# Driving the Heat Pump Market

LESSONS LEARNED FROM THE NORTHEAST

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**Maps in State Sections:**

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# Definitions

**Air-source heat pump (ASHP):** A heat pump system that transfers heat from air to another medium, typically air for space heating and water for water heating. This report uses **ASHP** to refer specifically to air-to-air applications and heat pump water heater (**HPWH**) when referring to air-to-water applications.

**Baseline:** The level of efficiency that would be achieved without any efficiency project or program.

**Cold climate air source heat pump (ccASHP):** Air source heat pumps optimized for performance in cold temperatures. Northeast Energy Efficiency Partnerships (NEEP) maintains a specification and product list for **ccASHPs** that meet standards for performance at low temperatures.

**Distributed energy resources (DER):** Physical and virtual assets, such as renewable energy, energy efficiency, demand response, and storage, that are deployed across the distribution grid, typically close to load, and usually behind the meter, which can be used individually or in aggregate to provide value to the grid, individual customers, or both (definition adapted from Advanced Energy Economy).

**Downstream programs:** Efficiency program that provides a rebate directly to a consumer for the purchase of a more efficient product.

**Ducted heat pump:** An air-source heat pump that is attached to ductwork to carry conditioned air to different parts of a building.

**Ductless heat pump:** An air-source heat pump that is not attached to ductwork.

**Ductless mini-split:** An air-source heat pump that is split (meaning that there is a coil, or heat transfer surface, inside the building and a coil outside the building). Mini-splits have an evaporator/air handling unit inside the building and a condenser/compressor outside the building.

**Geothermal heat pump:** Also known as Ground Source Heat Pump (**GSHP**). Exchanges heat with the ground or underground water source to provide efficient heating, cooling, and potentially hot water.

**Head:** This refers to the air-handling system installed as part of ductless air source heat pump inside a building. **ASHPs** are described as single-head or multi-head. A single-head system has one interior air handling system. A multi-head system includes multiple interior air-handling systems which allows air heating and cooling in multiple rooms.

**Heat pump:** An energy efficient technology that uses electricity to move heat from one place to another. Because it takes less energy to move heat than to generate heat, heat pumps can provide space heating and cooling or water heating using significantly less energy than other heating and cooling systems.

**Heat pump water heater (HPWH):** Domestic hot water system using heat pump technology to transfer heat from surrounding air to water in a tank. **HPWHs** have the ability to store energy in hot water, making them an option for grid integration opportunities.

**HVAC:** Heating, Ventilation, and Air Conditioning.

**Hybrid heat pump:** A heat pump system that combines heat pump technology with a traditional combustion system such as a gas furnace. These systems allow the homeowner to manually switch the fuel source from gas to electric or electric to gas.

**Market opportunity:** Constructing a new building, installing new equipment, or replacing equipment at the end of its useful life.

**Measure:** A specific energy efficiency technology installed through an efficiency program, often supported with incentives. For example: LED light bulb, efficient refrigerator, mini-split heat pump.

**Midstream program:** Efficiency program that provides incentives to wholesale distributors or retailers to stock and sell more efficient products. In heat pump programs, this may include incentives to installation contractors.

**Retrofit:** Replacing equipment early or retrofitting a building to make it more energy-efficient.

**TOU:** Time-of-use electric rate.

**Upstream program:** Typically refers to an efficiency program aimed at encouraging manufacturers to make the most efficient equipment available. Some states also use the term for programs that provide incentives to distributors.

**ZER:** Zero energy ready.

# Executive Summary

California, New York, and several New England states have identified electrification of space and water heating in buildings as a critical step to reach greenhouse gas (GHG) reduction goals. When coupled with clean electricity generation, electrification of heating and hot water systems using heat pump technology can reduce GHG emissions and fossil fuel use. Air-source heat pumps (ASHP) are a key technology for building electrification, but there are still a number of barriers to their adoption by customers, installation contractors, and other market actors.

While all the Northeastern states tend to benefit from the generally favorable customer economics associated with fuel switching from propane or oil to ASHPs, programs in the region are taking different approaches to incentivizing heat pumps and are at varying stages of maturity. As a result, market adoption of ASHPs is highly variable by state. **This report reviews the policy, regulatory, and program frameworks in Northeast states – New England plus New York – to identify the key factors driving program success and overcoming barriers to ASHP adoption.**

The report focuses specifically on ductless mini-split heat pumps used for heating and cooling, which are the most common and rapidly growing heat pump technology in the Northeast. However, many of the lessons learned and recommendations are also applicable to other heat pump technologies, most notably heat pump water heaters (HPWHs), which are suitable for residential applications. Ground source heat pumps (GSHPs) are much more expensive and, in the Northeast, best suited to new construction and commercial applications. As such, GSHPs face a different set of opportunities and barriers and are not the focus of this report.

## Lessons Learned from the Northeast

States across the Northeast have developed a number of different policies, programs, and mechanisms to incorporate heat pump technology into their energy efficiency portfolios and renewable energy goals. With one of the cleanest electric grids in the country, and widespread use of oil and propane for home heating, ASHPs – particularly ductless mini-split heat pumps – provide an efficient and affordable option for heating in this region.

In the policy arena, New England states have robust GHG emissions goals, Energy Efficiency Resource Standards (EERS), and Renewable Portfolio Standards (RPS). Depending on the jurisdiction and program administrator, heat pumps are either identified as an "**energy efficiency**" measure or as a "**renewable heating and cooling**" measure. From a policy perspective, as an energy efficiency measure, heat pumps are linked to a state's EERS, meaning that their purpose is to reduce energy use. As a renewable heating and cooling measure, it is more likely that heat pumps are linked to an RPS, meaning that their purpose is to enable buildings to be heated and/or cooled using renewable energy. In some states in the region, heat pumps are incentivized so that they can serve as both an energy efficiency measure and a renewable heating and cooling measure. As a result, there is not currently one clear regional policy, regulatory, or program framework for heat pump deployment. Each state has its own policy and programmatic approaches and these can vary widely between neighboring states.

For example, New York's many Reforming the Energy Vision (REV) proceedings seek to reduce GHG emissions and create a more efficient grid by expanding distributed and utility-scale renewables and other distributed energy resources (DER), while also reducing energy consumption in buildings in a fuel-neutral context. Governor Cuomo recently announced the establishment of a fuel-neutral New York State energy efficiency target by Earth Day, 2018. Vermont's Renewable Energy Standard not only sets requirements for renewable energy generation and distributed generation, but it also tasks electric utilities with reducing customer use of fossil fuels through "energy transformation" projects. Rhode Island recently adopted a new benefit-cost test known as the "Rhode Island Test" which aligns more broadly with the policy goals of the state. Massachusetts Clean Energy Center (MassCEC) promotes renewable heating and cooling initiatives using electrification as one of its primary priorities.[1]

States in the region have worked with Northeast Energy Efficiency Partnerships (NEEP) to develop cold-climate specifications and a list of qualified cold-climate ASHPs (ccASHP) that are particularly well-suited to use in New England and New York because they function well in cold temperatures and are highly efficient.[2] Efficiency programs in the Northeast generally target ASHPs to customers who currently use oil, propane, or electric resistance for heating. From a customer

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[1] Massachusetts Clean Energy Center, Summary Table for income thresholds on heat pump Incentives. http://www.masscec.com/file/summarytablejpg.

[2] Northeast Energy Efficiency Partnerships (NEEP), Cold Climate Air Source Heat Pump, Current ccASHP Specification. http://www.neep.org/initiatives/high-efficiency-products/emerging-technologies/ashp/cold-climate-air-source-heat-pump.

economics perspective, switching from propane or electric resistance heat to an ASHP usually saves money at current fuel prices, switching from oil heat to ASHP may make sense depending on customer usage patterns and fuel prices, and switching from natural gas to ASHP does not make financial sense for most customers at current fuel prices.

Many energy efficiency programs in the Northeast offer ASHPs as an electricity-saving measure for both heating and cooling applications. When ASHPs are installed as a fuel switching or "retrofit" measure, in which a customer switches from heating with a fossil fuel to heating with an electric heat pump, they add electric load. Traditionally, efficiency programs are operated to reduce electricity consumption and have performance targets for MWh savings. To get around this barrier, most ASHP initiatives run by utility or statewide efficiency programs, including Efficiency Maine, Energize Connecticut, Mass Save, National Grid Rhode Island, and New York utilities, only count the incremental, "market opportunity" electricity savings associated with installing a high-efficiency ASHP above a less efficient, "baseline" ASHP – even when the heat pumps are installed in homes that previously used oil and propane for heating.

ASHPs incentivized by programs operating under broader mandates to support renewable heating and cooling, such as those offered by MassCEC and the New York State Energy Research and Development Authority (NYSERDA), are not focused primarily on achieving electric savings and are not subject to the same performance metrics and cost-effectiveness screening as utility programs. Instead, program success is measured against goals related to program participation, fossil fuel displacement, or GHG emissions reduction. Similarly, Efficiency Maine and Efficiency Vermont have goals related to total energy and/or fossil fuel savings, and Efficiency Vermont counts the fossil fuel savings associated with fuel switches to ASHPs.

Table 1 summarizes incentive levels and savings assumptions by state and program. It is notable that the programs that only count the incremental, market opportunity electric savings tend to have lower incentives, in the range of $100-300 per unit for Connecticut, Massachusetts, New York, and Rhode Island utilities.[3] The programs that measure success against broader renewable heating and cooling goals, and/or that count the fossil fuel retrofit savings, such as Efficiency Maine, NYSERDA, and Efficiency Vermont, are able to offer higher incentives in the range of $500-600 per unit. Programs in the Northeast states offer incentives for a variety of heat pump technologies. Table 1 shows incentive levels and savings assumptions for a single representative heat pump technology, ductless mini-splits, for comparison purposes.

[3] Within the energy efficiency program framework, utilities in Massachusetts and Rhode Island can offer higher incentives for upgrades from electric resistance heat to heat pumps, but the number of units upgrading from electric resistance heat is low.

Table 1. Residential ductless mini-split incentives and savings

| State | Program/ Utility | Incentives | Incremental Electric Savings (kWh/unit/year) Heating | Incremental Electric Savings (kWh/unit/year) Cooling | Fuel Savings (MMBtu/unit/year) |
|---|---|---|---|---|---|
| **CT**[4] | Energize CT | $300 SEER 20+ | 136 kWh | 74 kWh | None |
| **MA**[5] | Mass Save (utility programs) | $100 SEER 18+<br>$300 SEER 20+ | SEER 18: 286 kWh<br>SEER 20: 330 kWh | | None |
| | Mass. Clean Energy Center | $625 per unit Up to $1000 for income-qualified customers | NA | | None |
| **ME** | Efficiency Maine | $500 first unit | 1,815 kWh | 88 kWh | None |
| **NH**[6] | NHSaves (utility programs) | $375 SEER 15+<br>$750 SEER 18+ | 328 kWh | 103 kWh | None |
| **NY**[7] | NYSERDA | $500 per unit | 260 kWh | 144 kWh | None |
| | Utility programs | $100-$300 | | | |
| **RI**[8] | National Grid | $100 SEER 18+<br>$300 SEER 20+ | SEER 18: 270 kWh<br>SEER 20: 248 kWh | SEER 18: 76 kWh<br>SEER 20: 70 kWh | 17.43 for fuel oil retrofit[9] |
| **VT** | Efficiency Vermont | $600-$800 per unit | SEER 20: 668 kWh | | 21.98/year for blended mix of fuels |
| | Utility RES Compliance | VEC $150<br>WEC $250<br>BED $375 | NA | | NA |

4 Connecticut calculates heating and cooling savings with a formula that accounts for the number of zones, equipment capacity, the difference between the equipment's HSPF and baseline HSPF, and climate zone. For this example, assumptions are for a 20 SEER, 18,000 BTU nominal capacity ductless mini-split in Hartford.

5 Mass Save, 2015. *Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures.* 2016 – 2018 Program Years – Plan Version: 73. http://ma-eeac.org/wordpress/wp-content/uploads/2016-2018-Plan-1.pdf.

6 Incentives based on $250 / ton SEER 15+ and $500 / ton SEER 18+ for a 1.5-ton system. NHSaves, 2017. *2018 – 2020 New Hampshire Statewide Energy Efficiency Plan*. NHPUC Docket DE-17-XXX. https://puc.nh.gov/Regulatory/Docketbk/2017/17-136/INITIAL%20FILING%20-%20PETITION/17-136_2017-09-01_NHUTILITIES_EE_PLAN.PDF.

7 New York uses a formula for heating savings that accounts for number of zones, nominal capacity, the difference between the equipment's HSPF and baseline HSPF, age and type of building, and climate of the nearest of seven reference cities. The formula also considers whether equipment is installed as an early replacement or as a normal replacement. For this example, assumptions are for a 20 SEER 18,000 BTU nominal capacity unit in a single-family detached home near Albany, built between 1979 and 2006.

8 MiniSplit HP SEER 18 and SEER 20. National Grid, 2015. *Rhode Island Technical Reference Manual for Estimating Savings from Energy Efficiency Measures,* 2016 Program Year: M-65-68. http://www.ripuc.org/eventsactions/docket/4755-NGrid-2018-TRM-RI.pdf

9 MMBtu savings are for a separate fuel oil switch to an ASHP measure.

Efficiency Vermont, which achieves the highest level of market penetration, uses a midstream program model that applies incentives as an instant discount via wholesale distributors rather than as an end-use customer rebate. This model, combined with supply channel engagement, has proven successful at driving market transformation. NYSERDA's midstream contractor incentive also takes a midstream approach, but incentivizes contractors rather than wholesale distributors; initial results are promising. Table 2 summarizes the incentive approach used by each utility or program and the number of units installed.

Table 2. ASHP incentive approach and installation rate

| State | Program/Utility | Incentive Approach | Estimated Annual Installations | Housing Units in State[10] | Annual Installation Rate (% of Homes) |
|---|---|---|---|---|---|
| **CT** | Energize CT (Eversource and United Illuminating) | Downstream from 2012-2015; now upstream | 1,475 | 1,499,116 | 0.10% |
| **MA*** | Mass Save | Downstream | 7,484 | 2,858,026 | 0.26% |
| | Mass. Clean Energy Center | Downstream | 4,050 | 2,858,026 | 0.14% |
| **ME** | Efficiency Maine | Downstream; customer can choose to direct payment to contractor | 6,000 | 730,705 | 0.82% |
| **NH** | NH Saves | Downstream | 1,230 | 730,705 | 0.16% |
| **NY*** | NYSERDA | Midstream to contractor | 5,280 | 8,231,687 | 0.06% |
| | Utility programs | Downstream | NA | 8,231,687 | NA |
| **RI** | National Grid | Downstream | 1,000 | 462,589 | 0.22% |
| **VT*** | Efficiency Vermont | Midstream | 4,141 | 329,525 | 1.26% |
| | Utility RES Compliance | Downstream | NA | 329,525 | NA |

* Multiple incentives in these states can be combined. For example, in the case of Massachusetts, most of the 4,050 units in the MassCEC program likely also participated in the Mass Save programs.

Note: Annual installation rates are based on reported or projected program measures and total housing units by state. Estimated program installation rates are based on program participation data from 2017 for Connecticut, Maine, NYSERDA and Vermont; 2016 for Mass Save; June 2016 to May 2017 for MassCEC; 2015 for Connecticut; and 2018 planning estimates for National Grid RI and NH Saves.

[10] U.S. Census Bureau, State Quick Facts. 2017. Housing Units, July 1, 2016. https://factfinder.census.gov/bkmk/table/1.0/en/PEP/2016/PEPANNHU.

Overall, the most successful programs in the Northeast combine two factors:

- Midstream program design and supply channel engagement to move the market and support marketing and training; and
- Significant incentives (at least $500/unit for ductless mini-splits), made possible because the program is either counting the fossil fuel savings towards program goals (e.g., Efficiency Vermont) or because the program operates outside of the utility efficiency program structure with broader goals for renewable thermal adoption or GHG reduction (e.g., MassCEC, NYSERDA).

In comparison with other regions of the country, ASHP adoption in the Northeast is driven in part by the generally favorable customer economics associated with switching from oil or propane to heat pumps. Market adoption of heat pumps will be more challenging in states where most customers use natural gas for heating, at least at current natural gas prices and electric rate structures.

Policymakers, regulators, and program administrators have taken many paths to support the deployment of heat pump technology for heating and cooling in the Northeast. With over 45,000 high-efficiency ASHPs incentivized to date, heat pump adoption in the region continues to grow and states are continuing to add or expand programs. The Northeast is positioned to lead the nation in transforming the market for heat pumps, and creating program models that other states can learn from and replicate.

## Program Design Recommendations

Based on this review of the existing programs in the Northeast, policymakers, regulators, and program administrators should consider the following program design best practices to drive market adoption of ASHPs for building electrification, as a component of a broader strategy to reduce fossil fuel use and GHG emissions.

1. **Move forward quickly with a targeted approach.** ASHPs are a good option for building heating in a number of situations. States should develop a master plan identifying the regions, customers, and buildings best suited for fuel switching through heat pump technology. Ideally, this plan would take into account customer characteristics (e.g., existing heating system fuel, whether the building envelope has been weatherized, and presence of solar photovoltaics (PV)), as well as grid characteristics (e.g., electric and natural gas transmission and distribution constraints, access to renewable generation sources). For example, at current fuel prices, in many regions it makes sense to target ASHPs to the following types of customers:
    - Homeowners who currently heat with electric resistance, oil, or propane; and
    - New construction and deep retrofits of buildings where ASHPs are installed in combination with solar PV and high-performance building shells.

    At current fuel prices, it is challenging to promote ASHPs in states with widespread use of natural gas for heating. Good options in these states include:
    - Incentivizing hybrid heat pumps for natural gas-heated homes with central air conditioning;

- Promoting ASHPs in new construction through all-electric high-performance program tiers and by incentivizing mini-split heat pumps as an alternative to central air conditioning; and
- Packaging ASHPs with weatherization and solar PV.

While advance planning is important, because heat pumps offer such significant net benefits, states need not wait to fully account for all of these factors in ramping up program achievement. Rather, states should act now to advance heat pump incentives while accounting for these factors to the extent practicable, and encourage programs to continue to evolve over time to address system needs and policy goals.

2. **Incentivize packages that include weatherization.** Pairing ASHPs with efficiency measures, solar PV, and/or electric vehicles (EVs) and incentivizing them as a package is appealing to customers, particularly for new construction applications. Promoting heat pumps in the context of total energy transformation may create program efficiencies, facilitate a streamlined process for customers, and help right-size distributed generation. It is particularly important to ensure that ASHPs for space heating are installed in combination with weatherization measures to support good performance and right-sizing of heating equipment.

3. **Explore funding options beyond electric system benefit charges.** Because fuel switching to ASHPs adds electricity load, utility programs that are funded by electric ratepayer charges and focus on MWh savings are often challenged to incentivize and count the full benefits of heat pumps. States can look to alternative funding sources, such as taxes on fossil fuels, renewable portfolio standard charges, or carbon market revenues to support heat pump programs. Alternatively, states can consider promoting ASHPs through a renewable heating and cooling or decarbonization initiative with a non-utility program administrator, with a focus on climate or market transformation climate goals. In the Northeast, MassCEC and NYSERDA have dedicated funding for renewable thermal market transformation from renewable portfolio charges and Regional Greenhouse Gas Initiative (RGGI) revenues, supporting a strong focus on driving the heat pump market. This may be a particularly appealing option in states with widespread natural gas, where it is currently difficult to promote heat pumps within a utility context because of cost-effectiveness challenges. In jurisdictions that have both utility and non-utility program administrators, close collaboration and coordination is vital to avoid customer and market confusion.

4. **When working within a utility efficiency framework, enhance program metrics.** In many states, efficiency program success metrics revolve around reducing *electricity* usage – a critically important and proven policy that has delivered substantial environmental, system, and customer benefits. As regulators seek to spur the deployment of heat pump technologies, they should consider augmenting the goal frameworks governing utility efficiency programs to more fully align with state policy goals. This can include adding binding performance targets that work hand-in-hand with essential electric and gas savings targets, such as goals for GHG reduction, net benefits, incorporation of renewables into the grid, or market transformation. Regulators can also explore setting metrics to promote grid flexibility, such as improved load factor or peak

demand reduction. Several Northeast states, including Massachusetts, Rhode Island, and Vermont are considering potential updates to performance metrics for utility-run energy efficiency programs. For example, Massachusetts is contemplating a shift to an MMBtu metric that would include both measure interactive effects (e.g. the impacts of lighting efficiency on increased fossil fuel consumption for heating), as well as the impacts of measures intentionally promoted for fuel switching purposes.[11]

5. **Include all of the benefits.** When using traditional methods of efficiency cost-benefit testing, it can be challenging to capture the full benefits of fuel switching to electricity. States like Rhode Island have found that fuel switching from fossil fuels to ASHPs did not pass screening until non-energy benefits such as carbon reduction and economic development were included in the cost-benefit test. Regulators should seek to include non-energy benefits such as comfort, GHG reduction, fuel security, health benefits, and economic development in cost-benefit tests to provide a more complete picture.

6. **Offer robust heat pump incentives through an upstream/midstream program model.** Of the programs in the Northeast, the Efficiency Vermont program has the highest installation rate using a midstream incentive model through wholesale distributors. This model has successfully engaged manufacturers, distributors, and other supply channel actors through instant discounts combined with a coordinated approach to marketing and training. Early results from NYSERDA, which is using a contractor incentive, area also promising. Efficiency Vermont and Efficiency Maine, which has the second highest installation rate, also offer substantial incentives of at least $500/unit for ASHPs.

7. **Provide contractor and customer training to encourage quality installation and efficient operation.** Because ASHPs in the Northeast typically operate alongside an existing fossil fuel heating system, their installation and how they are used is key to delivering the desired energy savings and performance. Several recent evaluations from Connecticut, Massachusetts, and Rhode Island have found lower savings than anticipated because systems are not being optimally designed and operated. Training contractors to select the best heat pump technology for the space and ensure quality installation are key elements of a successful heat pump program. Customer training on proper set points for both ASHPs and backup heating systems is also critical, to ensure that customers heat with ASHPs to the greatest extent possible.

8. **Support efforts to integrate controls.** Given the varied ways in which ASHPs are installed and operated in the Northeast, where most customers maintain a fossil fuel backup heating system, performance could be substantially improved – particularly for mini-split heat pumps – if the ASHP's thermostat and the fossil fuel system's thermostat could communicate with each other. This would enable set points to drop to lower temperatures when the room was no longer occupied,

[11] Personal communication with Glenn Reed, Energy Futures Group, January 16, 2018.

so that the ASHP could act as the primary, rather than supplemental, heating system.[12] Improved communications capabilities would also enable ASHPs to be leveraged for demand response and grid flexibility. Utilities and program administrators should work with ASHP and thermostat manufacturers to develop and integrate these control capabilities, so that the benefits of ASHPs for decarbonization can be fully realized.

[12] Cadmus Group, 2016. "Ductless Mini-Split Heat Pump Impact Evaluation," Prepared for the electric and gas program administrators of Massachusetts and Rhode Island, as part of the Residential Evaluation program area. http://ma-eeac.org/wordpress/wp-content/uploads/Ductless-Mini-Split-Heat-Pump-Impact-Evaluation.pdf

# Introduction

## Heat Pump Technology

Heat pump technology uses electricity to transfer heat energy between a heat source and a destination (heat sink) rather than to generate heat. Because heat transport uses less energy than heat generation, heat pumps are between 2-5 times more efficient than space and water heating alternatives. Aside from refrigerators (which also use heat pump technology), efficiency programs typically promote heat pumps for space heating, space cooling, and/or hot water heating applications.

**Air-source heat pumps (ASHPs)** and **ground-source heat pumps (GSHPs)** can be used for many heating and cooling applications. ASHPs transfer heat between outdoor air and indoor air or water for space heating, space cooling, water heating, and even clothes drying. GSHPs transfer heat between the ground or an external water source such as a well, and indoor air or water, for space heating.

**Heat pump water heaters (HPWHs)** are a type of ASHP used specifically for water heating. HPWHs transfer heat between the surrounding air and the water in the tank. This report uses the term **ASHP** to refer specifically to air-to-air applications and **HPWH** when referring to air-to-water applications.


Figure 1. Diagram of an air-source heat pump (mini-split)[13]

[13] ENERGY STAR Air-Source Heat Pump, https://www.energystar.gov/products/heating_cooling/ductless_heating_cooling.

Heat pumps have been used for decades to efficiently heat and cool homes in moderate climates. Recent technological advances have made them an attractive and cost-effective option in cold climates, and ASHPs are rapidly growing in popularity. While policies and programs in the Northeast often include multiple heat pump technologies, this paper focuses primarily on the most popular type of ASHP, ductless mini-splits, as a leading indicator for building electrification issues and opportunities. In heat pump potential studies, ASHPs have been found to be more cost-effective for all applications than GSHPs.[14]

ASHPs can be used in various configurations, either ducted or ductless. A ducted heat pump is a central heating and cooling system that relies on ductwork to distribute conditioned air from the heat pump throughout the interior of the building. When installed in an existing home, a heat pump could be connected to existing ductwork if it is in good condition. Ductless heat pumps (also known as mini-splits, as seen in Figure 1) can be installed in buildings without existing ductwork, which makes them a good option for installation in many existing buildings; many existing homes in the Northeast do not have ducts because they use hydronic heating and do not have central air conditioning. Single-head systems include one outdoor unit (compressor) and one indoor unit (evaporator). A multi-head system is made of one outdoor unit connected to multiple indoor units, usually located in different rooms.

**Cold-climate air source heat pumps (ccASHP)** meet a specification used to designate products that meet heating performance requirements in low temperatures. On behalf of energy efficiency stakeholders in the Northeast, Northeast Energy Efficiency Partnerships (NEEP) developed and maintains a list of heat pumps that provide optimal heating in cold conditions, which makes them suitable for use in the Northeast. This designation can apply to any type of ASHP including ducted, ductless, or centrally ducted systems.

Because of the cold climate in the Northeast, many customers who install ASHPs, particularly ductless mini-splits, retain their existing heating system for backup heat during very cold weather. This usually results in reduced fossil fuel use, but the percentage of heat load provided by the ASHP and the backup heating system (usually propane or oil) can vary widely depending on how the customer uses the system. When a heat pump provides some of the building's heat, but not all of it, the term used to describe the impact is "displacement." When a heat pump provides all of the heat for the building, the term used to describe the impact is "replacement." In most existing homes in the Northeast, ASHP installation results in the displacement of part of the heating once needed from the original heating system. However, high-performance, well-insulated new construction homes in the Northeast can be heated solely with ductless mini-splits.

[14] New York State Energy Research and Development Authority, 2015. *Heat Pumps Potential for Energy Savings in New York State.* Original release date, July 2014. Report No. 14-39. https://www.nyserda.ny.gov/-/media/Files/EDPPP/Energy-Prices/Current-Outlook/Presentations/Heat-Pumps-Potential.pdf.

## Beneficial Electrification in the Northeast

Electrification is a decarbonization strategy that relies on transitioning energy end uses from fossil fuel to electricity, while simultaneously reducing emissions from the electric power system through procurement of cleaner electricity generation and careful integration of additional electric load. Building electrification using heat pumps is one mechanism to reduce energy use and emissions from heating and cooling buildings and heating water for buildings. Northeast states are increasingly promoting heat pump technology to support energy and climate goals.

The electric grid in the Northeast is already among the cleanest in the nation and is continually becoming cleaner. Since 2000, CO2 emissions rates from the electric sector have decreased by 39 percent in New York and by 28 percent in New England (Figure 2).

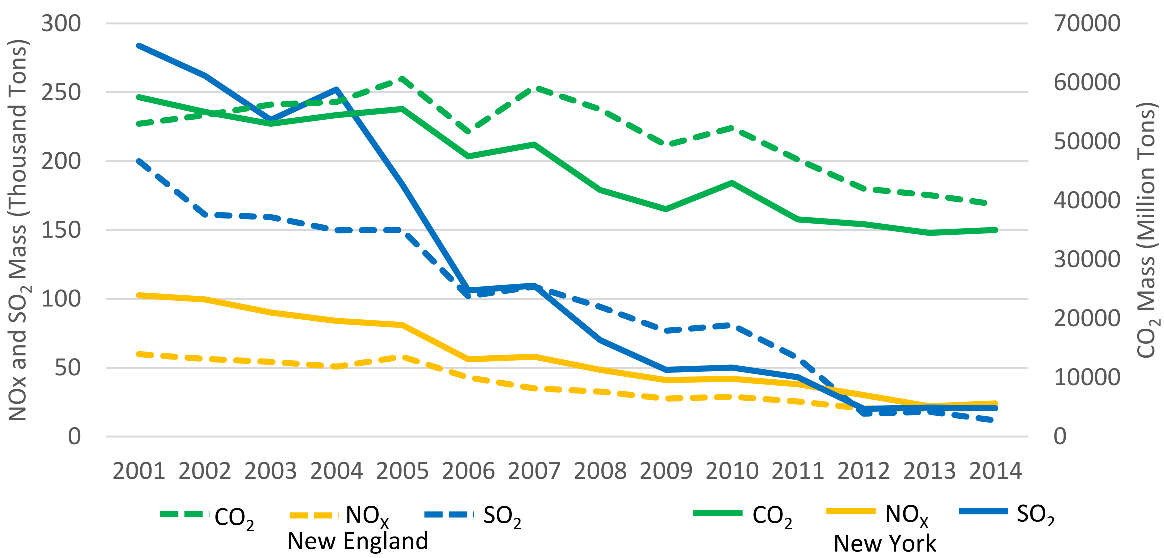


Figure 2. Emissions from electricity generation in New England and New York 2001-2014[15]

Robust clean energy policies in Northeast states such as Renewable Portfolio Standards (RPS) (Table 3), greenhouse gas (GHG) emission targets, and participation in the Regional Greenhouse Gas Initiative (RGGI) support continued reductions in GHG emissions.

[15] New York Independent System Operator, NYISO, 2015. *Power Trends 2015: Rightsizing the Grid.* http://www.nyiso.com/public/webdocs/media_room/press_releases/2015/Child_PowerTrends_2015/ptrends2015_FINAL.pdf; and Independent System Operator New England (ISO New England), n.d. "Resource Mix." http://www.iso-ne.com/about/key-stats/resource-mix.

Table 3. Renewable portfolio standards in Northeast states

| State | Renewable Portfolio Standard | Date | RPS Goal |
|---|---|---|---|
| Connecticut | Renewable Portfolio Standard | 1998 | 27% by 2020 |
| Maine | Renewable Portfolio Standard | 1999 | 40% by 2017 |
| Massachusetts | Renewable Portfolio Standard | 1997 | Class I: 15% by 2020 and an additional 1% each year after<br>Class II: 5.5% by 2015 |
| New Hampshire | Electric Renewable Portfolio Standard | 2007 | 24.8% by 2025 |
| New York | Renewable Portfolio Standard; Reforming the Energy Vision (REV) | 2004 | 30% by 2015<br>50% by 2030 |
| Rhode Island | Renewable Energy Standard | 2004 | 14.5% by 2019 |
| Vermont | Renewable Energy Standard | 2015 | 55% by 2017<br>75% by 2032 |

All of the New England states and New York currently have GHG emissions goals in place (Table 4). As electricity becomes cleaner in the Northeast, the benefits of building electrification continue to grow. The combination of progressively cleaner electricity generation, coupled with robust policies supporting GHG emissions reductions and increased renewable generation, provide an environment favorable to strategic electrification.

Table 4. GHG emission reduction goals in Northeast states

| State | Source | Date | GHG Emissions Reduction Goal |
|---|---|---|---|
| Connecticut | House Bill 5600 | 2008 | 10% below 1990 levels by 2020, 80% below 2001 levels by 2050 |
| Maine | Act to Provide Leadership in Addressing the Threat of Climate Change | 2003 | 1990 levels by 2010, 10% below 1990 levels by 2020, and 75-80% below 2003 levels long term |
| Massachusetts | 2008 Global Warming Solutions Act | 2008 | 80% below 1990 levels by 2050 |
| New Hampshire | Climate Change Action Plan | 2004 | 1990 levels by 2010, 10% below 1990 levels by 2020, and 75-80% below 2001 levels long term |
| New York | Executive Order No. 24 and State Energy Plan | 2009 | 40% below 1990 levels by 2030, 80% below 1990 levels by 2050 |
| Rhode Island | Climate Change Action Plan | 2001 | 1990 levels by 2010, 10% below 1990 levels by 2020, and 75-80% below 2001 levels long term |
| Vermont | S. 259 | 2006 | 25% below 1990 levels by 2012, 50% below 1990 levels by 2028 |

The use of natural gas to produce electricity in New England has grown from 15 percent of electricity generation in 2000 to almost 50 percent in 2016. Replacing coal-powered generation with electricity generation from natural gas, combined with continued improvements in energy efficiency and growing renewable energy in the region, has resulted in a significant decline in the region's GHG emissions. However, greater reliance on natural gas-fired generation has also increased demands on natural gas infrastructure in New England and southern New York, and resulted in increased usage of highly polluting oil for dual-fuel fired units in the region during times when natural gas supplies are most constrained. While more efficient use of gas infrastructure could help address these problems, achieving climate goals will also require more than a switch to gas.[16]

Acadia Center conducted an analysis comparing the annual GHG emissions generated by heating a typical house in the Northeast with different fuels. Given the current generation mix in the region, heating a home with heat pump technology and electricity results in a significant reduction in GHG emissions in comparison to heating with oil, propane, or natural gas (Figure 3).

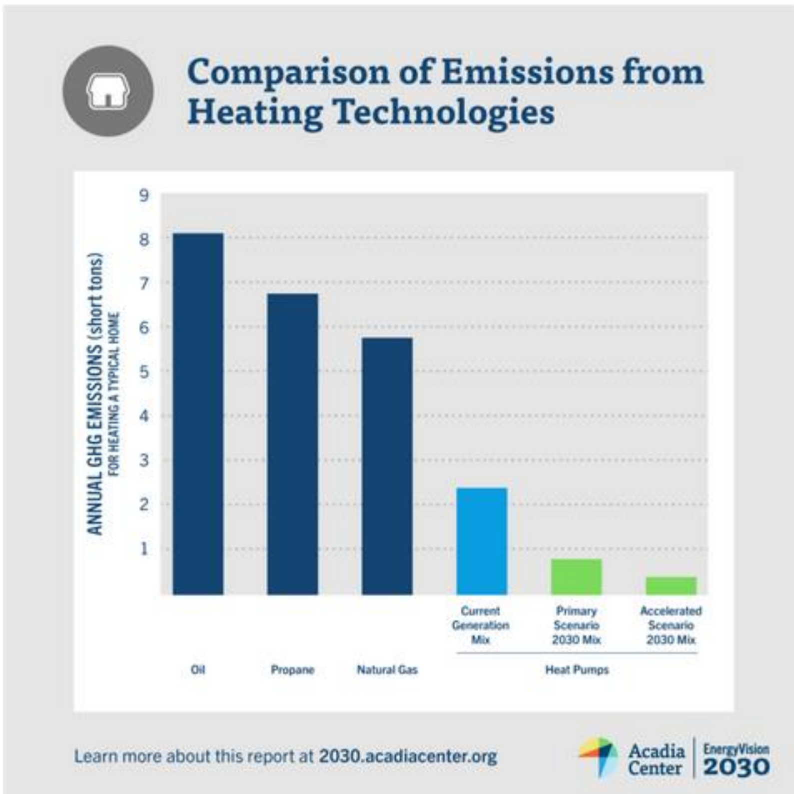


Figure 3. Emissions of heating technologies compared[17]

[16] Marks, Levi, Charles F. Mason, Kristina Mohlin, and Matthew Zaragoza-Watkins, n.d. "Vertical Market Power in Interconnected Natural Gas and Electricity Markets." Washington, DC: Environmental Defense Fund. https://www.edf.org/sites/default/files/vertical-market-power.pdf?_ga=2.95728859.69378466.1518446774-652022566.1515260274; and Peress, N. Jonathan, Natalie Karas, 2017. "Aligning U.S. Natural Gas and Electricity Markets to Reduce Costs, Enhance Market Efficiency and Reliability." Washington, DC: Environmental Defense Fund. https://www.edf.org/sites/default/files/aligning-us-natural-gas-and-electricity-markets.pdf?_ga=2.75798994.69378466.1518446774-652022566.1515260274.

[17] "Buildings: Efficiency and Electrification," *EnergyVision 2030.* Acadia Center, http://2030.acadiacenter.org/buildings/.

In addition, access to natural gas as a heating fuel varies widely in the region. New York and southern New England states heat between 33 and 57 percent of homes with natural gas, whereas northern New England states have limited access to natural gas, with between 6 and 20 percent of homes heating with natural gas (Table 5). Lack of access to low-cost natural gas for heating is a key driver for the interest in renewable heating and cooling technologies, including ASHPs, in the Northeast.

Table 5. Percent of housing units in the Northeast heated with natural gas[18]

| State | Homes Heated with Natural Gas |
|---|---|
| Connecticut | 33.6% |
| Maine | 6.0% |
| Massachusetts | 50.1% |
| New Hampshire | 19.7% |
| New York | 56.8% |
| Rhode Island | 51.8% |
| Vermont | 16.5% |

Overall, electrification of buildings using heat pump technology, combined with cleaner electricity generation, is an important pathway for Northeastern states to reach state and regional energy, climate, and fuel security goals. To support the region in advancing strategic electrification goals, NEEP recently published a regional assessment of strategic electrification[19] as well as a heat pump market strategies report.[20] This report builds on these foundational NEEP reports by providing an in-depth, state-by-state analysis of heat pump policies and programs and identifying best practices to drive heat pump market transformation in in other jurisdictions.

[18] U.S. Census Bureau, American FactFinder. "Selected Housing Characteristics, 2008 – 2012 American Community Survey 5-year Estimates." https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_12_5YR_DP04&prodType=table
[19] NEEP, 2017. "Northeastern Regional Assessment of Strategic Electrification." http://neep.org/sites/default/files/Strategic%20Electrification%20Regional%20Assessment.pdf
[20] NEEP, 2017, Northeast / Mid-Atlantic Air-Source Heat Pump Market Strategies Report 2016 Update. http://www.neep.org/sites/default/files/NEEP_ASHP_2016MTStrategy_Report_FINAL.pdf

# State Policies and Programs

## Connecticut

### Building Electrification Policies

Connecticut's comprehensive Energy Strategy supports building electrification. The previous strategy, published in 2013, supported fuel switching away from fuel oil in favor of other fuels, primarily natural gas. The strategy called for expanding natural gas distribution to serve more residential customers. Where gas service was not feasible, GSHPs and ccASHPs were encouraged through incentives and financing.

With the 2013 strategy reaching its fourth year, Connecticut's Department of Energy and Environmental Protection (DEEP) undertook a new draft energy strategy in 2017, and recently issued the final update, the *2018 Comprehensive Energy Strategy*.[21] Notably, the new version has strong support for strategic electrification. It recommends that the Conservation and Load Management Plan, with financing support from the Connecticut Green Bank, advance customer demand for "space cooling to strategically encourage installation and use of ductless air source heat pumps (especially models optimized for cold climates) that in the summer can provide efficient cooling and in the winter can cost-effectively displace heating supplied by oil, propane, or electric resistance units."[22] Previous emphasis on GSHPs has largely been replaced by interest in ASHPs due to lower initial cost, easier installation, and improvements in cold climate performance.

The new strategy cites recent analysis showing that ASHPs and other renewable thermal technologies are most appropriate for buildings using electric resistance heating, as historically low fossil fuel prices hampers the financial competitiveness of fuel switching. Specific policy recommendations include:

- Offering a pilot program to assess the potential for full replacement of oil and propane-fired furnaces with renewable thermal technologies, including high-efficiency ducted heat pumps, "such that residents do not need to keep fossil fuel equipment [including] whether homes with central air can successfully be retrofitted with ducted heat pumps using the existing ductwork";[23]
- Leveraging existing utility efficiency programs that already offer rebates for renewable thermal technologies;
- Using a partial building strategy, such as serving a single room or zone with ASHPs;

[21] State of Connecticut, Department of Energy & Environmental Protection. 2018. *2018 Comprehensive Energy Strategy (CES).* http://www.ct.gov/deep/lib/deep/energy/ces/2018_comprehensive_energy_strategy.pdf.
[22] Connecticut, *CES:* 27.
[23] The strategy does not specify a funding source.

- Acknowledging non-monetary climate change and air quality benefits in cost-benefit tests to better align utility-managed programs with state energy and emissions goals; and
- Testing real-time demand response through pilot projects addressing building electrification, electric vehicles, and distributed generation.

Nearly all Connecticut customers keep existing heating equipment as a backup to ASHP units. Meanwhile, the updated strategy suggests that 30 percent of ductless ASHPs are installed primarily to provide cooling. Cooling is not ubiquitous in Connecticut, where more than a quarter of households use window unit air conditioners or go without cooling. As more customers become interested in installing cooling equipment, the strategy notes the potential to gain heating season benefits from these ASHP installations.

***Web Links to Policy Resources***
2013 Comprehensive Energy Strategy:
http://www.ct.gov/deep/lib/deep/energy/cep/2013_ces_final.pdf

2017 Draft Comprehensive Energy Strategy:
http://www.ct.gov/deep/cwp/view.asp?a=4405&q=500752&deepNav_GID=2121%20

Feasibility of Renewable Thermal Technologies in Connecticut: Market Potential:
http://cbey.yale.edu/sites/default/files/FORTT_Market%20Potential_1b.pdf

Feasibility of Renewable Thermal Technologies in Connecticut: A Field Study on Barriers and Drivers
http://cbey.yale.edu/sites/default/files/FORTT_Barriers%20and%20Drivers.pdf

## Implementation – Programs Promoting Heat Pumps

Eversource and the United Illuminating Company are dual-fuel (electricity and natural gas) utilities that brand their efficiency programs as "Energize CT" in partnership with the Connecticut Green Bank and state Department of Energy and Environment. All other electric and gas distribution utilities in the state are municipal entities not required to participate in Energize CT. Efficiency programs are funded from a single Energy Efficiency Fund pooling revenues from systems benefit charges, RGGI funds, conservation-based rate adjustments, and the ISO-NE Forward Capacity Market (FCM).

Through Energize CT, all residential electric customers are eligible for an "instant discount" of $300 (single units of 20 SEER/12.5 EER/10 HSPF) or $500 (multi-units of 18 SEER/12.5 EER/9 HSPF) for an ENERGY STAR ductless ASHP system installed by an approved installer. Program administrators also offer up to $1,500 in incentives for residential ENERGY STAR-certified closed loop geothermal equipment. Commercial customers installing ASHPs receive between $70/ton and $150/ton depending on equipment efficiency and total system size.

Connecticut efficiency program administrators recently shifted to this upstream "instant discount" model for ducted and ductless ASHP incentives, as well as other HVAC equipment. Under this upstream approach, incentives are automatically applied by participating wholesale distributors, who are required to pass the incentive along to customers and list it as an invoice line item.

In homes of four or fewer units, program administrators offer unsecured, low-interest financing for heating system improvements, including ASHPs, at a rate of 0.99 percent APR, a lower rate than is available for other efficiency measures. Terms are 3-10 years, based on the simple payback period plus two years, require a down payment, and repayment is conducted through electricity bills. In its first full year, the loan product financed 664 heat pump installations. Of those 64 percent were for ductless ASHPs, 18 percent for ducted ASHPs, and the remainder for GSHPs or HPWHs.

***Funding Sources for Heat Pump Programs***

Electric efficiency programs supporting ASHP measures are administered by Connecticut's utilities and funded by a combination of system benefit charges, FCM, RGGI, and a Conservation Adjustment Mechanism. This mechanism is defined by United Illuminating as an on-bill customer charge that either "refunds or collects the difference between actual and allowed conservation expenses compared to that allowed in base rates."

***Program Rules—Restrictions/Encouragement of Fuel Switching***

Current program rules do not address fuel switching. Although ASHP measures are likely to reduce demand for natural gas, oil, or propane in homes heating with those fuels, marketing materials emphasize suitability for homes already using electric heat. Programs also suggest mini-split ASHPs in homes where they are a less expensive option than expanding existing ducts or hot water systems (such as construction of a new addition or winterizing a three-season porch). In addition, 2018 plans direct the utilities to develop an all-electric package for residential new construction.

***Energy Savings Calculations (Including Non-Electric Fuels)***

The Connecticut Program Savings Document calculates heating season savings and cooling season savings separately. ASHPs are considered exclusively electric measures; both cooling and heating savings are counted, although they are calculated separately.

Cooling savings calculations mirror the savings calculations for efficient air conditioners. Heating savings are calculated in one of two ways. Units installed in a home with electric resistance heating offer retrofit savings based on the difference between existing and newly installed equipment. Units installed in homes with fossil fuel heating offer market opportunity savings based on the difference between baseline and newly installed equipment. Baseline efficiency aligns with federal minimum standards.

Savings for commercial customers are based on the incremental electric savings for installed efficient equipment in comparison to baseline code-compliant equipment. While both heating and cooling energy savings are counted (in kWh), no peak demand savings (kW) are calculated for winter periods due to reliance on electric resistance backup heating at low temperatures.

Because ASHPs are considered electric-only measures, Connecticut utility programs do not count any savings related to fossil fuel savings.

***Fuel Switching in Cost Effectiveness Screening***

As electric-only measures, ASHP cost-benefit tests exclude any fuel switching benefits (e.g. reduction in fuel oil consumption) as well as non-energy benefits. Program administrators have requested to work with DEEP to better account for heat pump benefits for total customer savings and in support of the state's climate goals and include these benefits in cost-effectiveness screening. DEEP has stated they will address climate benefits in future cost-effectiveness tests, although timing is unclear.

***Impact on Electrification and Fuel Switching on Program Metrics***

Building electrification is not specifically addressed in program metrics. Program administrators have assigned goals and performance incentives related to energy savings and net economic benefit at the program level. Although program plans have discussed recognizing non-energy benefits related to fuel switching and climate goals, program metrics do not currently address these issues.

***Quality Assurance/Quality Control***

Energize CT offers a Quality Installation and Verification (QIV) program to ensure that newly installed HVAC equipment is functioning at peak performance. The program recommends that the customer participate in the Home Energy Solutions direct installation and air sealing program to improve shell performance before a heat pump installation. This allows the QIV contractor to right-size equipment. The program requires the selection of a qualified installer or contractor and requires post-installation verification to confirm proper installation.[24]

***Grid Flexibility***

In 2007, legislation was passed in Connecticut to offer voluntary real-time pricing to customers. By shifting electricity usage to off-peak hours, customers can save money and reduce load during peak hours. In response to this legislation, the Connecticut Public Utilities Authority (PURA) authorized Variable Peak Pricing (VPP). Eversource (Connecticut Power and Light) offers VPP as a form of Time-of-Use (TOU) pricing. Eversource also offers more traditional TOU pricing options with on-peak hours defined as 12:00 noon to 8:00 p.m. Monday through Friday. Meanwhile, United Illuminating expects to introduce voluntary Peak Time Rebates in the future.

While neither utility offers demand response programs specific to heat pumps, since 2016 Eversource has managed a residential Wi-Fi thermostat pilot controlling both heat pumps and central air conditioning units. The company offers customers a flat $25 per thermostat per year in exchange for participating.

[24] CNG, Quality Installation and Verification. http://www.cngcorp.com/wps/portal/cng/yourhome/energyconservation/quality%20installation%20and%20verification.

## Outcomes

***Community Outreach and Education***

Although most public-facing marketing focuses on promoting whole-house improvements, program administrators address ASHPs in many ways. First, basic information about equipment function, program rebates, and appropriate application is on the EnergizeCT public-facing website. The program also coordinates contractor program training with training offered by equipment manufacturers.

***Heat Pump Adoption Activity and Success***

Program administrators reported installing 6,176 air source heat pump measures during the four-year period from 2012 to 2015.

***Electrification Lessons Learned***

In 2016, the Connecticut Energy Efficiency Board funded a Ductless Heat Pump Evaluation prepared by DNV GL. The report found high levels of customer satisfaction but reported low realization rates caused by incorrect assumptions in the Program Savings Document (Connecticut's technical reference manual). Specifically, the study suggested customers changed behavior given the introduction of a handheld remote, increased heating use or operating hours given perceived lower operating costs, or otherwise controlled equipment in ways that reduced predicted unit efficiency.

Many heat pumps are not primary heating systems, and many units were installed in places that previously had no space cooling, resulting in a cooling load occurring for the first time. In addition, occupants were prone to misusing (or not using) their heat pumps in the winter heating season, thereby missing potential savings from non-electric fuels. The study recommended customer education and adjustments to the electric savings calculation to more accurately reflect energy savings.

***Web Links to Program Resources***

Energize CT Heat Pump Rebates:
https://www.energizect.com/your-home/solutions-list/ductless-split-heat-pump-rebates

Connecticut Program Savings Document:
https://www.energizect.com/sites/default/files/2017%20CT%20Program%20Savings%20Document_Final.pdf

# Maine

## Building Electrification Policies

As a largely rural, cold climate state, approximately 65 percent of Maine households heat with fuel oil. By comparison, only 5 percent of homes heat with natural gas. Given the state's reliance on oil, a number of policy drivers promote heat pump adoption in Maine.

In 2011, the Maine legislature passed legislation requiring state energy planning to focus on reducing oil dependence, including a 30 percent reduction from 2007 levels by 2030, and a 50 percent reduction by 2050. The law requires Efficiency Maine and other state entities to prioritize energy efficiency and alternative fuels for heating and transportation.

A marked increase in financial support for ASHPs was driven by Maine's 2013 omnibus energy bill, which included language directing a portion of both RGGI funds and other Efficiency Maine funds (such as FCM revenues) to be directed to reducing residential heating costs. In addition, Maine's 2015 state energy plan sets goals to significantly increase efficiency improvements and improve heating affordability, with policy emphasis on lowering total costs, expanding loan and on-bill financing, and targeting low income residents.

While policy emphasis and implementation has mostly involved Efficiency Maine, distribution utilities have also recognized the revenue implications of building electrification. In 2012, the legislature authorized each electric distribution utility to offer heat pump pilot projects and related offerings such as rebates and on-bill financing for up to 500 residential and small commercial customers. Following high customer interest, in 2015, Emera Maine, a distribution utility, sought to take advantage of interest in heat pumps by leasing equipment (with optional eventual sale) to customers using a separate heat pump rate. Emera cited a lower upfront cost barrier to better serve low and middle income customers. However, both traditional fuel dealers and by contractors who sell and service ASHPs criticized the program as an unfair competitive advantage for the utility. The Maine PUC rejected Emera's expansion, noting that it fell outside a core utility service and outside the scale of a pilot project specifically authorized by statute.

***Web Links to Policy Resources***

2011 Act To Reduce Maine's Dependence on Oil:
http://www.mainelegislature.org/legis/bills/bills_125th/chappdfs/PUBLIC400.pdf

2015 Maine Energy Plan:
http://maine.gov/energy/pdf/2015%20Energy%20Plan%20Update%20Final.pdf

## Implementation – Programs Promoting Heat Pumps

Efficiency Maine, the quasi-governmental agency implementing statewide efficiency programs, partners with 400 registered contractors to deliver its ductless heat pump program. The program is a downstream rebate program, although customers can choose to have the rebate mailed directly to the contractor. Ductless heat pump residential customer rebate amounts are $500 for the first indoor unit and $250 for the second, with a lifetime limit of $750 per dwelling. Commercial rebate amounts are $500 for the first zone and $250 for each additional zone up to $1,250 total. Rebates are offered downstream

Emera Maine, one of Maine's two investor owned utilities, has sought to expand its heat pump offerings. Emera currently has no heat pump program due to regulator pushback.

***Funding Sources for Heat Pump Programs***
Efficiency Maine is funded by a systems benefit charge, RGGI, FCM funds, and contracts with Maine utilities. The residential heat pump program has been primarily funded by the systems benefit charge (called Electric Procurement Funds) in Maine. Heat pump programs for low income customers and small businesses have been largely funded through RGGI.

***Program Rules—Restrictions/Encouragement of Fuel Switching***
Efficiency Maine designed its heat pump program to account for the state's cold climate while imposing few restrictions on customers or installers; one program manager noted "complex rules can be crippling." Efficiency Maine does not prohibit fuel switching; in fact, heat pumps have been most popular among residents using heating oil.

Because ENERGY STAR lacked a relevant cold climate heat pump level, and Efficiency Maine's program predated the NEEP cold climate specification, Efficiency Maine came up with its own by specifying a Heating Season Performance Factor (HSPF) requirement of 12.0 BTU/Wh for single zone units and 10.0 BTU/Wh for multizone units. This performance factor is now also recommended for cold climates by ENERGY STAR and NEEP. In Maine, the HSPF has averaged 13.2 BTU/Wh, indicating units that are well-suited for Maine winters while imposing few product requirements on distributors, contractors, or customers. The prescriptive commercial heat pump measure requires the same HSPF levels for single and multi-zone installations.

***Energy Savings Calculations (Including Non-Electric Fuels)***
Residential heat pump savings are limited to market opportunity electric savings. Efficiency Maine does not claim fossil fuel savings and only counts the incremental electric savings over standard efficiency heat pumps. Savings are based on improvement over baseline (8.2 HSPF, 14.0 SEER), with separate deemed savings calculations for single units and multihead. Notably, the savings calculations assume

the ductless unit does not exceed 35 percent of a home's heating load; the remaining 65 percent is served by the existing heating system.[25]

***Fuel Switching in Cost Effectiveness Screening***
Only electric savings are considered in Efficiency Maine's ductless heat pump measure, despite the fact that the measure has been most popular among residents using heating oil.

***Impact of Electrification and Fuel Switching on Program Metrics***
Efficiency Maine has not released program savings for heat pumps specifically, but staff indicate that ASHP measures are a major contributor to the residential program's electric savings.

Efficiency Maine's robust rebates and strong program focus on ASHPs is underpinned by 2013 legislation that specifically directed Efficiency Maine to use a portion of both RGGI and other funding sources to reduce residential heating costs. Efficiency Maine Trust is also guided by a suite of overarching performance targets that are broader than just electric savings. Efficiency Maine's goals include achieving electricity and natural gas savings of at least 30 percent and heating fuel savings of at least 20 percent by 2020 and reducing total energy costs for electricity consumers.[26]

***Quality Assurance/Quality Control***
Efficiency Maine addresses quality installation in a number of ways. The program provides customers a one-page list of questions to use in comparing contractors. Program-approved installers must complete program-specific training and manufacturer-specific training. In addition, Efficiency Maine has written its program rebate form (to be completed by installers) to require post-installation numeric measurements that act to confirm equipment has been correctly installed.

***Grid Flexibility***
Maine has robust participation in commercial demand response programs. However, Maine's utilities offer no peak pricing or demand response options to customers beyond voluntary time-of-use rates. Although each new ductless heat pump increases summer peak demand by 0.14 kW and winter peak demand by 0.35 kW, Maine program administrators and utilities do not directly address heat pump demand management at this time.

## Outcomes

***Community Outreach and Education***
Efficiency Maine has devoted significant outreach to marketing ASHP measures and educating end users. This has included advertising in online and print media, as well as online videos with equipment overviews, customer testimonials, and residential case studies.

[25] For a description of the measure, see Efficiency Maine Trust, 2017. *Retail / Residential Technical Reference Manual,* Version 2018.2: 86. https://www.efficiencymaine.com/docs/EMT-TRM_Retail_Residential_v2018_2.pdf.
[26] Efficiency Maine Trust, 2012. *Triennial Plan for Fiscal Years 2014-2016.* https://www.efficiencymaine.com/docs/TriPlan2-11-26-2012.pdf.

To improve in-home performance, Efficiency Maine developed a two-page tips sheet aimed at reducing inefficient use and improving post-installation customer satisfaction. The document discourages use of the “Auto” function which could inadvertently choose the wrong mode (e.g. provide cooling on a sunny winter day) or conflict with a home’s other heating systems. The guide also recommends basic maintenance actions such as cleaning dust filters and professionally servicing the outdoor unit annually. This tips sheet is available online; a print version is left with customers by contractors.

***Heat Pump Adoption Level of Activity***

Maine has had notable success in deploying high-efficiency cold climate ASHPs, seeing more than 4,800 residential installations (equal to nearly 1 percent of all households) and 900 commercial installations in FY2016. ASHP installations are the most popular residential program measure three years in a row (FY 2014-2016), with more than 25,000 units installed since 2011. A drop in heating oil prices (thus reducing economic competitiveness of heat pumps) has been countered by an expansion of market awareness, qualified installers and salespeople, meaning residential installations continue at similar rates seen in previous years.

***Electrification Lessons Learned***

Maine’s success is a result of multiple factors, namely wide reliance on fuel oil for space heating, relatively high fuel oil prices in 2012-2014, and both extensive marketing and generous incentives by the Efficiency Maine Trust. Combined, these factors have led to significant customer and contractor interest, a trend that has continued despite a recent fall in fuel oil prices.

Efficiency Maine’s program manager also noted the program’s success in introducing ductless heat pumps to the state, recruiting contractors, and recruiting customers. He discouraged extensive contractor requirements or instructions, but has found an installation checklist helpful for installers new to the technology.[27] Oil heat installers, for example, typically lack past experience with refrigerant systems.

***Web Links to Program Resources***

High Efficiency Heat Pumps:
https://www.efficiencymaine.com/heat-pumps/

[27] Efficiency Maine, n.d. “Ductless Heat Pump Installation Checklist – Submit with Claim Form.” https://www.efficiencymaine.com/docs/Ductless-Heat-Pump-Installation-Checklist.pdf.

# Massachusetts

## Building Electrification Policies

Massachusetts has several policies in place that support and fund building electrification. The Massachusetts Clean Energy and Climate Plan outlines policies and their expected impact on the Commonwealth in 2020. Robust energy efficiency programs are supported by an All Cost Effective Energy Efficiency Policy. Utility program administrators (PAs) in the Commonwealth have invested over $8.1 billion in electric and gas efficiency since 2010. Since 1990, a trend has emerged in Massachusetts of fuel switching buildings from fuel oil to natural gas, although this fuel-switching was never funded using energy efficiency funding. Recently, this trend has declined due to historically low oil prices combined with natural gas constraints in southern New England. Low-carbon alternatives to fossil-fuel thermal technologies such as ccASHPs, GSHPs, solar thermal systems, and biomass systems are currently being supported by Massachusetts' Developing a Mature Market for Renewable Thermal Technologies policy. The Commonwealth currently supports the deployment of renewable thermal installations through rebates and workforce development administered through the Massachusetts Clean Energy Center (MassCEC).

Massachusetts currently offers heat pump rebates through two mechanisms. Mass Save®, supported by the PAs, offers customer rebates on central heat pumps and mini-split heat pumps. MassCEC administers a $30 million Clean Heating and Cooling program. Through this program, heat pump technologies are incentivized based on household income.[28] The MassCEC program also supports commercial scale ASHPs.

The Renewable Portfolio Standard in Massachusetts includes an Alternative Portfolio Standard (APS) which is a statutory obligation established in 2009 under the Green Communities Act of 2008. The APS requires an increasing percentage of the Commonwealth's electric load to be met by eligible technologies. Alternative Compliance Payments for this standard provide an additional funding source to support thermal electrification through MassCEC.

In the regulatory arena, in 2014, the Massachusetts' Department of Public Utilities ordered utilities to develop grid modernization plans. The order outlined several key objectives: reduce the effects of outages, optimize demand, reduce system and customer costs, integrate DERs, and improve workforce and asset management. Proceedings are currently underway for the development of grid modernization plans for Investor-Owned Utilities in Massachusetts. There has been mention in these proceedings about the role of electrification of the thermal and transportation sector

[28] Massachusetts Clean Energy Center. October 31, 2017. Residential and Small-Scale Air-Source Heat Pump Program Manual. http://files.masscec.com/get-clean-energy/residential/air-source-heat-pumps/ASHPProgramManualSmallScale.pdf.

as a means to enable greater integration of intermittent renewables onto the grid. These proceedings are currently underway and more information is forthcoming.

***Web Links to Policy Resources***

An Act Relative to Credit for Thermal Energy Generated with Renewable Fuels:
https://malegislature.gov/Bills/188/Senate/S2214

All Cost Effective Energy Efficiency Policy:
http://www.mass.gov/eea/docs/eea/gwsa/building-fuels-and-energy-efficiency/all-cost-effective-energy-efficiency.pdf

Massachusetts Clean Energy and Climate Plan:
http://www.mass.gov/eea/docs/eea/energy/cecp-for-2020.pdf

Massachusetts RPS and APS Summary:
http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/rps-aps/rps-and-aps-program-summaries.html

Investigation by the Department of Public Utilities on its own Motion into Modernization of the Electric Grid:
http://170.63.40.34/DPU/FileRoomAPI/api/Attachments/Get/?path=12-76%2fOrder_1276B.pdf

Commonwealth Accelerated Renewable Thermal Strategy:
http://www.mass.gov/eea/docs/doer/renewables/thermal/carts-report.pdf

Statute Establishing Massachusetts Clean Energy Center:
https://malegislature.gov/Laws/GeneralLaws/PartI/TitleII/Chapter23j

## Implementation – Programs Promoting Heat Pumps

Massachusetts offers heat pump incentives through two mechanisms, the utility energy efficiency program, Mass Save, and MassCEC. The programs work together and the incentives from both programs can be combined.

Mass Save, which is a collaborative of Massachusetts' natural gas and electric utilities and energy efficiency service providers, offers downstream customer rebates on central heat pumps and mini-split heat pumps. Participants seeking an incentive on electric heating and cooling equipment contact a Mass Save qualified contractor to have a heat pump installed and receive a rebate based on the efficiency of the unit. Currently, incentive levels are $100 per indoor unit (or head) for 18 SEER or above and $300 for 20 SEER and above. Central heat pumps (ducted heat pumps) are also incentivized through the program.

MassCEC also offers incentives to support the installation of ASHPs and GSHPs in buildings through its Clean Heating and Cooling program, which was recently allocated $30 million in funding through 2020. Participants interested in receiving a heat pump rebate through MassCEC must schedule an energy audit (offered free through Mass Save) prior to having an ASHP installed. Heat pumps must meet (or in some cases exceed) the NEEP ccASHP standards to qualify for the incentive. MassCEC only offers downstream programs, meaning that the customer is the recipient of the rebate or incentive. If a contractor or installer applies for the rebate on behalf of their client, they are required to pass that rebate on to the customer.

Because MassCEC has an organizational focus of promoting clean energy for low-to-moderate income households, they provide larger incentive amounts to low and moderate income households (Table 6). Rebates range from $625 to $1500 depending on income.

Table 6. Massachusetts Clean Energy Center heat pump eligibility and rebates[29]

| | Income-Based Thresholds by Household Size | | System Type | |
|---|---|---|---|---|
| **Rebate Type** | **House hold Size** | **Annual Gross Income** | **Single-Head** | **Central and Multi-Head** |
| **Base Rebate**<br>Available to all households meeting project eligibility requirements | N/A | N/A | $625 | $625<br>per 12,000 BTU/hr<br>(up to a maximum rebate of $2,500) |
| **120% Income-Based Rebate**<br>Available to all households that meet project eligibility requirements **and** have verified that their income is below 120% of the Massachusetts state median income. | 1 | $68,003 | $800 | $800<br>per 12,000 BTU/hr<br>(up to a maximum rebate of $3,200) |
| | 2 | $88,926 | | |
| | 3 | $109,850 | | |
| | 4 | $130,775 | | |
| **80% Income-Based Rebate**<br>Available to all households that meet project eligibility requirements **and** offset electric resistance heat **and** have verified that their income is below 80% of the Massachusetts state median income. | 1 | $45,335 | $1,500 | $1,500<br>per 12,000 BTU/hr<br>(up to a maximum rebate of $6,000) |
| | 2 | $59,284 | | |
| | 3 | $73,233 | | |
| | 4 | $87,183 | | |

***Funding Sources for Heat Pump Programs***

The Mass Save programs receive funding through several sources. The primary sources of funding are a system benefit charge (SBC) and the Energy Efficiency Reconciliation Factor (EERF) created by the Green Communities Act. In addition to these SBCs, the programs receive funding from RGGI. Approximately 11 percent of the funding comes from the RGGI auction proceeds.

MassCEC receives funding from the Renewable Energy Trust Fund. It was created in 1998 by the Massachusetts Legislature as one of the outcomes of the deregulation of the electricity market. The Renewable Energy Trust Fund is supported by a systems benefit charge of $0.0005 per kilowatt hour paid by electric ratepayers of

[29] Massachusetts Clean Energy Center. October 31, 2017. Residential and Small-Scale Air-Source Heat Pump Program Manual. http://files.masscec.com/get-clean-energy/residential/air-source-heat-pumps/ASHPProgramManualSmallScale.pdf.

investor-owned utilities in Massachusetts. Municipal electric departments can also opt in to the program and collect a systems benefit charge so that its customers may participate in the program. The average Massachusetts household contributes $0.32 to the Renewable Energy Trust each month.[30]

***Program Rules—Restrictions/Encouragement of Fuel Switching***
Mass Save is not permitted to promote heat pumps as a fuel switching measure, but they do incentivize heat pumps as an electric efficiency measure. This means that if a customer installs a heat pump to offset oil or propane usage, only electric savings can be counted by Mass Save. MassCEC's clean heating and cooling program is expressly designed to promote technologies like heat pumps that integrate well with renewable energy sources.

***Energy Savings Calculations (Including Non-Electric Fuels)***
The MassCEC program does not focus strictly on energy savings. Instead, the success of the program is measured in terms of the number of incentives granted and the cumulative installed capacity of heat pumps deployed in the state. For Mass Save, heat pumps are not counted as a fuel switching measure, but are instead counted as a market opportunity electric measure with electric savings over baseline. The Massachusetts Technical Reference Manual includes algorithms for calculating primary energy impact.[31]

Savings assumptions for ASHPs have recently been updated based on a 2016 impact evaluation conducted for program administrators in Massachusetts and Rhode Island.[32] The study evaluated the on-site performance of ductless mini-split heat pumps in 132 Massachusetts homes and 20 Rhode Island homes. It sought to determine how much energy was being saved with the average mini-split installation, and to answer many utility and consumer questions about mini-split heat pumps related to power and energy consumption, heat output, efficiency, and interactions with existing HVAC equipment.

The study found significantly lower "equivalent full load hours," and therefore lower energy savings, than the Massachusetts and Rhode Island TRMs had originally estimated, for a variety of reasons:

- Not all units were used routinely for each season. Many units were lightly used (or not used at all) for heating or cooling;
- Many units remained off during the summer's cooler periods;
- Some units in heating mode operated coincidently with primary systems (many of which were fossil fuel-based); and
- Systems were sized larger than the cooling needs of the immediate spaces they served.[33]

[30] Massachusetts Clean Energy Center, Financial Information. http://www.masscec.com/financial-information
[31] Mass Save, *Massachusetts Technical Reference Manual:* 69-70. http://ma-eeac.org/wordpress/wp-content/uploads/2016-2018-Plan-1.pdf
[32] Cadmus Group, "Impact Evaluation." http://ma-eeac.org/wordpress/wp-content/uploads/Ductless-Mini-Split-Heat-Pump-Impact-Evaluation.pdf
[33] Cadmus Group, "Impact Evaluation."

***Fuel Switching in Cost Effectiveness Screening***
Cost-effectiveness screening of ASHP programs varies depending on which party is administering the program. The Mass Save programs, operated through the utility Program Administrators, undergoes the type of evaluation standard in more traditional energy efficiency programs. In Massachusetts, energy efficiency programs are screened using the Total Resource Cost (TRC) test. According to a recent presentation to the Massachusetts Energy Efficiency Advisory Council, heat pump programs have marginal cost-effectiveness, in part because of some old assumptions including free-ridership and non-energy impacts used in the screening.[34] The Massachusetts Technical Reference Manual includes the algorithms for calculating primary energy impact.[35]

The MassCEC program is not subject to the traditional energy efficiency cost/benefit testing that is required of the Mass Save programs.

***Impact of Electrification and Fuel Switching on Program Metrics***
MassCEC focuses on encouraging renewable thermal technologies, and therefore its key performance metrics are installed capacity and the number of heat pumps incentivized. In contrast, the Mass Save programs measure success based primarily on annual electricity savings and lifetime benefits, and do not currently value the fossil fuel reductions that heat pumps provide. However, the PAs are considering updated performance metrics for the 2019-2021 performance period, including an MMBtu metric that would include both measure interactive effects and the impacts of measures intentionally promoted for fuel switching purposes, such as ASHPs.[36]

***Quality Assurance/Quality Control***
MassCEC program participants are required to schedule a free energy audit for their home prior having a qualified contractor install their heat pump to ensure that the efficiency of the building envelope will maximize the benefits of the technology. Upon completion of the installation, program participants receive a customer tip sheet that provides information about how to maximize the savings and benefits of their heat pump (see Figure 4).

As noted above, a 2016 impact evaluation of the Mass Save heat pump incentive program identified a number of opportunities to increase savings and performance, which the Program Administrators are currently working to address.

***Grid Flexibility***
Both Eversource and National Grid offer TOU pricing options for residential customers, but none are targeted specifically to ASHPs. Off-peak hours for the R-4 rate are between 9:00 p.m. and 8:00 a.m. every day of the week and all day on weekends and holidays. The R-4 rate for Eversource varies by time of year. During the summer (June through September), peak hours are between 9:00 a.m. and 6:00 p.m. weekdays and between October and May peak hours are between 8:00 a.m.

[34] Massachusetts Energy Efficiency Advisory Council, 2016. “Residential Strategic Electrification and Heat Pumps.” Presentation by Consultant Team to the Council. http://ma-eeac.org/wordpress/wp-content/uploads/Residential-Strategic-Electrification-and-HPs-1.pdf
[35] Massachusetts Energy Efficiency Advisory Council, *Massachusetts Technical Reference Manual* : 69.
[36] Glenn Reed, personal communication, January 16, 2018.

and 9:00 p.m.[37] In 2016, Eversource launched a residential demand response demonstration project in which participants allowed the utility to control their thermostats during peak events in exchange for participating in demand response events.[38]

Figure 4. First page of customer tip sheet[39]


## Outcomes

***Community Outreach and Education***

Two recent developments at MassCEC contribute to a recent increase in education and awareness of electrification. MassCEC recently switched to a third party administrator of heat pump incentives through an online portal. This frees up CEC staff to engage contractors and focus on public awareness of heat pumps. The organization also hired a marketing director in the last six months, which has greatly increased focus on marketing the technology. Recent initiatives include a community-based outreach and education program to encourage clean heating and cooling in partnership between MassCEC and the MA Department of Energy Resources (DOER). The program, HeatSmart, is modeled on a successful Solarize Massachusetts program and is intended to drive down the installation cost of heat pumps and increase deployment through a group purchasing model.[40] In response to the workforce development goals of MassCEC, the organization partners with elementary and middle schools to host clean energy activity days. Clean Energy Activity Days expose students to clean energy concepts, higher-education opportunities, and career pathways in STEM and the field of clean energy.[41]

[37] NStar Electric, Boston Edison Company, 2006. "Optional Residential Time of Use; Rate R-4. https://www.eversource.com/Content/docs/default-source/rates-tariffs/123.pdf?sfvrsn=2.

[38] Mass Save, 2016. "National Grid Residential Demand Response, Demonstration Project Update." http://ma-eeac.org/wordpress/wp-content/uploads/NGrid_Resi_OctEEAC_Draft_10-17-16.pdf

[39] Mass Save. N.d. "First Came the Installation. Now Comes the Savings." http://files.masscec.com/get-clean-energy/residential/air-source-heat-pumps/ASHP_Tips_Web.pdf

[40] Massachusetts Clean Energy Center. "HeatSmart Mass." http://www.masscec.com/heatsmart-mass-0

[41] Massachusetts Clean Energy Center. "Clean Energy Activity Day." http://www.masscec.com/clean-energy-activity-day

***Heat Pump Adoption Level of Activity***

The MassCEC heat pump program was launched as a pilot in 2015. Heat pump installation volume has increased consistently since the program was launched, with over 9,000 rebates issued for ASHPs since the program began. For comparison, in 2016 Mass Save incentivized almost 9,000 ASHPs.[42] Since the incentives can be combined between the two programs, there is likely significant overlap between these programs.

***Electrification Lessons Learned***

Strong partnerships between organizations including the utility efficiency programs and MassCEC are key in Massachusetts. MassCEC's ability to promote heat pumps based on renewable thermal goals rather than energy efficiency program metrics provides them with more flexibility to focus on technology deployment instead of electricity savings goals.

Massachusetts is also working to improve performance and savings for heat pumps installations, informed by the 2016 impact evaluation. The study found that it was particularly challenging for homes with single-zone heating systems, like most furnaces, to optimize use of ductless heat pumps because there is a single thermostat and set point controlling a home's temperature. In such homes, if the mini-split heats only one or two rooms, relying only on the mini-split could under heat other portions of the home. To address this issue, the study noted that "substantially more savings could be achieved… if newly installed [mini-splits] are operated more regularly and continuously by better matching and integrating them zonally with primary heating systems, through better configuration design and installation and contractor and customer education and training. For example, contractors would focus their design efforts on specifying the appropriate number and size of [mini-split] heads to match and heat entire zone(s) rather than a single room. Customers would then be educated on how to properly set the set points for both their primary and [mini-split heating systems, which will depend on their primary fuel type and outdoor temperatures."[43] Improved training for both installation contractors and customers is therefore an important focus going forward.

***Web Links to Program Resources***

Ductless Mini-Split Heat Pump Impact Evaluation:
http://ma-eeac.org/wordpress/wp-content/uploads/Ductless-Mini-Split-Heat-Pump-Impact-Evaluation.pdf

Mass Save Funding Source Information:
https://www.mass.gov/service-details/massachusetts-energy-budgets-investments

Mass Save Electric Heating and Cooling Equipment Information:
https://www.masssave.com/en/saving/residential-rebates/electric-heating-and-cooling/

MassCEC Facts and Funding Information:
http://www.masscec.com/about-masscec

[42] Mass Save. "Welcome to Mass Save Data." http://www.masssavedata.com/Public/MeasuresDetails
[43] Cadmus Group, "Impact Evaluation."

MassCEC Clean Heating and Cooling Program Information:
http://www.masscec.com/residential/clean-heating-and-cooling

2016 Massachusetts Clean Energy Industry Report:
http://files.masscec.com/2016%20MassCEC_IndustryReport_Full_Web.pdf

# New Hampshire

## Building Electrification Policies

While New Hampshire has a Thermal Renewable Energy Certificate (T-REC) program, ASHPs are not currently included in the program. GSHPs, solar domestic hot water, and biomass are covered under the definition of "useful thermal renewable energy."[44] As a result of this classification, ASHPs and HPWHs are covered by utility-run energy efficiency programs under the NH Saves brand.

In 2016, the New Hampshire Public Utility Commission issued an order adopting a statewide Energy Efficiency Resource Standard (EERS). Currently, ASHPs are one measure that state efficiency programs are promoting to reach gradually increasing energy efficiency goals outlined in the EERS. An evaluation of air conditioning equipment in the residential and commercial and industrial sectors found that air conditioning contributed to demand for electricity during peak hours in the state and recommended a number of cooling measures to include in New Hampshire's energy efficiency programs.[45] Consequently, it may have been the desire to expand cooling efficiency measures, rather than electrification of heating, that sparked New Hampshire's interest in promoting ASHPs, including ductless mini-splits.

***Web Links to Policy Resources***

New Hampshire Public Utilities Commission (2016, August 8), Order No. 25,932, "Energy Efficiency Resource Standard – Order Approving Settlement Agreement": http://www.puc.state.nh.us/Regulatory/Orders/2016orders/25932e.pdf

2017 New Hampshire Statewide EE Plan NH Saves: https://www.iso-ne.com/static-assets/documents/2016/12/nh_ee_forecast_2017__2026.pdf

Electric Renewable Portfolio Standard: https://www.puc.nh.gov/Sustainable%20Energy/RPS/Draft%20Rules/PUC%20Rule%202500%20draft%2012_20_12.pdf

## Implementation – Programs Promoting Heat Pumps

New Hampshire Electric Retail Utilities (Liberty Utilities, New Hampshire Electric Co-op, Eversource, and Unitil; collectively NH Utilities) offer downstream incentives for both ASHPs and HPWHs. In addition, New Hampshire Electric Co-op (NHEC) offers 2% APR financing to customers installing qualified ASHP and HPWH systems in 2018.

[44] New Hampshire Public Utilities Commission, "Electric Renewable Portfolio Standard (RPS). https://www.puc.nh.gov/Sustainable%20Energy/Class%20I%20Thermal%20Renewable%20Energy.html

[45] NHSaves, 2018. *Revised EERS Plan:* 154. http://puc.nh.gov/Regulatory/Docketbk/2017/17-136/LETTERS-MEMOS-TARIFFS/17-136_2018-01-12_NH_UTILITIES_REV_EERS_PLAN.PDF.

***Funding***
ASHP and HPWH incentive programs in New Hampshire are currently offered exclusively by electric utilities through the NH Saves program. Funding for this program includes a portion of the system benefit charge (SBC) collected on bills of electric customers statewide. In addition to SBC funding, these incentives are funded in part through RGGI auction proceeds and FCM participation. Any unspent funds are carried forward from earlier program years and added to the budget of future years.

NHEC is an exception to this model and does not rely on SBC funds for its heat pump program. NHEC funds ASHP and HPWH incentives through a separate line item in its budget for a Social and Environmental Responsibility Fund.

***Program Rules—Restrictions/Encouragement***
ASHP and HPWH incentives are implemented by utilities through NH Saves. Because ASHP incentives are offered through individual electric utilities, program elements vary depending on the utility. While all of the NH Utilities offer consumer heat pump incentives, NHEC encourages customers to install heat pumps under specific conditions that improve building efficiency and displace a greater portion of heating load.

To encourage heat pump installations in more efficiency homes, NHEC offers a weatherization incentive. If a residential customer participates in the Home Performance with ENERGY STAR® program and installs all cost-effective shell measures and health and safety recommendations during a given program year, the customer is eligible for an additional $250/ton incentive for heat pump installation (in addition to the base incentive). NHEC also offers an additional $250 incentive if the ASHP system is designed to offset 80 percent of total heating load.

***Energy Savings Calculations (Including Non-Electric Fuels)***
Savings calculations for ductless mini-splits include summer (cooling) savings as well as winter (heating) savings. New Hampshire Utilities only count the market opportunity electric savings for ASHPs. Savings are calculated as the difference between an efficient measure and a baseline measure. No MMBtu savings are counted for switching from fossil fuel to electricity.

***Fuel Switching in Cost-Effectiveness Screening***
New Hampshire Utilities' energy efficiency programs rely on the Total Resource Cost (TRC) test to screen energy efficiency measures and programs. Like most utility run programs, ASHP screening only considers market opportunity electric savings.

***Impact of Electrification and Fuel Switching on Program Metrics***
No additional load is counted for the installation of ductless mini-splits or heat pump water heaters as the metrics are tied to the quantity of installations (different utilities have different numbers of heat pump installations forecast in their plans) and electric savings.

### *Quality Assurance/Quality Control*

The program for NHEC encourages installation of ASHPs and HPWHs to be completed by a licensed contractor and requires that any equipment is ENERGY STAR® certified to be eligible for the rebate. In addition, the incentive form language authorizes the utility to verify sales transactions and inspect the installed heat pump system incentivized by the program.

### *Grid Flexibility*

One utility, Liberty Utilities, currently offers a Time of Use rate to incentivize EV charging at night, but there are currently no TOU rates specific to electric space heating and cooling or water heating.

## Outcomes

### *Community Outreach and Education*

ASHP and HPWH incentives in New Hampshire are marketed through NH Saves. In addition to providing information about efficiency programs and measures, the NH Saves website offers a blog which features specific studies and technologies, including research and information about ductless heat pumps.

### *Heat Pump Adoption Level of Activity*

Heat pump programs in New Hampshire are projected to increase the number of incentivized mini-split heat pumps by approximately one-third over the next three years (Table 7).

Table 7. Efficiency program heat pump incentives, savings, and goals in New Hampshire[46]

| Measure | Incentive | Annual Savings | 2018 Plan Goal | 2019 Plan Goal | 2020 Plan Goal |
|---|---|---|---|---|---|
| Mini-Split Heat Pump SEER 18+ | $600 | 103 kWh (Cooling)<br>328 kWh (Heating) | 1,230 units[47] | 1,408 units | 1,923 units |

### *Electrification Lessons Learned*

New Hampshire's focus on the cooling savings from ASHPs highlights the increasing concern about summer peak demand, as New England states become cooling climates with increasingly warm summers.

In addition, NHEC's layered incentives are a promising model to incentivize heat pump installations that in a manner that encourages building shell efficiency and maximizes displacement of backup fossil fuel heating systems.

[46] *New Hampshire Statewide Energy Efficiency Plan*.
[47] Mini-split heat pump goals do not include NHEC units.

***Web Links to Program Resources***

New Hampshire Electric Co-op Rebate Form:
https://www.nhsaves.com/wp-content/uploads/2018/01/2018-Res-HP.pdf

Liberty Utilities Rebate Form:
https://www.nhsaves.com/wp-content/uploads/2018/01/2018-LU-Residential-Heating-Cooling-Water-Heating-Rebate-Form-FNL.pdf

Eversource Rebate Form:
https://www.nhsaves.com/wp-content/uploads/2018/01/2018-Eversource-Residential-HeatingCooling-Water-Heating-Rebate-form.pdf

Unitil Rebate Form:
https://www.nhsaves.com/wp-content/uploads/2018/01/2018-Unitil-Electric-Res-HtgCoolingandWtrHtg-Rebateform-Live-FINAL-013118.pdf

NH Statewide EE Plan 2018-2020:
https://puc.nh.gov/Regulatory/Docketbk/2017/17-136/INITIAL%20FILING%20-%20PETITION/17-136_2017-09-01_NHUTILITIES_EE_PLAN.PDF

## New York

### Building Electrification Policies

In 2015, the State Energy Plan was released as a roadmap for New York's Reforming the Energy Vision (REV) initiative launched by Governor Cuomo. The Plan includes a goal that by 2030, 50 percent of electricity in New York must come from renewable resources. To help reach this goal, the New York Public Service Commission authorized the Clean Energy Fund (CEF) framework and adopted the legally binding 50 percent renewables by 2030 portion of its Clean Energy Standard. The CEF is administered through New York State Energy Research and Development Authority (NYSERDA) and is funded through a combination of system benefit charge and Renewable Portfolio Standard (RPS) collections on the bills of investor-owned utilities in the state, along with a portion of the state's RGGI revenues.

The CEF is a 10-year, $5 billion commitment through 2025. It is fuel neutral, which allows it to fund a broad range of clean energy initiatives. In the regulatory proceeding that created the CEF, there was broad stakeholder support for a fuel neutral support, which was seen as essential to "enable whole building efficiency gains, increased GHG emission reductions, further technology innovation, and a simplified approach to ratepayer collections."[48] Use of CEF funds for fuel switching requires, "…a clear, superior economic advantage." Traditionally, electric systems benefits charge funds could only be used to incentivize electric efficiency, however, CEF funds can be used to displace fossil fuels instead of electricity as long as the project results in, "…greater GHG emission reductions and economic benefit than an electric-only approach."[49]

In the 2015 New York State Clean Energy Plan, NYSERDA is tasked with supporting the development of market infrastructure for renewable heating and cooling technologies including solar space and water heating and both air and ground source heat pumps.[50]

#### ***Web Links to Policy Resources***

Clean Energy Fund:
https://www.nyserda.ny.gov/About/Clean-Energy-Fund

2015 New York State Energy Plan:
https://energyplan.ny.gov/Plans/2015.aspx

[48] State of New York Public Service Commission, 2016. "Order Authorizing the Clean Energy Fund Framework." https://www.nyserda.ny.gov/About/Clean-Energy-Fund: 61.

[50] New York State Energy Planning Board, 2015. "The Energy to Lead: 2015 New York State Energy Plan," 1:75. https://energyplan.ny.gov/Plans/2015.

## Implementation – Programs Promoting Heat Pumps

The NYSERDA heat pump program was launched in August 2017 and is targeted to run through December 2020, at which point it will be reassessed. The program offers midstream heat pump incentives through contractors who, upon enrollment in the program and contingent on meeting QA/QC guidelines of the program, receive $500 for each qualifying heat pump they install. All ASHPs must meet NEEP ccASHP specifications. NYSERDA's approach differs from the midstream programs implemented in Connecticut and Vermont in that incentives are paid to contractors, rather than wholesale distributors, and are not required to be passed on to end-use customers.

NYSERDA developed its heat pump program based on comprehensive feedback from multiple stakeholder meetings involving manufacturers, distributors, and contractors.[51] Stakeholders agreed to focus initially on contractor incentives to incentivize contractors to provide valuable information regarding heat pumps installations, including the types of systems and fuels being displaced, age of buildings involved, and details about usage. This information would be more challenging to gather from distributors. Though no distributor incentives are currently being offered, there is flexibility built into the program. Once the program reaches its halfway point, NYSERDA may reconsider incentive levels and make adjustments based on program evaluation.

New York utilities, including PSEG, ConEd, Orange/Rockland, and Central Hudson offer separate downstream heat pump incentives. These incentives can be combined with the NYSERDA incentives, because the utility incentive goes to consumers while the NYSERDA midstream incentive is paid to contractors.

***Funding***

NYSERDA's heat pump program is funded by the CEF as part of a broader investment to accelerate the growth of New York's clean energy economy, address climate change, strengthen resiliency in the face of extreme weather and lower energy bills for New Yorkers starting this year.[52] PSEG Long Island is not under the explicit jurisdiction of the New York Public Service Commission (PSC) and so does not collect the SBC, therefore, it does not participate in the midstream NYSERDA heat pump program.

Notably, the New York Green Bank is a major component of the CEF, but to date it has not included a specific financing program or product to promote heat pumps like the one offered by the Connecticut Green Bank.

[51] New York State Department of Public Service, "In the Matter of the Clean Energy Fund Investment Plan." DPS Case # 16-00681. http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=16-00681

[52] New York State, Office of the Governor, 2016. "Governor Cuomo Launches $5 million Clean Energy Fund to Grow New York's Clean Energy Economy." https://www.governor.ny.gov/news/governor-cuomo-launches-5-billion-clean-energy-fund-grow-new-york-s-clean-energy-economy.

***Program Rules—Restrictions/Encouragement***

NYSERDA's heat pump program is fuel-neutral; customers using any type of heating fuel are eligible to participate. Utility programs in southern New York are also open to all fuel types, with a specific goal at reducing natural gas reliance because of natural gas transmission constraints in the area.

***Energy Savings Calculations (Including Non-Electric Fuels)***

Both utility-run and NYSERDA heat pump programs claim NY State deemed savings from the heat pumps. Currently, deemed savings for heat pumps are mainly based on cooling efficiency rather than heating. NYSERDA has two demonstration projects currently underway, one in the Hudson Valley and one in New York City, to collect energy savings information for heat pumps. As these projects progress and more data is available, savings calculations will be adjusted to reflect these findings. The NYSERDA program also focuses on the carbon reduction savings from heat pumps, in addition to the energy savings.

***Fuel Switching in Cost-Effectiveness Screening***

With regard to cost benefit testing, New York recently transitioned its cost-benefit screening test for efficiency programs from the Total Resource Cost (TRC) Test to the Societal Cost Test (SCT). However, because NYSERDA's heat pump program is a midstream program, and incentives go to contractors instead of directly to consumers, it is not required to pass traditional cost-benefit testing.

Utility heat pump programs offered through traditional energy efficiency programs are subject to the cost benefit testing requirements of the efficiency portfolio. For ConEd, this requires programs to be cost-effective at the portfolio level meeting a Societal Cost Test ratio of 1.0.[53] Because this cost-effectiveness requirement is at the portfolio level, less cost-effective measures can be balanced out by more cost-effective measures, providing some flexibility in utility offerings. Additionally, while New York's Societal Cost Test includes avoided carbon emissions from generating electricity, it does not currently value the costs associated with carbon emissions from other sources – potentially a limiting factor in fully valuing the benefits of heat pumps.

***Impact of Electrification and Fuel Switching on Program Metrics***

New York's Clean Energy Fund is not tied to traditional energy efficiency and renewable energy savings metrics, such as kWh savings. Instead, CEF progress is measured through the following metrics:[54]

- Greenhouse gas emission reductions
- Customer energy bill savings
- Energy efficiency and clean energy generation
- Mobilization of private sector capital

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[53] State of New York Public Service Commission, 2017. "Order Approving Electric and Gas Rate Plans." January 25: 70. http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B77923784-556A-47A6-B2CC-19F5C252C966%7D.

[54] NYSERDA, "Clean Energy Fund: Building New York's clean, resilient, and affordable energy system." https://www.nyserda.ny.gov/About/Clean-Energy-Fund.

Specifically, NYSERDA's heat pump program aims to deploy 21,000 high-efficiency heat pumps between the commencement of the program (August 17, 2017) and December 21, 2020.

Notably, while the CEF's fuel neutral approach presents advantages in terms of expanding the heat pump market, New York's lack of correspondingly robust and explicit kWh savings targets and programs for utilities in recent years has resulted in lower levels of electricity savings than in other leading states.[55] That trend illustrates the need for fuel neutral programs to supplement rather than supplant robust kWh targets.

***Quality Assurance/Quality Control***

Heat pump performance is highly dependent on proper installation and operation. NYSERDA's program has a comprehensive system in place for quality assurance that includes both program standards and comprehensive field and photo inspections.[56] To ensure that the unit is being operated properly to maximize performance, participating installers are required to train site owners on system operation and maintenance, focusing on the use of these systems for heating.

***Grid Flexibility***

Currently, New York utilities do not offer rate structures specifically targeted to ASHPs. However, ConEd is offering a downstream customer incentive of between $300 and $400 on qualifying ASHPs. In part, these are offered because ConEd is expecting increasing constraints on natural gas distribution in its service territory over the next five years.

In January of 2017, the Public Service Commission required that ConEd develop new service classifications, new rates, incentives and pilot programs for electric vehicles to incentivize off-peak charging and help ConEd improve its overall system efficiency.[57]

Another notable element of the order is that the goals for the utility efficiency programs focus on reducing system peak, but the utility program goals currently focus on GWh savings. These goals will likely be revisited as part of a recently launched EE docket.[58]

## Outcomes

***Community Outreach and Education***

NYSERDA launched an upstream cost-share promotion in December 2017 to provide assistance with marketing, advertising, public awareness and training. This

[55] New York State is currently achieving between only 0.4 to 0.9 percent electric savings relative to annual electric sales. American Council for an Energy-Efficient Economy, 2017. "State and Local Policy Database: New York." Washington, DC: ACEEE. https://database.aceee.org/state/new-york.
[56] NYSERDA, Air Source Heat Pump Program Manual, https://www.nyserda.ny.gov/-/media/Files/Programs/ASHP/Program-Manual.pdf.
[57] New York Public Service Commission, Order Approving Electric and Gas Rate Plans: 71.
[58] New York Public Service Commission, Joint Proposal re: Case 16-E-0060, Case 16-G-0061; Case 15-E-0050; and Case 16-E-0196: 77. http://blogs.edf.org/energyexchange/files/2016/09/Cases-16-E-0060-and-16-G-0061-Joint-Proposal-Final.pdf.

includes manufacturer training for consistent distribution and training on how to install and use heat pumps. Each entity (manufacturer, distributor, and installer) can receive a 50/50 match from NYSERDA for up to $50,000 a year toward marketing and advertising through home shows, radio, and print. The program is developing tools to support the dissemination of heat pumps in New York, including a mapping tool that highlights areas most suitable for heat pumps.

***Heat Pump Adoption Level of Activity***

The NYSERDA program started in August 2017, so it is too early to assess program performance or identify lessons learned. In the five months between the program start and the publication of this report, about 2,200 incentives have been awarded to participating contractors and there are 150 participating installers involved in the program. This rapid uptake is likely due to the large contractor incentive and active engagement of installation contractors. About 25 percent of those installers make up the bulk of the program. Each installer can be awarded up to 1,000 incentives, which translates to $500,000 per installer.

***Electrification Lessons Learned***

Although it is premature to report on lessons learned from NYSERDA's program, early results appear promising. Ongoing results from both NYSERDA and utility programs, as well as two demonstration projects, will inform continued efforts to deploy ASHPs in New York.

***Web Links to Program Resources***

NYSERDA Renewable Heating and Cooling Program:
https://www.nyserda.ny.gov/Residents-and-Homeowners/Your-Home/Heat-Pumps

PSEG Rebates:
https://www.psegliny.com/page.cfm/Efficiency/CoolingHeating/CentralAC/Option2

ConEd Rebates:
https://www.coned.com/-/media/files/coned/documents/save-energy-money/rebates-incentives-tax-credits/rebates-incentives-tax-credits-for-residential-customers/2017-residential-electric-rebate-application.pdf?la=en

Orange Rockland Rebates:
https://www.oru.com/en/save-money/rebates-incentives-credits/rebates-incentives-tax-credits-for-residential-customers/electric-appliance-rebates

Central Hudson Rebates:
http://www.savingscentral.com/rebates/

# Rhode Island

## Building Electrification Policies

The 2014 Resilient Rhode Island Act set ambitious greenhouse gas reduction targets that aimed to reduce GHG emissions to 80 percent below 1990 levels by 2050. The electrification of heating and transportation is integral to meeting those goals. Rhode Island's greenhouse gas modeling for long-term reduction pathways indicates that deep emissions cuts would require significant (>80 percent) electrification of heating and transportation end uses powered by a largely (~97 percent) zero carbon grid.

Rhode Island's efficiency policies also support progress toward meeting the GHG targets. Efficiency programs are driven by a policy of "least cost procurement" (LCP). Currently LCP is large focused on meeting electrical and natural gas energy needs in the state, but is broadly defined to include strategic electrification. This allows National Grid, the primary utility serving Rhode Island, to include cost-effective strategic electrification in its energy efficiency program offerings.

After a stalled 2016 electric rate case and a report from the Systems Integration RI (SIRI) group suggested a need to harmonize existing processes for modernizing energy systems in RI, the Rhode Island Public Utilities Commission (PUC) opened docket 4600. 4600 was an investigation into the changing electric distribution system and the modernization of rates. The docket did not directly address delivered fuels and fuel switching. However, as part of 4600, the RI PUC approved a new benefit-cost test, known as the Rhode Island test, which more fully reflects the policy objectives of the state with regard to energy, its costs, benefits, and environmental and societal impacts. While the specific benefits and costs are still under consideration, the inclusion of carbon and economic benefits in the screening methodology for efficiency measures has already improved screening for heat pumps and fuel switching.

More recently, Rhode Island regulators and energy officials have been leading a Power Sector Transformation initiative to develop goals and principles for modernizing the state's electric system. This initiative includes a work stream focused on beneficial electrification and recently issued a report with high-level principles for electrification of both buildings and vehicles.

***Web Links to Policy Resources***

Least Cost Procurement:
https://law.justia.com/codes/rhode-island/2013/title-39/chapter-39-1/section-39-1-27.7

Resilient RI Law:
https://law.justia.com/codes/rhode-island/2014/title-42/chapter-42-6.2/section-42-6.2-2

GHG Reduction Plan:
http://climatechange.ri.gov/documents/ec4-ghg-emissions-reduction-plan-final-draft-2016-12-29-clean.pdf

Public Documents in Docket 4600:
http://www.ripuc.org/eventsactions/docket/4600page.html

Rhode Island Renewable Thermal Market Development Strategy:
http://www.synapse-energy.com/sites/default/files/RI-Renewable-Thermal-15-119.pdf

Rhode Island Power Sector Transformation: Beneficial Electrification Principles and Recommendations:
http://www.ripuc.org/utilityinfo/electric/PST_BE_draft.pdf

### Implementation – Programs Promoting Heat Pumps

National Grid is the only program administrator in Rhode Island offering incentives for ASHPs. National Grid's 2017 residential electric heating and cooling incentives include downstream rebates for ASHPs ranging from $100-300 for mini-splits to $250-500 for central heat pumps. Residential ASHP installations can also access 0% financing through National Grid's HEAT Loan. Commercial heat pumps are promoted through an upstream HVAC program that incentivizes air-cooled, water-cooled, and ductless mini-split heat pumps.

***Funding Sources for Heat Pump Programs***
National Grid's ASHP programs in Rhode Island are funded by a system benefit charge, which can only be used to fund system reliability and energy efficiency procurement that is less expensive than the cost of the acquisition of additional energy supply. Traditionally this has limited spending to programs which provide electric and natural gas savings. However, there do not appear to be statutory limitations on using the funding for fuel switching and electrification if it can be demonstrated that the investment and associated savings meets the broad definition of least cost procurement.

***Program Rules—Restrictions/Encouragement of Fuel Switching***
The National Grid efficiency program focuses on electric savings, but fuel switching is also allowed and there is increased focus on beneficial electrification in the 2018-2020 plan. Mini-split heat pumps used only for cooling are excluded from the rebate program.

***Energy Savings Calculations (Including Non-Electric Fuels)***
There are two different types of heat pump measures included in the screening tool: fuel switching and market opportunity. The market opportunity measure claims electric savings between a baseline new heat pump and an efficient new heat pump. The fuel switching measure claims savings between electric resistance heating and an efficient heat pump for homes with electric heat, and between the baseline and high-efficiency heat pump equipment for oil equipment. The fuel switching measure

also counts the oil savings, but does not factor in the increase in electricity consumption associated with switching an oil customer to a heat pump.

***Fuel Switching in Cost-Effectiveness Screening***

Heat pumps screen as a market opportunity measure but have been marginally cost-effective as a fuel switch measure. Rhode Island recently shifted from the TRC test to a cost-effectiveness test known as the "Rhode Island Test," which adds new externalities to the test, including an avoided cost of carbon and a calculation for economic impact. Before the adoption of the RI Test, fuel switching from oil, propane, or natural gas to a heat pump did not screen. With the inclusion of these additional non-energy impacts, fuel switching from oil to heat pump now screens and National Grid was able to include fuel switch measures in its energy efficiency program plan for 2018-2020.

***Impact of Electrification and Fuel Switching on Program Metrics***

National Grid in Rhode Island has program targets with associated performance incentives for kWh savings, kW savings, and therm savings. Market opportunity heat pump measures contribute to electric savings. Fuel switch measures from oil to heat pump currently do not help National Grid achieve its program goals, since they do not contribute kWh savings.

***Quality Assurance and Quality Control***

The Rhode Island Electric Heating and Cooling Program follows the same QA/QC protocols as the equivalent National Grid program in Massachusetts. For heat pumps, this includes a quality check on the airflow and charge check on 10 percent of the contractor tune-ups conducted as part of the heat pump installation. The airflow and charge check is required to qualify a customer for the 0% Heat Loan Financing program.

***Grid Flexibility***

The existing Rhode Island heat pump programs do not explicitly leverage heat pumps as a grid flexibility resource. However, Rhode Island's Annual Energy Efficiency Plan for 2018 states an intention for the HVAC program to "work closely with the Demand Response and Connected Solutions program to ensure synergy between the two programs." These programs offer incentives for customers who enroll connected devices like Wi-Fi thermostats in load control programs. [59]

## Outcomes

***Community Outreach and Education***

National Grid's 2018 Annual Energy Efficiency Plan commits to targeted marketing strategies that will ensure customers who heat with electric resistance and fuel oil are aware of cost-effective heat pump program offerings. The plan also notes that the program will develop customer-focused heat pump marketing materials for contractors to distribute to customers.[60] The Rhode Island program also plans to add high-efficiency heating and cooling systems as one of the metrics in its Community

[59] State of Rhode Island and Providence Plantations Public Utilities Commission, 2017. *Annual Energy Efficiency Plan for 2018, Settlement of the Parties.* Re: Docket No. 4755. http://rieermc.ri.gov/wp-content/uploads/2017/11/4755-ngrid-eepp2018_11-1-17.pdf.

[60] Rhode Island Public Utilities Commission, *Annual Energy Efficiency Plan for 2018.*

Engagement Program and Community Based Initiative, which works with municipalities to promote energy efficiency.

***Heat Pump Adoption Level of Activity***

National Grid Rhode Island's three-year plan for 2018-2020 ramps up to approximately 1,000 market opportunity mini-split heat pump measures per year and 30 central heat pumps for each year of the 2018-2020 annual plan. While fuel switch measures from oil to heat pump are now included in National Grid's program plan, the plan only assumes 75 oil fuel switch measures over three years.

***Electrification Lessons Learned***

Rhode Island has strong policy goals encouraging building electrification. Further, there is no disincentive or political opposition to utility heat pump efficiency programs, as the utility also sells natural gas and should be made whole regardless of the heating fuel.

In spite of these factors, Rhode Island is on track to transform the heat pump market more slowly than some other Northeast states because it offers relatively low incentives and has not shifted to an upstream program design for residential offerings (although National Grid is considering an upstream program for 2019 or 2020). In addition, the state has not established goals for renewable thermal market development or heat pump installations, and National Grid's goals do not encourage it to aggressively pursue fuel switching, because the utility is does not have targets for heat pump adoption, carbon savings, or oil or propane savings from fuel switching.

***Web Links to Program Resources***

State of Rhode Island Office of Energy Resources:
http://www.energy.ri.gov/heating/heat-pumps/

Heat Pump Guide:
http://www.energy.ri.gov/heating/heat-pumps/learn-about-heat-pumps.php

National Grid Heat Pump Rebates:
https://www.nationalgridus.com/media/pdfs/resi-ways-to-save/2016-ri-hpwh-ee5385-rebate-form_1-13.pdf

# Vermont

## Building Electrification Policies

Vermont's building electrification policies are addressed through its Renewable Energy Standard (RES), signed into law as Act 56 by Vermont's Governor on June 11, 2015. The RES is described by the U.S. Department of Energy as "…the nation's first integrated renewable energy standard (RES), which makes utilities responsible both for supplying renewable electricity and for supporting reductions in customers' fossil fuel use."[61] Vermont's RES is made up of three parts: it requires an increase in renewable energy generation and distributed renewable generation, and through "Tier III," it requires distribution utilities (DUs) to reduce fossil fuel use through "energy transformation" projects that include additional distributed generation, building weatherization and other thermal efficiency measures, transportation electrification, and ASHPs.

Implementation of the energy transformation provisions (Tier III) of Act 56 was addressed by the VT Public Utility Commission (PUC) in Docket 8550.[62]

*Pursuant to Section 8005(a)(3)(F)(viii), if an energy transformation project increases the use of electric energy, the project shall incorporate best practices for demand management, use technologies appropriate for Vermont, and encourage the installation of the technologies in buildings that meet minimum energy performance standards. Recommended best practices:*

1. *enrollment in advanced rate program*
2. *verify high level of building performance*
3. *fair and accurate messaging and education for customers*

Vermont's 2016 Comprehensive Energy Plan identifies heat pumps as a mechanism to transform building heat from fossil fuel to renewable energy and help meet the state's goal of providing 30 percent of building energy through renewable sources in 2025. Funding for ASHP incentives is currently offered through the statewide electric Energy Efficiency Utilities (EEUs), Efficiency Vermont and Burlington Electric Department, and separately through DUs as part of their Tier III requirements. In 2016, Vermont Gas, the State's only regulated natural gas utility also became an EEU. While Vermont Gas offers energy efficiency services, it does not currently offer fuel-switching away from natural gas or heat pump incentives.

[61] U.S. Energy Information Administration, Vermont State Profile and Energy Estimates. https://www.eia.gov/state/?sid=VT.

[62] State of Vermont Public Service Board, 2016. "Order Implementing the Renewable Energy Standard," Docket No. 8550: 77. http://puc.vermont.gov/sites/psbnew/files/doc_library/8550-final-order.pdf.

***Web Links to Policy Resources***
Act 56: Vermont's Renewable Energy Standard:
http://legislature.vermont.gov/assets/Documents/2016/Docs/ACTS/ACT056/ACT056%20As%20Enacted.pdf

Final Order Docket 8550:
http://puc.vermont.gov/sites/psbnew/files/doc_library/8550-final-order.pdf

Vermont's Comprehensive Energy Plan:
https://outside.vermont.gov/sov/webservices/Shared%20Documents/2016CEP_Final.pdf

## Implementation – Programs Promoting Heat Pumps

Electric energy efficiency programs in Vermont have traditionally been implemented by the EEUs, Burlington Electric Department (BED), which serves the city of Burlington, and Efficiency Vermont, which serves the rest of the state. As a result of Act 56, DUs are now encouraged to either partner with the EEUs to provide services that result in the reduction of fossil fuel use, or to administer programs on their own.

In 2014, Efficiency Vermont launched a ductless ASHP program that incentivized high-efficiency ccASHPs. Efficiency Vermont currently offers ASHP incentives through a midstream program targeting wholesale distributors. Based on heat pump size, incentives range from $600-$800 per unit and go directly to the distributor. Distributors are required to pass the savings on to the contractor in the form of an instant discount at point of purchase. Contractors are not required to pass the savings on to the customer, but Efficiency Vermont sends a letter to end-use customers stating that their installer received a distributor instant rebate, which strongly encourages contractors to pass the incentive through to customers to remain competitive.

Several DUs also offer heat pump incentives to meet their RES energy transformation requirements. Vermont Electric Co-op (VEC) offers a $150 bill credit and Washington Electric Co-op (WEC) offers a $250 incentive for the installation of a ccASHP. These offers can be combined with the Efficiency Vermont incentive. Burlington Electric Department has partnered with Efficiency Vermont to offer an additional incentive of between $375-450 toward the purchase of an ASHP when switching from propane or fuel oil. Natural gas customers are not eligible for the BED incentive because ASHPs would likely lead to increased annual heating costs.

The state's largest utility, Green Mountain Power (GMP), does not offer an ASHP rebate program at the time of writing, but does offer lease options on ASHPs to help offset the high upfront cost of ccASHPs. Efficiency Vermont supports this leasing program by applying the value of its rebate to the first few months of the lease, essentially providing customers with the first few months of their heat pump lease at no charge.

***Funding Sources for Heat Pump Programs***
The ASHP program run by Efficiency Vermont is funded through a system benefit charge and through FCM and RGGI revenues. The efficiency program is structured

in such a way that electric savings can only be incentivized through the systems benefit charge and savings from other fuels (generally thermal and process fuels) can only be funded through the RGGI and FCM sources. Because of Efficiency Vermont's restrictions regarding fuel type and funding source, Efficiency Vermont's heat pump program was initially not incentivized as a fuel switching measure.

ASHP programs run by utilities in compliance with the Renewable Energy Standard are relatively new and funding for energy transformation projects is less clear. RES energy innovation projects appear to be recoverable in rates, but funding is not identified as a separate line item on the customer's bill. A retail electricity provider in Vermont may pay the Alternative Compliance Payment ($.06 kWh) in lieu of implementing energy transformation projects. ACP funds go into the Vermont Clean Energy Development Fund. There is no record of a utility making a compliance payment into this fund so far.

***Program Rules—Restrictions/Encouragement of Fuel Switching***

Vermont's RES required the PUC to open a proceeding to develop implementation guidelines. One of the outcomes of this proceeding (Docket 8550) was the creation of the Vermont Technical Advisory Group (TAG), which was tasked with developing consistent, statewide prescriptive energy transformation measures, including ccASHPs.

***Energy Savings Calculations***

ASHP installations through Efficiency Vermont are split into two separate savings components to align with regulations regarding funding source: 1) a market opportunity electric savings measure, and 2) a retrofit fuel switch measure that provides a blended average of oil, propane, and electric resistance heating savings. By counting a heat pump as two separate measures, based on fuel type, the costs and savings of the ASHP can be allocated based on the separate funding sources. This allowed Efficiency Vermont to begin counting the fuel savings from heat pump retrofits, which enabled it to significantly increase heat pump incentive levels.

The structure of having separate ASHP initiatives offered by both EEUs and DUs has led to some complexity regarding saving attribution. Both entities offer incentives on the same measures from different funding sources, and both have savings metrics to meet on an annual basis. As a result, the EEUs and DUs are required to work together to allocate savings from ASHPs. For example, an ASHP may be incentivized by Efficiency Vermont but may be leased to a customer by Green Mountain Power. In this scenario, the savings from the heat pump would be split evenly between the two entities. This arrangement of combined incentives and shared savings calculations, coupled with inconsistent cost-effectiveness screening criteria, has been challenging for parties to navigate.

***Fuel Switching In Cost-Effectiveness Screening***

The PUC Order regarding the implementation of the State's Renewable Energy Standard outlined cost-effectiveness screening criteria for RES measures.[63] An energy transformation project must result in a reduction in fossil fuel use and GHG emissions and meet the needs for goods or services at the lowest present-value life-

[63] Vermont Public Service Board, "Order Implementing the Renewable Energy Standard": 71.

cycle cost, including economic and environmental costs. Alternatives that do not increase electric consumption should be included in the analysis, and no project cost should exceed the alternative compliance payment amount ($.06/kWh). In addition, the analysis must include costs and benefits associated with increased electric sales and financing and lease income (such as in GMP's heat pump lease program).

In both Tier III implementation and the EEU heat pump programs, ASHPs offered by an EEU are required to meet cost-effectiveness criteria through the Societal Cost Test using the Vermont "State Screening Tool." However, there is currently some inconsistency in that DUs that offer heat pump programs without engaging an EEU are not required to meet the same cost-effectiveness criteria. In these cases, the DU is only required to have its program cost less than the Alternate Compliance Payment mandated in Act 56.

***Impact of Fuel Switching on Program Metrics***

In 2013, Efficiency Vermont began offering a High Performance Electric Heat Retrofit program targeted at displacing electric resistance heating. Starting at the end of 2014, EVT started an ASHP incentive program that only counted the incremental market opportunity electric savings in comparison to a less efficient new ASHP. In cases where heat pumps were installed to displace electric resistance heating, savings were calculated by counting the net electric savings from increased load from the heat pump combined with electric savings from reduced use of electric resistance heat. If the heat pump was installed to offset another type of heating fuel, electric savings were calculated only as the market opportunity savings from using a high-efficiency ASHP over a baseline ASHP.

In October 2016, EVT began to use FCM and RGGI funding to support ASHPs as a thermal fuel switching measure. Thus, heat pumps began to be evaluated as two separate measures:

- An electric market opportunity measure, using electric systems benefit charge funding and counting the efficiency savings toward MWh savings goals; and
- A retrofit fuel switching measure, using thermal funding sources and counting the reduced oil and propane use towards MMBtu savings goals.

Therefore, ASHPs now contribute to both electric and thermal program savings goals, which has enabled Efficiency Vermont to increase incentive levels.

***Quality Assurance and Quality Control***

Aside from contractor training, and consumer education and outreach programs, Vermont does not currently have in place a quality control program for heat pump installations. There are currently no inspections required for heat pump installations. Efficiency Vermont has developed an end-user education piece for use by installation contractors, for as well as a consumer guide, "How to Use Your Heat Pump." Efficiency Vermont also provides training and continuing education support to heat pump installers who are members of its trade ally network, the Efficiency Excellence Network, and encourages customers to select these qualified installers.

***Grid Flexibility***

GMP offers an ASHP and water heating load control program aimed at developing web-enabled utility control of the appliances using a Sensibo. This device enables GMP to control the appliances for demand response events and is available free of charge to utility customers investing in heat pump technology.[64] Aside from this pilot, Vermont currently has no programs or rate structures specifically targeting any type of strategic electrification.

## Outcomes

***Community Outreach and Education***

Community outreach and education are key components of ASHP programs in Vermont. To support its heat pump initiatives, Efficiency Vermont offers comprehensive customer support and a website offering information about how ASHPs work and in what conditions they perform best. Efficiency Vermont offers free workshops and community events through its speaker's bureau, which provides experts to present at community energy group meetings and provide information to support heat pump integration into town energy plans.

***Heat Pump Adoption Level of Activity***

In 2017, the Efficiency Vermont program incentivized more than 4,100 ASHPs, for an installation rate of 1.3 percent – the highest in the Northeast. Overall, more than 8,200 heat pumps have been incentivized since the beginning of the program. As seen in Figure 5, there appears to be some seasonal fluctuation in heat pump deployment with the first quarter of each year showing less activity, and increases in deployment as the year progresses.

[64] Green Mountain Power, "Control your heat pump from the palm of your hand." http://products.greenmountainpower.com/product/econtrol-heat-pump-control-program/

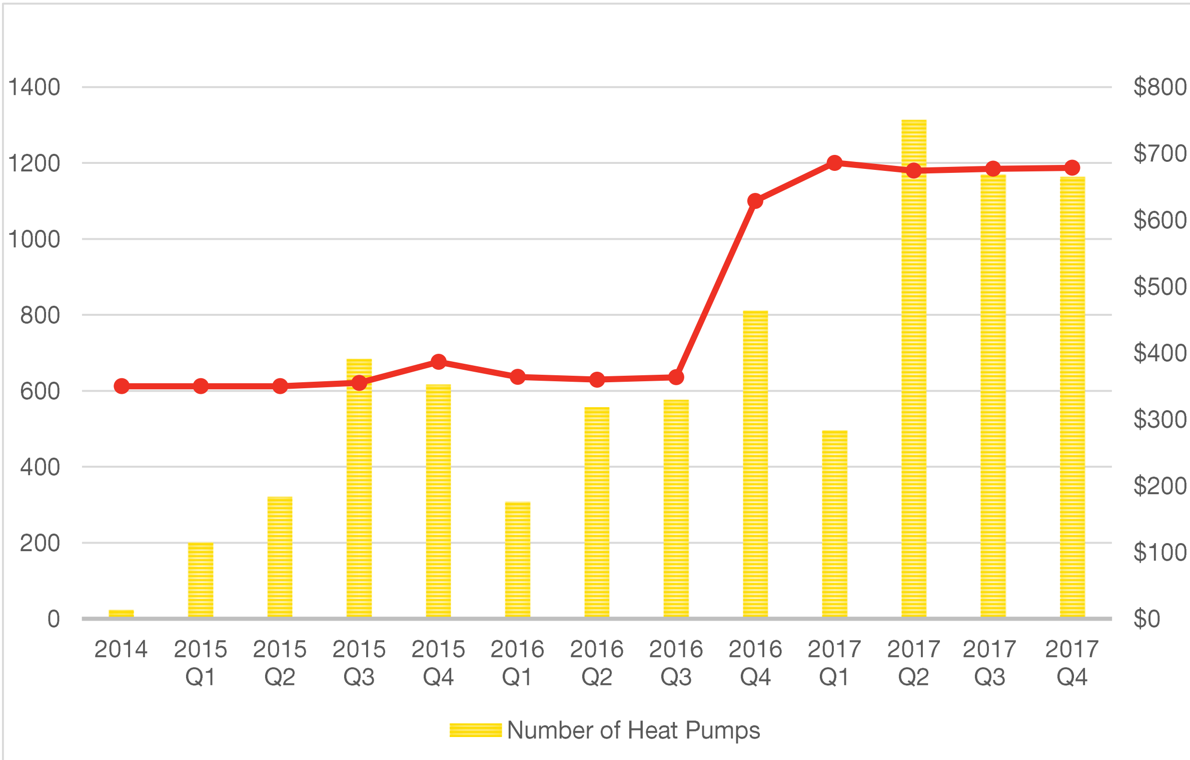


Figure 5. Efficiency Vermont heat pump program results

Renewable Energy Standard compliance by utilities in Vermont is in a nascent stage. Legislation was passed in 2015 and the PUC Implementation Order was passed in 2016. So far, energy innovation projects proposed by utilities have included weatherization, HPWHs, electric vehicles, charging stations, and electric transit buses, in addition to ASHPs. However, progress reporting on energy transformation projects has been limited to date.

***Electrification Lessons Learned***

The two key factors contributing to Efficiency Vermont's high rate of market adoption of ASHPs are the midstream program model through wholesale distributors and the ability to count fossil fuel savings from fuel switches from oil and propane towards program goals. Vermont has been particularly successful at developing the supply channel for ASHPs. Efficiency Vermont program managers strategically engage manufacturers, distributors, and contractors to develop collaborative sales, marketing, inventory management, and training approaches. By creating two measures out of a single ASHP installation, Efficiency Vermont has enabled both electric savings and fossil fuel savings can be counted and costs appropriated to the correct source. This allows for larger incentives to help drive the market.

***Web Links to Program Resources***

Burlington Electric Cold Climate Heat Pumps:
https://www.burlingtonelectric.com/cchp

Efficiency Vermont Heat Pumps:
https://www.efficiencyvermont.com/products-technologies/heating-cooling-ventilation/heat-pumps

Green Mountain Power Heat Pump Program:
https://www.greenmountainpower.com/2017/04/12/vtfrugal/

Vermont Electric Co-op Energy Transformation Program:
https://www.vermontelectric.coop/programs-services/energy-transformation-programs

Washington Electric Co-op Heat Pumps Rebates:
http://www.washingtonelectric.coop/button-up/

# Treatment of Building Electrification in Codes

## Energy Code Overview

### Building Energy Codes

Building energy codes are a mechanism to set minimum efficiency requirements and performance standards for new and renovated buildings. Adoption of and compliance with the energy code assures energy use and emissions reductions for the life of the building. The Pacific Northwest National Lab (PNNL) estimates that between 2012 and 2040 building energy codes will save residential and commercial building owners $126 billion, which translates to 841 million tons of avoided CO2 emissions.

National model energy codes for residential buildings are developed by a consensus process led by a nonprofit organization, the International Code Council (ICC). Since 1994, the ICC has developed national model codes that are not limited by region or climate zone, known as the International Codes, or I-Codes. The I-Codes are a comprehensive suite of codes covering all aspects of building construction. The International Energy Conservation Code (IECC) is the code within this suite that addresses energy efficiency and performance standards.

Although the U.S. Department of Energy (DOE) is required by law to participate in the development of the national model energy code, as well as provide assistance with adoption and compliance, the U.S. does not adopt or enforce a national code. Rather, code adoption happens at the state or local level. States and local jurisdictions may elect to adopt the national model energy code, some amended version of it, or a state-specific code. Most states have adopted some version of the IECC, or equivalent. There are a handful of states with no statewide energy code.

### Stretch Codes

The national model energy code, which increases in stringency over time, is considered a base code, in that it establishes the minimum level of efficiency a builder should be building to. Many states and local jurisdictions feel the national model energy code does not go far enough and will not get buildings to the level of efficiency needed to meet state or city zero energy and climate goals. These states or jurisdictions may develop and adopt stretch, or reach, codes. Sometimes a stretch code will provide a higher efficiency set of prescriptive requirements that builders must meet, a higher performance standard than the base code, or a combination of the two. Stretch codes can also be a way to allow builders to employ new technologies or designs that are not yet addressed by the base code.

Adoption of a stretch code is generally voluntary. However, some states may mandate a stretch code in certain development scenarios, or encourage stretch code adoption by offering a ‘green’ designation and/or additional funding. For example, Vermont requires Act 250 projects to meet its stretch code.[65] Massachusetts encourages voluntary adoption of stretch codes through its "Green Community" designation.[66]

## Code Compliance

The energy efficiency requirements of the IECC may be satisfied by two different approaches, prescriptive-based and performance-based. The prescriptive compliance path prescribes specific insulation and window requirements for each building component. In order to comply with the code, the building must meet those specific R-values or U-factors for the appropriate climate zone. All remaining sections of the code marked as "Prescriptive" must be met as well. Within the prescriptive path, a trade-off option is also allowed. The trade-off approach, or Total UA67 alternative, allows individual insulation and window efficiency values to vary from the prescribed values so long as the total heat loss (UA) of the proposed design is less than or equal to the total heat loss as calculated using the U-factors prescribed by the code. For instance, if the prescriptive window U-factor is difficult to meet for any reason, the additional heat loss from installing less efficient windows may be made up through higher roof, wall, and/or foundation insulation. The DOE energy code software, REScheck™, automates these calculations and is often utilized to demonstrate compliance when using the trade-off approach.[68] Only insulation and window requirements apply to the trade-off method; credit is not allowed for high-efficiency mechanical equipment.

Historically, the only performance-based compliance approach has been the Simulated Performance Alternative. Beginning with the IECC 2015, a second performance-based alternative was introduced, the Energy Rating Index (ERI). Compliance is demonstrated using The Simulated Performance Alternative by comparing the proposed design to a standard reference design, as specified by the IECC. In order to be compliant, the proposed design must have a lower total annual energy cost than the reference design home. REScheck, or another approved energy simulation software tool, must be used to demonstrate compliance using this approach. This approach also does not allow credit for high-efficiency mechanical equipment. The ERI compliance alternative utilizes the Residential Energy Services Network (RESNET) Home Energy Rating System (HERS) Index to demonstrate compliance. Introduced in the IECC 2015, the ERI was further clarified and target indices modified in the IECC 2018. Different from all other compliance paths, this alternative does provide credit for high-efficiency mechanical equipment as well as renewable energy systems. In addition to the compliance provisions written into the IECC, some states and/or jurisdictions recognize successful completion of an above-code voluntary certification, such as ENERGY STAR®, as demonstration of code compliance.

[65] State of Vermont Natural Resources Board. "Act 250 Program." http://nrb.vermont.gov/act250-program
[66] Commonwealth of Massachusetts, 2018. "Guide: Becoming a Designated Green Community." https://www.mass.gov/guides/becoming-a-designated-green-community
[67] U-factor times assembly area.
[68] U.S. Department of Energy, Building Energy Codes Program. "REScheck: Residential Compliance Using REScheck™." https://www.energycodes.gov/rescheck.

## Federal Preemption

The IECC is subject to federal preemption rules that prohibit the IECC from specifying minimum mechanical system and consumer product efficiencies above the minimum federal standard. Equipment and products covered under the federal preemption provision are generally known as "covered products." With respect to the IECC, pertinent products include HVAC and water heating equipment. These federal preemption rules are the result of national policies enacted to establish uniform testing procedures, labeling and minimum efficiency requirements across the U.S.[69] While these federal standards have led to great improvements in energy efficiency and savings since their enactment, they now may have an adverse effect on local building energy codes striving to meet Zero Energy (ZE) or Zero Energy Ready (ZER) targets. ZE or ZER homes need to have a well-insulated and tight building envelope, in addition to very high-efficiency mechanical systems. The prescriptive requirements of the code address the envelope but not the mechanical system efficiencies.

Under the federal preemption provision, building codes may not specify higher efficiencies for covered products than those currently established by federal standards through The National Appliance Energy Conservation Act (NAECA) and subsequent energy policy acts. The current preemption provision states that "no State regulation, or revision thereof, concerning the energy efficiency, energy use, or water use of [a product covered by a federal efficiency standard] shall be effective with respect of such covered product."[70] Studies have estimated that up to 80 percent of energy consumption in residential buildings is attributed to products covered ("covered products") by federal appliances standards and thus outside the purview of local building energy codes.[71] The inability for building energy codes to prescribe high-efficiency mechanical equipment makes it difficult to encourage ZE or ZER building practices through the prescriptive compliance path of the IECC, as well as encourage the inclusion of high-efficiency electric heating and hot water systems such as ASHPs and HPWHs.

However, some states and jurisdictions are successfully working around this limitation with local amendments to the standard IECC. Local amendment options include:

- Limiting the compliance options to only a performance-based path, which enables builders to choose what combination of envelope and mechanical equipment efficiencies meet the compliance requirement;
- Developing multiple prescriptive paths that include options for higher mechanical efficiencies, while maintaining at least one package that utilizes the federal minimum standard; or

[69] The Energy Policy and Conservation Act (EPCA) was enacted in 1975, and amended in 1987 by the National Appliance Energy Conservation Act (NAECA). U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. "Appliance & Equipment Standards: History and Impacts." https://energy.gov/eere/buildings/history-and-impacts.

[70] Chase, Alex, Jonathan McHugh, and Patrick Eilert, 2012. "Federal Appliance Standards Should be the Floor, Not the Ceiling: Strategies for Innovative State Codes & Standards. *Proceedings of the 2012 ACEEE Summer Study on Efficiency in Buildings.* Washington, DC: ACEEE: 13-36 – 13-51. https://aceee.org/files/proceedings/2012/data/papers/0193-000415.pdf .

[71] Chase, McHugh, and Eilert, "Federal Appliance Standards."

- Including an additional high-efficiency "Options" package from which builders must choose a minimum number of additional efficiency requirements. These options include high-efficiency mechanical systems, but because any given option is not required, but voluntary, the Options package approach is not restricted by federal preemption rules.

Massachusetts has taken both of these approaches by only allowing performance-based compliance approaches for its residential stretch code and amending the commercial stretch code Additional Efficiency Package options (IECC section C406) to require two of six options. The District of Columbia (D.C.), which is currently in the middle of an adoption process, also plans to incorporate an options package in the residential code in order to circumvent federal preemption rules. The D.C. code is also considering removing the original IECC performance-based compliance path (IECC Section R405) in favor of the Energy Rating Index (ERI) performance-based compliance path (IECC section R406). Setting ERI performance thresholds may effectively encourage high-efficiency electric heating and hot water equipment, especially in markets where this equipment is already the accepted or preferred building practice. A third example is Rhode Island, where the state is close to adopting a stretch code based on the U.S. DOE Zero Energy Ready Home (ZERH) specification. A key difference in Rhode Island is that the stretch code will not be a code that is adopted by municipalities, but rather will serve as a voluntary standard that builders or programs may elect to adopt. As such, it is not subject to federal preemption rules.

A key limitation to the examples above exists for states where the Prescriptive or Total UA Trade-off compliance paths are the most commonly used options for energy code compliance. Vermont provides an example of a recent code adoption process where federal preemption played a key role, discussed in more detail below. New Buildings Institute (NBI) has recently published a report on the subject of federal preemption and building energy codes. This report speaks further to the barriers to promoting high-performance buildings through energy codes, specifically limited by a prescriptive code as noted above. The report also provides current thinking on solutions to these barriers. Solutions include those discussed above such as performance-based codes and alternative compliance options. The report also suggests that states might follow California's lead by creating a cooperative approach to standards setting or a joint exemption petition to the Secretary of Energy allowing higher levels of efficiency to be cited by local codes.

***Web Links to Code Resources***

Local Energy Codes Hindered By Preemption Rules, 2017
https://newbuildings.org/news/local-energy-codes-hindered-by-preemption-rules/

Federal Preemption as a Barrier to Cost Savings and High Performance Buildings in Local Energy Codes, 2017
https://newbuildings.org/resource/federal-preememption-barrier-to-cost-savings/

Federal Appliance Standards Should be the Floor, Not the Ceiling: Strategies for Innovative State Codes & Standards, 2012
https://aceee.org/files/proceedings/2012/data/papers/0193-000415.pdf

## Northeast Examples: Building Electrification in Energy Codes

Throughout the Northeast, states and municipalities have opted to adopt the International Energy Conservation Code (IECC) with or without local amendments. Examples of state amendments and stretch code adoptions in the Northeast designed to work around federal preemption rules in order to help meet energy and climate goals are discussed below.

### Massachusetts

Massachusetts was the first state to adopt a stretch code. Adoption of the stretch code has been encouraged by the Green Communities Act of 2008, as stretch code adoption is required by municipalities in order to be designated a Green Community.[72] As of October 2017, Massachusetts estimates that 214 municipalities, comprising approximately 72 percent of the state's population, have adopted the Stretch Code.[73]

The Massachusetts stretch code emphasizes greater energy performance by requiring performance-based compliance as opposed to prescriptive compliance. This is achieved by amending the compliance option within the stretch code to only allow the performance compliance option written in the base code. Within the base code, the performance compliance option has also been amended to allow compliance by meeting either of three high-performance options:

1. ENERGY STAR version 3.1
2. Passive House Institute US (PHIUS) PHIUS+ 2015
3. HERS Index meeting a threshold as specified in the code

None of these three compliance options directly addresses fuel choice or encourages one fuel over another. However, the Massachusetts Department of Energy Resources (DOER) released an updated residential energy cash flow analysis in August 2017 that compares the energy cost savings for both gas and non-gas heated homes. The non-gas heated home shows a much higher positive cash flow than the homes heated with fossil fuel.[74]

The base and stretch codes do directly address and encourage renewable energy. In May 2017, the base code was further amended to require solar-ready roofs on all residential new construction.[75] Additionally, when complying with the stretch code by means of a HERS Index, the maximum HERS threshold table has been amended to allow a trade-off for onsite renewable energy. Renewable energy systems include photovoltaic, solar thermal, clean biomass, and/or ground source heat pumps. While this approach certainly encourages the use of renewable energy, it may have the

[72] Commonwealth of Massachusetts, Department of Energy Resources. 2018. "Green Communities Division." https://www.mass.gov/orgs/green-communities-division-massdoer.
[73] Commonwealth of Massachusetts, Department of Energy Resources, 2018. "Building Energy Codes: Summary of State Building Energy Codes, Including the Stretch Code." https://www.mass.gov/service-details/building-energy-codes
[74] Commonwealth of Massachusetts, 2018. "Stretch Code 'Residential Cash Flow Analysis,'". https://www.mass.gov/service-details/stretch-code-residential-cash-flow-analysis.
[75] NEEP, 2018. "MA Building Energy Code." http://www.neep.org/bulletin-board/ma-building-energy-code.

effect of negatively impacting the thermal shell efficiency by lowering the threshold for compliance (higher allowable HERS Index) when these systems are installed. There is too little data yet to know how builders will implement these new stretch code requirements, but the DOER intends to keep an eye on envelope efficiency when builders are installing renewable energy systems to meet the less stringent HERS threshold.

***Web Links to Code Resources***
Massachusetts State Building Energy Codes website with links to amendments listed below
https://www.mass.gov/service-details/building-energy-codes

Massachusetts Residential Code Amendments
https://www.mass.gov/files/2017-07/bbrs-780-cmr-chapter51-residential-aug16.pdf

Massachusetts Stretch Code Appendix Amendments
https://www.mass.gov/files/2017-07/bbrs-780-cmr-appendix115aa-aug16_0.pdf

2017 Stretch Code Residential Cost Analysis
https://www.mass.gov/service-details/stretch-code-residential-cash-flow-analysis

## Rhode Island

Rhode Island has adopted the 2012 IECC with Rhode Island amendments. Rhode Island is currently proposing commercial and residential stretch codes, as required by Executive Order 15-17.[76] The voluntary stretch code is one of the strategies cited in a white paper report prepared by National Grid, Zero Energy Building Pathway to 2035,[77] to support Zero Energy Building markets. The residential stretch code proposal is based on the U.S. DOE Zero Energy Ready Home (ZERH) specification.

The proposed stretch code includes provisions that address HVAC equipment efficiency levels, including heat pump efficiencies. Like the base code, the stretch code will not directly encourage electric heating equipment. However, it is the consensus of the codes development committee that significantly increasing thermal shell efficiencies to ZER levels will indirectly encourage heat pump installations. Installation of air-conditioning equipment is nearly universal in Rhode Island new construction. Heat pumps are the preferred option for supplying cooling and heating loads in low energy homes.[78]

It is yet to be determined whether Rhode Island's proposed stretch codes will encounter federal preemption issues. However, Rhode Island may already have a

[76] State of Rhode Island and Providence Plantations, 2015. Executive Order 15-17, "State Agencies to Lead by Example in Energy Efficiency and Clean Energy." http://www.governor.ri.gov/documents/orders/ExecOrder15-17.pdf.
[77] National Grid, 2016. "Zero Energy Building Pathway to 2035: Whitepaper Report of the Rhod Island Zero Energy Buliding Task Force." https://www.nationalgridus.com/media/pronet/ri-ee-task-force/cm6459-ri-zne-white-paper-12_16.pdf.
[78] Personal communication, Brian McCowan, Energy & Resource Solutions, Inc. consultant to the Rhode Island Office of Energy Resources, November 9, 2017.

market that favors high-efficiency heat pump technology in low energy homes. In this case, the building energy code may not serve to encourage the proliferation of heat pump technology directly, but by increasing the thermal efficiency requirements in the code, creates a building stock that is more likely to utilize high-efficiency heat pump technology.

***Web Links to Code Resources***
Rhode Island Office of Energy Resource Stretch Code Development
http://www.energy.ri.gov/policies-programs/lead-by-example/case-studies/stretch-code-development.php

## Vermont

Vermont provides a good case study of the intersection of ambitious state goals and a building energy code that may hinder those goals. Vermont's current Comprehensive Energy Plan identifies strategic electrification as key to achieving the state's energy goals.[79] One of the strategies listed to meet those goals is through local building energy codes. However, in its current state and due to federal preemption rules noted above, the code is not able to encourage widespread adoption of high-efficiency electric heating systems such as cold climate heat pumps. A brief history of the 2015 Residential Building Energy Standard (RBES) adoption process illustrates this limitation.

In Vermont, the most common energy code compliance path is the Prescriptive Path. As the name implies, this compliance option prescribes a specific set of thermal shell measures to meet compliance. Vermont has also had a longstanding HERS Index compliance path option.[80] The process by which Vermont came to its current Prescriptive Path options and HERS Index targets shows how the issue of federal preemption limits the ability of building energy codes to meet higher energy savings targets, and in parallel, hinders the adoption of high-efficiency electric heating options, at least through the energy code.

Vermont adopted the 2015 RBES in March 2015, based on Vermont amendments to the 2015 IECC. In order to provide multiple prescriptive path compliance options, several packages with different component efficiencies were modeled to meet the same, or very similar, energy consumption estimates and HERS Index. The original IECC 2015 set the HERS Index target for the ERI compliance alternative to HERS 54 for Vermont's climate zone. This target was derived by the IECC code development team modeling a baseline building to the IECC 2015 shell requirements, adding high-efficiency equipment and then adding 10 percent efficiency on top of that. The intent was to have an ERI complying home that was never less efficient than the Prescriptive requirements of the code. However, in Vermont the goal was to adopt a code that provided comparable compliance options.

[79] Vermont Department of Public Service, 2016. *2016 Vermont Comprehensive Energy Plan.* http://legislature.vermont.gov/assets/Legislative-Reports/Executive-summary-for-web.pdf.
[80] Residential Energy Services Network (RESNET), 2018. "What is the HERS Index?" https://www.resnet.us/hers-index.

In order to achieve the HERS 54 target, the Vermont code adoption team began by modeling high-efficiency heating equipment in the prescriptive packages. Consultants informed the team that we would be in violation of federal preemption rules if a prescriptive package including NAECA minimum mechanical equipment was not included. Modeling a high-performance heat pump would have led to a HERS Index and estimate energy consumption far below the other packages, and thus was not considered a comparable package. Likewise, maintaining the HERS 54 performance target across the prescriptive packages with NAECA minimum equipment efficiencies would have increased the thermal shell requirements to an unreasonable standard for the code. In the end, the Vermont team opted to downgrade the performance HERS Index target for the base code to 60 to better align with the thermal shell requirements of the code.[81]

Vermont also adopted a voluntary stretch code in 2015.[82] A similar process was followed by which a number of prescriptive packages were modeled to comparable energy consumption estimates and HERS Index. In this case, higher efficiency equipment (ENERGY STAR) was modeled and ultimately prescribed for the majority of packages. However, due to the preemption rules, a package was created using federal minimum standard efficiency equipment. This package is essentially a “SIP” (Structural Insulated Panels) home with continuous insulation surrounding the entire thermal shell. This is certainly a viable and highly efficient building design. However, in order to be compliant with the federal preemption rule, this high-performance building shell is paired with lower performing federal minimum standard mechanical equipment, creating an incongruous prescriptive package.

Vermont’s stretch code includes a provision for electric vehicle charging. Certain multifamily developments are required to provide electric vehicle charging capacity. While this requirement does not support strategic electrification of buildings directly, it does support Vermont’s statewide strategic electrification goals by supporting other policies and efforts that encourage the adoption of electric vehicles. The Vermont code also provides a provision for renewable energy when utilizing the HERS compliance path. The approach is to maintain the target HERS Index, but only allow five points to come from renewable energy. In other words, for the base code, the home must obtain at least a HERS 65 by energy efficiency only. The remaining five points may be achieved by renewable energy. This approach applies to the stretch code as well.

***Web Links to Code Resources***

Vermont 2015 Residential Building Energy Standard (RBES)
http://publicservice.vermont.gov/energy_efficiency/rbes

Vermont 2016 Comprehensive Energy Plan
http://legislature.vermont.gov/assets/Legislative-Reports/Executive-summary-for-web.pdf

[81] The 2018 International Energy Conservation Code maximum Energy Rating Index aligns with the Vermont 2015 Residential Building Energy Standards.

[82] Vermont’s stretch code is voluntary, but required for projects under Act 250 (Vermont’s land use and development control law) projects. Act 250 was enacted to balance environmental protection and sustainable development: http://nrb.vermont.gov.

## International Green Conservation Code (IgCC)

When reviewing and adopting new codes, states may want to consider adoption of the IgCC. The IgCC is fully compatible with the IECC and was created to regulate the design and performance "green" buildings. Like the IECC, the IgCC has both prescriptive and performance compliance options. However, unlike the IECC, the performance compliance option includes both energy performance and CO2e emissions thresholds.[83] Maryland and Rhode Island were among the leading states to adopt the 2012 IgCC. The code was adopted by both states as an optional code as required by high-performance buildings policies enacted by the states. As such, the IgCC is recognized as an equivalent high-performance green building standard, like LEED. D.C. and Keene, New Hampshire have also adopted the IgCC as a result of state policies promoting green and sustainable development. Washington, D.C. is currently reviewing the 2015 IgCC for adoption in its current code cycle.

***Web Links to Code Resources***
2015 International Green Conservation Code (IgCC)
https://www.iccsafe.org/codes-tech-support/codes/2015-i-codes/igcc/
https://codes.iccsafe.org/public/document/toc/548/

Rhode Island Adoption of the IgCC as an equivalent standard
http://www.ribcc.ri.gov/documents/green/RIGBAC%20%20Presentation.pdf

Maryland IgCC
http://www.dgs.maryland.gov/Documents/GreenBuilding/regulations/MDGBCSupplementalIgCC-Final111914.pdf

District of Columbia
https://www.buildgreendc.org/laws-regs/
https://dcra.dc.gov/sites/default/files/dc/sites/dcra/publication/attachments/2014-05-13_GBPM_FINALv1.pdf

## Summary – Building Electrification in Energy Codes

While there are many avenues to support strategic electrification through policies and programs, at present it is difficult to directly promote building electrification through local building energy codes. There may be an opportunity for states to come together to address the federal preemption rules that are currently preventing the specification of higher efficiency equipment standards in energy codes. In the meantime, states can bypass federal preemption rules by focusing on performance paths, high-efficiency options packages, and stretch codes. In certain markets, high-efficiency heat pump technology may be indirectly encouraged simply because it is most practical and lowest-cost means of meeting the higher performance requirements. Additionally, alternative codes such as the IgCC that include CO2e emissions thresholds as part of the compliance mechanism should be considered.

[83] International Code Council. "2015 International Green Construction Code: Chapter 6, Energy Conservation, Efficiency and $CO_2e$ Emission Reduction." https://codes.iccsafe.org/public/document/IgCC2015/chapter-6-energy-conservation-efficiency-and-co-2-e-emission-reduction.

# Appendix A: Technical Reference Manuals

# Connecticut Technical Reference Manual



## 4.2.12 HEAT PUMP – DUCTLESS

***Description of Measure***

Installation of energy efficient Ductless Heat Pump or Mini-Split Heat Pump.

***Savings Methodology***

Savings methodology is based on the impact evaluation of Ductless Heat Pump (DHP) pilot performed by KEMA (Ref [1]) Energy savings for DHP are determined by:

- Using savings factors from the pilot study adjusted for installed efficiencies
- or by performing a custom analysis such as DOE-2 or Billing analysis [PRISM] (Note [2] & [3]) for a specific project. If a custom analysis is done, the savings will be capped at 50% of the heating portion of the billing history. Heating savings are calculated on the basis of either Hartford or Bridgeport climate data. Savings for actual projects are calculated using the closest location on heating degree-day (HDD) basis.

DHP installed in an existing home with Electric Resistive heating system is considered to have Retrofit savings. DHP installed in a home with fossil fuel heating system is considered to have Lost Opportunity savings (or new construction).

In addition to electric savings, ductless heat pumps provide energy savings and environmental benefits that are not captured through C&LM Programs in situations where they are used to displace fossil fuel. Because C&LM does not take credit for fuel switching savings, the estimates of fossil fuel savings and emissions reductions are not presented here. However they can be derived based on the above assumptions and equations.

Note: The savings here are not to be applied to a heat pump with ducting. Only systems without ducts are addressed by this measure.

***Inputs***

| Symbol | Description |
|---|---|
| $HSPF_I$ | Heating Season Performance Factor, Installed |
| $SEER_I$ | Seasonal Energy Efficiency Ratio, Installed |
| $CAP_C$ | Cooling Capacity |
| $CAP_H$ | Heating capacity |
| N | Number of zones |
| | Primary existing heating fuel type |

***Nomenclature***

| Symbol | Description | Units | Value | Comments |
|---|---|---|---|---|
| 1 Ton | Capacity, Tonnage | Tons | 12,000 Btu/hr | Unit conversion |
| $AA_C$ | Hartford kWh cooling savings factor from pilot | kWh/1000 Btu | 3.1 | Ref [1] |
| $AA_H$ | Hartford kWh heating savings factor from pilot | kWh/1000 Btu | 130 | Ref [1] |
| AKWH | Annual Electric Energy Savings | kWh | | |
| $BB_C$ | Hartford kW cooling savings factor from pilot | kW/1000 Btu | 0.0017 | Ref [1] |
| $BB_H$ | Hartford kW heating savings factor from pilot | kW/1000 Btu | 0.019 | Ref [1] |
| $CAP_C$ | Nominal Cooling Capacity | Btu/hr | | Input |
| $CAP_H$ | Nominal Heating capacity | Btu/hr | | Input |
| $CC_C$ | Bridgeport kWh cooling savings factor from pilot | kWh/1000 Btu | 3.2 | Ref [1] |
| $CC_H$ | Bridgeport kWh heating savings factor from pilot | kWh/1000 Btu | 140 | Ref [1] |
| $DD_C$ | Bridgeport kW cooling savings factor from pilot | kW/1000 Btu | 0.0014 | Ref [1] |
| $DD_H$ | Bridgeport kW heating savings factor from pilot | kW/1000 Btu | 0.032 | Ref [1] |
| $EE_C$ | Efficiency conversion factor, cooling | | 0.037 | Ref [1] |

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| Symbol | Description | Units | Value | Comments |
|---|---|---|---|---|
| $EE_H$ | Efficiency conversion factor, heating | | 0.171 | Ref [1] |
| $HSPF_B$ | Heating Season Performance Factor, Baseline | Btu/Watt-hr | 8.2 – Lost Opportunity | Ref[2] |
| $HSPF_E$ | Heating Season Performance Factor, Existing | Btu/Watt-hr | 3.413 – Retrofit | Note [1] |
| $HSPF_I$ | Heating Season Performance Factor, Installed | Btu/Watt-hr | | Input |
| N | Number of ductless heat pump zones (or heads) | | 1 zone = 0.75<br>2 zones = 1.25<br>3 or more zones = 1.50 | Input |
| $SEER_B$ | Seasonal Energy Efficiency Ratio, Baseline | Btu/Watt-hr | 14.0– Lost Opportunity | Ref[2] |
| $SEER_E$ | Seasonal Energy Efficiency Ratio, Existing | Btu/Watt-hr | 10.1 – Retrofit | Note [1] |
| $SEER_I$ | Seasonal Energy Efficiency Ratio, Installed | Btu/Watt-hr | | Input |
| SKW | Summer Demand Savings | kW | | |
| WKW | Winter Demand Savings | kW | | |

***Retrofit Gross Energy Savings, Electric***

**Heating**

For Hartford:

$$AKWH_H = N \times CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times \frac{1}{EE_H} \times AA_H \times \frac{1}{1000}$$

For Bridgeport:

$$AKWH_H = N \times CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times \frac{1}{EE_H} \times CC_H \times \frac{1}{1000}$$

**Cooling**

For Hartford:

$$AKWH_C = N \times CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times \frac{1}{EE_C} \times AA_C \times \frac{1}{1000}$$

For Bridgeport:

$$AKWH_C = N \times CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times \frac{1}{EE_C} \times CC_C \times \frac{1}{1000}$$

***Retrofit Gross Energy Savings, Example***

An energy efficient ductless heat pump (DHP) is installed in an existing home with electric resistance heat in Hartford. The nominal heating capacity is 24,000 Btu, and the nominal cooling capacity is 28,000 Btu, installed HSPF is 11 and the installed SEER is 22. The system has two zones. What are the annual electric heating and cooling savings?

**Using the equation for annual electric heating savings,**

$$AKWH_H = N \times CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times \frac{1}{EE_H} \times AA_H \times \frac{1}{1000}$$

$$AKWH_H = 1.25 \times 24{,}000 \times \left(\frac{1}{3.413} - \frac{1}{11}\right) \times \frac{1}{0.1714} \times 130 \times \frac{1}{1{,}000} = 4{,}609\ kWh$$

**Using the equation for annual electric cooling savings,**

$$AKWH_C = N \times CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times \frac{1}{EE_C} \times AA_C \times \frac{1}{1000}$$

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$$AKWH_C = 1.25 \times 28{,}000 \times \left(\frac{1}{10.1} - \frac{1}{22}\right) \times \frac{1}{0.037} \times 3.1 \times \frac{1}{1000} = 157\ kWh$$

***Retrofit Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)***

**Winter Demand Savings:**

For Hartford: $$WKW = N \times CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times \frac{1}{EE_H} \times BB_H \times \frac{1}{1000}$$

For Bridgeport: $$WKW = N \times CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times \frac{1}{EE_H} \times DD_H \times \frac{1}{1000}$$

**Summer Demand Savings:**

For Hartford: $$SKW = N \times CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times \frac{1}{EE_C} \times BB_C \times \frac{1}{1000}$$

For Bridgeport: $$SKW = N \times CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times \frac{1}{EE_C} \times DD_C \times \frac{1}{1000}$$

***Retrofit Gross Peak Demand Savings, Example***

An energy efficient ductless heat pump (DHP) is installed in an existing home with electric resistive heat in Hartford. The rated heating capacity is 24,000 Btu, rated cooling capacity is 28,000 Btu, installed HSPF is 11 and the installed SEER is 22. The system has 2 zones. What are the annual summer and winter demand savings?

Using the equation for summer demand savings,

$$SKW = N \times CAP_C \times \left(\frac{1}{SEER_E} - \frac{1}{SEER_I}\right) \times \frac{1}{EE_C} \times BB_C \times \frac{1}{1000}$$

$$SKW = 1.25 \times 28{,}000 \times \left(\frac{1}{10.1} - \frac{1}{22}\right) \times \frac{1}{0.037} \times 0.0017 \times \frac{1}{1000} = 0.086\ kW$$

Using the equation for winter demand savings,

$$WKW = N \times CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times \frac{1}{EE_H} \times BB_H \times \frac{1}{1000}$$

$$WKW = 1.25 \times 24000 \times \left(\frac{1}{3.413} - \frac{1}{11}\right) \times \frac{1}{0.171} \times 0.019 \times \frac{1}{1000} = 0.674\ kW$$

***Lost Opportunity Gross Energy Savings, Electric***

**Heating**

For Hartford: $$AKWH_H = N \times CAP_H \times \left( \frac{1}{HSPF_B} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times AA_H \times \frac{1}{1000}$$

For Bridgeport: $$AKWH_H = N \times CAP_H \times \left( \frac{1}{HSPF_B} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times CC_H \times \frac{1}{1000}$$

**Cooling**

For Hartford: $$AKWH_C = N \times CAP_C \times \left( \frac{1}{SEER_B} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times AA_C \times \frac{1}{1000}$$

For Bridgeport: $$AKWH_C = N \times CAP_C \times \left( \frac{1}{SEER_B} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times CC_C \times \frac{1}{1000}$$

***Lost Opportunity Gross Seasonal Peak Demand Savings, Electric (Winter and Summer)***

**Winter Demand Savings:**

For Hartford: $$WKW = N \times CAP_H \times \left( \frac{1}{HSPF_B} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times BB_H \times \frac{1}{1000}$$

For Bridgeport: $$WKW = N \times CAP_H \times \left( \frac{1}{HSPF_B} - \frac{1}{HSPF_I} \right) \times \frac{1}{EE_H} \times DD_H \times \frac{1}{1000}$$

**Summer Demand Savings:**

For Hartford: $$SKW = N \times CAP_C \times \left( \frac{1}{SEER_B} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times BB_C \times \frac{1}{1000}$$

For Bridgeport: $$SKW = N \times CAP_C \times \left( \frac{1}{SEER_B} - \frac{1}{SEER_I} \right) \times \frac{1}{EE_C} \times DD_C \times \frac{1}{1000}$$

***Non Energy Benefits***

***Resource benefit from installing ductless heat pump to displace fossil fuel is $94.note (4)***

Ductless Heat Pump customers have reported high levels of satisfaction. Ref [1]

***Changes from Last Version***

Removed customer benefits
Added note on customer fuel switching benefits calculations

***References***

[1] Ductless Mini Pilot Study, Final Report, KEMA, June 2009, Pages vi, vii, 4-15 and 4-18.

[2] 10 CFR 430.32 -2015 Ch. II

***Notes***

[1] The minimum heating efficiency standard set by federal government effective January 1, 2015 for ductless heat pumps is 8.2 HSPF and cooling efficiency is 14.0 SEER. The minimum efficiency standard for electric resistive heating system is 3.4 HSPF.

[2] PRISM is an established statistical procedure for measuring energy conservation in residential housing. The PRISM software package was developed by the Center for Energy and Environmental Studies, Princeton University. The tool is used for estimating energy savings from billing data. <http://www.princeton.edu/~marean/>

[3] DOE-2 is a widely used and accepted building energy analysis program that can predict the energy use and cost for all types of buildings. DOE-2 uses a description of the building layout, constructions, operating schedules, conditioning systems (such as lighting & HVAC) and utility rates provided by the user, along with weather data, to perform an hourly simulation of the building and to estimate utility bills. <http://www.doe2.com/>

[4] The Connecticut Utilities do not claim any fuel switching savings however, annual fuel-switching customer monetary benefits can be calculated using the electrical savings calculated from the Ductless Heat Pump measure, the current cost of fuel (oil, gas, and propane), and equipment efficiencies. The Connecticut Utilities have a spreadsheet in order to make fuel switching calculations for demonstrational purposes.

# Maine Technical Reference Manual



| Ductless Heat Pump (CH) | | |
|---|---|---|
| Last Revised Date | 9/16/2016 | |
| **MEASURE OVERVIEW** | | |
| Description | This measure involves the purchase and installation of a high-efficiency ductless heat pump (DHP) system, instead of a standard efficiency DHP system, as a supplemental heating system. | |
| Energy Impacts | Electric | |
| Sector | Residential | |
| Program(s) | Home Energy Savings Program | |
| End-Use | Heating, Cooling | |
| Decision Type | New Construction, Replace on Burnout | |
| **DEEMED GROSS ENERGY SAVINGS (UNIT SAVINGS)** | | |
| Demand savings | For single head unit<br>$\Delta kW_{max} = 1.23$<br>$\Delta kW_{WP} = 0.40$<br>$\Delta kW_{SP} = 0.05$ | For multi-head or multiple units<br>$\Delta kW_{max} = 1.33$<br>$\Delta kW_{WP} = 0.785$<br>$\Delta kW_{SP} = 0.05$ |
| Annual energy savings | For single head unit<br>$\Delta kWh/yr = 1{,}902$<br>$\Delta kWh_H/yr = 1{,}815$<br>$\Delta kWh_C/yr = 88$ | For multi-head or multiple units<br>$\Delta kWh/yr = 3{,}603$<br>$\Delta kWh_H/yr = 3{,}516$<br>$\Delta kWh_C/yr = 88$ |

| GROSS ENERGY SAVINGS ALGORITHMS (UNIT SAVINGS) | |
|---|---|
| Demand Savings | Modeled[570] |
| Annual Energy Savings | Modeled[570]<br>Heating and cooling savings are modeled using TMY3 data for Portland, Bangor and Caribou. Results are weighted based on population (71.2% Portland, 23.4% Bangor, 5.4% Caribou).[571]<br><br>Savings were calculated based on a model employing the following key assumptions:<br>• Average annual heat Loss is 92 MMBtu corresponding to an average UA of 493 MMBtu/h/deg F.<br>• A single head DHP unit's contribution to heating does not exceed 35 percent of the home's heating load in any temperature bin. Even in temperature bins in which 100 percent of the home's heating load can be supplied by the DHP, the DHP supplies 35 percent of the heating load, and the remaining 65 percent is supplied by the existing heating system to account for distribution and behavior effects.[572]<br>• For DHP units with multiple heads or multiple units, the DHP contribution to heating is capped at 70 percent of the home's heating load in any temperature bin to account for more effective distribution.[573]<br>• DHP heating output capacity and DHP heating efficiency (both baseline and efficient units) vary with outside air temperature as defined by performance curves.<br>• Baseline unit heating capacity is the same as the efficient unit.<br>• Heating is called for when outside air temperature is less than or equal to 65°F. |

[570] Based on Excel Workbook for Ductless Heat Pump
[571] Calculated based on population of each region; U.S. Census Bureau Census 2010 Summary File 1 population by census tract
[572] Heat load offset of 35 percent is consistent with other findings. Ecotope, NEEA Final Summary Report for the Ductless Heat Pump Impact and Process Evaluation, February 19, 2014 reported savings were analyzed to be equivalent to 30%-40% heat load offset.
[573] Program assumption to be validated and refined during next evaluation.

**Ductless Heat Pump (CH)**

| | | |
|---|---|---|
| Definitions | Unit | = 1 single-head DHP. Multiple-head systems or more than one single head unit installed count as 2 units. No more than 2 units can be claimed per dwelling. |
| | $HSPF_B$ | = Heating seasonal performance factor of the baseline DHP (Btu/Watt-hr) |
| | $HSPF_{EE}$ | = Heating seasonal performance factor of the high-efficiency DHP (Btu/Watt-hr) |
| | $CAP_{Cool}$ | = Rated cooling capacity of the DHP (kBtu/h) |
| | $CAP_{Heat}$ | = Rated heating capacity of the DHP (kBtu/h) |
| | $SEER_B$ | = Seasonal energy-efficiency ratio for baseline DHP (Btu/Watt-hr) |
| | $SEER_E$ | = Seasonal energy-efficiency ratio for high-efficiency DHP (Btu/Watt-hr) |

**EFFICIENCY ASSUMPTIONS**

| | |
|---|---|
| Baseline Efficiency | The baseline case assumes the home retains its existing heating system and adds a new ductless heat pump that meets Federal minimum efficiency requirement for units manufactured on or after January 1, 2015: HSPF=8.2 and SEER=14.0. |
| Efficient Measure | The high-efficiency case assumes the home retains its existing heating system and adds a new high-efficiency DHP that meets minimum efficiency requirements for program rebate: HSPF=12.0 and SEER=18.0. |

**PARAMETER VALUES (DEEMED)**

| Measure | $CAP_{Heat}$ | $CAP_{Cool}$ | $HSPF_B$ | $HSPF_E$ | Life (yrs) | Cost ($) |
|---|---|---|---|---|---|---|
| Ductless Heat Pump | 17.5[574] | 14.2[574] | 8.2[575] | 13.2[574] | 18[576] | $682[577] |
| Measure | $SEER_B$ | $SEER_E$ | | | | |
| Ductless Heat Pump | 14[575] | 25.6[574] | | | | |

**IMPACT FACTORS**

| Measure | ISR | $RR_E$ | $RR_D$ | $CF_S$ | $CF_W$ | FR | SO |
|---|---|---|---|---|---|---|---|
| Ductless Heat Pump | 100%[578] | 100%[579] | 100%[579] | 100%[580] | 100%[580] | 25%[581] | 0%[582] |

574 Weighted average values of the most popular units that have been incentivized under the Efficiency Maine program.
575 Federal minimum efficiency requirement for units manufactured on or after January 1, 2015 (changes to 8.8 HSPF and 15 SEER January 1, 2023).
576 GDS Associates, Inc., Measure Life Report – Residential and Commercial/Industrial Lighting and HVAC Measures, June 2007; Table 1.
577 The incremental cost is the difference in cost between a typical high-efficiency unit ($1,645 based on Fujitsu model 12RLS2, ecomfort.com) and a typical baseline unit ($963 based on LG model LS093HE, ecomfort.com).
578 EMT assumes that all purchased units are installed (i.e. ISR = 100%). This is consistent with the MA 2013-2015 TRM.
579 The measure has not yet been evaluated. Until the next program impact evaluation, EMT assumes 100 percent realization rate.
580 The on-peak summer and winter kW savings are calculated directly from the modeling.
581 Program not yet evaluated, assume default FR of 25%.
582 Program not yet evaluated, assume default SO of 0%.

# Massachusetts Technical Reference Manual

## Electric – RHVAC – Mini Split HP SEER 18.0 HSPF 9 – All

| Measure # | Sector | Program Administrator |
|---|---|---|
| MAE16A2a05ALL | Residential | All |
| **Category** | **Type** | **Sub-Type** |
| HVAC | Heat Pump | Ductless |

**Description** The installation of a more efficient Ductless Mini Split HP system.

| | |
|---|---|
| **01: Version Info** | |
| **Report Edition** | 2016 Plan Year Report |
| **02: Measure Overview** | |
| **BCR Measure ID** | E16A2a05 |
| **BCR Measure Name** | Mini Split HP SEER 18.0 HSPF 9 |
| **End Use** | HVAC |
| **PA Type** | Electric |
| **Program Administrator** | All |
| **Program Name** | Residential Heating & Cooling Equipment |
| **Sector Applicability** | Residential |
| **State Applicability** | MA |
| **Target Savings Market** | Products and Services |
| **03: Savings - General** | |
| **Baseline Description** | The baseline efficiency case is a non- ENERGY STAR® rated ductless mini split heat pump with SEER 14, EER 10 and HSPF 8.2. |
| **High Efficiency Description** | The high efficiency case is an ENERGY STAR® qualified Ductless Mini Split System with SEER 18.0 and HSPF 9.0. |
| **Savings Attribute Notes** | Savings are calculated based on actual size and efficiency of equipment throughout year. Values used for planning are based on prior year production. |
| **Savings Calculation Method** | Algorithm using deemed inputs |
| **04: Savings - Electric** | |
| **Gross Annual Savings - kW** | 0.65 |
| kW = Tons x (12 kBtuh/Ton) x (1/HSPF_base - 1/HSPF_ee) | kW_heat: |
| kW = Tons x (12 kBtuh/Ton) x (1/EER_base - 1/EERee) | kWcool: |
| kW = max(kWcool,kW_heat) | Algorithm: |
| Conversion Factor | 12 kBtu/h-Ton: 12,000 BTU/Hour equals 1 Ton of HVAC |
| 8.2 | HSPF_base: The Cadmus Group (2016). Ductless Mini-Split Heat Pump Impact Evaluation |
| 2.1 | Tons: Average size (tons) of new efficient MSHP equipment |
| 12.7 | EER_ee: Average demand efficiency of new efficient HP equipment |

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| | | |
|---|---|---|
| 12 | | EER_base: The Cadmus Group (2016). Ductless Mini-Split Heat Pump Impact Evaluation |
| 10.4 | | HSPF_ee: Average heating efficiency of new efficient MSHP equipment. |
| **Gross Annual Savings - kWh** | 386 | |
| kWh = Tons x (12 kBtuh/Ton) x [(1/SEER_base - 1/SEER_ee) x Hours_c + (1/HSPF_base - 1/HSPF_ee) x Hours_h] | | Algorithm: |
| Conversion Factor | | 12 kBtu/h-Ton: 12,000 BTU/Hour equals 1 Ton of HVAC |
| 8.2 | | HSPF_base: The Cadmus Group (2016). Ductless Mini-Split Heat Pump Impact Evaluation |
| 451 | | Hours_h: The Cadmus Group (2016). Ductless Mini-Split Heat Pump Impact Evaluation |
| 218 | | Hours_c: The Cadmus Group (2016). Ductless Mini-Split Heat Pump Impact Evaluation |
| 2.1 | | Tons: Average size (tons) of new efficient MSHP equipment |
| 19.2 | | SEER_ee: Average seasonal efficiency of new efficient HP equipment |
| 14.5 | | SEER_base: The Cadmus Group (2016). Ductless Mini-Split Heat Pump Impact Evaluation |
| 10.4 | | HSPF_ee: Average heating efficiency of new efficient HP equipment. |
| **Summer Coincidence Factor** | 0.06 | |
| | | Source: ADM Associates, Inc. (2009). Residential Central AC Regional Evaluation. |
| **Winter Coincidence Factor** | 0.15 | |
| | | Source: ADM Associates, Inc. (2009). Residential Central AC Regional Evaluation. |
| **07: Measure Life** | | |
| **Measure Life** | 18 | |
| | | Source: GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. |
| **08: Non-Energy Impacts** | | |
| **Annual $ per Unit** | $3.26 | |
| | | Source: NMR Group, Inc., Tetra Tech (2011). Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. |
| **One time $ per Unit** | $40.35 | |
| | | Source: NMR Group, Inc., Tetra Tech (2011). Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. |
| **09: Impact Factors** | | |
| **In-Service Rate** | 1.00 | |
| | | Note: In-service rates are set to 100% since all PAs verify equipment installation. |
| **Realization Rate - kWh** | 1.00 | |
| | | Note: Realization rates are set to 100% since savings are deemed |
| **Realization Rate - Summer kW** | 1.00 | |
| | | Note: Realization rates are set to 100% since savings are deemed |

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| | |
|---|---|
| **Realization Rate - Winter kW** | 1.00 |
| | Note: Realization rates are set to 100% since savings are deemed |

### 10: Net-to-Gross

| | |
|---|---|
| **Free Ridership** | 0.45 |
| | Source: The Cadmus Group (2013). 2012 Residential Heating, Water Heating, and Cooling Equipment Evaluation: Net-to-Gross, Market Effects, and Equipment Replacement Timing. Savings have been adjusted to reflect the mix of replace on failure and early replacement. |
| **Net-to-Gross Ratio** | 0.62 |
| **Non-Participant Spillover Factor** | 0.00 |
| **Participant Spillover Factor** | 0.07 |
| | Source: The Cadmus Group (2013). 2012 Residential Heating, Water Heating, and Cooling Equipment Evaluation: Net-to-Gross, Market Effects, and Equipment Replacement Timing. Savings have been adjusted to reflect the mix of replace on failure and early replacement. |

## Electric – RHVAC – Mini Split HP SEER 20.0 HSPF 11 – All

**Measure #**
MAE16A2a06ALL

**Sector**
Residential

**Program Administrator**
All

**Category**
HVAC

**Type**
Heat Pump

**Sub-Type**
Ductless

**Description** The installation of a more efficient Ductless Mini Split HP system.

| | |
|---|---|
| **01: Version Info** | |
| **Report Edition** | 2016 Plan Year Report |
| **02: Measure Overview** | |
| **BCR Measure ID** | E16A2a06 |
| **BCR Measure Name** | Mini Split HP SEER 20.0 HSPF 11 |
| **End Use** | HVAC |
| **PA Type** | Electric |
| **Program Administrator** | All |
| **Program Name** | Residential Heating & Cooling Equipment |
| **Sector Applicability** | Residential |
| **State Applicability** | MA |
| **Target Savings Market** | Products and Services |
| **03: Savings - General** | |
| **Baseline Description** | The baseline efficiency case is a non- ENERGY STAR® rated ductless mini split heat pump with SEER 14, EER 10 and HSPF 8.2. |
| **High Efficiency Description** | The high efficiency case is an ENERGY STAR® qualified Ductless Mini Split System with SEER 20 and HSPF 11. 0. |
| **Savings Attribute Notes** | Savings are calculated based on actual size and efficiency of equipment throughout year. Values used for planning are based on prior year production. |
| **Savings Calculation Method** | Algorithm using deemed inputs |
| **04: Savings - Electric** | |
| **Gross Annual Savings - kW** | 0.56 |
| kW = Tons x (12 kBtuh/Ton) x (1/HSPF_base - 1/HSPF_ee) | kW_heat: |
| kW = Tons x (12 kBtuh/Ton) x (1/EER_base - 1/EERee) | kWcool: |
| kW = max(kWcool,kW_heat) | Algorithm: |
| Conversion Factor | 12 kBtu/h-Ton: 12,000 BTU/Hour equals 1 Ton of HVAC |
| 8.2 | HSPF_base: The Cadmus Group (2016). Ductless Mini-Split Heat Pump Impact Evaluation |
| 14 | EER_ee: Average demand efficiency of new efficient MSHP equipment |

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| | |
|---|---|
| 12.6 | HSPF_ee: Average heating efficiency of new efficient MSHP equipment. |
| 12 | EER_base: The Cadmus Group (2016). Ductless Mini-Split Heat Pump Impact Evaluation |
| 1.1 | Tons: Average size (tons) of new efficient MSHP equipment. |
| **Gross Annual Savings - kWh** | 338 |
| kWh = Tons x (12 kBtuh/Ton) x [(1/SEER_base - 1/SEER_ee) x Hours_c + (1/HSPF_base - 1/HSPF_ee) x Hours_h] | Algorithm: |
| 8.2 | HSPF_base: The Cadmus Group (2016). Ductless Mini-Split Heat Pump Impact Evaluation |
| 451 | Hours_h: The Cadmus Group (2016). Ductless Mini-Split Heat Pump Impact Evaluation |
| 25.3 | SEER_ee: Average seasonal efficiency of new efficient HP equipment |
| 218 | Hours_c: The Cadmus Group (2016). Ductless Mini-Split Heat Pump Impact Evaluation |
| 14.5 | SEER_base: The Cadmus Group (2016). Ductless Mini-Split Heat Pump Impact Evaluation |
| 12.6 | HSPF_ee: Average heating efficiency of new efficient MSHP equipment. |
| 1.1 | Tons: Average size (tons) of new efficient MSHP equipment. |
| | 12 kBtu/h-Ton: 12,000 BTU/Hour equals 1 Ton of HVAC |
| **Summer Coincidence Factor** | 0.09 |
| | Source: ADM Associates, Inc. (2009). Residential Central AC Regional Evaluation. |
| **Winter Coincidence Factor** | 0.15 |
| | Source: ADM Associates, Inc. (2009). Residential Central AC Regional Evaluation. |
| **07: Measure Life** | |
| **Measure Life** | 18 |
| | Source: GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. |
| **08: Non-Energy Impacts** | |
| **Annual $ per Unit** | $3.26 |
| | Source: NMR Group, Inc., Tetra Tech (2011). Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. |
| **One time $ per Unit** | $40.35 |
| | Source: NMR Group, Inc., Tetra Tech (2011). Massachusetts Special and Cross-Sector Studies Area, Residential and Low-Income Non-Energy Impacts (NEI) Evaluation. |
| **09: Impact Factors** | |
| **In-Service Rate** | 1.00 |
| | Note: In-service rates are set to 100% since all PAs verify equipment installation. |
| **Realization Rate - kWh** | 1.00 |
| | Note: Realization rates are set to 100% since savings are deemed |
| **Realization Rate - Summer kW** | 1.00 |

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| | |
|---|---|
| | Note: Realization rates are set to 100% since savings are deemed |
| **Realization Rate - Winter kW** | 1.00 |
| | Note: Realization rates are set to 100% since savings are deemed |
| **10: Net-to-Gross** | |
| **Free Ridership** | 0.45 |
| | Source: The Cadmus Group (2013). 2012 Residential Heating, Water Heating, and Cooling Equipment Evaluation: Net-to-Gross, Market Effects, and Equipment Replacement Timing. Savings have been adjusted to reflect the mix of replace on failure and early replacement. |
| **Net-to-Gross Ratio** | 0.62 |
| **Non-Participant Spillover Factor** | 0.00 |
| **Participant Spillover Factor** | 0.07 |
| | Source: The Cadmus Group (2013). 2012 Residential Heating, Water Heating, and Cooling Equipment Evaluation: Net-to-Gross, Market Effects, and Equipment Replacement Timing. Savings have been adjusted to reflect the mix of replace on failure and early replacement. |

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# New York Technical Reference Manual



## HEAT PUMP - AIR SOURCE (ASHP)

**Measure Description**

An air-source unitary heat pump model consists of one or more factory-made assemblies which normally include an indoor conditioning coil(s), compressor(s), and outdoor coil(s), including means to provide a heating function. ASHPs shall provide the function of air heating with controlled temperature, and may include the functions of air-cooling, air-circulation, air-cleaning, dehumidifying or humidifying.[86] Cooling mode savings outlined in this measure follow the residential Central Air Conditioner measure.

**Method for Calculating Annual Energy and Peak Coincident Demand Savings**

*Annual Electric Energy Savings*

$$\Delta kWh_{heating\ mode} = units \times \left(\frac{kBTUh_{out}}{unit}\right) \times \left(\frac{1}{HSPF_{baseline}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heating}$$

$$\Delta kWh_{cooling\ mode} = units \times tons/unit \times \left(\frac{12}{SEER_{baseline}} - \frac{12}{SEER_{ee}}\right) \times EFLH_{cooling}$$

*Peak Coincident Demand Electric Savings*

$$\Delta kW_{heating\ mode} = N/A$$

$$\Delta kW_{cooling\ mode} = units \times tons/unit \times \left(\frac{12}{EER_{baseline}} - \frac{12}{EER_{ee}}\right) \times CF$$

*Annual Gas Energy Savings*

$$\Delta therms_{heating\ mode} = N/A$$

$$\Delta therms_{cooling\ mode} = N/A$$

**where:**

| | |
|---|---|
| ΔkWh | = Annual electric energy savings |
| ΔkW | = Peak coincident demand electric savings |
| Δtherms | = Annual gas energy savings |
| units | = Number of units installed under the program |
| tons/unit | = Tons of air conditioning per unit, based on nameplate data |
| $kBTUh_{output}$ | = The nominal rating of the heating output capacity of the heat pump in kBTU/hr |

[86] ENERGY STAR® Program Requirements Product Specification for Air Source Heat Pump and Central Air Conditioner Equipment Eligibility Criteria
Version 4.1

(including supplemental heaters)
HSPF = Heating seasonal performance factor
SEER = Seasonal average energy efficiency ratio over the cooling season, BTU/watt-hour, (used for average U.S. location/region)
EER = Energy efficiency ratio under peak conditions
EFLH = Equivalent full-load hours
CF = Coincidence factor
out = Output capacity
heating = Heating
ee = Energy efficient condition or measure
cooling = Cooling
baseline = Baseline condition or measure
12 = kBTUh/ton of air conditioning capacity

**Summary of Variables and Data Sources**

| Variable | Value | Notes |
|---|---|---|
| $kBTUh_{output}$ / unit | | From application |
| $HSPF_{baseline}$ | 8.1 | Normal replacement |
| | 6.8 | Early replacement |
| $HSPF_{ee}$ | | From application |
| $EFLH_{heating}$ | | Lookup by vintage and city. Variability exceeds 5% across upstate (Albany, Binghamton, Buffalo, Massena and Syracuse) and NGRID (Albany, Massena and Syracuse) cities. City specific lookup must be used. |
| $EFLH_{cooling}$ | | Lookup by vintage and city. Variability exceeds 10% across upstate (Albany, Binghamton, Buffalo, Massena and Syracuse) and NGRID (Albany, Massena and Syracuse) cities. City specific lookup must be used. |
| tons | | From application, default to average system size from applications if unknown |
| $EER_{baseline}$ | 11.09 | Normal replacement |
| | 9.20 | Early replacement |
| $EER_{ee}$ | | Lookup from table below, based on unit SEER |
| $SEER_{baseline}$ | 13.00 | Normal replacement |
| | 10.00 | Early replacement |
| $SEER_{ee}$ | | From application |

The output capacity of the heat pump is the heating capacity of the heat pump plus backup electric resistance strip heaters at design conditions, expressed in $kBTU/hr_{output}$.

The HSPF is an estimate of the seasonal heating energy efficiency for an average US city. The average COP in the equation above is equal to the HSPF/3.412. Programs should use the manufacturers' rated HSPF until data can be developed that are more appropriate for NY climates. Efficiency assumptions for heat pumps of different SEER classes are shown below.

| | Cooling Seasonal Efficiency (SEER) | Heating Seasonal Efficiency (HSPF)[87] |
|---|---|---|
| Early replacement baseline | SEER 10 | 6.8 |
| Replace on failure baseline | SEER 13 | 8.1 |
| Measure | SEER 14 | 8.6 |
| | SEER 14.5 | 8.5[88] |
| | SEER 15 | 8.8 |
| | SEER 16 | 8.5[89] |
| | SEER 17 | 8.6 |
| | SEER 18 | 9.2 |

Early replacement units are assumed to be no more than 15 years old, with no less than 5 years of remaining life. According to the 2004-5 DEER update study, equipment of this vintage is generally SEER 10.

**Coincidence Factor (CF)**

The recommended value for the coincidence factor for the heating mode is 0.0
The recommended value for the coincidence factor for the cooling mode is 0.8

**Baseline Efficiencies from which Savings are Calculated**

New construction and replace on failure baseline efficiency should be consistent with a SEER 13 heat pump (HSPF = 8.1). Early replacement efficiency is assumed to be consistent with a SEER 10 heat pump (HSPF = 6.8).

The SEER is an estimate of the average efficiency of the air conditioner over the cooling season, based on an average U.S. city. Programs should use the manufacturers' rated SEER until data can be developed that is more appropriate for NY climates.

The EER is the ARI rated full-load efficiency of the unit, which is used to estimate the unit efficiency under peak conditions.

The baseline efficiency for new construction and replace on failure is SEER 13. Baseline for early replacement is SEER 10. Early replacement units are assumed to be no more than 10 years

[87] Average HSPF by SEER class taken from 2004 - 2005 DEER Update Study, with exceptions noted below.
[88] Average HSPF of SEER 14.5 Energy Star qualifying units listed in ARI/CEE directory
[89] Set at CEE Tier 2 minimum.

old, with no less than 5 years of remaining life. According to the 2004-5 DEER update study, equipment of this vintage is generally SEER 10.

| System Type | Baseline or Measure Assumption | Seasonal Efficiency (SEER) | Peak Efficiency (EER)[90] |
|---|---|---|---|
| Central Air conditioner | Early replacement baseline | SEER 10 | 9.20 |
| | Replace on failure baseline | SEER 13 | 11.09 |
| | Measure | SEER 14 | 11.99 |
| | | SEER 14.5 | 12.00[91] |
| | | SEER 15 | 12.72 |
| | | SEER 16 | 13.00[92] |
| | | SEER 17 | 13.00[93] |
| Central Heat Pump | Early replacement baseline | SEER 10 | 9.00 |
| | Replace on failure baseline | SEER 13 | 11.07 |
| | Measure | SEER 14 | 11.72 |
| | | SEER 14.5 | 12.00[94] |
| | | SEER 15 | 12.50[95] |
| | | SEER 16 | 12.50[96] |
| | | SEER 17 | 12.52 |
| | | SEER 18 | 12.80 |

**Compliance Efficiency from which Incentives are Calculated**

Heat pump and air conditioning efficiency must be greater than or equal to SEER 14, for single-family and multi-family residential applications

**Operating Hours**

EFLH data by location, building type and vintage are tabulated in Appendix G.

**Effective Useful Life (EUL)**

Years: 15

[90] Peak EER by SEER Class taken from 2004-2005 DEER Update Study, with exceptions noted below.
[91] Compliant with Energy Star specifications.
[92] Set to 13.0 in compliance with CEE Tier 3 Standard for SEER 16 and higher split system air conditioners
[93] Ibid.
[94] Compliant with Energy Star specifications
[95] Set to 12.5 in compliance with CEE Tier 2 Standard on SEER 15 and higher heat pumps.
[96] Ibid.

Source: DEER

**Ancillary Fossil Fuel Savings Impacts**

Minor heating interactions are expected with efficient furnace fans utilized in most high efficiency air conditioners. These have not been quantified at this time.

**Ancillary Electric Savings Impacts**

**References**


1. Unit seasonal and peak efficiency data taken from the California DEER update study: 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Final Report, Itron, Inc. Vancouver, WA. December, 2005. Available at www.calmac.org/publications/2004-05_DEER_Update_Final_Report-Wo.pdf
2. Typical values for rated load factor (RLF) taken from Engineering Methods for Estimating the Impacts of Demand-Side Management Programs. Volume 2: Fundamental Equations for Residential and Commercial End-Uses. TR-100984S Vol. 2. Electric Power Research Institute, Palo Alto, CA August, 1993.
3. Typical values for coincidence factor (CF) for cooling mode, taken from Engineering Methods for Estimating the Impacts of Demand-Side Management Programs. Volume 2: Fundamental Equations for Residential and Commercial End-Uses. TR-100984S Vol. 2. Electric Power Research Institute, Palo Alto, CA August, 1993.
4. SEER rated in accordance with AHRI Standard 210/240-2008. Available from the Air Conditioning Heating and Refrigeration Institute. See www.ahrinet.org


**Record of Revision**

| Record of Revision Number | Issue Date |
|---|---|
| 1 | 10/15/2010 |
| | |

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# Rhode Island Technical Reference Manual



## Mini Split HP SEER 18.0 HSPF 9

**Sector:** Residential
**Fuel:** Electric
**Program Type:** Prescriptive
**Measure Category:** HVAC
**Measure Type:** Heat Pumps
**Measure Sub Type:** Ductless

**Program:** Energy Star HVAC

**Measure Description**

The installation of a more efficient ENERGY STAR® rated Ductless MiniSplit system.

**Baseline Description**

The baseline efficiency case is a non- ENERGY STAR® rated ductless mini split heat pump with SEER 14, EER 8.5 and HSPF 8.2.

**Savings principle**

The high efficiency case is a high-efficiency Ductless Mini Split System.

**Savings Method**

Calculated using deemed inputs

**Unit**

Installed high-efficiency ductless minisplit system.

**Savings equation**

Gross kWh = Tons × (12 kBtu/hr per ton) × [(1/SEER_base - 1/SEER_EE) × Hours_c + (1/HSPF_base - 1/HSPF_EE) × Hours_h)]

Gross kW = Tons × (12 kBtu/hr per ton) × max[(1/SEER_base - 1/SEER_ee),(1/HSPF_base - 1/HSPF_ee)]

Where:

Tons = Deemed average equipment capacity: 1.8 tons for 18 SEER unit / 1.1 tons for 20 SEER unit

SEER_base = Seasonal Energy Efficiency Ratio of baseline equipment

SEER_ee = Seasonal Energy Efficiency Ratio of new equipment

HSPF_base = Heating Season Performance Factor of baseline equipment

HSPF_ee = Heating Season Performance Factor of new equipment

Hours_c = Equivalent full load cooling hours

Hours_h = Equivalent full load heating hours

**Hours:**

**Measure Gross Savings per Unit**

| Measure | KWh | KW | Gas Heat MMBtu | Gas DHW MMBtu | Gas Other MMBtu | Oil MMBtu | Propane MMBtu |
|---|---|---|---|---|---|---|---|
| Mini Split HP SEER 18.0 HSPF 9 | 345.80 | 0.50 | 0.00 | | | 0.00 | 0.00 |

Electric kWh Note: Calculated. Tonnage used in calculations is 1.25, as provided by Conservation Services Group

Electric kW Note: Calculated. Tonnage used in calculations is 1.25, as provided by Conservation Services Group

**Energy Impact Factors**

| Measure | Measure life | ISR | SPF | RRe Gas | RRe Electric | RR sp | RR wp | CF sp | CF wp |
|---|---|---|---|---|---|---|---|---|---|
| Mini Split HP SEER 18.0 HSPF 9 | 18 | 1.00 | 1.00 | | 1.00 | 1.00 | 1.00 | 0.25 | 0.50 |

| Measure | Winter Peak Energy % | Winter Off-Peak Energy % | Summer Peak Energy % | Summer Off-Peak Energy % |
|---|---|---|---|---|
| Mini Split HP SEER 18.0 HSPF 9 | 0.29 | 0.49 | 0.12 | 0.10 |

Measure life Source: GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group.

ISR Note: All installations have 100% in-service rate since programs include verification of equipment installations.

SPF Note: Savings persistence is assumed to be 100%.

RRe Note: Realization rate is 100% since gross savings values are based on evaluation results.

RRsp Note: Realization rate is 100% since gross savings values are based on evaluation results.

RRwp Note: Realization rate is 100% since gross savings values are based on evaluation results.

CFsp Source: ADM Associated, Inc. (2009). Residential Central AC Regional Evaluation. Prepared for NSTAR, National Grid, Connecticut Light & Power and United Illuminating.

CFwp Source: ADM Associated, Inc. (2009). Residential Central AC Regional Evaluation. Prepared for NSTAR, National Grid, Connecticut Light & Power and United Illuminating.

**Non Energy Impact Factors**

| Measure | Water: Gallons | Sewer: Gallons | Annual $ | One-time $ |
|---|---|---|---|---|
| Mini Split HP SEER 18.0 HSPF 9 | 0.00 | 0.00 | 3.26 | 40.35 |

Annual $ Note: MA values

One time $ Note: MA values

**Net to Gross Factors**

| Measure | FR | Sop | Sonp | NTG |
|---|---|---|---|---|
| Mini Split HP SEER 18.0 HSPF 9 | 0.45 | 0.07 | 0.00 | 0.62 |

NTG Source: The Cadmus Group (2013). 2012 Residential Heating, Water Heating, and Cooling Equipment Evaluation: Net-to-Gross, Market Effects, and Equipment Replacement Timing.

**Gross Measure TRC unit:** $ 700 per measure

**Incentive Unit:** $ 250 per measure

## MiniSplit HP SEER 20, HSPF 11

**Sector:** Residential **Fuel:** Electric **Program Type:** Prescriptive

**Measure Category:** HVAC **Measure Type:** Heat Pumps **Measure Sub Type:** Ductless

**Program:** Energy Star HVAC

**Measure Description**

The installation of a more efficient ENERGY STAR® rated Ductless MiniSplit system.

**Baseline Description**

The baseline efficiency case is a non- ENERGY STAR® rated ductless mini split heat pump with SEER 14, EER 8.5 and HSPF 8.2.

**Savings principle**

The high efficiency case is a high-efficiency Ductless Mini Split System.

**Savings Method**

Calculated using deemed inputs

**Unit**

Installed high-efficiency ductless minisplit system.

**Savings equation**

Gross kWh = Tons × (12 kBtu/hr per ton) × [(1/SEER_base - 1/SEER_EE) × Hours_c + (1/HSPF_base - 1/HSPF_EE) × Hours_h)]

Gross kW = Tons × (12 kBtu/hr per ton) × max[(1/SEER_base - 1/SEER_ee),(1/HSPF_base - 1/HSPF_ee)]

Where:

Tons = Deemed average equipment capacity: 1.8 tons for 18 SEER unit / 1.1 tons for 20 SEER unit

SEER_base = Seasonal Energy Efficiency Ratio of baseline equipment

SEER_ee = Seasonal Energy Efficiency Ratio of new equipment

HSPF_base = Heating Season Performance Factor of baseline equipment

HSPF_ee = Heating Season Performance Factor of new equipment

Hours_c = Equivalent full load cooling hours

Hours_h = Equivalent full load heating hours

**Hours:**

**Measure Gross Savings per Unit**

| Measure | KWh | KW | Gas Heat MMBtu | Gas DHW MMBtu | Gas Other MMBtu | Oil MMBtu | Propane MMBtu |
|---|---|---|---|---|---|---|---|
| MiniSplit HP SEER 20, HSPF 11 | 318.00 | 0.53 | 0.00 | | | 0.00 | 0.00 |

Electric kWh Note: Calculated. Tonnage used in calculations is 1.25, as provided by Conservation Services Group

Electric kW Note: Calculated. Tonnage used in calculations is 1.25, as provided by Conservation Services Group

# Vermont Technical Reference Manual



## Variable Speed Mini-Split Heat Pumps (Market Opportunity)

| | |
|---|---|
| Measure Number: | VII-C-11 b |
| Portfolio: | EVT TRM Portfolio 2017-12 |
| Status: | External Review |
| Effective Date: | 2018/1/1 |
| End Date: | [ None ] |
| Program: | Existing Homes |
| End Use: | HVAC |

### Update Summary

This update includes results from the VT Heat Pump Evaluation which informs EFLH used in the savings algorithms.

### Referenced Documents

- Navigant Consulting. (2013, January 16). Incremental Cost Study Phase Two Final Report.
- DHP 116 MOP LoadProfileAverager_final
- VT existing homeowner survey report - DRAFT
- Existing Heating System Efficiency Analysis
- Upstream EVT CCHP Program Data_Cost Analysis
- Upstream Program Data Natural Gas Territory Research
- evt-cchp-mop-and-retrofit-1-2017

### Description

This measure claims savings for the installation of single and multi-head variable speed mini-split heat pumps. Heating and cooling savings are claimed as a market opportunity to account for the incremental savings of an efficient heat pump versus the installation of a baseline heat pump. Given the use of heat pumps as a supplemental heating source, the characterization assumes a standard mode of operation regardless of installation location.

### Baseline Efficiencies

The baseline condition is assumed to 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 efficiencies:

**Table 1 - Single Head Baseline Efficiency**[1]

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

**Table 2 - Multi Head Baseline Efficiency**[2]

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

### Efficient Equipment

To qualify for savings under this measure, the installed equipment must be a new mini-split heat pump that has a variable speed inverter-driven compressor, COP at 5°F ≥ 1.75 (at maximum capacity operation), and be capable of providing heat using the heat

TRM Characterization:
Variable Speed Mini-Split Heat Pumps (Market Opportunity) [VII-C-11-b]

pump cycle down to -5°F. It must also meet or exceed the following efficiency criteria, per AHRI Standard 210-240-2008 for Unitary Air-Conditioning and Air-Source Heat Pump equipment.

**Table 3 - Single-Head High Efficiency**[3]

| Equipment | HSPF | EER | SEER |
|---|---|---|---|
| Air-Source Heat Pump | 10 | 12 | 20 |

**Table 4 - Multi-Head High Efficiency**

| Equipment | HSPF | EER | SEER |
|---|---|---|---|
| Air-Source Heat Pump | 10 | 12 | 17 |

## Algorithms

**Electric Demand Savings**

Given the primary impact is on heating, demand impact is characterized for heating.

| | |
|---|---|
| ΔkW | = (ΔkWh / EFLH) × New Construction Factor |

Symbol Table

**Electric Energy Savings**

For the market opportunity measure, electric energy impacts are characterized as savings. Cooling impact uses full load cooling hours, and seasonal cooling efficiency. Heating impacts are characterized from EFLH derived from a metering analysis in the VT Heat Pump Evaluation.

| | |
|---|---|
| ΔkWh | $= (\Delta kWh_{Cooling} + \Delta kWh_{Heating>=5F} - \Delta kWh_{Heating<5F}) \times$ New Construction Factor |
| $\Delta kWh_{Cooling}$ | $= Q_{Cooling} \times EFLH_{Cooling} \times (1/SEER_{Baseline} - 1/SEER_{Efficient}) \times$ 1kWh/1000 Wh |
| $\Delta kWh_{Heating>5F}$ | $= (\text{Max Capacity}_{5F}) \times EFLH \times (1/HSPF_{Baseline} \times 90\% - 1/HSPF_{Efficient} \times 90\%) \times$ 1 kWh/1000 Wh |
| $\Delta kWh_{Heating<5F}$ | $= \Delta MMBtu \times (1/COP_{<5F} - \%ElecHeat) \times$ 1 kWh/ 3412 Btu |

Where:

| | | |
|---|---|---|
| %ElecHeat | = | = portion of homes with electric space heat<br>= 2%[5] (deemed assumption for prescriptive savings) |
| %HeatSource | = | = Percent of existing heating systems using fuel type *j*[6169]<br>= 51% for fuel oil<br>= 26% for propane<br>= 4% for Wood<br>= 11% for Natural Gas<br>= 8% for Electric |
| ΔkW | = | Total average winter coincident peak kW reduction (deemed assumption for prescriptive) |
| $\Delta kWh_{Cooling}$ | = | = Cooling Energy Savings |
| $\Delta kWh_{Heating>=5F}$ | = | = Heating Energy Savings above 5°F |

TRM Characterization:
Variable Speed Mini-Split Heat Pumps (Market Opportunity) [VII-C-11-b]

| | | |
|---|---|---|
| $\Delta kWh_{Heating<5F}$ | = | = Heating Penalty below above 5°F |
| ΔkWh | = | = Gross customer electric energy savings |
| ΔMMBtu | = | MMBtu savings for each fuel type *j* (deemed assumption for prescriptive) |
| $\eta_{Heatj}$ | = | = Heating system efficiency for fuel type *j* (deemed assumption for prescriptive)[6170]<br>= 83% for fuel oil<br>= 86% for propane<br>= 66% for Wood/Other<br>= 87% for Natural Gas<br>=100% for Electric |
| 90% | = | = Climatic adjustment to HSPF[6] (deemed assumption for prescriptive savings) |
| $COP_{<5F}$ | = | = Assumed Coefficient of Performance below 5 degrees Fahrenheit<br>=2.0[7] |
| $EFLH_{Cooling}$ | = | = Equivalent Full Load Hours for heating<br>= 239.81[8] |
| EFLH | = | Equivalent Full Load Hours for heating<br>= 1,354.80[8] |
| $HSPF_{Baseline}$ | = | = Heating Seasonal Performance Factor for Baseline equipment, Btu/Wh<br>= 8.6[9](Single-head deemed assumption for prescriptive savings)<br>= 8.2[10] (Multi-head deemed assumption for prescriptive savings) |
| $HSPF_{Efficient}$ | = | = Heating Seasonal Performance Factor for Efficient equipment, Btu/Wh |
| Max $Capacity_{5F}$ | = | Average Maximum Capacity (Btu/hr) of the CCHP at 5 degrees Fahreneheit[11] |
| New Construction Factor | = | Factor to account for better thermal envelope of new construction homes<br>= 99.25%[4] |
| $Q_{Cooling}$ | = | = nominal cooling capacity, Btu/hr |
| $Q_{Heating<5F,i}$ | = | = Maximum of rated heating capacity and estimated load in weather bin *i* below 5°F, MMBtu |
| $SEER_{Baseline}$ | = | = Seasonal Energy Efficiency Ratio for Baseline equipment, Btu/Wh<br>= 15.6[10](Single-head deemed assumption for prescriptive savings)<br>= 14.5[10](Multi-head deemed assumption for prescriptive savings) |
| $SEER_{Efficient}$ | = | = Seasonal Energy Efficiency Ratio for Efficient equipment, Btu/Wh |

## Load Shapes

116b Prescriptive Cold Climate Variable Speed Heat Pump (Market Opportunity)

| Number | Name | Status | Winter On kWh | Winter Off kWh | Summer On kWh | Summer Off kWh | Winter kW | Summer kW |
|---|---|---|---|---|---|---|---|---|

TRM Characterization:
Variable Speed Mini-Split Heat Pumps (Market Opportunity) [VII-C-11-b]

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 116 | Prescriptive Cold Climate Variable Speed Heat Pump (Market Opportunity) | Active | 40.8 % | 47.7 % | 6.2 % | 5.4 % | 36.9 % | 3.8 % |

## Net Savings Factors

**Measures**

| | |
|---|---|
| SHRHPCVH | Cold climate single-head variable speed heat pump |
| SHRHPMHC | Cold climate multi head variable speed heat pump |

**Tracks [Base Track]**

| | |
|---|---|
| 6032UPST [6032EPEP] | Upstream - Residential |

## Lifetimes

The expected measure life is assumed to be 15 years.[12]

## Measure Cost

**Single Head Measure Costs**

The incremental installed measure cost of an efficient versus a baseline CCHP:

| Nominal Equipment Capacity (Btu/hr) | Incremental Costs |
|---|---|
| 6,000 | $483 |
| 9,000 | $493 |
| 12,000 | $591 |
| 15,000 | $588 |
| 18,000 | $611 |
| 24,000 | $693 |

**Multi-Head Measure Cost**[13]

Measure cost represents the market opportunity incremental installed cost of an efficient versus a baseline multi head CCHP.

| Nominal Equipment Capacity (Btu/hr) | Incremental Cost |
|---|---|
| 18,000 | $411 |
| 24,000 | $265 |
| 30,000 | $1,343 |
| 36,000 | $603 |
| 42,000 | $787 |
| 48,000 | $736 |

## Savings Summary

| Type | Capacity | ΔkWh Total | ΔkW |
|---|---|---|---|
| Single Zone | 6,000 | 600.78 | 0.41 |
| Single Zone | 9,000 | 607.61 | 0.41 |

TRM Characterization:
Variable Speed Mini-Split Heat Pumps (Market Opportunity) [VII-C-11-b]

| | | | |
|---|---|---|---|
| Single Zone | 12,000 | 596.74 | 0.40 |
| Single Zone | 15,000 | 855.98 | 0.58 |
| Single Zone | 18,000 | 667.76 | 0.44 |
| Single Zone | 24,000 | 778.12 | 0.51 |
| Multi Zone | 18,000 | 668.33 | 0.44 |
| Multi Zone | 24,000 | 1,138.73 | 0.77 |
| Multi Zone | 30,000 | 1,298.89 | 0.89 |
| Multi Zone | 36,000 | 1,726.21 | 1.17 |
| Multi Zone | 42,000 | 2,225.16 | 1.54 |
| Multi Zone | 48,000 | 1,758.25 | 1.16 |

## Footnotes

[1] Baseline single head CCHP efficiencies is derived from an analysis of installed heat pumps in Vermont from Vermont heat pump distributors. Review Efficiency Levels tab in EVT_CCHP MOP and Retrofit_12_2017.xlsx.

[2] Based on November 2014 TAG Agreement. Review of mutli-head CCHP shows HSPF average is below single-head units.

[3] High efficiencies for single and multi zone cold climate heat pumps are derived from various sources. HSPF rating based on NEEP criteria, refer to Cold Climate Air-source Heat Pump Specification-Version 2.0Jan2017 (1).pdf. EER rating based on ENERGY STAR specifications for air source heat pumps, refer to https://www.energystar.gov/products/heating_cooling/heat_pumps_air_source/key_product_criteria.

[4] See EVT_CCHP MOP and Retrofit_12_2017.xlsx, New Construction tab for detailed analysis

[5] 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."

[6] Energy & Resource Solutions. (2014). *Emerging Technology Program Primary Research – Ductless Heat Pumps.* Lexington, MA: NEEP Regional EM&V Forum. Table 1-2. Page 5.

[7] Conservative average of low temperature COP according to manufacturer's engineering documents.

[8] EFLH is calculated in an analysis of heat pump metered data. The partial load of each heat pump is summed up through the heating season, and taken as an average across all units metered. This analysis can be found on the EFLH Calculator tab in the EVT_CCHP MOP and Retrofit_12_2017.xlsx.

[9] Per TAG Agreement

[10] See Baseline Efficiency section

[11] This value is derived as an average of capacities that the CCHP can provide at 5 degrees Fahrenheit. These are from the engineering spec sheets of the CCHPs that are on the EVT QPL.

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

[13] Navigant Consulting Inc. (2013). Incremental Cost Study Phase Two Final Report. Burlington, MA: NEEP Evaluation, Measurement, and Verification Forum. Review Costs tab of EVT_CCHP MOP and Retrofit_12_2017.xlsx.

TRM Characterization:
Variable Speed Mini-Split Heat Pumps (Retrofit) [VII-C-12-a]

# Variable Speed Mini-Split Heat Pumps (Retrofit)

Measure Number: VII-C-12 a
Portfolio: 95
Status: Active
Effective Date: 2016/10/1
End Date: [ None ]
Program: Existing Homes
End Use: HVAC

## Update Summary

## Referenced Documents

- Energy & Resource Solutions. Emerging Technology Program Primary Research – Ductless Heat Pumps. Lexington, MA: NEEP Regional EM&V Forum, 2014.
- Navigant Consulting. (2013, January 16). Incremental Cost Study Phase Two Final Report.
- VT SF Existing Homes Onsite Report_final 021513
- DHP 123 Retrofit LoadProfileAverager_final
- DPS CCHP Tier III-Final Final
- EVT Single Zone CCHPSavingsAnalysis Update_Final_Demand_2017
- EVT Multi Zone CCHPSavingsAnalysis Update_Final_Demand_2017
- EVT Multi Zone CCHPSavingsAnalysis Update_2017_FINAL

## Description

This measure claims savings for the installation of single and multi-head variable speed mini-split heat pumps. Heating savings are claimed as a retrofit of the home's existing heating system, fossil fuel or electric resistance, to account for the heating offset where a heat pump is used to provide supplemental heat. For this case, the added electric load associated with the heat pump is counted as a penalty for both heating and cooling. This measure is in connection with the Market Opportunity characterization for single and multi-head variable speed mini-split heat pumps.

## Baseline Efficiencies

The baseline condition for a retrofit is assumed to be the existing residential fossil fuel heating system.

**Table 1 - Baseline Efficiency**

| Existing Fuel | Average System Efficiency[1] |
|---|---|
| Fuel Oil | 84.2% |
| Natural Gas | 87.8% |
| Propane | 87.4% |
| Wood | 65.0% |
| Electric | 100.0% |

## Efficient Equipment

For this installed heat pump is assumed to meet the efficiencies outlined in Table 2 and Table 3.

**Table 2- Multi-Head Base Efficiency**

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

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TRM Characterization:
Variable Speed Mini-Split Heat Pumps (Retrofit) [VII-C-12-a]

**Table 3- Multi-Head High Efficiency**

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

## Algorithms

### Electric Demand Savings

Demand penalties are calculated using a weather bin analysis based on the average demand during winter peak demand periods where maximum increases are anticipated[2]. Given the primary impact is on heating, demand impact is characterized for heating. The loadshape developed for the Retrofit analyzes heating and cooling demand impacts[3].

| | |
|---|---|
| ΔkW | $= (\Delta kWh_{Heating>5F} / EFLH_{Heating}) \times$ Controls Factor × Wx Factor × Construction Factor |

Symbol Table

### Electric Energy Savings

For the retrofit measure, electric energy impacts are characterized as penalties to account for the added electric load of the heat pump. Cooling impact assumes some existing cooling and is based on system capacity, full load cooling hours, and seasonal cooling efficiency. Heating impacts are characterized using a bin analysis in order to account for the variable heating capacity of CCHPs at different outdoor temperatures. The heating analysis assumes that the heat pump operates for temperatures between 5°F and 50°F, except in summer months (May to August), and that the heat pump provides heating based on its maximum capacity for each weather bin. Seasonal heating efficiency values have been used to approximate varying system efficiencies due to changes in operating conditions. Adjustments are made to account for the integration of thermostat controls, shell improvements to the home, and the portion of heat pump installations in new construction situations where a retrofit characterization would not be appropriate.

| | |
|---|---|
| ΔkWh | $= -((1- \%AC \times Q_{Cooling} \times FLH_{Cooling} \times (1/SEER) + \Sigma Q_{Heating>5F,i} \times (1/HSPF \times 90\%)) \times$ Controls Factor × Wx Factor × New Construction Factor |

Symbol Table

### Fossil Fuel Savings

Retrofit fossil fuel savings are taken for operation of the heat pump offsetting fuel use from the home's existing heating system.

| | |
|---|---|
| ΔMMBtu | $= \Sigma Q_{Heating>5F,i} \times (\%HeatSource/\eta_{Heat,j}) \times$ Controls Factor × Wx Factor × New Construction Factor |

Table 4

Table 5

Where:

| | | |
|---|---|---|
| %AC | = | = Percent air conditioning in Vermont existing homes<br>= 3.5% |
| %HeatSource | = | = Percent of existing heating systems using fuel type *j*[10]<br>= 51% for fuel oil<br>= 15% for propane<br>= 12% for Wood/Other<br>= 21% for Natural Gas |
| ΔkW | = | total average winter coincident peak kW increase |
| $\Delta kWh_{Heating>5F}$ | = | = Heating Energy Savings above 5°F |

TRM Characterization:
Variable Speed Mini-Split Heat Pumps (Retrofit) [VII-C-12-a]

| | | |
|---|---|---|
| ΔkWh | = | = total net kWh penalties for heating and cooling (deemed assumption for prescriptive savings, based on size category) |
| ΔMMBtu | = | = MMBtu savings for each fuel type *j* (deemed assumption for prescriptive) |
| $\eta_{Heatj}$ | = | = Heating system efficiency for fuel type *j*[11] (deemed assumption for prescriptive)<br>= 84.2% for fuel oil<br>= 87.4% for propane<br>= 65% for Wood/Other<br>= 88% for Natural Gas |
| 90% | = | = Climatic adjustment to HSPF[5] (deemed assumption for prescriptive savings) |
| Controls Factor | = | = Integrated Controls<br>= 95%[6] if integrated controls are not present<br>= 100% if integrated controls are present |
| $EFLH_{Heating}$ | = | = EquivalentFull Load Hours for heating<br>= 1337.2[4] |
| $FLH_{Cooling}$ | = | = full load cooling hours<br>= 375[7] |
| HSPF | = | = Heating Seasonal Performance Factor for new equipment, Btu/Wh<br>= 8.6 (Single-Head)<br>= 8.2 (Multi-Head) |
| New Construction Factor | = | = Factor to account for better thermal envelope of new construction homes<br>= 99.25%[8] |
| $Q_{Cooling}$ | = | = nominal cooling capacity, Btu/hr |
| $Q_{Heating>5F,i}$ | = | = heating capacity in weather bin *i* at or above 5°F, MMBtu |
| SEER | = | = Seasonal Energy Efficiency Ratio for new equipment, Btu/Wh<br>= 15.6 (Single-Head)<br>= 14.5 (Multi-Head) |
| Wx Factor | = | = Weatherization of existing building<br>= 100%[9] |

## Load Shapes

123a Prescriptive Cold Climate Variable Speed Heat Pump (Retrofit)

| Number | Name | Status | Winter On kWh | Winter Off kWh | Summer On kWh | Summer Off kWh | Winter kW | Summer kW |
|---|---|---|---|---|---|---|---|---|
| 123 | Prescriptive Cold Climate Variable Speed Heat Pump (Retrofit) | Active | 41.6 % | 48.6 % | 5.2 % | 4.6 % | 36.9 % | 5.5 % |

TRM Characterization:
Variable Speed Mini-Split Heat Pumps (Retrofit) [VII-C-12-a]

## Net Savings Factors

**Measures**

| | |
|---|---|
| SHRHPCVH | Cold climate single-head variable speed heat pump |
| SHRHPMHC | Cold climate multi head variable speed heat pump |

**Tracks [Base Track]**

| | |
|---|---|
| 6032UPST [6032EPEP] | Residential Upstream |

## Lifetimes

The expected measure life is assumed to be 15 years.[12]

## Measure Cost

**Table 4 - Single-Head Measure Costs**[13]

| Nominal Equipment Capacity (Btu/hr) | Retrofit Costs |
|---|---|
| 6,000 | $2,057 |
| 9,000 | $2,161 |
| 12,000 | $2,230 |
| 15,000 | $2,339 |
| 18,000 | $2,438 |
| 24,000 | $2,622 |

**Table 5 - Multi-Head Measure Cost**[14]

| Nominal Equipment Capacity (Btu/hr) | Retrofit Cost |
|---|---|
| 18,000 | $1,631 |
| 24,000 | $2,165 |
| 30,000 | $2,066 |
| 36,000 | $3,107 |
| 42,000 | $3,479 |
| 48,000 | $3,881 |

## Savings Summary

**Table 6 - Single Zone SavingsSummary**

| Retrofit | | | | | | | |
|---|---|---|---|---|---|---|---|
| Single Zone | | | | | | | |
| | Nominal Capacity | kWh | kW | ΔMMBtuoil | ΔMMBtupropane | ΔMMBtuwood | ΔMMBtunatural gas |
| | 6,000 | (3,416) | (2.45) | 15.71 | 4.45 | 4.79 | 6.20 |
| | 9,000 | (4,284) | (3.05) | 19.45 | 5.51 | 5.93 | 7.68 |

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TRM Characterization:
Variable Speed Mini-Split Heat Pumps (Retrofit) [VII-C-12-a]

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| With Controls | 12,000 | (4,887) | (3.44) | 21.95 | 6.22 | 6.69 | 8.66 |
| | 15,000 | (5,424) | (3.79) | 24.13 | 6.84 | 7.36 | 9.53 |
| | 18,000 | (5,981) | (4.16) | 26.42 | 7.49 | 8.05 | 10.43 |
| | 24,000 | (6,379) | (4.35) | 27.62 | 7.83 | 8.42 | 10.91 |
| | | | | | | | |
| | | | | | | | |
| | Nominal Capacity | kWh | kW | ΔMMBtuoil | ΔMMBtupropane | ΔMMBtuwood | ΔMMBtunatural gas |
| Without Controls | 6,000 | (3,246) | (2.33) | 14.93 | 4.23 | 4.55 | 5.89 |
| | 9,000 | (4,070) | (2.89) | 18.48 | 5.24 | 5.63 | 7.29 |
| | 12,000 | (4,642) | (3.27) | 20.85 | 5.91 | 6.36 | 8.23 |
| | 15,000 | (5,153) | (3.60) | 22.93 | 6.50 | 6.99 | 9.05 |
| | 18,000 | (5,682) | (3.95) | 25.10 | 7.11 | 7.65 | 9.91 |
| | 24,000 | (6,060) | (4.13) | 26.24 | 7.44 | 8.00 | 10.36 |

**Table 7 - Multi Zone Savings Summary**

| Multi Zone | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Nominal Capacity | kWh | kW | ΔMMBtuoil | ΔMMBtupropane | ΔMMBtuwood | ΔMMBtunatural gas |
| With Controls | 18,000 | (6,106) | (4.23) | 25.94 | 7.35 | 7.91 | 10.24 |
| | 24,000 | (6,570) | (4.46) | 27.47 | 7.79 | 8.38 | 10.85 |
| | 30,000 | (7,166) | (4.79) | 27.62 | 7.83 | 8.42 | 10.91 |
| | 36,000 | (7,801) | (5.16) | 29.41 | 8.33 | 8.97 | 11.61 |
| | 42,000 | (8,192) | (5.34) | 30.93 | 8.77 | 9.43 | 12.21 |
| | 48,000 | (8,338) | (5.33) | 32.01 | 9.07 | 9.76 | 12.64 |
| | | | | | | | |
| | | | | | | | |
| | Nominal Capacity | kWh | kW | ΔMMBtuoil | ΔMMBtupropane | ΔMMBtuwood | ΔMMBtunatural gas |
| Without Controls | 18,000 | (5,801) | (4.02) | 24.65 | 6.99 | 7.51 | 9.73 |
| | 24,000 | (6,242) | (4.24) | 26.10 | 7.40 | 7.96 | 10.30 |
| | 30,000 | (6,808) | (4.56) | 26.24 | 7.44 | 8.00 | 10.36 |
| | 36,000 | (7,411) | (4.90) | 27.94 | 7.92 | 8.52 | 11.03 |

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Variable Speed Mini-Split Heat Pumps (Retrofit) [VII-C-12-a]

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 42,000 | (7,783) | (5.07) | 29.38 | 8.33 | 8.96 | 11.60 |
| | 48,000 | (7,921) | (5.07) | 30.41 | 8.62 | 9.27 | 12.01 |

## Footnotes

[1] 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.)

[2] Refer to Demand tabs on EVT Single Zone CCHP Demand Impact Analysis.xlsx and Multi Zone Demand Impact CCHPSavingsAnalysis Update.xlsx.

[3] Refer to Loadshapes section.

[4] Sum of annual equivalent full load hours in 8760 analysis. Refer to Savings analysis tab in analysis document.

[5] Energy & Resource Solutions. (2014). *Emerging Technology Program Primary Research – Ductless Heat Pumps*. Lexington, MA: NEEP Regional EM&V Forum. Table 1-2. Page 5.

[6] TAG Agreement. Refer to DPS CCHP Tier III- Final Final.pdf

[7] ARI data indicates 500 full load hours for A/C use in Vermont. VEIC experience in other states suggests that ARI estimates for A/C use tend to be overstated. In an effort to compensate for this overstatement, Efficiency Vermont applied a .75 multiplier to the ARI estimate in determining residential A/C hours of use.

[8] See EVT Single Zone CCHPSavingsAnalysis Update.xlsx, New Construction tab, for detailed analysis

[9] TAG Agreement. Refer to DPS CCHP Tier III- Final Final.pdf May be adjusted in the future based on the outcome of evaluation studies investigating the impact of shell weatherization on heat pump savings potential.

[10] Split of primary heating fuels from the VT SF Existing Homes Onsite Report Table 5-1. (NMR Group, Inc., 2013).

[11] 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.)

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

[13] Incremental Cost Study Phase Two Final Report, Navigant Consulting Inc., January 16, 2013. See excerpted data on Measure Costs tab in EVT Single Zone CCHPSavingsAnalysis Update.xlsx and EVT Multi Zone CCHPSavingsAnalysis Update.xlsx.

[14] Full cost based on GREE +Multi Servies, available via online retailers. Refer to Measure Costs tab of EVT Multi Zone CCHPSavingsAnalysis Update.xlsx