RIDGELINE
energy analytics

To: Laura Martel, Efficiency Maine Trust
From: David Korn, Ridgeline Energy Analytics
Cc: Nancy Dickson, Ari Jackson, Tanner Schanzlin, Ridgeline Energy Analytics
Date: June 8, 2021
Re: Memorandum on New Construction HVAC Pricing (revised)

Executive Summary

This study examines the costs of various heating systems in residential new construction. One of our goals is to understand the potential cost barriers of installing efficient and low-carbon HVAC systems such as heat pumps in newly constructed homes. This study includes 1) costs as reported by builders gathered from a combination of projects and 2) firm quotes from HVAC contractors proposed for actual homes, but not necessarily installed. We also investigated costs advertised on the web for boilers, fin tube, and heat pump systems. These equipment costs were compared with actual bids but not used directly in constructing HVAC installed costs.

Fuel costs are not included or considered in the memorandum because they can vary. Comparative operating costs, while important in deciding which system is installed, are dependent on fuel costs and efficiencies and therefore best discussed elsewhere.

We worked with six builders and one HVAC contractor and obtained two to three or more project costs from each builder. We priced 29 heat pump systems and 11 fossil fuel systems from the interviewees. Several of the quotes had multiple variants for the same building allowing us to see the impact of the choice of brands, choice of models within a brand, and the choice of layout (e.g., ductless versus ducted).

The average boiler system costs $10,817 and $6.78 per square foot of conditioned floor area (Table 1). Because the cost of a boiler within a brand is not very sensitive to sizing, the cost per square foot will rise with smaller homes and will drop for large homes. The average ductless heat pump system costs $13,140 and $6.06 per square foot, about $2,300 more per project, but $0.70 less per square foot than a boiler system. The reason for the difference in the comparative project and per square foot costs is the size of the homes reviewed. Among prices reviewed, the average size of homes served by heat pumps was larger.

Heat pump systems are indirectly correlated with home size but are more proportional to the number of indoor units provided. The systems provide different features in that the boiler system also provides domestic hot water and the heat pump provides cooling. While adding domestic hot water to a heat pump system simply requires adding a storage unit at relatively low cost, the cost of adding cooling to a boiler-heated home is substantial.

Heat pump systems with limited numbers of indoor units and electric resistance strip heating in small zones such as bathrooms cost on average $10,244 or slightly less than the average boiler. One builder found that by reducing the number of indoor units and using electric strip heat for small zones like bathrooms they could cut costs, yet their customers were still satisfied with the systems.

Table 1. Summary of Heating System Costs

System Type	n	Average Project Cost	Cost/SF	Cost vs. Boiler	Cost/SF vs. Boiler
Combi Boilers	11	$10,817	$6.78	$0	$0.00
Simple Ductless	14	$10,244	$5.67	-$573	-$1.10
Ductless Heat Pumps	24	$13,140	$6.06	$2,323	-$0.71
All Heat Pumps	29	$14,334	$6.47	$3,517	-$0.30
Ducted Heat Pumps	5	$20,066	$8.40	$9,249	$1.63
Furnaces with AC	1	$22,000	$11.00	$11,183	$4.22

Using the data collected we developed an incremental cost intended for use in cost-effective analysis. We first removed one outlying boiler cost and four outlying heat pump costs. This tightened the data range but only slightly impacted average values. In Table 2 we show a mean cost difference of $2,500 and -$0.52/SF.

Table 2. Suggested Summary Pricing Differential Between Boilers and Ductless Heat pumps

System	Mean	Lower 80% CI	Upper 80% CI
Boiler (n = 10)	$10,486	$10,153	$10,818
Ductless (n = 20)	$12,986	$12,098	$13,874
Difference Between Ductless and Boiler	$2,500	$1,945	$3,056
Boiler ($/SF)	$6.75	$6.11	$7.38
Ductless ($/SF)	$6.23	$5.67	$6.79
Difference Between Ductless and Boiler ($/SF)	-$0.52	-$0.44	-$0.59

Builders did not cite pricing as the reason to install a boiler versus a heat pump. We sensed that builders installing boilers were more comfortable with that technology and that builders that had made the switch to heat pumps were happy with their choice. Experience and comfort with systems are changeable, however. Case in point, a 2008 new construction study showed that at that time, oil systems and furnaces were prevalent. These practices haves changed, and currently new homes are built with propane or gas boilers and heat pumps. Builders and contractors adapted and changed practices in a relatively short time. It is therefore highly possible that builders will grow in their comfort with heat pumps in coming years.

Where new high efficiency and low carbon systems cost more than conventional fossil fuel systems, the builder initially bears the cost of the new system, but the homeowner bears the cost of the long-term operation of the system—this is, in theory, a split incentive. We found in talking to builders, however, that their decision was not based on first cost and that they at least considered the cost of operation. This is likely because the slightly higher cost of a multi-zone heat pump is included in the price charged for the home, so the incentive is not entirely split.

Background

This study examines the costs of various heating systems in residential new construction. One of our goals is to understand the potential cost barriers of installing efficient and low-carbon HVAC systems such as heat pumps in newly constructed homes. This study includes 1) costs as reported by builders gathered from a combination of projects and 2) firm quotes from HVAC contracting firms proposed for actual homes, but not necessarily installed. We also investigated costs advertised on the web for boilers, fin tube, and heat pump systems. These equipment costs were compared with actual bids but not used directly in constructed HVAC installed costs.

These costs are useful for comparative purposes but are not necessarily indicative of the cost of systems for every situation. The costs are for new construction and are charged to builders. Primarily due to the nature of installing distribution systems, retrofit costs can be very different. They therefore should not be used by readers to compare with quotes for retrofits or quotes to homeowners. Fuel costs are not included or considered in the memorandum because they can vary. Comparative operating costs, while important in deciding which system is installed, are dependent on fuel costs and efficiencies and therefore best discussed elsewhere.

Approach

We interviewed builders seeking to first understand why builders choose various HVAC systems. We anticipated that reasons would include price, but that there might be other reasons as well. We then asked them for either actual historical costs or bids on actual projects. We chose to obtain actual project costs rather than request new bids for systems for two reasons: 1) actual project costs are more authentic than bids on hypothetical homes; and 2) builders would probably not view an HVAC quote as sensitive business information while an HVAC contractor might view their pricing as proprietary. To encourage participation, we emphasized to builders that the data would be anonymized and that we would not include their names in written reports. In this memorandum, we use the project costs to develop estimates of the costs of various HVAC systems.

We interviewed six builders and one HVAC contractor and obtained pricing for 29 heat pump systems and 11 fossil fuel systems from the interviewees. The strength of this approach is that the project costs are either projects actually built or are firm quotes for actual homes. Several of the quotes had multiple variants for the same building allowing us to see the impact of the choice of brands, choice of models within a brand, and the choice of layout (e.g., ducted versus ducted). We report both project costs and costs per square foot of conditioned space.

Builder Interviews

We asked builders a series of questions (see Attachment A), to understand why they chose particular systems and who had a role in choosing those systems.

Pricing

Each builder provided several HVAC project prices and generally included the following:

- Brand of system
- Size of home
- Number of single zone and multi-zone heat pumps
- Number of boiler zones
- Type of domestic hot water (DHW) system

Bottom-Up Pricing

We gathered data on wholesale pricing to develop bottom-up estimates and compare it with the builder project pricing developed above. These prices helped us understand the relationship between cost and attributes like capacity.

Results of Builder Interviews

Table 3 shows summary answers from the builder interviews. The themes are summarized below.

Fuel Choice

Among fossil fuel choices, the builders will use natural gas where it is available and otherwise prefer propane or electric-driven heat pumps. The builders have transitioned from oil to propane and will only install oil when requested by a homeowner. This matches Maine's 2021 New Construction Baseline Assessment where only 9% of heating capacity is provided by oil.

Systems with High Favorability Ratings

In general, builders liked boilers and heat pumps depending on their current installation practice. All builders contacted understood that the lack of cooling was an issue for boilers where homeowners desired cooling.

Systems with Low Favorability Ratings

The builders all agreed that ducted systems are difficult to install. They cite wood and oil as inefficient, but two builders also cite wall mounted boilers as inefficient. When builders were asked about systems that are prone to problems and callbacks, the builders cited a range of systems including ducted systems, oil systems, wall mounted boilers, and interestingly, one heat pump installer cited heat pump water heaters (HPWH) as problematic.

Ability of Heat Pumps to Work at Cold Temperatures

All the builders believed that heat pumps could work at cold temperatures. One stated that he prefers a backup system when temperatures drop below 0F.

Table 3. Answers from Builder Interviews

	Builder A	Builder B	Builder C	Builder D	Builder E	Builder F
Historical installs		Oil hydronic, condensing propane boiler	Oil boiler	Propane boilers, HP	Mixture of technologies in renovated buildings	Heat pumps since 2018
Current installs	Condensing propane boiler, HP for customers that want AC	HP: ducted, ductless	Condensing propane boiler; HP	Mostly renovations, recent large HP install	None current	Heat pumps, all electric homes, working towards net zero; radiant electric heat pads in bathrooms under tile – homeowners prefer
High comfort	Radiant	Ducted HP, ductless HP	HP	Hydronic, but no cooling, HP due to cooling	Wood stove for heating, ducted gives even heat, combines ductless with ceiling fans	Cold climate heat pumps, favors a leading brand. See comfort inextricably linked to envelope construction.
Easy to install	On demand, direct vent, HP	HP, by far	Ductless HP	HP by far, although sizing and low loads are an issue	Ductless HPs are the fastest	Boilers. Multi-splits: they install in up to 3 stages, rough in, outdoor; line sets behind walls; indoor units
Durable, low call backs	IBC, Mitsubishi, Amer. Std.	HP, ducted and ductless	HP – excellent warranty	HP, few call backs after 10 years, wall hung boilers	DHPs after consumer education	HP, they get a 12 year guarantee due to use of leading installer
Efficient	On demand	HP and HPWH	HP	HP		Heat pumps
Poor comfort	HP only	Old oil systems	PROPANE hydronic does not provide cooling	Old, forced air furnaces	No cooling is poor comfort, baseboard under leaky windows	Poor envelopes
Difficult to install	Duct systems	Full ducted systems	Full ducted systems	Ducted systems	Ducted systems	Ducted are expensive to install
Prone to problems, call backs	Hydro air, attic duct runs	Oil and wall mount boilers	HPWH (don't want to risk cold basement); ducts in unconditioned spaces	Oil needs maintenance; some HP issues with poor installs due to condensate piping and flare joints	Oil systems, freezing issues in hydronics, DHP with no education	Fossil fuel needs frequent maintenance,
Inefficient	Wood	Oil, wall mounted propane boilers	Oil and ducted	Boilers, furnaces	Wood	Fossil fuels

View of HP <10F	Some risk but OK with correct system	Recent improvements, no issues	Excellent results	Works well, likes to have a backup for <0F	Yes, but can result in some cold areas	Yes, no concerns
Roles	None for realtor, banks, homeowner has final choice	None for realtor, banks, homeowner has final choice	None for realtor, banks, homeowner has final choice	Homeowner has final choice but often defers to builder	Renovate for sale, no role for homeowner or distributor, views HVAC contracts as limiting.	Lenders request or require backups. He installs Cadet oil filled 240V ER heat. 1,000W per bedroom– almost never actually used
Fuel	Propane over oil, no electric boilers or furnaces	Propane over oil, no electric boilers or furnaces	Propane over oil, no electric boilers or furnaces	Propane, HP, natural gas if available	Likes flexibility of oil – multiple venders, committed to low carbon and electrification	Do all electric, no fossil

System Pricing

We asked builders to provide us with pricing of HVAC systems for actual homes. There are three bases for the prices: 1) actual single project prices of HVAC systems in built homes, 2) typical prices that a builder pays for a standard HVAC package that they install in homes that they build; and 3) actual bids for homes where the builder or homeowner chose another system, but the price was an actual firm bid from an HVAC contractor. The advantage of the third category was that some of these prices were for multiple options, allowing us to view price differentials for brands, models, and layouts.

Fossil Fuel-fired Systems

In general, there was low variation between prices of systems. As shown in the bottom-up pricing section, there is only minor variation in pricing by capacity, but a marked difference in pricing by brand. Fossil fuel-fired systems are generally oversized, making it possible to serve a larger home with little change in pricing.

Boilers

The 2021 New Construction Baseline study found that propane-fired boilers are the most common system installed in non-manufactured homes. Not surprisingly, several builders that we interviewed had readily available project pricing for propane boilers. The 11 project prices shown in Table 4 average $10,817. The boilers include 2 or 3 hydronic heating zones. Each of these boilers also serves DHW through an additional zone, so the total zones provided by the boilers are 3 and 4. The pricing was fairly tightly grouped among three builders, with a CV[1] of about 0.12. These boilers served floor areas ranging from 960 to 2,300 square feet. Normalized per square foot, propane boilers with integrated DHW cost an average of about $6.78 per square foot with one system as low as $5/SF (Table 5).

Furnaces

Ducted fossil systems were more expensive with one furnace system costing $11/SF. Combination boiler and ducted systems are more expensive still, at $12.50 - $20.00/SF. While we received additional quotes, the quotes were either for partial coverage of a home or were partial retrofits. The higher cost of the furnace system is primarily driven by the cost of ductwork. One builder noted a rule of thumb of roughly $2,000/ton, based on cooling capacity. While furnaces are nearly twice the cost of a boiler system for new construction, they provide cooling, and a hydronic system does not.

[1] The coefficient of variation (CV) is a ratio of the standard deviation (SD) to the mean value. The lower the CV the lower the variability of a set of data and in turn the higher precision possible from a given sample.

Table 4. Boiler Project Pricing

Boilers	1	2	3	4	5	6	7	8	9	10	11	Mean	SD	CV
Capacity MBTUH	141	112	125	125	125	125						126	9	0.07
CFA	1,997	2,000	1,412	2,233	1,305	2,302	960	1,620	1,560	1,560	1,410	1,669	416	0.25
Boiler, hydronics	$8,247	$5,838	$5,721	$6,713	$5,721	$6,713	$5,691	$5,954	$6,952	$5,954	$5,954	$6,314	$785	0.12
Boiler Labor	$5,880	$4,162	$4,079	$4,787	$4,079	$4,787	$4,058	$4,245	$4,957	$4,245	$4,245	$4,502	$560	0.12
Boiler Total	$14,127	$10,000	$9,800	$11,500	$9,800	$11,500	$9,749	$10,199	$11,909	$10,199	$10,199	$10,817	$1,346	0.12

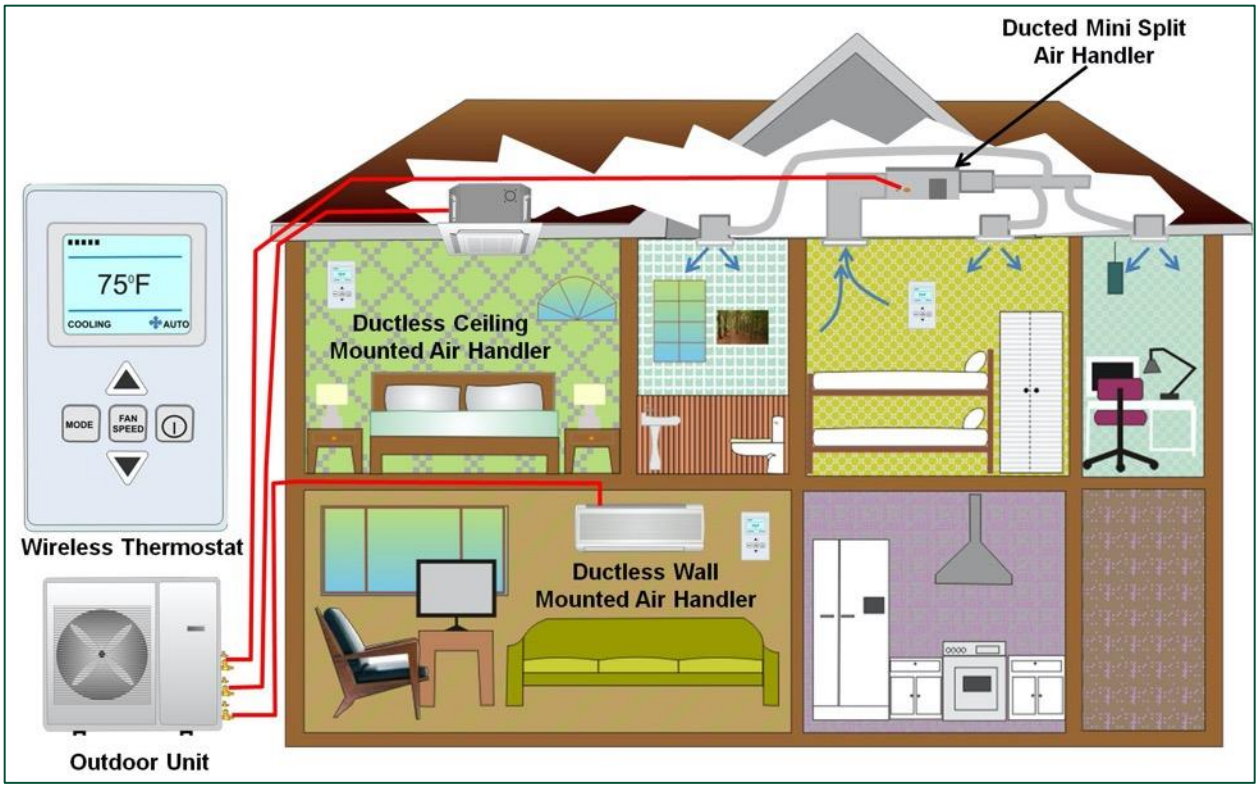
Table 5. Boiler Project Pricing Normalized by Area

Boilers	1	2	3	4	5	6	7	8	9	10	11	Mean	SD	CV
Boilers	1	2	3	4	5	6	7	8	9	10	11	Mean	SD	CV
Capacity MBTUH	141	112	125	125	125	125						125	9	0.07
CFA	1,997	2,000	1,412	2,233	1,305	2,302	960	1,620	1,560	1560	1410	1,669	416	0.25
$/SF Boiler Hydronics	$4.13	$2.92	$4.05	$3.01	$4.38	$2.92	$5.93	$3.68	$4.46	$3.82	$4.22	$3.96	$0.87	0.22
$/SF Boiler Labor	$2.94	$2.08	$2.89	$2.14	$3.13	$2.08	$4.23	$2.62	$3.18	$2.72	$3.01	$2.82	$0.62	0.22
$/SF Boiler Total	$7.07	$5.00	$6.94	$5.15	$7.51	$5.00	$10.16	$6.30	$7.63	$6.54	$7.23	$6.78	$1.49	0.22

Heat pumps

Heat pump pricing is more complex than fossil fuel systems because there are many possible variations of a heat pump system. At the high end of costs are ducted systems that use an outdoor unit similar to a ductless system and that unit is connected via a refrigerant line set to one or more coils in a ducted air handler system. Slightly less expensive than these systems are so-called mini-duct systems where the outdoor unit is attached to one or more indoor coils that serve short runs of low static pressure ducts. The builder has two choices with ductless systems: "multi-splits" where a single outdoor unit is connected to multiple indoor units or single zone systems that match the outdoor unit to a single indoor unit. Some builders put an indoor unit in each major zone. To reduce cost, the builder can reduce the number of indoor units, adding electrical resistance (ER) baseboard to smaller zones. Some builders use this strategy for bathrooms. Another strategy that can be used alone or in combination with ER baseboard is to encourage the homeowner to leave one or more indoor doors open, heating more than one room with each indoor unit. Some of the lowest cost systems use as few as two indoor units in combination with ER and multiroom heating. Figure 1 shows an outdoor unit serving a mini-ducted unit, a ceiling mounted cassette unit, and a wall hung unit.

Figure 1. Diagram of Multi-spilt Unit with. a "Mini-duct" Portion



Source: PNNL

Pricing for Heat Pumps

We have costs for 29 projects and project options. The systems vary in layout with a 3:1 factor between the highest and lowest prices. For example, one of the highest priced HP systems includes two fully ducted air handlers with backup electrical heaters. Other pricing factors, including manufacturer, are covered in this builder pricing section, and SEER and HSPF ratings are covered in the bottom-up pricing section.

The average heat pump system costs $14,334, was an average of 34,500 BTUH (Btu/hour), and served an average floor area of 2,311 square feet (Table 6). Two of the project costs included a DHW heater. In these cases, we subtracted a $500 allowance for the 50-gal electric storage heater. We then normalized the cost by floor area. The average heat pump system costs just over $6.47/SF. While this average is useful, it is a mixture of very simple heat pump systems with electric strip backup, multizone systems with up to 5 indoor units, inexpensive and expensive brands and models, and fully ducted heat pump air handling systems. The average is therefore dependent on the mix of systems. In the following sections we divide the systems into groups with similar characteristics.

Table 6. Heat Pump Project Pricing for All Heat Pumps

Heat Pumps (n = 29)	Mean	SD	CV
Capacity	34,500		
Floor Area (Sq. Ft.)	2,311		
DHP Total	$14,334	$4,993	0.35
$/SF DHP Total	$6.47	$2.12	0.33

Ducted Heat Pumps

Separating out the five ducted heat pump projects, we can see that the average project cost is higher than the average for all heat pumps at just over $20,000 per project (Table 7). In general, these systems cover more zones than ductless systems, but this coverage comes at a cost. Normalizing for floor area, the average ducted HP system cost is $8.40/SF.

Table 7. Heat Pump Project Pricing for Ducted Heat Pumps

Heat Pumps (n = 5)	2	13	14	15	16	Mean
Layout	Ducted	2 Ducted	2 Ducted	1 ducted 1 mini-duct	1 ducted 1 mini-duct	
Capacity	36,000	36,000	36,000	36,000	36,000	36,000
Floor Area (Sq. Ft.)	1,896	2,521	2,521	2,521	2,521	2,396
DHP Unit	$14,890					
DHP Labor	$2,000					
DHP Total	$16,890	$20,495	$22,525	$19,195	$21,225	$20,066
$/SF DHP Total	$8.91	$8.13	$8.93	$7.61	$8.42	$8.40

Ductless Heat Pumps

Examining the 24 ductless heat pump projects we can see that the average project cost is lower than the average for all heat pumps and well below that of ducted systems, at about $13,140 per project (Table 8). The systems are relatively large, and most are multi-splits with an average of 3.1 indoor units per outdoor unit. The CV is relatively large and similar to that for all heat pumps. Normalizing for floor area, the average ductless HP system cost is $6.06/SF.

Table 8. Heat Pump Project Pricing for Ductless Heat Pumps

Heat Pumps (n = 24)	Mean	SD	CV
Capacity	34,174		
Indoor Units/outdoor unit	3.1		
Floor Area (Sq. Ft.)	2,293		
DHP Total	$13,140	$4,574	0.35
$/SF DHP Total	$6.06	$2.11	0.35

There is a good deal of variability among heat pump systems. The number of indoor units varies from 2 to 5, and the number of outdoor units is 1 or 2. Some builders reduce the number of indoor units by including electric resistance baseboard for bathrooms and other small zones. One builder installs two standardized heat pump systems: 1) one using electric resistance baseboard to fill in zones and two heat pumps and 2) one that uses four heat pumps. The second system costs 60% more than the first but the builder perceived no advantage in comfort or efficiency. This may point to a means for cutting HP costs. Another builder constructs ranch homes with fully finished and insulated basements, and insulates the entire house with spray foam, resulting in a very low heating load. He installs one indoor unit per floor and notes that temperature differentials across each floor are low on the order of a few degrees. Presumably, homeowners would need to leave interior doors open for at least a portion of the day.

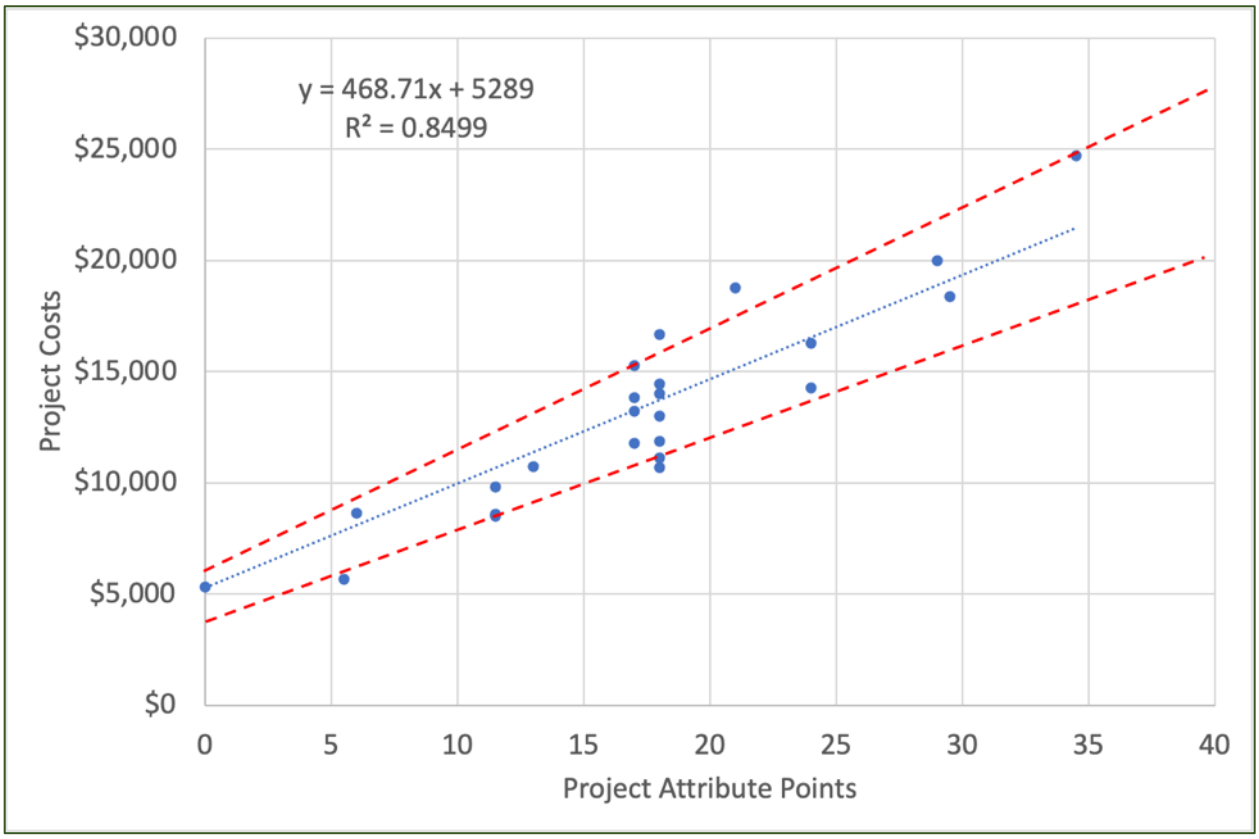
Ductless pricing will vary based on the physical attributes of the system including the capacity of the system, the number of outdoor units, and the number of indoor units. It will also depend on the brand, cold weather ability, and individual pricing attributes of the contractor. We examined the physical attributes using them to build a pricing model. We set the base price to a unit with one indoor unit, one outdoor unit, and 18,000 BTUH of capacity. We built a model that assigns one point for each additional indoor unit, 3 points for each additional outdoor unit, and 1 point for each additional 1,200 BTUH of capacity.

The resulting model predicted pricing well with a linear fit with an R^2 of 0.85. The base price is $5,289, and $469 per point. Essentially each additional outdoor unit costs about $1,407, each additional indoor unit is $469, and each 1,200 BTUH (0.1tons) also costs $469. The bands around the linear fit of the model are relatively tight, roughly about +-20% (Figure 2).

Price = $5,289 + $1,406 (additional outdoor units) +
$469 (additional indoor units) + $4,690 (capacity in tons – 1.5)

Naturally, the pricing of any project will depend on the brand of heat pump, project details, local logistics, and the current market for contractors. The use of this model is to explore the variation of pricing with these basic attributes.

Figure 2. Multi-spilt and Minisplit Pricing Model



Simple Ductless Heat Pumps

We refined our view of ductless heat pumps further, removing those that included mini-ducts and those that had more than four indoor units. This left 14 of the 24 reviewed above. The average project cost is lower than the average for all heat pumps at about $10,200 per project (Table 9). Normalizing for floor area, the average ductless HP system cost is $5.67/SF, less than for all ductless systems. These simpler systems cost less, and they serve slightly smaller homes, with an average floor area of 2,032.

Table 9. Heat Pump Project Pricing for Simple Ductless Heat Pumps

Heat Pumps (n = 14)	Mean	SD	CV
Capacity	29,538	6,226	0.21
Floor Area (Sq. Ft.)	2,032	713	0.35
Indoor Units/outdoor unit	2.82		
DHP Total	$10,244	$2,697	0.26
$/SF DHP Total	$5.67	$2.45	0.43

Cost Differentials

Table 10 summarizes the system costs from the previous sections. The average cost of combi boilers is just over $10,800. Heat pump costs vary widely. Dividing the heat pumps into four categories, average prices range from $10,244 for simple lower priced systems up to nearly $20,100 for ducted systems. The costs normalized per square foot vary similarly. Comparing heat pumps to boilers, the lowest price heat pump systems are similar in cost to boilers, and the 14 simple systems are on average about $1.10 less per square foot. Ducted systems cost quite a bit more at about $1.60/SF more than boilers. All of the system project costs are shown Figure 3.

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Table 10. Heat Pump Project Pricing

System Type	n	min	Mean	max	Cost/SF	Cost/SF vs. Boiler
Combi Boilers	11	$10,817	$6.78	$0	$0.00	Combi Boilers
Simple Ductless	14	$10,244	$5.67	($573)	($1.10)	Simple Ductless
Ductless Heat Pumps	24	$13,140	$6.06	$2,323	($0.71)	Ductless Heat Pumps
All Heat Pumps	29	$14,334	$6.47	$3,517	($0.30)	All Heat Pumps
Ducted Heat Pumps	5	$20,066	$8.40	$9,249	$1.63	Ducted Heat Pumps
Furnaces with AC	1	$22,000	$11.00	$11,183	$4.22	Furnaces with AC

Figure 3. Project Costs by Technology

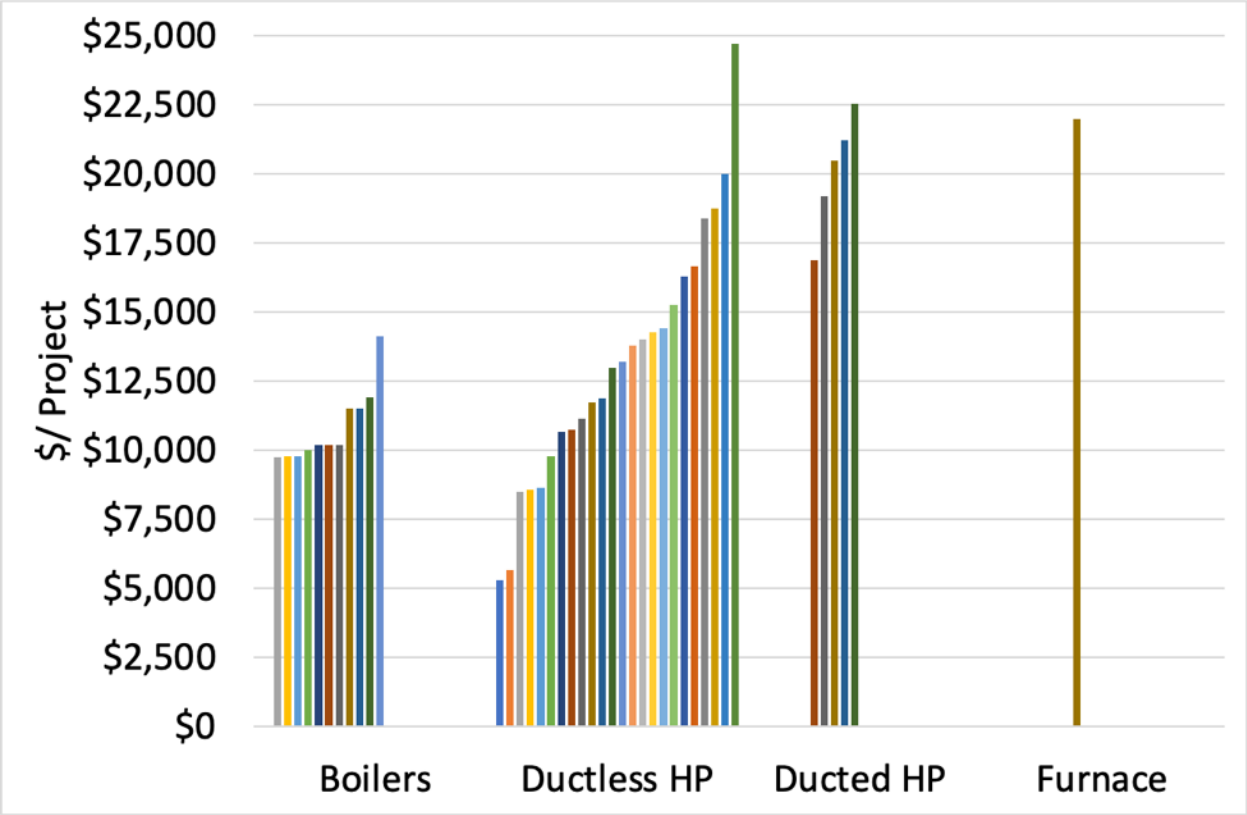
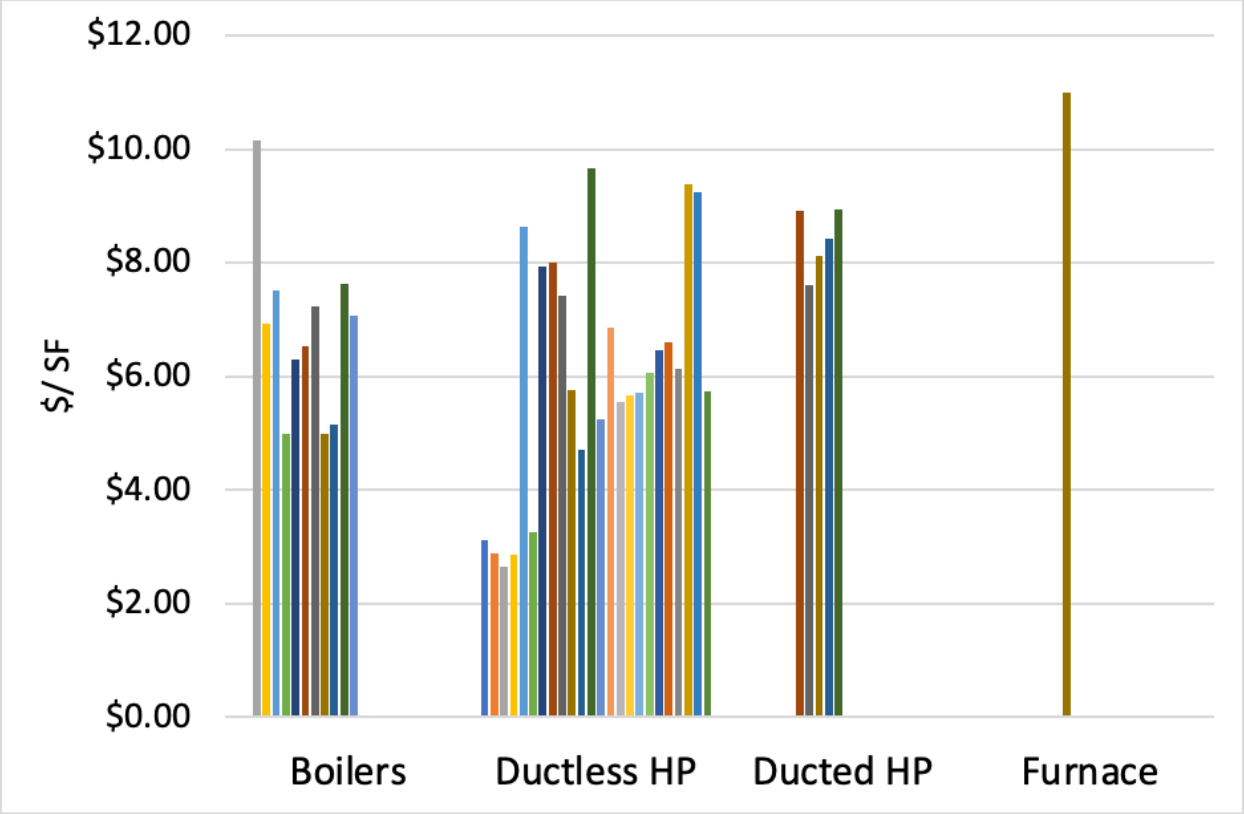


Figure 4 shows the same costs as Figure 3, but the costs are normalized per square foot. They are presented in the same order allowing comparisons between total cost and cost per square foot. Total cost and normalized cost are not necessarily correlated.

Figure 4. Project Costs by Technology Normalized by Square Foot



Cooling Considerations

All of the previous pricing comparisons are based on heating, however, heat pumps also provide cooling. There are several common options for providing cooling where the builder desires to offer it or where the prospective homeowner requests it:

1. Builders that customarily install boilers offer additional heat pumps to provide cooling, where the total cost is obviously greater than boilers or heat pumps alone.
2. Ducted furnace systems can accept an evaporator coil as part of a central air conditioner. Ducted furnaces are among the most expensive systems a builder can install.
3. Heat pumps natively provide cooling and heating.

A current ongoing baseline study found that 46 % of homes or 47 % of non-manufactured homes had cooling installed serving part or all of their floor area, and in most cases that cooling was provided by heat pumps.

A homeowner, after taking possession of a home with heating only, can choose to install relatively inefficient window air conditioners or portable coolers. While the portion of homes where a

homeowner adds portable cooling is not known, a 2018 low-income study of Maine homes found that 53% of homes had one or more window air conditioners[2].

Where a home has a ducted furnace but lacks air conditioning, the homeowner could choose to add a central air conditioner. This situation would be unusual, because most builders view ducted systems as expensive and difficult to install, so if they chose them, they would almost always include cooling.

Incremental Cost for Use in Cost-Effective Analysis

Using the data in previous sections we developed an incremental cost suitable for use in cost-effectiveness analysis. Boiler pricing was relatively straightforward and as shown in Table 11, is tightly grouped with only one outlier. Ductless heat pump costs vary more widely. As shown in Figure 3, there were two lower cost and two higher cost projects that appear distinct from the larger group. We removed those 4 projects and the outlier boiler price, leaving 20 heat pumps and 10 boilers, and calculated the mean and 80% confidence interval. The mean of $12,986, in Table 11, is nearly identical to the mean in Table 10, but the data is more tightly grouped. We show a mean cost difference below of $2,500 and -$0.52/SF.

Table 11. Suggested Summary Pricing Differential Between Boilers and Ductless Heat pumps

System	Mean	Lower 80% CI	Upper 80% CI
Boiler (n = 10)	$10,486	$10,153	$10,818
Ductless (n = 20)	$12,986	$12,098	$13,874
Difference Between Ductless and Boiler (High vs. low)	$2,500	$1,945	$3,056
Boiler ($/SF)	$6.75	$6.11	$7.38
Ductless ($/SF)	$6.23	$5.67	$6.79
Difference Between Ductless and Boiler ($/SF) (High vs. low)	-$0.52	-$0.44	-$0.59

Bottom up Pricing

We examined online pricing for boilers, heat pumps, and distribution system elements to look for pricing themes and as a check on our builder-supplied pricing. The pricing we show is for small quantities for an average contractor. Large volume pricing and the pricing given to preferred, factory trained contractors will be at least 10% lower.

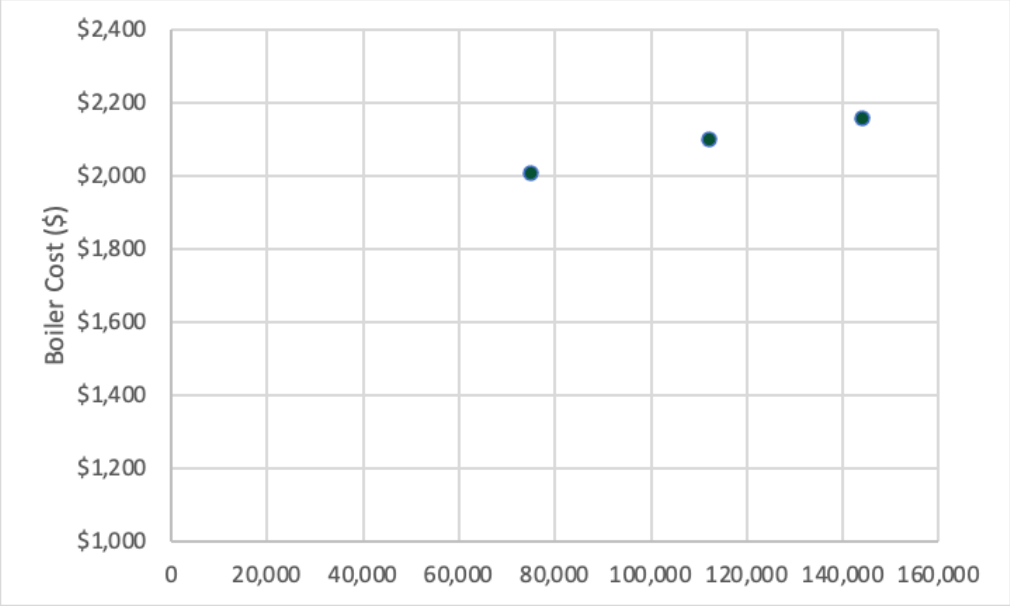
Boilers

Condensing boilers have efficiencies in the 90% to 95% range. Combi models provide instant hot water through a heat exchanger without the need for a storage tank. Prices vary widely by brand, model, and features and are relatively insensitive to size. Within a brand, installed boiler costs vary only moderately with capacity. This could mean that for smaller homes, heat pumps will be more cost-competitive

[2] https://www.maine.gov/meopa/sites/maine.gov.meopa/files/inline-files/Maine_EE_LI_Baseline_%20Study_1.pdf

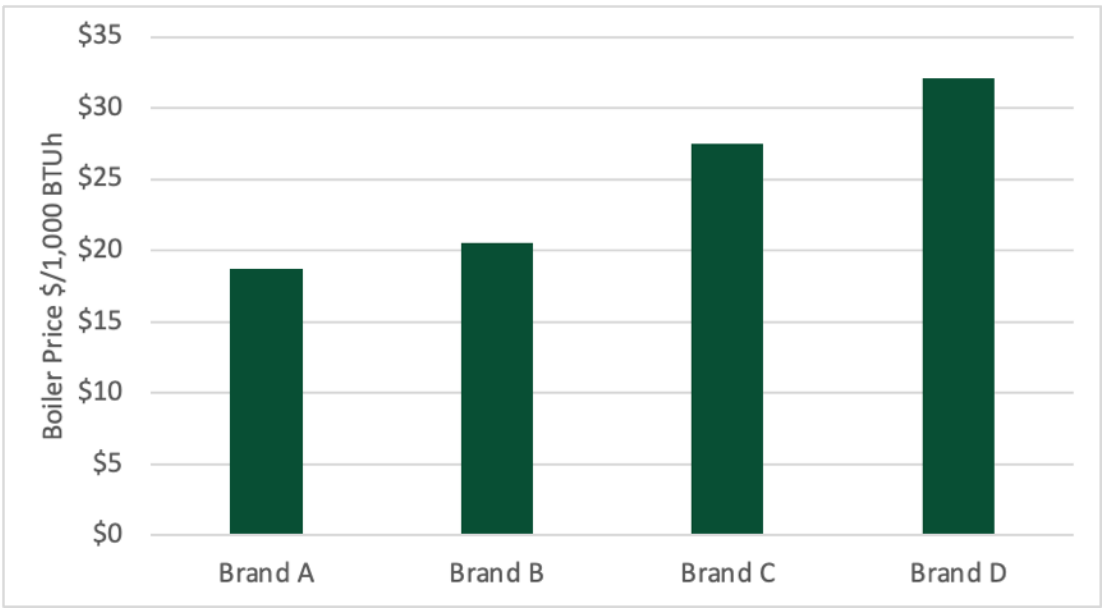
regarding installation costs. Figure 5 shows that for Brand A, nearly doubling the capacity of a combi boiler adds about 10% to the cost of the unit.

Figure 5. Wholesale Brand A Boiler Pricing by Capacity



Prices between brands can vary markedly, however. Figure 6 shows variation in pricing normalized per 1,000 BTUH among four common brands of boilers in the 120,000 BTUH range. The most expensive brand costs 60% more than the least expensive brand.

Figure 6. Wholesale Boiler Pricing by Brand



The average boiler price was about $3,000 and the average cost per 1,000 BTUH was $25 (Table 12).

Table 12. Wholesale Boiler Pricing

Brand	Heating Capacity	AFUE	Zones	Unit cost	Unit cost $/1,000 BTUH
Brand A	112,000	0.95	modulating direct vent	$1,865	$16.65
Brand B	112,000	0.95	modulating direct vent	$2,299	$20.53
Brand C	117,000	0.95	modulating direct vent	$3,329	$28.45
Brand C	134,000	0.95	modulating direct vent	$3,549	$26.49
Brand D	129,000	0.923	modulating direct vent	$4,140	$32.09
			average:	$3,036	$24.84

Pumps and Distribution System

Boilers require fin tube, or similar radiation devices, and zone pumps. Based on a cost of $200 for two pumps, $2,200 for 200 feet of fin tube, and about $1,000 for return piping and parts, the total parts for a boiler system would be about $6,400, nearly identical to three of the projects quoting parts (Table 4).

Heat Pumps

We examined heat pump pricing for both single zone and multi-zone units for several brands and sizes using several websites. We normalized the cost per MBTUH of heating capacity. For single zone units, the cost decreases with increasing capacity and averages about $109/M BTUH (Table 13). Multi-zone units range widely in cost with an average cost per 1,000 BTUH of about $133. Costs vary by brand, capacity, SEER, and HSPF rating. The multi-zone units cost more per BTU because of the cost of additional indoor units and line sets.

Table 13. Single Indoor Unit Heat Pump Equipment Costs

	BTU	SEER	EER	HSPF	Cost	$/MBTUH
Unit 1	9,000	30	16	15.2	$1,469	$163.22
Unit 2	24,000	20	12.5	10	$1,980	$82.50
Unit 3	18,000	23	13	12	$2,000	$111.11
Unit 4	12,000	23	12.5	11	$1,360	$113.33
Unit 5	12,000	27	15	13	$1,620	$135.00
Unit 6	18,000	21	12.5	10.5	$1,790	$99.44
Unit 7	24,000	18	10	10	$1,460	$60.83
Average	16,714	23.1	13.1	11.7	$1,668	$109.35

Examining pricing further we saw a strong correlation between parts cost and rating in SEER (Figure 7), and a similar correlation with HSPF (Figure 8). This may explain, in part, why we saw an average SEER of 20 in the New Construction Baseline Study although units with SEERs above 30 are generally available.

Figure 7. Normalized Single Zone HP Pricing Versus SEER Rating

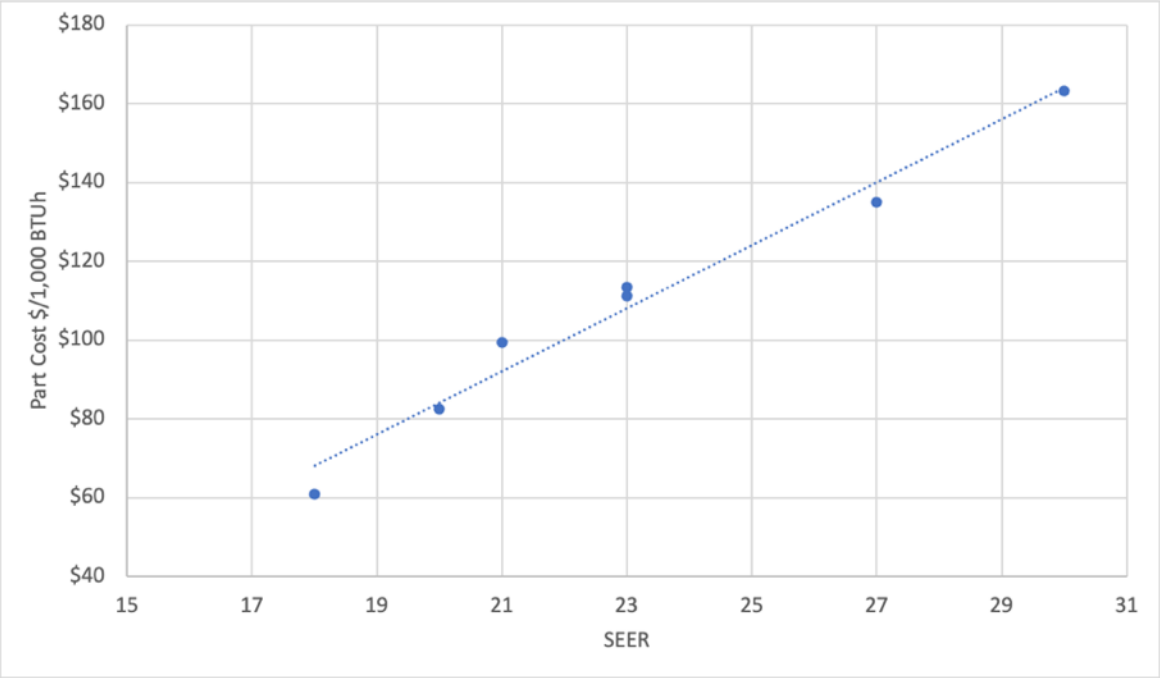
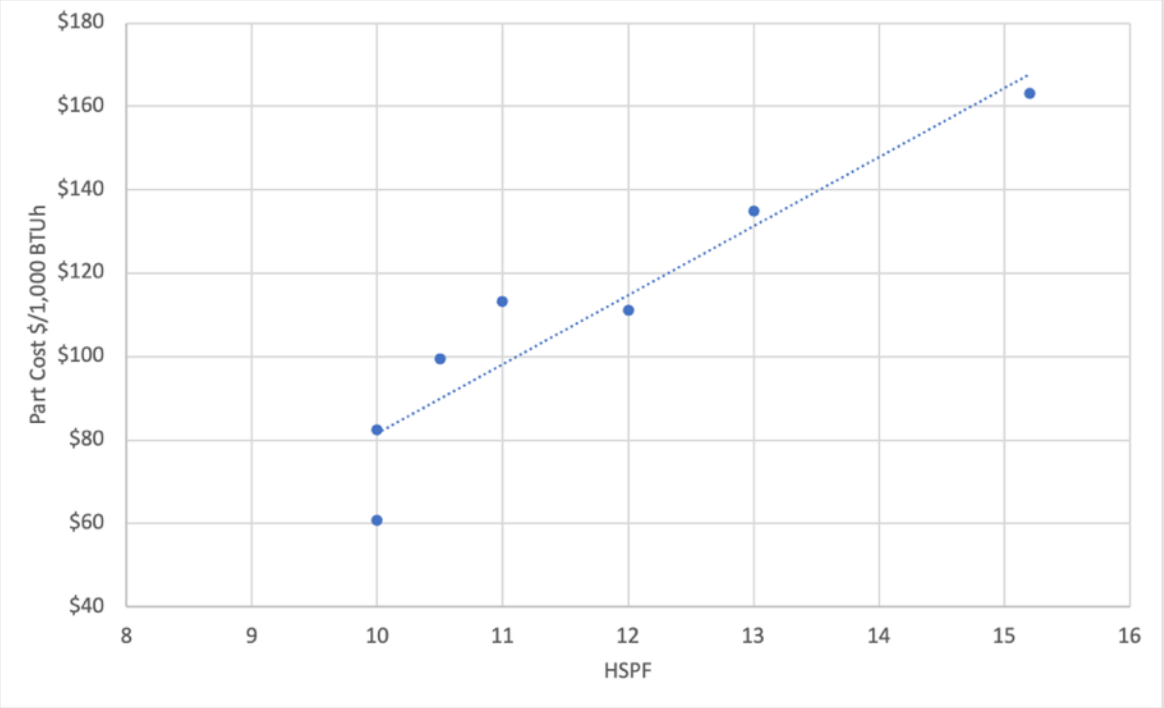


Figure 8. Normalized Single Zone HP Pricing Versus HSPF Rating



A contractor deploying 42,000 BTUH of heat pumps would need about $5,300 for the heat pump, plus additional costs for fittings and other parts. Actual project parts costs were $6,400 - $7,600, where the higher end of the range includes some electric resistance baseboard. The higher actual costs may reflect

higher end units than included in the prices and additional parts, and also might reflect some small pricing margins.

Conclusions

The 2021 Maine New Construction Baseline Study found that for non-manufactured homes, the most popular heating system for new homes is a combi propane boiler, followed by heat pumps, followed by a combination of boilers and heat pumps. The builders interviewed either favored boilers or heat pumps but most installed both systems for various reasons.

Boilers cost less than the average heat pump system, however, for non-ducted systems with few indoor units, boilers cost slightly more per home and over $1.00 more per square foot. Where cooling is desired by a builder or a homeowner, the builder needs to switch to heat pumps or add heat pumps to zones in the boiler-heated home. A home with both a boiler and heat pumps would cost far more than a home heated and cooled with heat pumps alone, so this approach is not commonly pursued for cost reasons. Similarly, a ducted furnace and air conditioner system is expensive and was not favored by the builders that we spoke with from both a cost and difficulty of installation perspective.

Builders did not cite pricing as the reason to install a boiler versus a heat pump. We sensed that builders installing boilers were more comfortable with that technology and that builders that had made the switch to heat pumps were happy with their choice. Experience and comfort with systems are changeable, however. Case in point, a 2008 new construction study showed that at that time, oil systems were dominant, and furnaces were more prevalent. Builders and contractors adapted and changed practices in a relatively short time. It is therefore highly possible that builders will grow in their comfort with heat pumps in coming years. The builders interviewed all recognized that new heat pumps were capable of providing heat even in Maine's cold climate.

Relative to the cost of a newly constructed home, the difference between the cost of a boiler and a heat pump system is small at $2,300. For smaller homes and simpler heat pumps, this cost differential goes to zero. Because a heat pump also provides cooling, anywhere that a builder desires to offer cooling or where customers are requesting cooling, a heat pump system becomes the lowest cost and most efficient alternative.

Attachment A – Builder Interviews

Builder Interview Questions

We interviewed builders to understand how they choose HVAC systems for new homes they build. We asked them a series of questions to understand why they chose particular systems and who had a role in choosing those systems. The questions are listed below.

What HVAC systems have you historically installed in homes that you have built?

- Why did you choose those systems?

What HVAC systems do you currently install?

- Why do you choose those systems?

What systems do you view as providing very good comfort or other user desirable features?

What systems do you view as providing poor comfort or not delivering other user features?

What systems do you view as easy to install, or that require low amounts of builder effort?

What systems do you view as difficult to install, or that require high amounts of builder input, effort?

What systems do you view as durable, or unlikely to result in call backs and complaints?

What systems do you view as prone to problems, or likely to result in call backs and complaints?

Describe the roles of each in choosing the HVAC system

- You, builder
- HVAC subcontractor
- Distributor
- Homeowner
- Homeowner choosing add-ons
- Realtor or other selling agent
- Bank or other lender

Fuel Type

- Propane
- Oil
- Electricity
    - Furnace
    - Boiler
    - Strip
    - Ducted heat pump
    - Ductless heat pump
- Wood

Do you always use natural gas where it is available?

Do you have a preference for oil or propane?

Do you ever install electric boilers, or electric furnaces?

Do you ever install wood systems?

Does fuel cost drive your fuel use decision?

Does eligibility of supply, power outages drive your fuel decision?

Do environmental concerns drive you fuel choice?

Do homeowners, realtors or lenders drive your fuel choice?

System Efficiency

What impacts your efficiency choices?

- Operating cost to homeowner
- Installed cost to you
- Environmental concerns

What systems do you view as efficient?

What systems do you view as inefficient?

For boilers and furnaces, do you have an opinion regarding condensing versus non-condensing systems?

Do you view heat pumps as efficient?

How do you regard heat pump efficiency at low temperatures (<10F)?

We need to follow up on what builders perceive as driving pricing. Aspects include:

- Choice of contractor
- Choice of brand
- Local distributor
- Rebates
- Choice of system details