Advanced Thermostat

Version Date & Revision History

Draft date: 8/17/2021

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End date: TBD

Referenced Documents

1. VT-RES-New-Construction-On-Site-Final-Report-2-13-13
2. Studies informing the TRM Savings Characterization for Advanced Thermostats
3. VT SF Existing Homes Onsite Report_final 021513
4. VGS Usage Regression Work_04182017
5. Programmable Thermostats Furnace Fan Analysis
6. IL SAG Smart Thermostat Preliminary Gas Impact Findings2015-12-08 to IL SAG
7. Efficiency Vermont Summer 2018 Seasonal Savings
8. Seasonal Savings Impacts Winter 2019_20_ Efficiency Vermont
9. EVT Advanced Thermostat and Optimization_2020_Tier III.xlsx

Description

This measure characterizes the household energy savings from the installation of a new thermostat(s) for reduced heating consumption through a configurable schedule of temperature set-points (like a programmable thermostat) and automatic variations to that schedule to better match HVAC system runtimes to meet occupant comfort needs. 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]. This class of products and services are relatively new, diverse, and rapidly changing. Generally, the savings expected for this measure aren't yet established at the level of individual features, but rather at the system level and how it performs overall. Note that it is a very active area of ongoing study to better map features to savings value, and establish standards of performance measurement based on field data so that a standard of efficiency can be developed. That work is not yet complete but does inform the treatment of some aspects of this characterization and recommendations.

Savings estimates are provided for both single and multifamily, which blend the fuels consumed for heating needs, as well as if existing or new construction.

The measure assumes that the advanced thermostat is controlling a portion of the whole home's heating load.

The thermostat must be installed and connected with the manufacturer to be eligible for a rebate.

Definition of Energy Transformation Equipment or Condition

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[1] For example, the capabilities of products and added services that use ultrasound, infrared, or geofencing sensor systems, automatically develop individual models of home's thermal properties through user interaction, and optimize system operation based on equipment type and performance traits based on weather forecasts demonstrate the type of automatic schedule change functionality that apply to this measure characterization.

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. As summarized in the description, this category of products and services is broad and rapidly advancing in regards to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication[2] and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default capabilities described above.

Definition of Baseline Equipment or Condition

For an existing building, the baseline is assumed to be a mix of programmable and manual thermostats. For New Construction, the baseline is a programmable thermostat.

Algorithms

Electric Energy Impacts

There are no electric energy impacts for this measure.

Demand Impacts

There are no demand impacts for this measure.

Fossil Fuel Impacts

ΔMMBtu $= \Sigma\ (\%FossilHeat \times (Thermostat\ Savings + Optimization\ Savings$

ΔMMBtu $= \Sigma\ (\%FossilHeat \times \Big(\big(Heating_{Consumption} \times \%Controlled\big) \times AdvThermostat_{HeatReduction}\Big) + (Heating_{Consumption} \times \%Controlled) \times (1 - AdvThermostat_{HeatReduction}) \times \%OptSavingsHeat)))$

ΔMMBtu $= \%Existing\ Homes(NG_{MMBtu\ Savings} \times \%NG + Oil_{MMBtu\ Savings} \times \%Oil + LP_{MMBtu\ Savings} \times \%LP) + \%New\ Construction(NG_{MMBtu\ Savings} \times \%NG + Oil_{MMBtu\ Savings} \times \%Oil + LP_{MMBtu\ Savings} \times \%LP)$

Where:

ΔMMBtu = Thermal savings from displacement of fossil fuels

%FossilHeat = Percentage of heating savings assumed to be fossil fuel. Multifamily is assumed to be the same as the equivalent single family values below.

= 100%

Thermostat Savings = Standard savings from Advanced Thermostat

Optimization Savings = Additional savings for Thermostat Optimization deployment

Heating_Consumption = Estimate of annual household heating consumption

[2] This measure recognizes that field data may be available, through this 2-way communication capability, to better inform characterization of efficiency criteria and savings calculations. Efficiency Vermont will be exploring ways to better utilize this data once the program is underway and once the ENERGY STAR specification and program process is finalized.

Gas_Heating_Consumption = see table below, units in MMBtu:

Fuel Type	Existing Homes[3]	Residential New Construction[4]	Multifamily Existing[5]	Multifamily New Construction [6]
Gas	80	67	31	26
Oil	85	70	33	27

%Controlled = Assumed percentage of total heating load being controlled by thermostat.
= 76% for Existing Homes, 53% for RNC[7] and 94% for Multifamily[8]

AdvThermostat_HeatReduction = Assumed percentage reduction in total household heating energy consumption due to advanced thermostat

[3] Estimate is based upon calculation of average heating load; (FLH * Capacity/1,000,000)/AFUE. FLH and Capacity are based upon natural gas billing data analysis provided by Vermont Gas Systems (VGS) (see 'VGS Usage Regression Work_04182017.xls'). AFUE assumptions are from Vermont Single-Family Existing Homes Onsite Report, 7/2018. Note the FLH calculation attempts to isolate heating only consumption (removing DHW and other loads). For calculation of savings see "EVT Advanced Thermostat and Optimization 2020 Update.xls" for details.

[4] Estimate is based upon calculation of average heating load; (FLH * Capacity/1,000,000)/AFUE. FLH and Capacity are based upon natural gas billing data analysis provided by Vermont Gas Systems (VGS) (see 'VGS Usage Regression Work_04182017.xls'). AFUE assumptions are from Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. Note the FLH calculation attempts to isolate heating only consumption (removing DHW and other loads). For calculation of savings see "EVT Advanced Thermostat and Optimization 2020 Update.xls" for details.

[5] Multifamily per unit consumption is estimated using relative (single v multi family) space heating consumption data for the Northeast from Table CE3.2 of 2015 RECS multiplied by the Existing Homes consumption assumption. See tab 'CE.2 2015' in "EVT Advanced Thermostat and Optimization 2020 Update.xls".

[6] Multifamily per unit consumption is estimated using relative (single v multi family) space heating consumption data for the Northeast from Table CE3.2 of 2015 RECS multiplied by the Existing Homes consumption assumption. See tab 'CE.2 2015' in "EVT Advanced Thermostat and Optimization 2020 Update.xls".

[7] Based on review of # of thermostats per home data from Vermont Single-Family Existing Homes Onsite Report, 7/2018 and Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. See "EVT Advanced Thermostat and Optimization 2020 Update.xls".

[8] Based on data from Table HC6.1 from 2009 EIA RECS showing number of thermostats in multi family buildings (note this information was not included in the 2015 RECS survey). See tab 'HC6.1 2009' in "EVT Advanced Thermostat and Optimization 2020 Update.xls".

Program	Existing Thermostat Type	AdvThermostat_HeatReduction [9]
Existing Homes	Unknown (Blended)	7.5 %
Multifamily Existing	Unknown (Blended)	8.1%
New Construction	Programmable	5.6%

%OptSavingsHeat = Estimated additional heat savings from users with Thermostat Optimization services.
= 0.79% [10]

%Existing Homes = Assumed percentage of thermostats being installed in existing homes
= 99.25%[11]

$NG_{MMBtu\ Savings}$ = Savings from thermostats installed in homes with natural gas burning heating systems
= Results can be found in associated analysis file

%NG = Assumed population of homes with Natural Gas heating systems
= 29.70% [12]

$Oil_{MMBtu\ Savings}$ = Savings from thermostats installed in homes with oil burning heating systems
= Results can be found in associated analysis file

%Oil = Assumed population of homes with Oil heating systems
= 38.18% [13]

[9] Savings of 8.8% for manual, and 5.6% for programmable thermostats as presented in Navigant's PowerPoint on Impact Analysis from Preliminary Gas savings findings (slide 28 of 'IL SAG Smart Thermostat Preliminary Gas Impact Findings 2015-12-08 to IL SAG.ppt'). These values are used as the basis for the weighted average savings value for existing buildings. The weighting of manual to programmable thermostats for when unknown is based upon Vermont Single-Family Existing Homes Onsite Report, 7/2018, 'Table 51 Type of Thermostat' for existing homes and data from Table HC6.1 from 2015 RECS.
[10] This assumption accounts for market share of the two suppliers of Optimization (Nest and Ecobee), % of season that optimization is applied (where appropriate), % of customers assumed to opt in to the service and the %savings expected to be achieved. These assumptions will be reviewed regularly to ensure they continue to be a reasonable estimation. See "Optimization Assumptions" tab of "EVT Advanced Thermostat and Optimization 2020 Update.xls" for more details.
[11] TAG negotiated value with discussion of new Vermont MLS records annually
[12] Percentage of heating fuel types in existing Vermont homes from NMR Group, "Survey Analysis of Owners of Existing Homes in Vermont (Draft)" December 5, 2016: page 29, Table 38 (Statewide Data). Kerosene, coal, and solar were excluded. The report states that "all nine respondents who use electricity as their primary heating fuel reported that they have electric resistance baseboard rather than an electric heat pump."
[13] Percentage of heating fuel types in existing Vermont homes from NMR Group, "Survey Analysis of Owners of Existing Homes in Vermont (Draft)" December 5, 2016: page 29, Table 38 (Statewide Data). Kerosene, coal, and solar were excluded. The report states that "all nine respondents who use electricity as their primary heating fuel reported that they have electric resistance baseboard rather than an electric heat pump."

$LP_{MMBtu\ Savings}$	= Savings from thermostats installed in homes with propane heating systems = Results can be found in associated analysis file
%LP	= Assumed population of homes with Propane heating systems = 32.12% [14]
%New Construction	= Assumed percentage of thermostats being installed in new construction = 0.75%[15]

Gross-to-Net Savings Factors

Gross-to-Net Savings Factors

Freerider	Spillover
1.0	1.0

Persistence

The persistence factor is assumed to be one.

Lifetime

The expected measure life for advanced thermostats is assumed to be similar to that of a programmable thermostat 10 years[16] based upon equipment life only.

Measure Cost

For DI and other programs for which installation services are provided, the actual material, labor, and other costs should be used, with a default of $265 ($225 for the thermostat and $40 for labor). For retail, Bring Your Own Thermostat (BYOT) programs[17], or other program types the average incremental cost for the new installation measure is assumed to be $175[18].

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[14] Percentage of heating fuel types in existing Vermont homes from NMR Group, "Survey Analysis of Owners of Existing Homes in Vermont (Draft)" December 5, 2016: page 29, Table 38 (Statewide Data). Kerosene, coal, and solar were excluded. The report states that "all nine respondents who use electricity as their primary heating fuel reported that they have electric resistance baseboard rather than an electric heat pump."

[15] TAG negotiated value with discussion of new Vermont MLS records annually

[16] Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS
Associates, 2007

[17] In contrast to program designs that utilize program affiliated contractors or other trade ally partners that support customer participation through thermostat distribution, installation and other services, BYOT programs enroll customers after the time of purchase through online rebate and program integration sign-ups.

[18] Market prices vary considerably in this category, generally increasing with thermostat capability and sophistication. The core suite of functions required by this measure's eligibility criteria are available on units readily available in the market roughly in the range of $200 and $250, excluding the availability of any wholesale or volume discounts. The assumed incremental cost is based on the middle of this range ($225) minus a cost of $50 for the baseline equipment blend of manual and programmable thermostats. Note that any add-on energy service costs, which may include one-time setup and/or annual per device costs are not included in this assumption.

For new construction, the incremental cost between a programmable and advanced thermostat is assumed to be $150[19].

O&M Cost Adjustments

N/A

Savings Summary[20]

Blended Advanced Thermostat Savings (ΔMMBtu)	
Singlefamily	5.11
Multifamily	2.64

[19] Assumed to be $225 minus $75 for programmable thermostat.

[20] Summary can be found in analysis document: advanced-thermostat-analysis-Tier III.xlsx. This blending analyzes the percent of homes in Vermont with heating systems of different fossil fuels and assumed new construction installation factor.

Variable Speed Mini-Split Heat Pumps (Single-Zone)

Version Date & Revision History

Draft date: 8/25/2021

Effective date: 1/1/2022

End date: TBD

Referenced Documents:

1. Navigant Consulting Inc. (2013). *Incremental Cost Study Phase Two Final Report.* Burlington, MA: NEEP Evaluation, Measurement, and Verification Forum.
2. NMR Group, Inc. (2013). *Vermont Single-Family Existing Homes Onsite Report FINAL.*
3. U.S. Department of Energy. (2010). *Residential Heating Products Final Rule Technical Support Document.*
4. DPS CCHP Tier III- Final Final.pdf
5. Tier III cchp mop and retrofit 2021.xlsx
6. Cadmus, *Evaluation of Cold Climate Heat Pumps in Vermont*. Montpelier, VT: Vermont Department of Public Service, July 31, 2017.
7. Upstream EVT CCHP Program Data_Cost Analysis.xlsx

Description

This measure claims savings for the installation of single-zone variable speed mini-split heat pumps in residential applications, as well as small commercial applications, including schools and small businesses, where hours of use and capacity are comparable to residential spaces. This measure is characterized as a retrofit claiming thermal energy savings for heating. If the heat pump has integrated controls, the controls must interact with the thermostatic sensor in the room and reduce short cycling.

Definition of Baseline Equipment or Condition

The baseline condition is assumed to be the existing fossil fuel heating system with the following efficiency criteria:

Table 1 – Baseline Efficiency Criteria

Equipment	AFUE
Existing Fossil Fuel System	85%[21]

Definition of Energy Transformation Equipment or Condition

To qualify for savings under this measure the installed equipment must be a be a new heat pump that is capable of providing heat using the heat pump cycle down to 5°F and meets the following minimum efficiency criteria:

[21] Weighted efficiencies based on VT SF Existing Homes Onsite Report Table 5-8 and 5-9. (NMR Group, Inc., 2013). Efficiency for homes using wood or pellet stoves based on review of EPA-Certified wood stoves. (U.S. Environmental Protection Agency, n.d.)

Table 2 – High Efficiency Criteria[22]

Equipment	HSPF	EER	SEER
Air-Source Heat Pump	8.6	9.8	15.6

Algorithms

Electric Energy Impacts

Electric energy heating penalties include increases in electric consumption based on the fuel switch. Seasonal efficiency values have been used to approximate varying system efficiencies due to changes in operating conditions.

$$\Delta kWh = -\left[Capacity \times EFLH \times \frac{1}{COP} \times \frac{1}{3412}\right] \times \%Fossil$$

Where:

ΔkWh = total net kWh penalties for heating and cooling (deemed assumption for prescriptive savings, based on size category)

Capacity = max heating capacity of heat pump at 5 degrees F (Btu/hr)

EFLH = Equivalent Full Load Hours[23]

= 1355

COP = Actual Heating Seasonal Performance Factor (HSPF) converted to COP

$= \frac{HSPF}{3.412}$

%Fossil = Average percentage of fossil fuels in electric generation mix for the program year, adjusted for measure lifetime. For electric distribution utilities generating 100% of electricity from renewable energy, %Fossil is 0%.

= Custom input from utility

Demand Impacts

Demand penalties are calculated using the energy penalty divided by the equivalent full load hours. Increased power draw for the efficient system compared to the baseline system is treated as a demand penalty for heating.

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[22] Average efficiencies of all capacity bins. Based on analysis of Vermont distributor sales data collected by Efficiency Vermont. Analysis can be found on the Analysis tab of the Tier III TAG CCHP TRM Savings Calculation_Single and Multi Zone.xlsx.

[23] EFLH is calculated in an analysis of heat pump metered data. This analysis can be found on the EFLH Calculator tab in the Tier III TAG CCHP TRM Savings Calculation_Single and Multi Zone.xlsx.

$$\Delta kW = -\frac{\Delta kWh}{EFLH}$$

ΔkW = total average winter coincident peak kW increase

Fossil Fuel Impacts

Thermal savings are calculated using efficiencies from manufacturer specification sheets and metered data from the VT Heat Pump Evaluation[24]. This analysis includes Vermont metered MMBtu adjustments by taking a 48% adjustment to the existing 85% heating offset assumed,[25] which results in a 41% offset. The analysis assumes that efficient heating systems operate below 50°F. Below 5°F the efficient system cuts off due to its inability to heat below this temperature.

An average consumption household bin is used to represent the average heating load in Vermont homes[26]. These bins can be found below:

Household Consumption	Fuel Oil (Gallons)	MMBTU per gallon	Total MMBTU
Average	600	0.138	82.8

$$\Delta MMBtu = \frac{Capacity \times EFLH}{1{,}000{,}000} \times Adjustment\ Factor \times Bonus\ Factor$$

Where:

ΔMMBtu = MMBtu savings (deemed assumption for prescriptive)

Adjustment Factor = Integrated Controls[27]

= 95% if controls are not present

= 100% if controls are present

Bonus Factor = Weatherization of existing building[28]

= 100% if in a high performing home

= 81% if in a low performing home

Loadshape

[24] Cadmus, Evaluation of Cold Climate Heat Pumps in Vermont. Montpelier, VT: Vermont Department of Public Service, July 31, 2017

[25] Table 3, Page 14. 6. Cadmus, Evaluation of Cold Climate Heat Pumps in Vermont. Montpelier, VT: Vermont Department of Public Service, July 31, 2017.

[26] The medium consumption bin is based off of guidance from the Vermont Department of Public Service and the +/- 25% consumption is based off of Efficiency Vermont modeling data.

[27] This value is derived from the Vermont Department of Public Service. Refer to DPS CCHP Tier III- Final Final.pdf

[28] These values are negotiated in Tier III TAG, October 26, 2017.

Loadshape #116, Residential Variable Speed Mini-Split and Multi-Split Heat Pumps

Gross-to-Net Savings Factors [29]

	Freerider	Spillover
Variable Speed Mini-Split Heat Pumps (Single-Zone) in Low Performing Home	0.81	1.07

Persistence

The persistence factor is assumed to be one.

Lifetimes

The expected measure life is assumed to be 15 years.[30]

Measure Cost[31]

Measure cost represents the total installed cost of a CCHP with Tier III efficiencies.

Nominal Equipment Capacity (Btu/hr)	Retrofit Costs
6,000	$2,759.80
9,000	$2,763.71
12,000	$2,761.05
15,000	$2,894.48
18,000	$3,132.36
24,000	$3,426.49
40,000	$3,981.00
56,500	$4,631.10

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

[29] Negotiated between the DU's and shall not have transferability to the Efficiency Vermont / EEU TRM

[30] California DEER Effective Useful Life values, updated October 10, 2008. Various sources range from 12 to 20 years, DEER represented a reasonable mid-range.

[31] Cost analysis of Vermont installed Cold Climate Heat Pumps through Efficiency Vermont's program. Distributor reported costs analyzed in Upstream EVT CCHP Program Data_Cost Analysis.xlsx.

Net Impacts[32]

$$\Delta MWh_{Net} = \Delta MWh_{Electric} + \Delta MWh_{FossilFuel}$$

[32] Refer to Savings tab of Tier III Single Zone CCHPSavingsAnalysis Update.xlsx

Variable Speed Mini-Split Multi Heat Pumps (Multi-Zone)

Version Date & Revision History

Draft date: 10/27/2017

Effective date: 1/1/2018

End date: TBD

Referenced Documents:

1. Navigant Consulting Inc. Incremental Cost Study Phase Two Final Report. Burlington, MA: NEEP Evaluation, Measurement, and Verification Forum, 2013.
2. NMR Group, Inc. "Vermont Single-Family Existing Homes Onsite Report FINAL." 2013.
3. U.S. Environmental Protection Agency. n.d. http://www.epa.gov/burnwise/woodstoves.html (accessed March 7, 2014).
4. DPS CCHP Tier III- Final Final.pdf
5. Tier III TAG CCHP TRM Savings Calculation_Single and Multi Zone.xlsx
6. Cadmus, Evaluation of Cold Climate Heat Pumps in Vermont. Montpelier, VT: Vermont Department of Public Service, July 31, 2017.
7. Upstream EVT CCHP Program Data_Cost Analysis.xlsx

Description

This measure claims savings for the installation of multi-zone variable speed mini-split heat pumps in a residential application, as well as small commercial applications, including schools and small businesses, where hours of use and capacity are comparable to residential spaces. The measure is characterized as a retrofit claiming thermal energy savings for heating. If the heat pump has integrated controls, the controls must interact with the thermostatic sensor in the room and reduce short cycling.

Definition of Baseline Equipment or Condition

The baseline condition is assumed to be the existing fossil fuel heating system with the following efficiency criteria:

Table – Baseline Efficiency Criteria

Equipment	AFUE
Existing Fossil Fuel System	85%[33]

[33] Weighted efficiencies based on VT SF Existing Homes Onsite Report Table 5-8 and 5-9. (NMR Group, Inc., 2013). Efficiency for homes using wood or pellet stoves based on review of EPA-Certified wood stoves. (U.S. Environmental Protection Agency, n.d.)

Definition of Energy Transformation Equipment or Condition

To qualify for savings under this measure the installed equipment must be a be a new heat pump that is capable of providing heat using the heat pump cycle down to 5°F and meets the following minimum efficiency criteria:

Table – High Efficiency Criteria

Equipment	HSPF	EER	SEER
Air-Source Heat Pump	8.2	12	14.5

Algorithms

Electric Energy Impacts

Electric energy heating penalties include increases in electric consumption based on the fuel switch. Seasonal efficiency values have been used to approximate varying system efficiencies due to changes in operating conditions.

$$\Delta kWh = -\left[Capacity \times EFLH \times \frac{1}{COP} \times \frac{1}{3412}\right] \times \%Fossil$$

Where:

ΔkWh = total net kWh penalties for heating and cooling (deemed assumption for prescriptive savings, based on size category)

Capacity = max heating capacity of heat pump at 5 degrees F (Btu/hr)

EFLH = Equivalent Full Load Hours[34]

= 1355

COP = Actual Heating Seasonal Performance Factor (HSPF) converted to COP

$= \frac{HSPF}{3.412}$

%Fossil = Average percentage of fossil fuels in electric generation mix for the program year, adjusted for measure lifetime. For electric distribution utilities generating 100% of electricity from renewable energy, %Fossil is 0%.

= Custom input from utility

[34] EFLH is calculated in an analysis of heat pump metered data. This analysis can be found on the EFLH Calculator tab in the Tier III TAG CCHP TRM Savings Calculation_Single and Multi Zone.xlsx.

Demand Impacts

Demand penalties are calculated using the energy penalty divided by the equivalent full load hours. Increased power draw for the efficient system compared to the baseline system is treated as a demand penalty for heating.

$$\Delta kW = -\frac{\Delta kWh}{EFLH}$$

ΔkW = total average winter coincident peak kW increase

Fossil Fuel Impacts

Thermal savings are calculated using efficiencies from manufacturer specification sheets and metered data from the VT Heat Pump Evaluation[35]. This analysis includes Vermont metered MMBtu adjustments by taking a 48% adjustment to the existing 85% heating offset assumed,[36] which results in a 41% offset. The analysis assumes that efficient heating systems operate below 50°F. Below 5°F the efficient system cuts off due to its inability to heat below this temperature.

An average consumption household bin is used to represent the average heating load in Vermont homes[37]. These bins can be found below:

Annual Household Consumption	Fuel Oil (Gallons)	MMBTU per gallon	Total MMBTU
Average	600	0.138	82.8

$$\Delta MMBtu = \frac{Capacity \times EFLH}{1{,}000{,}000} \times Adjustment\ Factor \times Bonus\ Factor$$

Where:

ΔMMBtu = MMBtu savings (deemed assumption for prescriptive)

[35] Cadmus, Evaluation of Cold Climate Heat Pumps in Vermont. Montpelier, VT: Vermont Department of Public Service, July 31, 2017

[36] Table 3, Page 14. 6. Cadmus, Evaluation of Cold Climate Heat Pumps in Vermont. Montpelier, VT: Vermont Department of Public Service, July 31, 2017.

[37] The medium consumption bin is based off of guidance from the Vermont Department of Public Service and the +/- 25% consumption is based off of Efficiency Vermont modeling data.

Adjustment Factor	= Integrated Controls[38]
	= 95% if controls are not present
	= 100% if controls are present
Bonus Factor	= Weatherization of existing building[39]
	= 100% if in a high performing home
	= 81% if in a low performing home

Loadshape

Loadshape #116, Residential Variable Speed Mini-Split and Multi-Split Heat Pumps

Gross-to-Net Savings Factors [40]

	Freerider	*Spillover*
Variable Speed Mini-Split Multi Heat Pumps	0.81	1.07

Persistence

The persistence factor is assumed to be one.

Lifetimes

The expected measure life is assumed to be 15 years.[41]

Measure Cost [42]

Measure cost represents the installed cost of a multi head CCHP with Tier III efficiencies.

Nominal Equipment Capacity (Btu/hr)	Total Cost
18,000	$3,494.93
24,000	$3,991.69

[38] This value is derived from the Vermont Department of Public Service. Refer to DPS CCHP Tier III- Final Final.pdf
[39] These values are negotiated in Tier III TAG, October 26, 2017.
[40] Negotiated between the DU's and shall not have transferability to the Efficiency Vermont / EEU TRM
[41] California DEER Effective Useful Life values, updated October 10, 2008. Various sources range from 12 to 20 years, DEER represented a reasonable mid-range.
[42] Cost analysis of Vermont installed Cold Climate Heat Pumps through Efficiency Vermont's program. Distributor reported costs analyzed in Upstream Efficiency Vermont CCHP Program Data_Cost Analysis.xlsx.

30,000	$3,754.15
36,000	$4,342.63
42,000	$5,036.26
48,000	$5,481.42

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Net Impacts[43]

$$\Delta MWh_{Net} = \Delta MWh_{Electric} + \Delta MWh_{FossilFuel}$$

[43] ΔMWh is calculated annual savings. Refer to Savings tab of Tier III Multi Zone CCHPSavingsAnalysis Update.xlsx

Electric Bicycles

Version Date & Revision History
Draft date: 8/27/2017
Effective date: 1/1/2018
End date: TBD

Referenced Documents

1. VTRANS, "The Vermont Transportation Energy Profile," October 2015

Description
This is a time of sale measure that applies to the purchase of a new electric bicycle to partially displace usage of a new, conventional gasoline-powered or diesel vehicle. The measure assumes the electric bicycle will be used to commute to or from work or social activities or to complete errands. Electric bicycle usage for exercise or recreation is not included in measure impacts.

Definition of Energy Transformation Equipment or Condition
The energy transformation equipment must be a new electric bicycle.

Definition of Baseline Equipment or Condition
The baseline equipment is a new, conventional gasoline-powered or diesel vehicle.

Algorithms

Demand Impacts

Demand impacts are estimated to be TBD.

Electric Energy Impacts

Using the algorithm and assumptions below, deemed electric impacts for an electric bicycle are 0.03 MWh.

$$\Delta MWh_{Electric} = (DDM\ x\ Wh/mile)\ /1{,}000{,}000$$

Where:

$\Delta MWh_{Electric}$	= Gross customer annual electric energy impacts for the measure
DDM	= Displaced driving miles, or number of conventional vehicle miles displaced by the electric bicycle annually
	=1,286 miles[44]
Wh/mile	= Electric efficiency (Wh/mile) of new electric bicycle
	= 20 Wh/mile[45]
1,000,000	= Factor to convert Wh to MWh

[44] Displaced driving miles (DDM) were calculated using data from a 2017 electric bicycle survey conducted by VEIC. DDM = (annual electric bicycle mileage for non-exercise or recreation purposes) x (% vehicle travel reduction). Values for "%vehicle travel reduction" were assigned based on the survey question "Prior to owning an E-bike would you typically have been driving to those places instead?" Responses were Often (75%), Sometimes (50%), Rarely (12%), and Never (0%).
[45] Average electric efficiency from Ithaca's Boxy Bikes (http://boxybikes.com/learn/) and electricbike.com (https://www.electricbike.com/watt-hours/).

Fossil Fuel Impacts

Using the algorithm and assumptions below, deemed fossil fuel impacts for an electric bicycle are 6.159 MMBtu.

$$\Delta MMBtu = DDM/\ EFF_{Fuel}\ x\ 121{,}160)/1{,}000{,}000$$

Where:

ΔMMBtu = Thermal savings from displacement of fossil fuels

EFF_{Fuel} = Fuel efficiency (miles/gallon or MPG) of new, conventional, light-duty vehicle

= 25.3 MPG[46]

121,160 = Weighted average energy content (Btu/gallon) of gasoline and diesel in Vermont privately-owned vehicle fleet[47]

1,000,000 = Factor to convert Btu to MMBtu

Other factors as defined above.

Loadshape

N/A

Gross-to-Net Savings Factors

Measure Category		**Transportation**	
Product Description		**Electric Bicycles**	
Measure Code		**TRNEBKE**	
Track Name	**Track No.**	**Spillover**	**Freerider**
TBD	TBD	1.0	1.0

Persistence

The persistence factor is assumed to be one.

Lifetime

The lifetime of an electric bicycle is assumed to be 8 years.

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46 Sales-weighted average miles per gallon of model year 2015 vehicles, calculated in University of Michigan Transportation Research Institute Eco-driving Index: http://www.umich.edu/~umtriswt/EDI_sales-weighted-mpg.html. This average includes all light duty vehicles (cars, SUVs, pick-up trucks) and may include a small number of alternative fuel vehicles.

47 Weight average based on energy content of gasoline and diesel from "Fuel Conversion Factors" provided by the Vermont Department of Public Service. The privately owned vehicle fleet in Vermont consists of 94.5% gasoline-powered vehicles and 5.3% diesel-powered vehicles. See Figure 3.1 from VTRANS, "The Vermont Transportation Energy Profile," October 2015.

Measure Cost

The measure cost is the average retail price of a new electric bicycle: $2,825.[48]

O&M Cost Adjustments

O&M costs for electric bicycles compared to new, conventional vehicles are presented in the table below along with incremental lifetime O&M savings.

Conventional Vehicle O&M Cost	Electric Bicycle O&M Cost	Incremental Lifetime O&M Costs
$77[49]	$137.50[50]	$484

[48] The measure cost is the average of new electric bicycle prices from Electric Bike Review (average of $3,300 for 2016 cruiser, mountain, road, city, folding, and cargo electric bicycles) and Electric Bike Report (price range of $500-$10,000+; average of $2,350 for a quality electric bicycle).

[49] Annual O&M cost for conventional vehicles is annual displaced driving miles (1,286 miles) x $0.0597/mile (average cost for maintenance and tires from AAA, "Your Driving Costs: How Much Are You Really Paying to Drive?" 2013, page 7.

[50] Electric bicycle O&M includes annual tune-up (based on Pedego maintenance schedule: http://www.pedegocotswolds.com/maintenance-videos/) at $75 (Electric Bike Review) and battery replacement every 4 years (http://www.pedegoelectricbikes.com/battery-details/#start) at $500 (Electric Bike Review).

Commercial Electric Vehicles

Version Date & Revision History

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Referenced Documents

1. U.S. Department of Transportation, "Bus Lifecycle Cost Model for Federal Land Management Agencies"
2. Columbia University, "Electric Bus Analysis for New York City Transit," May 2016.
3. U.S. Dept. of Transportation Federal Transit Administration (FTA), "Useful Life of Transit Buses and Vans, Report No. FTA VA-26-7229-07.1," April 2007
4. "Benefits of Zero Emissions School Buses," July 20, 2016
5. SAIC, "Transit Cooperative Research Program Report 146: Guidebook for Evaluating Fuel Choices for Post-2010 Transit Bus Procurements," 2011
6. NREL, "Foothill Transit Battery Electric Bus Demonstration Results," Jan 2016

Description

This is a time of sale measure that applies to the purchase of a new, commercial, all-electric vehicle instead of a new, commercial, conventional gasoline-powered or diesel vehicle. The measure characterizes transit buses, school buses, and paratransit vehicles.

Definition of Energy Transformation Equipment or Condition

The energy transformation equipment must be a new commercial, all-electric vehicle.

Definition of Baseline Equipment or Condition

The baseline equipment for paratransit vehicles is a new, conventional gasoline-powered paratransit vehicle. The baseline equipment for transit and school buses is a new, conventional diesel-powered transit or school bus.

Algorithms

Demand Impacts

Demand impacts are not estimated for this measure.

Electric Energy Impacts

$$\Delta MWh_{Electric} = VMT \ x \ EFF_{Electric}/1{,}000$$

Where:

$\Delta MWh_{Electric}$ = Gross customer annual electric energy impacts for the measure

VMT = Annual vehicle miles traveled

= Custom input

$EFF_{Electric}$ = Electric efficiency (kWh/mile) of new electric vehicle

= Custom Input

1,000 = Factor to convert kWh to MWh

Fossil Fuel Impacts

$$\Delta MMBtu = (VMT / EFF_{Fuel}\ x\ Btu/Gallon)/1{,}000{,}000$$

Where:

ΔMMBtu = Thermal savings from displacement of fossil fuels

EFF_{Fuel} = Fuel efficiency (miles/gallon or MPG) of new, commercial, conventional gasoline-powered or diesel vehicle

Vehicle Type	$EFF_{ConventionalFuel}$
Transit Bus	4.27 MPG[51]
School Bus	7 MPG[52]
Paratransit Vehicle	7.69 MPG[53]

Btu/Gallon = Weighted average energy content (Btu/gallon) of fuel used in baseline vehicle[54]

Vehicle Type	Btu/Gallon
Transit Bus and School Bus (diesel)	137,500
Paratransit Vehicle (gasoline)	120,500

1,000,000 = Factor to convert Btu to MMBtu

Other factors as defined above.

Loadshape

N/A

[51] Diesel transit bus efficiency based on 29,900 annual VMT and 7,000 gallons of fuel per year from Burlington Electric Department's November 7, 2016 filing in docket 8550. A similar value (4 MPG) can be found in U.S. Department of Transportation, "Bus Lifecycle Cost Model for Federal Land Management Agencies."

[52] Diesel school bus efficiency from "Bus Lifecycle Cost Model for Federal Land Management Agencies."

[53] Gasoline paratransit vehicle efficiency from U.S. DOE's Alternative Fuels Data Center, based on Federal Highway Administration Table VM-1 and American Public Transit Association's Public Transportation Fact Book Tables 6, 7, and 20: https://www.afdc.energy.gov/data/10310

[54] Energy content of diesel for transit and school buses and gasoline for paratransit vehicles from "Fuel Conversion Factors" provided by the Vermont Department of Public Service.

Gross-to-Net Savings Factors

Measure Category	Transportation		Transportation		Transportation	
Product Description	Electric Transit Bus		Electric School Bus		Electric Paratransit Vehicle	
Measure Code	TRNETBUS		TRNESBUS		TRNEPARA	
	Spillover	Freerider	Freerider	Spillover	Freerider	Spillover
	1.0	1.0	1.0	1.0	1.0	1.0

Persistence

The persistence factor is assumed to be one.

Lifetime

The lifetime of each commercial electric vehicle is shown in the table below.

Vehicle Type	Lifetime
Transit Bus and School Bus	12 years[55]
Paratransit Vehicle	8 years[56]

[55] Bus lifetime from Columbia University, "Electric Bus Analysis for New York City Transit," May 2016.
[56] Paratransit vehicle lifetime from U.S. Dept. of Transportation Federal Transit Administration (FTA), "Useful Life of Transit Buses and Vans, Report No. FTA VA-26-7229-07.1," April 2007, Table ES-2.

Measure Cost

The measure cost is the incremental cost difference between a new, commercial, conventional gasoline-powered or diesel vehicle (see table below) and a new commercial electric vehicle (custom input).

Vehicle Type	Baseline Cost
Transit Bus	$450,000[57]
School Bus	$128,796[58]
Paratransit Vehicle	$75,000[59]

O&M Cost Adjustments

O&M costs for electric vehicles compared to new, conventional vehicles are presented in the table below along with incremental lifetime O&M savings. Electric vehicles require minimal maintenance for batteries, motors, and associated electronics, require fewer fluid changes than conventional vehicles, have fewer moving parts, and experience less brake wear due to regenerative braking.

[57] Price of new diesel transit bus from "Electric Bus Analysis for New York City Transit."
[58] Price of new diesel school bus is MSRP with 8% sales tax removed, from webinar "Benefits of Zero Emissions School Buses," July 20, 2016.
[59] Price of new gasoline paratransit vehicle from FTA, "Useful Life of Transit Buses and Vans."

Vehicle Type	Conventional Vehicle O&M Cost ($/mile)	Electric Vehicle O&M Cost ($/mile)	Incremental Lifetime O&M Savings
Transit Bus	$0.59/mile[60]	$0.36/mile[61]	$0.23/mile x VMT x 12 years
School Bus	$0.50/mile[62]	$0.16/mile[63]	$0.34/mile x VMT x 12 years
Paratransit Vehicle	$1.00/mile[64]	$0.33/mile[65]	$0.67/mile x VMT x 8 years

[60] Maintenance cost for diesel transit buses from SAIC, "Transit Cooperative Research Program Report 146: Guidebook for Evaluating Fuel Choices for Post-2010 Transit Bus Procurements," 2011.
[61] Maintenance cost for electric transit buses based on "Transit Cooperative Research Program Report 146: Guidebook for Evaluating Fuel Choices for Post-2010 Transit Bus Procurements." The report estimates the cost of maintaining a diesel transit bus at between $0.47 and $0.72 per mile. Of these costs, between $0.17 and $0.35 per mile can be attributed to maintaining braking and propulsions systems. Using this data, VEIC used the mid-point maintenance cost for diesel buses ($0.59) and subtracted $0.23 per mile (braking and propulsion system costs) to estimate the cost of maintaining electric buses at $0.36 per mile.
[62] Maintenance cost for diesel school buses from fleet data reported in the February 3, 2016 issue of School Transportation News.
[63] Maintenance cost for electric school buses from NREL, "Foothill Transit Battery Electric Bus Demonstration Results," Jan 2016.
[64] Maintenance cost for gasoline paratransit vehicles from U.S. Department of Transportation, "Bus Lifecycle Cost Model for Federal Land Management Agencies," page 6.
[65] Maintenance cost for electric paratransit vehicles based on statement from Motiv Power Systems representative.

Low Flow Faucet Aerator

Version Date & Revision History

Draft date: 10/15/2017

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Referenced Documents:

1. 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.
2. Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013.
3. U.S. Census Bureau_ACS Table DP04 VT_2015.pdf.
4. Navigant Consulting, Inc. for the Ontario Energy Board, "Measures and Assumptions for Demand Side Management Planning, Appendix C: Substantiation Sheets," April 16, 2009.
5. U.S. DOE Standard Building America DHW Schedules, May 2014.
6. Navigant, "energySMART Energy Savings Kits, GPY 4 Evaluation Report (FINAL)," April 29, 2016.
7. Cadmus, "Ameren Missouri Efficient Products Impact and Process Evaluation: PY 2015," May 13, 2016.
8. NMR Group, Survey Analysis of Owners in Existing Homes in Vermont (Draft)," Dec 2016.
9. DEER2014-EUL-table-update_2014-02-05.xlsx.

Description

This measure relates to the installation of a low flow faucet aerator in a single-family home or multi-family building. Low flow faucet aerators reduce the consumption of hot water and as a result, the energy required to heat it. The measure applies to retrofit direct install implementation or to free giveaways.

Definition of Energy Transformation Equipment or Condition

The energy transformation equipment is a faucet aerator with a flow rate of 1.5 gpm. Savings assumptions include a 0.95 throttling factor for new faucets to account for the fact that faucets are not always operated at full flow, reducing the flow rate to 0.95 gpm.

Definition of Baseline Equipment or Condition

The baseline equipment is assumed to be a standard faucet aerator with a flow rate of 2.2 gpm. Savings assumptions include a 0.83 throttling factor for baseline faucets to account for the fact that faucets are not always operated at full flow, reducing the flow rate to 1.83 gpm.

Algorithms

Demand Impacts

N/A

Electric Energy Impacts

N/A

Fossil Fuel Impacts

$$\Delta MMBtu = \left(\left(\left(GPM_{base}\ x\ Throttle_{base}\right) - \left(GPM_{low}\ x\ Throttle_{low}\right)\right) x\ Tperson/day\ x\ \#\ people\ x\ usedays/\ year\ x\ DR\ x\ 8.3\ x\ 1.0\ x\ \left(TEMP_{faucet} - TEMP_{in}\right)/1{,}000{,}000/\eta Fuel\_DHW\right) x\ ISR\ x\ \%Fuel\_DHW$$

Where:

ΔMMBtu = Annual thermal savings from displacement of fossil fuels

GPM_{base} = Flow rate (gpm) of baseline faucet

= 2.2[66]

$Throttle_{base}$ = Ratio of user setting to full-throttle flow rate for baseline faucet

= 0.83[67]

GPM_{low} = Flow rate (gpm) of low flow faucet

= 1.5[68]

$Throttle_{low}$ = Ratio of user setting to full-throttle flow rate for low flow faucet

= 0.95[69]

Tperson/day = Average daily length of use per person, per faucet (min/person/faucet)
= 1.6[70]

people = Average number of people per household

= 2.33[71]

usedays/year = Days faucet is used per year

= 365

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[66] Federal standard for faucets, 10 CFR 430.32(o)
[67] 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.
[68] Federal standard for faucets, 10 CFR 430.32(o)
[69] 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.
[70] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, Table 6, page 10.
[71] Weighted average household size of owner-occupied versus renter-occupied housing units ((71% * 2.42) + (29% * 2.12)) based on 2011-2015 American Community Survey 5-Year Estimates for Vermont. See reference file U.S. Census Bureau_ACS Table DP04 VT_2015.pdf.

DR	= Percentage of water flowing down drain
	= 70%[72]
8.3	= Constant to convert gallons to lbs
	= Specific heat of water (Btu/lb-°F)
$TEMP_{faucet}$	= Assumed temperature of water used by faucet
	= 86 °F[73]
$TEMP_{in}$	= Assumed temperature of water entering residential building
	= 51.9 °F[74]
1,000,000	= Conversion factor from Btu to MMBtu
ηFuel_DHW	= Recovery efficiency of fuel water heater
	= 78%[75]
ISR	= In service rate, or the percentage of units rebated that are actually installed
	= 100% for direct install and 58%[76] for free giveaways
%Fuel_DHW	= Proportion of water heating supplied by fossil fuels
	= For direct install where DHW fuel type is known, 100% if fuel DHW system, 0% if non-fuel DHW system
	= For direct install where DHW fuel type is unknown or for free giveaways, assume 73%:[77]

Deemed fossil fuel impacts are shown in the table below, based on program implementation.

Program Type	ΔMMBtu

[72] 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.

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

[74] Average value for Burlington, Montpelier. Rutland, and Springfield, VT from U.S. DOE Standard Building America DHW Schedules, May 2014.

[75] Based on a review of fuel DHW systems available in AHRI database.

[76] Average of kits bathroom aerator in service rate (63%) from Navigant, "energySMART Energy Savings Kits, GPY 4 Evaluation Report (FINAL)," April 29, 2016, p. 20, and kits bathroom aerator in service rate for single family homes (52%) from Cadmus, "Ameren Missouri Efficient Products Impact and Process Evaluation: PY 2015," May 13, 2016, p. 23.

[77] Percentage of DHW fuels for free products giveaways based on data received by Efficiency Vermont on 08/21/2017 from NMR Group, Survey Analysis of Owners in Existing Homes in Vermont (Draft)," Dec 2016.

Direct Install (DHW fuel known)	0.1386 MMBtu
Direct Install (DHW fuel unknown)	0.1012 MMBtu
Free Giveaways	0.0587 MMBtu

Loadshape

N/A

Gross-to-Net Savings Factors

Measure Category	**Hot Water**	
Product Description	**Low Flow Faucet Aerator**	
Measure Code	**HWEFAUCT**	
	Freerider	**Spillover**
	1.0	1.0
	0.90	1.0

Persistence

The persistence factor is assumed to be one.

Lifetimes

10 years[78]

Measure Cost

For direct install implementation, the measure cost is the actual material and labor cost of installing the new aerator. If actual costs are unknown, assume a full install cost of $8 (market research average of $3 for faucet aerator and assess and install cost of $5.00, based on 20 minutes of labor at $15/hour).

For free giveaways, assume a measure cost of $3 (market research average).

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

[78] Measure lifetime from California DEER. See file DEER2014-EUL-table-update_2014-02-05.xlsx.

Low Flow Faucet Showerhead

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Referenced Documents:

1. Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013.
2. U.S. Census Bureau_ACS Table DP04 VT_2015.pdf.
3. U.S. DOE Standard Building America DHW Schedules, May 2014.
4. DEER2014-EUL-table-update_2014-02-05.xlsx.

Description

This measure characterizes the installation of a low flow (1.5 gallons per minute, or gpm) showerhead in a single-family home or a multi-family building. The measure applies to direct install implementation.

Definition of Energy Transformation Equipment or Condition

The energy transformation equipment is an energy efficient showerhead using 1.5 gpm.

Definition of Baseline Equipment or Condition

The baseline equipment is a standard showerhead using 2.5 gpm.

Algorithms

Demand Impacts

N/A

Electric Energy Impacts

N/A

Fossil Fuel Impacts

$$\Delta MMBtu = ((GPM_{base} - GPM_{low})\ x\ Tshower\ x\ \#\ people\ x\ \#\ showers\ x\ usedays/year\ /\ SH/home)\ x\ 8.3\ x\ 1.0\ x\ (TEMP_{sh} - TEMP_{in})/\eta Fuel\_DHW/1{,}000{,}000$$

Where:

ΔMMBtu = Annual thermal savings from displacement of fossil fuels

GPM_{base} = Flow rate (gpm) of baseline showerhead

= 2.5[79]

GPM_{low} = Flow rate (gpm) of low flow showerhead

= 1.5

Tshower = Average shower length in minutes

= 7.8[80]

\# people = Average number of people per household

= 2.33[81]

\# showers = Showers per person per day

= 0.6[82]

usedays/year = Days faucet is used per year

= 365

SH/home = Average number of showerheads per household

= 1.3[83]

8.3 = Constant to convert gallons to lbs

= Specific heat of water (Btu/lb-°F)

$TEMP_{sh}$ = Assumed temperature of water coming from showerhead

= 101 °F[84]

$TEMP_{in}$ = Assumed temperature of water entering residential building

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[79] The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm), which is the minimum qualifying flow rate for Efficiency Vermont programs. Baseline flow rate is verified on site by reviewing the equipment label and measuring the flow rate. However, baseline flow rates are not recorded.

[80] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 10, Table 6.

[81] Weighted average household size of owner-occupied versus renter-occupied housing units ((71% * 2.42) + (29% * 2.12)) based on 2011-2015 American Community Survey 5-Year Estimates for Vermont. See reference file U.S. Census Bureau_ACS Table DP04 VT_2015.pdf.

[82] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 11, Table 8.

[83] Average of values for single family and multifamily households from Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 12, Table 9.

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

= 51.9 °F[85]

ηFuel_DHW = Recovery efficiency of fuel water heater

= 78%[86]

1,000,000 = Conversion factor from Btu to MMBtu

Deemed fossil fuel impacts per low flow showerhead are 1.600 MMBtu.

Loadshape

N/A

Gross-to-Net Savings Factors

Measure Category	**Hot Water**	
Product Description	**Low Flow Showerhead**	
Measure Code	**HWESHOWR**	
	Freerider	**Spillover**
	1.0	1.0
	0.90	1.0

Persistence

The persistence factor is assumed to be one.

Lifetimes

10 years[87]

Measure Cost

The measure cost is the actual program cost (material and labor) of installing the new showerhead.

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

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[85] Average value for Burlington, Montpelier. Rutland, and Springfield, VT from U.S. DOE Standard Building America DHW Schedules, May 2014.
[86] Based on a review of fuel DHW systems available in AHRI database.
[87] Measure lifetime from California DEER. See file DEER2014-EUL-table-update_2014-02-05.xlsx.

Electric Vehicle Charging Stations

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End date: TBD

Referenced Documents

1. EV Project Electric Vehicle Charging Infrastructure Summary Report for January 2013 through December 2013. Idaho National Laboratory.
2. 20161028_EV_Project_Demand_Estimate.xlsx.
3. Electric Vehicle Registered in Vermont. Drive Electric Vermont, based on Vermont Department of Motor Vehicles vehicle registration database as of June 25, 2016.
4. An Assessment of Level 1 and Level 2 Electric Vehicle Charging Efficiency. Vermont Energy Investment Corporation, March 20, 2013.
5. 20161027_VT_EV_ElectricEstimates_Tier III_v2.xlsx.
6. The Vermont Transportation Energy Profile. VTrans, October 2015.
7. Incremental costs are the mid-range of installed costs from Electric Vehicle Charging Station Guidebook: Planning for Installation and Operation. Chittenden County Regional Planning Commission. June 2014.
8. Vermont Electric Utility EV Charging Usage Data Analysis, 20220818_VEIC_Compiled_Charging_Usage_NO_LOCATION.xlsx

Description
This measure applies to the installation of Level 2 or DC Fast Charging Electric Vehicle Supply Equipment (EVSE), commonly referred to as a “charging station” in a non-residential location. Promotion of charging stations encourages the use of electricity to power plug-in electric vehicles (EVs) instead of gasoline or diesel.

Definition of Energy Transformation Equipment or Condition
The energy transformation equipment must be a Level 2 or a DC Fast charging station. To determine savings annual charging station consumption can be based on the following approaches:

- metered energy consumption data;
- projections of energy consumption based on assumptions for an individual installation; or
- a deemed value derived from consumption data from current Vermont EV charger installations

Definition of Baseline Equipment or Condition
The baseline condition is a blended assumption of gasoline and diesel used to power a vehicle.

Algorithms

Demand Impacts

Demand impacts are estimated to be 0.73914 kW.[88]

Electric Energy Impacts

[88] Based on median weekday demand from residential Level 2, private nonresidential Level 2, public Level 2, and public DC Fast charging stations from EV Project Electric Vehicle Charging Infrastructure Summary Report for January 2013 through December 2013. Idaho National Laboratory. Demand was calculated based on 6,494 vehicles in the study. See 20161028_EV_Project_Demand_Estimate.xlsx for analysis.

When calculating net electric energy impacts, utilities should ensure that electric energy impacts (MWh) reflect the average percentage of fossil fuels in electric generation mix for the program year, adjusted for measure lifetime.

$$\Delta MWh_{Electric} = kWh_{ChargingStation} x\ \%Fossil/1{,}000$$

Where:

$\Delta MWh_{Electric}$ = Gross customer annual electric energy impacts for the measure, adjusted for percentage of fossil fuels in the generation mix

$kWh_{ChargingStation}$ = Annual electricity consumption per charging port[89]

= Custom input from utility based on actual metered data OR

= Custom input from utility based on assumptions for an individual installation OR

= Deemed value[90]

Charger Location	kWh/year per port
General Public Level 2	2,669
General Public DC Fast Charger	11,173
Workplace Level 2	4,261

%Fossil = Average percentage of fossil fuels in electric generation mix for the program year, adjusted for measure lifetime. For electric distribution utilities generating 100% of electricity from renewable energy, %Fossil is 0%.

= Custom input from utility

1,000 = Factor to convert kWh to MWh

Fossil Fuel Impacts

$$\Delta MMBtu = kWh_{ChargingStation} x\ EFF_{Charging}/\ EFF_{Electric}/\ EFF_{Fuel}\ x\ 121{,}160/1{,}000{,}000$$

$$\Delta MWh_{FossilFuel} = \ \Delta MMBtu/8.905$$

Where:

$\Delta MMBtu$ = Thermal savings from displacement of fossil fuels

$EFF_{Electric}$ = Electric efficiency (kWh/mile) of new electric vehicle

89 This is based on per port, so a two port charger would claim twice the deemed value.
90 Based on analysis of EV charging usage. See 20200805_VEIC_Compiled_Charging_Usage_NO_LOCATION.xlsx for data.

= 0.325 kWh/mile[91]

$EFF_{Charging}$ = Efficiency of charging station[92]

= 86.4%[93] for Level 2 and 100% for DC Fast

EFF_{Fuel} = Fuel efficiency (miles/gallon or MPG) of new, conventional, light-duty vehicle

= 25.3 MPG[94]

121,160 = Weighted average energy content (Btu/gallon) of gasoline and diesel in Vermont privately-owned vehicle fleet[95]

1,000,000 = Factor to convert Btu to MMBtu

$\Delta MWh_{FossilFuel}$ = Gross customer annual fossil fuel impacts for this measure, converted to MWh

8.905 = Factor to convert MMBtu to MWh[96]

Other factors as defined above.

Net Impacts

$$\Delta MWh_{Net} = \Delta MWh_{FossilFuel} - \Delta MWh_{Electric}$$

Loadshape

[91] Average of values for all-electric vehicles (AEV) and plug-in hybrid electric vehicles (PHEV). Electric efficiency values are a weighted average using Vermont electric vehicle registrations from Drive Electric Vermont, based on Vermont Department of Motor Vehicles vehicle registration database as of June 25, 2016 and electric vehicle efficiency values for most recent model years available from FuelEconomy.gov. See 20161027_VT_EV_ElectricEstimates_Tier III_v2.xlsx for analysis. Tesla Roadsters were excluded from the analysis because production ended in 2012.

[92] Electric energy losses occur during charging due to AC/DC power conversion within EVs and other energy demands associated with vehicle charging activity.

[93] Average Level 2 charge efficiency from "An Assessment of Level 1 and Level 2 Electric Vehicle Charging Efficiency." Vermont Energy Investment Corporation, March 20, 2013.

[94] Sales-weighted average miles per gallon of model year 2015 vehicles, calculated in University of Michigan Transportation Research Institute Eco-driving Index: http://www.umich.edu/~umtriswt/EDI_sales-weighted-mpg.html. This average includes all light duty vehicles (cars, SUVs, pick-up trucks) and may include a small number of alternative fuel vehicles.

[95] Weight average based on energy content of gasoline and diesel from "Fuel Conversion Factors" provided by the Vermont Department of Public Service. The privately owned vehicle fleet in Vermont consists of 94.5% gasoline-powered vehicles and 5.3% diesel-powered vehicles. See Figure 3.1 from "The Vermont Transportation Energy Profile." VTrans, October 2015. http://vtrans.vermont.gov/sites/aot/files/planning/documents/planning/Vermont%20Transportation%20Energy%20Profile%202015.pdf

[96] MMBtu to MWh conversion factor from the U.S. Energy Information Administration http://psb.vermont.gov/sites/psb/files/Fuel%20Conversion%20Factors.pdf

N/A

Gross-to-Net Savings Factors

Measure Category		**Transportation**		**Transportation**	
Product Description		**Level 2 Charging Station**		**DC Fast Charging Station**	
Measure Code		**TRNDCFCS**		**TRNLVTCS**	
Track Name	**Track No.**	**Freerider**	**Spillover**	**Freerider**	**Spillover**
TBD	TBD	1.0	1.0	1.0	1.0

Persistence

The persistence factor is assumed to be one.

Lifetime

The measure lifetime is 10 years[97]; except when using historical metered data as the basis for calculating Tier 3 credits. When using historical metered data, the amount of the Tier 3 credit shall be based on the duration of metered data used for analysis.

Measure Cost

The measure cost is the total installed cost of an electric charging station. See table below.

Type of Charging Station	**Incremental Cost[98]**
Level 2 Public	$5,900
Level 2 Workplace	$3,200
DC Fast	$55,000

O&M Cost Adjustments

Annual maintenance costs are $400.[99]

Electric Vehicles

Version Date & Revision History

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[97] An industry standard expectation based on conversations with equipment manufacturers.

[98] Incremental costs are the mid-range of installed costs from Electric Vehicle Charging Station Guidebook: Planning for Installation and Operation and the installation costs from two Idaho National Laboratory reports. Chittenden County Regional Planning Commission. June 2014. https://energy.gov/eere/vehicles/fact-910-february-1-2016-study-shows-average-cost-electric-vehicle-charger. February 1, 2016.

[99] O&M costs are from Electric Vehicle Charging Station Guidebook: Planning for Installation and Operation. Chittenden County Regional Planning Commission. June 2014. Costs for Level 2 Public are for 3.3-6.6 kW units and costs for DC Fast are for 25-50 kW units.

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Effective date: 1/1/2020
End date: TBD

Referenced Documents

1. California Air Resources Board, "Advanced Clean Cars Midterm Review, Appendix G: Plug-in Electric Vehicle In-Use and Charging Data Analysis," January 18, 2017.
2. Electric Vehicles Registered in Vermont. Drive Electric Vermont, based on Vermont Department of Motor Vehicles vehicle registration database as of June 30, 2018.
3. Tier III TAG_EV_ElectricEstimates_2018.xlsx
4. VTrans, "The Vermont Transportation Energy Profile," September 2017.
5. Total Cost of Ownership for Current Plug-in Electric Vehicles: Update to Model 2013 and 2014 Model Year Vehicles. Electric Power Research Institute, May 2014.
6. Idaho National Laboratory, "EV Project Electric Vehicle Charging Infrastructure Summary Report for January 2013 through December 2013."
7. 20161028_EV_Project_Demand_Estimate.xlsx

Description
This is a time of sale measure that applies to the purchase of a new or used all-electric vehicle (AEV) or plug-in hybrid electric vehicle (PHEV) instead of a new, conventional gasoline-powered or diesel vehicle. An AEV is powered exclusively by electricity, whereas a PHEV may be powered by both electricity and a gasoline-powered motor.

Definition of Energy Transformation Equipment or Condition
The energy transformation equipment must be a new or used all-electric vehicle (AEV) or plug-in hybrid electric vehicle (PHEV).

Definition of Baseline Equipment or Condition
The baseline equipment is a blend of new, conventional gasoline and diesel-powered vehicles.

Algorithms

Demand Impacts

Demand impacts are estimated to be 0.73914 kW.[100]

Electric Energy Impacts

When calculating net electric energy impacts, utilities should ensure that electric energy impacts (MWh) reflect the average percentage of fossil fuels in electric generation mix for the program year, adjusted for measure lifetime.

$$\Delta MWh_{Electric} = eVMT\ x\ EFF_{Electric} x\ x\ \%Split/1{,}000$$

Where:

$\Delta MWh_{Electric}$ = Gross customer annual electric energy impacts for the measure

eVMT = Annual electric vehicle miles traveled (per capita)

[100] Based on median weekday demand from residential Level 2, private nonresidential Level 2, public Level 2, and public DC Fast charging stations from Idaho National Laboratory, "EV Project Electric Vehicle Charging Infrastructure Summary Report for January 2013 through December 2013." Demand was calculated based on 6,494 vehicles in the study. See 20161028_EV_Project_Demand_Estimate.xlsx for analysis.

	= 10,900 miles for AEV and 6,098 miles for PHEV[101]
$EFF_{Electric}$	= Electric efficiency (kWh/mile) of a new or used electric vehicle
	= 0.30 kWh/mile for AEV and 0.34 kWh/mile for PHEV[102]
%Split	= Factor to divide EV impacts between EV and Charging Station measures
	= 83%[103]
1,000	= Factor to convert kWh to MWh

See table below for deemed electric energy impacts.

Type of Electric Vehicle	**$\Delta MWh_{Electric}$**
AEV	2.8
PHEV	1.7

[101] eVMT for AEV and PHEV are an average of values for certain vehicles from California Air Resources Board, "Advanced Clean Cars Midterm Review, Appendix G: Plug-in Electric Vehicle In-Use and Charging Data Analysis," January 18, 2017, Table 13 - Annual VMT for BEVs and Table 14 - Annual VMT for PHEV https://www.arb.ca.gov/msprog/acc/mtr/appendix_g.pdf See Tier III TAG_EV_ElectricEstimates_2018.xlsx for analysis. eVMT should be updated regularly. Values for PHEV are especially subject to change as larger batteries with more electric range become available.

[102] Electric efficiency values are a weighted average using Vermont electric vehicle registrations from Drive Electric Vermont, based on Vermont Department of Motor Vehicles vehicle registration database as of June 30, 2018 and electric vehicle efficiency values for most recent model years available from FuelEconomy.gov. See Tier III TAG_EV_ElectricEstimates_2018.xlsxfor analysis. Vehicles that are no longer in production were excluded from the analysis: Tesla Roadster, Mitsibishi iMiEV, Toyota RAV4 EV, Toyota Prius Plug-In, Cadillac ELR, and Honda Accord PHEV.

[103] %Split value from EV Project Electric Vehicle Charging Infrastructure Summary Report for January 2013 through December 2013. Idaho National Laboratory. 83% of charging took place at residential Level 2 charging stations, and 17% took place at private nonresidential or public charging stations.

Fossil Fuel Impacts

$$\Delta MMBtu_{AEV} = (eVMT / EFF_{Fuel\_Conventional}\ x\ 121{,}160)\ x\ \%Split / 1{,}000{,}000$$

$$\Delta MMBtu_{PHEV} = ((eVMT / EFF_{Fuel_{Conventional}}) + \left(GasVMT\ x\ \left(\frac{1}{EFF_{Fuel\_Conventional}} - \frac{1}{EFF_{Fuel_{PHEV}}}\right)\right)\right) x\ 121{,}160/1{,}000{,}000$$

Where:

$\Delta MMBtu_{AEV}$ = Thermal savings for an AEV from displacement of fossil fuels

$\Delta MMBtu_{PHEV}$ = Thermal savings from higher PHEV fuel efficiency

$EFF_{Fuel\_Conventional}$ = Fuel efficiency (miles/gallon or MPG) of new, conventional, light-duty vehicle

= 25.2 MPG[104]

EFF_{Fuel_PHEV} = Fuel efficiency (MPG) of a new or used PHEV

= 42 MPG[105]

GasVMT = Annual miles that the PHEV is powered by gasoline (per capita)

= 5,160 miles[106]

121,160 = Weighted average energy content (Btu/gallon) of gasoline and diesel in Vermont privately-owned vehicle fleet[107]

1,000,000 = Factor to convert Btu to MMBtu

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104 Sales-weighted average miles per gallon of model year 2017 vehicles, calculated in University of Michigan Transportation Research Institute Eco-driving Index: http://www.umich.edu/~umtriswt/EDI_sales-weighted-mpg.html. This average includes all light duty vehicles (cars, SUVs, pick-up trucks) and may include a small number of alternative fuel vehicles.

105 PHEV fuel efficiency values are a weighted average using Vermont electric vehicle registrations from Drive Electric Vermont, based on Vermont Department of Motor Vehicles vehicle registration database as of June 30, 2018 and electric vehicle efficiency values for most recent model years available from FuelEconomy.gov. See Tier III TAG_EV_ElectricEstimates_2018.xlsx for analysis. Vehicles that are no longer in production were excluded from the analysis: Toyota Prius Plug-In, Cadillac ELR, and Honda Accord PHEV.

106 GasVMT is the average of 2014 and 2015 annual per capita VMT values for Vermont from VTrans, "The Vermont Transportation Energy Profile," September 2017, page 6, Table 2-1, adjusted based on the percentage of miles a PHEV is powered by gasoline based on data from California Air Resources Board, "Advanced Clean Cars Midterm Review, Appendix G: Plug-in Electric Vehicle In-Use and Charging Data Analysis," January 18, 2017. See Tier III TAG_EV_ElectricEstimates_2018.xlsx for analysis.

107 Weighted average based on energy content of gasoline and diesel from “Fuel Conversion Factors” provided by the Vermont Department of Public Service. The privately owned vehicle fleet in Vermont consists of 94.5% gasoline-powered vehicles and 5.3% diesel-powered vehicles. See Figure 3.1 from VTrans, “The Vermont Transportation Energy Profile,” September 2017. http://psb.vermont.gov/sites/psb/files/Fuel%20Conversion%20Factors.pdf

Other factors as defined above.

See table below for deemed fossil fuel impacts.

Type of Electric Vehicle	ΔMMBtu
AEV	43.498
PHEV	32.446

Loadshape

N/A

Gross-to-Net Savings Factors

Measure Category	Transportation		Transportation	
Product Description	All-Electric Vehicle		Plug-in Hybrid Electric Vehicle	
Measure Code	TRNAELCV		TRNHELCV	
	Freerider	Spillover	Freerider	Spillover
	1.0	1.0	1.0	1.0

Persistence

The persistence factor is assumed to be one.

Lifetime

The lifetime of a new electric vehicle is assumed to be the same as the typical length of a manufacturer warranty for an electric vehicle battery: 8 years, or 100,000 miles.[108] The lifetime of a used electric vehicle is assumed to be 4 years[109].

[108] Battery warranty length from EV Everywhere: Electric Car Safety, Maintenance, and Battery Life. U.S. DOE. http://energy.gov/eere/eveverywhere/ev-everywhere-electric-car-safety-maintenance-and-battery-life

[109] The used electric vehicle lifetime is based on conversations in Tier III TAG on August 7, 2019.

Measure Cost

The measure cost is the incremental cost difference between a new, conventional, gasoline-powered vehicle and a new AEV or PHEV. The average price of a new, gasoline-powered vehicle is $25,000.[110]

Type of Electric Vehicle	Incremental Cost[111]
AEV	$15,708
PHEV	$7,301

O&M Cost Adjustments

Incremental lifetime O&M costs[112] for electric vehicles compared to new, conventional, gasoline powered vehicles are presented in the table below. Electric vehicles require minimal maintenance for batteries, motors, and associated electronics, require fewer fluid changes than conventional vehicles, have fewer moving parts, and experience less brake wear due to regenerative braking.

Conventional Vehicle Lifetime O&M Cost	Electric Vehicle Lifetime O&M Cost	Incremental O&M Cost (Savings)
$2,606	AEV - $529	$2,077
	PHEV - $1,340	$1,266

[110] Price of "generic conventional" vehicle from Total Cost of Ownership for Current Plug-in Electric Vehicles: Update to Model 2013 and 2014 Model Year Vehicles. Electric Power Research Institute (EPRI), May 2014.

[111] Incremental costs are a based on the weighted average MSRP of electric vehicles registered in Vermont as of June 30, 2018. MSRP for baseline models for the most recent model year available on FuelEconomy.gov were used. See Tier III TAG_EV_ElectricEstimates_2018.xlsxfor analysis. Vehicles that are no longer in production were excluded from the analysis: Tesla Roadster, Mitsibishi iMiEV, Toyota RAV4 EV, Toyota Prius Plug-In, Cadillac ELR, and Honda Accord PHEV.

[112] All O&M costs are from Total Cost of Ownership for Current Plug-in Electric Vehicles: Update to Model 2013 and 2014 Model Year Vehicles. EPRI, May 2014. AEV costs are based on maintenance costs for a 2013 Nissan Leaf. PHEV costs are based on average maintenance costs for a 2013 C-Max Energi, 2014 Chevrolet Volt, and 2013 Prius Plug-in Hybrid. Maintenance costs in the EPRI report were based on a 150,000 mile lifetime and were reduced by a third to account for typical electric vehicle battery warranty lengths of 8 years or 100,000 miles.

Electric Golf Cart

Version Date & Revision History

Draft date: 10/18/2018
Effective date: 1/1/2019
End date: TBD

Referenced Documents

- Tier III Golf Cart Analysis.xlsx
- Evaluation of Solar-Assisted Electric and Gas Golf Carts.pdf

Description

This measure claims savings for the conversion of an existing gasoline powered golf cart to an all-electric golf cart.

Definition of Energy Transformation Equipment or Condition

The efficient condition is an all-electric golf cart.

Definition of Baseline Equipment or Condition

The baseline condition is assumed to be a gasoline powered golf cart.

Algorithms

Electric Energy Impacts

$$\Delta kWh = (Gallons \times 120{,}500 \times Fossil\ Efficiency) \div 3412$$

ΔkWh	= Gross customer electric energy penalty (deemed assumption for prescriptive) = 760 kWh[113]
Gallons	= Annual consumption of a gasoline powered golf cart = 65[114]
120,500	= Btus per gallon of gasoline
Fossil Efficiency	= Efficiency of existing golf cart = 0.33[115]
3412	= kW per Btu

Fossil Fuel Impacts

$$\Delta MMBtu = Gallons \times 120{,}500$$

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[113] Analysis can be found on Tier 3 Value tab of Tier III Golf Cart Analysis.xlsx.
[114] Golf carts use between 65 to 85 gallons per year. For conservative purposes 65 gallons is used in this characterization. https://gsrpdf.lib.msu.edu/ticpdf.py?file=/article/moeller-golf-4-4-14.pdf
[115] Page 7 of the Evaluation of Solar-Assisted Electric and Gas Golf Carts, Toronto and Region Conservation.

ΔMMBtu = Gross MMBtu savings for each fuel type (deemed assumption for prescriptive)

= 7.83 MMBtu[116]

Gross-to-Net Savings Factors

Measure Category	Recreation	
Product Description	Electric Golf Cart	
	Freerider	Spillover
	1.00	1.00

Persistence

Persistence is assumed to be one.

Lifetime

The expected measure life is assumed to be 5 years[117] for a new electric golf cart.

Measure Cost

The retrofit cost for an all-electric golf cart is the full cost of a new electric golf cart[118].

O&M Cost Adjustments

N/A

[116] Analysis can be found on Tier 3 Value tab of Tier III Golf Cart Analysis.xlsx.

[117] Assumed measure life is four to six years, which a five year measure life was derived. https://gsrpdf.lib.msu.edu/ticpdf.py?file=/article/moeller-golf-4-4-14.pdf

[118] The cost of an electric golf cart is variable and the lack of evaluated costs supports the Distribution Utility using the actual cost the customer pays for the forklift.

Electric Forklift

Version Date & Revision History

Draft date: 10/4/2018
Effective date: 1/1/2019
End date: TBD

Referenced Documents

- Tier III Electric Forklift Analysis.xlsx
- PG&E Emerging Technology Fact Sheet Efficient Forklift Battery Charger.pdf
- GREET_fleet_footprint_calculator_2012.xls

Description

This measure claims retrofit and market opportunity savings for replacing a liquid propane gas-powered forklift with an equivalent new or used electric-powered forklift. This can also include a customer purchasing a forklift for the first time. The assumed working propane forklift has a four cylinder engine and uses an eight gallon fuel tank. The assumed application are one shift work days. A reduced measure life is assumed for a used electric forklift.

Definition of Energy Transformation Equipment or Condition

The efficient condition is an all-electric forklift.

Definition of Baseline Equipment or Condition

The retrofit and market opportunity baseline condition is a liquid propane-gas powered forklift.

Algorithms

Demand Impacts

$$\Delta kW = \Delta kWh \div Hours$$

ΔkW = Total average winter coincident peak kW increase (deemed assumption for prescriptive)

ΔkWh = Gross customer electric energy penalty (deemed assumption for prescriptive)

= 13,885.51[119]

Hours = Annual hours of use of a forklift

=1500[120]

[119] Analysis can be found on Tier 3 Value tab of Tier III Electric Forklift Analysis.xlsx.
[120] Negotiated value with the Vermont Public Service Department. Original value of 1750 hours per year from GREET program's Fleet Footprint Calculator. Argonne National Labs Greenhouse gases, Regulated Emissions, and Energy use in Transportation Model (GREET) Program

Electric Energy Impacts

$$\Delta kWh = (Gallons \times 91{,}600 \times Fossil\ Efficiency) \div Charger\ Efficiency \div 3412$$

Gallons = Annual consumption of liquid propane gas of existing forklift

= 1500[121]

91,600 = Btus per gallon of liquid propane

Fossil Efficiency = Efficiency of existing forklift's engine

= 0.30[122]

Charger Efficiency = Average efficiency of electric charger for electric forklift

= 0.87[123]

3412 = kW per Btu

Fossil Fuel Impacts

$$\Delta MMBtu = Gallons \times 91{,}600$$

ΔMMBtu = Gross MMBtu savings for each fuel type (deemed assumption for prescriptive)

= 137.4[124]

Loadshape

Indust. 1-shift (8/5) (e.g., comp. air)

[121] Toyota Material Handling of Northern California: https://www.tmhnc.com/blog/how-long-can-a-forklift-run-on-one-tank-of-propane-lpg.
[122] According to the US Department of Energy's Office for Energy Efficiency and Renewable Energy, internal combustion engines used in transportation realize between 12% and 30% efficiency. For purposes of this characterization, the more conservative 30% efficiency is used.
[123] Average power conversion efficiency performance based on study from PG&E: Emerging Technology Fact Sheet Efficient Forklift Battery Charger.
[124] Analysis can be fou don Tier 3 Value tab of Tier III Electric Forklift Analysis.xlsx.

Gross-to-Net Savings Factors

Measure Category	Industrial Process	
Product Description	Electric Forklift	
	Freerider	Spillover
	1.00	1.00

Persistence

Persistence is assumed to be one.

Lifetime

The expected measure life is assumed to be 8 years[125] for a new electric forklift and 4 years[126] for a used electric forklift.

Measure Cost

The retrofit cost for an all-electric forklift is the full cost of a new electric forklift[127].

O&M Cost Adjustments

N/A

[125] EPRI Study "PG&E Electrification Case Study Report 2017 Technical Report"

[126] Based on negotiations in Tier III TAG with the assumption that a used electric forklift will have a reduced life.

[127] The cost of an electric forklift is highly variable and the lack of evaluated costs supports the Distribution Utility using the actual cost the customer pays for the forklift.

Air to Water Heat Pump

Version Date & Revision History

Draft date: 7/23/2020
Effective date: 1/1/2021
End date: TBD

Referenced Documents

1. NEEP Incremental Cost Study Report 2011
2. VT Res Baseline SFNC Onsite report - DRAFT 051217
3. VT SF Existing Homes Onsite Report - DRAFT 122117
4. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs 2016
5. GDS Associates_Measure Life Report_Jun 2007
6. NEEP Incremental Cost Study Phase II_Jan 2013
7. Cadmus_VT Business Sector Market Characterization_Apr 2017
8. NREL_Optimizing Hydronic System Performance_Oct 2013
9. Air to Water Heat Pump Analysis_v11

Description

This measure claims savings for the installation of an air to water heat pump. Heating savings are claimed on the home's auxiliary fossil fuel hydronic heating system and accounts for the fossil fuel system providing supplemental heat at low outdoor air temperatures. The electric penalty is the result of the air to water heat pump operating in heating mode, down to 0°F outdoor air temperature, at which point the auxiliary heating system assumes the full heating load.

The heat pump extracts low temperature heat from outside air and transfers it to a fluid steam to be used by a hydronic distribution system. The characterization assumes a standard mode of operation regardless of installation, location, or application – residential or commercial. The installed air to water heat pump is intended to supplement the existing fossil fuel heating system and not completely replace it, and the characterization of this measure assumes a midstream program delivery method.

Air to water heat pumps are categorized as low temperature hydronic heating systems and typically operate at a maximum supply water temperature of 120°F. If an air to water heat pump is retrofitted on an existing high temperature hydronic fossil fuel system, additional emitters are required in order to meet the design load of the building. The minimum qualification criteria for an air to water heat pump is to generate 110°F supply water at an outdoor temperature of 5°F with a COP of 1.7 or greater.

Definition of Energy Transformation Equipment or Condition

The installed heat pump is assumed to meet the efficiency outlined in the tables below, which represents the average efficiency of qualifying equipment used in the energy savings algorithm. The values in the following table are a result of weighted averages of available equipment from local distributors binned across Burlington, VT weather data down to an outdoor air temperature of 0°F, averaged across 100°F, 110°F, and 120°F supply water temperatures.

Residential and Commercial Air to Water Heat Pump Efficiency

Equipment	Rating Heating Capacity Bin (Tons)	COP
Air to Water Heat Pump	2	2.75
	2.5	2.76
	3	2.78

	3.5	2.90
	4	2.91
	4.5	2.87
	5.0	2.71
	5.5	2.80
	6.0	2.89
	Overall Average	2.83

Definition of Baseline Equipment or Condition

For retrofit replacement scenarios, the baseline condition is assumed to be the existing fossil fuel hydronic heating system. For market opportunities, the baseline condition is assumed to be a code compliant fossil fuel hydronic heating system.

Residential Baseline Efficiency

Replacement Scenario	Equipment Fuel Type	Average Boiler Efficiency
RET[128]	Fuel Oil	83.6%
	Propane	87.8%
	Natural Gas	88.6%
	Wood	65.0%
MOP[129]	Fuel Oil	86.3%
	Propane	93.4%
	Natural Gas	93.4%
	Wood	75.0%

Commercial Baseline Efficiency

Replacement Scenario	Equipment Fuel Type	Average Boiler Efficiency
RET[130]	Fuel Oil	85.0%

128 Based on the average findings from the, "Vermont Single-Family Existing Homes Onsite Report, Draft", NMR Group, Inc., December 2017 (page 44). As the efficiency of wood boilers was not detailed in the report, the value is based on professional judgement.

129 "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits", NMR Group, Inc., May 12, 2017 (pages 49-50). The efficiency of natural gas and propane boilers was combined and not included separately in the report. In order to incorporate the natural gas and propane fuel types into the analysis, opted to use the combined efficiency values for observed natural gas and propane boilers. As the efficiency of wood boilers was not detailed in the report, the value is based on professional judgement.

130 Mean observed efficiency for boilers for existing commercial buildings, as sourced from; "2016 Vermont Business Sector Market Characterization and Assessment Study", Cadmus, April 2017 (page 65). The efficiency of natural gas and propane boilers was combined and not included separately in the report. In order to incorporate the natural gas and propane fuel types into the analysis, VEIC opted to use the combined efficiency values for observed natural gas and propane

	Propane	87.0%
	Natural Gas	87.0%
	Wood	65.0%
MOP[131]	Fuel Oil	80.0%
	Propane	80.0%
	Natural Gas	80.0%
	Wood	75.0%

Algorithms

Demand Impacts

$$\Delta kW = \Delta kWh \div EFLH$$

ΔkW = Total average winter coincident peak kW increase (deemed assumption for prescriptive)

ΔkWh = Gross customer electric energy penalty (deemed assumption for prescriptive)

EFLH = Equivalent full load heating hours

= 1,626 hours (residential)[132]

= 1,062 hours (commercial)[133]

Electric Energy Impacts

$$\Delta kWh = kBtuh \times (-1 \div COP \times 3.412)) \times EFLH$$

boilers. As the efficiency of wood boilers was not detailed in the report, the value is based on professional judgement.

131 Minimum efficiency requirements for gas- and oil-fired boilers <300,000 Btu/h, as sourced from the 2015 VT Commercial Building Energy Standards (CBES). As the efficiency of wood boilers is not governed in code compliance, the value is based on professional judgement.

132 Residential EFLH is estimated from an 8,760 equivalent full load hours analysis. The analysis assumes the heating system provides heating below 57.5°F, except in summer months May to August, and estimates savings based on incremental efficiency down to the lower heating limit of 0°F. The analysis assumes the heat pump provides heating based on its rated capacity up to the estimated load.

133 The commercial EFLH is sourced from the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, version 4, January 2017 (New York TRM). Hours are based on an average between the city of Massena and Albany; with it being an average between old and new building types and weighted by small commercial buildings.

kBtuh = Average rated heating capacity[134]

= 39.14 kBtu/h

COP = Coefficient of Performance for the installed air to water heat pump (see the previous tables in this measure for more detail)

Fossil Fuel Impacts

$$\Delta MMBtu = (kBtuh \div 1000) \times EFLH \times (1 \div AFUE)$$

ΔMMBtu = MMBtu savings for each fuel type (deemed assumption for prescriptive)

AFUE = Annual Fuel Utilization Efficiency; the efficiency of the fossil fuel heating system (see the previous tables in this measure for more detail)

Net Impacts

Deemed Energy Savings Summary[135]

Sector	Rated Heating Capacity (Tons)	Rated Heating Capacity Range (Tons)	ΔkWh	ΔkW	ΔMMBtu
Residential	2.0	≥ 2.0 and < 2.5	-4,473	-2.7511	48.3168
	2.5	≥ 2.5 and < 3.0	-5,083	-3.1262	55.1660
	3.0	≥ 3.0 and < 3.5	-5,693	-3.5013	62.0152
	3.5	≥ 3.5 and < 4.0	-6,595	-4.0561	75.5070
	4.0	≥ 4.0 and < 4.5	-7,497	-4.6109	88.9987
	4.5	≥ 4.5 and < 5.0	-7,770	-4.7786	87.2406

134 The equipment capacity is sourced as a weighted average of available equipment from local manufacturers, rated at varying outdoor air temperatures and supply water temperatures, and binned across Burlington, VT weather data down to an outdoor air temperature of 0°F at specified load conditions.

135 Due to the implementation of this measure through a midstream delivery mechanism, the actual replacement scenario (retrofit vs. market opportunity) will be unknown. As a result, the energy savings and incremental costs for the two replacement options were aggregated based on an assumption that 50% of installs will be retrofits.

	5.0	≥ 5.0 and < 5.5	-8,042	-4.9463	85.4825
	5.5	≥ 5.5 and < 6.0	-8,216	-5.0531	90.3201
	6.0	≥ 6.0	-8,390	-5.1599	95.1578
Commercial	2.0	≥ 2.0 and < 2.5	-2,922	-2.7511	51.0785
	2.5	≥ 2.5 and < 3.0	-3,320	-3.1262	58.3193
	3.0	≥ 3.0 and < 3.5	-3,718	-3.5013	65.5600
	3.5	≥ 3.5 and < 4.0	-4,308	-4.0561	79.8229
	4.0	≥ 4.0 and < 4.5	-4,897	-4.6109	94.0859
	4.5	≥ 4.5 and < 5.0	-5,075	-4.7786	92.2273
	5.0	≥ 5.0 and < 5.5	-5,253	-4.9463	90.3686
	5.5	≥ 5.5 and < 6.0	-5,366	-5.0531	95.4828
	6.0	≥ 6.0	-5,480	-5.1599	100.5970

Loadshape

Residential Space Heat and Commercial Space Heat

Gross-to-Net Savings Factors

Measure Category	HVAC	
Product Description	Air to water heat Pump	
	Freerider	Spillover
	1.00	1.00

Persistence

Persistence is assumed to be one.

Lifetime

The expected measure life is assumed to be 18 years.[136]

Measure Cost

The incremental cost is based on the rated heating capacity and replacement scenario, as detailed in the table below.

[136] The measure life is assumed to be similar to the measure life for an air source heat pump. While boilers and other hydronic heating systems will typically have measure lives exceeding 20 years, as a

For market opportunity replacement scenarios, the incremental cost is based on an average of equipment list prices supplied by local distributors plus an additional $1,336[137], which is the estimated cost of low temperature hydronic emitters. If an air to water heat pump is retrofitted on an existing high temperature hydronic fossil fuel system, additional emitters are required in order to meet the design load of the building. The added costs of the emitters are assumed in both the market opportunity and the retrofit scenario. It is included in the market opportunity costs because the baseline assumption is a code compliant high temperature fossil fuel hydronic heating system and the low temperature emitters represent an added cost to facilitate the low temperature requirements of the air to water heat pump.

For retrofit replacement scenarios, the incremental cost assumes an additional installation cost of $1,315[138].

Rated Heating Capacity Bins (Tons)	Retrofit Incremental Costs	Market Opportunity Incremental Costs	Overall Incremental Costs[139]
2	$6,404	$5,089	$5,746
3	$8,248	$6,934	$7,591
4	$10,199	$8,884	$9,542

O&M Cost Adjustments

N/A

conservative estimate, the measure life for an air source heat pump was sourced from "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", GDS Associates, June 2007.

137 "Optimizing Hydronic System Performance in Residential Applications", NREL, October 2013 (page 8). The cost of low temperature hydronic emitters represents a straight average of the three efficiency scenarios incremental costs' that were modeled in the report.

138 The installation cost is sourced from estimates of two local manufacturers who compared the installation of air to water heat pumps to that of; (1) multi-head mini-split heat pumps, and (2) low temperature condensing boilers. As a result, the estimated installation cost for these two measures was sourced from NEEP Incremental Cost Studies ($893 for a boiler and $1,736 for a multi-head mini-split heat pump) and averaged accordingly.

139 Due to the implementation of this measure through a midstream delivery mechanism, the actual replacement scenario (retrofit vs. market opportunity) will be unknown. As a result, the energy savings and incremental costs for the two replacement options were aggregated based on an assumption that 50% of installs will be retrofits.

ENERGY STAR Heat Pump Water Heater

Version Date & Revision History

Draft date: 8/27/21
Effective date: 1/1/2022
End date: TBD

Referenced Documents

1) NMR Group, Inc. "Vermont Single-Family Existing Homes Onsite Report FINAL." 2013.
2) Steven Winter Associates. "Heat Pump Water Heaters Evaluation of Field Installed Performance." Norwalk, CT, 2012.
3) U.S. Department of Energy. "Residential Heating Products Final Rule Technical Support Document." 2010.
4) Tier III trm-analysis-res-hpwh-neea-spec-2021.xlsx

Description

This measure claims savings for the installation of an ENERGY STAR heat pump water heater (HPWH) in place of the existing water heater in a residential application. The measure is characterized for retrofit applications. 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, and a heating penalty is assessed to account for the impact of the heat pump water heater on the home's heating load. This analysis has adopted the NEEA Northern Climate Specification, which provides added energy efficiency guidance to manufacturers developing HPWHs. The updated equipment specification is known as the Advanced Water Heater Specification.

Definition of Energy Transformation Equipment or Condition

To qualify the installed equipment must be an NEEA Northern Climate Specification qualified Heat Pump Water Heater.

Definition of Baseline Equipment or Condition

The baseline condition is the same fuel as the home's existing water heater with efficiency equal to the average energy factor of water heaters in existing Vermont homes for the corresponding fuel type.

Algorithms

Electric Energy Impacts

For homes with existing fossil fuel water heaters, the installation of a HPWH results in an electric penalty equal to the annual electricity use of the water heater to rerpresent the added electric load.

$$\Delta MWh_{Electric} = (-1/UEF_{HPWH} * Q_{DHW\text{-}kWh}) / 1{,}000\ x\ \%Fossil$$

Where:

$\Delta MWh_{Electric}$ = Gross customer annual electric energy impacts for the measure, adjusted for percentage of fossil fuels in the generation mix

UEF_{HPWH} = Uniform Energy Factor of heat pump water heater – prescriptive value based on NEEA Northern Climate Energy Factor, broken down by Tier & Volume capacity[140]

Please note, Efficiency Rating is either UEF or CCE depending on NEEA certificiation date. This is only a difference in name, not in calculation of tested value. There are currently no Tier 2 certified products on the NEEA QPL.

Tank Volume	EF Range	Rated UEF
< 55	Tier 1/Tier 2	2.33
< 55	Tier 3	2.95
< 55	Tier 4	3.15
≥ 55	Tier 1/Tier 2	2.41
≥ 55	Tier 3	3.10
≥ 55	Tier 4	3.20

$Q_{DHW\text{-}kWh}$ = Heat delivered to water in HPWH tank annually

= 2,649 kWh[141]

%Fossil = Average percentage of fossil fuels in electric generation mix for the program year, adjusted for measure lifetime. For electric distribution utilities generating 100% of electricity from renewable energy, %Fossil is 0%.

= Custom input from utility

Demand Impacts

The increase in electric demand due to the installation of a HPWH is derived below based on prescriptive energy savings found in Table 2 - Prescriptive Savings Values.

$\Delta kW = \Delta kWh / Hours$

Where:

Hours = Full load hours of water heater

=2533[142]

[140] NEEA Advanced Water Heater (Specification v7.0), Qualified Products List, accessed November 3, 2020. See sheet "NEEA QPL 2020" in Analysis file for a data summary or see file "NEEA_AWHS HPWH-qualified-products-list_Updated 11.3.2020.pdf " for the raw source data. Current link: https://neea.org/our-work/advanced-water-heating-specification
[141] Average annual DHW heat input for Vermont homes, derived from metered data for homes on CVPS Rate 3: Off-Peak Water Heating rate. See QDHW in Tier III trm-analysis-res-hpwh-neea-spec-2021.xlsx.
[142] Full load hours assumption based on Efficiency Vermont analysis of Itron eShapes.

Fossil Fuel Impacts

For homes with existing fossil fuel water heaters, fuel switching results in fuel savings equal to the annual fuel use that would have resulted if a baseline fossil fuel fired water heater had been installed in the home. A fossil fuel penalty is taken to account for the heating load placed on a home's heating system by the HPWH. For prescriptive purposes, the primary heating fuel is assumed to be the same fuel as the existing domestic hot water system.

$\Delta MMBtu = (1/UEF_{FFBASE} * Q_{DHW\text{-}MMBtu}) - (1/UEF_{HPWH} * Q_{DHW\text{-}MMBti} * WHHF * 1/ \eta Heat)$

$$\Delta MWh_{FossilFuel} = \frac{\Delta MMBtu}{Heat\ Rate}$$

Where:

UEF_{FFBase} = Uniform Energy Factor (efficiency) of baseline fossil fuel water heater

= 0.53[143] for all oil water heaters

= 0.56 for ≥ 20 gal & ≤ 55 gal propane water heaters and 0.76 for >55 gal & ≤ 100 gal propane water heaters

$Q_{DHW\text{-}MMBtu}$ = Heat delivered to water in HPWH tank annually

= 9.04 MMBtu[144]

ηHeat = efficiency of existing heating system[145]

Fuel Oil	Propane	Wood
82.8%	87.7%	73.0%

WHFF = Portion of reduced waste heat that results in increased heating

= 0.542[146]

$\Delta MWh_{FossilFuel}$ = Gross customer annual fossil fuel impacts for this measure, converted to MWh.

Heat Rate = Factor used to convert MMBtu to MWh savings, value changes annually and required input from Tier III planning tool

Storage Volume	NEEA Tier	ΔMMBtu
< 55	Tier 1/Tier 2	14.69
< 55	Tier 3	15.08

143 Average weighted efficiency of fossil fuel water heaters from VT SF Existing Homes Onsite Report Table 6-7 (NMR Group, Inc. 2013)
144 Average annual DHW heat input for Vermont homes, derived from metered data for homes on CVPS Rate 3: Off-Peak Water Heating rate. See QDHW in Tier III trm-analysis-res-hpwh-neea-spec-2021.xlsx
145 Average weighted efficiencies based on VT SF Existing Homes Onsite Report Table 5-8 and 5-9. (NMR Group, Inc. 2013).
146 Based on bin analysis of annual heating hours for Burlington, VT using TMY3 data: 4484 / 8760 = 51.2%. Tier III trm-analysis-res-hpwh-neea-spec-2021.xlsx.

< 55	Tier 4	15.18
> 55	Tier 1/Tier 2	12.46
> 55	Tier 3	12.86
> 55	Tier 4	12.90

Net Impacts

$$\Delta MWh_{Net} = \Delta MWh_{Electric} + \Delta MWh_{FossilFuel}$$

Loadshape

Loadshape #6 Residential DHW Fuel Switch

Gross-to-Net Savings Factors

Table 3 - Gross-to-Net Savings Factors

Freerider	**Spillover**
1.0	1.0

Persistence

The persistence factor is assumed to be one.

Lifetime

The expected measure life is assumed to be 12 years[147]. For retrofit measures, it is assumed that the existing water heating equipment has five years of remaining life and would be replaced with baseline equipment with the associated installed cost at end of life. Analysis period is the same as the lifetime.

Measure Cost

For retrofit measures, the measure cost is the full cost for the installation of a HPWH.[148]

Table 4 – Measure Costs

HPWH Volume	Full Cost of Installation[149]
<55	$2,087.41
>55	$2,820.23[150]

O&M Cost Adjustments

N/A

[147] NREL, National Residential Efficiency Measure Database Lifetime of Heat Pump measures. Please see files in Referenced Documents. Current link: https://remdb.nrel.gov/measures.php?gId=6&ctId=270

[148] Residential Heating Products Final Rule Technical Support Document pages 8-27 to 8-28 (U.S. Department of Energy 2010)

[149] Full cost is based on average Installed cost from NEEP Phase 3 Incremental Cost Study Data. See sheet "NEEP Raw Cost Data" & realted pivot table in "Misc Calcs" of Analysis file for a data summary. For the raw data source, please see file "NEEP_ImprovedHPWaterHeaters_Incremental Costs_2016.xlsx", Installed Costs Table (NEEP 2016).

[150] Average Full Cost Heat Pump Water Heater for 60, 66 & 80 gallon capacity categories (NEEP 2016).

Electric Lawnmowers

Version Date & Revision History

Draft date: 9/14/2022
Effective date: 1/1/2023
End date: TBD

Referenced Documents

1. TAG Tier III_Electric Lawnmowers_2022_FINAL.xlsx
2. DOE Clean Cities Guide to Alternative Fuel Commercial Law Equipment.pdf
3. GREET_fleet_footprint_calculator_2012.xls

Description

This measure claims savings for the conversion of an existing gasoline powered ride-on lawnmower to a new all-electric ride-on lawnmower. This measure is characterized for both residential and commercial applications.

Definition of Energy Transformation Equipment or Condition

The efficient condition is an all-electric ride-on lawnmower.

Definition of Baseline Equipment or Condition

The baseline condition is assumed to be a gasoline powered ride-on lawnmower.

Algorithms

Electric Energy Impacts

$$\Delta kWh = Charges\ per\ Year\ \times Charge\ Time\ \times kW_{Draw} \times Battery\ Quantity$$

ΔkWh = Gross customer electric energy penalty[151] (deemed assumption for prescriptive)

= 72.90 kWh for Residential

= 3,150.00 kWh for Commercial

Charges per Year = Assumed full charges of the battery per year based on activity by application[152]

= 32 for Residential

[151] Refer to Analysis sheet for kWh penalty calculation in the document: TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx
[152] Annual hours of use divided by Working Time Per Charge. Calculation can be found in the analysis tab of TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx

= 700 for Commercial

Charge Time = Assumed time (hours) required to fully charge battery of leafblower[153]

= 4 for Residential and Commercial

kW_{Draw} = Demand draw of battery while charging[154]

= 0.56 for Residential and Commercial

Battery Quantity = Number of batteries assumed to be attached to leafblower to allow operation[155]

= 1 for Residential

= 2 for Commercial

Fossil Fuel Impacts

$$\Delta MMBtu = (Annual\ Gas \times 120{,}476)\ \div 1{,}000{,}000$$

ΔMMBtu = Gross MMBtu savings for each fuel type (deemed assumption for prescriptive)[156]

= 4.3 for Residential

= 108.4 for Commercial

Annual Gas = Assumed annual gas consumption of leafblower by application[157]

= 36 gallons for Residential

= 900 gallons for Commercial

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[153] Battery Charging Time to 100% divided by 60 minutes. Calculation can be found in the analysis tab of TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx. Also refer to Home Depot Cub Cadet FAQ pdf for model battery data.

[154] Eco Equipment Supply provided Data, please see Analysis sheet in TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx.

[155] Per Eco Equipment Supply, Riding mowers typically 1 battery for Residential mowers, 2 for Commercial

[156] Refer to Analysis sheet for kWh penalty calculation in the document: TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx

[157] Refer to Analysis sheet for kWh penalty calculation in the document: TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx.

120,476 = Btu content in one gallon of finished gasoline[158]

1,000,000 = Conversion factor for Btu to MMBtu

Gross-to-Net Savings Factors

Measure Category	Landscaping	
Product Description	Electric Lawnmower	
	Freerider	Spillover
	1.00	1.00

Persistence

Persistence is assumed to be one.

Lifetime

The expected measure life is assumed to be 6[159] years for a new commercial all-electric ride-on lawnmower. The expected measure life is assumed to be 10[160] years for a new residential all-electric ride-on lawnmower.

Measure Cost

The retrofit cost for an all-electric ride-on lawnmower is the full cost of a new all-electric lawnmower[161]. The assumed cost for commercial is $21,373 and $3,889.69 for residential.

O&M Cost Adjustments

N/A

158 https://www.eia.gov/energyexplained/units-and-calculators/energy-conversion-calculators.php
159 Commercial Riding measure life was collected by industry data from Steve W. of Eco Equipment Supply (EES)
160 Residential Riding measure life - TAG did not agree with EPA Reported values (too conservative), therefore increased values slightly. Please see EPA Paper Table Sheet for original values in analysis document: TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx
161 Actual model data, see Mower Data sheet for details in analysis document: TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx

Electric Leaf Blower

Version Date & Revision History

Draft date: 9/18/2018
Effective date: 1/1/2020
End date: TBD

Referenced Documents

- Commercial Leaf Blower Tier III TAG Analysis.xlsx
- NCSAB-Report-Leaf-Blower-Environmental-Protection-Law-April-2019.pdf
- National Emissions from Lawn and Garden Equipment 09_2015.pdf

Description

This measure claims savings for the conversion of an existing commercial gasoline leaf blower to an all-electric leaf blower.

Definition of Energy Transformation Equipment or Condition

The efficient condition is a commercial all-electric leaf blower.

Definition of Baseline Equipment or Condition

The baseline condition is assumed to be a commercial gasoline powered leaf blower.

Algorithms

Electric Energy Impacts

$$\Delta kWh = kW_{Leaf\ Blower} \times Annual\ Hours$$

ΔkWh = Gross customer electric energy penalty (deemed assumption for prescriptive)

= 335.3 kWh[162]

$kW_{Leaf\ Blower}$ = Electric demand of a commercial electric leaf blower

= 1.189 kW[163]

Annual Hours = 282 hours[164]

[162] Analysis can be found on Commercial Leaf Blower Tier III TAG Analysis.xlsx.
[163] Assumes the higher range of possible electric lawnblower electric demand, https://www.cockeyed.com/science/power_use_database/leaf_blower.html
[164] Assumed annual run hours of a commercial leaf blower is from Table 3, Page 6, National Emissions from Lawn and Garden Equipment, September 2015, Quiet Communities and US EPA.

Fossil Fuel Impacts

$$\Delta MMBtu = \frac{Gallons}{hour} \times 0.1205 \times Annual\ Hours$$

ΔMMBtu = Gross MMBtu savings for each fuel type (deemed assumption for prescriptive)

= 16.99 MMBtu[165]

Gallons/Hour = Average gallons of gasoline that a baseline commercial leaf blower consumes in one hour

= 0.5 gallons per hour[166]

0.1205 = MMBtu per gallon of gasoline

Net Impacts

$$Net\ Lifetime\ \Delta MWh = \Delta MMBtu \div Heat\ Rate + (\Delta kWh + \%Fossil\ Fuel) \times Measure\ Life$$

Heat Rate = Custom Input from DU[167]

%Fossil Fuel = Reduction in electric penalty due to the percentage of fossil fuel in the residual mix of the utility's grid

= Custom DU Input

Measure Life = Anticipated useful effective life of the commercial electric leaf blower

= Refer to Lifetimes section below

Gross-to-Net Savings Factors

Measure Category	Lawncare	
Product Description	Electric Leaf Blower	
	Freerider	Spillover
	1.00	1.00

[165] Analysis can be found at Commercial Leaf Blower Tier III TAG Analysis.xlsx.
[166] Conservative estimate assuming throttle is not at 100% at all times. Report finds anywhere from .56 to .65 gallons per hour. Attachment A of New Castle's Proposed Leaf Blower Environmental Protection Law, New Castle Sustainability Advisory Board, April 2019.
[167] This value varies by the program year and is reported from the EIA's Monthly Energy Review Heat Rate.

Persistence

Persistence is assumed to be one.

Lifetime

The expected measure life is assumed to be 5 years[168] for a new electric commercial leaf blower.

Measure Cost

The retrofit cost for an all-electric leaf blower is the full cost of a new electric commercial lead blower[169].

O&M Cost Adjustments

N/A

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[168] Assumed measure life is sourced from a review of available warranties on electric leaf blowers in the market. It was found that there are many models available currently with a manufacturer 5 year warranty.

[169] The cost of an electric leaf blower is variable and the lack of evaluated costs supports the Distribution Utility using the actual cost the customer pays for the forklift.

Centrally Ducted Air Source Heat Pump

Version Date & Revision History

Draft date: 10/7/2020
Effective date: 1/1/2021
End date: TBD

Referenced Documents

1. VT SF Existing Homes Onsite Report – DRAFT 122117.docx
2. New York Standard Approach for Estimating Energy Savigns from Energy Efficiency Programs 2016.pdf
3. NEEP Air Source Heat Pump QPL.xlsx
4. Mid_Atlantic_TRM_V7_FINAL.pdf
5. GDS Associates_Measure Life Report_Jun 2007.pdf
6. Tier 3 centrally-ducted-ashp-analysis-2020.xlsx

Description

This measure claims savings for the installation of centrally ducted air source heat pumps. Heating savings are claimed as a retrofit of the home's existing fossil fuel heating system, and accounts for the fossil fuel system providing supplemental heat at low outdoor air temperatures. As only 2% of Vermont homes utilize central air conditioning[1], for this retrofit replacement scenario, the added electrical load associated with the heat pump is counted as a penalty for both heating and cooling. The installed air source heat pump must meet Energy Star efficiency standards and have a capacity of <= 72,000 Btu/hr. The characterization assumes a standard mode of operation regardless of installation, location, or application - residential or commercial. The installed air source heat pump is intended to supplement the existing fossil fuel heating system and not completely replace it, and the characterization of this measure assumes a midstream program delivery method.

Definition of Energy Transformation Equipment or Condition

The installed heat pump is assumed to meet the efficiencies outlined in the below table.

Residential and Commercial High Efficiency

Equipment	HSPF	SEER
Residential Air-Source Heat Pump	8.2	14
Commercial Air-Source Heat Pump	8.1	14

Definition of Baseline Equipment or Condition

The baseline condition is assumed to be the existing fossil fuel furnace.

Residential Baseline Efficiency[170]

Existing Fuel Type	Average Furnace Efficiency
Fuel Oil	81.3%
Propane	87.4%
Natural Gas	90.3%
Average	85.7%

[170] Average residential furnace efficiency of existing homes in Vermont, as sourced from homes surveyed in NMR Group's 2017 on site surveying; "Vermont Single-Family Existing Homes Onsite Report", NMR Group, December 2017 (page 45)

Commercial Baseline Efficiency[171]

Existing Fuel Type	Average Furnace Efficiency
Fuel Oil	82.0%
Propane	86.0%
Natural Gas	90.0%
Average	86.8%

[171] Mean observed efficiency for warm air fossil fuel furnaces for existing commercial buildings, as sourced from "Vermont Market Assessment Report", Cadmus (page 65). The efficiency of propane furnaces was not included in the report. In order to incorporate the propane fuel type into the analysis, opted to use the combined efficiency values for propane boilers and furnaces, as sourced from the data for the same report.

Algorithms

Demand Impacts

$$\Delta kW = kBtuh \times (\frac{-1}{HSPF_{Efficient}})$$

kBtuh = Average rated heating capacity[172]

$HSPF_{Efficient}$ = Heating Seasonal Performance Factor for Efficient equipment, Btu/Wh

Electric Energy Impacts

$$\Delta kWh = kBtuh \times \left(\frac{-1}{HSPF_{Efficient}}\right) \times EFLH_{Heating}$$

%CAC = Percent of existing homes in Vermont with central air conditioning

= 2%[173]

$\Delta kW_{Penalty}$ = Total average summer coincident peak kW penalty (deemed assumption for prescriptive)

$\Delta kWh_{Penalty}$ = Gross customer electric energy penalty (deemed assumption for prescriptive)

ΔMMBtu = MMBtu savings for each fuel type (deemed assumption for prescriptive)

$EFLH_{Heating}$ = Equivalent full load heating hours

= 1,383 hours (Residential)[174], 1,062 hours (Commercial)[175]

Fossil Fuel Impacts

$$\Delta MMBtu = \left(kBtuh \times EFLH_{Heating} \div \eta_{Efficiency}\right) \div 1000$$

$\eta_{Efficiency}$ = Efficiency of the fossil fuel heating system

Furnace Type Distribution[176]

Fuel Type	Residential	Commercial
Fuel Oil	43.2%	8.5%
Propane	22.7%	28.0%
Natural Gas	34.1%	63.4%

Savings Summary

The below deemed savings do not include the net conversion savings for Tier III saving claims. This can be found in the Tier III Planning Tool for the individual program years.

Residential Gross Savings[177]

Bin Capacity	ΔMMBtu	ΔkWh Heating	ΔkW Winter
9,000	14.1	-1,584	-1.037
12,000	17.8	-2,009	-1.308
15,000	24.2	-2,706	-1.775
18,000	26.0	-2,938	-1.907
24,000	34.0	-3,856	-2.498
30,000	49.0	-5,475	-3.596
36,000	51.0	-5,781	-3.745
42,000	70.1	-7,826	-5.151
48,000	66.2	-7,528	-4.863
54,000	81.8	-9,209	-6.006
60,000	79.7	-9,105	-5.858
66,000	99.5	-11,209	-7.307
72,000	108.4	-12,220	-7.965

Commercial Gross Savings[178]

Bin Capacity	ΔMMBtu	ΔkWh Heating	ΔkW Winter
9,000	10.7	-1,485	-1.050
12,000	13.5	-1,900	-1.324
15,000	18.3	-2,526	-1.797
18,000	19.7	-2,791	-1.930
24,000	25.8	-3,674	-2.529
30,000	37.1	-5,101	-3.640
36,000	38.6	-5,509	-3.791
42,000	53.1	-7,267	-5.214
48,000	50.1	-7,205	-4.923
54,000	61.9	-8,680	-6.080
60,000	60.4	-8,768	-5.930
66,000	75.3	-10,573	-7.397
72,000	82.1	-11,528	-8.063

Net Impacts

$$Net\ Lifetime\ \Delta MWh = \Delta MMBtu\ \div Heat\ Rate + \ (\Delta kWh + \%Fossil\ Fuel)\ \times\ Measure\ Life$$

[178] Analysis can be found on RET_CI tab of centrally-ducted-ashp-analysis-Tier III 9 24 2019.xlsx

Heat Rate = Custom Input from DU[179]

%Fossil Fuel = Reduction in electric penalty due to the percentage of fossil fuel in the residual mix of the utility's grid

= Custom DU Input

Measure Life = Anticipated useful effective life of the commercial electric leaf blower

= Refer to Lifetime section below

Gross-to-Net Savings Factors

Measure Category		**HVAC**	
Product Description		**Centrally Ducted Air Source Heat Pump**	
Measure Code		**SHRDASHP**	
Track Name	**Track No.**	**Freerider**	**Spillover**
TBD	TBD	1.0	1.0

Persistence

The persistence factor is assumed to be one.

Lifetime

The expected measure life is assumed to be 18 years[180].

Measure Cost

The assumed full retrofit cost of residential and commercial ducted air source heat pumps are below[181]:

Bin Capacity (Btu/hr)	Retrofit Cost
9,000	$1,517
12,000	$1,688
15,000	$1,803
18,000	$2,111
24,000	$3,240
30,000	$3,601

179 This value varies by the program year and is reported from the EIA's Monthly Energy Review Heat Rate.
180 "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", GDS Associates, June 2007.
181 Analysis can be found on the Retrofit Cost tab of evt-centrally-ducted-ashp-analysis-Tier III 9 24 2019.xlsx. Mid-Atlantic Technical Reference Manual, version 7.0, May 2017.

36,000	$4,461
42,000	$5,079
48,000	$5,498
54,000	$6,019
60,000	$7,532
66,000	$6,275
72,000	$6,491

O&M Cost Adjustments

N/A

Residential Induction Stovetop

Version Date & Revision History

Draft date: 9/25/2019
Effective date: 1/1/2020
End date: TBD

Referenced Documents

1. Residential Cooktop Performance and Energy Comparison Study Frontier Energy Report 501318071 R0 July 2019.pdf
2. Residential Induction Cooking Tier III Analysis 9_25_2019.xlsx
3. residential_ovens_nopr.pdf

Description

This measure claims savings for the installation of a residential induction stovetop. In induction cooking, the electricity flows through a coil to produce a magnetic field under the ceramic cooktop. When a cast iron or magnetic stainless steel pan is placed on the glass-ceramic surface, currents are induced in the cooking utensil and instant heat is generated due to the resistance of the pan. Induction only works with cooking vessels made of magnetic materials, such as cast iron and magnetic stainless steel (it will not work with aluminum or copper pots).

Definition of Energy Transformation Equipment or Condition

The efficient condition is assumed to be an electric induction stovetop installed in a residential application.

Definition of Baseline Equipment or Condition

The baseline condition is assumed to be a fossil fuel burning stove top in a residential application.

Algorithms

Electric Energy Impacts

$$\Delta kWh = \left(Heat\ Up\ Energy_{Per\ Day} + Simmer\ Energy_{Per\ Day} + Saute\ \ Energy_{Per\ Day}\right) \times Days\ Cooking_{Per\ Year}\ \div 1{,}000$$

ΔkWh = Gross customer electric energy penalty

= 258.18 kWh[182]

Heat Up $Energy_{Per\ Day}$ = Electric energy required to bring cookware to temperature[183]

= 568.33 Wh[184]

Simmer $Energy_{Per\ Day}$ = Electric energy consumed to keep cookware at temperature while cooking[185]

= 238.67 Wh[186]

Saute $Energy_{Per\ Day}$ = Electric energy consumed to pan-cook a typical food product[187]

= 186 Wh[188]

Days $Cooking_{Per\ Year}$ = Assumed days a year when stovetop is used in a residential application

= 260 days[189]

1,000 = Watt hour to Kilowatt Hour conversion factor

Fossil Fuel Impacts

$$\Delta MMBtu = \left(Heat\ Up\ Energy_{Per\ Day} + Simmer\ Energy_{Per\ Day} + Saute\ \ Energy_{Per\ Day}\right) \times Days\ Cooking_{Per\ Year}\ \div 1{,}000{,}000$$

ΔMMBtu = Gross fuel savings

= 2.119[190] MMBtu

Heat Up $Energy_{Per\ Day}$ = Thermal energy required to bring cookware to temperature

=5148 Btu[191]

Simmer $Energy_{Per\ Day}$ = Thermal energy consumed to keep cookware at temperature while cooking

=1676 Btu[192]

Saute $Energy_{Per\ Day}$ = Thermal energy consumed to pan-cook a typical food product

= 1326 Btu[193]

1,000,000 = Btu to MMBtu conversion factor

Net Impacts

$$Net\ Lifetime\ \Delta MWh = \Delta MMBtu\ \div Heat\ Rate + \ (\Delta kWh + \%Fossil\ Fuel) \times \ Measure\ Life$$

Heat Rate = Custom Input from DU[194]

%Fossil Fuel = Reduction in electric penalty due to the percentage of fossil fuel in the residual mix of the utility's grid

= Custom DU Input

Measure Life = Anticipated useful effective life of the commercial electric leaf blower

= Refer to Lifetime section below

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182 Analysis can be found on Residential Induction Stovetops tab on Residential Induction Cooking Tier III Analysis 9_25_2019.xlsx.

183 The energy and time to bring water to 200°F, which is used to both measure the production capability of the cooktop as well as the energy efficiency. In addition, the overshoot and cool-down from the water heat-up test is used to illustrate the temperature response of each cooktop.

184 Table 5: Simmer Energy Results, Residential Cooktop Performance Energy Comparison, Frontier Energy, July 2019.

185 – Once the water is boiling, the energy required to keep a pot of water at a simmer, which is used to measure energy consumption under regular cooking conditions for inclusion in an energy cost model.

186 Table 5: Simmer Energy Results, Residential Cooktop Performance Energy Comparison, Frontier Energy, July 2019.

187 The energy and time to pan-cook a typical food product, which is used to both measure the production capability of the cooktop as well as the energy efficiency.

188 Table 5: Simmer Energy Results, Residential Cooktop Performance Energy Comparison, Frontier Energy, July 2019.

189 Table 6: Energy Model Assumptions, Residential Cooktop Performance Energy Comparison, Frontier Energy, July 2019.

190 Analysis can be found on Residential Induction Stovetops tab on Residential Induction Cooking Tier III Analysis 9_25_2019.xlsx.

191 Table 5: Simmer Energy Results, Residential Cooktop Performance Energy Comparison, Frontier Energy, July 2019.

192 Table 5: Simmer Energy Results, Residential Cooktop Performance Energy Comparison, Frontier Energy, July 2019.

193 Table 5: Simmer Energy Results, Residential Cooktop Performance Energy Comparison, Frontier Energy, July 2019.

194 This value varies by the program year and is reported from the EIA's Monthly Energy Review Heat Rate.

Gross-to-Net Savings Factors

Measure Category		Cooking	
Product Description		**Induction Stove - Residential**	
Measure Code		**CKGINDST**	
Track Name	**Track No.**	**Freerider**	**Spillover**
TBD	TBD	1.0	1.0

Persistence

The persistence factor is assumed to be one.

Lifetime

The expected measure life is assumed to be 15 years[195].

Measure Cost

The actual full retrofit cost of the residential induction stove should be used[196].

O&M Cost Adjustments

N/A

[195] Energy Conservation Program: Energy Conservation Standards for Residential Conventional Oven, 2015, Department of Energy, Page 103, residential_ovens_nopr.pdf.

[196] A review of induction sales online found that induction stoves can range from $114.95 to $1,844, with an average of $593.69. A review of costs can be found on the Costs tab of the document: Residential Induction Cooking Tier III Analysis 9_25_2019.xlsx.

Battery Storage

Version Date & Revision History

Draft date: 5/18/2022
Effective date: 1/1/2023
End date: TBD

Referenced Documents

- 2022 Tier III Battery Analysis FINAL.xlsx
- eGrid 2020 Emissions Data.xlsx
- Lifecycle GHG Analysis 1 MW BESS.pdf
- Tesla Powerall 2 AC (Backup) Datasheet.pdf

Description

This measure claims savings for the installation of a battery as a mechanism for reducing system demand during system peak periods. These peak periods rely more heavily on fossil fuels than off peak periods. Units will be "Post Event Fractional Charged" until such time that low costs and threat of new peak has diminished. Some other parameters of this characterization include:

- Batteries are charged during off peak times using electricity less reliant on fossil fuels, ISO-NE average marginal emissions and the Distribution Utility's portfolio mix
- Batteries discharged during peak periods, avoiding ISO-NE peak marginal emissions
- Following discharge, fractional charging occurs to avoid peak impact and uses ISO-NE marginal emissions
- Once new peak is avoided, the batteries are charged at full rate, which will use the DU's portfolio mix
- Fossil fuel savings results from the difference in emissions rates between average and peak marginal

Definition of Energy Transformation Equipment or Condition

The efficient condition is a distribution utility qualified chemical energy storage system being installed on site and available to be controlled by the distribution utility for charging and discharging.

Definition of Baseline Equipment or Condition

The baseline condition is assumed to be a site consuming electricity from the ISO-NE grid during all periods of the year without onsite chemical energy storage.

Algorithms

Net Impacts

$$Net\ Lifetime\ \Delta MWh\ Equivalent = (\text{Battery Discharge} - \text{Post Fractional Charge Rate Penalty} - \text{Full Charge Rate Penalty}) \div \text{Heat Rate} \times \text{Measure Life}$$

$$Battery\ Discharge = Battery\ Energy\ Demand \times \frac{1MW}{1000\ kW} \times Annual\ Hours\ of\ Peak \times Deployment\ Rate \times ISO - NE\ Peak\ Marginal \times \frac{1MMBtu}{116.6\ lbs\ CO^2} \times (1 - Efficiency\ of\ Battery\ Charge)$$

$$Post\ Fractional\ Charge\ Rate\ Penalty = \%\ Post\ Event\ Fractional\ Charge \times Battery\ Energy\ Demand \times \frac{1MW}{1000\ kW} \times Annual\ Hours\ of\ Peak \times ISO - NE\ Average\ Marginal \times (1 + Efficiency\ of\ Battery\ Discharge) \times \frac{1MMBtu}{116.6\ lbs\ CO^2} \times Deployment\ Rate$$

$$Full\ Charge\ Rate\ Penalty = \%\ Full\ Rate\ Charging \times Battery\ Energy\ Demand \times \frac{1MW}{1000\ kW} \times Annual\ Hours\ of\ Peak \times ISO - NE\ Average\ Marginal \times (1 + Efficiency\ of\ Battery\ Discharge) \times \%Fossil\ Fuel \times \frac{1MMBtu}{116.6\ lbs\ CO^2} \times Deployment\ Rate$$

Battery Energy Demand	= Max continuous real power of battery[197]
	= Custom DU Input
Annual Hours of Peak discharging [198]	= Assumed hours that the battery will provide peak
	= Custom DU Input
1 MW / 1000 kW	= Conversion factor from kilowatts to megawatts
1 MMBtu / 116.6 lbs CO^2	= pounds of CO^2 in 1 MMBtu of Natural Gas[199]
ISO-NE Peak Marginal	= Marginal emission rate when battery is discharging

[197] This value can be found on the specification sheet of provided from the battery manufacturer.

[198] DU needs to determine the annual hours of deployment, rather than assume this equals the annual hours of peak.

[199] The assumed marginal fuel is natural gas. This means when more electricity is needed on the ISO-NE grid, it is assumed the generator providing that electricity utilizes natural gas as its fuel. This factor can be found on the Emission Conversions tab of analysis document: 2022 Tier III Battery Analysis FINAL.xlsx

	= 886.937 lbs/MWh[200]
ISO-NE Average Marginal	= Marginal emission rate when battery is charging
	= 532.979 lbs/MWh[201]
% Full Rate Charging rate[202]	= Percent of battery to be charged at the full charge
	= Custom Input from DU
% Post Event Fractional Charge fractional charge[203]	= Percent of battery to be charged at the post event
	= Custom Input from DU
% Fossil Fuel Average over 10 years	= Average Distribution Utility electric generation from fossil fuel sources over the life of the battery
	= Custom Input from DU
Efficiency of Battery Charge	= Losses associated with AC to battery while charging
	= 5.5%[204]
Efficiency of Battery Discharge discharging	= Losses associated with battery to AC while
	= 5.5%[205]

[200] 2020 eGRID Data for NPCC New Endlgand subregion SRL20 – eGRID subregion annual CO2e non-baseload output emission rate. Review spreadsheet: eGrid 2020 Emissions Data.xlsx for data.
[201] 2020 eGRID Data for NPCC New Endlgand subregion SRL20 – eGRID subregion annual CO2 equivalent total output emission rate. Review spreadsheet: eGrid 2020 Emissions Data.xlsx for data.
[202] This value will be decided by the Distribution Utility based on its grid design and restraints. The battery has a specified charging rate, which will commence when the distribution utility deems that a new peak has been avoided.
[203] This value will be decided by the Distribution Utility based on its grid design and restraints. This is to prevent a new peak from taking place. If all batteries that discharged during the peak event were to simultaneously charge at the same rate as the discharge, the distribution utility would have grid complications.
[204] Half of AC to Battery AC efficiency. Performance Specifications in Powerwall Spec Sheet, Tesla Powerall 2 AC (Backup) Datasheet.pdf
[205] Half of AC to Battery AC efficiency. Performance Specifications in Powerwall Spec Sheet, Tesla Powerall 2 AC (Backup) Datasheet.pdf

Deployment Rate = Percent of batteries successfully deployed by DU

= Custom Input from DU

Heat Rate = Conversion factor from MMBtu to MWh[206]

= Custom Input from DU

Measure Life = Expected measure life of a chemical storage battery

= 10 years[207]

Gross-to-Net Savings Factors

Measure Category	Storage	
Product Description	Battery Storage	
	Freerider	Spillover
	1.00	1.00

Persistence

Persistence is assumed to be one.

Lifetime

The expected measure life is assumed to be 10 years[208] for a new battery.

Measure Cost

The retrofit cost for a new battery is the full cost of the battery, software costs, and installation/labor costs.[209]

O&M Cost Adjustments

N/A

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206 EIA Heat Rate Table A6, Custom Input from DU, varies by program year

207 Measure life is based on current Tesla Powerwall warranty of 10 years. Can be found in Powerwall Spec Sheet, Tesla Powerall 2 AC (Backup) Datasheet.pdf

208 Measure life is based on current Tesla Powerwall warranty of 10 years. Can be found in Powerwall Spec Sheet, Tesla Powerall 2 AC (Backup) Datasheet.pdf

209 This cost will vary by utility and contractor.

Pellet Boiler and Furnace

Version Date & Revision History
Draft date: 8/10/2016
Effective date: 1/1/2017
End date: TBD

Referenced Documents

1. Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case. Prepared by Navigant Consulting and SAIC for the U.S. Energy Information Administration, March 2014.
2. Emerging Technologies Research Report. Prepared by Energy & Research Solutions for the Regional EM&V Forum, February 13, 2013.
3. Vermont Fuel Price Report. Vermont Department of Public Service, April 2016.
4. Pellet Boiler & Stove Analysis_2016.xlsx
5. Vermont Single-Family Existing Homes Onsite Report FINAL. NMR Group, 2013.
6. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Boilers. U.S. Department of Energy, December 22, 2015.
7. Vermont Residential Fuel Assessment for the 2014-2015 Heating Season. Vermont Department of Forests, Parks, and Recreation, March 2016.
8. 2011 Vermont Market Characterization and Assessment Study; Business Sector (Commercial and Industrial) Existing Buildings, FINAL. Prepared by Navigant for the Vermont Public Service Department, October 6, 2012.

Description
This measure is characterized as a retrofit and applies to the installation of a new pellet boiler or furnace rated less than or equal to 340,000 Btu/h (< 100 kW) in a residential or commercial building. It is assumed that new pellet systems will be a primary heating source, and existing fossil fuel boilers or furnaces will provide supplemental heat.

Pellet systems must be installed according to manufacturer's recommendations, and pellets and pellet systems must comply with renewability standards adopted under 10 V.S.A. §2751.

Equipment must meet the following minimum efficiency and emissions requirements:

Pellet Boilers and Furnaces: 85% peak efficiency and <0.08 lb/MMBtu of particulate matter less than 2.5 microns ($PM_{2.5}$)[210]

Definition of Energy Transformation Equipment or Condition
The new equipment must be a new pellet boiler or furnace installed according to manufacturer's recommendations and meeting minimum program eligibility requirements. It is assumed that pellet systems will provide primary heat and that the existing fossil fuel-fired system will be a supplemental heating source.

Definition of Baseline Equipment or Condition
The baseline condition is a building using an existing fossil fuel-fired boiler or furnace as a primary heating source.

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[210] Requirements from the Renewable Energy Resource Center, beginning in July 2015

Algorithms

Demand Impacts

It is assumed that demand impacts from pellet boiler and furnace installations are negligible.

Electric Energy Impacts

It is assumed that electric energy impacts from pellet boiler and furnace installations are negligible.

Fossil Fuel Impacts

$$\Delta MMBtu = \%Pellet\ x\ (FLH\ x\ \left(\frac{Capacity}{1{,}000{,}000}\right) x\ \%Heating_{Fossil}\ )/$$
ηHeat x $\%Compliance$

$$\Delta MWh_{FossilFuel} = \Delta MMBtu/9.104$$

Where:

ΔMMBtu = Thermal savings from displacement of fossil fuels

%Pellet = Percentage of annual heating load provided by pellet system

= 90%[211] for pellet boiler and furnace installations

FLH = Estimated average full load heating hours

= 810 for residential boilers and 1,024 for residential furnaces[212]

= 1,614 for commercial boilers or furnaces[213]

Capacity = Capacity of existing fossil fuel heating system (Btu/hr)

= For residential customers, use actual capacity, or if unknown, assume 125,000 Btu/hr for boilers and 73,000 Btu/hr for furnaces.[214] For commercial customers, use actual capacity.

1,000,000 = Factor to convert Btu/hr to MMBtu/hr

$\%Heating_{Fossil}$ = Percentage of existing heating load satisfied by fossil fuels

= 93%[215] for residential customers and 100% for commercial customers

η_{Heat} = Heating system efficiency

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211 Agreement made during June 9, 2016 Tier III TAG meeting.

212 From Efficiency Vermont TRM. Estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont's Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. The RNC data was limited to only those homes with annual gas consumption greater than 75MMBtus in an attempt to remove the high performance/ low load homes in RNC.

213 From Efficiency Vermont TRM. Based on 7,859 heating degrees days (HDD) for Vermont, a 0.77 correction factor to account for the fact that typical HDD data is based on a balance point of 65 degrees, and a design temperature difference of 90 degrees F (-20 F to 70 F).

214 Default capacities for residential applications from Efficiency Vermont TRM. Weighted average of capacity data from NEEP Incremental Cost Study Phase 1. See Workbook Volume 2 Market Characterization tab; http://neep.org/emv-forum/forum-products-and-guidelines/#Incremental. Includes data from Vermont, Massachusetts and New York.

215 Weighted average for a 96.6 MMBtu household based on wood and pellet use for supplemental heating from Vermont Residential Fuel Assessment for the 2014-2015 Heating Season. Vermont

= See table below

Customer Type	Fossil Fuel-Fired Heating System	Efficiency
Residential[216]	Boiler	85.8%
	Furnace	86.7%
Commercial[217]	Boiler	83%
	Furnace	81%

%Compliance = Average percentage of pellets that comply with Vermont's renewability standards adopted under 10 V.S.A. §2751

= 100%

$\Delta MWh_{FossilFuel}$ = Gross customer annual fossil fuel impacts for this measure, converted to MWh.

9.104 = Factor to convert MMBtu to MWh[218]

See table below for deemed fossil fuel impacts for residential customers.

Department of Forests, Parks, and Recreation, March 2016. 3.7% of Vermont households use pellets for supplemental heating, and the average annual pellet usage for supplemental heating is 3.3 tons per household. 17.6% of Vermont households use cordwood for supplemental heating, and the average annual cordwood usage for supplemental heating is 2.1 cords per household. Based on the April 2016 Vermont Fuel Price Report, the heat content of pellets is 16.4 MMBtu/ton, and the heat content of cordwood is 22,000 Btu/cord. It is assumed that the average efficiency of existing pellet and wood systems used for supplemental heating is 65%.

[216] Efficiencies for existing residential fossil fuel-fired boilers and furnaces are the average of oil, natural gas, and propane system efficiencies from VT SF Existing Homes Onsite Report Table 5-8 and 5-9. NMR Group, Inc. 2013.

[217] The efficiency for existing commercial fossil fuel-fired boilers is the average observed efficiency of hot water and steam boilers less than 300,000 Btu/hr. For commercial fossil fuel-fired furnaces, the efficiency is the average observed efficiency of warm air furnaces less than 225,000 Btu/hr. Efficiencies from 2011 Vermont Market Characterization and Assessment Study; Business Sector (Commercial and Industrial) Existing Buildings, FINAL. Prepared by Navigant for the Vermont Public Service Department, October 6, 2012.

[218] MMBtu to MWh conversion factor from the U.S. Energy Information Administration http://psb.vermont.gov/sites/psb/files/Fuel%20Conversion%20Factors.pdf

Energy Transformation Equipment	Fossil Fuel-Fired Heating System	ΔMMBtu	$\Delta MWh_{FossilFuel}$
Pellet Boiler and Furnace	Boiler	98.772	10.4
	Furnace	72.165	7.6

Net Impacts

$$\Delta MWh_{Net} = \Delta MWh_{Electric} + \Delta MWh_{FossilFuel}$$

Loadshape

#5 Residential Space Heat

Gross-to-Net Savings Factors

Measure Category		**HVAC**	
Product Description		**Pellet Boiler and Furnace**	
Measure Code		**SHEPLLTB**	
Track Name	**Track No.**	**Freerider**	**Spillover**
RES Retrofit	6036RETR	1.0	1.0

Persistence

The persistence factor is assumed to be one.

Lifetime

Energy Transformation Equipment	Lifetime
Pellet Boiler and Furnace[219]	20 years

Measure Cost

The measure cost is the cost of installation (labor and equipment) for a pellet boiler, furnace, or stove. If available, actual installation costs should be used. If costs are unavailable, use costs from table below.

Energy Transformation Equipment	Installed Cost
Pellet Boiler or Furnace[220]	$20,000

O&M Cost Adjustments

Annual O&M costs[221] for pellet systems and existing fossil fuel-fired heating systems are provided in the table below, along with incremental O&M costs (the increase in annual O&M costs for pellet systems compared to existing fossil fuel-fired systems).

Pellet Boiler, Furnace, and Stove Annual O&M Cost	Fossil Fuel-Fired Heating System Annual O&M Cost	Incremental O&M Cost
$250	#2 Fuel Oil Boiler - $135	$115
	#2 Fuel Oil Furnace - $65	$185
	Liquid Propane Boiler - $50	$200
	Liquid Propane Furnace - $45	$205
	Natural Gas Boiler - $50	$200
	Natural Gas Furnace - $45	$205

[219] Pellet boiler and furnace lifetime from Emerging Technologies Research Report. Prepared by Energy & Research Solutions for the Regional EM&V Forum, February 13, 2013.

[220] Pellet boiler installed cost from Emerging Technologies Research Report. Prepared by Energy & Research Solutions for the Regional EM&V Forum, February 13, 2013. Pellet furnace installed costs are assumed to be similar to pellet boiler costs.

[221] All O&M costs are from EIA - Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case. Prepared by Navigant Consulting and SAIC for the U.S. Energy Information Administration, March 2014. O&M costs for propane boilers are assumed to the be same as costs for gas boilers, costs for propane furnaces are assumed to be the same as costs for gas furnaces, and costs for pellet boilers and furnaces are assumed to be the same as costs for pellet stoves.

Biofuels

Version Date & Revision History
Draft date: 8/10/2016
Effective date: 1/1/2017
End date: TBD

Referenced Documents

Description
This measure applies to the use of biodiesel blends between B5 and B100 in place of No. 2 heating oil in oil boilers and furnaces installed in existing buildings. For blends above B20, it is assumed that heating systems will be retrofitted with burners designed to burn fuel with higher percentages of biodiesel.

B6 through B20 must meet ASTM D396 requirements, and B100 must meet ASTM D6751 requirements.

Definition of Energy Transformation Equipment or Condition
The new condition is biodiesel blends between B5 and B100 used in place of No. 2 heating oil.

Definition of Baseline Equipment or Condition
The baseline condition is No. 2 heating oil with a 2% biodiesel content[222] used in boilers and furnaces in existing buildings.

Algorithms

Demand Impacts

There are no demand impacts for this measure.

Electric Energy Impacts

There are no electric energy impacts for this measure.

Fossil Fuel Impacts

$$\Delta MMBtu = Gallons\ x\ \frac{138{,}480}{1{,}000{,}000}\ x\ (\%Biodiesel - 2\%)$$

[222] Baseline biodiesel content based on ten samples of heating oil collected directly from delivery trucks in Vermont in September 2016. Average biodiesel content was 1.65%. See Vermont Fuel Dealers Association "Memo: Biodiesel Blended Heating Oil/Current Market Conditions and Baseline Assumptions" for details. Biodiesel content used in the Vermont State Screening Tool is 2%.

$$\Delta MWh_{FossilFuel} = \Delta MMBtu/9.104$$

Where:

ΔMMBtu = Thermal savings from displacement of fossil fuels

Gallons = Gallons of biodiesel purchased

= Actual

138,480 = Energy content (Btu/gallon) of No. 2 heating oil[223]

1,000,000 = Factor to convert Btu/gallon to MMBtu/gallon

%Biodiesel = Percentage of biodiesel in blend

= Actual, based on biodiesel blend. For example, %Biodiesel is 10% for B10.

$\Delta MWh_{FossilFuel}$ = Gross customer annual fossil fuel impacts for this measure, converted to MWh.

9.104 = Factor to convert MMBtu to MWh[224]

Per-gallon fossil fuel impacts for several biodiesel blends are listed in the table below.

Biodiesel Blend	ΔMMBtu	$\Delta MWh_{FossilFuel}$
B5	0.00415	0.0004
B10	0.0111	0.001
B20	0.0249	0.003
B100	0.136	0.01

Net Impacts

Since there are no electric energy impacts for this measure, net impacts are equal to fossil fuel impacts.

Loadshape

N/A

Gross-to-Net Savings Factors

Measure Category		**HVAC**	
Product Description		**Biodiesel Heating**	
Measure Code		**SHEBIODL**	
Track Name	**Track No.**	**Freerider**	**Spillover**
RES Retrofit	6036RETR	1.0	1.0

[223] From "Fuel Conversion Factors" provided by the Vermont Department of Public Service. http://psb.vermont.gov/sites/psb/files/Fuel%20Conversion%20Factors.pdf
[224] MMBtu to MWh conversion factor from the U.S. Energy Information Administration http://psb.vermont.gov/sites/psb/files/Fuel%20Conversion%20Factors.pdf

Persistence

The persistence factor is assumed to be one.

Lifetime

The measure lifetime is one year.

Measure Cost

The incremental cost of biodiesel compared to No. 2 heating oil with a 2% biodiesel content is $0.01 per gallon for each additional % of biodiesel in the blend.[225] For example, the incremental cost of one gallon of B10 is $0.08 per gallon.

The additional cost of replacing a burner to accommodate biodiesel blends above B20 is $1,000 for boilers less than 300,000 Btu/hr and furnaces less than 225,000 Btu/hr and $2,500 for boilers equal to or greater than 300,000 Btu/hr and furnaces equal to or greater than 225,000 Btu/hr.

O&M Cost Adjustments

N/A

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[225] Integrating Renewable Fuel Heating Systems. Presentation from Better Buildings by Design, February 2009.

Telecommuting

Version Date & Revision History

Draft date: 10/2/2020
Effective date: 1/1/2021
End date: TBD

Referenced Documents

1. Telecommuting Analysis Tier III TAG PY2021.xlsx
2. University of Michigan Transportation Research Institute Eco-driving Index
3. Go! Vermont Data

Description

This analysis accounts for a utility incentivizing a company to have their employees telecommute for 1-5 days a week. This includes assumptions around average distance a Vermonter commutes for work and the average efficiency of a Vermont single occupancy vehicle. The associated analysis document provides a summary of company size and potential impact of having employees working remotely.

Definition of Energy Transformation Equipment or Condition

The energy transformation is an employee of a company now working remotely from their home office.

Definition of Baseline Equipment or Condition

The baseline is assumed to be an employee working from the office and using their own personal transportation to commute back and forth between the office.

Algorithms

Electric Energy Impacts

When calculating net electric energy impacts, utilities should ensure that electric energy impacts (MWh) reflect the average percentage of fossil fuels in electric generation mix for the program year, adjusted for measure lifetime.

$$\Delta MWh_{Electric} = \text{N/A}$$

Where:

$\Delta MWh_{Electric}$ = Gross customer annual electric energy impacts for the measure

N/A = There are no electric impacts calculated for this measure[226]

[226] In the 2020 TAG Tier III session, electric penalties will reviewed to reflect increased electric usage that an employee will now have at their residence due to working from home. This will include plug load use and potential HVAC impacts due to temperature setbacks now not taking place.

Fossil Fuel Impacts

$$\Delta MMBtu = \# \; of \; Employees \times \frac{Roundtrip \; Commute \; Distance}{MPG \; of \; SOV} \times MMBtu \; Gasoline \times (\# \; of \; Days \; a \; Week \; Telecommute \times \# \; of \; Annual \; Work \; Weeks)$$

Where:

ΔMMBtu	= Annual fossil fuel savings
# of Employees	= Total number of employees working remotely
	= Custom Input[227]
Roundtrip Commute Distance	= Average roundtrip commute of employee in miles
	= 32[228]
MPG of SOV	= Average fuel efficiency of Single Occupancy Vehicle
	= 25.3[229]
MMBtu Gasoline	= Heat content in one gallon of gasoline
	= 0.120286[230]
# of Days a Week Telecommute	= Number of days a week that employees are now working remotely
	= Custom Input[231]
# of Annual Work Weeks	= Assumed number of weeks a year that employees work
	=50[232]

227 Refer to the analysis document to input the custom # of employees and calculated savings associated with moving those employees to remote working. Telecommuting Analysis Tier III TAG PY2021.xlsx

228 Round trip distance is sourced doubling the one-way trip date from from Go!Vermont, which includes 77,648 trips from 537 Vermont commuters.

229 Sales-weighted average miles per gallon of model year 2015 vehicles, calculated in University of Michigan Transportation Research Institute Eco-driving Index: http://www.umich.edu/~umtriswt/EDI_sales-weighted-mpg.html. This average includes all light duty vehicles (cars, SUVs, pick-up trucks) and may include a small number of alternative fuel vehicles.

230 Reported MMBTu in one gallon of gasoline according to the EIA. https://www.eia.gov/energyexplained/units-and-calculators/british-thermal-units.php

231 Refer to the analysis document to input the custom # of Days a Week Telecommute and calculated savings associated with moving those employees to remote working. Telecommuting Analysis Tier III TAG PY2021.xlsx

232 Number of weeks in a year that an employee may work. This assumes two weeks of holidays and time off. This number can have a custom input if employee works more or less than 50 weeks a year.

Loadshape

N/A

Gross-to-Net Savings Factors

Measure Category		**Transportation**	
Product Description		**Telecommuting**	
Measure Code		**TELECOMM**	
Track Name	**Track No.**	**Freerider**	**Spillover**
TBD	TBD	1.0	1.0

Persistence

The persistence factor is assumed to be one.

Lifetime

The lifetime of telecommuting is assumed to be 1 year. A utility would have to report annually on the number of employees a company have working remotely and for how many days a year.

Measure Cost

The measure cost is the assumed cost for a company to move customers to remote working. This may include IT infrastructure and other related costs.

Motorcycles

Version Date & Revision History

Draft date: 9/29/2020
Effective date: 1/1/2021
End date: TBD

Referenced Documents

1. Motorcycles Tier III Analysis.xlsx

Description

This is a time of sale measure that applies to the purchase of a new electric scooter or electric motorcycle. This measure accounts for the complete offset of a fossil fuel powered scooter or motorcycle.

Definition of Energy Transformation Equipment or Condition

The energy transformation equipment must be a new all-electric vehicle scooter or motorcycle.

Definition of Baseline Equipment or Condition

The baseline equipment is an existing fossil fuel scooter or motorcycle.

Algorithms

Electric Energy Impacts

When calculating net electric energy impacts, utilities should ensure that electric energy impacts (MWh) reflect the average percentage of fossil fuels in electric generation mix for the program year, adjusted for measure lifetime.

$$\Delta MWh_{Electric} = kWh_{Battery} \times \frac{VMT}{Range} \times 1.1$$

Where:

$\Delta MWh_{Electric}$ = Gross customer annual electric energy impacts for the measure

$kWh_{Battery}$ = Average battery kwh[233]

= 3.95 for scooters

=12.16 for motorcycles

VMT = Vehicle miles traveled

= 1,286 for scooters[234]

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233 The average battery kWh of electric scooters and motorcycles is a review of available model's spec sheets. Analysis can be found on Models and Analysis tab of Motorcycles Tier III Analysis.xlsx.

234 Align with Tier III Electric Bicycle Measure's VMT. 1 Displaced driving miles (DDM) were calculated using data from a 2017 electric bicycle survey conducted by VEIC. DDM = (annual electric bicycle mileage for non-exercise or recreation purposes) x (% vehicle travel reduction). Values for "%vehicle travel reduction" were assigned based on the survey question "Prior to owning an E-bike would you typically have been driving to those places

= 2,300 for motorcycles[235]

Range = Average range of vehicle per charge[236] (miles)

= 62 for scooters

= 132.71 for motorcycles

1.1 = 10% efficiency losses associated with charging

See table below for deemed electric energy impacts.

Type of Electric Motorcycle	ΔkWh
Scooter	90.12
Motorcycle	231.89

Fossil Fuel Impacts

$$\Delta MMBtu = \frac{VMT}{MPG} \times 0.120286$$

Where:

ΔMMBtu = Annual fossil fuel savings

MPG = Miles per gallon of vehicle

= 75 for scooters[237]

= 35 for motorcycles[238]

0.120286 = MMBtu in one gallon of road gasoline

Other factors as defined above.

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instead?" Responses were Often (75%), Sometimes (50%), Rarely (12%), and Never (0%).
2 Average electric efficiency from Ithaca's Boxy Bikes (http://boxybikes.com/learn/) and electricbike.com (https://www.electricbike.com/watt-hours/).

[235] U.S. Department of Transportation Federal Highway Administration, Table VM-1, Annual Vehicle Distance Traveled in Miles and Related Data, 2017 value for motorcycles (https://www.fhwa.dot.gov/policyinformation/statistics/2017/vm1.cfm).

[236] The average range of electric scooters and motorcycles is a review of available model's spec sheets. Analysis can be found on Models and Analysis tab of Motorcycles Tier III Analysis.xlsx.

[237] Conservative assumption of miles per gallons according to Yamaha motors https://www.yamahamotorsports.com/scooter/pages/yamaha-scooter-mpg-ratings.

[238] Average mid-size Motorcycle 35-40 mpg (est) (250 est gal for 10,000 mi) US Dept of Transportation, Bajaj USA, and Ride to Work

See table below for deemed fossil fuel impacts.

Type of Electric Motorcycle	ΔMMBtu
Scooter	2.06
Motorcycle	7.90

Loadshape

N/A

Gross-to-Net Savings Factors

Measure Category		Transportation	
Product Description		**All-Electric Motorcycle**	
Measure Code		**TRNAECMO**	
Track Name	**Track No.**	**Freerider**	**Spillover**
TBD	TBD	1.0	1.0

Persistence

The persistence factor is assumed to be one.

Lifetime

The lifetime of a new electric scooter and motorcycle is assumed to be 10 years[239].

Measure Cost

The measure cost is the full cost of the new scooter or motorcycle

Type of Vehicle	Cost[240]
Scooter	$7,499
Motorcycle	$18,919

[239] Based on 1000 average charge cycles, and assume 100 charges a year.
[240] The average cost of electric scooters and motorcycles is a review of models on the market. Analysis can be found on Models and Analysis tab of Motorcycles Tier III Analysis.xlsx.

Push Lawnmowers, Chainsaws, Leafblowers, Trimmers, Edgers, and Cultivators

Version Date & Revision History
Draft date: 8/26/2022
Effective date: 1/1/2023
End date: TBD

Referenced Documents

1. TAG Tier III_Ride On Mowers and Small Gas Appliances_Analysis 2020.xlsx
2. EPA report, "Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling" (July 2010)
3. TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx

Description
This is a time of sale measure that applies to the purchase of new residential and commercial gas lawn equipment, which include trimmers, edgers[241], cultivators[242], leafblowers, chainsaws, and push lawnmowers. This measure assumes the offset of converting use of gas lawn equipment to electrical lawn equipment, which in turn saves fossil fuels and increases electric use.

Definition of Energy Transformation Equipment or Condition
The energy transformation equipment must be new residential or commercial gas lawn equipment, which includes trimmers, edgers, cultivators, leafblowers, chainsaws, and push lawnmowers.

Definition of Baseline Equipment or Condition
The baseline equipment is an existing fossil fuel residential or commercial gas lawn equipment, which includes trimmers, edgers, cultivators, leafblowers, chainsaws, and push lawnmowers.

Algorithms

Electric Energy Impacts

When calculating net electric energy impacts, utilities should ensure that electric energy impacts (kWh) reflect the average percentage of fossil fuels in electric generation mix for the program year, adjusted for measure lifetime.

$$\Delta kWh_{Electric} = Battery\ kW\ Draw\ \times Charge\ Time\ \times Charges\ per\ Year$$

Where:

$\Delta MWh_{Electric}$ = Gross customer annual electric energy impacts for the measure

Battery kW Draw= Available energy in the battery of the lawn equipment

[241] It is assumed that edgers and cultivators have the same use as trimmers, and therefore baseline and efficient conditions are similar. Savings are therefore the same for trimmers, edgers, and cultivators.
[242] It is assumed that edgers and cultivators have the same use as trimmers, and therefore baseline and efficient conditions are similar. Savings are therefore the same for trimmers, edgers, and cultivators.

= Varies by technology and market, refer to analysis document[243]

Charge Time = Time (minutes) required to fully charge the lawn equipment's battery

= Varies by technology and market, refer to analysis document[244]

Charges per Year = Assumed number of full charges in a year

= Varies by technology and market, refer to analysis document[245]

See table below for deemed electric energy impacts.

Type of Electric Equipment	Market	ΔkWh Annual
Trimmers, Edgers, and Cultivators	Residential	0.71
	Commercial	58.98
Leafblowers	Residential	0.78
	Commercial	121.40
Chainsaws	Residential	1.02
	Commercial	130.44
Push Lawnmowers	Residential	8.95
	Commercial	238.32

243 Battery draw is derived from a variety of manufacturer specification sheets by technology. Data can be found on Analysis sheet of the analysis documents: TAG Tier III_Ride On Mowers and Small Gas Appliances_Analysis 2020.xlsx and TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx.

244 Charge Time is derived from a variety of manufacturer specification sheets by technology. Data can be found on Analysis sheet of the analysis documents: TAG Tier III_Ride On Mowers and Small Gas Appliances_Analysis 2020.xlsx and TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx.

245 Charges per Year is derived from a variety of manufacturer specification sheets by technology. Data can be found on Analysis sheet of the analysis documents: TAG Tier III_Ride On Mowers and Small Gas Appliances_Analysis 2020.xlsx and TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx.

Fossil Fuel Impacts

$$\Delta MMBtu = (Average\ Daily\ Gas\ Usage \times Days\ of\ Use\ per\ Week \times Weeks\ per\ Year \times MMBtu_{Fuel}) \div 1{,}000{,}000$$

Where:

ΔMMBtu = Annual fossil fuel savings[246]

Average Daily Gas Usage = Average daily consumption of fossil fuel lawn equipment

= 1 gallon [247]

Days of Use Per Week = Assumed days per week when lawn equipment is used

= Varies by technology and market, refer to analysis document[248]

Weeks per Year = Assumed use of lawn equipment based on Vermont climate

= 23 weeks per year[249]

$MMBtu_{Fuel}$ = Energy content in one gallon of fuel

= Varies by fuel, refer to analysis document [250]

1,000,00 = Conversion factor from Btu to MMBtu

See table below for deemed fossil fuel impacts.

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[246] Analysis and assumptions for fossil fuel savings can be found on the Analysis sheet of TAG Tier III_Ride On Mowers and Small Gas Appliances_Analysis 2020.xlsx and TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx.

[247] Rough assumption based on conversation in TAG meeting on August 6, 2020.

[248] Data can be found on Analysis sheet of the analysis documents: TAG Tier III_Ride On Mowers and Small Gas Appliances_Analysis 2020.xlsx and TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx.

[249] Assuming every other week usage for Residential. For Commercial, assuming operating standard 5 days / wk (conservative estimate).

[250] EIA energy content of fuels, https://www.eia.gov/energyexplained/units-and-calculators/energy-conversion-calculators.php. Data can be found on Input sheet of the analysis documents: TAG Tier III_Ride On Mowers and Small Gas Appliances_Analysis 2020.xlsx and TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx.

Type of Electric Equipment	Market	ΔMMBtu Annual
Trimmers, Edgers, and Cultivators	Residential	1.38
	Commercial	13.83
Leafblowers	Residential	1.38
	Commercial	13.83
Chainsaws	Residential	1.38
	Commercial	13.83
Push Lawnmowers	Residential	1.00
	Commercial	16.10

Loadshape

N/A

Gross-to-Net Savings Factors

Measure Category		**Transportation**	
Product Description		**Lawnmowers and Small Gas Appliances**	
Measure Code		**LASGAPP**	
Track Name	**Track No.**	**Freerider**	**Spillover**
TBD	TBD	1.0	1.0

Persistence

The persistence factor is assumed to be one.

Lifetime

The lifetime[251] of new electric law equipment can be found in the below table.

[251] EPA report, "Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling" (July 2010), Table 3. "Example default activity levels and load factors for LGE"

Type of Electric Equipment	Market	Measure Life (years)
Trimmers, Edgers, and Cultivators	Residential	8
	Commercial	2
Leafblowers	Residential	8
	Commercial	2
Chainsaws	Residential	8
	Commercial	2
Push Lawnmowers	Residential	10
	Commercial	6

Measure Cost

The measure cost is the full cost[252] of the new lawn equipment and averages can be found below.

Type of Electric Equipment	Market	Measure Cost
Trimmers, Edgers, and Cultivators	Residential	$271.95
	Commercial	$594.94
Leafblowers	Residential	$206.20
	Commercial	$569.94
Chainsaws	Residential	$383.95
	Commercial	$777.45
Push Lawnmowers	Residential	$419.00
	Commercial	$500.00

[252] The actual costs were reviewed by major manufacturers of electric trimmers, leafblowers, chainsaws, and tractors. Cost data can be found on Lawn Equipment Costs, mower Model Data, and PIVOT Mower Costs sheets of analysis documents: TAG Tier III_Ride On Mowers and Small Gas Appliances_Analysis 2020.xlsx and TAG Tier III_Electric Lawnmowers_2021_FINAL.xlsx.

Heat Pump Pool Water Heater

Version Date & Revision History

Draft date: 9/9/2021
Effective date: 1/1/2022
End date: TBD

Referenced Documents

- Heat Pump Pool Water Heater Calcs_2021_9.17.2021.xlsx
- ASHRAE-D-Chapter 51_Service Water Heating_2019.pdf
- BTV_1269696_44.49_-73.22_tmy-2020.xlsx
- Montpelier AP_1290449_44.25_-72.58_tmy-2020.xlsx
- Rutland AP_1278891_43.53_-72.94_tmy-2020.xlsx
- Springfield AP_1293358_43.29_-72.50_tmy-2020_v2.xlsx
- SummitXLBrochure.pdf
- u-s-doe-building-american-standard-dhw-scedules-may-2014-xlsm.xlsm

Description

This measure claims savings for the conversion of an existing fossil fuel pool water heater with a heat pump pool water heater. The heat pump pool water heater uses heat pump technology to efficiently heat pool water heater. Pool heaters consume a large amount of energy, so converting to an electric heat pump will reduce site fuel consumption and overall carbon footprint. The efficiency of a fossil fuel pool water heater can be in the 80% range, whereas a heat pump pool water heater can have an efficiency as high as 500%.

Definition of Energy Transformation Equipment or Condition

The efficient condition is a new heat pump pool water heater with a COP of at least 4.0.

Definition of Baseline Equipment or Condition

The baseline condition is assumed to be a working fossil fuel pool water heater. These heaters may be power by natural gas, propane, or oil.

Algorithms

Electric Energy Impacts

$$\Delta kWh = \sum(Heat\ Loss\ \times Hours) \div (3{,}412 \times COP_{Heat\ Pump})$$ [253]

ΔkWh = Gross annual customer electric energy penalty (deemed assumption for prescriptive)[254]

= 16,924 kWh with Pool Cover

= 18,705 kWh with no Pool Cover

[253] Derived from ASHRAE Handbook, Chapter 51 Service Water Heating, Swimming Pools, page 51.25. Find analysis information on Pool Calcs tab of document: Heat Pump Pool Water Heater Calcs_2021_Final version.xlsx

[254] Find analysis information on Pool Calcs tab of document: Heat Pump Pool Water Heater Calcs_2021_Final version.xlsx

Heat Loss = Surface heat loss of pool

= Heat loss varies by temperature, refer to analysis document[255]

Hours = Average Hourly Temperature bin data, from June through September, for Burlington, Montpelier, Rutland, and Springfield, VT

= Hours in each bin vary by temperature, refer to analysis document[256]

3,412 = Conversion factor from Btu to kWh

$COP_{Heat\ Pump}$ = Coefficient of Performance of the Heat Pump Pool Water Heater

= 4.79[257]

Fossil Fuel Impacts

$$\Delta MMBtu = \sum Heat\ Loss\ \times Hours \div (1{,}000{,}000 \times \eta_{Fossil\ Fuel})$$ [258]

ΔMMBtu = Gross MMBtu savings by application (deemed assumption for prescriptive)[259]

= 325.6 MMBtu with Pool Cover

= 739.1 MMBtu with no Pool Cover

1,000,000 = Conversion factor for Btu to MMBtu

$\eta_{Fossil\ Fuel}$ = Efficiency of existing fossil fuel pool water heater

= 85%[260]

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[255] Find analysis information on Pool Calcs tab of document: Heat Pump Pool Water Heater Calcs_2021_Final version.xlsx

[256] Find analysis information on Pool Calcs tab of document: Heat Pump Pool Water Heater Calcs_2021_Final version.xlsx

[257] The minimum required efficiency is COP 4.0 for all sizes of heat pump pool heaters. While we reviewed decreasing to minimum standards, the VT pool market shows a greater COP value. Poultney Pools offers Hayward Summit XL #SUMXL140 with a COP 5.7 at peak performance. Allen Pools offers Hayward Summit XL as well, for in ground pools. We found a weighted average of COP, based on the average air temperature during these months.

[258] Derived from ASHRAE Handbook, Chapter 51 Service Water Heating, Swimming Pools, page 51.25. Find analysis information on Pool Calcs tab of document: Heat Pump Pool Water Heater Calcs_2021_Final version.xlsx

[259] Find analysis information on Pool Calcs tab of document: Heat Pump Pool Water Heater Calcs_2021_Final version.xlsx

[260] 85% to be conservative - Allen Pools says 85 to 90%; Poultney pools said 82-84%. Find analysis information on Pool Calcs tab of document: Heat Pump Pool Water Heater Calcs_2021_Final version.xlsx

Gross-to-Net Savings Factors

Measure Category	Recreation	
Product Description	Heat Pump Pool Water Heater	
	Freerider	Spillover
	1.00	1.00

Persistence

Persistence is assumed to be one.

Lifetime

The expected measure life is assumed to be 5 years[261].

Measure Cost

The retrofit cost for a heat pump pool water is assumed to be $4,200[262].

O&M Cost Adjustments

N/A

[261] 5 years is based on the parts warranty on heat pump pool water heaters.
[262] This is the actual cost of a Hayward Heat Pump Pool Water Heater. Find further information on Assumptions tab of document: Heat Pump Pool Water Heater Calcs_2021_Final version.xlsx

Replace Your Ride

Version Date & Revision History
Draft date: 8/27/2021
Effective date: 1/1/2022
End date: TBD

Referenced Documents

1. Tier III TAG_Replace your Ride_2021 Analysis.xlsx
2. The Vermont Transportation Energy Profile, September 2017

Description
This measure includes the opportunity to scrap older, higher polluting fossil fuel vehicles for other forms of clean transportation. This allows for a customer to receive an incentive for a new or used electric vehicle, transit vouchers, electric motorcycle/bicycle, or a shared-mobility voucher. This measure accounts for a customer replacing their combustion engine early and avoided future burning of fossil fuels.

Definition of Energy Transformation Equipment or Condition
The energy transformation equipment is the early retirement of an internal combustion engine with a cleaner transportation option, which can be measured in other characterizations.

Definition of Baseline Equipment or Condition
The baseline equipment is a blend of existing, conventional gasoline and diesel-powered vehicles.

Algorithms

Demand Impacts

There are no demand impacts for this measure.

Electric Energy Impacts

There are no electric energy impacts for this measure.

Fossil Fuel Impacts

$$\Delta MMBtu = ((VMT \div \eta_{2011\ Earlier}) - (VMT \div \eta_{2012\ New})) \times 0.12116$$

Where:

ΔMMBtu = Thermal savings for an AEV from displacement of fossil fuels

VMT = Vehicle miles traveled annually

= 12,000 miles[263]

$\eta_{2011\ Earlier}$ = Weighted average efficiency for 2011 and older based on Vermont age distribution

[263] Rounded value of average of 2014 and 2015 per capita VMT for Vermont from VTrans, "The Vermont Transportation Energy Profile," September 2017, page 6, Table 2-1. According to the report, total and per capita VMT in Vermont reached their lowest levels in 2014 and then increased in 2015 due to increased economic activity and lower gasoline prices. 2014 and 2015 VMT values were averaged to reflect gasoline price volatility.

= 20.43 mpg[264]

$\eta_{2012\ New}$ = Weighted average efficiency for 2012 and newer based on Vermont age distribution

= 24.70 mpg[265]

0.12116 = MMBtu per gallon of gasoline

Deemed savings value for first year:

12.29 MMBtu

Loadshape

N/A

Persistence

The persistence factor is assumed to be one.

Lifetime

The lifetime is assumed to be 5 years[266].

Measure Cost

The measure cost is assumed to be $0. There is no cost to the customer, but incentive from the distribution utility will serve as the reason why a customer would retire a vehicle early and then choose from a variety of clean transportation options, which would have other incentives and measure costs associated with them.

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[264] Based on Vermont registration data of models from 2011 and older. Review analysis document on VT REGs by MY sheet of Tier III TAG_Replace your Ride_2021 Analysis.xlsx

[265] Based on Vermont registration data of models from 2012 and newer. Review analysis document on VT REGs by MY sheet of Tier III TAG_Replace your Ride_2021 Analysis.xlsx

[266] Negotiated in 2021 Tier III TAG. 5 years serves as a conservative assumption on how much longer a car would remain on the road.

Pellet and Wood Stoves

Version Date & Revision History
Draft date: 8/25/2021
Effective date: 1/1/2022
End date: TBD

Referenced Documents

1. VT SF Existing Homes Onsite Report_final 021513
2. VGS Usage Regression Work_04182017
3. NMR_Survey Analysis of Owners in Existing Homes in Vermont_Dec 2016
4. VT Res Baseline SFNC Onsite report - DRAFT 051217
5. EIA_Updated Bldg Sector Appliance & Equipment Costs_June 2018
6. VT Dept of Forests_Residential Fuel Assessment Report_Mar 2016
7. VT Dept of Public Service_November 2016 Fuel Price Report
8. tier 3-pellet-wood-stoves-analysis-2021.xlsx

Description
This is a retrofit measure that applies to the installation by an approved contractor of a new wood or pellet stove in a new or existing residential building. It is assumed that the home will use a second space heating system in addition to the stove and that the stove will offset a portion of the existing heating system's fuel consumption.

Stoves must be installed according to manufacturer's recommendations and meet the following minimum efficiency and emissions requirements:

- 70% efficiency
- ≤2.0 of particulate matter less than 2.5 microns (PM2.5)[267]

This measure provides separate assumptions for replacement of existing wood stoves that are still operational. Existing stoves must be non-EPA certified or if EPA-certified, manufactured prior to 1998 and not meeting 2020 New Source Performance Standards.

Definition of Energy Transformation Equipment or Condition
The new equipment must be a new wood or pellet stove installed according to manufacturer's recommendations and meeting minimum efficiency and emissions requirements.

In 2018 and forward, in TEPF-funded programs, EVT will not count the increased wood fuel use associated with biomass fuel switches from fossil fuels. Therefore, this measure does not apply a biomass heating penalty, except when the baseline is wood or pellets.

Definition of Baseline Equipment or Condition
For customers who are not replacing an existing wood stove, the baseline is a blend of LP, oil, wood, pellet, and electric heating systems, based on the percentage of each system installed as a primary heating source in existing Vermont homes for retrofits or in new Vermont homes for new construction (NC).

For customers replacing an existing wood stove, the baseline is an existing wood stove that is still operational. Existing stoves must be non-EPA certified or if EPA-certified, manufactured prior to 1998 and not meeting 2020 New Source Performance Standards.

[267] Requirement from EPA New Source Performance Standards for year 2020.

Algorithms

Demand Impacts

$$\Delta \text{kW} = \Delta \text{kWh}_{Net} \div FLH_{Central}$$

x

Electric Energy Impacts

$$\Delta \text{kWh}_{Net} = \Delta \text{kWh}_{Save} - \Delta \text{kWh}_{Penalty}$$

$$\Delta \text{kWh}_{Save} = FLH_{Central} \times (Capacity \div 1{,}000{,}000) \div \eta_{Base,Electric} \times 293.071 \times \%Stove \times \%Elec$$

$$\Delta \text{kWh}_{Penalty} = FLH_{Stove} \times (Watts_{Stove} \div 1{,}000)$$

kWh_{Net} =

Building Type	New Stove Type	ΔkWh_{Save}	$\Delta kWh_{Penalty}$	ΔkWh_{Net}	ΔkW
Existing	Wood	190.5	N/A	190.5	0.24423
	Pellet	187.5	175.0	12.5	0.01603
NC	Wood	486.6	N/A	486.6	0.74290
	Pellet	479.1	175.0	304.1	0.46427

Fossil Fuel Impacts

$$\Delta MMBtu_{Net} = \Delta MMBtu_{Save} - \Delta MMBtu_{Penalty}$$

$$\Delta MMBtu_{Save,\ LP} = FLH_{Central} \times (Capacity \div 1{,}000{,}000) \div \eta_{Base,LP} \times \%Stove \times \%Fuel_{LP}$$

$$\Delta MMBtu_{Save,\ Oil} = FLH_{Central} \times (Capacity \div 1{,}000{,}000) \div \eta_{Base,Oil} \times \%Stove \times \%Fuel_{Oil}$$

$$\Delta MMBtu_{Save,\ Wood} = FLH_{Central} \times (Capacity \div 1{,}000{,}000) \div \eta_{Base,Wood} \times \%Stove \times \%Fuel_{Wood}$$

$$\Delta MMBtu_{Save,\ Pellet} = FLH_{Central} \times (Capacity \div 1{,}000{,}000) \div \eta_{Base,Pellet} \times \%Stove \times \%Fuel_{Pellet}$$

$$\Delta MMBtu_{Penalty} = FLH_{Central} \times (Capacity \div 1{,}000{,}000) \div \eta_{New\ Stove} \times \%Stove \times (\%Fuel_{Wood} + \%Fuel_{Pellet})$$

Building Type	New Stove Type	ΔMMBtuNet
Existing	Wood	51.39
	Pellet	50.65
NC	Wood	23.57
	Pellet	23.41

Variables for Algorithms

%Elec = Percentage of homes assumed to have electric heating systems; see table below

Building Type	%Elec
Existing[268]	1.4%
New Construction[269]	15.4%

$\%Fuel_{LP}$ = Percentage of homes assumed to use LP heating systems; see table within %FuelWood definition for each building type and fuel type.

$\%Fuel_{Oil}$ = Percentage of homes assumed to use oil heating systems; see table within %FuelWood definition.

$\%Fuel_{Pellet}$ = Percentage of homes assumed to use pellet heating systems; see table within %FuelWood definition.

$\%Fuel_{Wood}$ = Percentage of homes assumed to use wood heating systems; see table below for %Fuel for each building type and fuel type.

Building Type	Fuel Type	%Fuel
Existing[270]	LP	20.0%
	Oil	72.9%
	Wood	5.7%
	Pellet	0.0%

[268] Percentage of heating system fuel types in existing Vermont homes from NMR Group, "Survey Analysis of Owners of Existing Homes in Vermont (Draft)" December 5, 2016: page 29, Table 38 (Efficiency Vermont data). Natural gas, coal, and solar were excluded. The report states that "all nine respondents who use electricity as their primary heating fuel reported that they have electric resistance baseboard rather than an electric heat pump." Percentage of wood from boilers and furnaces (versus stoves) estimated as 4% based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment.

[269] Percentage of heating system fuel types in new residential buildings in Vermont based on data from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017: page 45, Table 46 (Efficiency Vermont data). Natural gas excluded.

[270] Percentage of heating system fuel types in existing Vermont homes from NMR Group, "Survey Analysis of Owners of Existing Homes in Vermont (Draft)" December 5, 2016: page 29, Table 38 (Efficiency Vermont data). Natural gas, coal, and solar were excluded. The report states that "all nine respondents who use electricity as their primary heating fuel reported that they have electric resistance baseboard rather than an electric heat pump." Percentage of wood from boilers and furnaces (versus stoves) estimated as 4% based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment.

New Construction[271]	LP	50.0%
	Oil	5.1%
	Wood	21.8%
	Pellet	7.7%

%Stove = Percentage of annual total heating load provided by stove

%stove	
Wood[272]	**Pellet**[273]
65%	64%

ΔkW = Gross customer annual connected load kW savings for the measure

ΔkWh_{Net} = Gross customer annual kWh savings for the measure after subtracting the kWh penalty from use of a pellet stove

$\Delta kWh_{Penalty}$ = Gross annual kWh penalty from the use of a pellet stove

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[271] Percentage of heating system fuel types in new residential buildings in Vermont based on data from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017: page 45, Table 46 (Efficiency Vermont data). Natural gas excluded.

[272] %stove for wood stoves is calculating using: the percentage of primary (53%) versus supplemental (47%) cordwood users in Vermont and the annual number of cords burned by primary (4.8) versus supplemental (2.1) cordwood users from Vermont Department of Forests, Parks, and Recreation, "Vermont Residential Fuel Assessment for the 2014-2015 Heating Season," March 2016, page 6; an average annual heat load of 80.832 MMBtu for Vermont homes (700 gallons/oil per year based on 2016 VT Tier III TAG agreement/84.2% oil heating system efficiency in existing VT homes); 68% stove efficiency based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment; and 22.0 MMBtu/cord heat content from the November 2016 VT Fuel Price Report. %stove is calculated as ((53% (4.8 cords/yr * 22.0 MMBtu/cord * 68% / 80.832)) + (47% (2.1 cords/yr * 22.0 MMBtu/cord * 68% / 80.832)). See %stove tab in file EVT_Pellet Wood Stove_Analysis_Aug 2018_v2.xlsx for calculation.

[273] %stove for pellet stoves is calculating using: the percentage of primary (70%) versus supplemental (30%) pellet users in Vermont and the annual tons of pelelts burned by primary (4.4) versus supplemental (3.3) pellet users from Vermont Department of Forests, Parks, and Recreation, "Vermont Residential Fuel Assessment for the 2014-2015 Heating Season," March 2016, pages 7-8; an average annual heat load of 80.832 MMBtu for Vermont homes (700 gallons/oil per year based on 2016 VT Tier III TAG agreement/84.2% oil heating system efficiency in existing VT homes); 77% stove efficiency based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment; and 16.4 MMBtu/ton heat content from the November 2016 VT Fuel Price Report. %stove is calculated as ((70% (4.4 tons/yr * 16.4 MMBtu/ton * 77% / 80.832)) + (30% (3.3 tons/yr * 16.4 MMBtu/ton * 77% / 80.832)). See %stove tab in file EVT_Pellet Wood Stove_Analysis_Aug 2018_v2.xlsx for calculation.

ΔkWh_{Save} = Gross customer annual kWh savings for the measure

$\Delta MMBtu_{Net}$ = Gross customer annual MMBtu fuel savings for the measure after subtracting the MMBtu penalty

$\Delta MMBtu_{Penalty}$ = Gross customer annual MMBtu fuel penalty from use of cordwood or pellets, based on the percentage of wood and pellet space heating in homes

$\Delta MMBtu_{Save,LP}$ = Gross customer annual MMBtu fuel savings for the measure (LP baseline)

$\Delta MMBtu_{Save,Oil}$ = Gross customer annual MMBtu fuel savings for the measure (oil baseline)

$\Delta MMBtu_{Save,Pellet}$ = Gross customer annual MMBtu fuel savings for the measure (pellet baseline)

$\Delta MMBtu_{Save,Wood}$ = Gross customer annual MMBtu fuel savings for the measure (wood baseline)

$\Delta MMBtu_{Save}$ = Gross customer annual MMBtu fuel savings for the measure (calculated separately for each baseline fuel type)

1,000,000 = Factor to convert Btu/hr to MMBtu/hr

293.071 = Factor to convert MMBtu to kWh

Capacity = Average capacity of primary space heating systems installed in Vermont homes

Building Type	Capacity[274]
Existing	91,562
NC	93,695

$FLH_{Central}$ = Average full load heating hours of central space heating systems in Vermont homes

Building Type	FLH[275]

[274] FLH and capacity values estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont's Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. For Existing Homes, the RNC data was limited to only those homes with annual gas consumption greater than 25kBtu/sq ft in an attempt to remove the high performance/ low load homes in RNC. See 'VGS Usage Regression Work_04182017.xls' for analysis. For existing homes, final FLH and capacity values were calculated using boiler and furnace weightings from NMR Group, "VT SF Existing Homes Onsite Report," 2013, page 58, Table 5-4. For new construction, weightings are from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017, page 47, Table 47.

[275] FLH and capacity values estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for

Existing	780
NC	655

FLH_{Stove} = Average full load heating hours of stoves

= 1,400[276]

$\eta_{Base,Electric}$ = Efficiency of baseline pellet heating system; see table within $\eta_{Base, Wood}$ definition

$\eta_{Base,LP}$ = Efficiency of baseline LP heating system; see table within $\eta_{Base, Wood}$ definition

$\eta_{Base,Oil}$ = Efficiency of baseline oil heating system; see table within $\eta_{Base, Wood}$ definition

$\eta_{Base,Wood}$ = Efficiency of baseline wood heating system; see table below for η_{Base} values based on building type and fuel type

Building Type	Fuel Type	n_{Base}
Existing[277]	Electric	1.00
	LP	0.871
	Oil	0.842
	Wood	0.65
New Construction[278]	Electric	3.7

homes that participated in Efficiency Vermont's Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. For Existing Homes, the RNC data was limited to only those homes with annual gas consumption greater than 25kBtu/sq ft in an attempt to remove the high performance/ low load homes in RNC. See 'VGS Usage Regression Work_04182017.xls' for analysis. For existing homes, final FLH and capacity values were calculated using boiler and furnace weightings from NMR Group, "VT SF Existing Homes Onsite Report," 2013, page 58, Table 5-4. For new construction, weightings are from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017, page 47, Table 47.

[276] FLH for stoves estimated by the Biomass Energy Resource Center

[277] Efficiencies of LP and oil heating systems in existing homes are a weighted average based on the percentage of boilers and furnaces used as single major heating system in existing Vermont homes from NMR Group, "Vermont Single-Family Existing Homes Onsite Report," February 15, 2013: pages 58-61, Tables 5-4, 5-8 and 5-9. Stoves in existing homes with electric space heating are assumed to replace electric resistance systems with an efficiency of 1.00. Efficiency of wood heating systems is based on professional judgment. See nBase & nExisting tab within file EVT_Pellet Wood Stove_Analysis_Aug 2018_v2.xlsx for calculations.

[278] Efficiencies of electric, LP, and oil heating systems in new homes are based on data from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report),"May 12, 2017. Boiler, furnace, and heat pump weightings are

	LP	0.938
	Oil	0.863
	Wood	0.75
	Pellet	0.76

$\eta_{Baseline\ Stove}$ = Efficiency of baseline stove that it is assumed a customer would install after the remaining life of the existing wood stove (10 years)

= 0.73[279]

$\eta_{Existing\ Stove}$ = Efficiency of existing wood stove that is being replaced

= 0.52[280]

$\eta_{New\ Stove}$ = Efficiency of new stove[281]

New Stove Type	$n_{New\ Stove}$
Wood	0.75
Pellet	0.76

$Watts_{Stove}$ = Energy consumption (watts) of new stove

New Stove Type	$Watts_{Stove}$
Wood	0

from page 47, Table 47, and equipment efficiencies are from pages 49-50, Tables 50-52. Oil boilers, combined appliances, wood stoves and furnaces, pellet stoves, natural gas units, and heat pumps were removed from boiler and furnace weighting calculations. Values for Efficiency Vermont used. nBase (LP) is a weighted average based on the percentage of LP boilers and furnaces installed in new Vermont homes. Nbase (oil) is the efficiency of oil boilers. Efficiencies of wood and pellet heating systems are the efficiencies of new stoves meeting 2020 NSPS and 70% efficiency requirements on EPA's list of certified wood heaters as of May 2018. See nBase & nExisting tab within file EVT_Pellet Wood Stove_Analysis_Aug 2018_v2.xlsx for calculations.

279 Efficiency of baseline stove is the average efficiency of stoves meeting 2020 NSPS requirements from EPA's list of certified stoves as of May 2018.

280 Efficiency of existing wood stove being replaced is an estimate provided by the Biomass Energy Resource Center based on review of information provided by the Alliance for Green Heat.

281 Average efficiency of new stoves meeting 2020 NSPS and 70% efficiency requirements on EPA list of certified wood heaters as of May 2018

Pellet	125[282]

Persistence

The persistence factor is assumed to be one.

Lifetime

The expected measure life is assumed to be 18 years.[283]

Measure Cost

The measure cost is the total installed cost (equipment and labor) for a wood or pellet stove:[284]

New Stove Type	Stove Cost	Installation Cost	Other Costs*	Total Installed Cost
Cordwood	$2,475	$383	$469	$3,319
Pellet	$3,366	$340	$694	$4,400

*Costs not included in "stove cost" or "installation cost," such as miscellaneous parts or recycling fees.

[282] Typical pellet stove energy consumption at normal burn rates estimated by the Biomass Energy Resource Center. Includes ignitor, feed auger, and blowers.
[283] Average of lifetimes provided for residential cordwood and pellet stoves in U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," June 2018.
[284] Average costs from the Renewable Energy Resource Center from December 2016 through April 2017. See Measure Cost tab within file EVT_Pellet Wood Stove Analysis_Aug 2018_v2.xlsx.

O&M Cost Adjustments

Building Type	New Stove Type	Annual Baseline O&M Cost[285]	Annual O&M Costs with New Stove[286]	Annual O&M Cost Adjustment (Penalty)
Existing	Wood	$106	$229	-$123
	Pellet		$298	-$192
NC	Wood	$125	$236	-$111
	Pellet		$305	-$180

[285] Baseline O&M costs for existing homes are based on the percentage of each heating system fuel type in existing Vermont homes from NMR Group, “Survey Analysis of Owners of Existing Homes in Vermont (Draft)” December 5, 2016: page 29, Table 38 (Efficiency Vermont data). LP and oil systems are weighted based on the percentage of boilers and furnaces in Vermont homes from NMR Group, "VT SF Existing Homes Onsite Report," 2013, page 58, Table 5-4. Baseline O&M costs for new construction are based on the percentage of each heating system in new Vermont homes from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," Prepared by NMR Group for Vermont DPS, May 12, 2017: page 47, Table 47 (Efficiency Vermont data). Combined appliances and natural gas and systems excluded. Costs for LP and oil boilers and furnaces, wood stoves, pellet stoves, and heat pumps are from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. According to the report, O&M costs for electric resistance heating systems are negligible; $10 was assumed in these calculations. Costs for cordwood boilers and furnaces are assumed to the same as costs for pellet boilers. See "O&M Costs" tab in file EVT_Pellet & Wood Stoves_Analysis_Aug 2018_v2.xlsx for calculation.

[286] O&M costs with new wood stove include the percentage of existing heat system O&M costs that are not displaced by the new stove (Baseline O&M Cost * (1 - %stove)), plus the full O&M costs associated with the new stove. New stove O&M costs are from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. See O&M Costs tab within file EVT_Pellet Wood Stoves_Analysis_Aug 2018_v2.xlsx for calculation.

Heat Recovery Ventilator and Energy Recovery Ventilator

Version Date & Revision History

Draft date: 8/14/2022
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Referenced Documents

- VT Res Baseline SFNC Onsite report - DRAFT 051217
- EVT_CCHP_MOP and Retrofit_2021.xlsx
- Tier III ERV_HRV_analysis 2022b.xlsx

Description

This measure claims savings for the installation of a new HRV or ERV.

Background, from Natural Resources Canada:

A heat recovery ventilator (HRV) is a ventilation device that helps make your home healthier, cleaner, and more comfortable by continuously replacing stale indoor air with fresh outdoor air. New homes built since 1977 are more airtight, which helps save energy but can make the inside air stale. To complement this airtightness, modern homes use HRVs to distribute fresh air throughout the house.

Recovering the heat: During the heating season, the HRV captures heat from the stale air leaving your house, and uses it to preheat the fresh air coming into your house. Similarly, an HRV can reverse this process during the cooling season, removing some of the heat from the incoming air and transferring it to the outgoing air.

Goodbye pollutants: Not only does an HRV bring in fresh air, but it will also get rid of many of the pollutants in your home like excess moisture and moulds, household chemicals and bacteria.

Energy recovery ventilators (ERVs) are a type of HRV that can exchange both heat and moisture.

Moisture control: An ERV can give you more control over moisture levels in your home during warm and humid weather, by keeping excess moisture out of your home. Because less energy is required to lower the temperature of dry air compared to moist air, an ERV can reduce the work your air conditioner needs to do and save you money.

Moisture recovery: If your winter climate is extremely dry, ERVs recover some of the moisture that would leave your house through a regular HRV. This helps you maintain a comfortable humidity level within your home, avoiding static electricity, sore throats and other discomforts caused by air that is too dry.

This characterization applies to Residential New Construction (single family detached) applications as a Market Opportunity measure.

Where do energy savings come from? Recovery units with a higher efficiency offer more efficient heat exchange, as well as a lower power draw.

ERV/HRV performance data is drawn exclusively from the Home Ventilation Institute database. Both HRVs and ERVs are assumed to be operational continuously to provide whole-house ventilation.

Each claimed system will be binned into one of 5 size categories based on the recovery unit's rated supply air performance, as determined by the Home Ventilation Institute. Supply air is the volumetric flow (CFM) of *outside air* that the unit is capable of moving. This is the maximum rated flow in CFM at 0.4" w.g.

HRV and ERV systems are generally operated below the maximum flow rate most of the time, with occasional higher flows for spot ventilation. The average operating supply flow for each size category is assumed to be equal to the average flow rate at which the ventilation systems rated SRE is measured.

Definition of Energy Transformation Equipment or Condition

The efficient condition is a new HRV/ERV. Two categories of high efficiency HRV/ERVs are defined below:

Efficiency Level	HRV	ERV
Tier 1	SRE 70% or above	SRE 70% or above
Tier 2	SRE 80% or above	SRE 80% or above

Definition of Baseline Equipment or Condition

The baseline condition is assumed to be no HRV/ERV currently installed.

Algorithms

Net Impacts

$$\Delta MMBtu = \sum((\%HeatSource_{Fuel} \times CFM \times HDH \times 1.08 \div 1{,}000{,}000) \times ASRE_{Eff} \div Eff_{Fuel}$$

$\%HeatSource_{Fuel}$ = Percentage of heating savings assumed to be each fuel type: propane, oil, wood, or wood pellets.

= See Percent Heat Source column of Table 1 in the Reference Tables section.

CFM =Assumed average operating supply CFM for the ventilation system. See the Assumed Average Supply CFM column in the table below[287].

Size	Average Nominal Net Supply CFM	Assumed Average Supply CFM
30 to less than 80 CFM	67	53
80 to less than 130 CFM	108	60
130 to less than 180 CFM	150	72
180 to less than 230 CFM	198	85

[287] HRV and ERV systems are generally operated below the maximum flow rate most of the time, with occasional higher flows for spot ventilation. The average operating supply flow for each size category is assumed to be equal to the average flow rate at which the ventilation systems rated SRE is measured. See 'Data Summary' and 'HVI_ER-HRV' sheets of Tier III ERV_HRV_Analysis_2022.xlsx for more details.

Size	Average Nominal Net Supply CFM	Assumed Average Supply CFM
230 or higher CFM	267	115

HDH = Heating degree hours

= 129,936[288]

1.08 = Specific heat of air (0.24 Btu/lb°F) x density of inlet air @ 70F (0.075 lbs/cf) x 60 min/hr in Btu/hr-°F-CFM

1,000,000 = Btu per MMBtu

$ASRE_{Eff}$ =HVI-Certified Adjusted Sensible Recovery Efficiency of the efficient unit.

= See Table 2 in the Reference Tables section.

EFF_{Fuel} = Heating system efficiency for each fuel type: propane, oil, wood, or wood pellets.

= See Average Efficiency column of Table 1 in the Reference Tables section.

Gross-to-Net Savings Factors

Measure Category	HVAC	
Product Description	ERV/ERV	
	Freerider	Spillover
	1.00	1.00

Persistence

Persistence is assumed to be one.

Lifetime

The expected measure life is assumed to be 15 years[289] for a new HRV or ERV.

Measure Cost

The retrofit cost for a new ERV/ERV can be found below[290].

[288] Based on analysis of TMY data with 58°F base temperature. See the 'Weather data' sheet of Tier III ERV_HRV_Analysis_2022.xlsx for more details.
[289] Conservative assumption based on reviewing specification sheets of available units.
[290] Internet-sourced pricing data used to establish incremental costs. See 'HVI_ER_HRV' and 'Cost data' sheets of Tier III ERV_HRV_Analysis_2022b.xlsx for more details.

Efficiency Level	HRV	ERV
Tier 1	$1,012	$1,172
Tier 2	$1,203	$1,583

O&M Cost Adjustments

N/A

Reference Tables

Table 1: Heating Fuel Types and Efficiencies

Heating Fuel Type	Percent Heat Source[291]	Average Efficiency	Unit
Oil	5.1%	86.3%	AFUE
Propane	48.7%	93.7%	AFUE
Wood	21.8%	75.0%	Overall Efficiency
Pellets	7.7%	76.0%	Overall Efficiency
Electric	16.7%	3.7	COP

Table 2: Average Efficiencies[292]

System Type	Efficiency Category	Average ASRE	Average ATRE
ERV	Baseline	70	50.2
	Tier 1	79.1	57.7
	Tier 2	85.3	66.2
HRV	Baseline	70.8	N/A
	Tier 1	79	N/A
	Tier 2	86.4	N/A

[291] Vermont Residential New Construction Baseline Study Analysis of On-Site Audits Draft Report (May 12, 2017), Table 47, with natural gas systems removed. See 'Assumptions' and 'Heating Efficiencies' sheets of Tier III ERV_HRV_Analysis_2022.xlsx for more details.

[292] Average of ASRE and ATRE for each efficiency category from Home Ventilating Institute list of HVI-Certified Products (https://www.hvi.org/hvi-certified-products-directory/) accessed February, 2022. See 'Data Summary' and 'HVI_ER-HRV' sheets of Tier III ERV_HRV_Analysis_2022.xlsx for more details.

Electric Snowmobiles

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End date: TBD

Referenced Documents

- Electric Snowmobiles Tier III TAG Analysis.xlsx

Description

This measure claims savings for the purchase of a new electric snowmobile, which assumes a fossil fuel savings by avoided a purchase of an internal combustion engine snowmobile. The measure has savings characterized for a recreational use and for commercial use.

Definition of Energy Transformation Equipment or Condition

The efficient condition is a new electric snowmobile for either recreational or commercial use.

Definition of Baseline Equipment or Condition

The baseline condition is assumed to be an internal combustion engine snowmobile.

Algorithms

Net Impacts

$$\Delta MMBtu = \text{Miles} \times \text{MPG} \times 120{,}286 \div 1{,}000{,}000$$

$$kWh = Miles \times Battery\ Range \times Battery\ Capacity$$

ΔMMBtu = Fossil Fuel Savings from Energy Transformation measure

= Savings can be found in analysis document[293]

kWh = Electric penalty from Energy Transformation Measure

= Penalty can be found in analysis document [294]

Miles = Annual miles traveled by snowmobile

[293] Fossil Fuel sheet of Electric Snowmobiles Tier III TAG Analysis.xlsx analysis document shows the MMBtu impacts of this measure.
[294] kWh sheet of Electric Snowmobiles Tier III TAG Analysis.xlsx analysis document shows the electric impacts of this measure.

= 750 miles for recreational[295] and 500 miles for commercial[296]

MPG = Miles per gallon of an ICE snowmobile

= 16 MPG for a 4 stroke engine and 10 MPG for a 2 stroke engine[297]

Battery Range = Average distance one battery can provide in miles off of one charge

= 62.14 miles[298]

Battery Capacity = Electrical energy in a single battery pack

= 23.72 kWh[299]

120,286 = Constant to convert gallons of gasoline to Btu

1,000,000 = Constant to convert Btu to MMBtu

Gross-to-Net Savings Factors

Measure Category	Transportation	
Product Description	Electric Snowmobiles	
	Freerider	Spillover
	1.00	1.00

Persistence

Persistence is assumed to be one.

Lifetime

The expected measure life is assumed to be 8 years[300] for a new electric snowmobile.

Measure Cost

The retrofit cost[301] for a new standard electric snowmobile is $17,490 and $19,490 for a performance electric snowmobile.

295 Assumption derived from conversations with GMP and retailers that sell snowmobiles for recreational purposes.
296 Assumption derived from conversations with GMP and their large ski resort partners.
297 Information provided from Taiga snowmobiles on ICE snowmobile consumption.
298 Actual data from Taiga Snowmobiles specification sheets.
299 Actual data from Taiga Snowmobiles specification sheets.
300 The manufacturer of the Taiga snowmobile was not able to provide a lifetime, so the TAG agreed to use the lifetime of the electric vehicle with that lack of information for an electric snowmobile. This assumption will be updated when more information is available.
301 Review of available Taiga snowmobiles from Manufacturer. Find cost review on Cost sheet of analysis document: Electric Snowmobiles Tier III TAG Analysis.xlsx.

O&M Cost Adjustments

N/A

Window Inserts

Version Date & Revision History

Draft date: 8/14/2022
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End date: TBD

Referenced Documents

- WexEnergy WindowSkin Energy Savings Calculator v6.3 VT 04282022.xlsx
- Taitem Review of Intertek U-factor Result Analysis 030922.pdf
- UFactor Analysis and Summary Table 030922.xlsx
- WindowSkin Savings Calculator Overview for VEIC 04282022.pdf

Description

This measure claims savings for the installation of a window insert[302] on an existing single pane window in either a single family or multifamily building that uses fossil fuel heating.

Definition of Energy Transformation Equipment or Condition

The efficient condition is a single pain window that has a window insert applied to the interior pain.

Definition of Baseline Equipment or Condition

The baseline condition is assumed to be a single pane.

Algorithms

Net Impacts

$$\Delta MMBtu = (8760\text{ Weather Data } \times (U_E - U_{WS}) \times A_E \times (1 \div 1{,}000{,}000)) \div E_{Dist}$$

ΔMMBtu = Per window fossil fuel savings

= 1.34 MMBtu for single family and 0.92 MMBtu for multifamily[303]

8760 Weather Data = Weather data from various sites[304]

= Refer to analysis document for data

[302] The current analysis is characterized for the installation of a Wex Windows WindowSkin which is custom sized for a customer's windows. This characterization will be updated once more window inserts are available on the market and have been evaluated.
[303] Calculations can be found on Summary sheet of analysis document: WexEnergy WindowSkin Energy Savings Calculator v6.3 VT 04282022.xlsx.
[304] New York State TRM data is used for this analysis. Weather data can be found on 8760 Data (with setback) sheet of analysis document: WexEnergy WindowSkin Energy Savings Calculator v6.3 VT 04282022.xlsx.

U_E = U-factor of existing window

= Refer to analysis document for data[305]

U_{WS} = Window Insert R-Value

= 0.7 R-Value[306]

A_E = Window glazing area in square feet

= 12 ft^2[307]

1,000,000 = Constant to convert to MMBtu

E_{Dist} = Efficiency of fossil fuel heating system

= Varies based on system, refer to analysis document[308]

Gross-to-Net Savings Factors

Measure Category	Thermal Shell	
Product Description	Window Inserts	
	Freerider	Spillover
	1.00	1.00

Persistence

Persistence is assumed to be one.

[305] Calculations can be found on Project Input sheet of analysis document: WexEnergy WindowSkin Energy Savings Calculator v6.3 VT 04282022.xlsx.
[306] WindowSkin R-Value derived from NFRC 102: procedure for Measuring the Steady-State Therman Transmittance of Fenestration Systems by Intertek and further validation by Taitem Engineering's review of the derivation of WindowSkin's R-value.
[307] In discussion with TAG stakeholders, it was agreed upon that the average window is approximately 3 feet by 4 feet and that 12 square feet will be used in this analysis.
[308] New York State TRM assumptions used and values can be found on Heating Source sheet of analysis document: WexEnergy WindowSkin Energy Savings Calculator v6.3 VT 04282022.xlsx.

Lifetime

The expected measure life is assumed to be 10[309] years for a new battery.

Measure Cost

The retrofit cost for a new $150[310].

O&M Cost Adjustments

N/A

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[309] The manufacturer provided a 25 year measure life for these inserts, but the TAG agreed upon using a more conservative value of 10 years to align with potential move out and change of windows.

[310] Wex Windows provided costs per square foot of Windowskins: $12.50. Assuming the average window is 12 square foot, the total cost of these inserts is $150.