NAVIGANT

Memorandum

To: Massachusetts Program Administrators and Energy Efficiency Advisory Council

From: Decker Ringo and David Basak; Navigant Consulting Inc.

Date: October 5, 2018

Re: Cost Study of Heat Pump Installations for Dual Fuel Operation (RES 23)
Quick Hit Study

The primary goal of the RES23 Cost Study of Heat Pump Installations for Dual Fuel Operation was to provide the PAs with an understanding of the total installed costs and cost categories (i.e., equipment, labor, supplies, and other costs) associated with early replacements and new installations of residential central A/C and heat pump (HP) products. The 2015 Cool Smart Incremental Cost Study[1] evaluated the equipment costs of residential A/C and HP products. However, the PAs had not recently evaluated the total installation cost of installing these products in the PAs' service areas. This memo summarizes the evaluation team's findings from a review of customer invoices that were submitted with rebate applications for residential A/C and HP installations.

The cost results from this study will be used by the Energy Optimization program to evaluate measures that would incentivize the installation of heat pumps to displace heating equipment fueled by oil or propane.

Methodology

The evaluation team received summary rebate data for 7,948 rebate records submitted for residential central A/C and central HP installations that occurred during the period 1/1/16-7/31/17. The evaluation team analyzed that set of records and developed a sample frame of 200 total rebate records, including 100 rebate records each for A/C and HP product types. The team selected these sample frames to proportionally represent the number of rebates in different geographic regions in the PAs' service areas. The team received scanned invoice images for each of the records in the sample frame. For each record, the team verified that the record contains useful information such that the record (1) is legible, (2) is a record that the team requested, and (3) contains itemized cost information for an A/C or HP installation. For each record with useful information, the team recorded the total installed cost for the installation; the cooling capacity in tons; and, if available, the itemized costs for equipment, labor, supplies, and other costs. For records that included installation costs for more than one A/C or HP installation, the team split the record into multiple records to provide a data point for each A/C or HP installation included in the original record. For each record with useful information, the team divided the total installation cost by the cooling capacity (in tons) to calculate the total installed cost per ton.

[1] http://ma-eeac.org/wordpress/wp-content/uploads/Cool-Smart-Incremental-Cost-Study.pdf

Boundary of the Total Installed Cost for A/C and HP Systems

HVAC contractors offer a wide array of services and products that may be installed alongside a residential HVAC system. In this study, where the team analyzed costs reported in different formats from different contractors with different installation packages, it was important to define the boundary around the products and services that are included in the reported costs. Defining a consistent boundary helped guarantee that the costs gathered from individual records are comparable to one another, and it will help PAs to articulate the costs that are included in the total resource cost. Table 1 provides a list of HVAC system components and a justification for whether they are included in the total resource cost. For invoice records where the team could not identify installation costs that meet this system boundary (for instance, if the AC or HP installation included a humidifier but the humidifier cost was not itemized on the invoice), the team did not include the invoice record in the analysis.

Table 1. HVAC System Components Included or Not Included in Total Installed Costs

HVAC System Component	Included in Total Installation Cost?	Justification
Outdoor condensing unit	Included	The outdoor unit is a main component of the A/C or HP system and is required for system operation.
Indoor air handler or indoor evaporator coil	Included	The indoor unit is a main component of the A/C or HP system and is required for system operation. In reviewing invoices, the team observed that some invoices included replacement of the full air handler, while other invoices covered coil replacement.
Thermostats, including programmable thermostats or wifi-enabled thermostats	Included	A thermostat is required to control the operation of the HVAC system. HVAC systems with 2-speed or variable-speed compressors typically require controls that are not available from older thermostats. Additionally, some HVAC suppliers require that their higher-efficiency systems be installed with proprietary wifi-enabled thermostats.
Air filter and air filter casing	Included	Return air filters are required to maintain proper operation of the HVAC system
Electrical upgrade costs	Included	HVAC systems have certain electrical requirements that must be met for proper system operation. The team observed that some invoices itemized the electrical upgrade costs, but some invoices did not (presumably because electrical costs were not incurred or were included in other reported costs).
Ductwork installation or ductwork modifications	Included	The HVAC system must be connected to a household's ductwork for proper operation.
Condenser pad, refrigerant lines, and other supplies	Included	New HVAC installations require placement and connection of the outdoor condenser unit.

HVAC System Component	Included in Total Installation Cost?	Justification
Backup electric heater	Included	For installations without a supplementary heating source (such as a furnace), some systems require backup heaters to provide sufficient heating capacity at colder outdoor temperatures.
Removal and disposal of old HVAC system	Included	In reviewing invoices, the team observed that the removal and disposal of older HVAC systems is a service that is usually included in the installation cost and is not usually itemized.
Humidifier	Not Included	Humidifier components improve occupant comfort but are not required for proper HVAC operation.
Air purifier or air cleaner	Not Included	Air purifiers improve occupant comfort but are not required for proper HVAC operation.
Condenser cover	Not Included	Condenser covers are useful for reducing system maintenance and improving longevity, but they are not required for system operation.

System Heating and Cooling Capacities

The program invoice data supplied by EFI did not include data regarding the cooling capacity or heating capacity for the rebated A/C and HP systems. The scanned invoice images supplied by EFI often described each system's cooling capacity rounded to the nearest half-ton of capacity, but typically did not describe the system heating capacity. To gather data for system cooling capacity and heating capacity (at 47°F and 17°F), the evaluation team used the AHRI certificate number cited in the invoice record to reference the AHRI Directory of Certified Product Performance.[2] For invoice records that covered more than one system installation but cited only one AHRI certificate number, the team confirmed that the correct AHRI record was referenced for each system listed in the invoice.

Results

Of the 200 program invoices analyzed, the team found that 138 invoice records contained useful information. Fourteen of the invoices with useful information described the installation of two or three A/C or HP systems, and the team split these 14 records into multiple data points. In total, the invoice review produced 153 data points for system installation costs.

The team compiled the cost data collected from invoice records and calculated summary statistics for each installation scenario (new or replacement installation) for each product class (A/C or HP). The summary results are presented in Figure 1 in the form of a box-and-whisker plot. In the plot, boxes show the 25%-75% range, the dark horizontal line inside the box shows the median, the "x" mark indicates the average, and the whiskers show the range from minimum to maximum. Outlier points are not plotted. For each installation scenario and product class, Table 1 presents the average, 25th percentile, and 75th percentile total installed costs from the program invoice samples.

[2] AHRI Directory of Certified Product Performance. Available at: https://www.ahridirectory.org/

Figure 1. Installed Cost per Ton for A/C and HP Installations, from Program Invoice Review

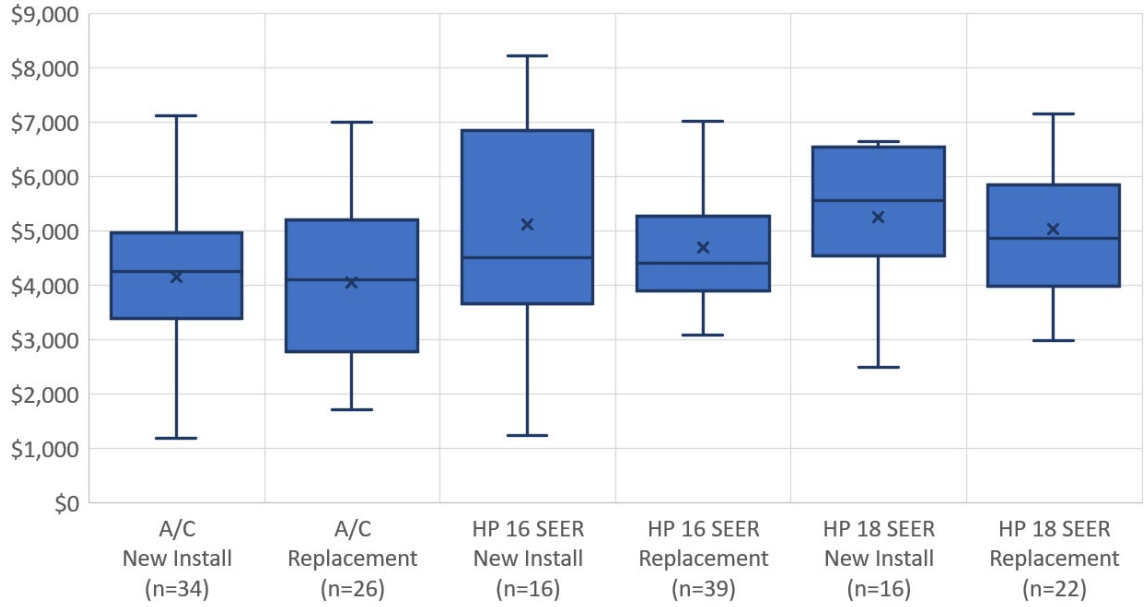


Table 2. Installed Cost per Ton for A/C and HP Installations from Program Invoice Review

Product Class and Installation Scenario	Total Installed Cost per Ton					
	New Installation			Replacement		
	25 %tile	Average	75 %tile	25 %tile	Average	75 %tile
A/C	$3,495	$4,156	$4,940	$2,838	$4,074	$5,150
HP 16 SEER	$3,676	$5,121	$6,705	$3,948	$4,685	$5,253
HP 18 SEER	$4,566	$5,259	$6,400	$3,999	$5,033	$5,766

As shown in Table 2, all three product classes in this analysis show a higher average cost/ton for new installations compared to replacement installations. Four reasons stand out for why new installations may cost more than replacement installations. (1) New installations require installing refrigerant lines between the condenser unit and the indoor unit, while replacement installations may sometimes make use of the already-installed lines (or at least use the pathway created for the previously installed lines without needing to drill new holes in the building envelope.) (2) New installations tend to require the installation of a complete air handler unit, while replacements may only require an indoor coil replacement. Air handler units are typically more expensive to install than coil replacements. (3) New installations may require ductwork to be installed throughout the house if they cannot be integrated with an existing furnace. (4) New installations are more likely to require electrical system upgrades, while replacement installations may already have adequate electrical supply available.

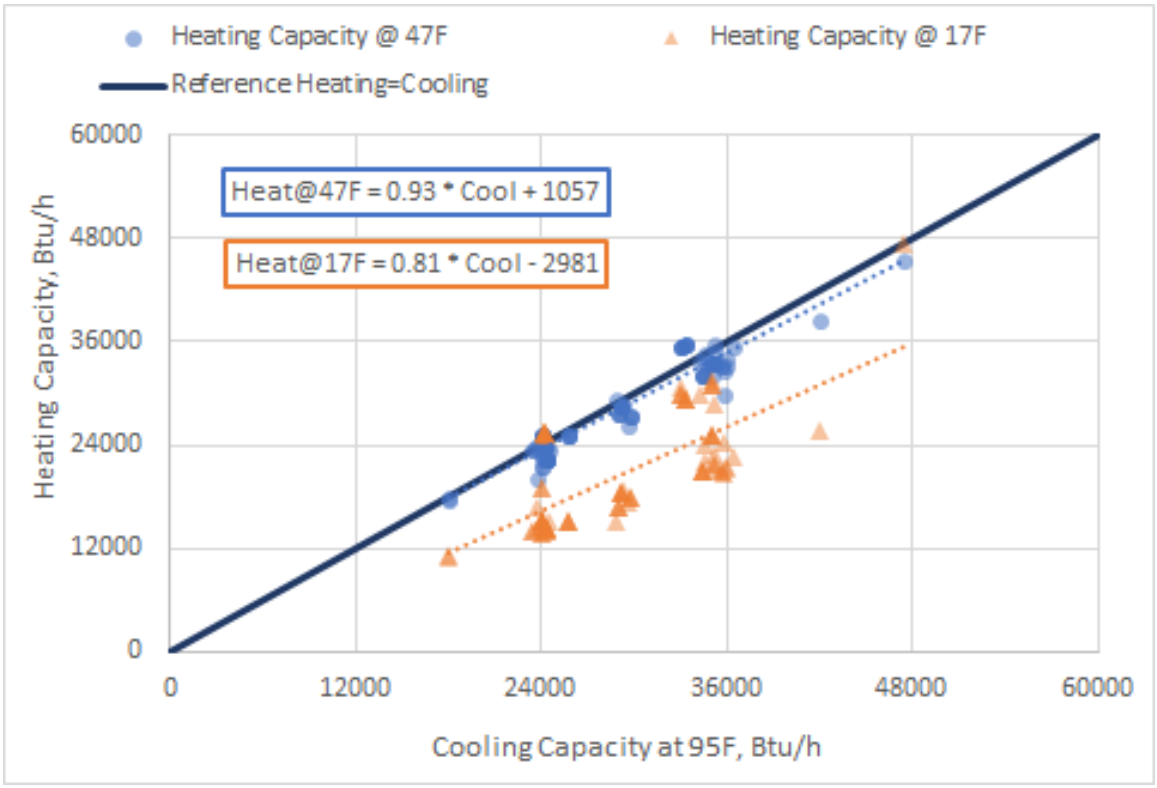
The team also attempted to quantify the different cost categories associated with A/C and HP installations, such as the costs of materials, labor, supplies, and other costs. However, the team could not calculate meaningful cost category statistics, since cost categories were reported on only 29 of the 200 invoices analyzed in this study.

Relationship between Cooling Capacity and Heating Capacity

The PAs requested that the evaluation team analyze the relationship between cooling capacity and heating capacity for the central HP models included in this invoice review. Figure 2 plots the heating capacities at 47°F and 17°F relative to the cooling capacity for all the HP systems included in this analysis. The points in Figure 2 are translucent to illustrate where multiple points are stacked on top of one another; darker clusters in the plot indicate capacity combinations that applied to multiple systems in the analysis.

The plot applies a linear curve fit to the data series for heating capacity at 47°F and at 17°F. The plot shows that, for most systems in this analysis, the heating capacity at 47°F is nearly equal to the cooling capacity. However, the relationship between heating capacity at 17°F and cooling capacity is more complicated. The 17°F heating capacity series shows two clusters of points, one with a higher average 17°F heating capacity and one with a lower average 17°F heating capacity. These clusters likely represent cold-climate systems that provide high-efficiency heating at low outdoor temperatures and non-cold-climate systems. The 17°F heating capacity series generally shows that, for a given HP system, the cooling capacity can be 1.5 to 2 times greater than the heating capacity. The implication for PAs is that customers should avoid oversizing HPs for heating because that would lead to grossly oversizing the cooling capacity, particularly in a partial displacement scenario where the heat pump need not provide the full heating load.

Figure 2. Relationship between Cooling and Heating Capacities for Sampled HP Models



Comparison to Prior Incremental Cost Studies

Compared to the 2015 CoolSmart Incremental Cost Study, the invoice review conducted in this study predicts smaller incremental costs between heat pump installations at 16 SEER and 18 SEER. The

CoolSmart Study final report[3] estimated the cost difference between 2-ton HP systems at 16 SEER and 18 SEER to be $1,377, while the current RES23 study estimates a $632 difference for the same incremental improvement. There could be several reasons behind this discrepancy: (1) The CoolSmart system focused only on systems produced by two prominent manufacturers, whose products are typically more expensive than the market average; this RES23 analysis included a more diverse set of manufacturers, including manufacturers that sell at below-average price points. (2) Incremental costs for high-efficiency systems have decreased over time as manufacturers have continued optimizing their approach to part-load operation. (3) The CoolSmart Incremental Cost Study was based on a unit teardown analysis and was designed to solely look at the incremental costs of the base equipment (condenser plus air handler or coil), did not consider installation costs, and excluded the costs of any identifiable non-efficiency-related features such as thermostats. In comparison, this RES23 cost study accounts for a wide range of installation and ancillary equipment costs associated with installing a new heat pump (see Table 1).

[3] Cadmus (2015). “Cool Smart Incremental Cost Study: Final Report.” Figure 2. Available at: http://ma-eeac.org/wordpress/wp-content/uploads/Cool-Smart-Incremental-Cost-Study.pdf