Appendix G:

Analysis of the Opportunity for High-Efficiency, Cold Climate Ductless Heat Pumps in Maine in Fiscal Years 2020-2022

10/22/2018

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By Ian G. Burnes and Laura Martel
10-22-2018

Introduction

1. What is the purpose of this testimony?

This testimony describes the measure that the Efficiency Maine Trust (the Trust or EMT) calls a "ductless heat pump" (DHP) and provides evidence about the quantity of DHP installations that are achievable for incorporation into the Trust's Fourth Triennial Plan.

2. Who is introducing this testimony?

The testimony is provided by Ian Burnes and Laura Martel. At the Trust, Mr. Burnes is the strategic initiatives team leader and Ms. Martel is the evaluations manager.

3. Mr. Burnes, please state your name, title and business addresses.

My name is Ian Burnes, and I am employed by EMT as the Strategic Initiatives Team Leader. My business address is 168 Capital Street, Suite 1, Augusta, ME 04330.

4. Please summarize your educational and professional experience.

I have a Bachelor of Arts Degree in Economics from Wesleyan College. I have been working at the Trust since 2009. My first assignment was the management of the Large Customer RFP that evolved to become the Large Customer Program. My responsibilities have expanded to include the oversight of the strategic initiatives team that implements the Trust's customer tracking database, maintains the Technical Reference Manuals, oversees the program evaluations and manages the Trust's resource in ISO-NE's Forward Capacity Market. Before coming to the Trust I worked at the Governor's Office of Energy Independence and Security.

5. Ms. Martel, please state your name, title and business addresses.

My name is Laura Martel, and I am employed by EMT as the Research and Evaluation Manager. My business address is 168 Capital Street, Suite 1, Augusta, ME 04330**.**

6. Please summarize your educational and professional experience.

I have a Bachelor of Science Degree in Ocean Engineering from Florida Atlantic University and a Master of Engineering in Acoustics from Pennsylvania State University. I have over 18 years of technical leadership, project management, and research and evaluation experience. I was hired by EMT in 2014 to design and implement impact and process evaluations for energy efficiency programs. Prior to joining EMT, I was with Lockheed Martin in Manassas, Virginia, where I served in various engineering, management and technical leadership roles of increasing responsibility.

Cost-Effectiveness of the DHP

7. What is the name of the measure that is the subject of this testimony?

EMT refers to this measure as the ductless heat pump (DHP) or sometimes as a mini-split system heat pump. The measure is characterized by a split heating system in which there is an outdoor unit connected to one or more indoor units using distribution lines that are not ducted.

8. Does EMT's DHP measure assume that the DHP is being employed as a supplement to the existing, central heating system or as a complete replacement of the central heating system?

EMT's DHP measure assumes that the DHP is being installed in a dwelling or business where it will be used to supplement a central heating system.

9. What are the performance criteria that are used by EMT to establish eligibility of a high-efficiency, cold climate DHP?

At the present time, a system eligible for EMT incentives must have a Heating Seasonal Performance Factor (HSPF) of at least: (a) 12.0 for systems with one indoor unit or (b) 10.0 for systems with more than one indoor unit.

The list of makes and models that are known to EMT to be meet the performance criteria for the Home Energy Savings Program and the C&I Prescriptive Program can be found at https://www.efficiencymaine.com/docs/Eligible-Mini-Split-Heat-Pump-Criteria-and-List.pdf .

10. Please explain your approach to calculating the cost-effectiveness of a high-efficiency, cold-climate, ductless heat pump (DHP) in the Fourth Triennial Plan.

(a) Home Energy Savings Program

In the Home Energy Savings Program (HESP), EMT promotes high-efficiency DHPs in the context of a Lost Opportunity, unchanged from how the measure was treated in the Third Triennial Plan. The incremental cost of a high-efficiency DHP compared to the baseline model heat pump is slightly more than $680. The lifetime benefits of the electricity savings between a high-efficiency DHP and a standard efficiency DHP is $772. In comparison to the electric savings against a standard efficiency DHP, program compliant DHPs can provide additional heat as outdoor temperatures decline, offsetting fuel use with increased electricity use. The lifetime benefit of the offset fuel is $3,574 and the extra electricity use has a lifetime cost of $1,517. Factoring in a net-to-gross ratio of 75% to account for freeridership, the measure delivers a net benefit-to-cost ratio of 2.24.

(b) CIP

In the Commercial and Industrial Prescriptive Program (CIP), EMT treats high-efficiency DHPs the same way as they are treated in the HESP program. The incremental cost of the eligible DHP units is slightly more than $680. The net energy benefit of using the DHP is $2,828. The net-to-gross ratio is 68%, resulting in a net benefit-to-cost ratio of 2.15 for the measure.

(c) the Low-Income Initiatives

In the Low-Income Initiatives, EMT promotes high-efficiency DHPs in the context of a Retrofit, the same way that the measure was characterized in the low-income programs in the Third Triennial

Plan. In the Retrofit context, the cost of a high-efficiency DHP comprises the full cost of the equipment, plus installation, plus the operating costs for the DHP. The benefits include the value of energy savings experienced as a result of the operation of the DHP (note that the increased electricity use is accounted for on the cost side of the equation). The total costs applied in the Retrofit scenario for Low Income Initiatives are $5,543 and the total benefits are $10,453. Given that these projects would not happen but for the support of the program, the Trust applies a net-to-gross ratio of 100%, resulting in a benefit-to-cost ratio of 1.89.

(d) Small Business Initiative

In the Small Business Initiative (SBI), DHPs will be considered a Retrofit measure. As such, the calculation of costs and benefits will be approached the same way as described in the Low-Income Initiatives section, above. The SBI costs and benefits vary slightly from the Low-Income Initiative due to differences in assumptions about usage and the baseline situation of the business as compared to usage and the baseline situation of a residential dwelling. The total costs applied in the Retrofit scenario for SBI are $7,278 and the total benefits are $11,024. The Trust applies a net-to-gross ratio of 75%, resulting in a benefit-to-cost ratio of 1.48.

11. Are there other key assumptions used in your calculation of measure costs and benefits for the DHP that are integral to understanding the cost-effectiveness of DHPs in the Fourth Triennial Plan?

EMT contracted Bruce Harley Energy Consulting, LLC to improve existing in-house DHP modeling at EMT. Mr. Harley leveraged experience gained working with the Canadian Standards Association (CSA) to establish a new Dynamic [Heat Pump] Test Procedure in making the model improvements for the EMT. The modeling uses TMY3 temperature bins with a behavioral model developed for the CSA Dynamic [Heat Pump] Test Procedure applied to avoid brief off-season periods of heating and cooling. This results in a heating and cooling temperature bin profile that models how heating and cooling is performed throughout a typical year. At each temperature, the capacity and coefficient of performance was calculated using temperature-dependent performance of a representative program-eligible DHP and a representative non-eligible DHP. Program-eligible DHP performance used in the modeling is a weighted average of program-eligible models, in proportion to program participation, using engineering data. For non-eligible units, a weighted average performance was calculated using corresponding non-program eligible unit engineering data in comparable proportions. The actual heat delivered by the DHPs for any given temperature is a function of the heat load of the building, the capacity of the DHP and the interaction between the DHP and the central heating system. A factor (termed "Load Factor") was introduced to model the interaction between the DHP and the central heating system. This factor is used to adjust the point at which the DHP can not fully meet the heat loss of the area being served and triggers the addition of heat generated by the central system. Since the heat called for at any given temperature is fixed, any heat provided by the central system is heat that can not be provided by the DHP even if it has the capacity to do so. The portion of the heat provided by the DHP, when both the DHP and central system are providing heat, is directly proportional to the capacity ratio between the DHP and the central system. The capacity of the central system was set to 1.5 times the design capacity of the DHP and the "Load Factor" was set to 1.5. This results in the central system contributing a significant portion of the heat needed when the capacity of the DHP falls below 1.5 times the heat loss. Ideal interaction between the central system and DHP would have a load factor of 1. A load factor of 2.7 represents a scenario where little care is taken to prioritize the DHP over the central system (for example, if the customer were to use the DHP only in the shoulder seasons). A load factor of 1.5 was selected as it represents a realistic operation strategy that prioritizes the DHP while also working in combination with a central system.

12. **How does the performance of the high-efficiency DHP compare to the standard efficiency DHP?**

    Over the course of a heating season, program-eligible DHPs provide heat more efficiently that non-eligible DHPs and they provide cooling more efficiently over the cooling season. Additionally, the high-efficiency DHP models have more heating capacity, with higher efficiency, at lower outdoor temperatures than non-eligible models. This means that the point at which the central system is required to provide supplemental heat occurs at a warmer outdoor temperature for non-eligible DHPs. Therefore, the savings realized in the lost opportunity case include both electricity savings from more efficient heating and cooling plus fuel savings from the high-efficiency DHP providing more of the home's total annual heat load.

13. **For a retrofit scenario, how does the high-efficiency DHP compare to a typical central heating system furnace or boiler?**

    The high-efficiency DHP offers efficiency advantages in two ways. First, it converts source energy to useful heat more efficiently than a typical central heating system. At peak performance, the high-efficiency DHP is making heat at a COP above 3.0. The average COP of a high-efficiency DHP, making heat over the course of a full heating season is 2.7. That is equivalent to an efficiency of 270% at the point of end-use. Even when the losses from the power generator and line losses across the grid are factored in, the high-efficiency DHP is still significantly more efficient than a fossil-fired furnace or boiler. Second, as a supplemental heating system, the DHP delivers heat directly into a room avoiding some of the losses that a central heating system typically incurs from ductwork (in furnaces) and radiators (from boilers) of the distribution system. Because the modern, highest efficiency models can efficiently produce heat even at outdoor temperatures below -10^{o} F., unlike the earlier generation of heat pump models, it is appropriate, from a cost-effectiveness perspective, for users to run the heat pump so that it continues to deliver heat throughout the entirety of the heating season. One exception to this would be in a space where the central heating system runs on natural gas. In a natural gas-heated space, a Retrofit heat pump would not be cost effective under current avoided costs.

14. **What is the outside temperature at which a high-efficiency cold climate DHP will no longer deliver heat into the home or business?**

    Manufacturer reported performance is that the cold climate, high-efficiency DHPs promoted by EMT's programs effectively deliver heat at temperatures below -10^{o}F. One of the most popular models purchased in Maine reports an operating range down to -15°F.

15. **Does the eligible DHP switch over to a resistance coil heat element at extreme low temps or during the defrost cycle?**
    No. Although earlier models of heat pumps sometimes were combined with a resistance heating

element that would turn on to boost the heat output when outside temperatures got cold, the new models that are promoted by EMT do not have such an element.

Also, it is a misconception that the modern, high-efficiency models automatically switch to resistance heating in order to periodically defrost the outdoor unit to melt any build-up of ice. In fact, during the defrost cycle the DHP models that are eligible for EMT programs simply divert the heat produced by the DHP's normal process for making heat to the outdoor unit instead of transferring it into the lines for distribution into the home or business. This is a logical and far more efficient strategy than using resistance heating, since the defrost process is typically needed when the outside temperature is very close to "freezing" (i.e., 32° F). This is a temperature at which the DHP is highly efficient and effective at producing heat.

16. What is the impact of low, outside temperatures on the economics of DHPs as a supplemental heating system? Does it make economic sense to shut off a DHP when outside temperatures sink below a certain level?

The Trust modeled the performance of a typical DHP and a typical central system used as back up. It assumed $2.75/gallon of heating oil, a central furnace or boiler having a system efficiency of 80.5%, and a HSPF 12 DHP providing supplemental space heat with electricity at $0.16/kWh. The analysis showed that during the period of time when the outside temperature is below -1° F., it would be less expensive for the consumer to heat the space with the oil-fired central heating system than the high-efficiency DHP.

EMT applied this modeling to a typical home in Caribou, ME and found that if the home switched off its DHP during periods when the outside temperature was below -1°F., and then turned it back on any time the outside temperature rose above -1°F., the customer could save less than $4 per year. The analysis shows that there are relatively few hours of the year when outside temperatures in Maine are below -1°F., these hours do not typically persist for extended periods, and they are relatively spread out across the winter months. Because heat pumps are most efficient when they operate in a steady state (as opposed to being ramped up and down), and because customers are unlikely to perfectly time switching the DHP on and off whenever the outdoor temperature passes the -1° mark, EMT generally recommends that customers purchase the cold climate, high-efficiency heat pump (instead of the standard efficiency heat pump) and leave it on during all hours of the heating season.

An important point to understand about DHP economics is that due to their high efficiency in cold climates, the models promoted by EMT – the cold climate, high-efficiency heat pumps -- are able to make more heat than the lower-efficiency models when the outside temperature falls, and they are able to do so more economically.

17. Since EMT started incentivizing DHPs, to what extent/how much have EMT programs promoted messages, education, or training that would tend to help customers understand operational practices that will maximize the cost-effectiveness of their DHPs?

Almost none. Some attention has been paid to establishing appropriate DHP specifications (specifically the HSPF standard) and minimum requirements for proper installation and maintenance. EMT has also provided scholarships for training of DHP installers offered at community colleges. However, there has been no significant consumer education campaign by EMT about best practices for maximizing savings.

18. Does EMT intend to continue the “hands off” approach from the Third Triennial Plan to consumer education about operation of the DHPs going forward?

No. EMT is commencing a comprehensive consumer education and training initiative for DHPs starting in FY2019 and will extend that effort into the period of the Fourth Triennial Plan. The initiative will start with collecting and analyzing DHP usage data in Maine and modeling the economics of that usage. EMT will develop background information about strategies for maximizing the economic benefit of a DHP and will convert that information into consumer education materials and training materials. EMT’s plans are to produce and distribute written materials for vendors to leave behind with customers after installing DHP systems, and for 24-hour reference online. EMT will also continue to develop and publish “User Tips” in video form, which will be accompanied by testimonials and case studies demonstrating how real Mainers have found success in optimizing the performance and economic benefits of their DHPs. EMT will also work more closely with the sales force, installers and manufacturers in the DHP community. This work will include offering or subsidizing trainings in which “best practices” can be shared and promoted and new technicians entering the field can be brought up to speed on proper installation and how to help customers get the most from their DHPs.

19. How does EMT recommend running heat pumps in Maine?

Generally, EMT recommends that customers set the thermostats on the heat pump at a high enough temperature to keep the space comfortable to the customer’s tastes for a typical cold day. This setting may be higher than customers are accustomed to but is appropriate given that the thermostat on the DHP’s indoor unit is typically 6-8 feet above the floor and during cold weather it is likely the temperature at floor level will be several degrees cooler than where the indoor unit is located. Where it is expected that there will be an interactive effect between the DHP and the central heating system, EMT generally recommends that users set the thermostat controlling the central heating system 10 degrees F. lower than the setting on the DHP. In this way, the customer will establish the DHP is the primary space heater that is called upon first to meet the heating load of the space. The central heating system then becomes the secondary, backup system to meet load when the DHP cannot fully satisfy the heating load

20. What is the basis of the forecast for the sales of cold climate, high-efficiency DHPs in Triennial Plan IV?

The Trust developed the sales forecast for cold climate, high-efficiency DHPs through both HESP and CIP in the Triennial Plan Four period based on the rate of growth in those programs. The price of oil and propane is the major driver of DHP sales. In FY2016 there was a decline in DHP sales in the HESP program coincident with lower oil prices. Since the increase in oil prices we have seen an increased interest in the DHP measure. In FY2017, two large multifamily building projects resulted in a higher number of DHP installations in the C&I Prescriptive program. For HESP and CIP the Trust calculated a linear growth based on the program participation in fiscal year 2016 through 2018 and applied that to each of the three years of the Triennial Plan period. Those results are shown in the following charts:

Table 1: Home Energy Savings Program DHP Results and Forecast

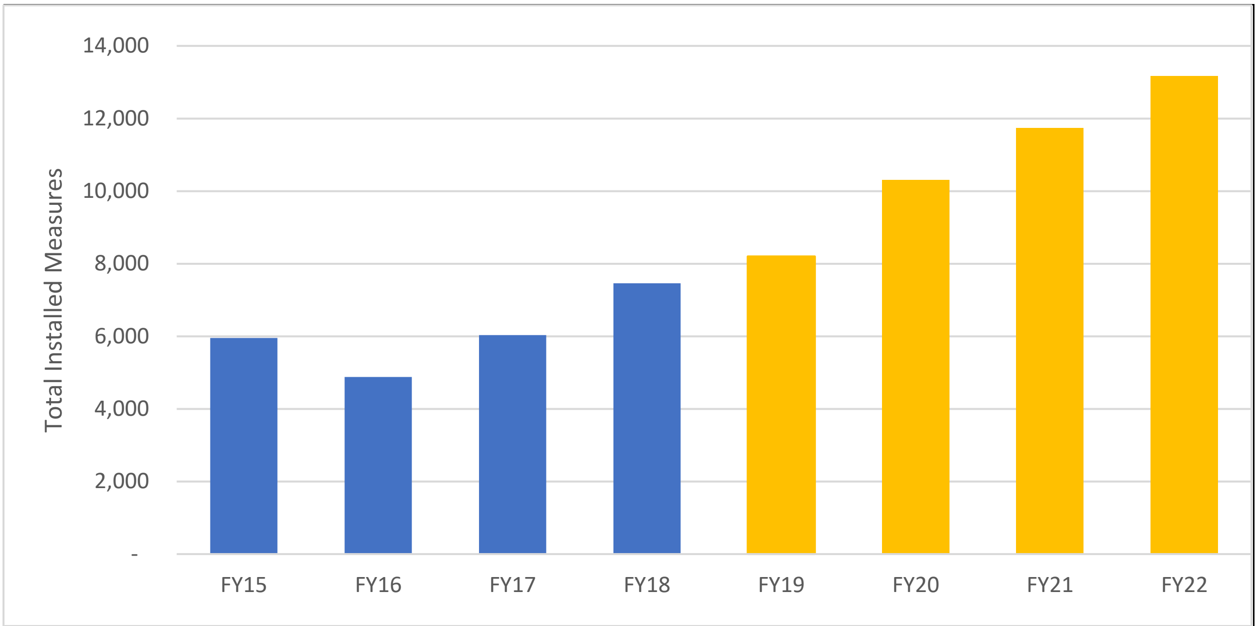
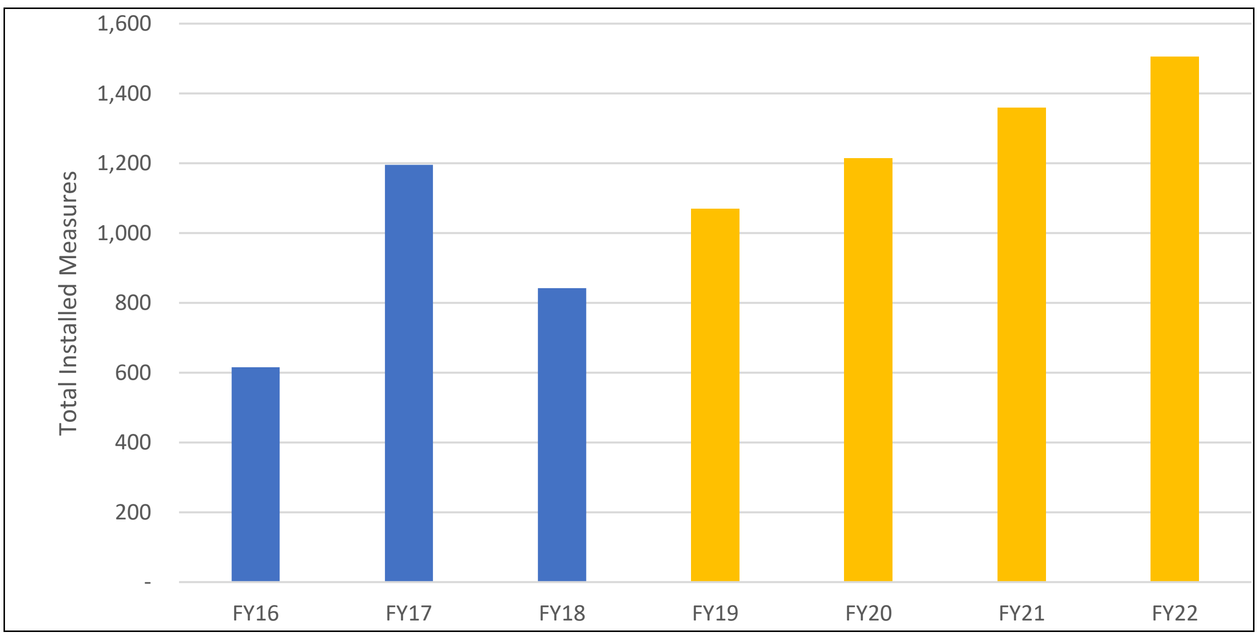


Table 2: Commercial DHP Results and Forecast



For Low Income and Small Business Initiatives, the ductless heat pumps are retrofit measures subject to the limited RGGI funding budgets.

21. Does this conclude your testimony?

Yes.