Advanced Thermostat

Version Date & Revision History

Draft date: 8/1/2017
Effective date: 1/1/2018
End date: TBD

Referenced Documents

1) VT-RES-New-Construction-On-Site-Final-Report-2-13-13
2) IL SAG Smart Thermostat Preliminary Gas Impact Findings 2015-12-08 to IL SAG
3) Studies informing the TRM Savings Characterization for Advanced Thermostats
4) VT SF Existing Homes Onsite Report_final 021513
5) Advanced Thermostat Analysis_04182017_FINAL
6) VGS Usage Regression Work_04182017

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[2]. That work is not yet complete but does inform the treatment of some aspects of this characterization and recommendations.

Savings estimates are provided for Existing Homes and New Construction. Note all savings will be claimed through Efficient Products, however the baseline for New Construction is a programmable thermostat (due to code requirements) while the baseline for Existing Homes is assume to be a mix of manual and programmable thermostats.

The measure assumes that the advanced thermostat is controlling a portion of the whole home's heating load. Efficiency Vermont will track and provide incentives for up to two advanced thermostats per home.

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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.

[2] The ENERGY STAR program discontinued its support for basic programmable thermostats effective 12/31/09, and is presently developing a new specification, 'Connected Thermostats V1.0'. This measure will be updated in 2017 to reflect the forthcoming final ENERGY STAR spec and performance values reported on the qualified product list, as well as results from the Efficiency Vermont pilot (e.g. system run time, # zones per home, # of smart thermostats installed, installation type).

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

Definition of Energy Transformation Equipment or Condition

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[3] 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 existing homes the baseline is assumed to be a mix of programmable and manual thermostats (67% manual and 33% programmable - based upon Vermont Single-Family Existing Homes Onsite Report, 2/15/2013, ‘Table 5-13 Type of Thermostat’).

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

$$\Delta MMBtu = \Sigma\ (Heating\_Consumption \times \%Controlled) \times Heating\_Reduction$$

Where:

ΔMMBtu	= Thermal savings from displacement of fossil fuels
%Controlled	= Assumed percentage of total heating load being controlled by thermostat. = 69% for EH and 53% for RNC[4]
Heating_Consumption	= Estimate of annual household heating consumption

[3] 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.

[4] Based on review of # of thermostats per home data from Vermont Single-Family Existing Homes Onsite Report, 2/15/2013 and Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. See 'Advanced Thermostat Analysis_04182017_FINAL.xls'

	Gas Heating Consumption (MMBtu)	
	Existing Homes[5]	New Construction[6]
Gas	81	67
Oil	84	70
Unknown	82	67

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

Program	Existing Thermostat Type	Heating Reduction[7]
Existing Homes	Unknown (Blended)	7.7%
New Construction	Programmable	5.6%

Gross-to-Net Savings Factors

Table 1 - 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[8] 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).

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[5] 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, 2/15/2013. Note the FLH calculation attempts to isolate heating only consumption (removing DHW and other loads). For calculation of savings see “Advanced Thermostat Analysis_04182017.xlsx”, for details.

[6] 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 “Advanced Thermostat Analysis_04182017.xlsx”, for details.

[7] 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 homes. The weighting of manual to programmable thermostats for when unknown is based upon Vermont Single-Family Existing Homes Onsite Report, 2/15/2013, ‘Table 5-13 Type of Thermostat’.

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

For retail, Bring Your Own Thermostat (BYOT) programs[9], or other program types the average incremental cost for the new installation measure is assumed to be $175[10].

For new construction, the incremental cost between a programmable and advanced thermostat is assumed to be $150[11].

O&M Cost Adjustments

N/A

Savings Summary[12]

Blended Advanced Thermostat Savings	
ΔMMBtu	4.36

[9] 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.

[10] 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.

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

[12] 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: 10/27/2017

Effective date: 1/1/2018

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 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 single-zone variable speed mini-split heat pumps in a residential application. 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 2 – Baseline Efficiency Criteria

Equipment	AFUE
Existing Fossil Fuel System	85%[13]

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:

[13] 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 3 – High Efficiency Criteria[14]

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[15]

= 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

[14] 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.

[15] 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 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[16]. This analysis includes Vermont metered MMBtu adjustments by taking a 48% adjustment to the existing 85% heating offset assumed,[17] 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[18]. 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[19]

= 95% if controls are not present

= 100% if controls are present

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

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

[18] 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.

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

Bonus Factor = Weatherization of existing building[20]

= 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

Freeridership/Spillover Factors[21]

Measure Category	HVAC	
Product Description	Efficient ductless mini-split, heat pump	
	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.[22]

Measure Cost[23]

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

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

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

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

[23] 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.

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

O&M Cost Adjustments

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

Net Impacts[24]

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

[24] 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. 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 4 – Baseline Efficiency Criteria

Equipment	AFUE
Existing Fossil Fuel System	85%[25]

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 5 – High Efficiency Criteria

[25] 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.)

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[26]

= 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.

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

[26] 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.

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[27]. This analysis includes Vermont metered MMBtu adjustments by taking a 48% adjustment to the existing 85% heating offset assumed,[28] 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[29]. 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)

Adjustment Factor = Integrated Controls[30]

= 95% if controls are not present

= 100% if controls are present

Bonus Factor = Weatherization of existing building[31]

= 100% if in a high performing home

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

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

[29] 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.

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

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

= 81% if in a low performing home

Loadshape

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

Table 6 – Freeridership/Spillover Factors[32]

Measure Category	HVAC	
Product Description	Efficient ductless mini-split, multi head heat pump	
	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.[33]

Measure Cost [34]

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

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

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

[34] 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.

O&M Cost Adjustments

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

Net Impacts[35]

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

[35] 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[36]
Wh/mile	= Electric efficiency (Wh/mile) of new electric bicycle
	= 20 Wh/mile[37]

[36] 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%).

[37] Average electric efficiency from Ithaca's Boxy Bikes (http://boxybikes.com/learn/) and electricbike.com (https://www.electricbike.com/watt-hours/).

1,000,000 = Factor to convert Wh to MWh

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[38]

121,160 = Weighted average energy content (Btu/gallon) of gasoline and diesel in Vermont privately-owned vehicle fleet[39]

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.

[38] 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.

[39] 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.[40]

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[41]	$137.50[42]	$484

[40] 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).

[41] 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.

[42] 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
Draft date: 8/27/2017
Effective date: 1/1/2018
End date: TBD

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 estimated to be TBD.

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[43]
School Bus	7 MPG[44]
Paratransit Vehicle	7.69 MPG[45]

Btu/Gallon = Weighted average energy content (Btu/gallon) of fuel used in baseline vehicle[46]

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

[43] 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."

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

[45] 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

[46] 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**	
Track Name	**Track No.**	**Spillover**	**Freerider**	**Freerider**	**Spillover**	**Freerider**	**Spillover**
TBD	TBD	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[47]
Paratransit Vehicle	8 years[48]

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[49]
School Bus	$128,796[50]
Paratransit Vehicle	$75,000[51]

[47] Bus lifetime from Columbia University, "Electric Bus Analysis for New York City Transit," May 2016.
[48] 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.
[49] Price of new diesel transit bus from "Electric Bus Analysis for New York City Transit."
[50] Price of new diesel school bus is MSRP with 8% sales tax removed, from webinar "Benefits of Zero Emissions School Buses," July 20, 2016.
[51] Price of new gasoline paratransit vehicle from FTA, "Useful Life of Transit Buses and Vans."

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.

Vehicle Type	Conventional Vehicle O&M Cost ($/mile)	Electric Vehicle O&M Cost ($/mile)	Incremental Lifetime O&M Savings
Transit Bus	$0.59/mile[52]	$0.36/mile[53]	$0.23/mile x VMT x 12 years
School Bus	$0.50/mile[54]	$0.16/mile[55]	$0.34/mile x VMT x 12 years
Paratransit Vehicle	$1.00/mile[56]	$0.33/mile[57]	$0.67/mile x VMT x 8 years

[52] 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.

[53] 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.

[54] Maintenance cost for diesel school buses from fleet data reported in the February 3, 2016 issue of School Transportation News.

[55] Maintenance cost for electric school buses from NREL, "Foothill Transit Battery Electric Bus Demonstration Results," Jan 2016.

[56] Maintenance cost for gasoline paratransit vehicles from U.S. Department of Transportation, "Bus Lifecycle Cost Model for Federal Land Management Agencies," page 6.

[57] 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

Effective date: 1/1/2018

End date: TBD

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 multifamily 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

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

Where:

ΔMMBtu = Annual thermal savings from displacement of fossil fuels

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

= 2.2[58]

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

= 0.83[59]

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

= 1.5[60]

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

= 0.95[61]

Tperson/day = Average daily length of use per person, per faucet (min/person/faucet)
= 1.6[62]

people = Average number of people per household

[58] Federal standard for faucets, 10 CFR 430.32(o)
[59] 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.
[60] Federal standard for faucets, 10 CFR 430.32(o)
[61] 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.
[62] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, Table 6, page 10.

= 2.33[63]

usedays/year = Days faucet is used per year

= 365

DR = Percentage of water flowing down drain

= 70%[64]

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[65]

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

= 51.9 °F[66]

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

ηFuel_DHW = Recovery efficiency of fuel water heater

= 78%[67]

ISR = In service rate, or the percentage of units rebated that are actually installed

= 100% for direct install and 58%[68] 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

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63 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.

64 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.

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

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

67 Based on a review of fuel DHW systems available in AHRI database.

68 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.

= For direct install where DHW fuel type is unknown or for free giveaways, assume 73%:[69]

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

Program Type	∆MMBtu
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**	
Track Name	**Track No.**	**Freerider**	**Spillover**
LISF Retrofit	6034LISF	1.0	1.0
Res Retrofit	6036RETR	0.90	1.0

Persistence

The persistence factor is assumed to be one.

Lifetimes

10 years[70]

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).

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[69] 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.

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

O&M Cost Adjustments

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

Low Flow Faucet Showerhead

Version Date & Revision History

Draft date: 10/15/2017

Effective date: 1/1/2018

End date: TBD

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 multifamily 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[71]

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

= 1.5

Tshower = Average shower length in minutes

= 7.8[72]

people = Average number of people per household

= 2.33[73]

showers = Showers per person per day

= 0.6[74]

usedays/year = Days faucet is used per year

= 365

SH/home = Average number of showerheads per household

= 1.3[75]

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[76]

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

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[71] 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.

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

[73] 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.

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

[75] 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.

[76] 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[77]

ηFuel_DHW = Recovery efficiency of fuel water heater

= 78%[78]

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**	
Track Name	**Track No.**	**Freerider**	**Spillover**
LISF Retrofit	6034LISF	1.0	1.0
Res Retrofit	6036RETR	0.90	1.0

Persistence

The persistence factor is assumed to be one.

Lifetimes

10 years[79]

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.

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

Electric Vehicle Charging Stations

Version Date & Revision History
Draft date: 1/12/2018
Effective date: 1/1/2018
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, 20180104 EV charging usage summary_nolocations.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.[80]

Electric Energy Impacts

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[80] 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[81]

= Custom input from utility based on actual metered data OR

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

= Deemed value[82]

Charger Location	**kWh/year per port**
General Public Level 2	889
General Public DC Fast Charger	1,067
Workplace Level 2	1,222

%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

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

$$\Delta MWh_{FossilFuel} = \ \Delta MMBtu/9.31$$

Where:

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

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

= 0.325 kWh/mile[83]

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[81] This is based on per port, so a two port charger would claim twice the deemed value.

[82] Based on analysis of EV charging usage. See 20180104 EV charging usage summary_nolocations.xlsx for data.

[83] 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

$EFF_{Charging}$ = Efficiency of charging station[84]

= 86.4%[85] 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[86]

121,160 = Weighted average energy content (Btu/gallon) of gasoline and diesel in Vermont privately-owned vehicle fleet[87]

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

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

9.541 = Factor to convert MMBtu to MWh[88]

Other factors as defined above.

Net Impacts

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

Loadshape

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.

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

[85] 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.

[86] 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.

[87] 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

[88] 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 varies based on the savings claim approach.

- For metered data, measure lifetime is the duration of the metering.
- For a custom input, measure lifetime is based on installation specific assumptions.
- For a deemed approach, the measure lifetime is 10 years.

Measure Cost

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

Type of Charging Station	**Incremental Cost**[89]
Level 2 Public	$11,800
DC Fast	$55,000

O&M Cost Adjustments

Annual maintenance costs are $400.[90]

[89] 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.
[90] 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.