Opinion Dynamics

Memorandum

To: Deirdre Morris and Tom Knauer, Vermont Public Utility Commission

CC: Clean Heat Standard (CHS) Technical Advisory Group

From: The Opinion Dynamics Team

Date: June 28, 2024

Re: Early Win Measure Characterization Deliverable

Opinion Dynamics has contracted with the Vermont Public Utility Commission (PUC) to develop a technical resource manual (TRM) providing measure characterizations for clean heat measures installed under the Clean Heat Standard (CHS). This memo is an introduction to our second formal deliverable for this project, a package of "early win" measure characterizations for measures that are already comparatively well understood. This package is a limited set of draft measure characterizations for already well-established measures that will provide an early opportunity for the PUC and TAG to provide early feedback on the comprehensiveness and technical approach to our measure characterization efforts. Table 1 provides detail on the measures included in the package.

Table 1. Measures Included in Early Win Package

Sector	Measure	Enduse	Measure ID	CHS Measure Area	Source of CO_2e Savings
Residential	Insulation	Envelope	RE_ENVE_INSU	(1) thermal energy efficiency improvements and weatherization	Efficiency
Residential	Advanced Thermostats	HVAC	RE_HVAC_ADVT	(1) thermal energy efficiency improvements and weatherization	Efficiency
Residential	Heat Pump Water Heater	Domestic Hot Water	RE_DOHW_HPWH	(3) heat pump water heaters	Efficiency and fuel source
Residential	Low Flow Faucet Aerator	Domestic Hot Water	RE_DOHW_LFFA	(1) thermal energy efficiency improvements and weatherization	Efficiency
Residential	Low Flow Showerhead	Domestic Hot Water	RE_DOHW_LFSH	(1) thermal energy efficiency improvements and weatherization	Efficiency
Residential	Induction Cooktop	Appliances	RE_APPL_INCT	(6) electric appliances providing thermal end uses	Efficiency and fuel source
C&I	Advanced Thermostats	HVAC	CI_HVAC_ADVT	(1) thermal energy efficiency improvements and weatherization	Efficiency
C&I	Low Flow Faucet Aerator	Domestic Hot Water	CI_DOHW_LFFA	(1) thermal energy efficiency improvements and weatherization	Efficiency
C&I	Low Flow Showerhead	Domestic Hot Water	CI_DOHW_LFSH	(1) thermal energy efficiency improvements and weatherization	Efficiency

Below, we offer context to help reviewers understand the measure characterizations presented in the deliverable and ensure feedback provided is as targeted as possible.

General Approach to Measure Characterizations

In preparing these measure characterizations, we leaned upon our experience developing and administering energy efficiency TRMs, existing Vermont-specific documents (specifically the Efficiency Vermont TRM and the Tier III TRM), our review of the requirements of Act 18, and guidance provided by the Vermont PUC and TAG.

In this work, we give some deference to existing Vermont-specific documents in the interest of ensuring alignment across multiple Vermont efforts where possible, but make updates to parameters/approaches used where we felt appropriate and/or where gaps needed to be filled in to meet the needs of the CHS TRM. When we deliver the first full measure characterization deliverable, currently scheduled for the end of August, we will include a summary of changes in measure characterizations as compared to other Vermont-specific documents and why those changes were made.

The measure characterizations are structured consistent with the previously submitted measure structure deliverable.

Status of Emissions Analysis

Measure characterizations in the CHS TRM are intended to be used to determine carbon dioxide equivalent (CO_2e) reductions associated with the implementation of CHS measures. Each measure characterization first estimates changes in energy use associated with the implementation of the clean heat measure, and then converts changes in energy use to CO2e reductions using emissions factors associated with each fuel type for which energy changes occur. In this early deliverable, we have not yet finalized emissions factors associated with each fuel type, and therefore summary tables for CO2e emissions are not yet finalized. For use in example calculations, we suggest calculations can be worked through using the following placeholder values. Placeholder values are not intended to have any meaningful relationship to actual emissions factors, which are under development, and were selected as multiples of 10 for ease of use. Placeholder emissions factors can be assumed to be temporally static.

Table 2. Placeholder Emissions Factors

Fuel	gCO_2e/MJ
Liquid/Gaseous Fuels	100
Electricity	10
Wood	1000

Comments on Measure Format

The measure characterizations presented in the early win deliverable are in a “partially deemed” form that prescribes algorithms and parameters that can be used to estimate carbon reductions. This form requires calculations be completed in order to estimate carbon reductions. As discussed with the PUC and TAG, we will consider the benefits of defining measures in “fully deemed” forms in the final CHS TRM that prescribe set carbon reductions for a given common set of measure characteristics. This decision is one that is downstream of the underlying measure characterization work conducted to date and can be easily implemented as needed. We welcome feedback from the PUC and TAG on which measures, if any, would benefit from “fully deemed” characterizations.

We also welcome feedback on how the “Decarbonization Summary” tables are presented. The intent of these tables is to provide a high level summary/overview of expected lifecycle CO_2e savings for common existing and proposed conditions – we think that these tables will help support some of the requests we received early in this project to present carbon reduction ranges by measure. However, this is challenging for measures with a large number of input combinations, and those with grid electricity impacts, given that lifecycle electricity emissions factors will change over time. We welcome feedback on how best to structure this section (or if it is even needed).

Opinion Dynamics

Vermont Clean Heat Standard

Early Win Measure Characterizations

June 28, 2024

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2.1.1 Building Shell Insulation

CHS Measure ID: RE_ENVE_INSU
Market Sector: Residential
End Use: Envelope
Applicable Building Types: Single Family, Multifamily
Decarbonization Pathways: Weatherization
Applicable Baseline Fuels: Natural gas, propane, fuel oil #2, electricity, wood
Decision/Action Type: Retrofit
Program Delivery Type: Downstream

Measure Description

This measure involves adding insulation to building shell assemblies to reduce conductive heat loss to the outside. It is a Retrofit measure in which the baseline is the thermal resistance of the assembly prior to the installation and the proposed condition is the thermal resistance of the structure after the installation. This characterization may be applied to sloped ceiling, attic, wall, and rim joist insulation. This characterization calculates CO_2e savings on a per square foot basis from actual pre- and post- R-values for insulation alone.

Baseline Conditions

The baseline is the R-value of the assembly prior to the retrofit. The assembly may have some existing insulation or none.

Proposed Conditions

The proposed condition is the R-value of the assembly after the retrofit. This characterization does not require a minimum level of insulation following the retrofit.

Eligibility Criteria

At a minimum, the interior space must be mechanically heated and maintained continuously at typical comfort temperatures.

Decarbonization Summary

Table 1 provides lifecycle CO2e reductions for example existing and proposed conditions over the expected useful life of the measure. These estimates are not inclusive of all eligible conditions; other conditions may be calculated from the algorithms herein.

Assumptions:

- Central A/C presence is unknown/not collected

- Heating efficiencies per Table 6
- Building type (single family or multifamily) is unknown/not collected

Table 1. Residential Building Shell Insulation CO2e Reduction Summary

Assembly Type	System Type	Heating Fuel	R-Value of Insulation Alone		Lifetime CO2e Reduction Per Sq Ft of Insulation [g/sq ft]
			Baseline	Proposed	
Attic, Standard Wood Framing	Boiler	Oil	None	R-49	
	Boiler	Propane	None	R-49	
	Boiler or Furnace	Natural Gas	None	R-49	
	Boiler, Furnace, or Baseboard	Electric	None	R-49	
	Furnace	Oil	None	R-49	
	Furnace	Propane	None	R-49	
	Heat Pump	Electric	None	R-49	
	Pellet Stove	Wood	None	R-49	
Exterior Wall, Standard Wood Framing	Boiler	Oil	None	R-15	
	Boiler	Propane	None	R-15	
	Boiler or Furnace	Natural Gas	None	R-15	
	Boiler, Furnace, or Baseboard	Electric	None	R-15	
	Furnace	Oil	None	R-15	
	Furnace	Propane	None	R-15	
	Heat Pump	Electric	None	R-15	
	Pellet Stove	Wood	None	R-15	
Basement Exterior Wall, Concrete Block With Standard Wood Framing	Boiler	Oil	None	R-15	
	Boiler	Propane	None	R-15	
	Boiler or Furnace	Natural Gas	None	R-15	
	Boiler, Furnace, or Baseboard	Electric	None	R-15	
	Furnace	Oil	None	R-15	
	Furnace	Propane	None	R-15	
	Heat Pump	Electric	None	R-15	
	Pellet Stove	Wood	None	R-15	

Decarbonization and Energy Impacts Algorithms

$$CO2e\ [grams] = (\Delta E_{hf} \times EF_{hf}) + ((\Delta E_{cool} + \Delta E_{fan}) \times EF_{elec})$$

ΔE_{hf} = Reduction in primary heating fuel consumption in megajoules [MJ] as a result of installing this measure.

ΔE_{cool} = Reduction in cooling electrical energy in megajoules [MJ] as a result of installing this measure.

ΔE_{fan} = Reduction in fan electrical energy in megajoules [MJ] as a result of installing this measure.

EF_{hf} = Heating fuel emissions factor in grams of carbon diode equivalent per megajoule [gCO2e/MJ], based on fuel type. See Table x in Reference Section. If the primary heating fuel type is unknown, am average emissions factor may be calculated with the following weights:[1]

Table 2. Vermont Primary Heating Fuel Mix, Residential Buildings

Heating Fuel	Building Type		
	Single Family	Multifamily	Unknown
Oil	45%	5%	41%
Propane	17%	5%	16%
Natural Gas	23%	66%	27%
Electricity	6%	23%	8%
Wood	8%	1%	7%

EF_{elec} = Grid electricity emissions factor [gCO2e/MJ]; see Table x in Reference Section.

Energy Impacts Algorithms

ΔE_{heat} = Heating energy savings [MJ] = $\left(\frac{1}{R_{pre}} - \frac{1}{R_{post}}\right) \times A_{ins} \times HDH \times Adj_{heat} \times \frac{1}{\eta_{heat}} \times 0.00106$

ΔE_{cool} = Cooling energy savings [MJ] = $\%Cool \times \left(\frac{1}{R_{pre}} - \frac{1}{R_{post}}\right) \times A_{ins} \times CDH \times Adj_{cool} \times \frac{1}{\eta_{cool}} \times 0.00106$

ΔE_{fan} = Fan energy savings [MJ] = %Fossil x ΔE_{heat} x F_e

Input variable definitions

0.00106 = Conversion factor, MJ per BTU.

F_e = Furnace/boiler fan/pump energy as a percentage of annual fuel consumption = 3.14%[2]

%Fossil = Percent of Vermont homes with fossil-fuel furnaces or boilers (from Table 2)

Fossil Fuel Furnace or Boiler?	%Fossil
Yes	100%
No	0%
Unknown, Single Family	85%
Unknown, Multifamily	76%
Unknown, Building Type Unknown	84%

%Cool = Percent of Vermont homes with central cooling

Central Cooling?	%Cool
Yes	100%
No	0%
Unknown, Single Family[3]	7%
Unknown, Multifamily[4]	8%

Unknown, Building Type Unknown[5]	7.1%

R_{pre} = Pre-installation R-value [(ft2°F hr)/Btu] of assembly, derived from tables below. For alternate construction types, refer to ASHRAE 90.1 Appendix A.

R_{post} = Post-installation R-value [(ft2°F hr)/Btu] of assembly, derived from tables below. For alternate construction types, refer to ASHRAE 90.1 Appendix A.[6]

Table 3. Residential Insulation: Assembly R-Factors for Attic Roofs with Wood Joists

Rated R-Value of Insulation Alone	Overall R-Factor For Entire Assembly
Wood-Framed Attic, Standard Framing	
None	R-1.6
R-11	R-11.0
R-13	R-12.3
R-19	R-18.9
R-30	R-29.4
R-38	R-37.0
R-49	R-47.6
R-60	R-58.8

Table 4. Residential Insulation: Assembly R-Factors for Wood-Frame Walls

Framing Type and Spacing Width (Actual Depth)	Cavity Insulation R-Value: Rated	Overall R-Factor For Entire Base Assembly	Overall R-Factor for Assembly of Base Wall Plus Continuous Insulation (Uninterrupted by Framing)				
			Rated R-Value of Continuous Insulation				
			R-1.00	R-2.00	R-3.00	R-4.00	R-5.00
Wood Studs at 16 in. on Center							
3.5 in. depth	None	R-3.4	R-4.5	R-5.5	R-6.6	R-7.6	R-8.6
	R-11	R-10.4	R-11.5	R-12.7	R-13.7	R-14.7	R-15.9
	R-13	R-11.2	R-12.5	R-13.5	R-14.7	R-15.9	R-16.9
	R-15	R-12.0	R-13.3	R-14.5	R-15.6	R-16.7	R-17.9
5.5 in. depth	R-19	R-14.9	R-16.1	R-17.2	R-18.5	R-19.6	R-20.8
	R-21	R-15.9	R-17.2	R-18.5	R-19.6	R-20.8	R-22.2
+ R-10 headers	R-19	R-15.9	R-16.9	R-18.2	R-19.2	R-20.4	R-21.3
	R-21	R-16.9	R-18.2	R-19.6	R-20.4	R-21.7	R-22.7

R-6.00	R-7.00	R-8.00	R-9.00	R-10.00	R-11.00	R-12.00	R-13.00
R-9.6	R-10.6	R-11.6	R-12.7	R-13.7	R-14.7	R-15.6	R-16.7
R-16.9	R-17.9	R-18.9	R-20.0	R-20.8	R-21.7	R-22.7	R-23.8
R-17.9	R-18.9	R-20.0	R-21.3	R-22.2	R-23.3	R-24.4	R-25.0
R-18.9	R-20.0	R-21.3	R-22.2	R-23.3	R-24.4	R-25.6	R-26.3
R-21.7	R-22.7	R-23.8	R-25.0	R-26.3	R-27.0	R-27.8	R-29.4
R-23.3	R-24.4	R-25.6	R-26.3	R-27.8	R-28.6	R-29.4	R-31.3
R-22.2	R-23.3	R-24.4	R-25.6	R-26.3	R-27.8	R-28.6	R-29.4
R-23.8	R-25.0	R-26.3	R-27.0	R-28.6	R-29.4	R-30.3	R-31.3

R-14.00	R-15.00	R-20.00	R-25.00	R-30.00	R-35.00	R-40.00
R-17.9	R-18.9	R-23.8	R-28.6	R-33.3	R-38.5	R-43.5
R-25.0	R-26.3	R-31.3	R-35.7	R-41.7	R-45.5	R-50.0
R-26.3	R-27.0	R-32.3	R-37.0	R-41.7	R-47.6	R-52.6
R-27.8	R-28.6	R-33.3	R-38.5	R-43.5	R-50.0	R-52.6
R-30.3	R-31.3	R-37.0	R-41.7	R-47.6	R-52.6	R-55.6
R-32.3	R-33.3	R-38.5	R-43.5	R-47.6	R-52.6	R-58.8
R-30.3	R-32.3	R-37.0	R-41.7	R-47.6	R-52.6	R-58.8
R-32.3	R-33.3	R-38.5	R-43.5	R-50.0	R-55.6	R-58.8

Table 5. Residential Insulation: Assembly R-Factors for Below-Grade Walls

A_{ins} = Area in square feet of insulation applied.

HDH = Heating degree hours [°F hr], dependent on structure being treated (see below)[7]

CDH = Cooling degree hours [°F hr][8]

Structure	HDH [°F hr]	CDH [°F hr]
Flat attic or sloped ceiling	127,961.3	6,619.0
Exterior walls		
Basement/crawlspace rim joists and walls	99,194.6	

Adj_{heat} = Heating adjustment factor to reconcile this simplified algorithm with evaluation bill analysis results = 0.55 [dimensionless].[9]

Adj_{cool} = Cooling adjustment factor to account for people not always operating their air-conditioning systems when the outside temperature is greater than 75°F = 0.75 [dimensionless].[10]

η_{heat} = Heating system efficiency, dependent on fuel and system type[11]:

Table 6. Residential Deemed Heating System Efficiencies

System Type	Fuel	Efficiency
Boiler	Oil	0.85
	Propane	0.90
	Natural gas	0.86
	Electric	1.00
Furnace	Oil	0.82
	Propane	0.90
	Natural gas	0.94
	Electric	1.00
Heat Pump	Electric	3.28
Baseboard	Electric	1.00
Other	Pellet stove	0.70
	Newer EPA woodstove	0.60
	Catalytic woodstove	0.50
	Non-catalytic woodstove	0.40
	Outdoor wood boiler	0.25
	Open hearth fireplace	0.10
	Propane stove	0.65

η_{cool} = Cooling system efficiency = 3.72.[12]

Measure Life

Lifetime for attic and sloped ceiling insulation is 30 years.
Lifetime for exterior wall insulation is 30 years.
Lifetime for basement insulation is 15 years.[13]

Measure Cost

Measure costs of $3.5/sq ft is assumed for attic insulation.
Measure costs of $6.0/sq ft is assumed for sloped ceiling insulation.
Measure costs of $3,000 per job is assumed for basement insulation.

Measure costs of $2/sq ft is assumed for wall insulation. [14]

Program Data Tracking Recommendations

The key input variables for this measure are the following:

- Heating fuel type
- Heating system type
- Total square feet of insulation installed (A_{ins})
- Insulation location (attic/ceiling, exterior walls, basement wall/rim joist)
- Pre- R-value of insulation alone
- Post- R-value of insulation alone

For greater accuracy, the following variables could additionally be collected:

- Central cooling presence
- Building type (single family or multifamily)

Energy Codes and Standards

This characterization is code-agnostic; however, implementers should comply with any and all local code requirements concerning insulation standards.

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[1] Derived from NMR Group, *2020 Vermont Single Family Existing Homes Baseline Study* and NMR Group, *2020 Vermont Multifamily Residential Baseline Study.* Assumes 50%/50% split between wood stoves and gas fireplaces. Gas fireplaces are split between natural gas and propane according to survey results for each fuel. The single family and multifamily results are combined for the "unknown" building type category by weighting according to the population of each building type in the respective studies.

[2] Illinois TRM v12.0. "F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBTU/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%."

[3] NMR Group, *2020 Vermont Single Family Existing Homes Baseline Study*, January 24, 2023, page 57, Table 82. Sum of Central AC and MSHP/ASHP/GSHP, Statewide-Scaled & Adjusted.

[4] NMR Group, *2020 Vermont Multifamily Residential Baseline Study,* page 55, Table 85. Sum of Central AC and MSHP, Statewide-Scaled & Adjusted.

[5] Weighted-average figure calculated from population sizes for single family and multifamily homes in *2020 Vermont Single Family Existing Homes Baseline Study* and *2020 Vermont Multifamily Residential Baseline Study.*

[6] Insulation tables are derived from ASHRAE 90.1-2016 Normative Appendix A.

[7] NMR Group, *2020 Vermont Single Family Existing Homes Baseline Study,* statewide mean values for each system type/fuel from Appendix A, except propane furnace efficiency carried forward from *Efficiency Vermont TRM Program Year 2023,* HPwES 2.0 Insulation: Attic and/or Basement.

[8] *Efficiency Vermont TRM Program Year 2023,* ERV/HRV, page 219.

[9] *Efficiency Vermont TRM Program Year 2023,* HPwES 2.0 Insulation: Attic and/or Basement, page 302, footnote 5.

[10] Energy Center of Wisconsin, *Central Air Conditioning in Wisconsin: A Compilation of Recent Field Research,* 2008, page 31.

[11] Efficiencies for fossil fuel systems and heat pumps are sourced from NMR Group, *2020 Vermont Single Family Existing Homes Baseline Study*, with the exception of propane furnaces. Propane furnaces and the "Other" category are sourced from the *2023 Efficiency Vermont TRM.*

[12] Calculated from statewide mean SEER = 12.7 of central air conditioner in VT from NMR Group, *2020 Vermont Single Family Existing Homes Baseline Study*, Table 88: Central Air Conditioner Efficiency (SEER). COP = SEER / 3.412..

[13] *Efficiency Vermont TRM Program Year 2023,* HPwES 2.0 Insulation: Attic and/or Basement, HPwES 2.0 Insulation: Exterior Walls.

[14] Ibid.

2.2 Residential – HVAC

2.2.1 Advanced Thermostats

CHS Measure ID: RE_HVAC_ADVT
Market Sector: Residential
End Use: HVAC
Applicable Building Types: Single Family, Multifamily
Decarbonization Pathways: Thermal Efficiency
Applicable Baseline Fuels: Natural Gas, Propane, Fuel Oil #2, Electricity
Decision/Action Type: Early Replacement, New Construction
Program Delivery Type: Downstream

Measure Description

This measure involves the installation of an advanced thermostat to control a residential HVAC system. An advanced thermostat is capable of automatically establishing a schedule of temperature setpoints and automatic variations to better match HVAC system run times to meet occupant comfort requirements, resulting in energy savings. These schedules may be defaults, established through user interaction, and be changed manually at the device or remotely through a web or mobile app. Automatic variations to that schedule could be driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, optimization based on historical or population-specific trends, weather data and forecasts.[1]

Baseline Conditions

The baseline for Early Replacements is assumed to be a mix of programmable and manual thermostats.

The baseline for New Construction is assumed to be a programmable thermostat.

Proposed Conditions

The proposed condition is an advanced thermostat.

Eligibility Criteria

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the default enabled capability—or the capability to automatically—establish a schedule of temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. This category of products and services is broad and rapidly advancing in regard to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default capabilities described above.[2]

This measure must be paired with one of the following system types: gas or oil furnace, combination furnace/central AC, gas or oil fossil-fuel boiler, or heat pump.

Decarbonization Summary

Table 7 provides lifecycle CO2e reductions for this measure across eligible heating fuels and Decision/Action Types over the effective useful life of this measure.

Table 7. Residential Advanced Thermostats: Lifetime CO2e Reductions

Decision/Action Type	Heating Fuel	Lifetime CO2e Reductions [g]
Early Replacement	Oil	
	Propane	
	Natural Gas	
	Electricity	
New Construction	Oil	
	Propane	
	Natural Gas	
	Electricity	

Decarbonization and Energy Impacts Algorithms

CO2e [grams] = $(\Delta E_{heat} \times EF_{hf}) + (\Delta E_{cool} \times EF_{elec})$

EF_{hf} = Heating fuel emissions factor in grams of carbon diode equivalent per megajoule [gCO2e/MJ]. See emissions schedule in Table x in Reference Section. If the primary heating fuel type is unknown or not collected, an average emissions factor may be calculated with the following weights: [3]

Table 8. Residential Advanced Thermostat: Primary Heating Fuel Mix, Excluding Wood, Residential Buildings

Heating Fuel	Building Type		
	Single Family	Multifamily	Unknown
Oil	49%	5%	45%
Propane	19%	5%	17%
Natural Gas	25%	66%	29%
Electricity	7%	23%	9%

ΔE_{heat} = Reduction in heating fuel energy consumption in MJ.

ΔE_{cool} = Reduction in electric cooling energy consumption in MJ.

EF_{elec} = Grid electricity emissions factor in grams of carbon diode equivalent per megajoule [gCO2e/MJ]. See emissions schedule in Table x in Reference Section.

Energy Impacts Algorithms

ΔE_{heat} [MJ] = $(EFLH_{heat} \times Capacity_{input,heat} \times SF_{heat}) \times 0.00106$

ΔE_{cool} = $\%Cool \times (EFLH_{cool} \times Capacity_{cool} / COP_{cool} \times SF_{cool}) \times 0.00106$

Input Variable Definitions

$EFLH_{heat}$ = Estimate of annual household equivalent full load heating hours for heating equipment

Table 9. Residential Advanced Thermostat $EFLH_{heat}$

Decision/Action Type	EFLHheat[4]
Early Replacement	878
New Construction	855

$Capacity_{input,heat}$ = Input Capacity of Heating System in Btu/h controlled by thermostat.

For fossil fuel system, use rated if known, or defaults in Table 10.

For heat pump system, $Capacity_{heat} = HCAP / COP_{heat}$ where HCAP = rated heating output capacity at 47°F in Btu/h. Use rated output capacity if known, or defaults in Table 11. COP_{heat} = Heating coefficient of performance (COP) of heat pump = 3.28.[5]

Table 10. Residential Advanced Thermostat: Input Capacity of Fossil Heating System

Household Type	$Capacity_{heat}$ [Btu/h][6]	
	Early Replacement	New Construction
Single Family	70,979	41,532
Multifamily	34,260	28,585

Table 11. Residential Advanced Thermostat: Heating Output Capacity of Heat Pump System

Household Type	HCAP [Btu/h][7]	
	Early Replacement	New Construction
Single Family	80,124	44,510
Multifamily	76,874	30,354

SF_{heat} = Assumed savings factor for total household heating energy consumption due to installation of advanced thermostat, including 0.79% additional savings for thermostat optimization services. See Table 12.

SF_{cool} = Assumed savings factor for total household cooling energy consumption due to installation of advanced thermostat, including 0.65% additional savings for thermostat optimization services. See Table 12.

Table 12. Advanced Thermostat Heat Reduction Factor

Decision/ Action Type	Building Type	Heating Savings Factor[8]	Cooling Savings Factor[9]
Early Replacement	Single Family	7.6%	8.5%
	Multifamily	8.2%	8.5%

Decision/ Action Type	Building Type	Heating Savings Factor[8]	Cooling Savings Factor[9]
New Construction	Either	5.6%	8.5%

%Cool = Percentage of customers with central air conditioning[10]

Table 13. Percentage of Residential Customers with Central Cooling

Central Air Conditioning?	%Cool	
	Early Replacement	New Construction
Yes	100%	
No	0%	
Unknown, Single Family	6.9%	10.0%
Unknown, Multifamily	4.1%	6.0%
Unknown, Unknown Building Type	6.6%	9.6%

$EFLH_{cool}$ = Estimate of annual equivalent full load cooling hours for heat pump or air conditioner = 375[11]

$Capacity_{cool}$ = Output cooling capacity of heat pump or AC in Btu/h

Table 14. Advanced Thermostat Capacity of AC Unit

Household Type	Capacity (Btu/h) [12]
Single Family	37,200
Multifamily	18,542

COP_{cool} = Cooling coefficient of performance for air-conditioner or heat pump

Table 15. Residential Advanced Thermostat: Cooling COP

Decision/Action Type	COP_{cool}
Early Replacement[13]	3.72
New Construction[14]	4.45

0.00106 = Conversion factor, MJ per BTU.

Measure Life

The expected measure life of installed equipment is estimated to be 10 years.[15]

Measure Cost

For early replacement, measure costs, including labor and equipment, for installing an advanced thermostat is $225. For new construction, the incremental cost between a programmable and advanced thermostat is assumed to be $150.[16]

Program Data Tracking Recommendations

The key input variables for this measure are the following:

- Heating Fuel Type

For greater accuracy, the following variables could also be collected:

- Heating System Capacity
- Cooling System Capacity
- Presence of Central Cooling System

In addition, collecting the existing thermostat type would not affect the results but would create a dataset that could be used to inform future revisions to this measure.

Energy Codes and Standards

Not Applicable.

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[1] Efficiency Vermont TRM Program Year 2023, Advanced Thermostats, page 204
[2] Ibid.
[3] Derived from NMR Group, *2020 Vermont Single Family Existing Homes Baseline Study* and NMR Group, *2020 Vermont Multifamily Residential Baseline Study*. Assumes 50%/50% split between wood stoves and gas fireplaces. Gas fireplaces are split between natural gas and propane according to survey results for each fuel. The single family and multifamily results are combined for the "unknown" building type category by weighting according to the population of each building type in the respective studies. Wood is excluded from the mix because advanced thermostats are not known to be capable of controlling wood-fired heating systems.
[4] Efficiency Vermont TRM Program Year 2023, Advanced Thermostats.
[5] Derived from NMR Group, *2020 Vermont Single Family Existing Homes Baseline Study*. The mean HSPF of Heat Pump Systems is 11.2.
[6] Calculated using assumptions from Efficiency Vermont TRM Program Year 2023, Advanced Thermostats (Capacity = Gas Heating Consumption × 1,000,000/EFLHheat × %Controlled
[7] Calculated using assumptions from Efficiency Vermont TRM Program Year 2023, Advanced Thermostats (Capacity = Elec Heating Consumption × 3412/$EFLH_{heat}$ × %Controlled × COP_{heat}) where COP_{heat} = 3.72.
[8] Efficiency Vermont TRM Program Year 2023, Advanced Thermostats.
[9] Ibid.
[10] Derived from NMR Group, *2020 Vermont Single Family Existing Homes Baseline Study* and NMR Group, *2020 Vermont Multifamily Residential Baseline Study*. 90% of homes are single family residences and 10% of homes are multifamily residences.
[11] Efficiency Vermont TRM Program Year 2023, Advanced Thermostats, page 206, footnote 3
[12] Efficiency Vermont TRM Program Year 2023, Advanced Thermostats, page 206, footnote 14,15
[13] Calculated from statewide mean SEER = 12.7 of central air conditioner in VT from NMR Group, *2020 Vermont Single Family Existing Homes Baseline Study*, Table 88: Central Air Conditioner Efficiency (SEER). COP = SEER / 3.412.
[14] Calculated from statewide mean SEER = 15.2 of central air conditioner in VT from NMR Group, *2020 Vermont Single Family Residential New Construction Baseline and Code Compliance Study*, Table 82: Central Air Conditioner Efficiency (SEER). COP = SEER / 3.412.
[15] Efficiency Vermont TRM Program Year 2023, Advanced Thermostats, page 207
[16] Ibid.

2.3 Residential – Domestic Hot Water

2.3.1 Heat Pump Water Heater

CHS Measure ID: RE_DOHW_HPWH
Market Sector: Residential
End Use: Domestic Hot Water
Applicable Building Types: Single Family, Multifamily
Decarbonization Pathways: Electrification
Applicable Baseline Fuels: Natural Gas, Propane, Fuel Oil #2, Electricity
Decision/Action Type: Market Opportunity (MOP)
Program Delivery Type: Downstream

Measure Description

This measure involves installation of a Heat Pump Water Heater (HPWH) to provide domestic hot water in a residential application. The HPWH may replace a water heater fueled by grid electricity, natural gas, propane, or fuel oil #2. The HPWH efficiency has been reduced to account for differences in field performance versus rated efficiency due to ambient conditions, hot water demand, and other factors. The characterization includes additional space heating load as a result of the HPWH. This characterization calculates CO2e savings based on the size of the installed water heater, the fuel-type of the existing water heater, and the existing heating system.

Baseline Conditions

The baseline condition is a new water heater of the same size, using the same fuel as the home's existing water heater that meets the current federal standard for residential water heaters.

Proposed Conditions

The proposed condition is an installed HPWH of the same size as the existing water heater. The proposed HPWH must be on the NEEA Northern Climate Specification qualified list. [1]

Eligibility Criteria

To qualify, the installed HPWH must be a NEEA Tier 1, 2, 3 or 4 certified HPWH.

Decarbonization Summary

Table 16 provides estimated lifecycle decarbonization ranges for example baseline and proposed conditions over the effective useful life of the measure. These estimates are not inclusive of all eligible possibilities; other values may be calculated from following algorithms.

Table 16. Heat Pump Water Heater CO2e Reductions

Baseline Condition	Proposed Condition	Space Heating System Type	Lifetime CO2e Reductions [g]
50 Gallon Natural Gas Storage Water Heater	50 Gallon HPWH Tier 1	Heat Pump	
		Electric Resistance	
		Natural Gas Boiler	
		Propane Boiler	
		Fuel Oil Boiler	
		Natural Gas Furnace	
		Oil Furnace	
		Wood	
50 Gallon Propane Storage Water Heater	50 Gallon HPWH Tier 1	Heat Pump	
		Electric Resistance	
		Natural Gas Boiler	
		Propane Boiler	
		Fuel Oil Boiler	
		Natural Gas Furnace	
		Oil Furnace	
		Wood	
50 Gallon Fuel Oil Storage Water Heater	50 Gallon HPWH Tier 1	Heat Pump	
		Electric Resistance	
		Natural Gas Boiler	
		Propane Boiler	
		Fuel Oil Boiler	
		Natural Gas Furnace	
		Oil Furnace	
		Wood	

Decarbonization and Energy Impacts Algorithms

$\Delta CO2e$ [g] = $\Delta CO2e_{fuel\ switch}$ - $\Delta CO2e_{heat}$

$\Delta CO2e_{fuel\ switch}$ = CO2e reduction due to fuel switch = $(E_{base} \times EF_{base}) - (E_{HPWH} \times EF_{elec})$

$\Delta CO2e_{heat}$ = Increase in CO2e emissions due to increased space heating load as a result of HPWH installation = $\Delta E_{heat} \times EF_{hf}$

EF_{base} = Baseline water heater fuel emissions factors in grams of carbon diode equivalent per megajoule [gCO2e/MJ]. See emissions schedule in Table x in Reference Section.

EF_{elec} = Grid electricity emissions factor [gCO2e/MJ].

EF_{hf} = Heating fuel emissions factors [gCO2e/MJ]. If the heating fuel is unknown, an average emissions factor may be calculated using the following weights:

Table 17. Vermont Primary Heating Fuel Mix, Residential Buildings

Heating Fuel	Building Type		
	Single Family	Multifamily	Unknown
Oil	45%	5%	41%
Propane	17%	5%	16%
Natural Gas	23%	66%	27%
Electricity	6%	23%	8%
Wood	8%	1%	7%

Energy Impacts Algorithms

E_{base} [MJ] = Baseline water heater energy consumption = (Q_{load} / UEF_{base}) x 1,055

E_{HPWH} [MJ] = HPWH energy consumption = (Q_{load} / CCE_{HPWH}) x 1,055

ΔE_{heat} [MJ] = Increase in space heating energy caused by HPWH

= (((Q_{load} x IF) / CCE_{HPWH}) / η_{Heat}) x 1,055

Input Variable Definitions

UEF_{base} = Uniform energy factor of baseline water heater. Assumes Medium draw pattern. See Table 18.[2]

Table 18. Residential HPWH: Baseline UEF

Baseline Fuel	Tank Volume (Vr)	UEF_{base}
Electric	20 gal ≤ Vr ≤ 55 gal	= 0.9307 – (0.0002 x Vr)
	55 gal ≤ Vr ≥ 100 gal	= 2.1171 – (0.0011 x Vr)
Natural Gas	20 gal ≤ Vr ≤ 55 gal	= 0.6483 – (0.0017 x Vr)
	55 gal < Vr ≤ 100 gal	= 0.7897 – (0.0004 x Vr)
Propane	20 gal ≤ Vr ≤ 55 gal	= 0.6483 – (0.0017 x Vr)
	55 gal < Vr ≤ 100 gal	= 0.7897 – (0.0004 x Vr)
Fuel Oil	All Tank Sizes	0.53

Q_{load} = Annual water heating load [MMBTU] = 9.04.[3]

CCE_{HPWH} = NEEA HPWH Cool Climate Efficiency rating. Use actual or minimum CCE by tier.[4]

Tier	Minimum CCE
Tier 1.0	2.0
Tier 2.0	2.3
Tier 3.0	2.6
Tier 4.0	3.0

η_{Heat} = Efficiency of existing space heating system[5]

Table 19. Residential Deemed Heating System Efficiencies

System Type	Fuel	Efficiency
Boiler	Oil	0.85
	Propane	0.90
	Natural gas	0.86
	Electric	1.00
Furnace	Oil	0.82
	Propane	0.90
	Natural gas	0.94
	Electric	1.00
Heat Pump	Electric	3.28
Baseboard	Electric	1.00
Other	Pellet stove	0.70
	Newer EPA woodstove	0.60
	Catalytic woodstove	0.50
	Non-catalytic woodstove	0.40
	Outdoor wood boiler	0.25
	Open hearth fireplace	0.10
	Propane stove	0.65

IF = Interactive factor, portion of HPWH ambient cooling impact that results in increased space heating = 0.542.[6]

1,055 = Conversion factor, MJ per MMBTU

Measure Life

The expected measure life is assumed to be 12 years.[7]

Measure Cost

The market opportunity incremental cost is $818 for heat pump water heaters with less than 55 gallons of tank volume and $934 for heat pump water heaters with at least 55 gallons of tank volume. [8]

Program Data Tracking Recommendations

The following variables should be tracked for this measure:

- Tank size of proposed heat pump water heater
- Cool Climate Efficiency of proposed heat pump water heater
- Fuel source of existing water heater

For increased accuracy, the following variable may optionally be tracked:

- Existing heating system

Energy Codes and Standards

Minimum efficiencies for water heaters are prescribed in federal standard 10 CFR § 430.32.

Heat pump water heaters must conform to NEEA Advanced Water Heating Specification to use this characterization.

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[1] NEEA, Advanced Water Heating Specification Version 8.0, March 1, 2022. (AWHS v8.0 (neea.org))
2 Source: 10 CFR § 430.32, except fuel oil UEF source is 2022 Tier III TRM Characterizations, HPWH. Vr is the Rated Storage Volume (in gallons), as determined pursuant to 10 CFR § 429.17.
3 2022 Tier III TRM Characterizations, HPWH, page 54.
4 NEEA Advanced Water Heating Specification Version 8.0. March 1, 2022.
[5] Efficiencies for fossil fuel systems and heat pumps are sourced from NMR Group, 2020 Vermont Single Family Existing Homes Baseline Study, with the exception of propane furnaces. Propane furnaces and the “Other” category are sourced from the 2023 Efficiency Vermont TRM.
6 2022 Tier III TRM Characterizations, HPWH, page 54
7 Efficiency Vermont TRM Program Year 2023, HPWH, page 244
8 Ibid.

2.3.2 Low Flow Faucet Aerator

CHS Measure ID: RE_DOHW_LFFA
Market Sector: Residential
End Use: Domestic Hot Water
Applicable Building Types: Single Family, Multifamily
Decarbonization Pathways: Thermal Efficiency
Applicable Baseline Fuels: Natural Gas, Propane, Fuel Oil #2, Grid Electricity
Decision/Action Type: Early Replacement, New Construction
Program Delivery Type: Direct Install, RNC, Free Products, Dropship

Measure Description

This measure relates to the installation of low flow faucet aerators in single family and multifamily bathroom and kitchen faucet fixtures. Low flow aerators reduce the volume of hot water consumed and thus the thermal energy needed to heat it.

This measure may be installed through one of the following mechanisms:

- Residential new construction program
- Direct install implementation
- Free giveaways
- Dropship: product is ordered by building owner or implementer and drop-shipped to the site for self-installation. The program delivery agent shall verify the installation with the owner and reserve the right to inspect the installation.

Baseline Conditions

Early Replacement: Existing bath or kitchen faucet aerator rated at 2.2 GPM.[1]

New Construction: New standard flow rate faucet aerator rated at 1.5 GPM.[2]

Proposed Conditions

Direct Install: Faucet aerator rated at 1.0 GPM for bathroom faucets and 1.5 GPM for kitchen faucets.

New Construction: Faucet aerator rated at 1.3 GPM [3]

Eligibility Criteria

For Direct Install, Free Products, and Dropship programs, the qualifying efficient flow rate for faucet aerators must be 1.0 GPM for bathroom and 1.5 GPM for kitchen. For RNC, the aerator must be WaterSense-labeled.

Decarbonization Summary

Table 20 provides lifecycle CO2e reductions for eligible existing and proposed conditions over the expected useful life of the measure.

Assumptions:

- Average water heating fuel mix in Table 21
- Water heater efficiencies per Table 22

Table 20. Residential Low Flow Faucet Aerator: Lifetime CO2e Reductions

Program Delivery Type	Faucet Type	Baseline Condition	Proposed Condition	Lifetime CO2e Reductions [g CO2e]
Direct Install	Kitchen	2.2 GPM aerator	1.5 GPM aerator	
Direct Install	Bath	2.2 GPM aerator	1.0 GPM aerator	
New Construction	Kitchen	1.5 GPM aerator	1.3 GPM aerator	
New Construction	Bath	1.5 GPM aerator	1.3 GPM aerator	
Free Products	Kitchen	2.2 GPM aerator	1.5 GPM aerator	
Free Products	Bath	2.2 GPM aerator	1.0 GPM aerator	
Dropship	Kitchen	2.2 GPM aerator	1.5 GPM aerator	
Dropship	Bath	2.2 GPM aerator	1.0 GPM aerator	

Decarbonization and Energy Impacts Algorithms

CO2e [grams] = ΔE_{whf} x EF_{whf}

EF_{whf} = Water heating fuel emissions factors in grams of carbon dioxide equivalent per megajoule [g CO2e/MJ]. See Table x in Reference Section. If the water heating fuel is unknown, an average emissions factor may be calculated with the following weights:[4]

Table 21. Vermont Water Heating Fuel Mix, Residential Buildings

Water Heating Fuel	Single Family	Multifamily	Unknown Building Type
Electricity	43%	40%	43%
Propane	24%	0%	22%
Natural Gas	23%	60%	27%
Oil	9%	0%	8%

ΔE_{whf} = Reduction in water heating fuel energy in MJ as a result of this measure.

Energy Impacts Algorithms

ΔE_{whf} [MJ] = (GPM_{Base} x $Throttle_{Base}$ – GPM_{Low} x $Throttle_{Low}$) x (Minutes/Person/Day) x (People/Household) x (Days/Year) x DR / (Faucets/Home) x 8.3 x (T_{Faucet} – T_{inlet}) / η_{RE}) x ISR x 0.00106

Input Variable Definitions

GPM_{Base} = Flow rate of existing faucet aerator = 2.2 GPM for early replacement; 1.7 GPM for new construction

GPM_{Low} = Flow rate of low flow faucet aerator

= 1.3 GPM for New Construction

= 1.0 GPM (bathroom) and 1.5 GPM (kitchen) for Direct Install

= 1.5 GPM for free products

$Throttle_{Base}$ = Percentage of full-throttle flow rate for baseline faucet = 83% [5]

$Throttle_{Low}$ = Percentage of full-throttle flow rate for low flow faucet = 95% [6]

Minutes/Person/Day = Average length of faucet use per person = 1.6 (bathroom); 4.5 (kitchen)[7]

People/Household = Average number of people per household = 2.30 [8]

Days/Year = Days the faucet is used per year = 365

DR = Percentage of water that flows down the drain and is not collected in a sink or basin = 50% (bathroom); 70% (kitchen)[9]

Faucets/Home = Average number of faucet fixtures per household = 2.83 (SF bathroom); 1.5 (MF bathroom); 1.0 (kitchen)[10]

T_{Faucet} = Mixed water temperature (°F) of hot water coming from faucet = 86°F (bathroom); 93°F (kitchen)[11]

T_{inlet} = Inlet water temperature (°F) of water entering the household = 51.8°F[12]

η_{RE}= Water heater recovery efficiency [13]

Table 22. Water Heater Recovery Efficiency by Unit Type and Program Delivery Type

Water Heater Type	Program Delivery Type	η_{RE}
Fossil Fuel	New Construction	0.89
	All Other	0.83
Electric Resistance	Any	0.98
Heat Pump	Any	3.49
Unknown Electric	Any	1.71

ISR = In-service rate, the percentage of incentivized units actually installed [14]

Table 23. Low Flow Faucet Aerator ISRs

Program Delivery Type	ISR
Direct Install	100%
New Construction	100%
Free Products	62%
Dropship	90%

8.3 = Specific heat of water, the amount of energy needed to raise 1 gal of water by 1°F [BTU/(gal °F)]

0.00106 = Conversion factor, MJ per BTU

Measure Life

The expected measure life of installed equipment is estimated to be 10 years.[15]

Measure Cost

Direct Install: Combined labor and material costs. Default is $13 if actual is unknown.

New Construction: Incremental material cost is $6.

Free Products and Dropship: The measure cost for free giveaways and the dropship program is the actual program cost of a new aerator. Default = $2 if actual is unknown. [16]

Program Data Tracking Recommendations

The following variables should be tracked for this measure:

- Faucet type (bath or kitchen)
- Program delivery type (direct install, new construction, free products, or dropship)

Optionally, the water heater fuel and type may be tracked for additional accuracy.

Energy Codes and Standards

The baseline assumption for new construction is assumed to be the state standard which took effect on 7/1/2020[17].

- 9 V.S.A. § 2795.14: maximum faucet flow rate is 1.5 GPM at 60 psi

The baseline assumption for existing buildings is assumed to be the federal standard.

- 10 CFR § 430.32: maximum faucet flow rate is 2.2 GPM at 60 psi

For RNC, the installed aerator must be meet the US EPA's WaterSense criteria.

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[1] Existing faucets are assumed to comply with the federal standard which is 2.2 GPM at 60 psi. 10 CFR § 430.32.

[2] New construction faucets are assumed to comply with the Vermont state standard for faucets which is 1.5 GPM at 60 psi. 9 V.S.A. § 2795.14. The Vermont standard took effect on 7/1/2020.

[3] Efficiency Vermont Technical Reference Manual. 2023. Average flow rate of products on the WaterSense Labeled Products list as of October 18, 2022.

[4] NMR Group, *2020 Vermont Single Family Existing Homes Baseline Study* and NMR Group, *2020 Vermont Multifamily Residential Baseline Study*. The single family and multifamily results are combined for the "unknown" building type category by weighting according to the population of each building type in the respective studies.

[5] Efficiency Vermont Technical Reference Manual. 2023. Schultdt, Marc, and Debra Tachibana, "Energy Related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings," 2008, page 1-265.

[6] Ibid.

[7] Efficiency Vermont Technical Reference Manual. 2023. Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 11, Table 7.

[8] Efficiency Vermont Technical Reference Manual. 2023. Weighted average household size of owner-occupied versus renter-occupied housing units ((70.8% * 2.41) + (29.2% * 2.04)) based on 2015-2019 American Community Survey 5-Year Estimates for Vermont. See reference file US Census_2019_ACS_5YR_DP04_VT.csv.

[9] Efficiency Vermont Technical Reference Manual. 2023. Because faucet usages are at times dictated by volume (for example, filling a sink to wash dishes), only usage that would allow water to go straight down the drain will provide savings. DR values are from Navigant Consulting, Inc. for the Ontario Energy Board, "Measures and Assumptions for Demand Side Management Planning, Appendix C: Substantiation Sheets," April 16, 2009, pages C-57 and C-61. DR values weighted by typical number of kitchen faucets (1 faucet) and bath faucets (2 faucets) in a household: (1/3 * 0.50) + (2/3* 0.70) = 0.63.
Additonal explanation of DR logic: During continuous flow of the system, when faucet flow time is equal (LFFA vs Baseline), savings are achieved. However, during batch flow (i.e. filling sink to X gallons) since time is not equal between the two scenarios, (timeLFFA > timeBaseline) we would not see savings related to draw on WH / water consumption. DR represents frequency of continuous flow events.

[10] Illinois Technical Reference Manual. V12.0. September 2023. Effective January 2024.

[11] Ibid.

[12] Efficiency Vermont Technical Reference Manual. 2023. Average value for Burlington, Montpelier. Rutland, and Springfield, VT from U.S. DOE Standard Building America DHW Schedules, May 2014. Values found on Weather Inputs sheet on spreadsheet. http://energy.gov/eere/buildings/downloads/building-america-standard-dhw-schedules

[13] Efficiency Vermont Technical Reference Manual. 2023. Faucet Aerator. See footnotes 5, 6, 18, and 19.

[14] Efficiency Vermont Technical Reference Manual. 2023. Faucet Aerator. See footnotes 12, 13.

[15] Efficiency Vermont Technical Reference Manual. 2023. Measure lifetime from California DEER. See file DEER2014-EUL-table-update_2014-02-05.xlsx.

[16] Efficiency Vermont Technical Reference Manual. 2023. See footnotes 21-23.

[17] “Vermont 2018”. Appliance Standards Awareness Project, https://appliance-standards.org/state-legislation/vermont-2018.

2.3.3 Low Flow Showerhead

CHS Measure ID: RE_DOHW_LFSH
Market Sector: Residential
End Use: Domestic Hot Water
Applicable Building Types: Single Family, Multifamily
Decarbonization Pathways: Thermal Efficiency
Applicable Baseline Fuels: Natural Gas, Propane, Fuel Oil #2, Grid Electricity
Decision/Action Type: Early Replacement, New Construction
Program Delivery Type: Direct Install, RNC, Free Products, Dropship

Measure Description

This measure relates to the installation of low flow showerheads in single family and multifamily homes. Low flow showerheads reduce the volume of hot water consumed and thus the thermal energy needed to heat it.

This measure may be installed through one of the following mechanisms:

- Direct install implementation
- Residential new construction program
- Free giveaways
- Dropship: product is ordered by building owner or implementer and drop-shipped to the site for self-installation. The program delivery agent shall verify the installation with the owner and reserve the right to inspect the installation.

Baseline Conditions

Early Replacement: Existing showerhead rated at 2.5 GPM.[1]

New Construction: New standard flow rate showerhead rated at 2.0 GPM. [2]

Proposed Conditions

Early Replacement: Low flow showerhead rated at 1.5 GPM. [3]

New Construction: Showerhead rated at 1.8 GPM [4]

Eligibility Criteria

The qualifying efficient flow rate for showerheads is 1.5 GPM for Direct Install, Free Products, and Dropship programs. For New Construction, the showerhead must be WaterSense-labeled.

Decarbonization Summary

Table 24 provides lifecycle CO2e reductions for eligible existing and proposed conditions over the expected useful life of the measure.

Assumptions:

- Average water heating fuel mix in Table 21

- Water heater efficiencies per Table 26

Table 24. Residential Low Flow Showerhead CO_2e Reductions

Program Delivery Type	Baseline Condition	Proposed Condition	Lifetime CO2e Reductions [g CO2e]
Direct Install	2.5 GPM showerhead	1.5 GPM showerhead	
New Construction	2.0 GPM showerhead	1.8 GPM showerhead	
Free Products	2.5 GPM showerhead	1.5 GPM showerhead	
Dropship	2.5 GPM showerhead	1.5 GPM showerhead	

Decarbonization and Energy Impacts Algorithms

CO_2e [grams] = ΔE_{whf} x EF_{whf}

EF_{whf} = Water heating fuel emissions factor in grams of carbon dioxide equivalent per megajoule [g CO2e/MJ]. See Table x in Reference Section. If the water heating fuel is unknown, an average emissions factor may be calculated with the following weights:[5]

Table 25. Vermont Water Heating Fuel Mix, Residential Buildings

Water Heating Fuel	Single Family	Multifamily	Unknown Building Type
Electricity	43%	40%	43%
Propane	24%	0%	22%
Natural Gas	23%	60%	27%
Oil	9%	0%	8%

ΔE_{whf} = Reduction in water heating fuel energy in MJ as a result of this measure.

Energy Impacts Algorithms

ΔE_{base} [MJ] = Baseline fuel energy impacts

= ((GPM_{Base} - GPM_{Low}) x (Minutes/Shower) x (People/Household) x (Showers/Person/Day) x (Days/Year) / (Showerheads/Home) x 8.3 x (T_{Sh} – T_{inlet}) / nEff x ISR x 0.00106

Input Variable Definitions

GPM_{Base} = Flow rate of existing showerhead = 2.5 for early replacement; 2.0 GPM for new construction.

GPM_{Low} = Flow rate of low flow showerhead = 1.5 GPM for early replacement; 1.8 GPM for new construction

Minutes/Shower = Average shower length in minutes per person = 7.8 [6]

People/Household = Average number of people per household = 2.30 [7]

Showers/Person/Day = Number of showers per person per day = 0.6 [6]

Days/Year = Days the showerhead is used per year = 365[8]

Showerheads/Home = Average number of showerhead fixtures per household = 1.79 (SF); 1.30 (MF) [9]

T_{Sh} = Mixed water temperature (°F) of hot water coming from showerhead = 101°F [10]

T_{inlet} = Inlet water temperature (°F) of water entering the household = 51.8°F [11]

n_{RE} = Water heater recovery efficiency[12]

Table 26. Water Heater Recovery Efficiency by Program Type

Program Delivery Type	n_{RE}
Direct Install	0.83
New Construction	0.89
Free Products	0.83
Dropship	0.83

ISR = In-service rate representing the number of units installed[13]

Table 27. Low Flow Showerhead ISRs

Program Delivery Type	ISR
Direct Install	100%
New Construction	100%
Free Products	56%
Dropship	90%

8.3 = Specific heat of water, the amount of energy needed to raise 1 gal of water by 1°F [BTU/(gal °F)]

0.00106 = Conversion factor, MJ per BTU

Measure Life

The expected measure life of installed equipment is estimated to be 10 years. [14]

Measure Cost

Direct Install: Combined labor and material costs. Default is $22 for a fixed showerhead and $27 for a handheld model.

New Construction: Incremental material cost is $6.

Free Products and Dropship: The measure cost for free giveaways and the dropship program is the actual program cost of a new showerhead. Default = $4 if unknown.[15]

Program Data Tracking Recommendations

The following variables should be tracked for this measure:

- Program delivery type (direct install, new construction, free products, or dropship)

Optionally, the water heater fuel and type, and building type (Single Family or Multifamily) may be tracked for additional accuracy.

Energy Codes and Standards

The baseline assumption for new construction is assumed to be the state standard which took effect on 7/1/2020[16].

- 9 V.S.A. § 2795.14: maximum faucet flow rate is 2.0 GPM at 80 psi

The baseline assumption for existing buildings is assumed to be the federal standard.

- 10 CFR § 430.32: maximum faucet flow rate is 2.5 GPM at 80 psi

For New Construction, the installed showerhead must meet the US EPA's WaterSense criteria.

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1 Existing showerheads are assumed to comply with the federal standard which is 2.5 GPM at 80 psi. 10 CFR § 430.32

2 New construction showerheads are assumed to comply with the Vermont state standard for faucets which is 2.0 GPM at 80 psi. 9 V.S.A. § 2795.14. The Vermont standard took effect on 7/1/2020

3 Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 196. See footnote 10

4 Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 196. See footnote 11

5 NMR Group, 2020 Vermont Single Family Existing Homes Baseline Study and NMR Group, 2020 Vermont Multifamily Residential Baseline Study. The single family and multifamily results are combined for the "unknown" building type category by weighting according to the population of each building type in the respective studies.

6 Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 11, Table 7.

7 Efficiency Vermont Technical Reference Manual. 2023. Weighted average household size of owner-occupied versus renter-occupied housing units ((70.8% * 2.41) + (29.2% * 2.04)) based on 2015-2019 American Community Survey 5-Year Estimates for Vermont. See reference file US Census_2019_ACS_5YR_DP04_VT.csv.

8 Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 197

9 Illinois Technical Reference Manual. V12.0. September 2023. Effective January 2024.

10 Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 197. See footnote 16

11 Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 197. See footnote 17

12 Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 196. See footnotes 5 - 7.

13 Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 196. See footnotes 12, 13.

14 Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 197. See footnote 21

15 Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 198. See footnotes 22 – 25.

16 "Vermont 2018". Appliance Standards Awareness Project, https://appliance-standards.org/state-legislation/vermont-2018.

2.4 Residential - Appliances

2.4.1 Induction Cooktop

CHS Measure ID: RE_APPL_INCT
Market Sector: Residential
End Use: Appliances
Applicable Building Types: Single Family, Multifamily
Decarbonization Pathways: Electrification
Applicable Baseline Fuels: Natural gas, propane, electricity
Decision/Action Type: Early Replacement, MOP
Program Delivery Type: Downstream

Measure Description

This measure involves the installation of an induction cooktop in a residential home to replace a standard electric, natural gas, or propane cooktop. CO2e savings are achieved through switching from fossil fuel usage to electricity for cooking (if applicable), and through the higher efficiency of an induction cooktop compared to a standard electric cooktop, which reduces electrical usage.

Baseline Conditions

The baseline is an existing electric, natural gas, or propane cooktop. Existing electric cooktops are assumed to be electric resistance, not induction.

Proposed Conditions

The proposed condition is an induction cooktop.

Eligibility Criteria

The installed cooktop is electric induction. The existing cooktop must be a standard electric, natural gas or propane cooktop.

Decarbonization Summary

Table 28 provides lifecycle CO2e reductions over the expected useful life of the measure.

Table 28. Induction Cooktop CO2e Reduction Summary

Existing Cooktop	Lifetime CO2e Reductions
Standard Electric	
Natural Gas	
Propane	

Decarbonization and Energy Impacts Algorithms

$\Delta CO2e_{total} = \Delta CO2e_{fuel\ switch} + \Delta CO2e_{eff\ gain}$

$\Delta CO2e_{fuel\ switch}$ = CO2e savings [g] due to fuel switch = $(E_{base} \times EF_{base}) - (E_{std\ elec} \times EF_{elec})$

$\Delta CO2e_{eff\ gain}$ = CO2e savings [g] due to greater efficiency of induction cooktop versus standard electric cooktop = $(E_{std\ elec} \times (1 - \eta_{std\ elec} / \eta_{induction})) \times EF_{elec}$

EF_{base} = Baseline fuel emissions factor in grams of carbon diode equivalent per megajoule [gCO2e/MJ]. See emissions schedule in Table x in Reference Section.

EF_{elec} = Grid electricity emissions factor in grams of carbon diode equivalent per megajoule [gCO2e/MJ]. See emissions schedule in Table x in Reference Section.

Energy Impacts Algorithms

E_{base} [MJ] = Energy consumption of baseline cooktop in MJ = (Heat Up Energy + Simmer Energy + Saute Energy) x Days. See Table 29.

$E_{std\ elec}$[MJ] = Energy consumption of standard electric cooktop in MJ = (Heat Up Energy + Simmer Energy + Saute Energy) x Days. See Table 29.

Table 29. Baseline Cooktop Energy Usage

Cooktop Fuel Source	Heat Up Energy (MJ/Day)	Simmer Energy (MJ/Day)	Saute Energy (MJ/Day)	Total Energy (MJ/Day)
Electricity (Standard Cooktop)[1]	2.05	0.86	0.67	3.58
Natural Gas[2]	5.43	1.77	1.40	8.60
Propane[3]	5.43	1.77	1.40	8.60

Input variable definitions

Days = Cooking days per year = 260.[4]

$\eta_{std\ elec}$ = Cooking efficiency of standard electric cooktop = 0.74.[5]

$\eta_{induction}$ = Cooking efficiency of electric induction cooktop = 0.84.[6]

Measure Life

The measure life for an induction cooktop is 15 years.[7]

Measure Cost

The actual installed cost of the induction cooktop should be used if possible; if unknown, assume $2,100.[8]

Program Data Tracking Recommendations

The key input variables for this measure are the following:

- Existing cook top fuel
- Cost of induction cook top

Energy Codes and Standards

10 CFR 430.32(j)(1) prescribes maximum integrated annual energy consumption (IAEC) for electric and gas cooktops.

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[1] *Tier III TRM Characterizations*, page 69

[2] Ibid.

[3] Ibid.

[4] Ibid.

[5] Energy+Environmental Economics. *Residential Building Electrification in California: Consumer economics, greenhouse gases and grid impacts*. April 2019. Figure 2-8, p. 34.

[6] Ibid.

[7] *Tier III TRM Characterizations*, page 69

[8] Energy+Environmental Economics. *Residential Building Electrification in California: Consumer economics, greenhouse gases and grid impacts*. April 2019. Figure 2-8, p. 34. Midpoint of $1,900-$2,300 range.

2.5 C/I – HVAC

2.5.1 Advanced Thermostats

CHS Measure ID: CI_HVAC_ADVT
Market Sector: Commercial & Industrial
End Use: HVAC
Applicable Building Types: C/I, Multifamily CA
Decarbonization Pathways: Thermal Efficiency
Applicable Baseline Fuels: Natural Gas, Propane, Fuel Oil #2, Electricity
Decision/Action Type: Early Replacement, New Construction
Program Delivery Type: Downstream

Measure Description

This measure involves the installation of an advanced thermostat to control a commercial HVAC system in a small to medium business location. An advanced thermostat is capable of automatically establishing a schedule of temperature setpoints and automatic variations to better match HVAC system run times to meet occupant comfort requirements, resulting in energy savings. These schedules may be defaults, established through user interaction, and be changed manually at the device or remotely through a web or mobile app. Automatic variations to that schedule could be driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, optimization based on historical or population-specific trends, weather data and forecasts.[1]

Baseline Conditions

The baseline for early replacements is assumed to be a mix of programmable and manual thermostats. The assumed baseline mix is 89% manual and 11% programmable thermostats.[2]

The baseline for new construction is assumed to be a programmable thermostat.

Proposed Conditions

The proposed condition is an advanced thermostat.

Eligibility Criteria

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the default enabled capability—or the capability to automatically—establish a schedule of temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. This category of products and services is broad and rapidly advancing in regard to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default capabilities described above.[3]

The advanced thermostat must be installed in a small to medium business.

This measure must be paired with one of the following heating systems: fossil-fuel furnace, fossil-fuel boiler, or heat pump.

Decarbonization Summary

Table 30 provides lifecycle CO2e reductions for this measure across eligible heating fuels and Decision/Action Types over the effective useful life of this measure.

Table 30. Commercial Advanced Thermostats: Lifetime CO2e Reductions

Decision/Action Type	Heating Fuel	Lifetime CO2e Reductions [g]
Early Replacement	Oil	
	Propane	
	Natural Gas	
	Electricity	
New Construction	Oil	
	Propane	
	Natural Gas	
	Electricity	

Decarbonization and Energy Impacts Algorithms

CO_2e [MJ] = (ΔE_{heat} x EF_{hf}) – (ΔE_{cool} x EF_{elec})

EF_{hf} = Heating fuel emissions factor in grams of carbon diode equivalent per megajoule [gCO2e/MJ]. See emissions schedule in Table x in Reference Section. If the primary heating fuel type is unknown or not collected, an average emissions factor may be calculated with the following weights:

Table 31. Commercial Advanced Thermostat: Primary Heating Fuel Mix, Excluding Wood, Commercial Buildings[4]

Heating Fuel	Decision / Action Type	
	Early Replacement	New Construction
Oil	16%	2%
Propane	29%	26%
Natural Gas	22%	15%
Electricity	33%	57%

ΔE_{heat} = Reduction in heating fuel energy consumption in MJ.

ΔE_{cool} = Reduction in electric cooling energy consumption in MJ.

EF_{elec} = Grid electricity emissions factor in grams of carbon diode equivalent per megajoule [gCO2e/MJ]. See emissions schedule in Table x in Reference Section.

Energy Impacts Algorithms

ΔE_{heat} [MJ] = ($EFLH_{heat}$ × $Capacity_{input,heat}$ x SF_{heat}) x 0.00106

ΔE_{cool} = %Cool x ($EFLH_{cool}$ × $Capacity_{cool}$ / COP_{cool} × SF_{cool}) × 0.00106

Input Variable Definitions

$EFLH_{heat}$ = Estimate of annual equivalent full load heating hours for heating equipment = 1062[5]

$Capacity_{input,heat}$ = Input Capacity of Fossil Heating System in Btu/h controlled by thermostat.

For fossil fuel system, use rated if known, or defaults in Table 32.

For heat pump system, $Capacity_{heat}$ = HCAP / COP_{heat} where HCAP = rated heating output capacity at 47°F in Btu/h. Use rated output capacity if known, or defaults in Table 33. COP_{heat} = heating coefficient of performance (COP) of heat pump = 2.9.[6]

Table 32. Commercial Advanced Thermostat: Input Capacity of Fossil Heating System

Decision / Action Type	$Capacity_{heat}$ [Btu/h] [7]
Early Replacement	53,277
New Construction	33,427

Table 33. Commercial Advanced Thermostat: Heating Output Capacity of Heat Pump System

Decision / Action Type	HCAP [Btu/h] [8]
Early Replacement	53,186
New Construction	31,683

SF_{heat} = Assumed savings factor for total heating energy consumption due to installation of advanced thermostat. See Table 34.

SF_{cool} = Assumed savings factor for total cooling energy consumption due to installation of advanced thermostat. See Table 34.

Table 34. Commercial Advanced Thermostat Heating and Cooling Savings Factors

Decision / Action Type	Heating Savings Factor[9]	Cooling Savings Factor[10]
Early Replacement	8.0%	8.0%
New Construction	5.6%	8.0%

%Cool = Percentage of customers with central air conditioning

Table 35. Percentage of Commercial Customers with Central Cooling

Central Air Conditioning?	%Cool
Yes	100%
No	0%
Unknown[11]	56%

$EFLH_{cool}$ = Estimate of annual equivalent full load cooling hours for heat pump or AC = 755 [12]

$Capacity_{cool}$ = Output cooling capacity of heat pump or AC in BTU/h = 41,400 [13]

COP_{cool} = Cooling coefficient of performance for heat pump or AC

Table 36. Commercial Advanced Thermostat Cooling COP

Decision / Action Type	COP_{cool}
Early Replacement[14]	4.10
New Construction[15]	5.04

Measure Life

The expected measure life of installed equipment is estimated to be 10 years.[16]

Measure Cost

For early replacement, measure costs, including labor and equipment, for installing an advanced thermostat is $265. For new construction, the incremental cost between a programmable and advanced thermostat is assumed to be $150.[17]

Program Data Tracking Recommendations

The key input variables for this measure are the following:

- Heating Fuel Type

For greater accuracy, the following variables could also be collected:

- Heating System Capacity
- Cooling System Capacity
- Presence of Central Cooling System

In addition, collecting the existing thermostat type would not affect the results but would create a dataset that could be used to inform future revisions to this measure.

Energy Codes and Standards

Not Applicable

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[1] Efficiency Vermont TRM Program Year 2023, Advanced Thermostats, page 152
[2] Ibid.
[3] Ibid.

[4] Derived from 2021 Vermont Business Sector Market Characterization and Assessment Study, page 55, 156. Wood is excluded from the mix because advanced thermostats are not known to be capable of controlling wood-fired heating systems. Other and Unknown fuel types are also excluded from the mix.
[5] Efficiency Vermont TRM Program Year 2023, Advanced Thermostats, page 153, footnote 5
[6] Observed mean of heating efficiency of commercial heat pumps <65,000 BTU/h from 2021 Vermont Business Sector Market Characterization and Assessment Study, page 156. (Mean HSPF = 9.9)
[7] Calculated using assumptions from Efficiency Vermont TRM Program Year 2023, Advanced Thermostats (Capacity = Gas Heating Consumption × 1,000,000/$EFLH_{heat}$).
[8] Calculated using assumptions from Efficiency Vermont TRM Program Year 2023, Advanced Thermostats (Capacity = Electric Heating Consumption × 3412/$EFLH_{heat}$ × %Controlled × COP).
[9] Efficiency Vermont TRM Program Year 2023, Advanced Thermostats, page 154, footnote 15
[10] Efficiency Vermont TRM Program Year 2023, Advanced Thermostats, page 153, footnote 11
[11] Efficiency Vermont TRM Program Year 2023, Advanced Thermostats, page 154, footnote 6
[12] Efficiency Vermont TRM Program Year 2023, Advanced Thermostats, page 152, footnote 4
[13] Efficiency Vermont TRM Program Year 2023, Advanced Thermostats, page 152, footnote 10
[14] Calculated from statewide mean SEER = 14.0 of central air conditioner in VT from Cadmus, 2021 Vermont Business Sector Market Characterization and Assessment Study, Table 32. Cooling Efficiency of Single-Zone Unitary HVAC Systems. COP = SEER/3.412
[15] Calculated from statewide mean SEER = 17.2 of central air conditioner in VT from Cadmus, 2021 Vermont Business Sector Market Characterization and Assessment Study, Table 58. Cooling Efficiency of Single-Zone Unitary HVAC Systems. COP = SEER/3.412.
[16] Efficiency Vermont TRM Program Year 2023, Advanced Thermostats, page 154
[17] Efficiency Vermont TRM Program Year 2023, Advanced Thermostats, page 155

2.6 C/I – Domestic Hot Water

2.6.1 Low Flow Faucet Aerator

CHS Measure ID: CI_DOHW_LFFA
Market Sector: Commercial/Industrial
End Use: Domestic Hot Water
Applicable Building Types: Commercial, Industrial, Multifamily Common Area
Decarbonization Pathways: Thermal Efficiency
Applicable Baseline Fuels: Natural Gas, Propane, Fuel Oil #2, Grid Electricity
Decision/Action Type: Early Replacement, New Construction
Program Delivery Type: Direct Install, New Construction, Free Products, Dropship

Measure Description

This measure relates to the installation of low flow faucet aerators in commercial and industrial buildings. Low flow aerators reduce the volume of hot water consumed and thus the thermal energy needed to heat it.

This measure may be installed through one of the following mechanisms:

- Commercial new construction program
- Direct install implementation
- Free giveaways
- Dropship: product is ordered by building owner or implementer and drop-shipped to the site for self-installation. The program delivery agent shall verify the installation with the owner and reserve the right to inspect the installation.

Baseline Conditions

Early Replacement: Existing bath or kitchen faucet aerator rated at 2.2 GPM.[1]

New Construction: New standard flow rate faucet aerator rated at 1.5 GPM.[2]

Proposed Conditions

Direct Install: Faucet aerator rated at 1.0 GPM for bathroom faucets and 1.5 GPM for kitchen faucets.

New Construction: Faucet aerator rated at 1.3 GPM [3]

Eligibility Criteria

For Direct Install, Free Products, and Dropship programs, the qualifying efficient flow rate for faucet aerators must be 1.0 GPM for bathroom and 1.5 GPM for kitchen. For New Construction, the aerator must be WaterSense-labeled.

Decarbonization Summary

Table 37 provides lifecycle CO2e reductions for example existing and proposed conditions over the expected life of the measure.

Assumptions:

- CO2e reductions are calculated assuming the average water heating fuel mix in Table 38
- Water heater efficiencies per Table 39

Table 37. Low Flow Faucet Aerator CO_2e Reductions

Program Delivery Type	Faucet Type	Baseline Condition	Proposed Condition	CO2e Reductions [g CO2e]
Direct Install	Kitchen	2.2 GPM aerator	1.5 GPM aerator	
Direct Install	Bath	2.2 GPM aerator	1.0 GPM aerator	
New Construction	Kitchen	1.7 GPM aerator	1.5 GPM aerator	
New Construction	Bath	1.7 GPM aerator	1.0 GPM aerator	
Free Products	Kitchen	2.2 GPM aerator	1.5 GPM aerator	
Free Products	Bath	2.2 GPM aerator	1.0 GPM aerator	
Dropship	Kitchen	2.2 GPM aerator	1.5 GPM aerator	
Dropship	Bath	2.2 GPM aerator	1.0 GPM aerator	

Decarbonization and Energy Impacts Algorithms

CO2e [grams] = ΔE_{whf} x EF_{whf}

EF_{whf} = Water heating fuel emissions factors in grams of carbon dioxide equivalent per megajoule [g CO2e/MJ]. See Table x in Reference Section. If the water heating fuel is unknown, an average emissions factor may be calculated with the following weights:[4]

Table 38. Vermont Water Heating Fuel Mix, Commercial Buildings

Water Heating Fuel	Existing Building	New Construction
Electricity	42%	41%
Propane	32%	27%
Natural Gas	15%	32%
Oil	11%	0%

ΔE_{whf} = Reduction in water heating fuel energy in MJ as a result of this measure.

Energy Impacts Algorithms

ΔE_{whf} [MJ] = (GPM_{Base} x $Throttle_{Base}$ – GPM_{Low} x $Throttle_{Low}$) x 60 x (Hrs/Day) x (Days/Year) x 8.3 x (T_{Faucet} – T_{inlet}) / η_{RE}) x ISR x 0.00106

Input Variable Definitions

GPM_{Base} = Flow rate of existing faucet aerator = 2.2 GPM for early replacement; 1.7 GPM for new construction

GPM_{Low} = Flow rate of low flow faucet aerator

= 1.3 GPM for New Construction

= 1.0 GPM (bathroom) and 1.5 GPM (kitchen) for Direct Install

= 1.5 GPM for free products

$Throttle_{Base}$ = Percentage of full-throttle flow rate for baseline faucet = 83% [5]

$Throttle_{Low}$ = Percentage of full-throttle flow rate for low flow faucet = 95% [6]

Hours/Day = Hours per day the faucet is used = 0.25 [7]

Days/Year = Operating days per year, based on facility type:[8]

Facility Type	Days/Year
Community College	283
Fast Food	363
Full Restaurant	321
Grocery	365
Hospital	365
Hotel	365
Miscellaneous	365
Primary School	180
Secondary School	180
Small Office	250
University	283

T_{Faucet} = Mixed water temperature (°F) of hot water coming from faucet = 86°F (bathroom); 93°F (kitchen)[9]

T_{inlet} = Inlet water temperature (°F) of water entering the household = 51.8°F[10]

η_{RE}= Water heater recovery efficiency [11]

Table 39. Water Heater Recovery Efficiency by Unit Type and Program Delivery Type

Water Heater Type	Program Delivery Type	η_{RE}
Fossil Fuel	New Construction	0.89
	All Other	0.83
Electric Resistance	Any	0.98
Heat Pump	Any	3.49
Unknown Electric	Any	1.71

ISR = In-service rate, the percentage of incentivized units actually installed [12]

Table 40. Low Flow Faucet Aerator ISRs

Program Delivery Type	ISR
Direct Install	100%
New Construction	100%
Free Products	62%
Dropship	90%

8.3 = Specific heat of water, the amount of energy needed to raise 1 gal of water by 1°F [BTU/(gal °F)]

60 = 60 minutes per hour

0.00106 = Conversion factor, MJ per BTU

Measure Life

The expected measure life of installed equipment is estimated to be 10 years.[13]

Measure Cost

Direct Install: Combined labor and material costs. Default is $13 if actual is unknown.

New Construction: Incremental material cost is $6.

Free Products and Dropship: The measure cost for free giveaways and the dropship program is the actual program cost of a new aerator. Default = $2 if actual is unknown. [14]

Program Data Tracking Recommendations

The following variables should be tracked for this measure:

- Faucet type (bath or kitchen)
- Program delivery type (direct install, new construction, free products, or dropship)

Optionally, the water heater fuel and type may be tracked for additional accuracy.

Energy Codes and Standards

The baseline assumption for new construction is assumed to be the state standard which took effect on 7/1/2020[15].

- 9 V.S.A. § 2795.14: maximum faucet flow rate is 1.5 GPM at 60 psi

The baseline assumption for existing buildings is assumed to be the federal standard.

- 10 CFR § 430.32: maximum faucet flow rate is 2.2 GPM at 60 psi

For New Construction, the installed aerator must meet the US EPA's WaterSense criteria.

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[1] Existing faucets are assumed to comply with the federal standard which is 2.2 GPM at 60 psi. 10 CFR § 430.32.

[2] New construction faucets are assumed to comply with the Vermont state standard for faucets which is 1.5 GPM at 60 psi. 9 V.S.A. § 2795.14. The Vermont standard took effect on 7/1/2020.

[3] Efficiency Vermont Technical Reference Manual. 2023. Average flow rate of products on the WaterSense Labeled Products list as of October 18, 2022.

[4] NMR Group, *2020 Vermont Single Family Existing Homes Baseline Study* and NMR Group, *2020 Vermont Multifamily Residential Baseline Study*. The single family and multifamily results are combined for the "unknown" building type category by weighting according to the population of each building type in the respective studies.

[5] Efficiency Vermont Technical Reference Manual. 2023. Schultdt, Marc, and Debra Tachibana, "Energy Related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings," 2008, page 1-265.

[6] Ibid.

[7] FEMP, Domestic Water Conservation Technologies, p. 35.

[8] California Energy Commission, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, Appendix E.

[9] Ibid.

[10] Efficiency Vermont Technical Reference Manual. 2023. Average value for Burlington, Montpelier. Rutland, and Springfield, VT from U.S. DOE Standard Building America DHW Schedules, May 2014. Values found on Weather Inputs sheet on spreadsheet. http://energy.gov/eere/buildings/downloads/building-america-standard-dhw-schedules

[11] Efficiency Vermont Technical Reference Manual. 2023. Faucet Aerator. See footnotes 5, 6, 18, and 19.

[12] Efficiency Vermont Technical Reference Manual. 2023. Faucet Aerator. See footnotes 12, 13.

[13] Efficiency Vermont Technical Reference Manual. 2023. Measure lifetime from California DEER. See file DEER2014-EUL-table-update_2014-02-05.xlsx.

[14] Efficiency Vermont Technical Reference Manual. 2023. See footnotes 21-23.

[15] "Vermont 2018". Appliance Standards Awareness Project, https://appliance-standards.org/state-legislation/vermont-2018.

2.6.2 Low Flow Showerhead

CHS Measure ID: CI_DOHW_LFSH
Market Sector: Commercial
End Use: Domestic Hot Water
Applicable Building Types: Commercial and Industrial
Decarbonization Pathways: Thermal Efficiency
Applicable Baseline Fuels: Natural Gas, Propane, Fuel Oil #2, Grid Electricity
Decision/Action Type: Early Replacement, New Construction
Program Delivery Type: Direct Install, New Construction, Free Products, Dropship

Measure Description

This measure relates to the installation of low flow showerheads in commercial and industrial buildings. Low flow showerheads reduce the volume of hot water consumed and thus the thermal energy needed to heat it.

This measure may be installed through one of the following mechanisms:

- Direct install implementation
- Residential new construction program
- Free giveaways
- Dropship: product is ordered by building owner or implementer and drop-shipped to the site for self-installation. The program delivery agent shall verify the installation with the owner and reserve the right to inspect the installation.

Baseline Conditions

Early Replacement: Existing showerhead rated at 2.5 GPM.[1]

New Construction: New standard flow rate showerhead rated at 2.0 GPM. [2]

Proposed Conditions

Early Replacement: Low flow showerhead rated at 1.5 GPM. [3]

New Construction: Showerhead rated at 1.8 GPM. [4]

Eligibility Criteria

The qualifying efficient flow rate for showerheads is 1.5 GPM for Direct Install, Free Products, and Dropship programs. For New Construction, the showerhead must be WaterSense-labeled.

Decarbonization Summary

Table 41 provides example lifecycle CO2e reductions for eligible existing and proposed conditions over the expected useful life of the measure. This is a partially deemed measure; actual reductions will depend on the Uses/Day input collected from applications.

Assumptions:

- Average water heating fuel mix in Table 42
- Water heater efficiencies per Table 43
- One shower taken per day for 365 days per year (example only, not a deemed parameter)

Table 41. C/I Low Flow Showerhead CO2e Reductions (Example)

Program Delivery Type	Baseline Condition	Proposed Condition	Lifetime CO2e Reductions [g CO2e]
Direct Install	2.5 GPM showerhead	1.5 GPM showerhead	
New Construction	2.0 GPM showerhead	1.8 GPM showerhead	
Free Products	2.5 GPM showerhead	1.5 GPM showerhead	
Dropship	2.5 GPM showerhead	1.5 GPM showerhead	

Decarbonization and Energy Impacts Algorithms

CO2e [grams] = ΔE_{whf} x EF_{whf}

EF_{whf} = Water heating fuel emissions factor in grams of carbon dioxide equivalent per megajoule [g CO2e/MJ]. See Table x in Reference Section. If the water heating fuel is unknown, an average emissions factor may be calculated with the following weights:[5]

Table 42. Vermont Water Heating Fuel Mix, Commercial Buildings

Water Heating Fuel	Existing Building	New Construction
Electricity	42%	41%
Propane	32%	27%
Natural Gas	15%	32%
Oil	11%	0%

ΔE_{whf} = Reduction in water heating fuel energy in MJ as a result of this measure.

Energy Impacts Algorithms

ΔE_{base} [MJ] = Baseline fuel energy impacts

= ((GPM$_{Base}$ - GPM$_{Low}$) x (Minutes/Use) x (Uses/Day) x (Days/Year) / 8.3 x (T_{Sh} – T_{inlet}) / η_{RE} x ISR x 0.00106

Input Variable Definitions

GPM_{Base} = Flow rate of existing showerhead = 2.5 GPM for Early Replacement, 2.0 GPM for New Construction.

GPM_{Low} = Flow rate of low flow showerhead = 1.5 GPM for Early Replacement; 1.8 GPM for new construction

Minutes/Shower = Average shower length in minutes per person = 7.8 [6]

Uses/Day = Estimated number of showers taken per day for one showerhead; collected from application

Days/Year = Days the showerhead is used per year = 365

T_{Sh} = Mixed water temperature (°F) of hot water coming from showerhead = 101°F [7]

T_{inlet} = Inlet water temperature (°F) of water entering the building= 51.8°F [8]

η_{RE}= Water heater recovery efficiency [9]

Table 43. Water Heater Recovery Efficiency by Unit Type and Program Delivery Type

Water Heater Type	Program Delivery Type	η_{RE}
Fossil Fuel	New Construction	0.89
	All Other	0.83
Electric Resistance	Any	0.98
Heat Pump	Any	3.49
Unknown Electric	Any	1.71

ISR = In-service rate, the percentage of incentivized units actually installed [10]

Table 44. Low Flow Showerhead ISRs

Program Delivery Type	ISR
Direct Install	100%
New Construction	100%
Free Products	56%
Dropship	90%

8.3 = Specific heat of water, the amount of energy needed to raise 1 gal of water by 1°F [BTU/(gal °F)]

0.00106 = Conversion factor, MJ per BTU

Measure Life

The expected measure life of installed equipment is estimated to be 10 years. [11]

Measure Cost

Direct Install: Combined labor and material costs. Default is $22 for a fixed showerhead and $27 for a handheld model.

New Construction: Incremental material cost is $6.

Free Products and Dropship: The measure cost for free giveaways and the dropship program is the actual program cost of a new showerhead. Default = $4 if unknown.[12]

Program Data Tracking Recommendations

The following variables should be tracked for this measure:

- Program delivery type (direct install, new construction, free products, or dropship)
- Number of showers per day

Optionally, the water heater fuel and type may be tracked for additional accuracy.

Energy Codes and Standards

The baseline assumption for new construction is assumed to be the state standard which took effect on 7/1/2020[13].

- 9 V.S.A. § 2795.14: maximum faucet flow rate is 2.0 GPM at 80 psi

The baseline assumption for existing buildings is assumed to be the federal standard.

- 10 CFR § 430.32: maximum faucet flow rate is 2.5 GPM at 80 psi

For New Construction, the installed showerhead must meet the US EPA's WaterSense criteria.

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[1] Existing showerheads are assumed to comply with the federal standard which is 2.5 GPM at 80 psi. 10 CFR § 430.32

[2] New construction showerheads are assumed to comply with the Vermont state standard for faucets which is 2.0 GPM at 80 psi. 9 V.S.A. § 2795.14. The Vermont standard took effect on 7/1/2020.

[3] Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 196. See footnote 10

[4] Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 196. See footnote 11

[5] Cadmus 2023, 2021 Vermont Business Sector Market Characterization and Assessment Study. Statewide Distribution of Water Heating Fuel Types for existing and new construction facilities. See Figures 70, 150.

[6] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 11, Table 7.

[7] Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 197. See footnote 16

[8] Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 197. See footnote 17

[9] Efficiency Vermont Technical Reference Manual. 2023. Faucet Aerator. See footnotes 5, 6, 18, and 19.

[10] Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 196. See footnotes 12, 13.

[11] Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 197. See footnote 21

[12] Efficiency Vermont Technical Reference Manual. 2023. Low Flow Showerhead. Page 198. See footnotes 22 – 25.

[13] "Vermont 2018". Appliance Standards Awareness Project, https://appliance-standards.org/state-legislation/vermont-2018.

Opinion **Dynamics**

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PORTLAND
SAN DIEGO
SAN FRANCISCO