximated based on the SEER standard (14) and equals EER 11.8. To perform this calculation we are using this formula: (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder).

[66] Estimated from SEER = 15.0 with the help of the following algorithm: EER = (-0.02 * SEER^2) + (1.12 * SEER)

[67] Mid-Atlantic TRM 2016, p. 108. Based on BG&E's "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the Maryland Peak Definition coincidence factor is 0.69.

$$\Delta kW_{VA} = \frac{28{,}720\ Btu/h \times \left(\frac{1}{11.0} - \frac{1}{12.0}\right) \times 0.69}{1{,}000\ W/kW}$$

$$= 0.15\ kW$$

Charlotte, NC:

$$\Delta kW_{NC} = \frac{30{,}889\ Btu/h \times \left(\frac{1}{11.0} - \frac{1}{12.0}\right) \times 0.69}{1{,}000\ W/kW}$$

$$= 0.16\ kW$$

Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2016, p. 103-110.

3.1.2 Heat Pump Upgrade – Geothermal

Measure Description

This measure realizes energy savings for the installation of a new geothermal heat pump that replaces an existing air source heat pump or geothermal heat pump. The measure could be installed in an existing or new home. The baseline is always assumed to be a new baseline Air Source Heat Pump. The installation is assumed to occur during a natural time of sale of the heat pump.

One way this manual deviates from the Mid-Atlantic TRM 2016 is that a desuperheater is not eligible to participate in this program.

Savings Estimation Approach

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

$$\Delta kWh/year = \frac{FLH_{cool} \times Btuh \times \left(\frac{1}{SEER_{base}} - \frac{1}{EER_{PLee}}\right)}{1{,}000\ W/kW} + \frac{FLH_{heat} \times Btuh \times \left(\frac{1}{HSPF_{base}} - \left(\frac{1}{(COP_{PLee} \times 3.412\ Btu/Wh)}\right)\right)}{1{,}000\ W/kW}$$

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

$$\Delta kW = \frac{Btuh \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{FLee}}\right) \times CF}{1{,}000\ W/kW}$$

Where:

ΔkWh/year = gross annual electric energy savings
ΔkW = gross coincident demand reductions. The above equation is for estimating the summer peak demand reduction. At present, both VA and NC do not consider the winter peak demand in their utility tariff structure. However, when needed, this reference manual can be updated with algorithm on winter peak demand reduction calculation.
FLH_{cool} = annual cooling full load hours (FLH)
FLH_{heat} = annual heating FLH
Btuh = capacity of geothermal heat pump (1 ton = 12,000 Btu/h). Btuh appearing in energy savings and peak demand reduction equations above refers to the cooling nameplate rated capacity, converted to Btu.
$SEER_{base}$ = seasonal energy efficiency ratio (SEER) of baseline unit
EER_{base} = energy efficiency ratio (EER) of baseline unit
EER_{PLee} = part load energy efficiency ratio (EER) of efficient (post-retrofit) unit[68]

[68] Mid-Atlantic TRM 2016, p. 157. As per conversations with David Buss territory manager for Connor Co, the SEER and COP ratings of an ASHP equate most appropriately with the part load EER and COP of a GSHP.

EER_{FLee} = full load EER of efficient unit[69]
$HSPF_{base}$ = heating system performance factor (HSPF) of baseline unit
COP_{PLee} = part load coefficient of performance (COP) of efficient unit[70]

CF = summer peak coincidence factor

[69] Mid-Atlantic TRM 2016, p. 160. As per conversations with David Buss territory manager for Connor Co, the EER rating of an ASHP equate most appropriately with the full load EER of a GSHP.

[70] Mid-Atlantic TRM 2016, p. 158. As per conversations with David Buss territory manager for Connor Co, the SEER and COP ratings of an ASHP equate most appropriately with the part load EER and COP of a GSHP.

Input Variables

Table 17: Input Values for Geothermal Heat Pump Upgrade Savings Calculations

Component	Type	Value	Unit	Source(s)
FLH_{cool}	Fixed	Richmond, VA = 842; Charlotte, NC = 939; See Table 131	hours/year	ENERGY STAR® calculator[71]
FLH_{heat}	Fixed	Richmond, VA = 789; Charlotte, NC = 744; See Table 131	hours/year	ENERGY STAR® calculator[72]
Btuh	Variable	See customer application	Btu/h	Customer application
		Default = 38,467		Dominion's Residential Heat Pump Upgrade program[73]
$SEER_{base}$	Variable	See Table 132 for federal minimum baseline	Btu/watt-hour	Mid-Atlantic TRM 2016, p. 157[74]
EER_{base}	Variable	See Table 132 for federal minimum baseline	Btu/watt-hour	Mid-Atlantic TRM 2016, p. 108[75]
EER_{PLee}	Variable	See customer application	Btu/watt-h	Customer application
		Default see Table 18		ENERGY STAR® geothermal heat pump key product criteria
EER_{FLee}	Variable	See customer application	Btu/watt-h	Customer application
		Default see Table 18		ENERGY STAR® geothermal heat pump key product criteria
$HSPF_{base}$	Variable	See Table 132 for federal minimum baseline	-	Mid-Atlantic TRM 2016, p. 158[76]
COP_{PLee}	Variable	See customer application	-	Customer application
		Default see Table 18		ENERGY STAR® geothermal heat pump key product criteria
CF	Fixed	0.69	-	Mid-Atlantic TRM 2015, p. 160[77]

[71] ENERGY STAR®. Heat Pumps "Savings Calculator," Heating Usage, http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=EP. Accessed 7/14/2016

[72] Ibid.

[73] The average capacity (3.21 tons or 38,467 Btu/h) was calculated using data from 140 geothermal heat pump units enrolled in the Dominion Residential Heat Pump Upgrade program in Virginia and North Carolina. This average reflects the number of geothermal heat pump units with a listed capacity from the program start date in May 2010

through the end of 2015 (12/31/2015). At the end of 2015, there were 16 North Carolina geothermal heat pump participants in this program. The average capacity was converted to Btu/h using the conversion factor of 12,000 Btu/h per ton.

[74] Mid-Atlantic TRM 2016, p. 157. Minimum Federal Standard as of 1/1/2015

[76] The federal Standard does not currently include an EER component. The value is approximated based on the SEER standard (14) and equals EER 11.8. To perform this calculation we are using this formula: (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder).

[76] Mid-Atlantic TRM 2016, p. 158. Minimum Federal Standard as of 1/1/2015

[77] Mid-Atlantic TRM 2016, p. 160. Based on BG&E's "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research, the Maryland Peak Definition coincidence factor is 0.69.

Table 18. Default Geothermal Source Heat Pump System Efficiencies

System Type[78]	2012 IECC Baseline Requirement[79]		ENERGY STAR® Tier 3 Requirements[80] (Effective December 1, 2012)	
	EERbase	COPbase	EERee, EERPLee, EERFLee	COPee, COPPLee
Air Source Heat Pump	See Table 132		-	-
Closed Loop Water-to-Air	12.0	3.6	17.1	3.6
Water source	12.0	3.6[81]	17.1	3.6
Ground water source	12.0	3.6	21.1	4.1
Closed Loop Water-to-Water	10.6	3.1	16.1	3.1
Water source, water to water	10.6	3.1	16.1	3.1
Ground source, Brine to water	12.1	2.5	20.1	3.5
Direct Geoexchange (DGX)[82]				
Ground source	10.6	3.1	16.0	3.6
ISO 13256 consists of the following parts, under the general title water-source heat pumps — testing and rating for performance: — Part 1: Water-to-air and brine-to-air heat pumps — Part 2: Water-to-water and brine-to-water heat pumps Direct GeoExchange Heat Pumps (DGX) are tested according to ANSI/AHRI Standard 870 (formerly ARI Standard 870)				

The following definitions, as provided in ENERGY STAR® website, refer to the terminologies used in Table 18.

[78] GSHP types were mapped from ENERGY STAR® Tier 3 Geothermal Heat Pump Key Product Criteria (Effective January 1, 2012) to the 2012 International Energy Conservation Code (IECC) GSHP system types. Where the categories are not direct one-to-one, conservative efficiency values were selected.

[79] 2012 International Energy Conservation Code (IECC), Table C403.2.3(2) Minimum Efficiency Requirements: Electrically Operated Unitary and Applied Heat Pumps, p. C-40 – C-41. International Code Council.

[80] Geothermal heat pump key product criteria, Tier 3 Requirements (Effective January 1, 2012). ENERGY STAR®. http://www.energystar.gov/index.cfm?c=geo_heat.pr_crit_geo_heat_pumps. Accessed January 6, 2015.

[81] 2012 IECC heating efficiency COP value for water-to-air, water source ground source heat pump was 4.2, more efficient than the ENERGY STAR® Tier 3 heating efficiency COP value for the same type of system. It has proven to be difficult to map the 2012 IECC GSHP systems with those eligible for ENERGY STAR®; we are assigning the baseline heating efficiency COP value for water-to-air equal to that of the ENERGY STAR® Tier 3 case, a COP value of 3.6.

[82] There is no code minimum equivalent of the DGX. DGX baseline system efficiency has been set to the most conservative 2012 IECC baseline system efficiency, water-to-water, water source, water to water system with an EER of 10.6 and a COP of 3.1.

Closed Loop

A ground heat exchange method in which the heat transfer fluid is permanently contained in a closed piping system. Also called a ground-loop system.

Open Loop

A ground heat exchange method in which the heat transfer fluid is part of a larger environment. The most common open loop systems use ground water, reclaimed water, or surface water as the heat transfer medium. Also called a ground-water system.

Water-to-Air

A geothermal heat pump model that provides space conditioning primarily by the use of an indoor air heat exchange coil. Water-to-air models may also provide domestic water heating and hydronic space heating by using desuperheater and/or demand water heating functions.

Water-to-Water

A geothermal heat pump model that provides space conditioning and/or domestic water heating by the use of indoor refrigerant-to-water heat exchanger(s). Water-to-water models may provide domestic water heating by using desuperheater and/or demand water heating functions.

Direct Geoexchange (DGX)

A geothermal heat pump model in which the refrigerant is circulated in pipes buried in the ground or submerged in water that exchanges heat with the ground, rather than using a secondary heat transfer fluid, such as water or antifreeze solution in a separate closed loop.

ENERGY STAR® specifies three different tiers of efficiency requirement based on their effective dates of implementation. Tier 1 requirements became effective December 1, 2009. The second phase of this specification, Tier 2, became effective January 1, 2011. Tier 3 requirements became effective January 1, 2012. Tier 1 specified values will be used as default values.

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:

Richmond, VA:

$$\Delta kWh/year = \frac{FLH_{cool} \times BtuH \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{ee}}\right)}{1{,}000\ W/kW} + \frac{FLH_{heat} \times BtuH \times \left(\frac{1}{COP_{base}} - \frac{1}{COP_{ee}}\right)}{3.412\ BtuH/W\ \times 1{,}000\ W/kW}$$

$$\Delta kWh/year_{VA} = \frac{842\ hrs/yr \times 38{,}467 Btuh \times \left(\frac{1}{12.0} - \frac{1}{17.1}\right)}{1{,}000\ W/kW} + \frac{789\ hrs/yr \times 38{,}467 Btuh \times \left(\frac{1}{3.6} - \frac{1}{3.6}\right)}{3.412\ BtuH/W\ \times 1{,}000\ W/kW}$$

$$= 794\ kWh/year$$

Charlotte, NC:

$$\Delta kWh/year_{NC} = \frac{939\,hrs/yr \times 38{,}467Btuh \times \left(\frac{1}{12.0} - \frac{1}{17.1}\right)}{1{,}000\;W/kW} + \frac{744\,hrs/yr \times 38{,}467\;Btuh \times \left(\frac{1}{3.6} - \frac{1}{3.6}\right)}{3.412\;BtuH/W\;\times 1{,}000\;W/kW}$$

$$= 885\;kWh/year$$

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

$$\Delta kW = \frac{BtuH \times \left(\frac{1}{EER_{base}} - \frac{1}{EER_{FLee}}\right) \times CF}{1{,}000\;W/kW}$$

$$\Delta kW_{VA} = \frac{38{,}467BtuH \times \left(\frac{1}{12.0} - \frac{1}{17.1}\right) \times 0.69}{1{,}000\;W/kW}$$

$$= 0.650\;kW$$

$$\Delta kW_{NC} = \frac{38{,}467BtuH \times \left(\frac{1}{12.0} - \frac{1}{17.1}\right) \times 0.69}{1{,}000\,\frac{W}{kW}}$$

$$= 0.650\;kW$$

Source(s)

The primary sources for this deemed savings approach are the Mid-Atlantic TRM 2016, p. 155 - 162, ENERGY STAR® Tier 3 Geothermal Heat Pump Key Product Criteria, accessed on January 6, 2015, and the 2012 International Energy Conservation Code (IECC).

4 RESIDENTIAL HEAT PUMP TUNE-UP PROGRAM

Dominion's Residential Heat Pump Tune-Up program offers incentives to residential homeowners to have a contractor tune-up their existing air source heat pump once every five years to achieve maximum operational performance.

Measure Description

This measure realizes energy savings by tuning up an existing air source heat pump system.

Savings Estimation Approach

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

$$\Delta kWh/year = tonnage \times \frac{12\ kBtu/hr}{ton} \times \left(\frac{1}{SEER} \times FLH_{cool} + \frac{1}{HSPF} \times FLH_{heat}\right) \times SF$$

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

$$\Delta kW_{cool} = tonnage \times \frac{12\ kBtu/hr}{ton} \times \frac{1}{EER} \times SF$$

$$\Delta kW_{heat} = tonnage \times \frac{12\ kBtu/hr}{ton} \times \frac{1}{HSPF} \times SF$$

$$\Delta kW = \max(\Delta kW_{cool}, \Delta kW_{heat})$$

Where:

ΔkWh/year = gross annual electric energy savings
ΔkW = gross coincident demand reductions
Capacity = cooling capacity in tons
SEER = seasonal energy efficiency ratio of heat pump
EER = energy efficiency ratio of heat pump
HSPF = heating seasonal performance factor of heat pump
FLH_{cool} = annual cooling full load hours (FLH)

FLH_{heat} = annual heating FLH

SF = savings factor attributed to tune-up

Input Variables

Table 19: Input Values for Heat Pump Tune-Up Savings Calculations

Componen t	Type	Value	Unit	Source(s)
Capacity	Variable	See customer application	tons	Customer application
		Richmond, VA default = 2.39 Charlotte, NC default = 2.57		Dominion's portfolio of residential energy efficiency programs program[83]
SEER	Variable	Default see Table 132	Btu/watt-hour	Mid-Atlantic TRM 2016, p. 105[84] Actual customer application SEER is inaccurate in most cases because of aging system.
EER	Variable	Default see Table 132	Btu/watt-hour	Mid-Atlantic TRM 2016, p. 108[85] Actual customer application EER is inaccurate in most cases because of aging system.
HSPF	Variable	Default see Table 132	Btu/watt-hour	Mid-Atlantic TRM 2016, p. 106[86] Actual customer application HSPF is inaccurate in most cases because of aging system.
FLH_{cool}	Fixed	Richmond, VA = 842; Charlotte, NC = 939;	hours/year	See Table 131 Mid-Atlantic TRM 2016, p. 104-105; ENERGY STAR® calculator[87]
FLH_{heat}	Fixed	Richmond, VA = 789; Charlotte, NC = 744; See Table 131	hours/year	See Table 131 Mid-Atlantic TRM 2016, p. 106
SF	Fixed	0.05	-	Massachusetts TRM 2014, p. 74[88]

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:

$$\Delta kWh/year = tonnage \times \frac{12\ kBtu/hr}{ton} \times \left(\frac{1}{SEER} \times FLH_{cool} + \frac{1}{HSPF} \times FLH_{heat}\right) \times SF$$

Richmond, VA:

$$\Delta kWh/year_{VA} = 2.39\ tons \times \frac{12\ kBtu/hr}{ton} \times \left(\frac{1}{14} \times 842\ hours/year + \frac{1}{8.2} \times 789 hours/year\right) \times 0.05$$
$$= 224\ kWh/year$$

Charlotte, NC:

$$\Delta kWh/year_{NC} = 2.57\ tons \times \frac{12\ kBtu/hr}{ton} \times \left(\frac{1}{14} \times 939\ hours/year + \frac{1}{8.2} \times 744\ hours/year\right) \times .05$$
$$= 243\ kWh/year$$

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

$$\Delta kW_{cool} = capacity\ \times 12 \frac{kBtu}{hr}/ton \times \frac{1}{EER} \times SF$$

$$\Delta kW_{heat} = capacity\ \times\ 12 \frac{kBtu}{hr}/ton \times \frac{1}{HSPF} \times SF$$

$$\Delta kW = \max(\Delta kW_{cool}, \Delta kW_{heat})$$

Richmond, VA:

$$\Delta kW_{cool,VA} = 2.39\ tons\ \times 12 \frac{kBtu}{hr}/ton \times \frac{1}{11.8} \times 0.05$$
$$= 0.122\ kW$$

$$\Delta kW_{heat,NC} = 2.39\ \times\ 12 \frac{kBtu}{hr}/ton \times \frac{1}{8.2} \times 0.05$$

[83] DNV GL reviewed the customer application data on heat pump size of participants in the Residential AC Cycling Program, Residential Duct Testing Program, Residential Heat Pump Upgrade Program and Residential Heat Pump Tune-Up Programs from program start dates through the end of 2015 (12/31/2015). The average heat pump capacity in VA (2.39 tons or 28,720 Btu/h) was calculated using data from 85,412 air source heat pump units enrolled in these programs in Virginia. The average capacity in NC (2.57 tons or 30,889 Btu/h) was calculated using data from 5,292 air source heat pump units enrolled in these programs in North Carolina. The average capacity was converted to Btu/h using the conversion factor of 12,000 Btu/h per ton. These values were not updated for 2016 as average heat pump capacity varied little beween 2014 and 2015.

[84] Mid-Atlantic TRM 2016, p. 105. Minimum Federal Standard.

[85] The federal Standard does not currently include an EER component. The value is approximated based on the SEER standard (14) and equals EER 11.8. To perform this calculation we are using this formula: (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder).

[86] Mid-Atlantic TRM 2016, p. 106. Minimum Federal Standard.

[87] ENERGY STAR®. Heat Pumps "Savings Calculator," Heating Usage, https://www.energystar.gov/products/heating_cooling/heat_pumps_air_sourhttps://www.energystar.gov/products/heating_cooling/heat_pumps_air_sourcece. Accessed 7/14/2016.

[88] Massachusetts TRM 2014, p. 74. "Massachusetts Common Assumption."

$= 0.175\ kW$

Charlotte, NC:

$$\Delta kW_{cool,NC} = 2.57\ tons \times 12 \frac{kBtu}{hr}/ton \times \frac{1}{11.8} \times 0.05$$
$$= 0.131\ kW$$

$$\Delta kW_{heat,NC} = 2.57 \times 12 \frac{kBtu}{hr}/ton \times \frac{1}{8.2} \times 0.05$$

$$= 0.188\ kW$$

Source(s)

The primary sources for this deemed savings approach are the Massachusetts TRM 2014, p. 74 and the Mid-Atlantic TRM 2016, p. 103-110.

5 RESIDENTIAL DUCT SEALING PROGRAM PROGRAM

Dominion's Residential Duct Sealing program may test residential duct systems for air leakage, will seal the ducts using a variety of methods (e.g. mastic sealant, metal tape, aerosol based products such as aeroseal), and then confirms that leakage after duct sealing with a final duct testing conducted either by the contractor or the Dominion implementation contractor.

This Program is open to Dominion Virginia Power residential customers with heat pumps living in existing, single family residences or townhomes. Customer must be on a residential rate schedule. The customer must be responsible for his/her electric bill and either own the home or be able to secure permission from the owner to perform the repairs or improvements recommended. Homes must be at least five years old. Apartments, condos, mobile homes, geothermal systems, and individual systems in homes equipped with non-electric heat are not eligible.

There are two paths to participate in this program:

Pre- and post-sealing duct testing: Contractors will test duct leakage using two potential methods (e.g. modified blower door subtraction method, total leakage test) before and after the sealing, to confirm that the sealing work meets the program requirements.

Prescriptive duct testing and sealing: Contractors will seal the ducts without conducting the pre- or post-sealing tests. For the first five projects conducted by a contractor using this prescriptive method, Dominion's implementation contractors will conduct post-sealing leakage tests using the total leakage testing method for quality assurance. Following those first five projects, leakage results will not be provided for participants who choose to use the prescriptive path.

Measure Description

This measure realizes energy savings by identifying and sealing leaky duct work in unconditioned space using mastic sealant or metal tape.

Three methodologies for estimating the savings associated with sealing the ducts are provided. The first method requires the use of a blower door and the second requires the use of a duct blaster:

1. Modified Blower Door Subtraction - this technique is described in detail on p. 44 of the Energy Conservatory Blower Door Manual; http://www.energyconservatory.com/sites/default/files/documents/mod_3-4_dg700_-_new_flow_rings_-_cr_-_tpt_-_no_fr_switch_manual_ce_0.pdf
2. Total Leakage Test – this technique is described in detail on p. 18 – 24 of the Energy Conservatory Duct Blaster Manual; http://www.energyconservatory.com/sites/default/files/documents/duct_blaster_manual_series_b_-_dg700.pdf
3. Prescriptive – this method will make assumptions about the pre-sealing leakage value, calculate the energy savings and demand reductions for those first five participants where total leakage testing was used, and make assumptions about the energy savings and demand

reductions for remaining participants (using data gathered from the first five participants) who used the same contractor.

The existing baseline condition is leaky duct work within the unconditioned space. The efficient condition is sealed duct work throughout the unconditioned space in the home.

Savings Estimation Approach

Gross annual electric energy savings are calculated according to duct leakage reduction and based on the methodology used:

Methodology 1: Modified Blower Door Subtraction Leakage

$$Duct\ leakage\ (CFM50_{DL}) = (CFM50_{\text{whole house}} - CFM50_{envelope\ only}) \times SCF$$

$$Duct\ leakage\ reduction\ (\Delta CFM25_{DL}) = (Pre\ CFM50_{DL} - Post\ CFM50_{DL}) \times 0.64 \times (SLF + RLF)$$

Methodology 2: Total Leakage Test

$$Duct\ leakage\ reduction\ (\Delta CFM25_{DL}) = (Pre\ CFM25_{DL} - Post\ CFM25_{DL}) \times DLF$$

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

$$\Delta kWh/year_{cool} = \left[\left(\frac{\Delta CFM25_{DL}}{(tonnage \times 400\ CFM/ton)}\right) \times FLH_{cool} \times BtuH\right] \div 1{,}000 \div SEER$$

$$\Delta kWh/year_{heat} = \left[\left(\frac{\Delta CFM25_{DL}}{(tonnage \times 400\ CFM/ton)}\right) \times FLH_{heat} \times BtuH\right] \div 1{,}000{,}000 \div COP \times 293.1$$

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

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

$$\Delta kW = \frac{\Delta kWh/year}{FLH_{cool}} \times CF$$

Where:

ΔkWh/year = gross annual electric energy savings
ΔkW = gross coincident demand reductions
$CFM25_{DL}$ = duct blaster test result finding cubic feet per minute at 25 Pascal[89] pressure differential with all supply and return registers sealed
$CFM50_{\text{whole house}}$ = standard blower door test result finding cubic feet per minute at 50 Pascal pressure differential
$CFM50_{\text{envelop only}}$ = blower door test result finding cubic feet per minute at 50 Pascal pressure differential with all supply and return registers sealed

[89] Mid-Atlantic TRM 2016, p. 115. "25 Pascal is the typical pressures experienced in the duct system under normal operating conditions. To convert CFM50 to CFM25 you multiply by 0.64 (inverse of the "Can't Reach Fifty" factor for CFM25; see Energy Conservatory Blower Door Manual)."

SCF = subtraction correction factor used to account for underestimation of duct leakage due to connections between duct system and the home. This value is determined by measuring pressure in duct system with registers sealed and using look up table provided by Energy Conservatory.
SLF = supply loss factor; percentage of leaks sealed located in supply ducts x 1[90]
RLF = return loss factor; percentage of leaks sealed located in return ducts x 0.5[91]
$\Delta CFM25_{DL}$ = duct leakage reduction in CFM25
FLH_{cool} = annual cooling full load hours (FLH)
FLH_{heat} = annual heating full load hours (FLH)
Btuh = capacity of equipment in Btu/h (1 ton = 12,000 Btu/h)
SEER = seasonal energy efficiency ratio of air conditioning equipment
COP = coefficient of performance of heating equipment[92]

DLF = duct leakage to outside factor

CF = peak coincidence factor

90 Mid-Atlantic TRM 2016, p. 115. Assumes that for each percent of supply air loss there is one percent annual energy penalty. This assumes supply side leaks are direct losses to the outside and are not recaptured back to the house. This could be adjusted downward to reflect regain of usable energy to the house from duct leaks. For example, during the winter some of the energy lost from supply leaks in a crawlspace will probably be regained back to the house (sometimes 1/2 or more may be regained). More information provided in "Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements" from http://www.energyconservatory.com/sites/default/files/documents/duct_blaster_manual_series_b_-_dg700.pdf. Accessed 7/21/2016.

91 Mid-Atlantic TRM 2016, p. 116. Assumes that for each percent of return air loss there is a half percent annual energy penalty. Note that this assumes that return leaks contribute less to energy losses than do supply leaks. This value could be adjusted upward if there was reason to suspect that the return leaks contribute significantly more energy loss than "average" (e.g., pulling return air from a super-heated attic), or can be adjusted downward to represent significantly less energy loss (e.g. pulling return air from a moderate temperature crawl space). More information provided in "Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements" from http://www.energyconservatory.com/sites/default/files/documents/duct_blaster_manual_series_b_-_dg700_revised.pdf.Accessed 7/21/2016.

92 If a HSPF value is provided for residential split heat pump systems, COP = HSPF x 3.412.

Input Variables

Table 20: Input Values for Residential Duct Testing and Sealing Savings Calculations

Component	Type	Value	Unit	Source(s)
$CFM50_{whole\ house}$	Variable	See customer application	feet^3/ minute	Customer application
$CFM50_{envelope\ only}$	Variable	See customer application	feet^3/ minute	Customer application
SCF	Variable	See Table 21: Correction Table for Blower Door Subtraction	-	Mid-Atlantic TRM 2016, p. 115
SLF	Fixed	0.5	-	Mid-Atlantic TRM 2016, p. 115[93]
RLF	Fixed	0.25	-	Mid-Atlantic TRM 2016, p. 116[94]
$PreCFM25_{DL}$	Variable	See customer application	feet^3/ minute	Customer application
		Prescriptive method default = 30% x Btu/h / (12,000 Btu/ton-h) x 400 CFM/ton Or—if Btu/h not available— Richmond, VA default = 289 Charlotte, NC default = 287		Dominion Residential Duct Testing Program participant data[95]
$PostCFM25_{DL}$	Variable	See customer application	feet^3/ minute	Customer application
		Prescriptive method default = Lowest of either average of available PostCFM25DL for similar contractor or $PreCFM25_{DL}$ default		Dominion Residential Duct Testing Program participant data
$\Delta CFM25_{DL}$	Variable	See duct leakage calculations	feet^3/ minute	Mid-Atlantic TRM 2016, p. 115
FLH_{cool}	Fixed	Richmond, VA = 842; Charlotte, NC = 939; See Table 131	hours/year	Mid-Atlantic TRM 2016, p. 116; ENERGY STAR® calculator[96]
FLH_{heat}	Fixed	Richmond, VA = 789; Charlotte, NC = 744; See Table 131	hours/year	Mid-Atlantic TRM 2016, p. 118
Btuh	Variable	See customer application	Btu/h	Customer application
		Richmond, VA default = 28,720 Charlotte, NC default = 30,889		Dominion's portfolio of residential energy efficiency programs program[97]
SEER	Variable	See customer application	Btu/watt-hour	Customer application
		Default: see Table 132		Mid-Atlantic TRM 2016, p. 116-117, which is based on Table C403.2.3(2) of 2012 IECC.
COP	Variable	See customer application	-	Customer application

Component	Type	Value	Unit	Source(s)
		Default: see Table 132		Mid-Atlantic TRM 2016, p. 118, which is based on Table C403.2.3(2) of 2012 IECC.
DLF	Variable	1 floor: 0.75 2 floors: 0.67	-	DEER Update Study (2004-2005), p. 8-19[98]
CF	Fixed	0.69	-	Mid-Atlantic TRM 2016, p. 120[99]

[93] Mid-Atlantic TRM 2016, p. 115. Assumes 50% of leaks are in supply ducts.

[94] Mid-Atlantic TRM 2016, p. 116. Assumes 50% of leaks are in return ducts.

[95] DNV GL reviewed the customer application data on total leakage duct blaster method PreCFM25DL percentages in the Residential Duct Testing Program from program start dates through the end of 2014 (12/31/2014). The average pre-sealing duct leakage percentage (PreCFM25DL / (system size in tons x 400 CFM/ton)) was 30% for VA customers. There were no NC participants in this program at the end of 2014. To calculate customer specific PreCFM25DL, 30% was converted to 289 CFM for VA and 287 CFM for NC. For VA, the calculation = 28,903Btu/h 400CFM/ton x 30% / 12,000 Btu/ton-hr, assuming a default of 28,903 Btu/h for Richmond, VA. These values were not updated for 2016 as average heat pump capacity varied little beween 2014 and 2015.

[96] ENERGY STAR®. Heat Pumps "Savings Calculator," Heating Usage, http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=EP. Accessed December 24, 2014.

[97] DNV GL reviewed the customer application data on air source heat pump size of participants in the Residential AC Cycling Program, Residential Duct Testing Program, Residential Heat Pump Upgrade Program and Residential Heat Pump Tune-Up Programs from program start dates through the end of 2015 (12/31/2015). The average air source heat pump capacity in VA (2.39 tons or 28,720 Btu/h) was calculated using data from 85,412 air source heat pump units enrolled in these programs in Virginia. The average capacity in NC (2.57 tons or 30,889 Btu/h) was calculated using data from 5,292 air source heat pump units enrolled in these programs in North Carolina. The average capacity was converted to Btu/h using the conversion factor of 12,000 Btu/h per ton. These values were not updated for 2016 as average heat pump capacity varied little beween 2014 and 2015.

[98] Itron prepared for SCE, Database for Energy Efficiency Resources (DEER) Update Study, Final Report (2004 – 2005), p. 8-19, http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf. Accessed 8/16/2016.

[99] Mid-Atlantic TRM 2016, p. 120. Summer system peak coincidence factor for central A/C (hour ending 5pm on hottest summer weekday). "Based on BG&E "Development of Residential Load Profiler for Central Air Conditioner and Heat Pumps" research, the Maryland Peak Definition coincidence factor is 0.69.

Table 21: Correction Table for Blower Door Subtraction[100]

House to Duct Pressure (Taped Off)	Subtraction Correction Factor (SCF)	House to Duct Pressure (Taped Off)	Subtraction Correction Factor (SCF)
50	1.00	30	2.23
49	1.09	29	2.32
48	1.14	28	2.42
47	1.19	27	2.52
46	1.24	26	2.64
45	1.29	25	2.76
44	1.34	24	2.89
43	1.39	23	3.03
42	1.44	22	3.18
41	1.49	21	3.35
40	1.54	20	3.54
39	1.60	19	3.74
38	1.65	18	3.97
37	1.71	17	4.23
36	1.78	16	4.51
35	1.84	15	4.83
34	1.91	14	5.20
33	1.98	13	5.63
32	2.06	12	6.12
31	2.14	11	6.71

Default Savings

No default savings will be awarded for this measure if pre- and post- duct testing values are not provided in the customer application.

Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2016, p. 111 – 123.

[100] Table 18 sourced from p. 45 of Energy Conservatory blower door manual: http://www.energyconservatory.com/sites/default/files/documents/mod_3-4_dg700_-_new_flow_rings_-_cr_-_tpt_-_no_fr_switch_manual_ce_0.pdf. Accessed 9/8/2016

6 RESIDENTIAL INCOME AND AGE QUALIFYING HOME IMPROVEMENT PROGRAM

The Residential Income and Age Qualifying Home Improvement Program provides direct install energy efficiency improvements to age and income qualifying homeowners in order to reduce electric use. The program includes the following electric measures:

- Kitchen aerators changed from an estimated 2.2 GPM to low flow 1.5 GPM aerators
- Bathroom aerators changed from an estimated 2.2 GPM to low flow 1.5 GPM aerators
- Showerhead changed from an estimated 2.5 gallons per minute (GPM) to low flow 2.0 GPM aerators
- Incandescent lighting changed to LEDs
- Attic insulation brought up to a maximum of R-49 Pipe wrap installed on any exposed and accessible hot water supply lines from electric water heater

The algorithms to calculate savings for each measure are presented in the following sections.

The program is offered in Virginia beginning May 1, 2015.

6.1.1 Kitchen and Bathroom Aerator

Measure Description

Under both the Residential Home Energy Check-Up Program and the Residential Income and Age Qualifying Home Improvement Program, this measure realizes energy savings by installing a low-flow faucet aerator in a home's kitchen faucet and/or bathroom.

According to the program design and implementation contractors, in both programs the installed kitchen aerator flow rate is assumed at 2.0 gallons per minute (gpm).

The bathroom faucet aerator flow rate in the Residential Home Energy Check-Up Program is 1.5 gpm, and in the Residential Income and Age Qualifying Home Improvement Program is 2.0 gpm.

The baseline condition is a faucet aerator with a flow rate of 2.2 gpm.

Savings Estimation Approach

Gross annual water savings are calculated according to the following equation:

$$\Delta Water = \left[\left(\frac{Flow_{base} - Flow_{ee}}{Flow_{base}}\right) \times \#\, people \times gals/person/day \times 365\, days/year \times DR \div faucets/home\right]$$

Gross annual electric energy savings[101] are calculated according to the following equation:

[101] Mid-Atlantic TRM 2017, p. 149. Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all faucet aerator installations.

$$\Delta kWh/year = \frac{\Delta Water \times 8.3\, lbs/gal \cdot Btu/lb/°F \times \Delta T_{[°F]}}{\eta_{HW} \times 3{,}412\, Btu/kWh}$$

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

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

Where:

ΔWater = gross annual water savings per faucet
ΔkWh/year = gross annual electric energy savings per faucet
ΔkW = gross coincident demand reductions
$Flow_{base}$ = baseline faucet flow rate
$Flow_{ee}$ = energy efficient (low-flow) faucet flow rate
# people = number of people per household
DR = percentage of water flowing down drain
gals/person/day = average gallons per person per day used for faucet
faucets/home = average number of faucets in a home
ΔT = change in temperature of the water used for kitchen and bathroom faucets and temperature entering the house ($\Delta T = T_{faucet} - T_{in\ house}$)
η_{HW} = recovery efficiency of electric water heater house
HOU = annual hours of use per faucet
CF = peak coincidence factor

Input Variables

Table 22: Input Values for Kitchen and Bathroom Aerators Savings Calculations

Component	Type	Value	Unit	Source(s)
$Flow_{base}$	Fixed	2.2	gallons/minute	Mid-Atlantic TRM 2017, p. 149[102]
$Flow_{ee}$	Variable	Residential Home Energy Check-Up: Kitchen aerator default = 2.0 Bathroom aerator default = 1.5	gallons/minute	Program design[103]
		Residential Income and Age Qualifying Home Improvement: Kitchen and bathroom aerator default = 1.5		
# people	Variable	See customer application	-	Customer application
		Default = 2.53		Mid-Atlantic TRM 2017, p. 150[104]
gals/person/day	Fixed	10.9	gallons/person/day	Mid-Atlantic TRM 2017, p. 150[105]
DR	Fixed	0.5	-	Mid-Atlantic TRM 2017, p. 150[106]
faucets/home	Fixed	3.5	faucets/home	Mid-Atlantic TRM 2017, p. 150[107]
ΔT	Fixed	19.1	°F	Mid-Atlantic TRM 2017, p. 150 (T_{faucet} = 80°F[108], $T_{in\ house}$ = 60.9°F[109]; ΔT = 80 – 60.9 = 19.1°F)
η_{HW}	Fixed	0.98	-	Mid-Atlantic TRM 2017, p. 150[110]
HOU	Fixed	22	hours/year/faucet	Mid-Atlantic TRM 2017, p. 151[111]
CF	Fixed	0.00262	-	Mid-Atlantic TRM 2017, p. 151[112]

Default Savings

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

The default gross annual water savings will be assigned according to the following calculation:

Residential Home Energy Check-Up Kitchen Aerator:

$$\Delta Water = \left[\left(\frac{Flow_{base} - Flow_{ee}}{Flow_{base}}\right) \times \#\, people \times gals/person/day \times 365\, days/year \times DR\right] \div faucets/home$$

$$= \left[\left(\frac{2.2\, gpm - 2.0\, gpm}{2.2\, gpm}\right) \times 2.56\, people \times 10.9 \frac{\frac{gals}{person}}{day} \times 365\, days/year \times 0.5\right] \div 3.5\, faucets/home$$

$$= 132\, gallons/year/faucet$$

Residential Home Energy Check-Up Bathroom Aerator, and Residential Income and Age Qualifying Kitchen and Bathroom Aerators:

$$\Delta Water = \left[\left(\frac{Flow_{base} - Flow_{ee}}{Flow_{base}}\right) \times \#\, people \times gals/person/day \times 365\, days/year \times DR\right] \div faucets/home$$

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102 Mid-Atlantic TRM 2017, p. 149. In 1998, the Department of Energy adopted a maximum flow rate standard of 2.2 gpm at 60 psi for all faucets: 63 Fed. Reg. 13307; March 18, 1998.

103 Based on program eligibility requirements.

104 Mid-Atlantic TRM 2017, p. 150. U.S. Energy Information Administration, Residential Energy Consumption Survey; http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc3demographics/pdf/tablehc11.3.pdf.

105 Mid-Atlantic TRM 2017, p. 150. Most commonly quoted value of gallons of water used per person per day, including in U.S. Environmental Protection Agency's "water sense" document: http://www.epa.gov/watersense/docs/home_suppstat508.pdf.

106 Mid-Atlantic TRM 2017, p. 150. Estimate consistent with Ontario Energy Board, "Measures and Assumptions for Demand Side Management Planning."

107 Mid-Atlantic TRM 2017, p. 150. Estimate based on East Bay Municipal Utility District; "Water Conservation Market Penetration Study," http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf.

108 Mid-Atlantic TRM 2013, p. 127. Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year. Source in Mid-Atlantic TRM 2016 had bookmark error, so retained Mid-Atlantic TRM 2013 source, as the value remained the same from 2013 to 2015.

109 Mid-Atlantic TRM 2017, p. 150. Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Residential Retrofit Programs." April 4, 2014, Appendix E, page 66.

110 Mid-Atlantic TRM 2017, p. 150. Electric water heater has recovery efficiency of 98%. http://www.ahrinet.org/App_Content/ahri/files/Certification/GAMA/PG-CMW.pdf. Accessed 6/9/2017.

111 Mid-Atlantic TRM 2017, p. 151. "HOU = (Gal/person * # people * 365 days/year) /(faucets/home) / GPM / 60 minutes/hour = (10.9 * 2.56 * 365) / 3.5 / 2.2 / 60" = 22 hours.

112 Mid-Atlantic TRM 2017, p. 151. "Calculated as follows: Assume 13% faucet use takes place during peak hours (based on http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf). 13% * 3.6 minutes per day (10.9 * 2.56 / 3.5 / 2.2 = 3.6) = 0.47 minutes = 0.47 / 180 (minutes in peak period) = 0.00262." Website was provided in Mid-Atlantic TRM and could not be accessed when DNV GL attempted on 8/4/2016.

$$= \left[\left(\frac{2.2\ gpm - 1.5\ gpm}{2.2\ gpm} \right) \times 2.56\ people \times 10.9 \frac{\frac{gals}{person}}{day} \times 365\ days/year \times 0.5 \right]$$

$$\div\ 3.5\ faucets/home$$

$$= 463\ gallons/year/faucet$$

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

Residential Home Energy Check-Up Kitchen Aerator:

$$\Delta kWh/year = \Delta Water \times 8.3\ lbs/gal \cdot Btu/lb/°F \times \Delta T_{[°F]} \times \frac{1}{\eta_{HW}} \times \frac{1}{3{,}412\ Btu/kWh}$$

$$= 132\ gallons/year \times 8.3\ lbs/gal \cdot Btu/lb/°F \times 19.1°F \times \frac{1}{.98} \times \frac{1}{3{,}412\ Btu/kWh}$$

$$= 6.3\ kWh/year/faucet$$

Residential Home Energy Check-Up Bathroom Aerator, and Residential Income and Age Qualifying Kitchen and Bathroom Aerators:

$$\Delta kWh/year = \Delta Water \times 8.3\ lbs/gal \cdot Btu/lb/°F \times \Delta T_{[°F]} \times \frac{1}{\eta_{HW}} \times \frac{1}{3{,}412\ Btu/kWh}$$

$$= 463\ gallons/year \times 8.3\ lbs/gal \cdot Btu/lb/°F \times 19.1°F \times \frac{1}{.98} \times \frac{1}{3{,}412\ Btu/kWh}$$

$$= 22.0\ kWh/year/faucet$$

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

Residential Home Energy Check-Up Kitchen Aerator:

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

$$= \frac{6.3\ kWh/year/faucet}{22\ hours/year} \times 0.00262$$

$$= 0.001\ kW/faucet$$

Residential Home Energy Check-Up Bathroom Aerator, and Residential Income and Age Qualifying Kitchen and Bathroom Aerators:

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

$$= \frac{463\ kWh/year/faucet}{22\ hours/year} \times 0.00262$$

$$= 0.055\ kW/faucet$$

Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2017, p. 149-153.

6.1.2 Low-Flow Showerhead

Measure Description

Under the Residential Home Energy Check-Up Program and the Residential Income and Age Qualifying Home Improvement Program, this measure realizes energy savings by replacing an existing showerhead with a low-flow showerhead with a flow rate of 2.0 gallons per minute (gpm).

The baseline condition is a showerhead with a flow rate of 2.5 gpm.

Under the Residential Low Income Program, this measure realizes energy savings by replacing an existing showerhead with a low-flow showerhead with a flow rate of 1.8 gpm.

The baseline condition is a showerhead with a flow rate of 2.2 gpm.

Savings Estimation Approach

The savings estimation approach is the same for this measure as it is implemented in both the Residential Home Energy Check-Up and Residential Low Income Programs.

Gross annual water savings are calculated according to the following equation:

$$\Delta Water = \left[\left(\frac{Flow_{base} - Flow_{ee}}{Flow_{base}}\right) \times \#\,people \times gallons/person/day \times 365\,days/year\right] \div showers/home$$

Gross annual electric energy savings[113] are calculated according to the following equation:

$$\Delta kWh = \frac{\Delta Water \times 8.3\ lbs/gal \cdot Btu/lb/{}^{\circ}\mathrm{F}\ \times \Delta T}{\eta_{HW} \times 3{,}412\ Btu/kWh}$$

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

$$\Delta kW\ = \Delta kWh \times CF \times \left(\frac{showers/home}{gals/person/day}\right) \times \left(\frac{Flow_{base} \times 60\ min/hr}{\#\ people}\right) \times \left(\frac{1}{365\ days/year}\right)$$

Where:

ΔWater = gross annual water savings per showerhead
ΔkWh/year = gross annual electric energy savings per showerhead
ΔkW = gross coincident demand reduction per showerhead
$Flow_{base}$ = baseline showerhead flow rate
$Flow_{ee}$ = energy efficient (low-flow) showerhead flow rate
people = number of people per household
gals/person/day = average gallons per person per day used for showering
showers/home = average number of showers in a home

[113] Mid-Atlantic TRM 2017, p. 144. Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all showerhead installations.

ΔT = change in temperature of the water used for shower and temperature entering the house ($\Delta T = T_{shower} - T_{in\ house}$)
η_{HW} = recovery efficiency of electric water heater
CF = peak coincidence factor

Input Variables

Table 23: Input Values for Low-Flow Shower Head Savings Calculations

Component	Type	Value	Unit	Source(s)
$Flow_{base}$	Fixed	Residential Home Energy Check-Up and Income and Age Qualifying Home Improvement = 2.5	gpm	Mid-Atlantic TRM 2017, p. 144[114]
		Residential Low Income = 2.2		Program design
$Flow_{ee}$	Variable	Residential Home Energy Check-Up and Income and Age Qualifying Home Improvement = 2.0	gpm	Program design
		Residential Low Income = 1.8		
# people	Variable	See customer application	-	Customer application
		Default = 2.53		Mid-Atlantic TRM 2017, p. 145[115]
gals/person/day	Fixed	11.6	gallons/person/day	Mid-Atlantic TRM 2017, p. 145[116]
showers/home	Fixed	1.6	showers/home	Mid-Atlantic TRM 2017, p. 145
ΔT	Fixed	44.1	°F	Mid-Atlantic TRM 2017, p. 145 (T_{shower} = 105°F[117], $T_{in\ house}$ = 60.9°F[118]; ΔT = 105 – 60.9 = 44.1°F)
η_{HW}	Fixed	0.98	-	Mid-Atlantic TRM 2017, p. 145[119]
CF	Fixed	0.00371	-	Mid-Atlantic TRM 2017, p. 146[120]

Default Savings

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

The default gross annual water savings will be assigned according to the following calculation:

Residential Home Energy Check-Up and Income and Age Qualifying Home Improvement Programs:

$$\Delta Water = \left[\left(\frac{Flow_{base} - Flow_{ee}}{Flow_{base}}\right) \times \#\,people \times gallons/person/day \times (365\,days/year)\right] \div showers/home$$

$$= \left[\left(\frac{2.5\,gal/min - 2.0\,gal/min}{2.5\,gal/min}\right) \times 2.56\,people \times\ 11.6\,gallons/person/day \times 365\,days/year\right] \div 1.6\,showers/home$$

$$= 1{,}354.9\,gallons/year\,/showerhead$$

Residential Low Income Program:

$$\Delta Water = \left[\left(\frac{Flow_{base} - Flow_{ee}}{Flow_{base}}\right) \times \#\,people \times gallons/person/day \times (365\,days/year)\right] \div showers/home$$

$$= \left[\left(\frac{2.2\,gal/min - 1.8\,gal/min}{2.2\,gal/min}\right) \times 2.56\,people \times\ 11.6\,gallons/person/day \times 365\,days/year\right] \div 1.6\,showers/home$$

$$= 1{,}231.7\,gallons/year/showerhead$$

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114 Mid-Atlantic TRM 2017, p. 144. "The Energy Policy Act (EPAct) of 1992 established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm)."

115 Mid-Atlantic TRM 2017, p. 145. "U.S. Energy Information Administration, Residential Energy Consumption Survey;

http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc3demographics/pdf/tablehc11.3.pdf. Accessed 9/8/2016

116 Mid-Atlantic TRM 2017, p. 145. "Most commonly quoted value of gallons of water used per person per day, including in U.S. Environmental Protection Agency's "water sense" documents: http://www.epa.gov/watersense/docs/home_suppstat508.pdf ." Accessed 9/8/2016

117 Mid-Atlantic TRM 2013, p. 123. Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year. The Mid-Atlantic TRM 2016 source has a bookmark error, but since the value is the same as that listed in the Mid-Atlantic TRM 2013, the same source was retained.

118 Mid-Atlantic TRM 2017, p. 145. Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Residential Retrofit Programs." April 4, 2014, Appendix E, page 66.

119 Mid-Atlantic TRM 2017, p. 145. Electric water heater has recovery efficiency of 98%. http://www.ahrinet.org/App_Content/ahri/files/Certification/GAMA/PG-CMW.pdf. Accessed 8/4/2016

120 Mid-Atlantic TRM 2017, p. 146. Calculated as follows: Assume 9% showers take place during peak hours (based on http://s3.amazonaws.com/zanran_storage/www.aquacraft.com/ContentPages/47768067.pdf). Accessed 8/4/2016

9% x 7.42 minutes per day (11.6 x 2.56 / 1.6 / 2.5 = 7.42) = 0.668 minutes; 0.668 / 180 (minutes in peak period) = 0.00371." Website was provided in Mid-Atlantic TRM could not be accessed when DNV GL attempted on 8/4/2016.

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

Residential Home Energy Check-Up and Age Qualifying Home Improvement Programs:

$$\Delta kWh/year = \Delta Water \times 8.3\ lbs/gal \cdot Btu/lb/°\mathrm{F}\ \times \Delta T \times \frac{1}{\eta_{HW}} \times \frac{1}{3{,}412\ Btu/kWh}$$

$$= 1{,}354.9\ gallons/year \times 8.3\ lbs/gal \cdot Btu/lb/°\mathrm{F} \times 44.9°\mathrm{F} \times \frac{1}{0.98} \times \frac{1}{3{,}412\ Btu/kWh}$$

$$= 151.0\ kWh/year/showerhead$$

Residential Low Income Program:

$$\Delta kWh/year = \Delta Water \times 8.3\ lbs/gal \cdot Btu/lb/°\mathrm{F}\ \times \Delta T \times \frac{1}{\eta_{HW}} \times \frac{1}{3{,}412\ Btu/kWh}$$

$$= 1{,}232\ gallons/year \times 8.3\ lbs/gal \cdot Btu/lb/°\mathrm{F} \times 5044.9°\mathrm{F} \times \frac{1}{.98} \times \frac{1}{3{,}412\ Btu/kWh}$$

$$= 137.3\ kWh/year/showerhead$$

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

Residential Home Energy Check-Up and Age Qualifying Home Improvement Programs:

$$\Delta kW\ = \Delta kWh \times CF \times \left(\frac{showers/home}{gallons/person/day}\right) \times \left(\frac{Flow_{base} \times 60\ min/hr}{\#\ people}\right) \times \left(\frac{1}{365\ days/year}\right)$$

$$= 151.0\ kWh/year \times 0.00371 \times \left(\frac{1.6\ showers/home}{11.6\ \ gallons/person/day}\right) \times \left(\frac{2.5\ gallons/min \times 60\ min/hr}{2.56\ people}\right)$$
$$\times \left(\frac{1}{365\ days/year}\right)$$

$$= 0.012\ kW/showerhead$$

Residential Low Income Program:

$$\Delta kW\ = \Delta kWh \times CF \times \left(\frac{showers/home}{gals/person/day}\right) \times \left(\frac{Flow_{base} \times 60\ min/hr}{\#\ people}\right) \times \left(\frac{1}{365\ days/year}\right)$$

$$= 137.3\ kWh/year \times 0.00371 \times \left(\frac{1.6\ showers/home}{11.6\ \ gallons/person/day}\right) \times \left(\frac{2.2\ gallons/min \times 60\ min/hr}{2.56\ people}\right)$$
$$\times \left(\frac{1}{365\ days/year}\right)$$

$$= 0.010\ kW/showerhead$$

Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2016, p. 144-148.

6.1.3 LED Lighting

Measure Description

Forty and sixty Watt incandescent light bulbs will be replaced with their respective equivalent 9 Watt and 14.5 watt LED bulbs.

Savings Estimation Approach

Per unit savings are multiplied by the number of total bulbs installed based on the program tracking data. Based on the program design, the maximum number of bulbs installed is six.

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

$$\Delta kWh/year = \frac{watts_{base} - watts_{ee}}{1{,}000\, W/kW} \times ISR \times HOU \times (WHF_{eHeat} + (WHF_{eCool} - 1))$$

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

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

Where:

ΔkWh/year = gross annual electric energy savings
ΔkW = gross coincident peak demand savings
$watts_{base}$ = wattage of incandescent bulb being replaced
$watts_{ee}$ = wattage of new efficient LED bulb
ISR = in service rate
HOU = hours of use per year
WHF_{eHeat} = waste heat factor to account for electric heating increase due to reduced waste heat from efficient lighting
WHF_{eCool} = waste heat factor to account for electric cooling savings due to reduced waste heat from efficient lighting
WHF_d = waste heat factor for summer coincident peak demand savings to account for cooling savings from efficient lighting
CF = peak coincidence factor

Input Variables

Table 24: Input Values for LED Lighting Savings

Component	Type	Value	Units	Sources
$watts_{base}$	Variable	40	watts	Dominion program requirements
		60		
$watts_{ee}$	Variable	9 Watt (for 40W base)	watts	Dominion program requirements
		14.5 Watt (for 60W base)		
ISR	Fixed	0.98	-	Mid-Atlantic TRM 2017, p. 30
HOU	Fixed	Richmond, VA = 920	hours/year	Mid-Atlantic TRM 2017, p. 31
		Charlotte, NC = 1,059		Opinion Dynamics 2016, p. 23
WHF_{eHeat}	Fixed	0.899	-	Mid-Atlantic TRM 2017, p. 32
WHF_{eCool}	Fixed	1.077	-	Mid-Atlantic TRM 2017, p. 31
WHF_d	Fixed	1.17	-	Mid-Atlantic TRM 2017, p. 33
CF	Fixed	0.084	-	Mid-Atlantic TRM 2017, p. 34

Default Savings

Table 25. Default savings for LED Lighting Savings

State	Savings Type	$Watt_{base}$ = 40W	$Watt_{base}$ = 60W
VA	kWh/year	27.28	40.04
	kW	0.003	0.004
NC	kWh/year	31.40	46.09
	kW	0.003	0.004

Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2017 p. 28 - 37.

6.1.4 Attic Insulation

Measure Description

This measure characterization is for the installation of new insulation in the attic/roof/ceiling of a residential building. The measure assumes that an auditor, contractor or utility staff member is on location, and will measure and record the existing and new insulation depth and type (to calculate R-values), the surface area of insulation added, and where possible the efficiency of the heating and cooling system used in the home.

Savings Estimation Approach

R-values:

$R_{existing} = R_{existing\_insulation} + R_{roof}$

$R_{new} = R_{new\_insulation} + R_{roof}$

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

$$\Delta kWh/year_{cooling} = \left(\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times CDH \times DUA \times Area\right) \div 1{,}000 \div \eta_{cool}$$

Heating savings are only applicable for homes with electric heating.

$$\Delta kWh/year_{heating} = \left(\left(\left(\frac{1}{R_{existing}} - \frac{1}{R_{new}}\right) \times HDD \times 24\ hours/day \times Area\right) \div 1{,}000{,}000 \div \eta_{heat}\right) \times 293.1\ kWh/MMBtu$$

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

$$\Delta kWh/year = \Delta kWh/year_{heating} + \Delta kWh/year_{cooling}$$

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

$$\Delta kW = \frac{\Delta kWh_{cooling}}{FLH_{cooling}} \times CF_{SSP}$$

Where:

$\Delta kWh/year_{cooling}$ = gross annual electric energy savings from reduced cooling load
$\Delta kWh/year_{heating}$ = gross annual electric energy savings from reduced heating load
$\Delta kWh/year$ = gross annual electric energy savings
ΔkW = gross summer coincident peak demand savings

R_{roof} = R-value of roof assembly
$R_{existing\_insulation}$ = R-value of any existing insulation
$R_{existing}$ = R-value of roof assembly plus any existing insulation
$R_{new\_insulation}$ = R-value of new insulation
R_{new} = R-value of roof assembly plus new insulation
CDH = cooling degree hours
DUA = discretionary use adjustment
Area = square footage of area covered by new insulation
η_{cool} = efficiency (in SEER) of air conditioning equipment
HDD = heating degree days
η_{heat} = efficiency (in COP) of heating equipment
$FLH_{cooling}$ = full load cooling hours
CF_{SSP} = summer system peak coincidence factor

Input Variables

Table 26: Input Values, Income and Age Qualifying Insulation Upgrades

Component	Type	Value	Units	Source(s)
R_{roof}	Fixed	R-5	Hr-F-ft^2/Btu	Mid-Atlantic TRM 2017, p. 228-229[121]
$R_{existing\_insulation}$	Variable	$R_{existing}$	Hr-F-ft^2/Btu	Customer application
$R_{new\_insulation}$	Fixed	See customer application	Hr-F-ft^2/Btu	See customer application; Maximum of R-49 from program planning
CDH	Fixed	Richmond, VA = 7,786 Charlotte, NC = 8,040	degree hours	See Table 130[122] National Solar Radiation Data Base, National Renewal Energy Laboratory (NREL)
DUA	Fixed	0.75	-	Mid-Atlantic TRM 2017, p. 229
Area	Variable	Variable	ft^2	Customer application
η_{cool}	Fixed	Default = 14	Btu/watt-hour	See Table 132 Mid-Atlantic TRM 2017[123]
HDD	Fixed	Richmond, VA = 2,881 Charlotte, NC = 2,197	degree days	See Table 130[124] National Solar Radiation Data Base, National Renewable Energy Laboratory (NREL)
η_{heat}	Fixed	Heat pump: HSPF = 8.2 COP = 2.40 Electric resistance: HSPF = 3.4 COP = 1.00	HSPF = Btu/watt-hour COP -	See Table 132 Mid-Atlantic TRM 2017[125]
$FLH_{cooling}$	Fixed	Richmond, VA: Heat pump = 842 Central AC = 613 Window unit or room AC = 368 Charlotte, North Carolina: Heat pump = 939 Central AC = 684 Window unit = 411	hours/year	See Table 131 Mid-Atlantic TRM 2017, p. 72; ENERGY STAR® calculator[126]
CF_{SSP}	Fixed	0.69	-	Mid-Atlantic TRM 2017, p. 76

Table 27: Average R-Values per Inch by Insulating Material

Insulating Material	Avg. R-value, per inch
Blanket: batts and rolls (fiberglass)	3.4
Loose-fill and blown-in (cellulose, fiberglass, mineral (rock or slag) wool)	3.3
Foam board or rigid foam (polystyrene, polyisocyanurate, polyurethane)	5.1

R-values per inch are from the 2013 ASHRAE Handbook – Fundamentals, Table 1. Building and Insulating Matierlas: Design Values. The values given are average R-values. If needed, insulation manufacturers can be contacted for the R-values of insulating materials not listed above.

Default Savings

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

Source(s)

The primary sources for this deemed savings approach are the Mid-Atlantic TRM 2017, 1989 ASHRAE Handbook Fundamentals, and ENERGY STAR®.

[121] "The R-5 assumption for roof assembly is based on J.Neymark & Associates and National Renewable Energy Laboratory, June 2009; "BESTEST-EX Interim Test Procedure" p. 27. The attic floor and roof should be modeled as a system including solar gains and attic ventilation, and R-5 is the standard assumption for the thermal resistance of the whole attic/roof system." Mid-Atlantic TRM 2017, p. 288.

[122] These CDH values are calculated by DNV GL using base temperatures of 65°F rather than 75°F for cooling degree hours, as was done in the Mid-Atlantic TRM. Since all weather sensitive measures that reference the cooling degree days and heating degree days values in this document use a base temperature of 65°F, it was DNV GL's engineering judgement to be consistent throughout the document rather than to use different base temperatures for different measures.

[123] Assumed same as baseline efficiency used for residential HVAC measures for consistency.

[124] These HDD values are calculated by DNV GL using base temperatures of 65°F rather than 60°F for heating degree days, as was done in the Mid-Atlantic TRM. Since all weather sensitive measures that reference the cooling degree days and heating degree days values in this document use a base temperature of 65°F, it was DNV GL's engineering judgement to be consistent throughout the document rather than to use different base temperatures for different measures.

[125] Assumed same as baseline efficiency used for residential HVAC measures for consistency.

[126] ENERGY STAR®. Heat Pumps "Savings Calculator," Heating Usage, https://www.energystar.gov/index.cfm?c=airsrc_heat.pr_proc_as_heat_pumps. Accessed 7/20/2016.

6.1.5 Domestic Hot Water Pipe Insulation

Refer to Section 2.1.3, Domestic Hot Water Pipe Insulation, in the Residential Home Energy Check-Up program section for the measure description, savings estimation approach, input variables, default savings and source.

7 RESIDENTIAL APPLIANCE RECYCLING PROGRAM

The Residential Appliance Recycling Program provides a financial incentive to residential customers to recycle aged refrigerators and/or freezers. Customers are limited to two units per electric account and eligible units must be at least 10 years old and operational. The program is offered in Virginia beginning August 1, 2015.

Measure Description

Under this measure, Dominion will remove older, less efficient refrigerators and/or freezers directly from customer's homes. Savings are realized through the decommissioning of secondary refrigerators, or replacing older primary refrigerators with new units.

Savings Estimation Approach

Gross energy savings for refrigerators and freezers are based on a linear regression model. The coefficients can be found in Table 29 and Table 30.

Refrigerators:

$$\begin{aligned}\Delta kWh/year = \Big[&0.80460 + (Age \times .02107) + (Pre1990 \times 1.03605) + (Size \times 0.05930) \\ &+ (SingleDoor \times -1.75138) + (SideBySide \times 1.11963) + (Primary \times 0.55990) \\ &+ \left(\frac{HDD}{365} \times Unconditioned \times -0.04013\right) + \left(\frac{CDD}{365} \times Unconditioned \times 0.02622\right)\Big] \times 365 \times PUF\end{aligned}$$

Freezers:

$$\begin{aligned}\Delta kWh/year = \Big[&-0.95470 + (Age \times 0.04536) + (Pre1990 \times 0.54341) + (Size \times 0.12023) \\ &+ (ChestFreezer \times 0.29816) + \left(\frac{HDD}{365} \times Unconditioned \times -0.03148\right) \\ &+ \left(\frac{CDD}{365} \times Unconditioned \times 0.08217\right)\Big] \times 365 \times PUF\end{aligned}$$

Summer Coincident Peak Demand Savings for both refrigerators and freezers are calculated according to the following equation:

$$\Delta kW = (\frac{\Delta kWh}{8{,}760}) \times TAF \times LSAF$$

Where:

ΔkWh/year = gross annual electric energy savings
ΔkW = gross coincident peak demand savings
Age = age of refrigerator or freezer in years
Pre1990 = adjustment variables for refrigerators and freezers manufactured before 1990
Size = size of refrigerator or freezer in cubic feet
SingleDoor = adjustment factor for single door refrigerators
SideBySide = adjustment factor for side by side refrigerators
ChestFreezer = adjustment factor for chest freezers
Primary = adjustment factor for refrigerators or freezers that were primary units
HDD = heating degree days

CDD = cooling degree days
Unconditioned = adjustment factor for refrigerators or freezers that are in unconditioned space
PUF = part use factor to account for units that do not run throughout the entire year
TAF = temperature adjustment factor
LSAF = load shape adjustment factor

Input Variables

Table 28: Input Values for Refrigerator and Freezer Recycling

Component	Type	Value	Unit	Source(s)
Age	Variable	See customer application	years	Customer application
Pre1990	Variable	See customer application	-	Customer application
Size	Variable	See customer application	feet^3	Customer application
SingleDoor	Variable	See customer application	-	Customer application
SideBySide	Variable	See customer application	-	Customer application
ChestFreezer	Variable	See customer application	-	Customer application
Primary	Variable	See customer application	-	Customer application
HDD	Variable	See Table 130	heating degree days (HDD)	See Table 130
Unconditioned	Variable	See customer application	-	Customer application
CDD	Variable	See Table 130	cooling degree days (CDD)	See Table 130
PUF	Variable	See customer application	-	Customer application
		Default = 0.95 for refrigeration and 0.86 for freezers		Mid-Atlantic TRM 2016, p. 88[127]
TAF	Fixed	1.23	-	Mid-Atlantic TRM 2016, p. 89[128]
LSAF	Fixed	1.066	-	Mid-Atlantic TRM 2016, p. 89[129]

[127] Based on EmPower DRAFT EY6 Participant Survey Results: Appliance Recycling Program Report.

[128] Temperature adjustment factor based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47) and assuming 78% of refrigerators are in cooled space (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates) and 22% in uncooled space.

[129] Daily load shape adjustment factor also based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study," July 29, 2004 p. 48, using the average Existing Units Summer Profile for hours ending 15 through 18.

Table 29: Model Coefficients Used for Refrigerator Energy Savings[130]

Independent Variable Description	Estimate Coefficient
Intercept	0.80460
Age (years)	0.02107
Pre-1990 (=1 if manufactured pre-1990)	1.03605
Size (cubic feet)	0.05930
Dummy: Single Door (=1 if single door)	-1.75138
Dummy: Side-by-Side (=1 if side-by-side)	1.11963
Dummy: Primary Usage Type (=1 if primary unit)	0.55990
Interaction: Located in Unconditioned Space x HDD/365.25	-0.04013
Interaction: Located in Unconditioned Space x CDD/365.25	0.02622

Table 30: Model Coefficients Used for Freezer Energy Savings[131]

Independent Variable Description	Estimate Coefficient
Intercept	-0.95470
Age (years)	0.0453
Pre-1990 (=1 if manufactured pre-1990)	0.54341
Size (cubic feet)	0.12023
Chest Freezer Configuration (=1 if chest freezer)	0.29816
Interaction: Located in Unconditioned Space x HDD/365.25	-0.03148
Interaction: Located in Unconditioned Space x CDD/365.25	0.08217

Default Savings

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

Refrigerators[132]:

130 EmPower Maryland Impact Evaluation, Program Year 6.

131 Ibid.

132 HDD/365, CDD/365 and unconditioned variables from the Mid-Atlantic TRM 2015 default equation were not provided, therefore they were adjusted using the ratio of the Mid-Atlantic TRM 2015 HDD (4,529) and CDD (1,266) for Baltimore, MD to the HDD (4,600) and CDD (1,233) for Baltimore, MD listed in Table 130 of this document. HDD and CDD from the Mid-Atlantic TRM for Baltimore are based on "the 10-year average annual HDD value... for each location, using a balance point of 65 degrees as used in the EmPower Appliance Recycling Evaluation." The HDD and CDD in Table 130 of this manual are from TMY3 weather data.

$$\Delta kWh/year = \Big[0.80460 + (18.61 \times 0.02107) + (0.20 \times 1.03605) + (19.43 \times 0.05930) + (0.02 \times -1.75138) + (0.34 \times 1.11963) + (0.64 \times 0.55990) + \left(2.91 \times (\frac{4,600}{4,529}) \times -0.04013\right) + \left(0.77 \times (\frac{1,233}{1,266}) \times 0.02622\right)\Big] \times 365 \times 0.95$$

= 1,098 kWh/year

Freezers:

$$\Delta kWh/year = \Big[-0.95470 + (23.79 \times 0.04536) + (0.46 \times 0.54341) + (15.86 \times 0.12023) + (0.21 \times 0.29816) + \left(6.83 \times \left(\frac{4,600}{4,529}\right) \times -0.03148\right) + \left(1.80 \times (\frac{1,233}{1,266}) \times .08217\right)\Big] \times 365 \times 0.86$$

= 715 kWh/year

Summer Coincident Peak Demand Savings for both refrigerators and freezers are calculated according to the following equation:

Refrigerators:

$$\Delta kW = (\frac{1,098}{8,760}) \times 1.23 \times 1.066$$

= 0.164 kW

Freezers:

$$\Delta kW = (\frac{715}{8,760}) \times 1.23 \times 1.066$$

= 0.164 kW

Source

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2016, p. 86 – 90.

8 RESIDENTIAL AC CYCLING PROGRAM

Measure Description

At the conclusion of the 2014 program event season, DNV GL conducted an ex ante regression analysis to predict kW impacts per dispatched AC Cycling participant specific to hour of day and weather conditions. This ex ante value was derived by averaging historical ex-ante impacts over the 2011–2014 event seasons. However, due to the elapsed time between 2011 and 2014, and the decline in average connected load per participant, and other longitudinal factors, the 2015 ex ante model was based solely on 2015 ex post impacts.The same methodology has been applied through 2017.

The regression analysis that DNV GL used to estimate the ex post kW impacts per participant in 2016 is derived by fitting a linear regression model for each event hour (15:00–19:00) with THI as a predictor variable. The event hours included in the ex post analysis is determined by the start and end times of each event.

Savings Estimation Approach

Ex ante event day demand reductions are calculated according to the following equations:

$$Predicted\ Ex\ Ante\ kW\ Impact_{15:00,day} = \hat{\beta}_{0,15:00} + \hat{\beta}_{1,15:00} * (THI_{15:00})$$

$$Predicted\ Ex\ Ante\ kW\ Impact_{16:00,day} = \hat{\beta}_{0,16:00} + \hat{\beta}_{1,16:00} * (THI_{16:00})$$

$$Predicted\ Ex\ Ante\ kW\ Impact_{17:00,day} = \hat{\beta}_{0,17:00} + \hat{\beta}_{1,17:00} * (THI_{17:00})$$

$$Predicted\ Ex\ Ante\ kW\ Impact_{18:00,day} = \hat{\beta}_{0,18:00} + \hat{\beta}_{1,18:00} * (THI_{18:00})$$

$$Predicted\ Ex\ Ante\ kW\ Impact_{19:00,day} = \hat{\beta}_{0,19:00} + \hat{\beta}_{1,19:00} * (THI_{19:00})$$

Where:

$Predicted\ Ex\ Ante\ kW\ Impact_{hour}$ = Estimated ex ante load impact estimate for hour

$\hat{\beta}_{0,hour}$= fixed estimate for the ex-ante kW impact

$\hat{\beta}_{1,hour}$ = increase to the ex ante kW impact estimate when THI increases by one

THI_{hour} = THI value for a specific hour.

The Dominion peak condition for planning purposes is assumed to be 95 degrees with 43 percent relative humidity in hour ending 17:00. This corresponds with a THI of 83.4. Therefore, the gross coincident summer peak demand savings are calculated according to the following equation

$$Predicted\ Ex\ Ante\ kW\ Impact_{17:00,day} = \hat{\beta}_{0,17:00} + \hat{\beta}_{1,17:00} * (83.4)$$

Input Variables

Table 31: Input Values for Residential AC Cycling Program Reductions Calculations

Component	Type	Value	Unit	Source(s)
$\hat{\beta}_{0,15:00}$	Fixed	-3.93	kW	Ex ante model regression
$\hat{\beta}_{0,16:00}$	Fixed	-3.16	kW	Ex ante model regression
$\hat{\beta}_{0,17:00}$	Fixed	-3.58	kW	Ex ante model regression
$\hat{\beta}_{0,18:00}$	Fixed	-4.05	kW	Ex ante model regression
$\hat{\beta}_{0,19:00}$	Fixed	-5.87	kW	Ex ante model regression
$\hat{\beta}_{1,15:00}$	Fixed	0.055	kW	Ex ante model regression
$\hat{\beta}_{1,16:00}$	Fixed	0.045	kW	Ex ante model regression
$\hat{\beta}_{1,17:00}$	Fixed	0.051	kW	Ex ante model regression
$\hat{\beta}_{1,18:00}$	Fixed	0.058	kW	Ex ante model regression
$\hat{\beta}_{1,19:00}$	Fixed	0.079	kW	Ex ante model regression
$THI_{15:00}$	Variable	–	THI	National Oceanic and Atmospheric Administration (NOAA)
$THI_{16:00}$	Variable	–	THI	NOAA
$THI_{17:00}$	Variable	-	THI	NOAA
$THI_{18:00}$	Variable	-	THI	NOAA

Default Savings

The kW impact per AC Cycling Program participant during Dominion peak conditions for 2017 is 0.70 kW. DNV GL recommends that this estimate be updated after each event season to reflect updates to the ex ante impact model based on updated historical ex post impacts and weather data.

Source (s)

National Oceanic and Atmospheric Administration (NOAA)

9 NON-RESIDENTIAL LIGHTING SYSTEMS AND CONTROLS PROGRAM

The Non-Residential Lighting Systems and Controls Program is offered in Virginia beginning August 1, 2014, and in North Carolina beginning January 1, 2015. The program provides incentives to non-residential customers 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 are:

- T8s
- T5s
- LEDs
- CFLs
- Delampings
- Occupancy sensors
- Refrigeration occupancy sensors

9.1.1 Lighting Fixtures, Lamps, and Delamping

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 install T8, T5, LED, or CFL lamps/ ballasts.

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

Gross coincident demand reductions for delamping measures are included in PJM EE Resource nominations when reflectors or tombstones are installed such that the measure is defined as persistent.

This measure is offered in the Non-Residential Energy Audit program (Section 11), Non-Residential Lighting Systems and Controls program, and the Non-Residential Small Business Improvement program (Section 15).

Savings Estimation Approach

Retrofit:

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

$$\Delta kWh/year = \frac{(Watts_{baseline} \times Quantity_{baseline} - Watts_{installed} \times Quantity_{installed}) \times HOU \times WHF_e \times ISR}{1{,}000\, W/kW}$$

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

$$\Delta kW = \frac{(Watts_{baseline} \times Quantity_{baseline} - Watts_{installed} \times Quantity_{installed}) \times CF \times WHF_d \times ISR}{1{,}000\, W/kW}$$

New construction:

When developing STEP Manual 7.0.0 (year-end 2016), DNV GL used existing program data from Virginia and North Carolina Non-Residential Lighting Systems and Controls program participants to generate a list of ratios for each eligible measure type that is used as a multiplier to be applied to the customer provided installed quantity times installed wattage to estimate a baseline default wattage times quantity for new construction measures, where no baseline information is available. The default ratios were generated using the following variables from available lighting retrofit measure records for all program particiapnts through the end of 2016.

- installed wattage
- installed quantity
- baseline wattage
- baseline quantity

DNV GL collaborates with Dominion during program launch to specify the required data fields that implementers should collect for evaluation purposes. At the end of 2016, years after program launch, there were sufficient new construction records that it was necessary to identify a deemed savings method specific to those records. The Mid-Atlantic TRM deemed savings method for new construction projects could not be appropriately applied using the collected data (designed for retrofit projects). Therefore, DNV GL implemented the method described below.

$$\Delta kWh/year = \frac{(Watts_{installed} \times Quantity_{installed} \times Ratio - Watts_{installed} \times Quantity_{installed}) \times HOU \times WHF_e \times ISR}{1{,}000\, W/kW}$$

$$\Delta kW = \frac{(Watts_{installed} \times Quantity_{installed} \times Ratio - Watts_{installed} \times Quantity_{installed}) \times CF \times WHF_d \times ISR}{1{,}000\, W/kW}$$

$$Ratio = (Watts_{baseline} \times Quantity_{baseline})/(Watts_{installed} \times Quantity_{installed})$$

Where:

ΔkWh/year = gross annual electric energy savings