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

Case No. PUE-2016-00111 (Virginia)
Docket No.: E-22 Sub 545 (North Carolina)

VOLUME 3 OF 4

PUBLIC VERSION

Prepared by DNV GL (KEMA, Inc.)

Date: May 1, 2018

Appendix F

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Appendix F
Standard Tracking and Engineering Protocols Manual

(Version 8.0.0)

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

Virginia Electric and Power Company
Prepared by DNV GL (KEMA, Inc.)
May 1, 2018

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1 INTRODUCTION

This manual presents Standard Tracking and Engineering Protocols (STEP) for 14 demand-side management (DSM) programs approved by State Corporation Commission of Virginia (SCC) Order as well as the North Carolina Utilities Commission's (NCUC) Orders. These protocols assess gross program impacts and resource savings, including annual electric energy and peak capacity savings, for technologies and measures supported by Virginia Electric and Power Company (Dominion, or the Company) in Virginia and North Carolina. Protocols to determine resource savings for each program are presented for each eligible measure and technology.

1.1 Purpose

The STEP Manual was developed to estimate resource savings from installed DSM technologies and measures, and will serve as the primary estimates of annual energy and peak demand reductions for tracking, monitoring, and reporting. Consulting firm DNV GL, under contract with Dominion, developed the STEP Manual using industry-standard approaches for estimating annual energy savings and peak demand reductions. This document references authoritative studies in Technical Reference Manuals (TRMs) issued by regulatory agencies in other states, primarily the Mid-Atlantic TRM version 2016 managed by the Northeast Energy Efficiency Partnerships (NEEP) for its Mid-Atlantic partners, Maryland, Delaware, and the District of Columbia, with significant involvement by the respective states' Public Service Commissions (PSCs). Other reference sources include TRMs and impact study results from California, Connecticut, Maine, Massachusetts, New Jersey, New York, Michigan, North Carolina, Ohio, Pennsylvania, the Tennessee Valley Authority, and Vermont, as well as other engineering resources such as the American Society of Heating, Refrigeration & Air Conditioner Engineers (ASHRAE), the 2012 International Energy Conservation Code, the National Electrical Manufacturers Association (NEMA) Standards Publication Condensed MG 1-2007, ENERGY STAR, the US Energy Information Administration (2005). Residential Energy Consumption Survey and Commercial Building Energy Consumption Survey, and the Energy Conservatory.

The STEP Manual is not intended to be the sole source or final word on gross annual energy and peak demand reductions estimates. Rather, the STEP Manual will serve as the foundation to guide ongoing program operations and as the basis for further refinement through Evaluation, Measurement & Verification (EM&V). Savings estimates from the STEP Manual will be coupled with the results of actual EM&V activities to calibrate the annual energy and peak demand reductions estimates derived from the STEP Manual to report population level estimates.

This version of the STEP Manual is version 8.0.0 (v8.0.0). This version is currently designed to estimate gross savings in concert with program tracking data received from Dominion through its Business Intelligence (BI) data system, which is populated by its program implementation vendors. Dominion has developed data specification requirements (listed in Table 1) for each of the programs and this STEP manual is designed to leverage that data.

Table 1: Program Tracking Data Specifications

Program	Data Specification Version	
	Virginia	North Carolina
Residential Home Energy Check-Up	1.4	1.0
Residential Duct Sealing	1.7	1.0
Residential Heat Pump Upgrade	2.7	1.0
Residential Heat Pump Tune-Up	1.7	1.0
Residential AC Cycling	2.0	-
Residential Income and Age Qualifying Home Improvement	1.2	Final
Residential Appliance Recycling	2.0	-
Non-Residential Energy Audit	4.2	Final
Non-Residential Duct Testing and Sealing	2.8	1.0
Non-Residential Distributed Generation	Final	-
Non-Residential Window Film	2.0	1.0
Non-Residential Lighting Systems and Controls	4.0	2.0
Non-Residential Heating and Cooling Efficiency	3.3	3.3
Non-Residential Small Business Improvement	1.5	-

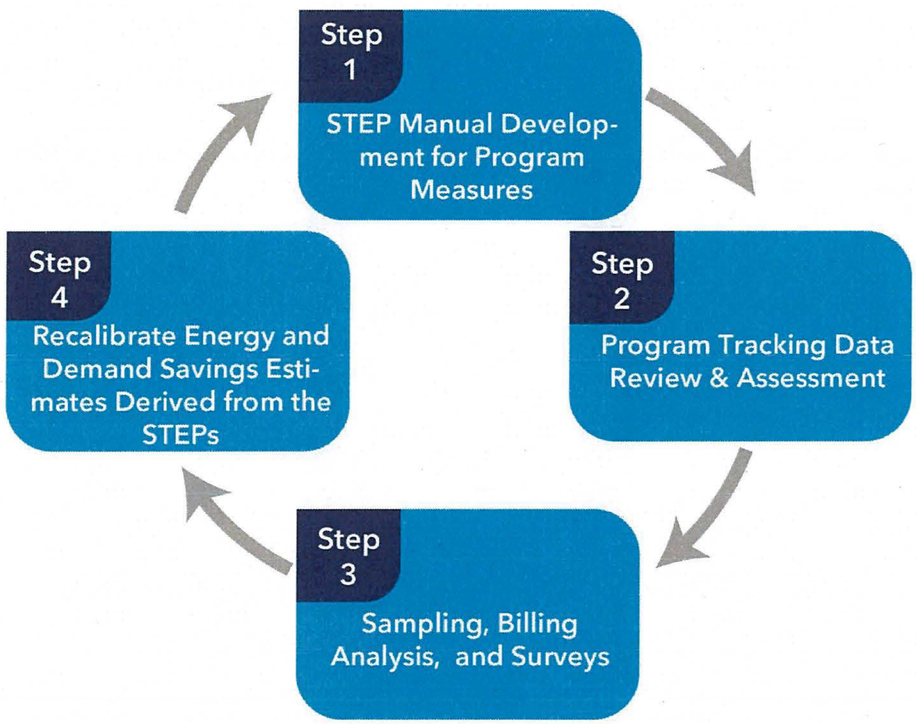
For Dominion, these protocols will also serve the following purposes:

1. Establish a common resource for Dominion's gross annual energy and peak demand reductions estimates across business units.
2. Ensure all internal parties (*e.g.*, Program Managers, implementation contractors, *etc.*) use the same protocols, input values, assumptions, and algorithms.
3. Assist in defining program data tracking elements in the change management process.
4. Serve as a basis to assess performance of program implementation progress.
5. Allow Dominion Program Managers and their implementation contractors to manage the programs to their annual energy savings (kWh/year) and peak demand (kW) reductions objectives.

Figure 1, below, shows how these protocols should be updated regularly to reflect the addition of new programs, modifications to existing programs, updates based on measured data, regulatory requirements, and the results of future program evaluations. Some examples of key drivers to updating and revising the STEP Manual include the following:

- Updates of input factors based on primary research;
- Updates of input approaches or input factors in source documents of secondary data or revised modeled outputs;
- Added efficiency measures; and
- Corrections of errors in prior STEP Manuals.

Figure 1: STEP Manual DSM development, measurement, and update cycle



The next scheduled update of the STEP Manual is in fall 2018.

This version of the STEP manual (for the May 1, 2018 Virginia and North Carolina EM&V report filing) applies to the period from January 1 through December 31, 2017 in both states.

1.2 Algorithms

The algorithms calculate gross customer electric savings without counting line losses (from the generator to the customer), spillover, or persistence. A free-ridership assumption is specified for each program. For energy efficiency programs, the algorithms are driven by a change in efficiency level for the installed measure compared to a baseline level of efficiency. This change is reflected in both energy savings and demand reductions. The basic algorithms are presented below.

$$Electric\ demand\ savings = \Delta kW = kW_{baseline} - kW_{energy\ efficient\ measure}$$

$$Electric\ energy\ savings = \Delta kW \times EFLH$$

$$Electric\ peak\ coincident\ demand\ savings = \Delta kW \times Coincidence\ factor$$

Where:

EFLH = Annual equivalent full load hours of operation for the installed measure

Algorithms for each of the program measures may incorporate additional factors to reflect specific conditions associated with a program or measure such as accounting for coincidence of multiple installations, or interaction between different measures.[1] In some cases, a savings factor is provided in place of the expanded algorithm if the factor is properly documented and applicable.

1.3 Measure Life

Measure lives are provided at the end of each section of this manual for each measure for estimating lifetime savings for planning or in benefit/cost studies spanning more than one year. Measure lives are included in the initial planning assumptions as filed with the SCC and NCUC state regulatory commissions when each program was considered for approval. Programs' measure lives are a composite estimate of the associated measures that comprise the program.

Table 2: Measure Life Assumptions

Program	Measure Life (Years)
Residential Programs	
Residential Appliance Recycling	8.0
Residential Duct Testing and Sealing	18.0
Residential Heat Pump Tune-Up	5.0
Residential Heat Pump Upgrade	15.0
Residential Home Energy Check-up	10.0
Residential Income and Age Qualifying Home Improvement	14.0
Residential Lighting	9.4
Residential Low Income	13.6
Residential Retail LED Lighting	20.0
Non-residential Programs	
Non-residential Duct Testing and Sealing	25.0
Non-residential Energy Audit	7.0
Non-residential Heating and Cooling	15.0

[1] Interactive effects include those from the installation of multiple measures at a single participant site. Where those interactive effects are accounted for in referenced technical reference manuals, they will also be documented in this STEP Manual.

Program	Measure Life (Years)
Non-residential Lighting & Controls	9.0
Non-residential Prescriptive	6.3
Non-residential Small Business Improvement	14.0
Non-residential Window Film	10.0
Commercial HVAC Upgrade	15
Commercial Lighting	10
Peak Shaving Programs	
Residential AC Cycling	15.0
Non-residential Distributed Generation	N/A

1.4 Data and Input Values

Input values and algorithms in the protocols and on the program application forms are based primarily on the best available and applicable data for Dominion's programs. In more detail, the input values are taken primarily from two sources: program application forms completed during enrollment, or from standard values based on measured or industry data. As stated earlier, the STEP Manual leverages the Mid-Atlantic TRM whenever possible.

Many input values, including site-specific data, are taken directly from program application forms, worksheets, and field tools. Site-specific data on the application forms are used for measures with important variations in one or more input values (e.g., delta watts, efficiency level, capacity, etc.).

Standard input values are based on the best available measured or industry data, including metered data, measured data from prior evaluations (applied prospectively), field data and program results, and standards from industry associations. Many input values are based on evaluations of programs in other similar regions.

For the standard input assumptions for which metered or measured data were not available, the input values (e.g., delta watts, delta efficiency, equipment capacity, operating hours, coincidence factors (CFs)) were based on the best available industry data or standards. These input values were developed from a review of literature from industry organizations, equipment manufacturers, and suppliers.

Program evaluation will be used to assess key data and input values to either confirm that current values should continue to be used or update the values going forward.

1.5 Peak Definition

Gross coincident peak demand reduction or potential represents the average expected connected load over a peak period defined by the power system operators. In most cases, demand reductions are calculated using a CF, which represents the fraction of the annual average connected load expected to be coincident with the defined peak period.

Peak demand reduction calculations for individual measures in this document are based on the respective source TRM's demand reduction calculations, as referenced in each section. Depending on the TRM referenced and the jurisdiction that it applies to, peak demand reduction can be defined differently per TRM and thus per measure in this Manual. Table 3 lists the peak period definitions for TRMs referenced in this Manual.

The Mid-Atlantic TRM uses data and assumptions specific to the Mid-Atlantic region, wherever possible. For this reason, the DNV GL leverages energy and demand calculations from the Mid-Atlantic TRM in its STEP calculations. However, several assumptions and peak coincidence factors originate in other regions because they are the most transferable resources available.[2] These other TRMs have some variation in peak performance period definition, geography, climate, and customer characteristics.

[2] For more discussion about the transferability of consumption data, see the EM&V Forum Report: Cataloguing Available End-Use and Efficiency Measure Load Data, October 2009 at http://www.neep.org/file/1010/download?token=XDUhN8Aq.

Table 3: Definition of Peak Demand in STEP Manual Reference TRMs

Peak period definition source	TRMs using this period	Dates[3]	Hours Ending[4]
PJM Summer Peak Performance Hours	All versions of the Mid-Atlantic TRM (non-cooling measures), Pennsylvania TRM, and Ohio TRM	June 1 – August 31	3:00 p.m. - 6:00 p.m.
ISO New England Seasonal Peak Demand Savings	2016 CT TRM, 2016 Maine Commercial TRM, 2014 Massachusetts TRM	Summer: June 1 through August 31 Winter: December 1 through January 31	Summer: 1pm-5pm Winter: 5pm-7pm
2011 Avoided Energy Supply Costs in New England report	2015 Vermont TRM	Summer: June to September Winter: October to May	Summer and winter: 7AM - 11PM
TVA	2016 Tennesee Valley Authority (TVA) TRM	Summer: June 1 through September 30 Winter: December 1 through March 31	Summer: 2pm-5pm Winter: 6am-8am
Summer System Peak	2014 Mid-Atlantic TRM (cooling measures), 2013 TVA TRM (weather-sensitive measures), 2016 New Year TRM	Mid-Atlantic TRM: Summer System Peak days (hottest summer weekdays); TVA TRM: Summer and Winter System Peak hours (10 hottest and 10 coldest hours) New York TRM: hottest summer non-holiday weekday in June through August	Mid-Atlantic TRM: 5pm; TVA Summer and Winter System Peak hours (10 hottest and 10 coldest hours) New York: 5PM

As this Manual provides deemed energy savings and peak demand, impact evaluations conducted on a regular basis can be used to adjust them for Dominion's needs. Dominion peak demand is defined as the hour ending at 1700 hour on Dominion's July summer peak day for that year. Coincidence factor is defined as the ratio of this coincident peak load to annual (non-coincident) peak for that measure's load shape.

Gross coincident demand reduction results are used for comparison against Dominion's program goals for this same metric. They are also used for bidding energy efficiency resources in

[3] Excluding weekends and federal holidays

[4] Local time zone

wholesale electric capacity markets operated by regional bulk power system operators, such as the PJM Reliability Pricing Model and the ISO New England Forward Capacity Market.

1.6 Document Structure

Sections 2 through 15 of this document provide descriptions of each program and the protocol for calculating energy savings and demand reductions for the measures under each program. For each measure, its section gives the energy savings and demand reduction algorithms, input values, default savings calculations, measure lives and sources for the protocols.

Dominion's residential programs are listed in Sections 2 through 8 and non-residential programs are listed in Sections 9 through 15. Unless the states in which they are implemented are specifically listed below, the programs are implemented in both Virginia and North Carolina.

Section 2: Residential Home Energy Check-Up

Section 3: Residential Heat Pump Upgrade

Section 4: Residential Heat Pump Tune-Up

Section 5: Residential Duct Sealing

Section 6: Residential Income and Age Qualifying Home Improvement

Section 7: Residential Appliance Recycling (Virginia only)

Section 8: Residential AC Cycling

Section 9: Non-Residential Lighting Systems and Controls

Section 10: Non-Residential Heating and Cooling Efficiency

Section 11: Non-Residential Energy Audit

Section 12: Non-Residential Duct Sealing and Testing

Section 13: Non-Residential Window Film

Section 14: Non-Residential Distributed Generation (Virginia only)

Section 15: Non-Residential Small Business Improvement

Section 16: Non-Residential Prescriptive

Section 17: Residential Retail LED Lighting Program

1.7 Version Control and Naming Conventions

To maintain consistency with revisions and modifications over time, DNV GL has developed the following three-digit version control and naming convention system beginning with the STEP Manual DSM Version 3.0.0.

The first digit in the STEP Manual document version is based on the year of the document release to the SCC and NCUC (*e.g.*, 3 represents 2013). With every change in the vintage year in which the STEP Manual is issued, the second and third digits are reset to zero.

The second digit indicates whether new measures are added to a program contained within the STEP Manual and is increased when a new measure or measure(s) is/are added.

The third digit indicates whether changes or updates are made to the STEP Manual and is increased when edits are made to the document.

Table 4: Document Change Descriptions from Version 7.0.0

Section	Description of Change
General	• Updated default values and protocols according to the latest versions of sources available as of June, 2017, when the 2017 version of the Mid-Atlantic TRM was released. • Minor wording and formatting updates.
Introduction	• Minor wording and formatting updates.
Residential Home Energy Check-Up Program	• No updates to measures exclusive to Residential Home Energy Check-Up program, only to those measures that are shared with the Residential Income and Age Qualifying Home Improvement Program, if any.
Residential Low Income Program	• Removed section. Program has closed.
Residential Heat Pump Upgrade Program	• No updates. Program closed, and no new tracking data as of March 2017.
Residential Heat Pump Tune-Up Program	• No updates. Program closed, and no new tracking data as of March 2017.
Residential Duct Sealing Program	• No updates. Program closed, and no new tracking data as of March 2017.
Residential Income and Age Qualifying Home Improvement Program	• General updates as mentioned above • Increase lighting measure baseline to conform to Federal guidelines
Residential Appliance Recycling Program	• No updates. Program closed.
Residential AC Cycling Program	• Minor wording and formatting updates.
Non-Residential Lighting Systems and Controls Program	• General updates as mentioned above • Added new construction default lighting ratio table, to assign default baseline wattage for new construction projects • Reinstated "existing quantity" from lamp and fixture measure calculation, such that estimate is based on the actual installed quantity of fixtures replacing the actual existing quantity of old fixtures
Non-Residential Heating and Cooling Efficiency Programs	• General updates as mentioned above.
Non-Residential Energy Audit Program	• No updates. Program closed, and no new tracking data as of March 2017
Non-Residential Duct Testing and Sealing Program	• No updates. Program closed, and no new tracking data as of March 2017
Non-Residential Window Film Program	• No updated. Minor corrections to make default assignments reported in this document to be consistent with values used in savings calculations.
Non-Residential Small Business Improvement Program	• General updates as mentioned above.
Non-Residential Distributed Generation	• No updates.

Section	Description of Change
Non-Residential Prescriptive Program	• New section
Residential Midstream LED Lighting	• New section

2 RESIDENTIAL HOME ENERGY CHECK-UP PROGRAM

Dominion's Residential Home Energy Check-Up program provides a residential walk-through inspection and improvements to the homeowners to identify potential electric energy savings. The incentivized measures include the following:

- Domestic Hot Water Heater Wrap
- Domestic Hot Water Heater Temperature Adjustment
- Domestic Hot Water Pipe Insulation
- Kitchen and Bathroom Aerator
- Low-Flow Showerhead
- Central Air Conditioner, Heat Pump or Window Unit Filter Change
- Door Sweep and/or Door Weatherization
- Compact Fluorescent Light Bulb Replacement
- Smart Strip Plug

2.1 Domestic Hot Water (DHW) End Use

2.1.1 Domestic Hot Water Heater Wrap

Measure Description

This measure realizes energy savings by installing a tank wrap, or "blanket," around a domestic hot water heater. The tank wrap serves to reduce standby losses during hours of non-use.

Savings Estimation Approach

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

$$\Delta kWh/year = \frac{\left(\frac{A_{base}}{R_{base}} - \frac{A_{insul}}{R_{insul}}\right) \times \Delta T \times HOU}{3{,}412\, Btu/kWh \times \eta DHW}$$

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

$$\Delta kW = \frac{\Delta kWh}{8{,}760\, hours/year}$$

Where:

ΔkWh/year = gross annual electric energy savings

ΔkW = gross coincident demand reductions
A_{base} = surface area of storage tank prior to adding tank wrap (ft^2)
A_{insul} = surface area of storage tank after addition of tank wrap (ft^2)
R_{base} = overall thermal resistance (R-value) prior to adding tank wrap (Hr-F-ft^2/Btu)
R_{insul} = overall thermal resistance (R-value) after addition of tank wrap (Hr-F-ft^2/Btu)
ΔT = average temperature difference between tank water and outside air temp. (°F)
HOU = number of hours in a year (since savings are assumed to be constant over year).
3,412 Btu/kWh = conversion from Btu to kWh
η_{DHW} = recovery efficiency of electric hot water heater

Input Variables

Table 5: Input Values for Domestic Water Heater Wrap Savings Calculations

Component	Type	Value	Unit	Source(s)
R_{base}	Fixed	8	hour-F°-feet^2/Btu	Mid-Atlantic TRM 2016, p. 180-181[5]
R_{insul}	Fixed	18	hour-F°-feet^2/Btu	Mid-Atlantic TRM 2016, p. 180-181[6]
A_{base}	Fixed	23.18	feet^2	Mid-Atlantic TRM 2016, p. 180-181[7]
A_{insul}	Fixed	25.31	feet^2	Mid-Atlantic TRM 2016, p. 180-181[8]
ΔT	Fixed	60	°F	Mid-Atlantic TRM 2016, p. 180-181[9]
HOU	Fixed	8760	hours/yr	Mid-Atlantic TRM 2016, p. 180-181
η_{DHW}	Fixed	0.98	-	Mid-Atlantic TRM 2016, p. 180-181[10]

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:

$$\Delta kWh/year = \frac{\left(\frac{A_{base}}{R_{base}} - \frac{A_{insul}}{R_{insul}}\right) \times \Delta T \times Hours}{3{,}412\ Btu/kWh \times \eta_{DHW}}$$

$$= \frac{\left(\frac{23.18}{8} - \frac{25.31}{18}\right) \times 60 \times 8{,}760}{3{,}412\ Btu/kWh \times .98}$$

$$= 234\ kWh/year$$

5 Mid-Atlantic TRM 2016, p. 180-181. Assumptions are from Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM) for a poorly insulated 40-gallon tank.

6 Mid-Atlantic TRM 2016, p. 180-181. Assumes an R-18 tank wrap is added, references Mid-Atlantic TRM 2014 p. 167.

7 Mid-Atlantic TRM 2016, p. 180-181. Assumptions from PA TRM for 40 gallon tank. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.

8 Ibid.

9 Mid-Atlantic TRM 2016, p. 180-181. Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.

10 Mid-Atlantic TRM 2016, p. 180-181. NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40.

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

$$\Delta kW = \frac{\Delta kWh}{8{,}760\ hours/year}$$
$$= \frac{234\ kWh/year}{8{,}760\ hours/year}$$
$$= 0.027\ kW$$

Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2016, p. 180-183.

2.1.2 Domestic Hot Water Heater Temperature Turndown

Measure Description

This measure realizes energy savings by downwardly adjusting the hot water tank temperature to 120°F, typically from 135°F or higher. Savings for this measure are generated by a reduction in standby losses.

Savings Estimation Approach

Gross annual electric energy savings[11] are assigned per unit as follows:

$$\Delta kWh/year = \frac{U \times A \times (T_{pre} - T_{post}) \times Hours}{3{,}412 \frac{Btu}{kWh} \times RE_{electric}}$$

Gross coincident demand reductions are assigned per unit as follows:

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

Where:

ΔkWh/year = gross annual electric energy savings
ΔkW = gross coincident demand reductions
U = overall heat transfer coefficient of tank (Btu/h-°F-ft2)
A = surface area of storage tank (ft^2)
T_{pre} = tank setpoint prior to turndown (°F)
T_{post} = tank setpoint after turndown (°F)
HOU = number of hours per year that tank is turned on
$RE_{electric}$ = recovery efficiency of electric hot water heater

[11] Mid-Atlantic TRM 2016, p. 205. Note this algorithm provides savings only from reduction in standby losses. Vermont Energy Investment Corporation (VEIC) considered avoided energy from not heating the water to the higher temperature but determined that the potential impact for the three major hot water uses was too small to be characterized: (1) Dishwashers are likely to boost the temperature within the unit (roughly canceling out any savings), (2) faucet and shower use is likely to be at the same temperature so there would need to be more lower temperature hot water being used (cancelling any savings), and (3)clothes washers will only see savings if the water from the tank is taken without any temperature control.

Input Variables

Table 6: Input Values for Domestic Hot Water Temperature Turndown Savings Calculations

Component	Type	Value	Unit	Source(s)
U	Fixed	0.083	Btu/h-°F-feet^2	Mid-Atlantic TRM 2016, p. 205
A	Fixed	24.99	feet^2	Mid-Atlantic TRM 2016, p. 206[12]
T_{pre}	Fixed	135	°F	Mid-Atlantic TRM 2016, p. 206
T_{post}	Fixed	120	°F	Mid-Atlantic TRM 2016, p. 206
HOU	Fixed	8,760	hours	Mid-Atlantic TRM 2016, p. 206
$RE_{electric}$	Fixed	0.98	-	Mid-Atlantic TRM 2065, p. 206[13]

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:

$$\Delta kWh/year = \frac{U \times A \times (T_{pre} - T_{post}) \times HOU}{3{,}412\frac{Btu}{kWh} \times RE_{electric}}$$

$$= \frac{0.083\ Btu/hour - °F - ft^2 \times 24.99ft^2 \times (135°F - 120°F) \times 8{,}760\ hours/year}{3{,}412\frac{Btu}{kWh} \times 0.98}$$

$$= 81.5\ kWh/year$$

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

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

$$= \frac{81.5\ kWh}{8{,}760\ hours}$$

$$= 0.009\ kW$$

[12] Mid-Atlantic TRM 2016, p. 206. Assumptions from Pennsylvania TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation.

[13] Mid-Atlantic TRM 2016, p. 206. Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx.

Source(s)

The source for this deemed savings approach is the Mid-Atlantic TRM 2016, p. 205-208.

2.1.3 Domestic Hot Water Pipe Insulation

Measure Description

This measure is offered in both the Residential Home Energy Check-Up program and the Residential Income and Age Qualifying Home Improvement Program. It realizes energy savings by adding insulation to uninsulated domestic hot water piping. The measure assumes the pipe wrap is installed to the first elbow of the hot water carrying pipe.

The baseline condition is uninsulated hot water copper piping.

Savings Estimation Approach

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

$$\Delta kWh/year = \frac{\left(\left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right) \times L \times C \times \Delta T \times 8{,}760\ hours/year\right)}{\eta_{DHW}} \div 3{,}412\ Btu/kWh$$

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

$$\Delta kW = \frac{\Delta kWh}{8{,}760\ hours/year}$$

Where:

ΔkWh/year = gross annual electric energy savings
ΔkW = gross coincident demand reductions
R_{base} = assumed R-value of existing uninsulated piping
R_{ee} = R-value of existing pipe plus installed insulation
L = length of piping insulated in feet
C = circumference of piping in feet
ΔT = temperature difference between water inlet pipe and ambient air
h_{DHW} = domestic hot water heater recovery efficiency

Input Variables

Table 7: Input Values for Domestic Water Heater Pipe Insulation Savings Calculations

Component	Type	Value	Unit	Source(s)
R_{base}	Fixed	1.0	hour.- °F-feet^2/Btu	Mid-Atlantic TRM 2017, p. 158[14]
R_{ee}	Variable	Residential Home Energy Check-up: 0.50-in diameter: R-2.3 0.75-in diameter: R-3.0	hour- °F-feet^2/Btu	Customer application and Program design[15]
		Residential Income and Age Qualifying Home Improvement: R-2.5		Program design
L	Variable	See customer application	feet	Customer application
		Default = 1		Per unit savings
C	Variable	Residential Home Energy Check-up: 0.50-in diameter: 0.13 0.75-in diameter: 0.20	feet	Customer application and program design[16]
		Residential Income and Age Qualifying Home Improvement: See customer application		Customer application
ΔT	Fixed	65	°F	Mid-Atlantic TRM 2017, p. 159[17]
η_{DHW}	Fixed	0.98	-	Mid-Atlantic TRM 2017, p. 159[18]

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:

Residential Home Energy Check-Up Program:

[14] Mid-Atlantic TRM 2016, p. 184. Navigant Consulting Inc., April 2009; "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets," p. 77, presented to the Ontario Energy Board. http://www.ontarioenergyboard.ca/oeb/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf. Accessed 8/26/2016.

[15] Based on program eligibility requirements.

[16] Based on program eligibility requirements.

[17] Mid-Atlantic TRM 2016, p. 185. Assumes 130°F water leaving the hot water tank and an average basement temperature of 65°F.

[18] Mid-Atlantic TRM 2016, p. 185. Electric water heaters have recovery efficiency of 98%. http://www.ahrinet.org/App_Content/ahri/files/Certification/GAMA/PG-CMW.pdf. Accessed 8/26/2016.

$$\Delta kWh/year = \frac{\left(\left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right) \times L \times C \times \Delta T \times 8{,}760\ hours/year\right)}{\eta_{DHW} \times 3{,}412\ Btu/kWh}$$

$$= \frac{\left(\left(\frac{1}{1.0} - \frac{1}{2.3}\right)\frac{Btu}{hr \cdot °F \cdot ft^2} \times 1ft \times 0.13\ ft \times 65°F \times 8{,}760\ hours/year\right)}{0.98 \times 3{,}412 Btu/kWh}$$

$$= 12.5\ kWh/year$$

Residential Income and Age Qualifying Home Improvement Program:

$$\Delta kWh/year = \frac{\left(\left(\frac{1}{R_{base}} - \frac{1}{R_{ee}}\right) \times L \times C \times \Delta T \times 8{,}760\ hours/year\right)}{\eta_{DHW} \times 3{,}412 Btu/kWh}$$

$$= \frac{\left(\left(\frac{1}{1.0} - \frac{1}{2.5}\right)\frac{Btu}{hr \cdot °F \cdot ft^2} \times 1ft \times 0.13\ ft \times 65°F \times 8{,}760\ hours/year\right)}{0.98 \times 3{,}412 Btu/kWh}$$

$$= 13.3\ kWh/year$$

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

Residential Home Energy Check-Up Program:

$$\Delta kW = \frac{\Delta kWh}{8{,}760\ hours/year}$$
$$= \frac{12.5\ kWh/year}{8{,}760\ hours/year}$$
$$= 0.001\ kW$$

Residential Income and Age Qualifying Home Improvement Program:

$$\Delta kW = \frac{\Delta kWh}{8{,}760\ hours/year} = \frac{13.3\ kWh/year}{8{,}760\ hours/year}$$
$$= 0.002\ kW$$

Source(s)

The primary source for this deemed savings approach is the Mid-Atlantic TRM 2017, p. 158-160.

2.1.4 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:

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

Gross annual electric energy savings[19] are calculated according to the following equation:

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

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

[19] Mid-Atlantic TRM 2016, p. 175. Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all faucet aerator installations.

CF = peak coincidence factor

Input Variables

Table 8: 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 2016, p. 175[20]
$Flow_{ee}$	Variable	Residential Home Energy Check-Up: Kitchen aerator default = 2.0 Bathroom aerator default = 1.5	gallons/minute	Program design[21]
		Residential Income and Age Qualifying Home Improvement: Kitchen and bathroom aerator default = 1.5		
# people	Variable	See customer application	-	Customer application
		Default = 2.56		Mid-Atlantic TRM 2016, p. 176[22]
gals/person/day	Fixed	10.9	gallons/person/day	Mid-Atlantic TRM 2016, p. 176[23]
DR	Fixed	0.5	-	Mid-Atlantic TRM 2016, p. 176[24]
faucets/home	Fixed	3.5	faucets/home	Mid-Atlantic TRM 2016, p. 176[25]
ΔT	Fixed	19.1	°F	Mid-Atlantic TRM 2016, p. 176 (T_{faucet} = 80°F[26], $T_{in\ house}$ = 60.9°F[27]; ΔT = 80 – 60.9 = 19.1°F)
η_{HW}	Fixed	0.98	-	Mid-Atlantic TRM 2016, p. 176[28]
HOU	Fixed	22	hours/year/faucet	Mid-Atlantic TRM 2016, p. 177[29]
CF	Fixed	0.00262	-	Mid-Atlantic TRM 2016, p. 177[30]

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:

$$\Delta Water = \left[\left(\frac{Flow_{base} - Flow_{ee}}{Flow_{base}}\right) \times \#\, people \times gals/person/day \times 365\, days/year \times DR\right]$$
$$\div\ faucets/home$$
$$= \left[\left(\frac{2.2\, gpm - 1.5\, gpm}{2.2\, gpm}\right) \times 2.56\, people \times 10.9 \frac{\frac{gals}{person}}{day} \times 365\, days/year \times 0.5\right]$$
$$\div\ 3.5\, faucets/home$$
$$= 463\, gallons/year/faucet$$

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

Residential Home Energy Check-Up Kitchen Aerator:

$$\Delta kWh/year = \Delta Water \times 8.3\, lbs/gal \cdot Btu/lb/°\mathrm{F} \times \Delta T_{[°\mathrm{F}]} \times \frac{1}{\eta_{HW}} \times \frac{1}{3{,}412\, Btu/kWh}$$
$$= 132\, gallons/year \times 8.3\, lbs/gal \cdot Btu/lb/°\mathrm{F} \times 19.1°\mathrm{F} \times \frac{1}{.98} \times \frac{1}{3{,}412\, Btu/kWh}$$
$$= 6.3\, kWh/year/faucet$$

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

$$\Delta kWh/year = \Delta Water \times 8.3\, lbs/gal \cdot Btu/lb/°\mathrm{F} \times \Delta T_{[°\mathrm{F}]} \times \frac{1}{\eta_{HW}} \times \frac{1}{3{,}412\, Btu/kWh}$$
$$= 463\, gallons/year \times 8.3\, lbs/gal \cdot Btu/lb/°\mathrm{F} \times 19.1°\mathrm{F} \times \frac{1}{.98} \times \frac{1}{3{,}412\, Btu/kWh}$$
$$= 22.0\, kWh/year/faucet$$

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 2016, p. 175-179.

2.1.5 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 gallons per minute (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[31] are calculated according to the following equation:

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

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

[31] Mid-Atlantic TRM 2016, p. 170. Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all showerhead installations.

showers/home = average number of showers in a home
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 9: 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 2016, p. 170[32]
		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 = 2.56		Mid-Atlantic TRM 2016, p. 171[33]
gals/person/day	Fixed	11.6	gallons/ person/ day	Mid-Atlantic TRM 2016, p. 171[34]
showers/home	Fixed	1.6	showers/home	Mid-Atlantic TRM 2016, p. 171
ΔT	Fixed	44.1	°F	Mid-Atlantic TRM 2016, p. 171 (T_{shower} = 105°F[35], $T_{in\ house}$ = 60.9°F[36]; ΔT = 105 – 60.9 = 44.1°F)
η_{HW}	Fixed	0.98	-	Mid-Atlantic TRM 2016, p. 171[37]
CF	Fixed	0.00371	-	Mid-Atlantic TRM 2016, p. 172[38]

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:

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

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

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:

$$\Delta kWh/year = \Delta Water \times 8.3\, lbs/gal \cdot Btu/lb/°F\ \times \Delta T \times \frac{1}{\eta_{HW}} \times \frac{1}{3{,}412\, Btu/kWh}$$
$$= 1{,}354.9\, gallons/year \times 8.3\, lbs/gal \cdot Btu/lb/°F \times 44.9°F \times \frac{1}{0.98} \times \frac{1}{3{,}412\, Btu/kWh}$$
$$= 151.0\, kWh/year/showerhead$$

Residential Low Income Program:

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32 Mid-Atlantic TRM 2016, p. 170. "The Energy Policy Act (EPAct) of 1992 established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm)."

33 Mid-Atlantic TRM 2016, p. 171. "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.

34 Mid-Atlantic TRM 2016, p. 171. "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

35 Mid-Atlantic TRM 2013, p. 127. 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.

36 Mid-Atlantic TRM 2016, p. 171. 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.

37 Mid-Atlantic TRM 2016, p. 171. 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

38 Mid-Atlantic TRM 2016, p. 172. 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.

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

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

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

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. 170 – 174.

2.2 Heating Ventilation and Air Conditioning (HVAC) End Use

2.2.1 Central Air Conditioner, Heat Pump, or Window Unit Filter Change

Measure Description

Under the Residential Home Energy Check-Up Program, this measure realizes energy savings by replacing a central air conditioning, heat pump or window unit filter, and leaving extra filters to cover one year of regular filter replacements. The air flow over the filters are assumed values based on the Dominion residential energy efficiency program participant heating and cooling system type and sizes.

Under the Residential Low Income Program, this measure realizes savings the same way, by replacing a central air conditioning or heat pump unit filter and leaving extra filters to cover one year of regular filter replacement. Window units are not eligible for this program.

Savings Estimation Approach

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

$$\Delta kWh/year = \frac{Q \times \Delta P \times ANOP_{min} \times 3.755 \times 10^{-7}\, kWh/ft \cdot lb_f}{\eta_{AC}}$$

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

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

Where:

ΔkWh/year = gross annual electric energy savings
ΔkW = gross coincident demand reductions
Q = flow rate over the filter area
ΔP = pressure over the filter area
$ANOP_{min}$ = annual operating minutes
η_{AC} = efficiency of the system
FLH = annual full load hours

Input Variables

Table 10: Input Values for Residential A/C or Heat Pump Filter Change Savings Calculations

Component	Type	Value	Unit	Source(s)
Q (CFM)	Variable	Richmond, VA Heat Pump, Central AC, Central furnace: 957 Charlotte, NC Heat Pump, Central AC, Central furnace: 1030	feet³/ minute	Dominion's portfolio of residential energy efficiency programs[39] Mid-Atlantic TRM 2016, p. 116
		Richmond, VA and Charlotte, NC Window Unit: 240		DNV GL judgment based on common window unit specifications
ΔP	Fixed	0.52	lbf/ft²	Manufacturer data for new filter. Average difference calculated for deemed savings. Changing fiberglass filter or pleated filter from dirty to new with same filter type. 0.1 inch of water [4 °C] = 0.52 lbf/ft²[40]
$ANOP_{min}$	Variable	Richmond, VA Heat pump = 97,860 Central AC = 36,780 Central furnace = 47,340 Window unit = 22,080 Charlotte, NC Heat pump = 100,980 Central AC = 41,040 Central furnace = 44,640 Window unit = 24,660	minutes/year	FLH x 60 minutes/hr

[39] 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 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. The average capacity was converted to a flow rate by using a conversion factor of 400 CFM/ton, found on p. 116 of the Mid-Atlantic TRM 2016. These values were not updated for 2016 as average heat pump capacity varied little beween 2014 and 2015.

[40] Beware of Filter Pressure Drop, by Kevin O'Neill. (www.hvac.amickracing.com/Air%20Cleaners/BEWARE%20OF%20FILTER.doc)

Component	Type	Value	Unit	Source(s)
FLH[41]	Variable	Richmond, VA Heat pump = 1,631 Central AC = 613 Central furnace = 789 Window unit = 368 Charlotte, NC Heat pump = 1,683 Central AC = 684 Central furnace = 744 Window unit = 411	hours/ year	Table 131 ENERGY STAR® Room AC Calculator Mid-Atlantic TRM 2016, p. 116
η_{AC}	Fixed	0.6	-	Assumed standard efficiency

Table 11: Estimated Savings by System Type for Filter Change

System Type	Location	Energy Savings (kWh/year)	Peak Demand Reductions (kW)
Heat Pump	Richmond, VA	30.7	0.019
	Charlotte, NC	31.4	0.019
Central AC	Richmond, VA	11.5	0.019
	Charlotte, NC	12.8	0.019
Central Furnace	Richmond, VA	14.8	0.019
	Charlotte, NC	13.9	0.019
Window Unit	Richmond, VA	1.7	0.005
	Charlotte, NC	1.9	0.005

[41] Full load hours are calculated by converting the annual operating minutes to hours (dividing by 60 minutes/hour).

Default Savings

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

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

$$\Delta kWh/year = \frac{Q \times \Delta P \times ANOP_{min} \times 3.755 \times 10^{-7}\, kWh/ft \cdot lb_f}{\eta_{AC}}$$

Richmond, VA:

$$\Delta kWh/year_{VA} = \frac{240\, ft^3/minute \times 0.52\, lbf/ft^2\ \times 22{,}080\, minutes/year \times\ 3.755 \times 10^{-7}\, kWh/ft \cdot lb_f}{0.60}$$

$$= 1.7\, kWh/year$$

Charlotte, NC:

$$\Delta kWh/year_{NC} = \frac{240\, ft^3/minute \times 0.52\, lbf/ft^2\ \times 24{,}660\, minutes/year \times\ 3.755 \times 10^{-7}\, kWh/ft \cdot lb_f}{0.60}$$

$$= 1.9\, kWh/year$$

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

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

Richmond, VA:

$$\Delta kW_{VA} = \frac{1.7\, kWh/year}{368\, hours/year}$$

$$= 0.005\, kW$$

Charlotte, NC:

$$\Delta kW_{NC} = \frac{1.9\, kWh/year}{411\, hours/year}$$

$$= 0.005\, kW$$

Source(s)

The sources for this deemed savings approach are the Mid-Atlantic TRM 2016, p. 116; and the ENERGY STAR® Central AC and Air Source Heat Pump calculators at https://www.energystar.gov/index.cfm?c=airsrc_heat.pr_proc_as_heat_pumps.

2.2.2 Door Sweep and/or Door Weatherization

Measure Description

This measure realizes energy savings by installing a door sweep and/or weather-stripping on doors leading outside to reduce air infiltration from outside of the house to inside the house.

Savings from this measure may only be claimed if a blower door test is not feasible. Savings estimates based on actual measured infiltration reduction (through blower door testing) are more precise.

Infiltration reduction measures must be located between conditioned space and unconditioned space (outdoors) to be eligible for energy savings. Savings may not be claimed for both door sweep and door kit for weatherization of a single door.

No summer gross coincident demand reductions may be claimed since cooling energy savings are not quantified.

Savings Estimation Approach

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

Door sweep:

$$\Delta kWh/year = \Delta kWh/year_{door\ sweep}$$

Door weatherization:

$$\Delta kWh/year = \frac{\Delta kWh/year}{ft_{door\ weatherize}} \times L$$

Savings should only be applied for either door sweep or door weatherization per door, not combined.

Gross coincident demand reductions are assigned as follows:

$$\Delta kW = 0\ kW$$[42]

Where:

ΔkWh/year = gross annual electric energy savings
ΔkW = gross coincident demand reductions
$\Delta kWh/year_{door\ sweep}$ = gross annual electric energy savings per door sweep installation
$\Delta kWh/year \cdot ft_{door\ weatherize}$ = gross annual electric energy savings per linear foot of door weather strip

[42] There are no demand reductions assigned for this measure, per the CT TRM.

L = linear feet of weather-strip

Input Variables

Table 12: Input Values for Door Sweep and Door Weatherization Savings Calculations

Component	Type	Value	Unit	Source(s)
L	Variable	See customer application	feet	Customer application
		Default = 16.33		DNV GL judgment based on standard door size and weatherization applied to only 3 sides (80" + 36" +80")
$\Delta kWh/year_{door\ sweep}$	Variable	173 kWh (Electric resistance heating) 86.5 kWh (Heat pump and electric "Furnace - Ducted")	kWh/ year	Connecticut Program Savings Document (PSD) 2015, p. 258[43] and DNV GL judgement for electric "Furance - Ducted" systems
$\Delta kWh/year\cdot ft_{door\ weatherize}$	Variable	9.9 kWh/ft (Electric resistance heating) 4.95 kWh/ft (Heat pump and electric "Furnace - Ducted")	kWh/ft/year	Connecticut PSD 2015, p. 258[44] and DNV GL judgement for electric "Furance - Ducted" systems

Default Savings

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

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

Door sweep:

$$\Delta kWh/year = \Delta kWh/year_{door\ sweep}$$

[43] Connecticut Program Savings Document (2015), p. 258. Original source: KEMA, Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps), Sept. 10, 2010.
[44] Ibid.

$$= 86.5\ kWh/year$$

Door weatherization:

$$\Delta kWh/year = \frac{\Delta kWh/year}{ft_{door\ weatherize}} \times L$$

$$= \frac{4.95\ kWh/year}{ft_{door\ weatherize}} \times 16.33\ ft$$

$$= 80.9\ kWh/year$$

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

$\Delta kW = 0\ kW$

Source(s)

The primary source for this deemed savings approach is the 2015 Connecticut Program Savings Document, p. 258.

2.3 Lighting End Use

2.3.1 Compact Fluorescent Light Bulb Replacement

Measure Description

Under both the Residential Home Energy Check-Up Program and the Residential Low Income Program, this measure realizes energy savings by installing a compact fluorescent light bulb (CFL) in place of a less efficient bulb. When installed CFL wattages are known, per unit savings are calculated using the algorithms described in this section. An in-service rate is not applied because the bulbs are directly installed by a technician.

Specific to the Residential Low-Income program is the requirement that a household is only eligible for a maximum of 6 CFL bulb replacements.

Savings Estimation Approach

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

$$\Delta kWh/year = \frac{(Watts_{base} - Watts_{ee})}{1{,}000\ W/kW} \times HOU \times ISR \times (WHFe_{heat} + (WHFe_{cool} - 1))$$

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

$$\Delta kW = \frac{(Watts_{base} - Watt_{ee})}{1{,}000\ W/kW} \times ISR \times WHFd \times CF$$

Where:

ΔkWh/year = gross annual electric energy savings
ΔkW = gross coincident demand reductions
$watts_{base}$ = wattage of the lightbulb being replaced
$watts_{ee}$ = wattage of the replacement CFL
HOU = lighting hours of use per year
CF = summer peak coincidence factor
$WHFe_{cool}$ = waste heat factor for energy to account for cooling savings from reducing waste heat from efficient lighting
$WHFe_{heat}$ = waste heat factor for energy to account for electric heating savings from reducing waste heat from efficient lighting
WHFd = waste heat factor for demand to account for cooling savings from efficient lighting
ISR = in service rate or percentage of units rebated that are installed and operational

Input Variables

Table 13: Input Values for CFL Lighting Savings

Component	Type	Value	Unit	Source(s)
$watts_{base}$	Variable	See Table 14: Baseline wattage values	-	Mid-Atlantic TRM 2016, p. 21
$watts_{ee}$	Variable	See customer application	watts	Customer application
		Default = 15		DNV GL judgment
		Use the middle wattage rating for 3-way lamps		
		Use the maximum wattage rating for dimmable lamps		
HOU	Fixed	Richmond, VA: 898	hours/year	Mid-Atlantic TRM 2016, p. 22[45]
		Charlotte, NC: 1,067		Duke Energy Progress, Docket E-2, Sub 950, p. 21[46]
ISR	Fixed	Direct install = 0.82	-	Mid-Atlantic TRM 2016, p. 22[47]
$WHFe_{cool}$	Fixed	1.10	-	Mid-Atlantic TRM 2016, p. 23[48]
$WHFe_{heat}$	Fixed	0.894	-	Mid-Atlantic TRM 2016, p. 23[49]
WHFd	Fixed	Unknown = 1.21	-	Mid-Atlantic TRM 2016, p. 25[50]
CF	Fixed	0.084	-	Mid-Atlantic TRM 2016, p. 25[51]

[45] Mid-Atlantic TRM 2016, p. 22. Selected "Unknown" installation location as details about installation location are not collected. Daily hours for unknown installation is 2.46, and annual hours = 2.46 hours/day x 365 days/year = 898 hours/year.

[46] Duke Energy Progress on July 11, 2016 in Docket E-2, Sub 950, entitled "Energy Efficient Lighting Program (PY2014) Evaluation Report – FINAL " Daily hours is 2.922 hours/day, and annual hours = 2.922 hours/day x 365 days/year = 1,067 hours/year.

[47] Mid-Atlantic TRM 2016, p. 22. Assumption is based on the EmPOWER _EY5 Res Lighting Results Memo_20Jan2015 DRAFT discussed above, but not adjusted upwards since those people removing bulbs after being installed in Direct Install program are likely to do so because they dislike them, not to use as replacements. The only evaluation we are aware of specifically for Direct Install installation (and persistence) rates is Megdal & Associates, 2003; "2002/2003 Impact Evaluation of LIPA's Clean Energy Initiative REAP Program", which estimated 81%.

Table 14: Baseline wattage values[52]

Minimum Lumens	Maximum Lumens	$watts_{base}$	Typical ENERGY STAR Qualified Lighting Replacement Options[53]
1,490	2,600	72	23 – 26W CFL
1,050	1,489	53	18 -20W CFL
750	1,049	43	13 - 15W CFL
310	749	29	9 – 11W CFL

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:

$$\Delta kWh/year = \frac{(Watts_{base} - Watts_{ee})}{1{,}000\ W/kW} \times HOU \times ISR \times (WHFe_{heat} + (WHFe_{cool} - 1))$$

$$= \frac{43\ W - 15\ W}{1{,}000\ W/kW} \times 898\ hours \times 0.82 \times (0.894 + (1.09 - 1))$$

$$= 20.3\ kWh/year$$

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

$$\Delta kW = \frac{(Watts_{base} - Watts_{ee})}{1{,}000\ W/kW} \times ISR \times WHFd \times CF$$

$$= \frac{43\ W - 15\ W}{1{,}000\ W/kW} \times 0.82 \times 1.18 \times 0.084$$

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[48] Mid-Atlantic TRM 2016, p. 23. The value is estimated at 1.10 (calculated as 1 + (0.89*(0.33 / 2.8)). Based on assumption that 89% of homes have central cooling (based on KEMA Maryland Energy Baseline Study. Feb 2011.).

[49] Mid-Atlantic TRM 2016, p. 23. 1 - ((HF / ηHeat) * %ElecHeat). Calculated using defaults; 1+ ((0.47/1.67) * 0.375) = 0.894.

[50] Mid-Atlantic TRM 2016, p. 25. The value is estimated at 1.21 (calculated as 1 + (0.89 * 0.66 / 2.8)).

[51] Mid-Atlantic TRM 2016, p. 25. Assumed "unknown" installation location.

[52] For installed fixture wattages that fall between the ranges listed in "Typical ENERGY STAR Qualified Lighting Replacement Options" in this table, the default baseline wattage is assumed to be the higher one. For example, if the installed fixture wattage was 20W, it would be assigned the typical ENERGY STAR® Qualifying Lighting Replacement Option for "23-26W CFL" and a default baseline wattage of 72W.

[53] Residential Lighting Programs and Federal Minimum Lighting Standards: An Overview for Regulator. ENERGY STAR. https://www.energystar.gov/ia/partners/manuf_res/LightingfactsheetFinal.pdf?0544-2a1e. Accessed 7/22/2016.

$= .002\ kW$

Source(s)

The primary source for this deemed savings approach are the Mid-Atlantic TRM 2016, p. 20-28. ENERGY STAR (2015), "Residential Lighting Programs and Federal Minimum Lighting Standards: An Overview for Regulator."