Energy Efficient Heating Options: Pilot Projects and Relevant Studies

April 8, 2013

Efficiency Maine is an independent trust dedicated to promoting the efficient and cost-effective use of energy in order to save money for Maine residents and businesses, grow the economy, and create jobs. The Efficiency Maine Trust's energy-saving programs deliver Maine's lowest-cost energy resource by saving electricity and heating fuels through energy efficiency improvements and the increased use of cost-effective alternative energy. The Trust's programs provide a combination of technical assistance, cost-sharing, training, information and quality assurance.

Efficiency Maine Trust, 151 Capitol Street, Suite 1, Augusta, Maine 04330
1-866-37-MAINE
www.efficiencymaine.com

Contents

Introduction 3

Efficiency Maine's Innovation Program and the Bangor Hydro Electric – Maine Public Service Heat Pump Pilot Proposal 3

Pilot guidelines 3

About Heat Pumps 4

Bangor Hydro Electric and Maine Public Service Preliminary Results 7

Program Overview 7

Financial Incentives 8

Preliminary Results 9

Measurement and Verification 11

Efficiency Maine's Low Income Heat Pump Installations 11

Program Objectives 11

Preliminary Activity 12

Related Programs 12

Efficiency Maine's Home Energy Savings Program (PACE and PowerSaver Loans) 12

Central Maine Power's Electric Thermal Storage Heat Pilot 13

Other Incentive Programs 14

Efficiency and Effectiveness of Heating Options 14

Barriers 20

Recommendations 21

Introduction

Recognizing that high heating costs remain one of the greatest economic challenges to Maine homeowners and businesses, the 125th Maine Legislature directed the Efficiency Maine Trust (Efficiency Maine) to report on "efficient heating options."

This document constitutes Efficiency Maine's report to the Legislature pursuant to the directive of LD 1864 Section 10 *An Act To Improve Efficiency Maine Trust Programs To Reduce Heating Costs and Provide Energy Efficient Heating Options for Maine's Consumers*. It describes Efficiency Maine's preliminary results from the ongoing pilot for high-efficiency electric heating, results of past and related programs, market barriers to the increased use of high-efficiency heating systems, and policy recommendations related to financing.

Efficiency Maine's Innovation Program and the Bangor Hydro Electric – Maine Public Service Heat Pump Pilot Proposal

Pilot guidelines

Technological improvements are a cornerstone of energy efficiency, and early investments in technology innovation can pay off handsomely in terms of both energy savings and economic development. Efficiency Maine's Innovation Program provides funding for pilot projects that demonstrate new types of energy efficiency or alternative energy measures. To be eligible for Efficiency Maine's Innovation Program, technologies must be commercially available, show significant potential to provide cost-effective energy savings, [1] but remain in need of further demonstration in the Maine marketplace. It is understood that these energy measures may or may not prove to be cost-effective or popular, or that their performance may not satisfy customers' needs, in the Maine marketplace. One purpose of the Innovation Program is to use smaller pilot projects to make such findings before making larger investments on incentives and program administration.

In order to further catalyze the marketplace in which Maine's homeowners and small businesses will install high-efficiency heating products, Efficiency Maine launched a pilot program seeking to demonstrate innovative space and water heating alternatives. A request for proposals was issued in March 2012. For the purposes of the pilot, Efficiency Maine solicited proposals that would introduce residents to new options in their search for cost-effective heating solutions. Proposals were judged on the research and field testing of the technology, cost-effectiveness compared to other fuel sources, total energy savings or, where supported by documentation, savings of greenhouse gas emissions.

Bangor Hydro Electric Company and Maine Public Service Company's joint proposal on heat pump space heating solutions (the BHE-MPS pilot) was selected due to its potential for cost-effective energy savings and large-scale market adoption. Recent air source heat pump pilots in the Pacific Northwest, other New England states and the Eastern Canadian Provinces have demonstrated significant heat pump operating efficiencies and energy cost savings. The BHE-MPS pilot project proposed incenting

[1] In cases where Efficiency Maine uses funds from the Regional Greenhouse Gas Initiative to fund the Innovation Program, this criteria may be expanded to encourage technologies that show significant potential to reduce greenhouse gases, as provided by Maine statute at Title 35-A, Section 10109.

residential and small business customers to install ductless air-source heat pumps for supplemental space heating, an application which has recently become effective in cold-weather settings but has not penetrated the Maine home heating market.

About Heat Pumps

Heat pump technology works by extracting energy from the outside air and delivering it to interior spaces in the winter; in the summer, heat pumps extract heat from interior spaces and expel it outdoors.[2] Air-source heat pumps have an outdoor unit connected to one or more indoor units via small, copper refrigerant lines. Indoor units deliver heat (or cooling) to one room but the outdoor unit can be sized to serve more than one indoor unit. The heat transfer process relies on the refrigeration cycle to move heat from one side of the system to the other. This technology is already at work in Maine homes in refrigerators (heat is expelled from the interior of the refrigerator and released into the kitchen) and air conditioning units (heat is expelled from the interior and released outside as the refrigerant in the coil is compressed).

Figure 1: Indoor Component of a Ductless Air-Source Heat Pump Courtesy Mitsubishi Electric Heating and Cooling

Whole-house heat pumps have been used for heating and cooling in warmer parts of the country for decades. But cold climate heat pumps and smaller, ductless room unit heat pumps are a more recent technology. Experience with an earlier generation of air-source heat pumps designed for cold climates was poor, and an important function of the BHE-MPS pilot project is to collect more data about performance of the newly improved technology, to confirm that the units function and save energy as advertised, and to increase familiarity of customers and contractors with the new technology. Room unit ductless heat pumps (or "mini-split" heat pumps) distribute heat and cooling directly to the spaces where they are installed, rather than through a ducted system. By using refrigerant lines instead of ducts, new units are easily retrofitted into existing homes and minimize distribution losses due to air leaks. They may be installed in living spaces with high use (living rooms and kitchens) in order to offset as much of the primary heating system as possible, or in spaces which are not well-served by the primary distribution system like additions. Room-scale units are also sized to control temperature and humidity better than larger, centralized systems.

Heat pumps can significantly improve home comfort because they can be located where heat is needed most, but they also can reduce home energy costs because of their high efficiencies and the current price advantage of electricity over certain heating fuels. New refrigerants, variable speed inverters, efficient compressors, the elimination of ductwork, and advanced controls have significantly improved efficiencies in air source heat pump technologies over the past decade. Traditional air source heat pumps have never been widely adopted for heating Maine homes due to their low heat output when outdoor temperatures drop below 20° Fahrenheit. However newer ductless heat pumps can deliver

[2] For more information on heat pumps, see Efficiency Maine's "Heat Pumps" http://www.efficiencymaine.com/renewable-energy/heat-pumps.

heat even when the outside temperature is -15° Fahrenheit, a manufacturer's claim that has been substantiated by laboratory and field evaluations.[3] Because Maine's climate requires heating systems to meet the demands of sub-zero days, and also because many homes have functioning central heating systems that are still working, ductless heat pumps are most frequently installed as supplemental heating systems. The original central heating system (the boiler or furnace) remains in place to meet heating demands on the coldest days and in rooms not directly served by the air source heat pump. The BHE-MPS proposal included a significant evaluation component. This evaluation will address the fact that past heat pump technologies did not achieve high operating efficiencies in cold climates, and that no published data exists about the operating efficiencies of ductless heat pumps in Maine. The pilot proposed to better measure and estimate energy savings associated with supplemental heat pump installations in order to better inform Maine consumers and policy makers about the technology's possibilities. Preliminary data suggests that auxiliary heat pumps could reduce the average Maine homeowner's energy costs by 50%.[4]

Efficiency Maine modeling suggests that heat pumps can offset a significant portion of the primary heat system load if they continue to perform as advertised. Assuming that a typical Maine household consumes 900 gallons of heating oil per year for heating and hot water, the energy savings through a 12,000 BTU/hr heat pump that performs according to manufacturer's claims should total $1,676 per year at current energy prices, with an installation payback of 1.7 to 2.3 years after rebate:

Table 1: Heat Pump Cost Illustration

Heat Pump Cost Illustration -- Average Maine Home		
System Type	**One Zone System**	**Two Zone System**
Upfront Purchase and Installation Cost of Heat Pump[5]	$3,500	$4,500
BHE-MPS Rebate	($600)	($600)
Capital Expense Subtotal	**$2,900**	**$3,900**
Original Annual Heating Costs (assuming 900 gal/year)[6]	$3,321	$3,321
Post-Installation Annual Heating Costs (Oil and Electricity Combined)[7]	$1,645	$1,645
Annual Cost Savings Subtotal	**($1,676)**	**($1,676)**
Simple Payback Before Rebate	2.1 years	2.7 years
Simple Payback After Rebate	**1.7 years**	**2.3 years**

[3] Jon Winkler, *Laboratory Test Report for Fujitsu 12RLS and Mitsubishi FE12NA Mini-Split Heat Pumps* (Oak Ridge, TN: U.S. Department of Energy, 2011).
[4] Bangor Hydro Electric Company, "Request for Proposals for Energy Efficiency Innovation: Round III" (proposal presented to the Efficiency Maine Trust, April 2012).
[5] Modeling assumes a heat pump with a 12,000 BTU/hr capacity.
[6] Heating Oil Fuel Costs calculated at $3.69/gallon Courtesy Governor's Energy Office, 25 March 2013.
[7] Heating Oil Fuel Cost calculated at $3.69/gallon and electricity at .15 kWh.

Heat pump installation costs are lowest when a significant portion of the primary heating load can be displaced from one heat pump indoor unit (called a "head") in a central location. If a home has multiple heating zones, or heat cannot be easily circulated from a single head, multiple heat pump heads may be installed. In the example above, the upfront installation costs are higher for multiple heads while energy savings remain the same.

As the figures below illustrate, Maine households with higher and lower oil consumption can also achieve significant energy and cost savings with heat pump installations because the heat pumps have such high on-site efficiency and the electricity price per unit compares favorably to the cost of home heating oil.[8]

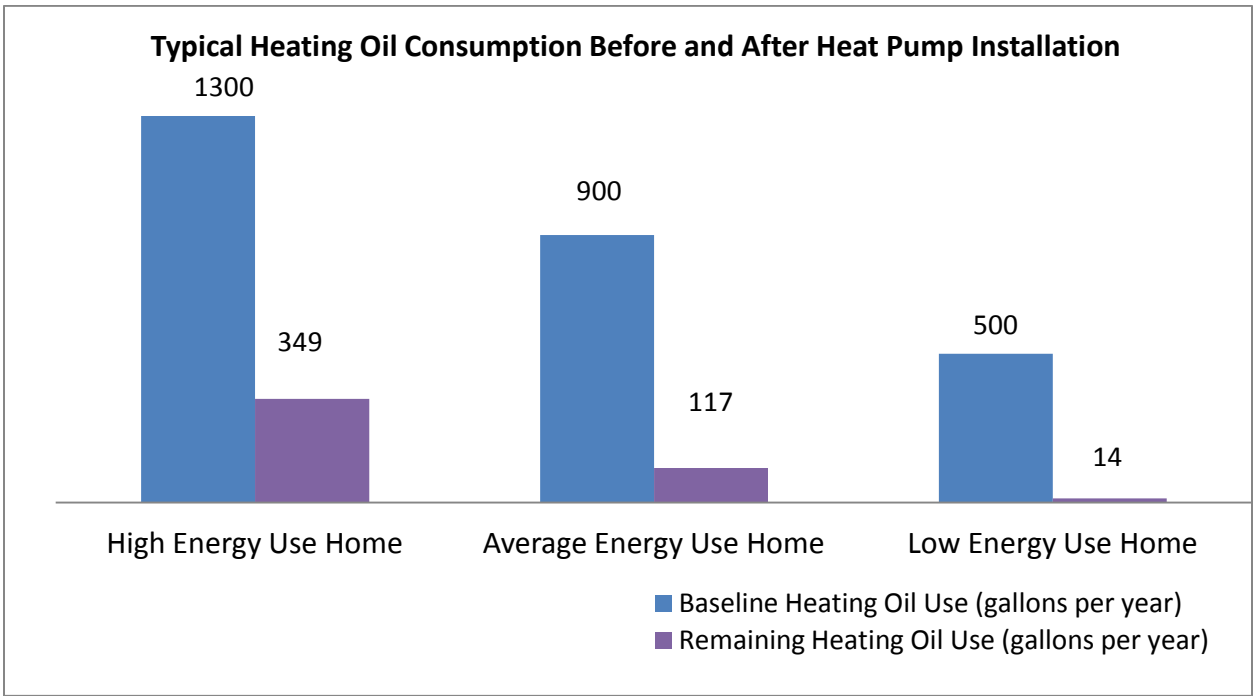

Figure 2: Typical Heating Oil Consumption Before and After Heat Pump Installation

[8] Calculations assume an electricity cost of $0.15 per kWh and home heating oil cost of $3.69, and an oil boiler AFUE of 78% and a heat pump of 12 HSPF. The baseline heating degree day location is Bangor, Maine and the thermostat set point is 65°F. This is true despite the significant energy losses at the source of the electricity generator and across the transmission and distribution lines.

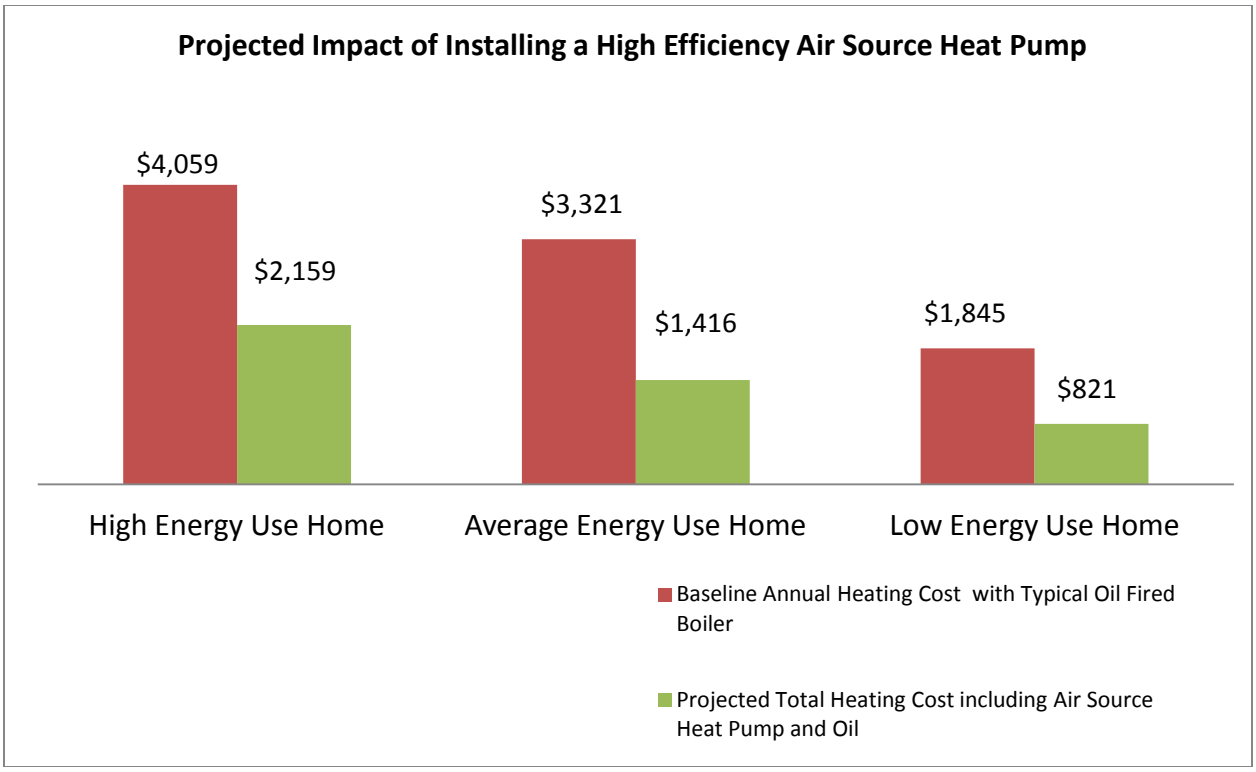

Figure 3: Projected Impact of Installing a High Efficiency Air Source Heat Pump

Bangor Hydro Electric and Maine Public Service Preliminary Results

Program Overview

The heat pump pilot is designed to encourage residential and small business customers to install ductless air source heat pumps as supplemental space heaters and to demonstrate their performance in terms of effectiveness, energy savings, cost, and ease of use. Bangor Hydro and Maine Public Service territories span 9,350 square miles and roughly 153,000 customers in northern and eastern Maine. Natural gas distribution systems are limited to the Bangor area, and most customers heat with #2 distillate heating oil. The utilities convened an Advisory Panel to inform the pilot program's development. This panel concluded that participating homes should represent diverse primary heating fuel sources including electricity, oil, kerosene and propane so that cost savings could be evaluated in relationship to multiple fuel types and heating delivery technologies.

The pilot is designed to offer a $600 rebate to qualifying homeowners or business owners (only owner-occupied residential properties were eligible for the rebate). Rebates are only available to building owners working with installers that are registered with Efficiency Maine. To be registered with Efficiency Maine, installers must have insurance, commit to a code of conduct, be trained in installation and hold an EPA refrigerant handling certificate. Under the pilot, not all heat pump models are eligible for a

rebate. Heat pumps technologies qualifying for rebates are not dictated by brand but are required to be ENERGY STAR certified and have a Heating Seasonal Performance Factor (HSPF) of at least 10.[9] A number of air source heat pumps meet these ENERGY STAR criteria. Those installed as part of the pilot include heat pumps manufactured by Daikin, Fujitsu, and Mitsubishi. Because the ductless heat pump technology had not been widely adopted in Maine, and because the energy efficiency standards by which heat pumps are rated (HSPF and Coefficient of Performance) are unfamiliar to some Maine consumers, education about heat pump technology are a primary component of the program.

At the launch of the pilot there were a number of qualified heat pump installers in Maine, and Efficiency Maine and BHE-MPS worked with Mitsubishi and Fujitsu to offer free introductory trainings to interested energy advisors and heating, ventilation, and air conditioning professionals. These sessions were well attended and as a result of these workshops and increased interest due to the pilot, the heat pump installer community has grown to 400 trained installers.

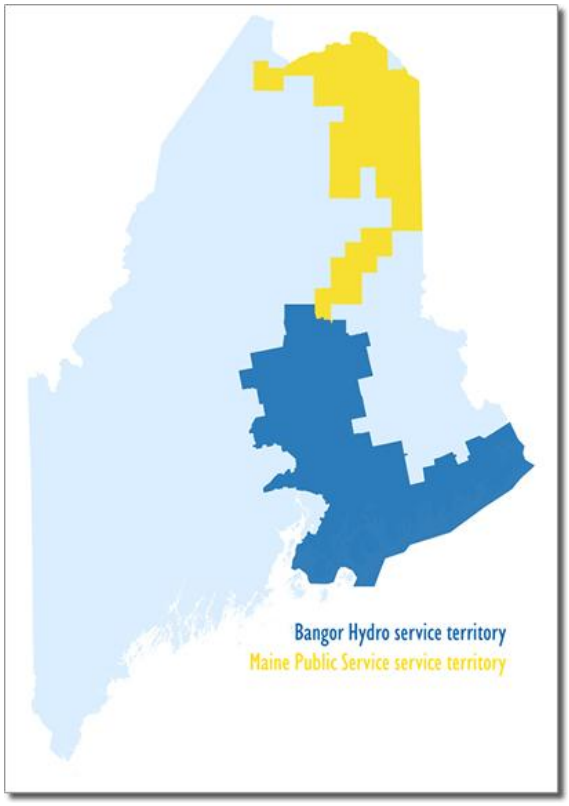

Figure 4: Map of Bangor Hydro and Maine Public Service Utility Territories Courtesy of Bangor Hydro.

Financial Incentives

To encourage homeowners to become early adopters of the heat pump technology, the utilities, in cooperation with Efficiency Maine and the Advisory Panel, agreed that a cash rebate would need to be in the range of ten- to twenty-percent of the installation costs. To start the pilot, they decided a $600 rebate would be appropriate given that the average cost of a ductless heat pump installation at the time of the pilot launch was $3,500. The initial pilot grant from Efficiency Maine totaled $150,000 which was matched by an investment of $150,000 by BHE and MPS. This investment guaranteed enough funds for a total of 330 rebates, plus costs to administer and market the program. An additional round of funding through the BHE-MPS pilot and Efficiency Maine has extended this to a total of 560 rebates, which should provide a sufficient sample size to evaluate cost-effectiveness, consumer interest and scalability.

On a parallel track with the pilot program design, BHE and MPS filed a request with the Maine Public Utilities Commission (PUC) pursuant to LD 1864, Section 11. This provision, enacted together with the requirement for the instant report, authorized transmission and distribution utilities to implement and advertise electric heating pilot programs on the condition that they seek and secure approval from the PUC.

[9] The Heating Seasonal Performance Factor measures energy efficiency over one heating season; it represents the total heating output of a heat pump during the normal heating season (in BTUs) as compared to the total electricity consumed (in watt-hours) during the same period.

In addition to offering the rebates, the BHE-MPS filing proposed to provide on-bill financing for utility customers installing heat pumps. It also requested a PUC review of program design to ensure that it was reasonably designed and consistent with the legislation. The BHE-MPS proposal was approved by the PUC on September 19, 2012.[10]

The on-bill financing provision of the program is an important innovation that is being piloted. The interest rate on the loan is 7.75%. To ensure that energy savings from a new heat pump will be substantial enough to cover financing and loan costs, participating households are pre-screened before acceptance into the pilot. If their existing (pre-pilot participation) spending on heating is at least $1,400 per year on oil, propane, kerosene or electric baseboard heat, they are eligible to participate. Annual heating costs of $1,400 per year will guarantee that, even after paying the 7.75% interest rate, the initial cost of the heat pump installation should be recouped in five years or less.

Preliminary Results

The pilot program was launched on October 15, 2012 shortly after completion of the docket at the PUC. The pilot achieved 330 reservations by February 19, 2013. BHE and MPS financed an additional 100 rebates to meet demand and most were reserved by March 15, 2013. At the March 27, 2013 meeting of its Board of Trustees, Efficiency Maine approved extending the pilot program with additional funds projected to last through June, 2013. The term of the pilot is scheduled to conclude October 30, 2013. By that time, BHE and MPS expect 560 units to have been installed. BHE and MPS will report to Efficiency Maine at the conclusion of the pilot on the performance of the installed units, customer satisfaction and program administration.[11]

A third-party evaluation team – Energy Market Innovations (EMI) – has been secured by BHE and MPS to evaluate the pilot program. The evaluation is expected to include market research, customer satisfaction and energy performance of installed units. Preliminary market characterization results provided by the heat pump pilot evaluation team, EMI, indicate that heat pump sales during the pilot are five- to seven-times greater than sales just two years ago.[12] While this significant increase suggests that the pilot rebates and marketing have been effective, it also reflects the fact that there were essentially no sales of heat pumps in the residential market two years ago. As a total percentage of the heating market in Maine the market penetration of heat pumps is barely perceptible.

Moreover, the technology still suffers from a lack of awareness on the part of consumers. The pilot program's evaluation team recently conducted two focus groups as well as telephone surveys of residential and small commercial customers in BHE and MPS territories. This survey found that awareness of heat pumps is low with respondents reporting:

- 31% are not aware of the technology;
- 18% are aware but not familiar;
- 40% are somewhat familiar; and
- 11% are very familiar.

[10] Order Approving Stipulation, Maine PUC Docket No. 2012-00343, September 19, 2012.
[11] BHE and MPS are also directed to deliver a report on the pilot project to the Legislature by November 15, 2013, pursuant to the provisions of LD1864, Section 11.
[12] Ellen Steiner, Jeremy Kraft, Danny Molvik, Chelsey Erway, Ellie Smith, "Bangor Hydro Heat Pump Pilot Program Market Characterization Results and Recommendations" (paper presented at the quarterly meeting of the Bangor Hydro Pilot Advisory Panel, Augusta, Maine, February 2013), p. 6.

The surveys and focus groups revealed that most Mainers misunderstand how heat pumps work and their effectiveness in cold climates. Not surprisingly, the surveys revealed that the message respondents found most compelling for heat pumps is that they could reduce total energy costs. The most common way customers were made aware of the pilot was through a bill insert, and most made use of the Efficiency Maine website for more information about heat pumps. Given the generally low awareness of heat pump technologies, the preliminary evaluation analysis suggests that an expanded heat pump program would require significant efforts in homeowner education about the technology and would benefit from incentives.

Participants who were interviewed indicated that the upfront cost of the installation is the primary barrier for adopting the technology. When asked to identify barriers to buying a heat pump:

- 27% percent cited the upfront cost;
- 12% percent cited belief that the technology did not work well in cold climates;
- 7% percent cited lack of available information about heat pumps; and
- 4% percent cited belief that the cost savings were insufficient to justify the investment.[13]

EMI also interviewed home heating professionals as part of its survey. All of the contractors interviewed were aware of the technology and recommend heat pumps to their customers. A sufficient number of heating, ventilation and air conditioning and electrical contractors have received the requisite training for heat pump installations to meet current demand.

Energy saving results and unit performance will be better understood after the units have been operating for a longer period of time and the evaluation team, BHE, MPS and Efficiency Maine have had more time to analyze the data and interview program participants. But at this preliminary stage of the pilot, interviews with participating homeowners indicate strong customer satisfaction, with homeowners citing reduced energy costs and greater comfort at home as the primary benefits. Installed units are reported to be quiet and deliver heat to the rooms where heat is needed most.

Efficiency Maine frequently introduces new technologies first through the pilot program so as to gain meaningful energy performance data before launching a state-wide initiative. The BHE-MPS pilot data will enable Efficiency Maine to quantify the electricity load added and primary fuel consumption reduced through the average installation, as well as the efficiency gains in summer cooling compared to room air conditioner units.

Installed performance is expected to be comparable to recent studies conducted by the National Renewable Energy Laboratory on heat pump efficiencies. The results of their experiments on the effect of outdoor temperature on heat pump efficiency indicate that heat pump capacity decreases with cooler outdoor temperatures but that the efficiency still exceeds conventional combustion or electric resistance systems. The study also revealed that performance efficiency is not negatively affected by fan speed. As demonstrated in Figure 5, the NREL study also established that experimental test data aligned with manufacturer reported values for the models listed.

[13] Ellen Steiner et al, 11.

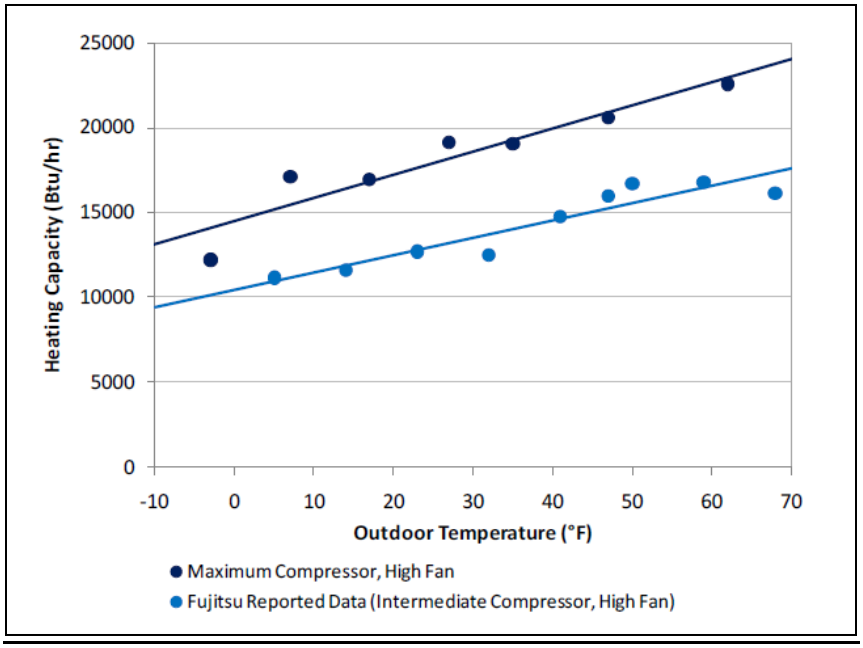

Figure 5: Fujitsu 12RLS maximum steady-state heating capacity compared to manufacturer-reported data. Source: Jon Winkler, Laboratory Test Report for Fujitsu 12RLS and Mitsubishi FE12NA Mini-Split Heat Pumps (Oak Ridge, TN: U.S. Department of Energy, 2011).

Measurement and Verification

The pilot's measurement of installed energy savings will be based on the real-time tracking of 64 units installed in homes and business across the BHE and MPS territories with eMonitor software. The whole building's energy usage will be compared before and after the installation, normalized by weather data, to determine total energy savings attributable to the heat pump. Comparing whole building energy usage is the most appropriate way to measure the impact of auxiliary heat sources; all pilot installations are supplementing rather than replacing primary heating systems. EMI will report to BHE and MPS and subsequently to Efficiency Maine by October 30, 2013.

Efficiency Maine's Low Income Heat Pump Installations

Program Objectives

Among Efficiency Maine's portfolio of programs is its program to increase the efficiency of electricity use in low income eligible homes. Currently, the focus of this program is on saving energy in multi-family homes that primarily use electricity for heat. This initiative began in January of 2012, when Efficiency Maine developed a data set of nearly 10,000 eligible, electrically heated residential units. These units have been targeted for air sealing, insulation and heating system upgrades where appropriate.

Preliminary Activity

Efficiency Maine's analysis of the data set revealed that there are more multi-family electrically-heated homes eligible for efficiency upgrades than single-family homes. As such, program efforts in Fiscal Year (FY) 2012 and FY2013 have focused on multi-unit properties. These properties are prioritized by their energy intensity and then given an energy audit. After the owner's permission is secured, the energy upgrades recommended in the energy audit report are put out for bid and completion by independent contractors. All installations are inspected by energy auditors as part of the quality-control process. Energy modeling of these building has projected that supplementing electric resistance baseboard heat with ductless heat pumps results in significant energy savings. These savings are increased where the heat pumps also displace inefficient room air conditioning units, which has been found to exist in the majority of units thus far served by the program.

Figure 6: Multifamily heat pump installation.

To date, 301 heat pumps have been installed in low-income households heated with electricity since the program's launch. Preliminary analysis indicates that these installations save the average household 23% in energy use, or about $345 a year. The lifetime energy savings from these installations is projected to average 45,880 kWh per heat pump. This data does not reflect a full-season of performance results, with full heating and cooling seasonal efficiencies.

An evaluation of the low-income weatherization program is in the planning stages. Program results and verified energy savings data will be published in 2014, but this data will cover only a short time horizon of program implementation since the program began mid-year in 2012. This evaluation is expected to demonstrate that ductless heat pumps are more efficient and cost-effective than electric resistance heating technologies (as has been demonstrated elsewhere in the country) and that additional energy savings can be expected from the heat pumps' displacement of window air conditioning units.

Related Programs

In addition to the BHE-MPS pilot and Efficiency Maine's Low Income Program, other projects can shed light on the cost-effectiveness of alternative heating options. These include Efficiency Maine's Home Energy Savings Program, Central Maine Power's Electric Thermal Storage Heat Pilot and other utility incentive programs.

Efficiency Maine's Home Energy Savings Program (PACE and PowerSaver Loans)

The Home Energy Savings Program was designed to raise awareness about the benefits of home weatherization and to encourage homeowners to make efficiency upgrades. This started as a rebate program in January 2010 in which more than 3,200 Maine homes completed energy upgrades. It transitioned to a loan program (referred to as PACE and PowerSaver loans) in 2011. The program now

offers low-interest financing for customers who complete an energy audit and achieve a minimum 20% energy savings through home energy improvements.

To date, 400 home energy retrofit projects have been financed with PACE or PowerSaver loans from Efficiency Maine. Twenty of these projects included the installation of ductless air source heat pumps. The loan program has also financed the installation of:

- 118 ENERGY STAR rated natural gas heating systems,
- 43 ENERGY STAR rated oil-fired boilers and furnaces, and
- 4 pellet burning boilers and stoves.

Nearly all projects involve varying levels of air sealing and insulation in attics, walls, and basements reducing heating load regardless of type of heating fuel used. The average loan value for program participants is $12,838; program participants' projected energy savings average $1,400 a year from reduced heating fuels.

Central Maine Power's Electric Thermal Storage Heat Pilot

In the fall of 2012, Central Maine Power (CMP) launched a pilot program to encourage Maine homeowners and small businesses to install electric thermal storage heating systems. Electric thermal storage units contain high-density ceramic bricks that store heat. These bricks are heated by electric resistance coils and then release heat throughout the day. Under normal conditions, these systems will be heated (or "charged") at night, during off-peak hours, but if the desired inside temperature should fall during very cold periods, the systems can also be charged during the day. Electric thermal storage units can be installed as a primary heat source, with ducted or hydronic distribution systems, or as room-size units for supplemental heat. Under the pilot, CMP has been offering a $1,500 rebate for the installation of a room unit heater, and a $4,500 rebate on whole-house central heating systems. Central Maine Power estimates that room units cost between $2,700 and $3,900 to install; whole-house systems average $13,000.[14]

The installations can reduce household energy costs by displacing the need to purchase more expensive heating fuels (such as oil) and by taking advantage of lower off-peak electric rates. Overnight time-of-use rates, where available from the local utility, are generally the cheapest available. Electric thermal storage units can use this lower-cost energy to store heat for later use which, in many Maine homes, means displacing heating oil consumption.

CMP's pilot program is limited to 500 units or $900,000 of incentive funds. According to a recent interview with the Program Manager for CMP's Electric Thermal Storage Pilot, a total of eight units had received incentives as of March 18, 2013. Four of the projects used whole-house systems and the other four used room unit heaters.[15]

[14] "ETS Estimated Savings Spreadsheet," accessed March 8, 2013, http://www.cmpco.com/ETS/faq.html#ETS_Cost.
[15] James McCarthy, "Rebate Programs Inspire New Look at Electric Heat," *MaineBiz*, 18 February 2013.

Other Incentive Programs

Efficiency Maine has been monitoring the inclusion of air source heat pumps in utility and efficiency programs in other cold climate states. A number of programs offer incentives on heat pump installation, including:

- Connecticut Energy Efficiency Fund -- $250 rebate
- New Jersey Clean Energy Program -- $500 rebate
- Massachusetts Cool Smart Program -- $150-$500 rebate
- Columbia River People's Utility District, Oregon -- $1,000 rebate

Efficiency Maine is closely following how these programs design and implement incentive programs and their saving assumptions and energy efficiency calculations.

Recently the Rocky Mountain Institute published a report on heat pumps for policy-makers to provide context for adding heat pump incentive programs. The study found that entirely replacing oil heating with heat pumps would save the Northeast (New England, New York, New Jersey, and Pennsylvania) $5.5-6.0 billion annually, a 40% savings on regional heating costs.[16] The study recommended that Northeastern states consider providing incentives for heat pumps, as well as on-bill financing and third-party ownership to speed the adoption of heat pump technologies across the region.[17]

Efficiency and Effectiveness of Heating Options

High-efficiency alternative heating systems are challenging to compare to conventional heating systems because they aren't measured by steady-state efficiency or AFUE like the conventional combustion appliances they are replacing or supplementing. In order to compare systems, it is most useful to project annual energy savings based on the fuel usage of the typical Maine home. For the purpose of this comparison, Table 2 assumes the average combustion efficiency of primary heating systems in Maine (78% AFUE) and annual fuel consumption of 900 oil gallons.[18] The table's listing of average cost for installation and the projected annual savings are based on Efficiency Maine data from PACE and PowerSaver-funded projects, interviews with Maine vendors of heating equipment and fuels, and available literature.

Table 2 treats each energy option as a stand-alone measure; it does not depict the energy savings and payback costs of bundling together energy retrofit projects. Therefore it would not necessarily be accurate to add the savings projections from multiple measures. For example, air sealing and insulation installed prior to a heating system replacement allows for the installation of a smaller heating system which would reduce system replacement costs. Similarly, air sealing prior to installing a ductless heat pump can ensure that more of the heat provided by the system stays in the house, and displaces more of the load served by the primary heat system.

[16] Ryan Matley, "Heat Pumps: An alternative to oil heat for the Northeast – input for planners and policy-makers" (Snowmass, CO: Rocky Mountain Institute, 2013): 11.
[17] Matley, 16-17.
[18] Maine Governor's Energy Office, "Space Heating Fuel Comparison Calculator," accessed March 28, 2013, http://www.maine.gov/energy/fuel_prices/heating-calculator.php

Table 2: Efficiency and Cost-Savings of Typical Energy Efficiency Projects (Displacing Oil Heat)

Residential Energy Project Type	System Efficiency	Average Total Installed Cost	Projected Average Annual Savings[19]	Payback Period on Total Cost (Years)[20]
Basic Air Sealing	N/A	$600	$300	2
Air Source Heat Pump (Providing 50% of heating)	COP 3.0[21]	$3,500	$1,676	2.1
Burner Conversion Only (Oil to Natural Gas)	78% AFUE[22]	$2,500	$1,121	2.2
Wood Stove (Providing 50% of heating)	75% AFUE	$3,300	$1,170	2.8
Natural Gas Direct Vent Space Heater (Providing 50% of heating)	80% AFUE	$3,500	$802	4.4
Wood Pellet Stove (Providing 50% of heating)	78% AFUE	$4,000	$878	4.6
Insulation Project – 25% Energy Savings	N/A	$4,000	$750	5.3
Insulation Project – 50% Energy Savings	N/A	$10,000	$1,662	6.0
Furnace Replacement (standard oil to ENERGY STAR Natural Gas)	95% AFUE	$8,500	$1,369	6.2
Boiler Replacement (standard oil to ENERGY STAR natural gas)	85% AFUE	$10,000	$1,600	7.7
Solar PV (Running Ductless Air Source Heat Pump)	COP 3.0	$29,500	$2,786	10.6
Solar Hot Water (Providing 70% of water heating)	COP 3.4	$12,000	$1,080	11.1
Electric Thermal Storage (whole house system)[23]	COP 1.0	$13,000	$1,000	13
Geothermal Heat Pump (closed-loop system)	COP 3.6	$30,000	$2,260	13.3
Furnace Replacement (standard oil to ENERGY STAR oil)	88% AFUE	$8,500	$385	22.1
Boiler Replacement (standard oil to ENERGY STAR oil)	88% AFUE	$10,000	$370	27

Note: assumptions in this table regarding efficiency and installed costs are for illustration purposes only, based on units commonly sold in Maine at the time this report was written. Actual efficiencies and prices will vary depending on location, size of system, and application, and will change over time.

[19] Based on the average Maine home where 100% of the heating load is met by a 78% efficiency oil-fired boiler with an average annual consumption of 900 gallons of distillate oil. Fuel calculations based on Governor's Energy Office data dated March 26, 2013 (Natural Gas at $1.75/therm; Home Heating Oil $3.69/gallon; Electricity $0.15/kWh; Wood Pellets $244/ton; Cord Wood $210/ton).

[20] These values do not reflect any tax credits and/or other financial incentives that may be available to reduce the total installed cost or operating costs.

[21] COP or Coefficient of Performance is the ratio of heat or cooling provided per unit of electricity consumed. For example, the heat pump delivers three kWh of heat for every one kWh it consumes.

[22] AFUE is the ratio of annual heat output of the combustion appliance compared to the total annual energy consumed. An AFUE of 78% means that 78% of the energy in the fuel is converted to useful heat.

[23] Electric Thermal Storage installation cost and savings estimated with Central Maine Power's Estimated Savings Tool. Accessed 10 March 2013, http://www.cmpco.com/ETS/default.html.

The projects described above vary in terms of energy efficiency, capital expense and payback at current energy prices. Homeowner choice of alternative heating technologies is not dictated solely by payback but also by access to certain heating fuels, feasibility, ease of use, existing heat distribution system in the home, and environmental considerations. Not every home is a candidate for every technology. A brief discussion of these technologies highlights the possibilities and limitations of these alternatives.

Air Sealing and Insulation:

As illustrated in the table above, air sealing is one of the most cost-effective energy saving options for Maine homeowners. Air sealing measures range from installing spray foam insulation along rim joists to sealing plumbing chases between floors to weather-stripping attic hatches. A significant portion of Maine's home heating costs can be attributed to heat loss through air leakage, so air sealing investments are quickly recouped. While air sealing activities must be carefully undertaken so as to promote healthy indoor air quality, most Maine homes can be air sealed without making the home "too tight." In addition, air sealing before insulating allows insulation to function optimally, and Maine homeowners can save between 25% and 50% of their home heating costs when both measures are installed simultaneously.

Insulating and air sealing have additional benefits including fewer drafts, reduced noise, and reduced summer cooling costs. The project installation costs, and annual energy costs, can be reduced further still if air sealing and insulation projects to the building envelope are performed in conjunction with the heating system upgrades. In addition to saving energy, these building envelope improvements may allow the homeowner to downsize the capacity of the new central or supplemental heating system, reducing capital costs. A more efficient building envelope also reduces the run-time on the new heating system, as well as any existing central system that is left in place, extending the useful life of those systems.

Efficiency Maine currently funds a pilot program for air sealing; initial funding for this pilot was allocated by Efficiency Maine from the federal Better Buildings Grant from the U.S. Department of Energy. This program encourages homeowners across the state to engage energy auditors, develop a plan for making energy upgrades to their homes, and complete basic air sealing to their homes at the same time the audit is performed. Homeowners undertaking this minimum amount of air sealing are saving about $300 annually in home heating costs, and significantly greater savings if additional air sealing and insulation is included in the work scope. Air sealing and insulation may be financed with the PACE and Power Saver loans.

Air Source Heat Pump:

Air source heat pump technologies have been described at length above. As illustrated in the cost table, offsetting home heating oil with an electric heat pump has a short payback at current energy prices. Beyond the BHE-MPS pilot, Efficiency Maine has underwritten the cost of installing air source heat pumps in low-income households heated with electric resistance heat. Heat pump installations may also be financed with PACE and PowerSaver loans.

Oil to Natural Gas:

For those customers located near a natural gas line, a burner conversion is an opportunity to achieve cost savings simply from switching from a what is currently a higher price heating fuel (oil) to lower price

fuel (natural gas) without upgrading the efficiency of the operating system or removing the existing distribution system in the home. Burner conversions are not appropriate for every existing system, and newer oil boilers and furnaces are better candidates for burner conversions than older models.

Additional reductions and stability in annual household energy costs over the long term can be achieved when an existing heating system is replaced or supplemented with a higher efficiency (e.g., ENERGY STAR) model. A central furnace or boiler's efficiency is measured by annual fuel utilization efficiency (AFUE). In Table 2, we assume a 78% AFUE oil boiler is replaced with an 85% AFUE gas boiler and a 78% oil furnace is replaced with a 95% AFUE gas furnace, and that efficiency difference results in significantly reduced fuel consumption over the life of the new system (15 to 30 years). Many of these higher efficiency systems condense flue gases to achieve a higher combustion efficiency and will require changes to the venting system.

Many homeowners claiming rebates through Efficiency Maine's Replacement Heating Equipment program (2010-2011) replaced older oil boilers with high-efficiency gas appliances. High-efficiency gas appliances were also part of many Home Energy Saving Program rebate projects during that same period. Although the funding (from the American Recovery and Reinvestment Act (ARRA)) that enabled Efficiency Maine to offer the cash incentives of those two programs was exhausted in 2011, homeowners may still finance high-efficiency gas appliances with PACE and Power Saver loans. To date, 118 homeowners have used these loans to finance the installation of ENERGY STAR natural gas heating appliances.

Wood and Wood Pellet Stoves:

Wood stoves are a promising option due to the fuel's affordability over other fuels and the fact that Maine has significant, locally produced wood fuel resources. Wood stove inefficiency stems primarily from over-sized systems that are burned at a low-smolder to prevent over-heating. High-efficiency, smaller-scale systems can be better sized to meet heating demand without the fuel inefficiency that stems from low-smolder burning. Additionally, advances in stove design have dramatically reduced particulate emissions of wood burning while increasing output efficiency.

Similarly, wood pellet stoves are being installed as supplemental heat sources and as primary, central heating systems.[24] Wood pellet stoves and boilers boast higher combustion and heating efficiencies than ordinary wood stoves and produce fewer particulate emissions. In many cases, wood pellet stoves can be installed with a direct vent to the exterior, allowing flexible installation options. Like air source heat pumps, pellet stoves can be located where heat is needed most or in a central location, and they are most frequently installed as supplemental heating systems. Indoor temperatures are more easily controlled with pellet stoves than with conventional wood stoves because pellet stoves are better able to modulate the rate at which fuel is fed to the burner. Pellet stoves require electricity to run fans, controls and the feeder. According to the U.S. Department of Energy, this need adds about 100kWh to the average electricity bill per month of operation.[25]

[24] For more information on biomass heating, go to http://www.efficiencymaine.com/renewable-energy/biomass-heating.
[25] U.S. Department of Energy, "Wood and Pellet Heating" accessed 28 March 2013 http://energy.gov/energysaver/articles/wood-and-pellet-heating

Efficiency Maine does not currently offer rebates for high-efficiency biomass systems, however, these units are eligible for the PACE and PowerSaver loans that Efficiency Maine has offered since 2011.

Natural Gas Direct Vent Space Heater:

Natural gas or propane fueled direct-vent space heaters can also provide zone heating solutions. Energy efficient models can modulate their output and blower speed to meet the call for heat, and like wood pellet stoves, can be installed where safe venting to the exterior is possible. Direct-vent space heaters have been a fixture in Maine homes for many years but recent technology advances in the industry mean that new models can achieve combustion efficiencies in excess of 80% AFUE. Maine homeowners with access to propane or natural gas can add direct-vent space heaters as space heating solutions, although the cost savings are greater for those run from natural gas given its currently lower price. Natural gas direct vent space heaters have been installed in Maine homes through the Efficiency Maine's Home Energy Savings Program rebates, as well as through its PACE and Power Saver loans.

Solar Photovoltaic and Hot Water:

Solar systems can make hot water directly, or can make electricity that can be used to heat hot water or power a ductless air source heat pump. Both technology solutions can displace significant amounts of home heating fuel use. Solar photovoltaic (PV) arrays can be sized to meet the increased electric load required to run an air source heat pump. Although the initial cost of installation of the heat pump is significantly increased with the addition of the PV panel array, the annual savings are significant since ongoing heating costs are then limited to domestic hot water and auxiliary heat. This configuration has significant greenhouse gas savings and scores well in source energy analyses since the efficiency penalty of transmission and distribution losses is mitigated with on-site energy generation.

Solar hot water systems are also a potential solution for homeowners with significant, year-round domestic hot water needs. Hot water consumption accounts for about one-third of residential fuel consumption. For homeowners using a combined hot water and heating system, a solar hot water system can meet all of the domestic hot water needs in shoulder and summer months, allowing homeowners to turn off the primary heat system during that period. This can result in fuel savings from hot water production, as well as reduced system cycling and jacket losses.
Efficiency Maine offers a $500 rebate per 1,000 kW of system capacity. These rebates have been funded through a combination of ARRA funds and a charge collected by utilities. The ARRA funds for this program are fully spent and the authority creating the utility charge has "sunset." Efficiency Maine expects to exhaust all funds for this program by June, 2013. Homeowners may still finance solar thermal and solar photovoltaic projects through PACE and PowerSaver loans.

Electric Thermal Storage:

As described in the section above on the CMP pilot project, electric thermal storage is a form of electric resistance heating. It may save customers money by displacing more expensive heating oil. It may also ultimately reduce greenhouse gases if the power supply is very clean (such as from a co-located renewable energy source).

It should be understood, however, that electric thermal storage systems do not produce a net savings of energy.[26] They do not operate more efficiently than conventional electric resistance baseboards, and are about one-third as efficient as a ductless air source heat pump. ENERGY STAR does not currently rate or provide performance standards for electric thermal storage units. When the question is what combination of fuel and heating system uses less energy at the source, electric thermal storage that receives power from the grid cannot be said to be inherently energy efficient.

Efficiency Maine does not currently offer rebates for electric thermal storage units, however, these units are eligible for PACE loans that Efficiency Maine has offered since 2011, so long as they are "bundled" with insulation and other measures that, taken together, achieve a minimum energy saving threshold. This saving threshold is required by the terms of the federal grant that funds the PACE loan pool.

Geothermal:

Like air source heat pumps, geothermal systems do not make heat but transfer it from one place to another and in this way can provide both heat and cooling. Geothermal systems use the ground as a heat exchanger – piping filled with a heat-conductive fluid are warmed by the earth in the winter to deliver heat to the interior. In the summer, heat is extracted from the home interior and exchanged with ground. Because the earth is at a relatively constant temperature year round, 50° Fahrenheit, geothermal heat pumps can more efficiently move heat in and out of a home than air source heat pumps, which are required to exchange heat with the outside air at higher and lower temperatures.

Efficiency Maine does not offer rebates on geothermal systems but Maine homeowners can finance geothermal systems through the PACE and PowerSaver loan programs. A number of large-scale commercial geothermal systems have been built through Efficiency Maine's High Performance Schools program.

Oil to Oil Conversions:

ENERGY STAR rates a number of high-efficiency oil combustion appliances. Upgrading oil systems are an option for homeowners who do not have good access to other heating fuels and for homeowners who have old, and over-sized heating systems. Oil-fired furnaces and boilers are also popular with homeowners who heat with biodiesel, or oil blended with biodiesel. Like the high-efficiency gas appliances described above, modern oil combustion appliances operate far more efficiently than their predecessors, extract more energy out of combustion gases, and can be modulated to meet heating needs.

[26] U.S. Department of Energy, "Electric Resistance Heating," accessed March 8, 2013, http://energy.gov/energysaver/articles/electric-resistance-heating. Following the federal approach and the practice in commercial/industrial energy analysis, Efficiency Maine's calculation of total energy savings accounts for the energy use from the source to the end use. When end-use products use the same energy or fuel type, their efficiencies can be compared without consideration of energy losses at the source or during distribution to the end-use site. However, when the end-use products employ different energy or fuel types (e.g., electricity versus heating oil), energy losses upstream are relevant. In the case of technologies that consume electricity, energy losses at the electricity generator and along the transmission and distribution lines must be accounted for, as well as any losses at the site when the energy is converted to heat. Source energy is the appropriate basis on which program administrators, policymakers and consumers to meaningfully compare energy savings or greenhouse gas emissions where fuel switching is contemplated. Source energy is the basis that is used in the ENERGY STAR program (see, e.g., *ENERGY STAR Performance Ratings Methodology for Incorporating Source Energy Use*, March 2001, p. 5) and by Efficiency Maine.

In 2010-2011, many boiler and furnace replacements were rebated with Efficiency Maine's Replacement Heating Equipment program, as well as through Home Energy Savings Program rebates. Currently the upgrade to a high-efficiency oil appliance can be financed through PACE and PowerSaver loans. To date, 43 homeowners have financed oil heat systems through Efficiency Maine's loan programs.

Barriers

Installation contractors report that when they speak with potential customers the most common barriers to purchasing heat pumps are: upfront cost of equipment, lack of information, uncertainty regarding savings, and uncertainty or misconceptions about the technology and its reliability.
In the experience of Efficiency Maine and other efficiency program administrators around the U.S., these barriers apply to the purchase of all energy efficient equipment wherever it is priced higher than comparable (but less efficient) models or where customers, contractors and suppliers are unfamiliar with the technology. These barriers are especially pronounced in the "retrofit" scenario, where the customer's building and existing equipment are operating adequately and have not reached the end of their useful lives. In such cases, the barrier to installing high-efficiency equipment is heightened due to the inconvenience of interrupting normal use of the building and equipment, accommodating contractors as they remove older equipment, and the inertia of "making do" with equipment that is still functioning. This is true even when customers are aware that over the long term the higher efficiency models will save enough energy to achieve a payback on the "incremental cost" associated with the upgrade.

The challenge of upfront costs can be mitigated through a variety of tools. Providing a financial incentive such as a rebate to cost-share the incremental cost of a high-efficiency product has proved the simplest and most effective approach to addressing this barrier. Another approach is to offer easy financing, such as on-bill financing provided by the utility or the Efficiency Maine's PACE/Power Saver loans, which can be most effective when coupled with a financial incentive. Thus far, few homeowners participating in the BHE-MPS pilot have taken advantage of on-bill financing (18% percent) and a small fraction of Efficiency Maine's loans have underwritten the cost of heat pump installations.
Limited awareness of heat pump and other alternative heating technologies is also a significant barrier to market penetration. The preliminary results from the BHE-MPS pilot demonstrate that consumer education remains an important aspect of market adoption, and other Efficiency Maine programs have found the same holds true for other technologies. All of Efficiency Maine's incentive programs are paired with educational efforts and Efficiency Maine's Innovation Program is an important way to identify consumer acceptance of new technologies, customer awareness levels and information needs. Efficiency Maine's website and other consumer education activities – including home show attendance and informational brochures – are a key resource for the widespread adoption of energy efficiency measures.

Another form of barrier is experienced when the there is a lack of awareness or capacity in the workforce or in the supply chain to promote, stock, and service new efficiency technologies. Air source heat pumps installed through the BHE-MPS pilot have not met these obstacles, but Efficiency Maine closely follows the pathway of heat pumps and other technologies from cradle to installation and attempts to ensure that customer adoption is not slowed by product availability and support. Efficiency Maine's residential and commercial programs work closely with distributors, wholesalers, and retailers,

and also with contractors, to carry and service the most cost-effective energy efficient products available.

Consumer uncertainty about energy and cost savings also remains a barrier. Efficiency Maine has developed a number of resources on its website (www.efficiencymaine.com) to help homeowners better understand efficiency opportunities. The "Home Energy Usage" calculator allows homeowners to benchmark their home's performance against others and estimate the energy savings possible through efficiency measures. The "Cost of Heating Comparison Calculator" allows homeowners to estimate cost and fuel savings from heating efficiency upgrades. These upgrades can also calculate cost savings through switching from one fuel to another. Tools like the cost comparison calculator are particularly important because homeowners consider energy use primarily in delivered units (like gallons), and projecting cost savings through a conversion to a different fuel is not an intuitive or simple process. The Governor's Energy Office provides consumers with updated fuel costs measured in units such as gallons, as well as the price per 1,000,000 BTUs, a practice which helps grow consumer familiarity with fuel costs measured in energy per unit delivered.

Alternative heat systems technologies have specific installation requirements and some installation constraints and uncertainty about those variables remains a major barrier to adopting new technologies. For example, closed-loop geothermal systems require a significant amount of yard space that might not be available in urban settings. Storing biomass in the form of cord wood or pellets can also be a barrier for homes with limited space. Biomass, natural gas space heaters, and boiler and furnace switches can all require changes in exhaust ventilation whether adding a chimney liner or directly venting combustion gases to the exterior. Venting requirements for all combustion appliances can limit where they can be placed in the home, especially supplemental heating solutions like wood stoves or natural gas direct vent space heaters. Air source heat pumps have fewer siting limitations, but a unit's location within a house can have a major impact on how much of the primary heat load is offset through the installation. Obviously, any home or small business heating system hoping to take advantage of low-priced natural gas needs to have access to a natural gas distribution system.

In all cases, clear information about the alternative heating system, and its efficiency, cost effectiveness, and siting limitations, helps customers overcome the technical and installation barriers to adoption. This need for information extends to Residential Energy Advisors, HVAC technicians, and other energy professionals serving residential heating customers. Every home is unique, and homeowners require support in determining which alternative heating systems meet their needs and are most cost-effective.

Recommendations

The legislation that directed Efficiency Maine to prepare this report (LD 1864, Section 10) provides:

> The report must specifically identify options for any changes in statute or rules needed to provide loans or utility on-bill financing to consumers for efficient heating equipment. (Emphasis added.)

Efficiency Maine has not identified any changes in law or rule that are needed to provide loans for the types of energy efficient heating equipment discussed in this report. Maine's banks offer standard financing that might be used to purchase residential and commercial heating systems, and Efficiency Maine offers PACE and PowerSaver loans.

Efficiency Maine's understanding of the current statutes and rules applicable to utilities is that, with approval from the Maine Public Utilities Commission, these utilities may offer on-bill financing for appliances or equipment that run on the type of energy supplied by the utility. This understanding is supported by the fact that in the Bangor Hydro Electric-Maine Public Service pilot program, the utilities are already offering on-bill financing as a means for customers to pay back over time the un-rebated costs of their heat pump installations.