Cool Smart
Incremental Cost Study:
Final Report

July 2015

Prepared for:

The Electric and Gas Program Administrators of Massachusetts

Part of the Residential Evaluation Program Area

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Notice Regarding How Results of This Study Should Be Used and Interpreted

The purpose of this study is to support energy-efficiency program design and cost-effectiveness analysis, including traditional customer rebates and upstream incentive programs that may be offered by Massachusetts' Program Administrators (PAs). This analysis and its methodology differ greatly from engineering analyses conducted to support the development of mandatory energy conservation standards (such as analyses published by the U.S. Department of Energy (DOE)). Key distinctions include:

- **This analysis focuses on a limited number of products from two manufacturers.** This subset of the market was selected to represent the products that are typically rebated through the Cool Smart program. In contrast, analyses that support energy conservation standards include all manufacturers that make products in a given product class.

- **The component part prices and estimated unit costs in this analysis have not been reviewed with manufacturers.** This analysis relied on estimates of component part prices and comments were not solicited from manufacturers. In contrast, the analyses that support DOE's energy conservation standards incorporate manufacturer input and feedback regarding component prices and unit costs.

- **The Cool Smart rebate program considered in this analysis is a voluntary program and is not market forcing.** This analysis assumes that the production volumes for residential HVAC products are not influenced by Cool Smart rebate levels. In contrast, analyses of mandatory product standards assume that those standards force changes in product markets because they establish mandatory minimum efficiencies for products.

- **For rebating purposes, this analysis evaluates the lowest possible cost to achieve a given efficiency level (i.e., the "efficiency frontier").** In contrast, analyses that quantify the costs and benefits of mandatory efficiency rules use the market shares of various manufacturers to determine the weighted average cost (**not** the lowest possible cost) for the industry to achieve a given efficiency level.

Because of these fundamentally different approaches, the results published in this analysis cannot be compared to the results from analyses supporting mandatory energy conservation standards.

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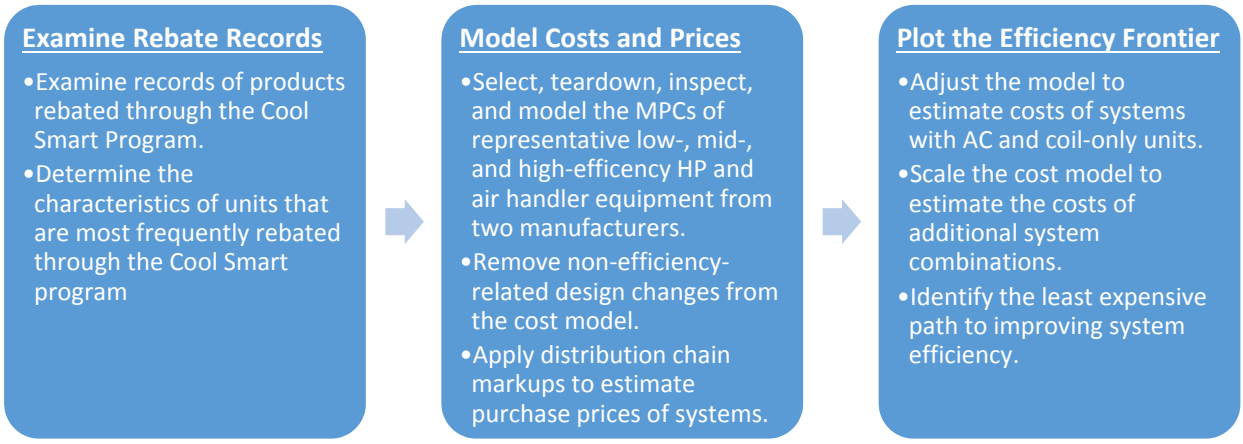
Summary

This incremental cost study estimates how manufacturing production costs (MPCs) and purchase prices of residential air conditioning (AC) and heat pump (HP) equipment change as equipment efficiency increases. The results of this study will support Cool Smart program enhancements and cost-effectiveness analysis, as well as potential upstream residential upstream heating, ventilation and air conditioning (HVAC) incentive programs.

This study used the methodology summarized in Figure 1 to characterize the relationship between efficiency and cost.

Figure 1: Stages of Analysis in the 2015 Cool Smart Incremental Cost Study



The Residential Evaluation Team ("the team") began by examining Cool Smart tracking data provided by the Massachusetts Program Administrators (the PAs). The team analyzed the data to determine the characteristics (manufacturer, equipment class, capacity, and efficiency rating) of units that are most frequently rebated through the Cool Smart program. The team observed that the AC and HP units most frequently rebated by Cool Smart from 2012-2014 had cooling capacity of 2 tons (24,000 BTU/h) and were manufactured by Carrier, Trane, or Lennox.

Based on these observations, the team selected a set of twelve units (six indoor air handler units and six outdoor HP units) for teardown and cost modeling. To best represent the population of recent Cool Smart rebate recipients, the team selected products with cooling capacities of 2 tons refrigeration (24,000 BTU/h) made by Carrier and Lennox.[1] The team selected indoor and outdoor units that can be

[1] Lennox units comprised a modestly smaller portion of the rebate population (19.5%) compared to the portion of the population comprised by Trane units (24.9%). However, data from Trane teardowns are difficult to translate across the rest of the industry, since Trane is the only manufacturer to use spine fin tube heat exchangers. In addition, the Lennox units were more readily available for purchase and teardown than the Trane units. In the equipment category most frequently rebated by Cool Smart (the AC with Blower Coil category), Lennox showed a

paired in different combinations to achieve the efficiency ratings rebated by 2015 Cool Smart Central AC/HP Program (Seasonal Energy Efficiency Ratio (SEER) 16.0 and SEER 18.0), as well as efficiency levels below, above, and between the rebated levels.

The team completely disassembled (tore down) the lowest and highest efficiency unit pairs, inspected the remaining medium efficiency units by removing their service panels and viewing their components, and created bottom-up cost models of all twelve units that were selected. We developed these cost models using assumptions about factory parameters and distribution chain markups published from the 2011 U.S. Department of Energy rulemaking that established minimum efficiency standards for central AC equipment.[2] The output of these cost models includes an estimated MPC and retail purchase price for each unit modeled.

On May 27, 2015, the team hosted a site visit to present preliminary cost estimates resulting from the teardown analysis to the electric PAs and the Energy Efficiency Advisory Council (EEAC) consultants. During the site visit, the team presented observations regarding product upgrades that are frequently bundled into high efficiency units. In the units we examined, we observed that several bundled upgrades (such as louvered cases, sound dampening, and specialty thermostats) increase a unit's production costs without increasing the unit's efficiency. After the site visit, the team received the following feedback from the attendees:

- The cost-efficiency curves developed in this study should omit product upgrades that increase product costs without increasing efficiency.
- Since product markups are different for replacement units compared to new construction units, the team should estimate the proportion of Cool Smart rebates that were given between these two scenarios, and apply markups in a way that reflects that proportion.

In response to this feedback, the team adjusted the manufacturing cost models to exclude features that are not efficiency related, namely louvered or plasticized panel cases/tops, sound dampening, and integration with specialty thermostats. The team could not discern the proportion of Cool Smart rebates awarded for replacement versus new construction, so the team used national estimates of AC and HP shipments for these subgroups. This resulted in a weighted average markup of 2.70; each MPC is multiplied by this weighted average markup to estimate the retail purchase price of the unit.

The team continued the analysis by adapting the cost model to estimate the costs and prices of units that were not physically torn down in this analysis. The team did not conduct teardowns of AC or coil-only units, or of complete systems at the baseline levels of 13.0 SEER for ACs and 14.0 SEER & 8.2 HSPF

similar proportion of rebates (22%) compared to the proportion of Trane rebates (24%). See Tables 9 and 10 in Appendix A.

[2] A full discussion of factory parameter assumptions and a full list of assumptions are publicly available in the Engineering Analysis (Chapter 5) of the 2011 DOE rulemaking regarding central AC equipment, at: http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012

(heating seasonal performance factor) for HPs.[3] To model these units and systems, the team conducted "catalog teardowns" by applying scaling factors to the teardown data and simulating teardowns using catalog information provided by manufacturers. In total, the team used catalog teardowns to model the costs of an additional 79 units based on the original 12 units that were physically torn down or inspected. Cost estimates for these units were combined to produce MPC and price points for more than 450 unique system combinations.

After completing the catalog teardowns described above, the team plotted the resulting cost estimates in a series of cost-efficiency plots, which are presented below and in the Results sections of this report. On each of these charts, the team mapped the "efficiency frontier," which is defined here as the minimum incremental price (above a baseline of 13.0 SEER for ACs and 14.0 SEER & 8.2 HSPF for HPs) required to achieve a given efficiency for the systems that were modeled. The team mapped the efficiency frontier by identifying and recording the lowest cost system at each increment of efficiency gain (e.g., the frontier is mapped at SEER values of 13.0, 13.5, 14.0, and so forth). The team created separate plots for each of the four categories of paired indoor and outdoor products considered in this analysis:

- Air-conditioning outdoor units with an indoor air handler (AC-AH);
- Air-conditioning outdoor units with an indoor coil only (AC-CO);
- Heat pump outdoor units with an indoor air handler (HP-AH); and
- Heat pump outdoor units with an indoor coil only (HP-CO).

Data points generated through catalog teardowns may not have the same level of confidence as data points generated by physical teardown data alone, so the tables and charts of results in this report distinguish between data points generated from teardown and catalog data. Each set of incremental cost results has up to four sources of data. Figures 2, 3, 4, and 5 below note systems where:

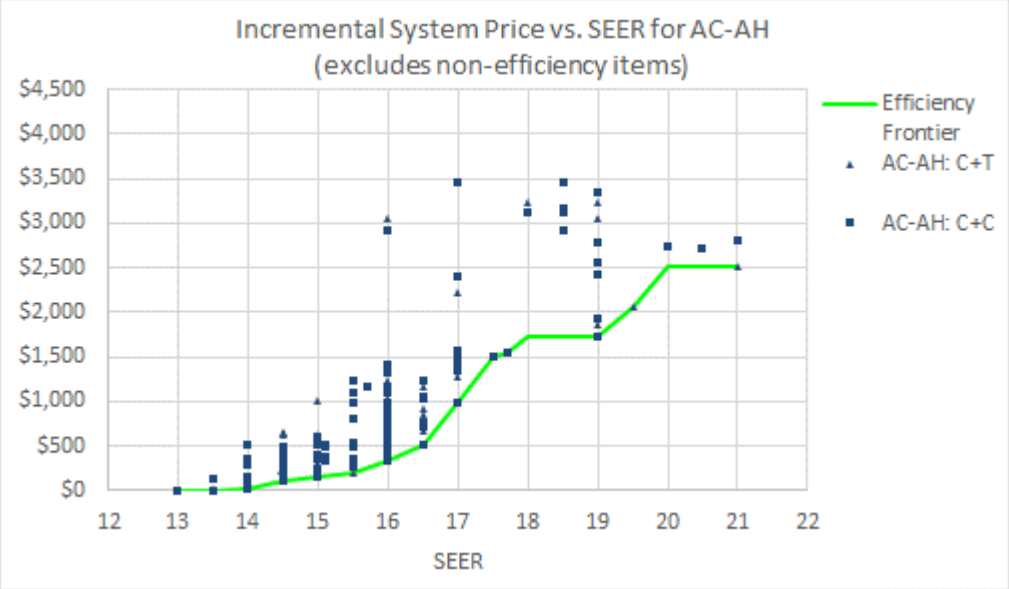
- Both the outdoor and indoor units were directly torn down or inspected (T+T);
- The outdoor unit was torn down/inspected and the indoor unit was modeled with catalog data (T+C);
- The outdoor unit was modeled using catalog data and the indoor unit was torn down/inspected (C+T); and
- Both the outdoor and indoor units were modeled using catalog data (C+C).

The incremental prices presented in the cost-efficiency plots represent the price increase above the least expensive baseline system in each category, at 13.0 SEER for ACs and 14.0 SEER & 8.2 HSPF for HPs.

[3] This analysis assumes that the baseline efficiency levels for residential HVAC products sold in Massachusetts are the federal minimum efficiency standards currently in place, which effective January 1, 2015, are SEER 13.0 for AC and SEER 14.0 / HSPF 8.2 for HPs, as described in Table 3 at: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

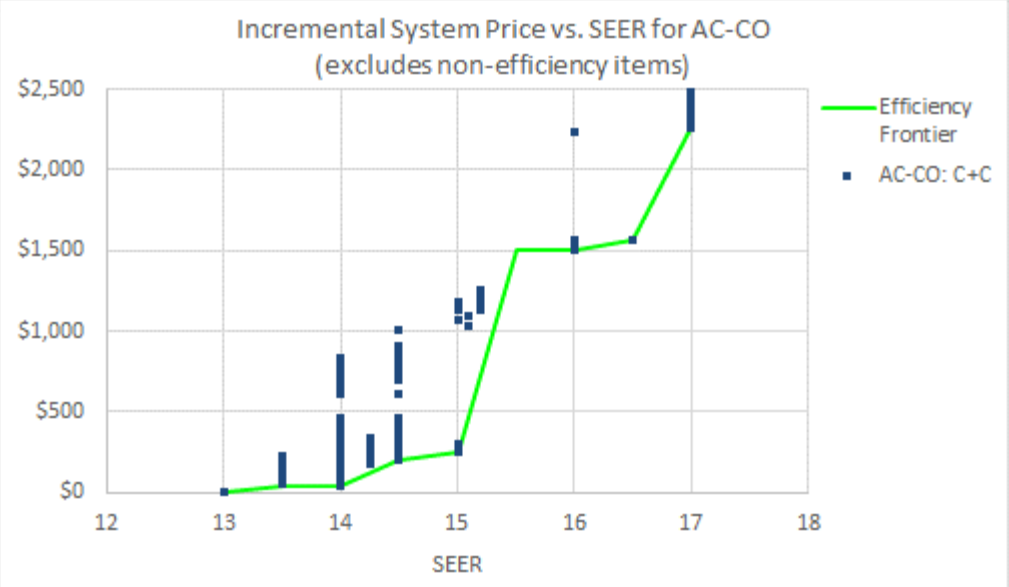
The Methodology and Results sections of this report provide a detailed breakdown of these results, as well as cost-efficiency charts based on energy efficiency ratio (EER) and heating seasonal performance factor (HSPF) ratings.

Figure 2: Incremental System Cost Curve for AC-AH as Function of SEER



Efficiency Frontier	
SEER	**Incremental Price**
13.5	$0
14.0	$13
14.5	$109
15.0	$147
15.5	$207
16.0	$325
16.5	$522
17.0	$993
17.5	$1,496
17.7	$1,552
18.0	$1,725
18.5	$1,725
19.0	$1,725
19.5	$2,056
20.0	$2,506

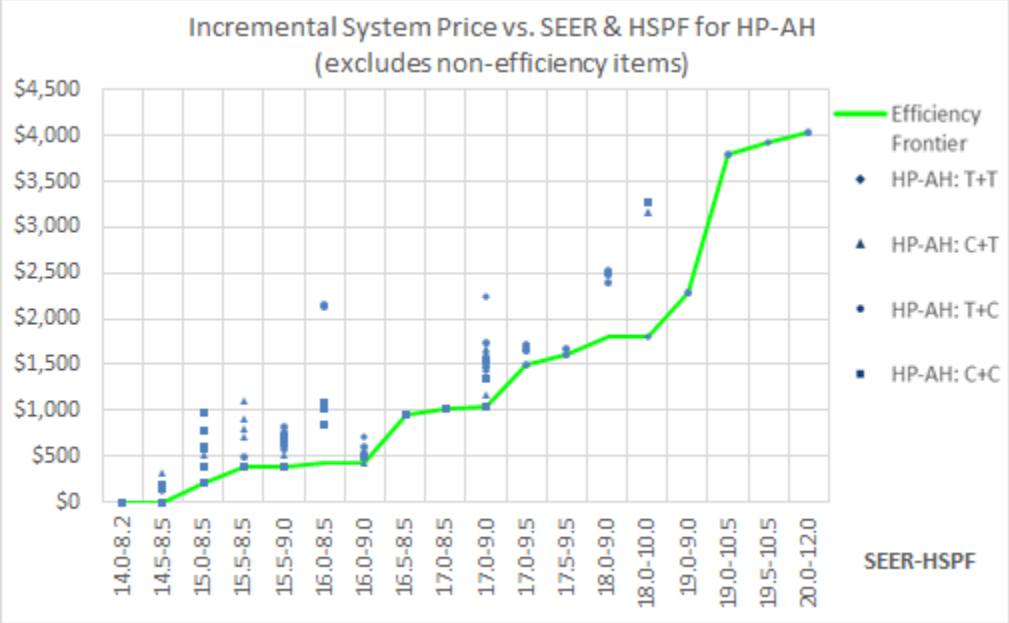
Figure 3: Incremental System Cost for AC-CO as Function of SEER[4]



Efficiency Frontier	
SEER	**Incremental Price**
13.5	$38
14.0	$38
14.5	$204
15.0	$256
15.5	$1,502
16.0	$1,502
16.5	$1,566
17.0	$2,264

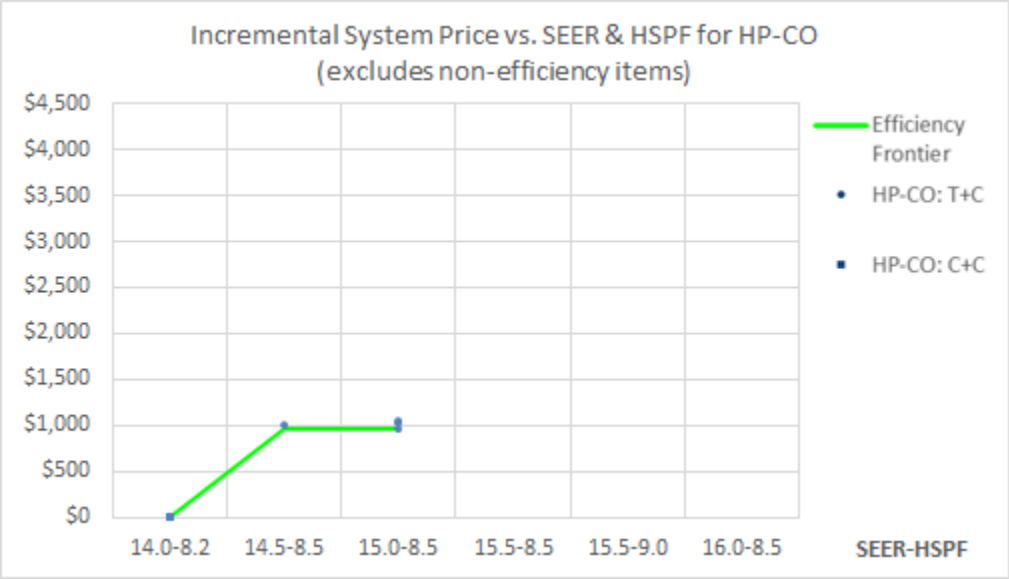
[4] Systems with indoor coil-only units do not exceed SEER ratings of 17.0. Indoor coil-only units require the circulation blower in a furnace or similar device to function. Because coil-only units are rated in test setups using less efficient permanent split capacitor (PSC) fan motors, systems with coil-only units typically cannot achieve SEER ratings higher than those of systems with air-handlers (which can take advantage of an electronically-commutated motor).

Figure 4: Incremental System Cost Curve for HP-AH as Function of SEER and HSPF



Efficiency Frontier	
SEER-HSPF	**Incremental Price**
14.5-8.5	$0
15.0-8.5	$200
15.5-8.5	$379
15.5-9.0	$379
16.0-8.5	$431
16.0-9.0	$431
16.5-8.5	$954
17.0-8.5	$1,007
17.0-9.0	$1,034
17.0-9.5	$1,501
17.5-9.5	$1,608
18.0-9.0	$1,808
18.0-10.0	$1,808
19.0-9.0	$2,294
19.0-10.5	$3,794
19.5-10.5	$3,925
20.0-12.0	$4,033

Figure 5: Incremental System Cost Curve for HP-CO as Function of SEER and HSPF[5]



Efficiency Frontier	
SEER	**Incremental Price**
14.5-8.5	$963
15.0-8.5	$963

[5] Two-ton heat pump systems with indoor coil-only units from Lennox and Carrier do not exceed ratings of 16.0 SEER or 9.0 HSPF. See previous footnote for explanation. In addition, there are few available ratings for HP-CO systems manufactured by Lennox and Carrier, which limits our analysis of their incremental costs.

Methodology

This section describes the methodology of the 2015 Cool Smart Incremental Cost Study. The analytical stages of this study are summarized above in Figure 1 and detailed in the sub-sections that follow.

Examination of Cool Smart Rebate Population

The purpose of this study is to model the incremental costs of improving efficiency in the residential central AC and HP equipment that are rebated by the Cool Smart program. The team began by examining Cool Smart tracking data provided by the Massachusetts Cool Smart PAs. The team analyzed the data to determine the characteristics (manufacturer, equipment class, capacity, and efficiency rating) of units that are most frequently rebated through the Cool Smart program.

The team determined that the AC and HP units most frequently rebated by Cool Smart from 2012-2014 had the following characteristics (percentages indicate the percent of Cool Smart rebate records for which the relevant information was available[6]):

- Equipment class of air conditioner (82.0%) or heat pump (18.0%);
- Manufactured by Carrier (37.1%), Trane (24.9%), Lennox (19.5%), Goodman (7.3%), or other (11.3%);
- Cooling capacity[7] of 2.0 tons (35.0%), 2.5 tons (23.1%), 1.5 tons (14.1%) or other (27.8%); and
- Efficiency level[7] of SEER 16.0 (47.1%), SEER 15.0 (11.7%), SEER 16.5 (8.3%) or other (32.9%).

These results enabled the team to select units that represent the Cool Smart market. A detailed analysis of the Cool Smart rebate record data is presented in Appendix A.

Product Selection, Teardown, and Cost Modeling

Based on the examination of Cool Smart rebate records, the team selected a set of twelve units (six indoor air handler units and six outdoor HP units) for teardown and cost modeling. To best represent the population of recent Cool Smart rebate recipients, the team selected products with cooling capacities of 2 tons refrigeration (24,000 BTU/hr) made by Carrier and Lennox[8]. The team selected

[6] Some rebate records that the team received did not contain all four data of interest (equipment type, manufacturer, capacity, and efficiency). The percentages reported here indicate the percent of Cool Smart rebate records for which the relevant information was available. For instance, of all the records that named a manufacturer (37.4% of all total records), 37.1% listed the manufacturer as Carrier or one of Carrier's licensed brands. Based on the sample sizes for which different data types are available, the team believes that these percentages are representative of the Cool Smart rebate population as a whole.

[7] To create comparable data bins, the team rounded cooling capacities down to the nearest 0.5 tons cooling and efficiency levels down to the nearest 0.5 SEER.

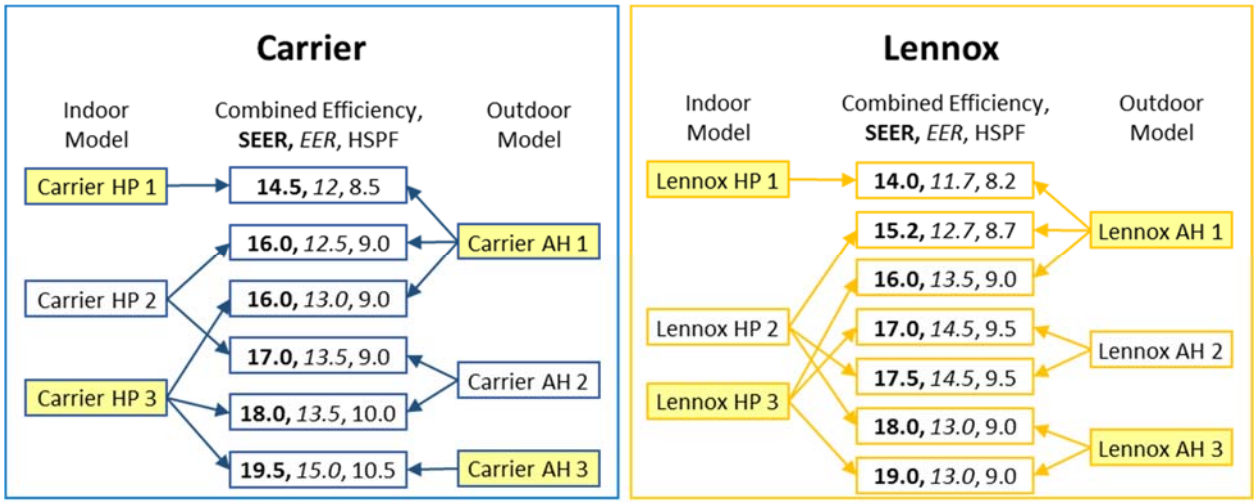
[8] Lennox units comprised a modestly smaller portion of the rebate population (19.5%) compared to the portion of the population comprised by Trane units (24.9%). However, data from Trane teardowns are difficult to translate across the rest of the industry, since Trane is the only manufacturer to use spine fin tube heat exchangers. In addition, the Lennox units were more readily available for purchase and teardown than the Trane units. In the equipment category most frequently rebated by Cool Smart (the AC with Blower Coil category), Lennox showed a

indoor and outdoor units that can be paired in different combinations to achieve the efficiency ratings rebated by 2015 Cool Smart Central AC/HP Program (SEER 16.0 and SEER 18.0), as well as efficiency levels below, above, and between the rebated levels. The team selected combinations of heat pump condensers and air handlers for teardowns because the costs of AC units and indoor coil-only units can be readily estimated based on teardown data from HPs and indoor air handlers.

To select the specific product models for teardown, the team used certification data from the AHRI Directory of Certified Product Performance.[9] Where possible, the team selected models within a given product line or platform whose construction does not change in meaningful ways from one efficiency level to another other than to accommodate efficiency-related changes (such as larger heat exchangers).

Figure 6 presents the selected units[10] and the AHRI-rated efficiencies of their different pairings. As illustrated, the selected units may be combined in different system pairings to achieve a wide range of rated efficiency levels. The team completely disassembled (tore down) the lowest and highest efficiency unit pairs (the eight units indicated in Figure 6 by yellow highlights), and inspected the remaining four medium efficiency units by removing their service panels and viewing their components.

Figure 6: Equipment Selected for Teardown Analysis (Highlight Indicates Destructive Teardown)



Based on the teardown data, additional measurements, and manufacturer catalog data, the team created bottom-up cost models of all twelve units that were selected. These cost models contain detailed bills of materials that delineate the dimensions, materials, and value adding operations performed on every component piece of each machine. This information is then used to estimate the costs of materials, labor, capital, depreciation, and overhead needed to produce a unit at a given manufacturing volume of each model.

similar proportion of rebates (22%) compared to the proportion of Trane rebates (24%). See Tables 9 and 10 in Appendix A.

[9] The AHRI Directory is available online at: https://www.ahridirectory.org/ahridirectory/pages/home.aspx

[10] The model numbers of individual units have been anonymized for this report.

In this analysis, the assumed baseline efficiency levels for residential HVAC products sold in Massachusetts are equal to the Federal minimum energy conservation standards currently in place. Effective January 1, 2015, these minimum standards are 13.0 SEER for central air conditioners and 14.0 SEER & 8.2 HSPF for central heat pumps.[11] To extend the reach of this analysis down to the baseline level for air conditioners, the team estimated the cost of lower-efficiency models using information from manufacturer catalogs regarding the dimensions, components, and efficiency ratings of models that have similar construction to the selected models.

To facilitate the cost model calculations, it was necessary to make certain estimates regarding the factories in which these products are manufactured. In particular, the annual factory production volume will affect the manufacturer's purchasing power and the per-unit depreciation costs of equipment (such as brazing equipment and presses) used to fabricate components that are installed across multiple product or model lines. Similarly, the annual model production volume affects the per-unit depreciation costs of tooling (such as dies and molds) used to fabricate components specific to a particular model. The residential AC and HP equipment modeled in this study are produced in United States factories with the parameters (and their estimated values) described in Table 1.[12]

Table 1: Factory Parameter Assumptions for Residential AC, Heat Pump, and Coil Equipment

Factory Parameter	Residential AC and HP Estimate
Annual Factory Production Volume	1,250,000 units per year
Annual Model Unit Volume	1,000,000 for low-efficiency models 200,000 for mid-efficiency models 50,000 for high-efficiency models
Assembly Shifts Per Day	2 shifts
Fabrication Shifts Per Day	2.5 shifts
Fabrication/Assembly Labor Wages	$16 per hour
Burdened Fabrication/ Assembly Labor Wage	$24 per hour
Building Cost	$177 per square foot
Supervisor Span	25 workers per supervisor
Market Prices of Materials	The cost of raw materials was determined using prices for copper, steel, and aluminum from the American Metals Market.[13] This analysis used a 5-year average in material prices from 2010–2015, so material price increases are normalized to better represent long-term material prices.

[11] Current Federal minimum energy conservation standards are described in Table 3 at: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

[12] Carrier has some assembly facilities in Mexico, but we estimate that the per-unit cost advantage of using those facilities would be small, and we have therefore not included them in this analysis. For residential AC and HP equipment, the labor costs associated with equipment assembly are typically less than 5% of the total MPC.

[13] American Metals Market. Available online at http://www.amm.com/. (Last accessed June 2015)

The team based the assumptions in Table 1 on publicly available analysis from the 2011 DOE rulemaking that established minimum efficiency standards for central AC equipment.[14] The building cost of $177 per square foot reported in Table 1 has been adjusted to account for inflation using producer price indices from the Bureau of Labor Statistics (BLS).[15] The unburdened wage of $16 per hour has not been adjusted, since hourly wage data from the BLS indicate that, in the industrial subsector of HVAC and commercial refrigeration equipment manufacturing, wages of production and nonsupervisory employees showed little increase from 2011 to 2014.[16] As indicated in the second row of Table 1, we estimated the production volumes of low-efficiency units are about twenty times higher than the production volumes of high-efficiency units.[17] We based this assumption on observations of the proportion of equipment certified at different efficiency levels in the AHRI Directory of Certified Product Performance.[18]

Removal of Non-Efficiency-Related Design Changes

Aside from estimating the production costs of different systems, the team also considered the design choices that manufacturers make in the higher efficiency models that they offer. During the teardown analysis, the team observed that many design choices directly affect equipment efficiency, but some choices are more cosmetic in nature. Table 2 and Table 3 show how different design aspects changed from lower efficiency models to mid-efficiency and higher efficiency models, with those features that appear not to be efficiency-related listed in ***bold italics***.

As expected, the indoor and outdoor heat exchangers are larger in higher efficiency systems. Larger heat exchangers allow more heat transfer, which improves efficiency. Another trend the team observed is that, as system efficiency increases, there is an increase in motor power and a shift from permanent split capacitor (PSC) motors to electronically commutated motors (ECM). These two motor styles have the following characteristics:

[14] A full discussion of factory parameter assumptions and a full list of assumptions are publicly available in the Engineering Analysis (Chapter 5) of the 2011 DOE rulemaking regarding central AC equipment, at: http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012

[15] U.S. Bureau of Labor Statistics. Available online at http://www.bls.gov/. (Last accessed June 2015)

[16] U.S. Bureau of Labor Statistics. Employment, Hours, and Earnings from the Current Employment Statistics survey. Series Id: CEU3133340008. Available online at http://data.bls.gov/pdq/querytool.jsp?survey=ce. (Last accessed July 2015)

[17] This assumption differs from the approach used in DOE rulemakings. DOE efficiency standards force changes in product markets because they establish mandatory minimum efficiencies for products. To account for these forced market changes, DOE evaluates efficiency levels above the baseline by assuming that once a standard is promulgated, baseline production volumes would be converted (or would "roll up") to production volumes at the new minimum efficiency level. The Cool Smart rebate program considered in this analysis is a voluntary program and is not market forcing. The assumption here that production volumes vary with efficiency level is appropriate for this analysis of non-mandatory product rebates.

[18] The AHRI Directory of Certified Product Performance contains certification records of different combinations of indoor and outdoor AC and HP equipment. Though the number of records in the database is not a direct indicator of sales volume, analysts often use the proportions of records in the database as a proxy for market share.

- PSC motors are driven by alternating current (AC) power and in the horsepower range used in residential HVAC applications, they achieve around 60% efficiency, in terms of converting electric power to mechanical work.
- ECMs are more expensive, but they achieve higher motor efficiencies up to 80%. ECMs typically incorporate permanent magnets and rely on electronics to vary the frequency that a 3-phase motor is supplied with to adjust its speed.
- Depending on the electronics driving them, ECMs may use different control strategies (constant torque or constant speed) to vary air flow. ECMs with constant speed controls are typically found in higher-end equipment, where their wider range of air flow speed benefits the measured efficiency of the equipment.

Table 2: Incremental Design Changes in Carrier Systems, from Lower to Higher Efficiency

Efficiency	Outdoor Unit (HP)	Indoor Unit (Air Handler)

Lower	• Single-stage compressor
	• PSC fan motor at 0.03 hp
	• Heat exchanger:
	  o Copper tube & aluminum fin
	  o 1 tube row, 20.4 ft^2 area
	• ***Wireframe case***
		• Fan Motor: ECM X13 at 0.33 hp
		• No integrated controls
		• Heat exchanger
		  o Aluminum tube & aluminum fin
		  o 3 tube rows, 2.2 ft^2 area

Medium	• Upgrade to 2-stage compressor
	• Upgrade motor to ECM at 0.20 hp
	• Heat exchanger:
	  o Add 2nd tube row
	  o Increase area by 23%
	• ***Louvered panel case***
	• ***Add sound blanket***
		• Upgrade motor to ECM 2.3 at 0.50 hp
		• HX: Increase area by 56%

Higher	• Upgrade to variable speed compressor
	• Increase motor power to 0.33 hp
	• Heat exchanger:
	  o Increase area by 8.5%
	• ***Louvered panel case***
	• ***Add 2nd sound blanket***
		• Upgrade motor to ECM 3.0 at 0.50 hp
		• Heat exchanger: No change
		• Controls:
		  o PC board for monitoring & control
		  o ***Required integration with Carrier touch-screen thermostat***

Table 3: Incremental Design Changes in Lennox Systems, from Lower to Higher Efficiency

Efficiency	Outdoor Unit (HP)	Indoor Unit (Air Handler)
Lower	• Single-stage compressor • PSC fan motor at 0.17 hp • Heat exchanger: o Copper tube & Aluminum fin, o 1 tube row, 21.0 ft^2 area • ***Sound dampening jacket*** • ***Louvered panel case***	• Fan Motor: PSC at 0.33 hp • No integrated controls • Heat exchanger: o Aluminum tube & Aluminum fin o 3 tube row, 3.6 ft^2 area
Medium	• Upgrade motor to ECM at 0.33 hp • Heat exchanger: o Add 1 tube row o Decrease area by 2% • ***Sound dampening jacket*** • ***Louvered panel case***	• Increase motor power to 0.50 hp • Heat exchanger: o Increase thickness by 25%
Higher	• Upgrade to 2-stage compressor • Fan motor: No change. • Heat exchanger: No change • ***Add sound isolation chamber*** • ***Louvered panel case***	• Upgrade motor to ECM at 0.50 hp • Heat exchanger: o Increase area by 13%

The team also observed that compressors change from 1-stage to 2-stage and then (for Carrier) to variable-speed in higher efficiency equipment. Compressors with multiple stages or variable speeds can change their output for part-load conditions, which increases equipment's SEER rating. Because part-load conditions predominate in SEER testing, a variable speed system will usually perform better than a 1-stage or 2-stage system. Under EER test conditions, however, staging or variable-speed operation is unlikely to offer any measured benefit.

The team observed other changes that may not impact efficiency:

- At the medium- and higher-efficiency levels, Carrier switches from a wireframe case to a louvered panel case. A louvered panel case uses more material and increases cost without improving efficiency. The louvered panels may actually reduce efficiency by increasing the pressure drop that an outdoor unit fan motor needs to overcome.
- Carrier bundles sound dampening blankets with its medium- and higher-efficiency units. Sound blankets increase costs without improving efficiency.
- For its higher-end models, Carrier requires that models be integrated with its touchscreen Infinity thermostat. This can improve comfort by providing more consistent humidity and temperature control, but it is unclear if such controls improve system efficiency, as measured by the SEER and EER metrics.

Similar to Carrier, Lennox made design changes that may not impact efficiency:

- Lennox bundles casing upgrades in its medium- and higher-efficiency models.
- Lennox switches from pressed metal outdoor unit case tops to injection molded plastic tops.
- Lennox bundles sound dampening technology into all of the units we examined. Lennox includes a compressor jacket with its lower- and medium-efficiency models, and then switches to an insulated metal compressor chamber for its higher-efficiency model.
- Lennox offers a touchscreen thermostat option, but for the units we examined, they do not require it.

The intent of this study is to isolate and examine the cost of increasing energy efficiency in residential AC an HP systems. Therefore, the team adjusted the manufacturing cost models to exclude features that are not efficiency related, namely louvered or plasticized panel cases/tops, sound dampening, and integration with specialty thermostats.

Distribution Chain Markups

The cost modeling methodology yields an estimate of the MPCs incurred by manufacturers on a per-unit basis. The purchase price paid by consumers will be significantly higher than the manufacturers' production costs because of the price markups applied along the distribution chain. Here, the total markup is defined as a multiplier that converts the MPC of a product to the consumer purchase price for the product.[19]

The distribution channels are different for replacement of existing systems compared to new construction. As illustrated in Table 4, the equipment replacement scenario includes a 26% markup by the manufacturer, a 36% markup by the wholesaler, and a 38% markup by a mechanical contractor, in addition to a sales tax. These markups are multiplied to give a total overall markup of 2.53, meaning that consumers will typically pay a purchase price of 2.53 times the MPC for replacement equipment. In the new construction scenario, a general contractor also applies a 48% markup and sales tax is not applied, so the total markup for new construction products is 3.25. The team based these markup assumptions on publicly available analysis from the U.S. Dept. of Energy's 2011 rulemaking that establishes minimum efficiency standards for central AC equipment.[20]

[19] This assumption differs from the approach used in DOE rulemakings. DOE's analysis applies two markups: a baseline markup to baseline equipment MPCs, and an incremental markup to incremental costs above the baseline MPCs. DOE takes this approach because (as described in a previous footnote) its product standards are market forcing and its analysis predicts the resulting prices in an altered product market. The Cool Smart rebate program is voluntary and will not significantly alter the market for HVAC products, so it is appropriate to use one single markup in this analysis.

[20] A full discussion of distribution chain markups is publicly available in the Markups Analysis (Chapter 6) of the 2011 DOE rulemaking regarding central AC equipment, available at: http://www.regulations.gov/contentStreamer?documentId=EERE-2011-BT-STD-0011-0012&attachmentNumber=7

The Cool Smart program allows rebates for equipment in either a new construction scenario or an equipment replacement scenario. This analysis applies a weighted average markup to reflect the proportion of products that are installed in each scenario. The team could not discern the proportion of Cool Smart rebates awarded for replacement versus new construction scenarios, so the team used estimates of AC and HP shipments at the national scale.[21] The shipments analysis conducted in the 2011 DOE rulemaking for residential AC equipment indicates that in 2015, about 77% of residential AC and HP equipment will be installed as replacement equipment, while about 23% will be installed in new construction.[22] This yields the weighted average markup of 2.70 presented in Table 4.

Table 4: Distribution Chain Markups for AC and HP Equipment

	Baseline Markup	
Distribution Link	**New Construction**	**Replacement**
Manufacturer	1.26	1.26
Wholesaler	1.36	1.36
Mechanical Contractor	1.28	1.38
General Contractor	1.48	n/a
Sales Tax	n/a	1.07
Total Markup	**3.25**	**2.53**
Weighted Average Markup	**2.70**	

Cost Model Scaling and Catalog Teardowns

At this point in the analysis, the team had modeled the MPCs and purchase prices of the twelve teardown or inspected units (six heat pumps and six air handlers) that could pair in thirteen different system combinations ranging from 14.0 SEER to 19.5 SEER and 8.2 HSPF to 10.5 HSPF. The team did not conduct teardowns of AC or coil-only units, or of complete AC systems at the 13.0 SEER baseline level (baseline for AC systems). To model the costs of AC and coil-only units, and to extend the analysis down to the baseline of 13.0 SEER (the baseline for AC systems) and up to 20.0 SEER, the team applied scaling factors to the teardown data and simulated teardowns using catalog information provided by manufacturers. The methodology for catalog teardowns is described below.

[21] The application form for the Cool Smart rebate program includes a question that asks applicants to indicate whether their equipment is being purchased to replace old equipment or to be installed in new construction. However, applicants are not required to answer this question and, as a result, there is insufficient data to reliably estimate the proportion of Cool Smart rebates that are awarded in MA for use in replacement or new construction.

[22] The Shipments Analysis (Chapter 9) of the 2011 DOE rulemaking regarding central AC equipment is available at: http://www.regulations.gov/contentStreamer?documentId=EERE-2011-BT-STD-0011-0012&attachmentNumber=10

Using the AHRI Directory of Certified Product Performance, the team identified different system combinations of indoor and outdoor products that meet the criteria specified for this analysis. That is, the systems identified were manufactured by Carrier or Lennox and were rated at roughly 2 tons of cooling capacity. The team identified systems in four categories of paired indoor and outdoor products:

- Air-conditioning outdoor units with an indoor air handler (AC-AH);
- Air-conditioning outdoor units with an indoor coil only (AC-CO);
- Heat pump outdoor units with an indoor air handler (HP-AH); and
- Heat pump outdoor units with an indoor coil only (HP-CO).

The team retrieved publicly available product specification data for each system identified.[23] This specification data describes the key aspects of the indoor and outdoor units in the identified systems. In particular, the team noted the unit dimensions, heat exchanger dimensions, motor ratings and configurations, and key components from the manufacturer specification sheets. The team applied scaling factors to the cost model that adjust the sheet metal dimensions, heat exchanger dimensions, and other characteristics. In addition to modeling the changes in material costs, the cost model accounts for changes in process times that depend on unit and component dimensions. For example, the model accounts for the fact that a larger heat exchanger will require more materials, more labor, and more tool time to fabricate.

Using catalog teardowns, the team simulated teardowns of outdoor AC units and indoor coil-only units. The team modeled the costs of outdoor AC-only units by scaling the heat exchanger and sheet metal as appropriate, substituting component parts as necessary, and removing heat-pump-related parts such as accumulators and reversing valves from the cost model. Similarly, indoor coil-only units were modeled by removing the blower and electrical section of an air handler and scaling sheet metal and heat exchangers as necessary. The team also simulated teardowns of additional heat pump and air handler units that were not physically torn down in this analysis.

In total, the team used catalog teardowns to model the costs of an additional 79 units based on the original 12 units that were physically torn down or inspected. Cost estimates for these units can be combined to produce MPC and price points for more than 450 unique system combinations. However, data points generated through catalog teardowns likely have a lower level of confidence (i.e., higher uncertainty) as data points generated by physical teardown data, so the tables and charts in the Results section of this report distinguish between data points generated from teardown and catalog data. In particular, data points for outdoor AC units, indoor coil units, and most systems modeled at the highest efficiency levels (e.g., above SEER 19 for AC-AH systems) are largely derived from only catalog data and therefore have a higher level of uncertainty.

[23] Carrier and Lennox publish product specification sheets online at the following web addresses:
http://www.catalog.residential.carrier.com/wcs/model_search/0,2732,CLI1_DIV41_ETI4931,00.html
http://www.lennoxcommercial.com/technical-documents/product-specifications.asp

After completing the catalog teardowns described above, the team plotted the resulting cost estimates in a series of cost-efficiency plots, which are presented in the Summary and Results sections of this report. On each of these charts, the team mapped the "efficiency frontier," which is defined here as the minimum incremental price (above a 13.0 SEER baseline for ACs and a 14.0 SEER & 8.2 HSPF baseline for HPs) required to achieve a given efficiency for the systems that were modeled. The team mapped the efficiency frontier by identifying and recording the lowest cost system at each increment of efficiency gain (e.g., the frontier is mapped at SEER values of 13.0, 13.5, 14.0, 14.5, and so forth).

Results

Cost Estimates

The estimates of MPC, purchase price, and incremental prices resulting from this study are listed in Appendix B for all of the system combinations modeled. The incremental retail prices for the different equipment categories are depicted graphically in the following figures:

- Figure 7 through Figure 10 depict incremental retail prices related to SEER;
- Figure 11 through Figure 14 depict incremental retail prices related to EER;
- Figure 15 and Figure 16 depict incremental retail prices related to HSPF (HP only); and
- Figure 17 and Figure 18 depict incremental retail prices related to both SEER and HSPF (HP only).[24]

Each set of incremental cost results has up to four sources of data, and the figures note systems where:

- Both the outdoor and indoor units were directly torn down or inspected (T+T);
- The outdoor unit was torn down/inspected and the indoor unit was modeled with catalog data (T+C);
- The outdoor unit was modeled using catalog data and the indoor unit was torn down/ inspected (C+T); and
- Both the outdoor and indoor units were modeled using catalog data (C+C).

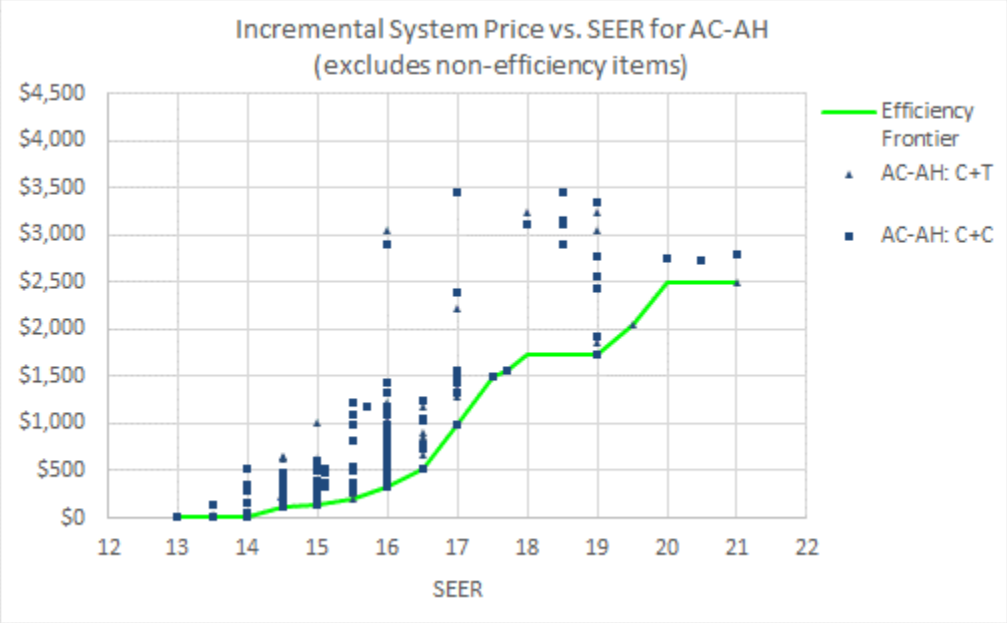
The EER of a cooling system, expressed in BTU/Watt-hour, is the ratio of output cooling energy (in BTU) to input electrical energy (in Watt-hours) at a single operating point. EER is measured at full-load operation in 95°F outdoor ambient conditions. The SEER is also expressed in BTU/Watt-hour, but instead of being evaluated at a single operating condition (namely, a single outdoor temperature), the SEER metric measures performance at a variety of conditions, including part-load operation. SEER ratings represent the overall expected performance of a cooling system for a typical year. The HSPF is analogous to the cooling measurement SEER but is used for determining the heating performance. It is also expressed in BTU/Watt-hour. The HSPF metric measures performance at a variety of conditions, including part-load operation. HSPF ratings represent the expected overall performance of an air source heat pump for a typical heating season's weather. Appendix B lists the AHRI-certified SEER, EER, and HSPF ratings used in this analysis.

The incremental prices presented in the cost-efficiency plots represent the price increase above the least expensive baseline system (at 13.0 SEER for ACs and 14.0 SEER & 8.2 HSPF for HPs) for each manufacturer in each category. For example, the incremental prices illustrated for AC-AH systems describe the incremental price above the prices of the least expensive AC-AH systems rated at 13.0 SEER

[24] Because the federal minimum efficiency standard for HPs (baseline) is based on both SEER and HSPF ratings, Figure 17 and Figure 18 are prepared to depict the incremental retail prices of HP systems that may be offered rebates according to both ratings.

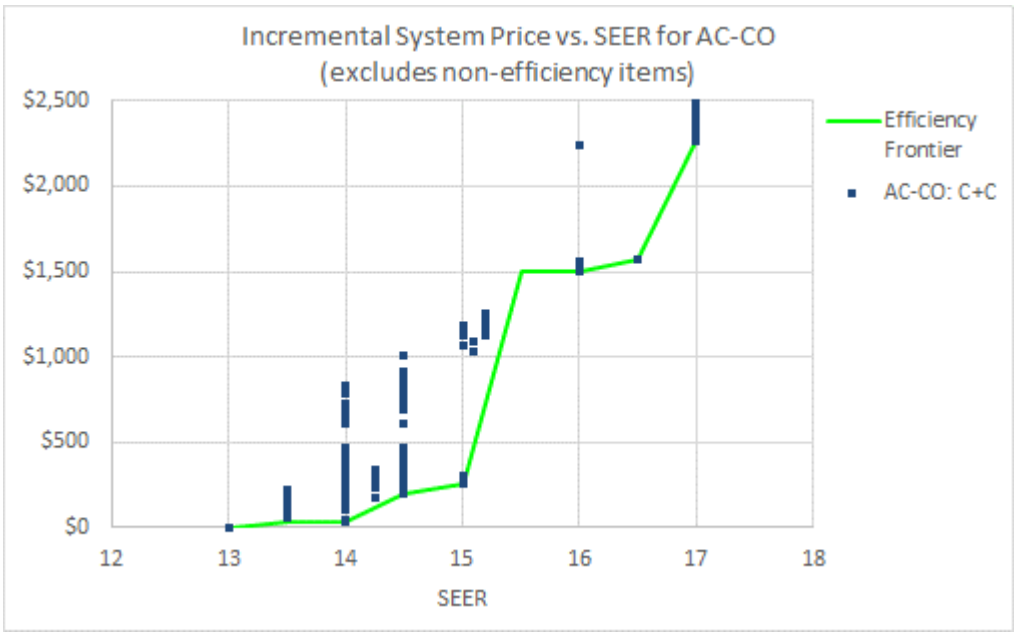
from each manufacturer. The efficiency frontier is plotted as a green line on the charts in this report, and it depicts the minimum incremental system price a consumer will have to pay to obtain a system that is more efficient than the baseline of 13.0 SEER for ACs or 14.0 SEER & 8.2 HSPF for HPs. At some efficiency levels (such as 18.0 SEER in Figure 7), the least expensive system has a higher estimated price than systems at a higher efficiency level. In these cases, the efficiency frontier follows the lowest prices at higher efficiency levels. The incremental cost curves presented in this report must be used with caution because they omit costs of features that are not efficiency related (such as sound blankets, specialty thermostats, and upgraded cases). The equipment costs presented here will appear low compared to current equipment on the market since manufacturers frequently bundle non-efficiency-related features, especially in high-efficiency units.

Figure 7: Incremental System Cost Curve for AC-AH as Function of SEER



Efficiency Frontier	
SEER	**Incremental Price**
13.5	$0
14.0	$13
14.5	$109
15.0	$147
15.5	$207
16.0	$325
16.5	$522
17.0	$993
17.5	$1,496
17.7	$1,552
18.0	$1,725
18.5	$1,725
19.0	$1,725
19.5	$2,056
20.0	$2,506

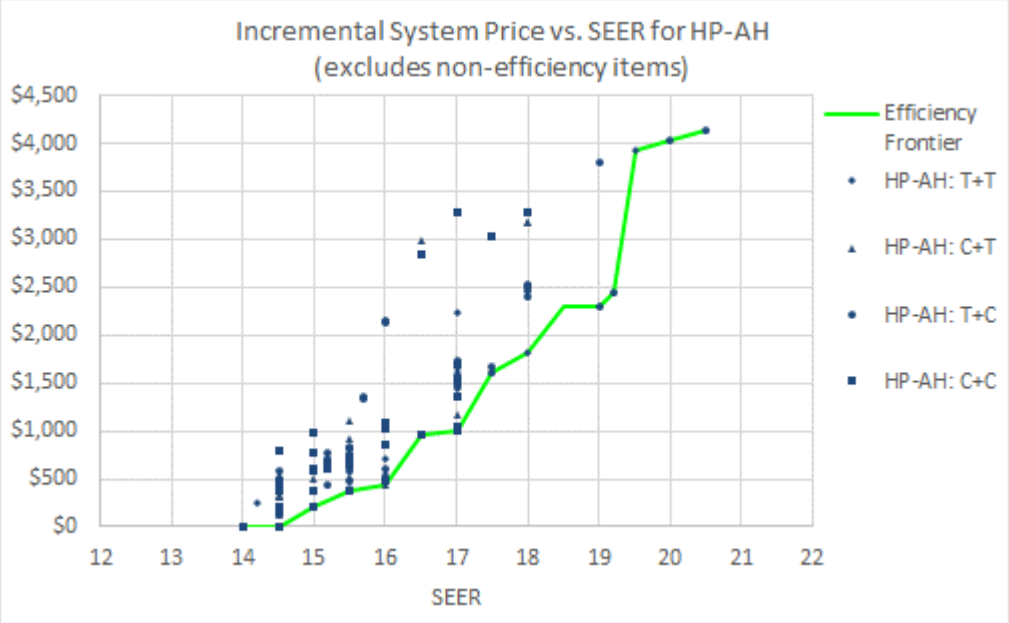
Figure 8: Incremental System Cost for AC-CO as Function of SEER[25]



Efficiency Frontier	
SEER	**Incremental Price**
13.5	$38
14.0	$38
14.5	$204
15.0	$256
15.5	$1,502
16.0	$1,502
16.5	$1,566
17.0	$2,264

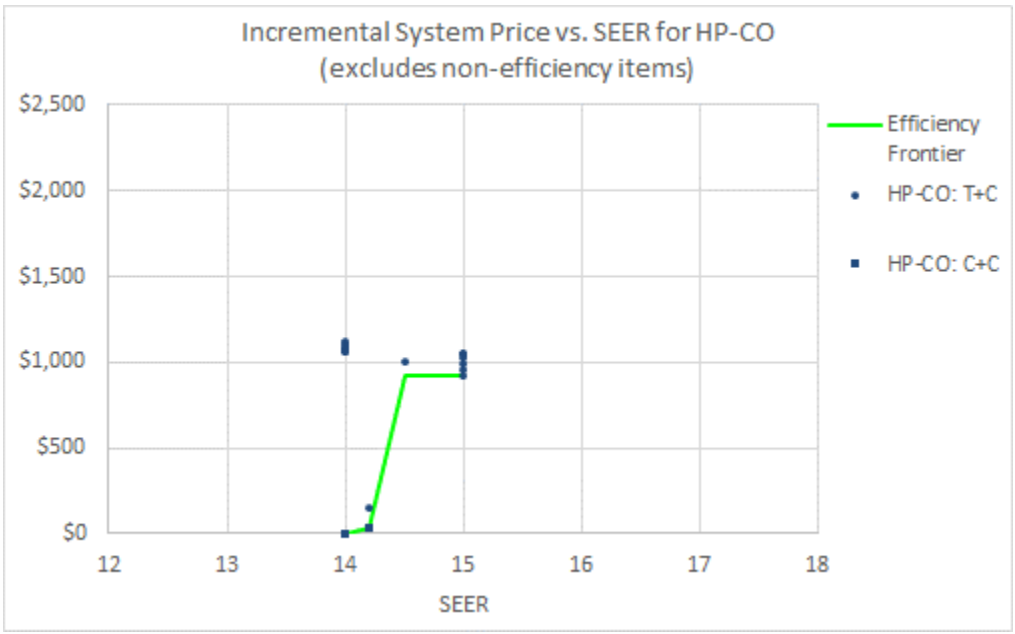
[25] Systems with indoor coil-only units do not exceed SEER ratings of 17.0. Indoor coil-only units require the circulation blower in a furnace or similar device to function. Because coil-only units are rated in test setups using less efficient permanent split capacitor (PSC) fan motors, systems with coil-only units typically cannot achieve SEER ratings higher than those of systems with air-handlers (which can take advantage of an electronically-commutated motor).

Figure 9: Incremental System Cost Curve for HP-AH as Function of SEER



Efficiency Frontier	
SEER	**Incremental Price**
14.5	$0
15.0	$200
15.5	$379
16.0	$431
16.5	$954
17.0	$1,007
17.5	$1,608
18.0	$1,808
18.5	$2,294
19.0	$2,294
19.2	$2,453
19.5	$3,925
20.0	$4,033

Figure 10: Incremental System Cost Curve for HP-CO as Function of SEER[26,27]

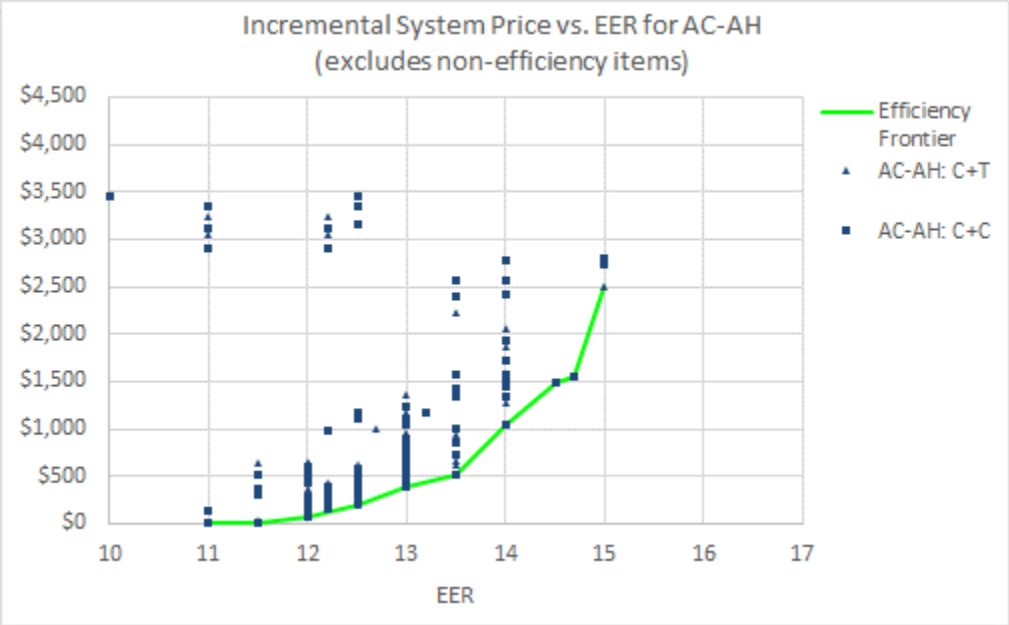


Efficiency Frontier	
SEER	**Incremental Price**
14.2	$40
14.5	$926
15.0	$926

[26] Two-ton heat pump systems with indoor coil-only units from Lennox and Carrier do not exceed ratings of 16.0 SEER or 9.0 HSPF. See previous footnote for explanation. In addition, there are few available ratings for HP-CO systems manufactured by Lennox and Carrier, which limits our analysis of their incremental costs.

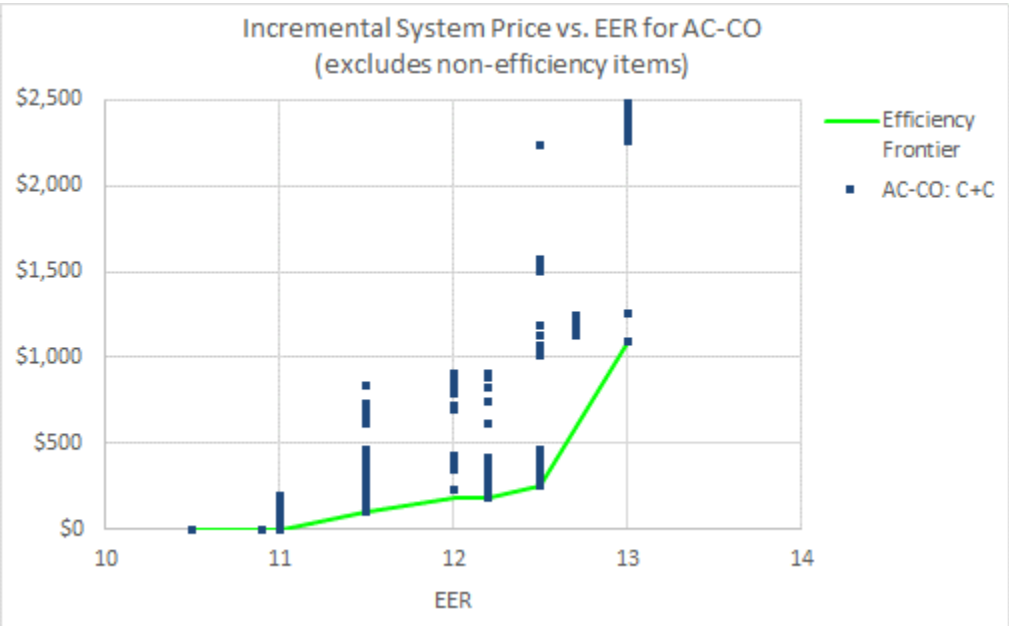
[27] The baseline for HP-AH and HP-CO systems is at 14.0 SEER and 8.2 HSPF. In this figure, several 14.0 SEER systems show a positive incremental cost because they have HSPF ratings above the baseline of 8.2 HSPF.

Figure 11: Incremental System Cost Curve for AC-AH as Function of EER



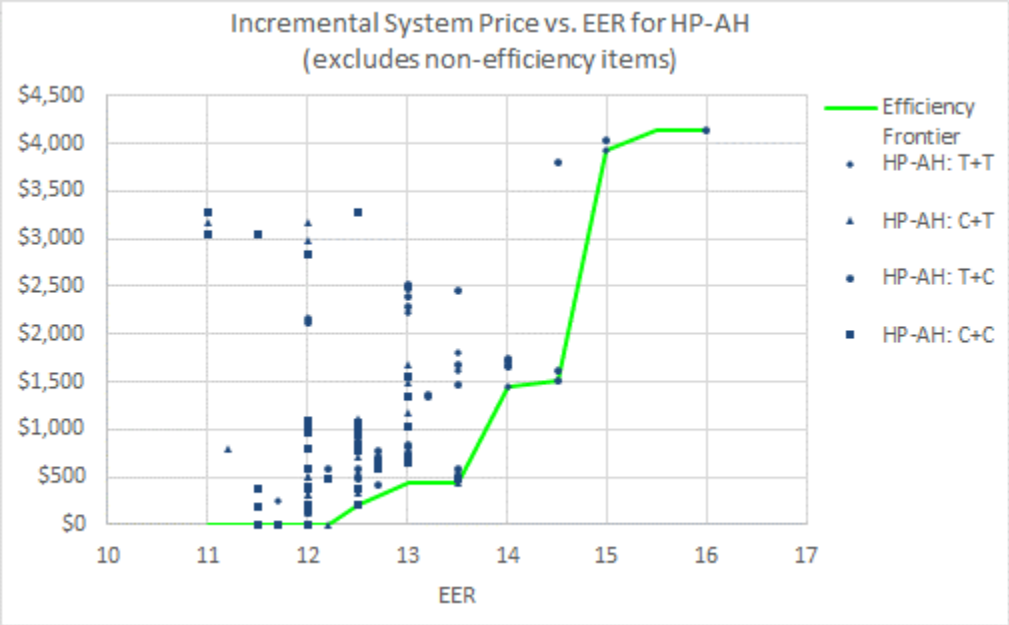
Efficiency Frontier	
EER	**Incremental Price**
11.0	$0
11.5	$0
12.0	$61
12.5	$207
13.0	$396
13.5	$522
14.0	$1,049
14.5	$1,496
14.7	$1,552
15.0	$2,506

Figure 12: Incremental System Cost for AC-CO as Function of EER



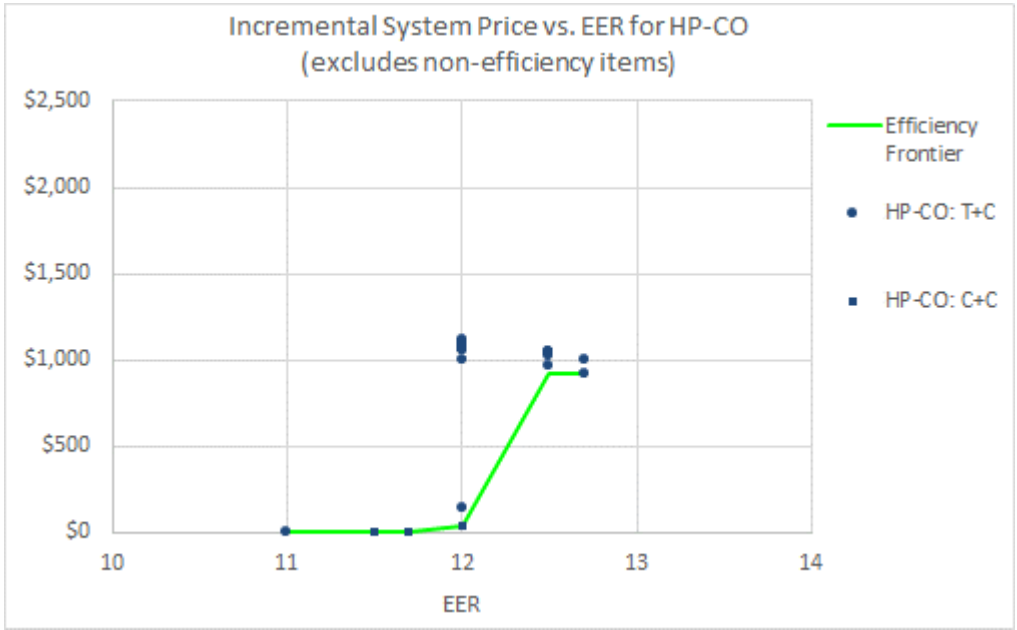
Efficiency Frontier	
EER	**Incremental Price**
11.0	$0
11.5	$102
12.0	$184
12.2	$184
12.5	$256
13.0	$1,088

Figure 13: Incremental System Cost for HP-AH as Function of EER



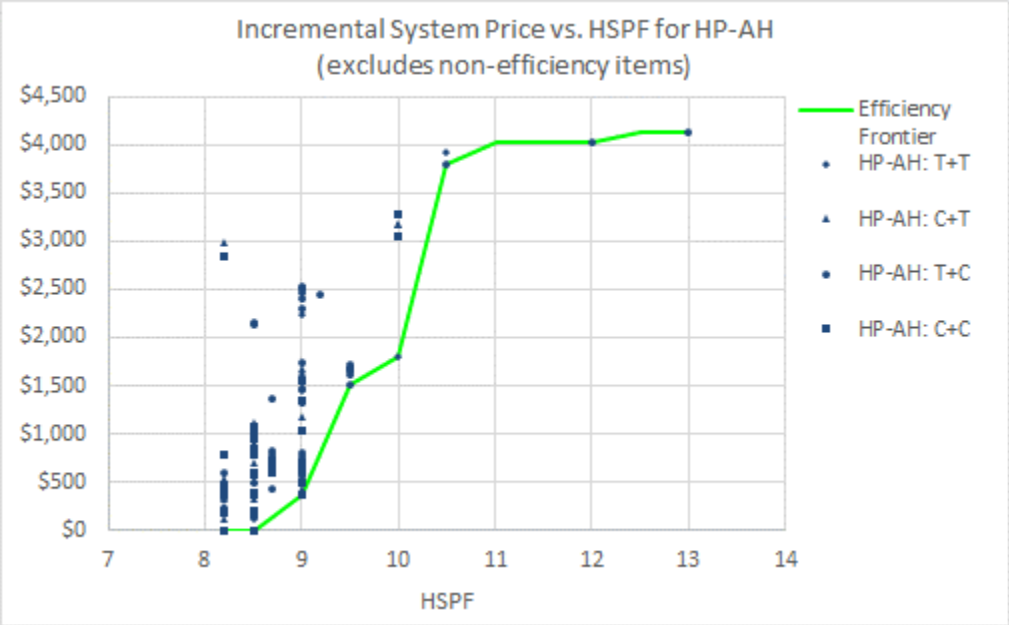
Efficiency Frontier	
EER	**Incremental Price**
11.0	$0
11.5	$0
12.0	$0
12.2	$0
12.5	$200
13.0	$431
13.5	$431
14.0	$1,443
14.5	$1,501
15.0	$3,925
15.5	$4,128
16.0	$4,128

Figure 14: Incremental System Cost for HP-CO as Function of EER



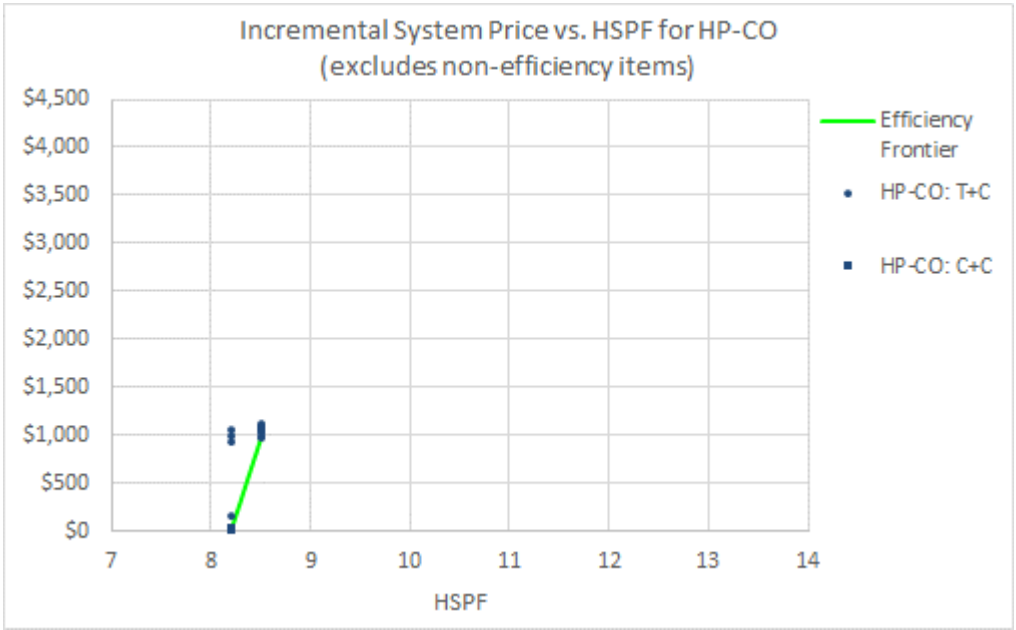
Efficiency Frontier	
EER	**Incremental Price**
11	$0
11.5	$0
11.7	$0
12	$40
12.5	$926
12.7	$926

Figure 15: Incremental System Cost for HP-AH as function of HSPF[28]



Efficiency Frontier	
HSPF	**Incremental Price**
8.5	$0
9	$379
9.5	$1,501
10	$1,808
10.5	$3,794
11	$4,033
11.5	$4,033
12	$4,033
12.5	$4,128
13	$4,128

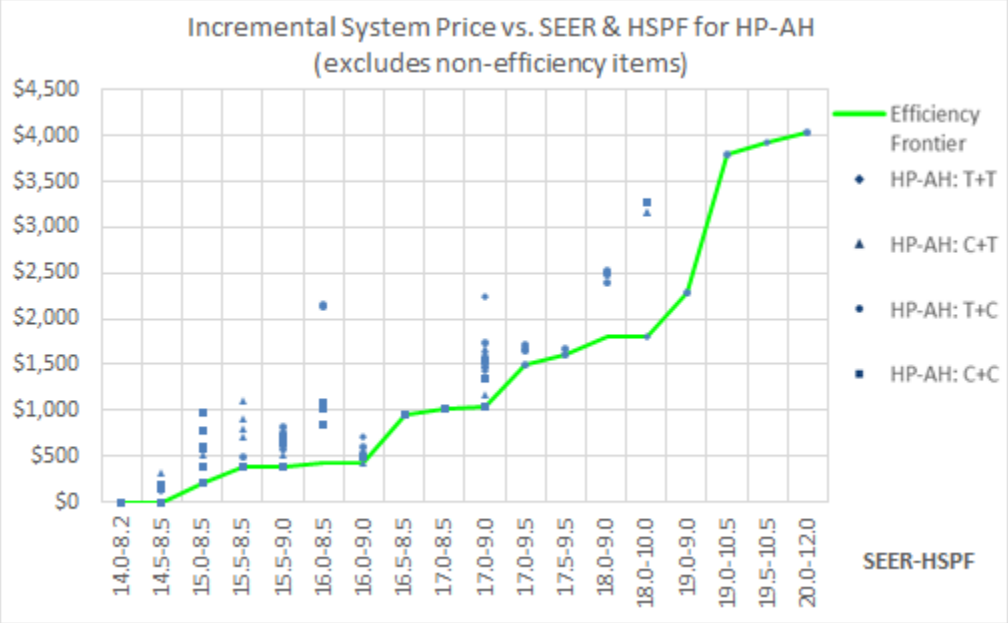
Figure 16: Incremental System Price for HP-CO as function of HSPF[28]



Efficiency Frontier	
HSPF	**Incremental Price**
8.5	$963

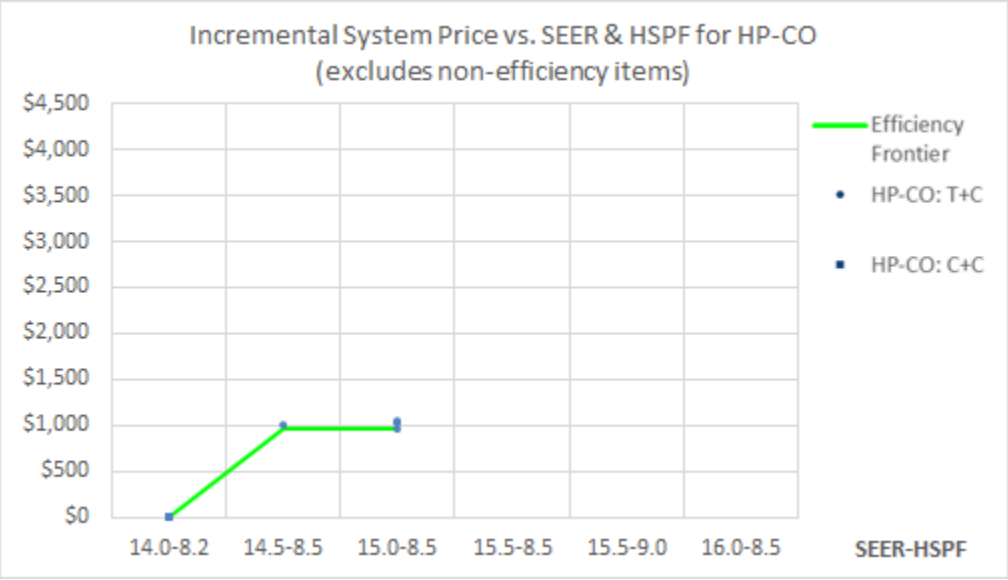
[28] The baseline for HP-AH and HP-CO systems is at 14.0 SEER and 8.2 HSPF. In Figure 15 and Figure 16, several systems at 8.2 HSPF show a positive incremental cost because they have SEER ratings above the baseline of 14.0 SEER.

Figure 17: Incremental System Cost Curve for HP-AH as Function of SEER and HSPF



Efficiency Frontier	
SEER-HSPF	**Incremental Price**
14.5-8.5	$0
15.0-8.5	$200
15.5-8.5	$379
15.5-9.0	$379
16.0-8.5	$431
16.0-9.0	$431
16.5-8.5	$954
17.0-8.5	$1,007
17.0-9.0	$1,034
17.0-9.5	$1,501
17.5-9.5	$1,608
18.0-9.0	$1,808
18.0-10.0	$1,808
19.0-9.0	$2,294
19.0-10.5	$3,794
19.5-10.5	$3,925
20.0-12.0	$4,033

Figure 18: Incremental System Cost Curve for HP-CO as Function of SEER and HSPF[29]



Efficiency Frontier	
SEER	**Incremental Price**
14.5-8.5	$963
15.0-8.5	$963

[29] Two-ton heat pump systems with indoor coil-only units from Lennox and Carrier do not exceed ratings of 16.0 SEER or 9.0 HSPF. See previous footnote for explanation. In addition, there are few available ratings for HP-CO systems manufactured by Lennox and Carrier, which limits our analysis of their incremental costs.

Observations

Overall, the prices followed expected trajectories (i.e., the incremental prices generally increase with efficiency level), as they reflect the incremental costs of integrating features to increase system efficiency, such as increased or upgraded heat exchangers, compressors, and fan motors.

Manufacturers can trade off a number of variables to create a more energy efficient combination of indoor and outdoor units. For example, to improve EER performance, manufacturers may increase heat exchangers, select high-efficiency single-stage compressors, and/or improve the blower technology used. For improvements that the SEER metric measures, manufacturers can opt for multi-stage compressors, variable-speed compressors, and refrigerant control strategies.

As systems are designed, manufacturers can trade off these variables to arrive at a unit combination that meets the needs of their customers. For example, a customer with limited installation space for an outdoor unit and a desire for a high-SEER system may prefer an outdoor unit with a variable-speed compressor and a (relatively speaking) smaller enclosure. However, on an EER basis, such systems may perform similar to entry-level units (see Figure 9 and Figure 11, for example). We observed that manufacturers typically raised system efficiency from the baseline to 16 SEER by upgrading fan motors and increasing heat exchanger area. There are diminishing returns to heat exchanger growth, though. A heat exchanger can only grow so much until the refrigerant inside it derives little benefit from additional surface area (i.e. the refrigerant is already exiting the heat exchanger near ambient air temperature). Larger heat exchangers also require larger and more costly blower systems.

Above 16 SEER, the units in the data set generally use two-stage compressors, but there is overlap with single-stage systems. The SEER cost curve steepens at this point as two-stage compressors incur a significant cost premium over single-stage units. There is no EER benefit from switching to a two-stage compressor. Two-stage compressors can be found in systems with up to 21 SEER rating for AC-AH and 19 SEER for HP-AH unit combinations. For variable-speed compressor systems there is also an area of overlap with 2-stage compressor systems.[30]

Some high-efficiency outdoor units use ECM motors instead of the PSC motor type that is typical for outdoor units. ECM motors are more common in indoor units, even in low efficiency units. The highest efficiency models considered in this study showed enhanced refrigerant control strategies (such as the use of electronic expansion valves, thermal sensors, and humidity sensors). Enhanced refrigerant control strategies likely offer only a marginal improvement to a system's SEER performance, but they can increase user comfort with improved temperature and humidity control.

[30] All things being equal, a variable-speed compressor system actually reduces a system's EER performance compared to a single- or dual-stage compressor because of the additional power consumption of the variable-speed drive electronics.

Comparison of Estimated Prices and Surveyed Prices

Once the team completed the cost and price estimation analysis, we compared our estimated prices to the prices quoted to the team by wholesalers and contractors. Based on this comparison, the team finds that our estimated prices are generally within 20% of the available vendor quotes. As described previously, our estimates are subject to uncertainty as they are derived from a number of assumptions regarding factory and model production volume, distribution chain markup, and catalog data. Additionally, the quoted vendor prices the team analyzed may be artificially low or high due to price discounts and differences between our assumed markups and the actual markups the vendors place on their equipment.

To facilitate the comparison of analytical results to actual price quotes, the price estimates discussed in this section include the non-efficiency related features that are removed from results reported elsewhere in this document.

As discussed in the *Distribution Chain Markups* Section of this report, the purchase price paid by consumers will be significantly higher than the manufacturers' production costs because of the price markups applied along the distribution chain. We expect the price of a unit to increase at each step in the distribution chain. For example, the team expects a lower price for the same product model from a wholesaler than from a contractor.

To estimate a retail price that can be compared to vendor price quotes, the team applied the appropriate markup to the estimated MPCs based on the step in the distribution chain that the team associated with each vendor. For this discussion, the team had two types of vendors: wholesalers and contractors. The cumulative markup for each is discussed in Table 4, and the markups for this part of the analysis (i.e., price verification) range from 1.84 for products bought from a wholesaler to 2.53 for products bought from a contractor. Table 5 presents the expected prices and the actual quotes received from vendors for various indoor and outdoor units. Units 1-12 in Table 5 were purchased and either torn down or inspected in this analysis. Unit 13 in Table 5 was not torn down, and the expected price for Unit 13 is estimated using catalog data.

Table 5: Estimated Prices and Vendor Quotes for Equipment

Unit #	Source	Expected Price	Vendor Quote	Difference (%)
1	Wholesaler 1	$1,488	$2,397	38%
	Wholesaler 2	$1,488	$1,595	7%
	Contractor 1	$2,054	$2,260	9%
2	Wholesaler 2	$2,077	$3,115	33%
	Contractor 1	$2,866	$4,158	31%
3	Wholesaler 1	$3,447	$5,022	31%
	Wholesaler 2	$3,447	$3,545	3%
4	Contractor 2	$962	$842	-14%
5	Contractor 2	$1,121	$1,231	9%
6	Contractor 2	$1,140	$1,425	20%
7	Wholesaler 1	$520	$1,154	55%
	Wholesaler 2	$520	$644	19%
8	Wholesaler 1	$1,007	$2,180	54%
	Wholesaler 2	$1,007	$1,267	20%
	Contractor 1	$1,390	$1,795	23%
9	Wholesaler 2	$752	$1,177	36%
	Contractor 1	$1,037	$1,668	38%
10	Contractor 2	$2,050	$2,391	14%
11	Contractor 2	$2,749	$2,640	-4%
12	Contractor 2	$3,340	$3,473	4%
13	Contractor 1	$4,001	$3,552	-13%

Quoted prices varied significantly. For example, Wholesaler 1 and Wholesaler 2 quoted prices for the same condenser unit (unit #3) ranging from $3,545 to $5,022. Since price quotes from Wholesaler 1 were consistently over 40% higher than quotes provided by Wholesaler 2, the team classified the Wholesaler 1 quotes as non-representative and removed them from this price verification analysis.

Since this was a limited data set, the team supplemented the vendor quotes with additional quotes from other web-based equipment resellers.[31] Because web-based resellers source their products from a wholesaler, we classified them as 'contractor' in the distribution chain markup.[32] Table 6 presents original and supplemental outdoor units. For each SEER level a predicted unit price is compared to quotes from wholesalers, contractors, and online vendors.

[31] Price discovery for brands like Carrier and Lennox appears to have been made difficult by design, as there are very few online vendors that sell Carrier and Lennox units.

[32] Shipping costs are generally included in purchase prices from web-based retailers, and this allows a side-by-side comparison with the "brick and mortar" retailers from whom quotes are also presented. Additionally, any prices published on a page more than a year old were inflated to present day dollars using the HVAC Producer Price Index series from the Bureau of Labor Statistics (BLS.GOV)

Table 6: Estimated Prices and Vendor Quotes for Outdoor Equipment at multiple nominal SEER levels

Unit Type	Source	Expected Price	Vendor Quote	Difference ($)	Difference (%)
AC - 13 SEER	Web Retailer 1	$1,434	$1,389	-$45	-3%
HP - 13 SEER	Web Retailer 1	$1,790	$1,969	$179	9%
	Web Retailer 2	$1,790	$2,164	$374	17%
AC - 14 SEER	Web Retailer 1	$1,622	$1,639	$17	1%
	Web Retailer 2	$1,622	$1,736	$115	7%
HP - 14 SEER	Contractor 2	$2,050	$2,391	$340	14%
	Web Retailer 2	$2,050	$1,642	-$409	-25%
HP - 15 SEER	Web Retailer 1	$2,054	$2,439	$385	16%
	Wholesaler 2	$1,488	$1,595	$107	7%
	Web Retailer 2	$2,054	$2,522	$469	19%
	Contractor 1	$2,054	$2,260	$206	9%
AC - 16 SEER	Web Retailer 2	$1,828	$2,305	$477	21%
HP - 16 SEER	Web Retailer 1	$2,007	$1,679	-$328	-20%
	Web Retailer 2	$2,007	$1,821	-$185	-10%
AC - 17 SEER	Web Retailer 2	$2,298	$2,494	$196	8%
HP - 17 SEER	Contractor 2	$2,749	$2,640	-$109	-4%
	Web Retailer 2	$2,749	$2,463	-$286	-12%
HP - 18 SEER	Contractor 1	$4,001	$3,552	-$449	-13%
HP - 19 SEER	Wholesaler 2	$2,077	$3,115	$1,038	33%
	Contractor 1	$2,866	$4,158	$1,292	31%
	Web Retailer 2	$2,866	$2,821	-$45	-2%
HP - 20 SEER	Wholesaler 2	$3,447	$3,545	$98	3%
AC - 21 SEER	Web Retailer 2	$3,318	$3,295	-$23	-1%
HP - 21 SEER	Contractor 2	$3,340	$3,473	$133	4%
	Web Retailer 2	$3,340	$2,789	-$551	-20%

Assigning a nominal SEER value to a particular indoor unit is somewhat difficult because the outdoor unit that is paired with a given indoor unit can have a large impact on final SEER. As a result, the team assigned a nominal SEER value to each indoor unit on the basis of the midpoint SEER of its AHRI ratings. Table 7 presents price estimates and vendor quotes for the original and the supplemental indoor units.

Table 7: Calculated Prices and Vendor Quotes for Indoor Equipment

Unit Type	Source	Unit #	Expected Price	Vendor Quote	Difference ($)	Difference (%)
Indoor - Nominal 14 SEER	Contractor 2	1	$962	$842	-$120	-14%
	Wholesaler 2	2	$520	$644	$124	19%
	Web Retailer 3	2	$717	$919	$202	22%
Indoor - Nominal 15 SEER	Wholesaler 2	3	$752	$1,177	$425	36%
	Contractor 1	3	$1,037	$1,668	$631	38%
Indoor - Nominal 16 SEER	Contractor 2	4	$1,140	$1,425	$285	20%
	Wholesaler 2	5	$1,007	$1,267	$260	20%
	Contractor 1	5	$1,390	$1,795	$405	23%
	Web Retailer 2	5	$1,390	$1,602	$211	13%
Indoor - Nominal 17 SEER	Contractor 2	6	$1,121	$1,231	$111	9%
	Web Retailer 2	7	$1,316	$1,404	$88	6%
	Web Retailer 2	8	$1,358	$1,539	$181	12%
	Web Retailer 2	9	$1,347	$1,643	$296	18%
Indoor - Nominal 18 SEER	Web Retailer 2	10	$1,579	$1,923	$344	18%

For outdoor units, the average absolute difference between our estimated prices and vendor quotes is 12.4%. For indoor units, the average absolute difference is 19.1%. These discrepancies could be caused by several factors. Product vendors may discount certain models based on their inventory management; or they may receive incentives from manufacturers to push certain models. Product vendors may take a higher markup on indoor units and a lower markup on outdoor units, since they typically sell indoor and outdoor units in combined systems. It is also possible that our cost analysis underestimated the costs of key components in the indoor units.

Appendix B of this report presents the efficiencies and costs of all of the systems modeled, with costs broken out by sub-system (shell, heat exchangers, electrical system, and sealed system), with non-efficiency costs reported separately.

Appendix A: Analysis of Cool Smart Rebate Data

This appendix provides more details on the methodology and results of the analysis of Cool Smart rebate records conducted in the first stage of the 2015 Cool Smart Incremental Cost Study.

Data Sources and Analysis

The team compiled a database of Cool Smart rebate records using two main data sets it received from PAs over the last few years. The first set of data was tracking data from program years 2012 and 2013, provided in November of 2013[33]. The second data set included a more recent data request for program year 2014 participants[34]. Since AC and HP equipment were the focus of this study, the team filtered these records to remove all ductless mini-split records and retain only central AC/HP equipment rebated through Cool Smart. The team scrubbed personal information from the data, and harmonized data from different sources so that it can easily be organized and filtered. Whenever records were missing data (e.g., if the cooling capacity was not recorded), the team attempted to replace missing data using manufacturer catalogues, specification sheets, and the AHRI Directory of Certified Product Performance.

The resulting database includes 12,441 records of rebates through the Cool Smart program from 2012-14. The following information is recorded in these records:

- Outdoor equipment type (AC or HP) is recorded in 11,863 records (95.4% of total). Indoor equipment type (air handler or coil-only) is recorded in 3,356 records (27.0% of total). All of the records that list an indoor equipment type also list an outdoor equipment type, so the number of records that list both an indoor and outdoor type is also 3,356 records (27.0% of total).
- Manufacturer or brand is recorded in 4,657 records (37.4% of total)
- Cooling capacity is recorded in 1,591 records (12.8% of total)
- Efficiency rating is recorded in 8,580 records (69.0% of total). Many records indicated the Cool Smart rebate tier for which the unit qualified, but did not specify the exact rated efficiency of the equipment or a model number that could be used to retrieve efficiency ratings.

The following sections present excerpts of the database constructed for this analysis.

Equipment Category

This analysis considers four major categories that each indoor/outdoor unit combination can fall into:

- AC-only outdoor unit with indoor Air Handler;
- HP outdoor unit with indoor Air Handler;
- AC-only outdoor unit with indoor coil only; and
- HP outdoor unit with indoor coil only.

[33] Tracking data provided by NGRID, NSTAR, WMECO, Cape Light, and Unitil.
[34] Data provided by NGRID, NSTAR, and Cape Light Compact.

Table 8 describes the percentage of Cool Smart rebates by equipment category for 2012-2014.[35] Of the AC and HP rebate records that indicate an indoor and outdoor equipment type (3,356 of 12,441 total records, or 27.0%, contain both outdoor and indoor equipment type), 82% are records of AC equipment rebates and almost half are for AC units with coil only. A very small proportion (3.7%) of the rebate records are for heat pumps with coil only.

Table 8: Equipment Category Shares of Cool Smart Rebate Population, for 2012-14

	Rebates by Equipment Category, as Percent of Records that Specify the Equipment Category			
	AC with Indoor Air Handler	AC with Coil Only	HP with Indoor Air Handler	HP with Coil Only
Percent of Records	36.5%	45.5%	14.3%	3.7%

Note: Reflects the percentages of only those Cool Smart program rebate records that contain both outdoor and indoor equipment type information (3,356 of 12,441 records, or 27.0%).

Equipment Manufacturers

The source data from PAs often lists the brand name of the rebated product instead of the manufacturer name. For instance, the Carrier Corporation manufactures AC and HP equipment under the brand names Bryant, Carrier, Comfort Maker, Heil, ICP, Payne, and TempStar. The product models available under these brand names are typically identical except for packaging, brand stickers, and printed product information. To determine which manufacturers have models with the highest volume of Cool Smart rebates, the team used the brand names recorded in Cool Smart data to identify the original equipment manufacturers (OEMs) of the rebated products. Table 9 describes manufacturers' shares of the overall Cool Smart rebate market. Of the rebate records that specify the equipment manufacturer, the majority specify either Carrier (37.1%), Trane (24.9%), or Lennox (19.4%).

[35] Ductless mini-split configurations are outside the scope of this analysis.

Table 9: Manufacturer Shares of Total Cool Smart Rebate Population, for 2012-14

Original Equipment Manufacturer	Rebates by Manufacturer, as Percent of Records that Specify Manufacturer
Carrier	37.1%
Trane	24.9%
Lennox	19.5%
Goodman	7.3%
York	5.5%
Rheem	2.5%
Nordyne	1.7%
Other[36]	< 1 %
Total	100.0%

Note: Reflects the percentages of only those Cool Smart program rebate records that contain manufacturer or brand information (4,657 of 12,441 records, or 37.4%).

Table 10 describes manufacturers' shares of the Cool Smart rebate market, broken down by the four equipment categories considered in this analysis. Carrier has over 50% of the heat pump rebate market compared to less than 40% of the AC rebate market.

Table 10: Manufacturer Shares of Cool Smart Rebate Population by Equipment Category, for 2012-14

Original Equipment Manufacturer	Shares of Cool Smart Rebate Market by Equipment Category, as Percent of Records that Specify Manufacturer and Equipment Type			
	AC with Indoor Air Handler	AC with Coil Only	HP with Indoor Air Handler	HP with Coil Only
Carrier	38%	32%	53%	52%
Trane	29%	24%	25%	13%
Lennox	18%	22%	14%	27%
Goodman	7%	9%	4%	2%
York	4%	7%	2%	3%
Rheem	3%	3%	1%	< 1%
Nordyne	1%	2%	1%	2%
Other	< 1%	< 1%	< 1%	< 1%
Total	100%	100%	100%	100%

Note: Reflects the percentages of only those Cool Smart program rebate records that contain both manufacturer and outdoor and indoor equipment type information (3,337 of 12,441 records, or 26.8%).

[36] Other manufacturers with products rebated by Cool Smart in 2012-14 included: Advanced Distributor Products, Aire-Flo, Bard, Heat Controller, Infinity, Kenmore, Lochinvar, Mitsubishi, and ThermoProducts.

Unit Efficiency Rating

The majority of Cool Smart rebate records for 2012-14 recorded the efficiency rating of the equipment. Some records (omitted here) recorded the rebate tier that was selected, but did not record the actual equipment efficiency. Table 11 and Table 12 below show the distribution of rebates awarded across the reported ranges of SEER and EER levels. The efficiency levels with the highest proportions of rebates were 16.0 SEER and 13.0 EER. In 2014, the maximum Cool Smart rebate was offered for equipment with 18.0 SEER and 13.0 EER or higher, so this result suggests that consumers are considering the benefits of rebates in their purchasing decisions.

Table 11: Efficiency Shares by SEER of Total Cool Smart Rebate Population, for 2012-14

	Rebates by SEER, as Percent of Records that Specify SEER															
SEER	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	>20
Percent of Records	5.8%	0.1%	1.1%	4.3%	11.7%	5.7%	47.1%	8.3%	5.5%	3.7%	2.1%	1.1%	1.6%	0.5%	0.7%	<1%
				Teardown analysis focused on this range.												

Note: Reflects the percentages of only those Cool Smart program rebate records that contain actual (not rebate- tiered) equipment SEER rating information (8,580 of 12,441 records, or 69.0%).

Table 12: Efficiency Shares by EER of Total Cool Smart Rebate Population, for 2012-14

	Rebates by EER, as Percent of Records that Specify EER						
EER	12.0	12.5	13.0	13.5	14.0	14.5	> 14.5
Percent of Records	7.0%	19.6%	58.6%	9.4%	2.6%	2.4%	< 1%
	Teardown analysis focused on this range.						

Note: Reflects the percentages of only those Cool Smart program rebate records that contain actual (not rebate-tiered) equipment EER rating information (2,837 of 12,441 records, or 22.8%).

Table 13 below shows the breakdown of SEER distribution by equipment category.

Table 13: Efficiency Ratings of Cool Smart Rebate Population by Equipment Category, for 2012-14

Seasonal Energy Efficiency Ratio (SEER)	Shares of Cool Smart Rebate Market by Equipment Category, as Percent of Records that Specify SEER Rating			
	AC with Indoor Air Handler	AC with Coil Only	HP with Indoor Air Handler	HP with Coil Only
13.0	10%	14%	1%	0%
13.5	< 1%	0%	0%	0%
14.0	2%	3%	0%	1%
14.5	1%	8%	3%	4%
15.0	5%	18%	21%	8%
15.5	2%	6%	7%	14%
16.0	59%	37%	19%	30%
16.5	6%	6%	4%	6%
17.0	4%	3%	11%	10%
17.5	4%	2%	7%	6%
18.0	2%	< 1%	9%	2%
18.5	1%	1%	1%	8%
19.0	1%	< 1%	6%	4%
19.5	1%	0%	2%	0%
20.0	1%	0%	2%	6%
20.5	< 1%	0%	< 1%	< 1%
21.0	0%	0%	0%	0%
21.5	0%	0%	4%	< 1%
22 - 26	< 1%	< 1%	< 1%	< 1%
Total	100%	100%	100%	100%

Note: Reflects the percentages of only those Cool Smart program rebate records that contain both actual (not rebate-tiered) equipment SEER rating and outdoor and indoor equipment type information (3,356 of 12,441 records, or 27.0%).

Unit Capacity

The cooling capacity of an AC or HP unit is the measure of a cooling system's ability to remove heat from the conditioned space. Table 14 presents the distribution of Cool Smart rebates across the range of capacities that were rebated in 2012-14. The largest share of rebates, at 35.0%, was for equipment with 2-ton cooling capacity. Less than 5% of rebates records were for units with cooling capacity less than 1.5 tons or greater than 4 tons cooling.

Table 14: Manufacturer Shares of Total Cool Smart Rebate Population for 2012-14

Cooling Capacity	Shares of Cool Smart Rebate Market, as Percent of Records that Specify Cooling Capacity
1.0 tons (12,000 Btu/h)	1.1%
1.5 tons (18,000 Btu/h)	14.1%
2.0 tons (24,000 Btu/h)	35.0%
2.5 tons (30,000 Btu/h)	23.1%
3.0 tons (36,000 Btu/h)	11.8%
3.5 tons (42,000 Btu/h)	7.9%
4.0 tons (48,000 Btu/h)	4.0%
4.5 tons (54,000 Btu/h)	2.9%
5.0 tons (60,000 Btu/h)	0.1%
Total	100%

Note: Reflects the percentages of only those Cool Smart program rebate records that contain cooling capacity information (1,591 of 12,441 records, or 12.8%).

The team determined the representative cooling capacity for different equipment categories and efficiency levels. The capacities reported in Table 15 represent the average capacity of equipment rebated in the category and efficiency level indicated. In general, the representative capacity of AC equipment below 18 SEER is 2.0-2.5 tons cooling capacity. The representative capacity of HP equipment categories tended to be higher than that for AC equipment at the same efficiency level.

Table 15: Representative Cooling Capacities of Different SEER Levels in Cool Smart Rebate Population by Equipment Category, for 2012-14,

Seasonal Energy Efficiency Ratio (SEER)	Representative Cooling Capacity, by Equipment Category and Efficiency Rating (Btu/h Cooling)			
	AC with Indoor Air Handler	AC with Coil Only	HP with Indoor Air Handler	HP with Coil Only
14.5	2.5 tons (30,000 Btu/h)	2 tons (24,000 Btu/h)	-	-
15.0	2.5 tons (30,000 Btu/h)	2.5 tons (30,000 Btu/h)	3 tons (36,000 Btu/h)	-
15.5	2.5 tons (30,000 Btu/h)	2.5 tons (30,000 Btu/h)	-	2.5 tons (30,000 Btu/h)
16.0	2 tons (24,000 Btu/h)	2 tons (24,000 Btu/h)	3 tons (36,000 Btu/h)	-
16.5	2.5 tons (30,000 Btu/h)	3 tons (36,000 Btu/h)	3 tons (36,000 Btu/h)	-
17.0	2 tons (24,000 Btu/h)	2 tons (24,000 Btu/h)	3.5 tons (42,000 Btu/h)	1 ton (12,000 Btu/h)
17.5	2.5 tons (30,000 Btu/h)	2 tons (24,000 Btu/h)	-	3.5 tons (42,000 Btu/h)
18.0	-	-	2.5 tons (30,000 Btu/h)	-
18.5	3 tons (36,000 Btu/h)	3 tons (36,000 Btu/h)	-	-
19.0	2.5 tons (30,000 Btu/h)	1.5 tons (18,000 Btu/h)	2.5 tons (30,000 Btu/h)	-
20.0	2 tons (24,000 Btu/h)	-	2.5 tons (30,000 Btu/h)	-
23.0	2.5 tons (30,000 Btu/h)	2.5 tons (30,000 Btu/h)	-	-
25.0	1.5 tons (18,000 Btu/h)	-	-	-
26.0	1.5 tons (18,000 Btu/h)	-	-	-

Note: Based on an analysis of the subset of Cool Smart rebate records that contain both actual (not rebate-tiered) equipment SEER rating, cooling capacity, and outdoor and indoor equipment type information (418 of 12,441 records, or 3.4%).

Appendix B: Cost Table Estimates of Manufacturing Cost and Price

This appendix provides detailed results of the cost modeling activities conducted in the 2015 Cool Smart Incremental Cost Study. The four tables in this appendix present MPC and purchase price estimates for more than 450 different system combinations. Each system combination consists of one indoor unit and one outdoor unit. These estimates are based on the twelve units that were physically torn down or inspected and cost modeled during the study. Units not torn down during the study were modeled using catalog information provided by manufacturers.

The results are separated into four tables based on the four major categories of paired indoor and outdoor equipment, consisting of:

- Air-conditioning outdoor units with an indoor air handler (AC-AH);
- Air-conditioning outdoor units with an indoor coil only (AC-CO);
- Heat pump outdoor units with an indoor air handler (HP-AH); and
- Heat pump outdoor units with an indoor coil only (HP-CO).

The tables in this appendix present the following data:

- The system unit combination, where unit model numbers are replaced by designators such as "AC" and "AH";
- AHRI-certified ratings of SEER, EER, and HSPF;
- Cost breakdowns for sub-systems, including the Shell (packaging, casing, and final assembly), the Heat Exchangers (condenser and evaporator), the Electricals (controls, fan motors, and fans), and the Sealed System (compressor, tubing, expansion devices, 4-way valves, refrigerant);
- Non-efficiency related costs, including costs for features such as sound dampening, specialty thermostats, and casing upgrades;
- The total estimated MPC, which excludes non-efficiency related features;
- The estimated supply chain markups applied to the total MPC;
- The total estimated system purchase price (sum of the MPC and markups), not including delivery or installation; and
- The incremental system purchase price, which describes the increase in purchase price above the least expensive baseline (13.0 SEER for ACs and 14.0 SEER & 8.2 HSPF for HPs) configuration for each manufacturer in each equipment category. For example, the incremental prices illustrated for AC-AH systems describe the incremental price above the prices of the least expensive AC-AH systems rated at 13.0 SEER from each manufacturer. The two baseline systems (one for each manufacturer) are indicated in each table.

Table 16: Manufacturing Cost and Price Estimates for Air Conditioner, Air Handler (AC-AH) Unit Combinations (excludes non-efficiency items)

Air Conditioner, Air Handler System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
AC (C) + AH (C) – Baseline 1	13.0	11.0	0.0	$178	$114	$137	$260	$0	$689	$1,169	$1,859	$0
AC (C) + AH (T) – Baseline 2	13.0	11.0	0.0	$225	$213	$135	$243	$0	$816	$1,384	$2,199	$0
AC (C) + AH (C)	13.0	11.0	0.0	$197	$124	$140	$260	$0	$721	$1,223	$1,944	$0
AC (C) + AH (T)	13.0	11.0	0.0	$178	$132	$137	$260	$0	$707	$1,199	$1,906	$0
AC (C) + AH (T)	13.0	11.0	0.0	$235	$213	$135	$246	$0	$829	$1,407	$2,236	$0
AC (C) + AH (C)	13.0	11.0	0.0	$228	$226	$137	$243	$0	$835	$1,416	$2,251	$0
AC (C) + AH (C)	13.0	11.0	0.0	$238	$227	$137	$246	$0	$848	$1,439	$2,287	$0
AC (C) + AH (C)	13.5	11.0	0.0	$172	$111	$136	$261	$0	$680	$1,154	$1,834	$0
AC (C) + AH (C)	13.5	11.0	0.0	$197	$142	$140	$260	$0	$739	$1,253	$1,992	$133
AC (C) + AH (T)	13.5	11.5	0.0	$221	$221	$125	$243	$0	$810	$1,374	$2,184	$0
AC (C) + AH (T)	13.5	11.5	0.0	$231	$221	$125	$246	$0	$824	$1,397	$2,221	$22
AC (C) + AH (C)	14.0	11.5	0.0	$178	$121	$139	$257	$0	$694	$1,178	$1,872	$13
AC (C) + AH (C)	14.0	11.5	0.0	$201	$148	$166	$292	$0	$807	$1,369	$2,176	$317
AC (C) + AH (T)	14.0	11.5	0.0	$172	$129	$136	$261	$0	$698	$1,184	$1,882	$23
AC (C) + AH (C)	14.0	11.5	0.0	$200	$144	$275	$260	$90	$879	$1,492	$2,371	$512
AC (C) + AH (C)	14.0	11.5	0.0	$194	$129	$222	$260	$0	$805	$1,365	$2,171	$312
AC (C) + AH (C)	14.0	11.5	0.0	$226	$240	$226	$243	$0	$935	$1,585	$2,520	$321
AC (C) + AH (C)	14.0	11.5	0.0	$236	$241	$226	$246	$0	$948	$1,608	$2,557	$357
AC (C) + AH (C)	14.0	12.0	0.0	$191	$121	$139	$261	$0	$712	$1,208	$1,920	$61
AC (C) + AH (C)	14.0	12.0	0.0	$189	$126	$221	$261	$0	$796	$1,350	$2,146	$287
AC (C) + AH (C)	14.0	12.2	0.0	$190	$132	$144	$282	$0	$749	$1,269	$2,018	$159
AC (C) + AH (T)	14.5	11.5	0.0	$224	$166	$278	$260	$90	$928	$1,574	$2,502	$643
AC (C) + AH (C)	14.5	12.0	0.0	$201	$148	$146	$292	$0	$787	$1,335	$2,123	$264
AC (C) + AH (T)	14.5	12.0	0.0	$201	$166	$166	$292	$0	$825	$1,399	$2,224	$365
AC (C) + AH (T)	14.5	12.0	0.0	$246	$174	$190	$315	$53	$924	$1,568	$2,492	$633
AC (C) + AH (C)	14.5	12.0	0.0	$191	$139	$139	$261	$0	$730	$1,238	$1,967	$109
AC (C) + AH (T)	14.5	12.0	0.0	$219	$154	$224	$260	$0	$857	$1,454	$2,311	$452

Air Conditioner, Air Handler System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
AC (C) + AH (T)	14.5	12.0	0.0	$293	$288	$148	$327	$0	$1,056	$1,792	$2,848	$649
AC (C) + AH (C)	14.5	12.0	0.0	$238	$257	$138	$243	$0	$876	$1,485	$2,361	$161
AC (C) + AH (C)	14.5	12.0	0.0	$248	$258	$138	$246	$0	$889	$1,508	$2,397	$198
AC (C) + AH (C)	14.5	12.0	0.0	$246	$257	$139	$243	$0	$886	$1,502	$2,388	$189
AC (C) + AH (C)	14.5	12.0	0.0	$256	$258	$139	$246	$0	$899	$1,525	$2,425	$225
AC (C) + AH (C)	14.5	12.0	0.0	$242	$262	$229	$243	$0	$977	$1,657	$2,635	$435
AC (C) + AH (C)	14.5	12.0	0.0	$252	$263	$229	$246	$0	$991	$1,680	$2,671	$472
AC (C) + AH (T)	14.5	12.2	0.0	$214	$151	$223	$261	$0	$848	$1,438	$2,287	$428
AC (C) + AH (T)	14.5	12.2	0.0	$244	$236	$149	$253	$0	$881	$1,494	$2,375	$175
AC (C) + AH (T)	14.5	12.2	0.0	$258	$238	$149	$253	$0	$898	$1,522	$2,420	$220
AC (C) + AH (C)	14.5	12.2	0.0	$247	$250	$151	$253	$0	$900	$1,526	$2,426	$227
AC (C) + AH (C)	14.5	12.2	0.0	$261	$252	$151	$253	$0	$917	$1,555	$2,471	$272
AC (C) + AH (C)	14.5	12.2	0.0	$267	$271	$156	$253	$0	$946	$1,605	$2,551	$352
AC (C) + AH (C)	14.5	12.2	0.0	$281	$273	$156	$253	$0	$963	$1,633	$2,596	$397
AC (C) + AH (T)	14.5	12.2	0.0	$240	$244	$139	$253	$0	$875	$1,485	$2,360	$160
AC (C) + AH (T)	14.5	12.2	0.0	$255	$246	$139	$253	$0	$892	$1,513	$2,405	$205
AC (C) + AH (C)	14.5	12.5	0.0	$194	$141	$275	$261	$90	$870	$1,476	$2,346	$488
AC (C) + AH (T)	15.0	12.0	0.0	$201	$166	$146	$292	$0	$805	$1,365	$2,171	$312
AC (C) + AH (C)	15.0	12.0	0.0	$197	$148	$142	$257	$0	$744	$1,262	$2,005	$147
AC (C) + AH (C)	15.0	12.0	0.0	$259	$271	$232	$243	$0	$1,005	$1,704	$2,709	$510
AC (C) + AH (C)	15.0	12.0	0.0	$269	$271	$232	$246	$0	$1,018	$1,727	$2,746	$546
AC (C) + AH (C)	15.0	12.0	0.0	$259	$272	$251	$243	$0	$1,025	$1,738	$2,762	$563
AC (C) + AH (C)	15.0	12.0	0.0	$269	$272	$251	$246	$0	$1,038	$1,761	$2,799	$599
AC (C) + AH (C)	15.0	12.5	0.0	$220	$158	$149	$292	$0	$819	$1,389	$2,208	$350
AC (C) + AH (C)	15.0	12.5	0.0	$220	$158	$169	$292	$0	$839	$1,423	$2,262	$403
AC (C) + AH (T)	15.0	12.5	0.0	$219	$163	$277	$261	$90	$919	$1,559	$2,478	$619
AC (C) + AH (C)	15.0	12.5	0.0	$226	$215	$213	$243	$0	$898	$1,522	$2,420	$220
AC (C) + AH (C)	15.0	12.5	0.0	$236	$216	$213	$246	$0	$911	$1,545	$2,456	$257
AC (C) + AH (C)	15.0	12.5	0.0	$259	$272	$244	$243	$0	$1,018	$1,726	$2,744	$544

Air Conditioner, Air Handler System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
AC (C) + AH (C)	15.0	12.5	0.0	$269	$272	$244	$246	$0	$1,031	$1,749	$2,780	$581
AC (C) + AH (T)	15.0	12.7	0.0	$264	$312	$299	$290	$58	$1,184	$2,008	$3,192	$993
AC (C) + AH (C)	15.1	12.0	0.0	$251	$272	$231	$243	$0	$997	$1,691	$2,688	$488
AC (C) + AH (C)	15.1	12.0	0.0	$261	$272	$231	$246	$0	$1,011	$1,714	$2,724	$525
AC (C) + AH (C)	15.1	12.5	0.0	$257	$280	$151	$253	$0	$941	$1,595	$2,536	$337
AC (C) + AH (C)	15.1	12.5	0.0	$271	$282	$151	$253	$0	$957	$1,624	$2,581	$382
AC (C) + AH (C)	15.5	12.2	0.0	$298	$308	$248	$327	$0	$1,181	$2,003	$3,184	$984
AC (C) + AH (T)	15.5	12.5	0.0	$190	$150	$144	$282	$0	$766	$1,299	$2,066	$207
AC (C) + AH (T)	15.5	12.5	0.0	$190	$152	$159	$285	$0	$785	$1,332	$2,117	$258
AC (C) + AH (C)	15.5	12.5	0.0	$210	$159	$147	$282	$0	$798	$1,353	$2,151	$292
AC (C) + AH (C)	15.5	12.5	0.0	$210	$161	$161	$285	$0	$817	$1,385	$2,202	$344
AC (C) + AH (T)	15.5	12.5	0.0	$241	$246	$186	$243	$0	$916	$1,554	$2,470	$271
AC (C) + AH (T)	15.5	12.5	0.0	$251	$247	$186	$246	$0	$930	$1,577	$2,507	$307
AC (C) + AH (C)	15.5	12.5	0.0	$251	$255	$189	$243	$0	$938	$1,591	$2,529	$329
AC (C) + AH (C)	15.5	12.5	0.0	$261	$256	$189	$246	$0	$951	$1,614	$2,565	$366
AC (C) + AH (C)	15.5	12.5	0.0	$245	$263	$239	$253	$0	$1,000	$1,696	$2,696	$496
AC (C) + AH (C)	15.5	12.5	0.0	$259	$266	$239	$253	$0	$1,016	$1,724	$2,740	$541
AC (C) + AH (C)	15.5	12.5	0.0	$315	$330	$252	$327	$0	$1,223	$2,075	$3,298	$1,099
AC (C) + AH (C)	15.5	13.0	0.0	$238	$220	$272	$261	$90	$991	$1,681	$2,672	$814
AC (C) + AH (C)	15.5	13.0	0.0	$331	$339	$274	$327	$0	$1,271	$2,155	$3,426	$1,226
AC (C) + AH (C)	15.7	13.2	0.0	$281	$348	$312	$290	$58	$1,249	$2,119	$3,368	$1,169
AC (C) + AH (T)	16.0	11.0	0.0	$307	$208	$884	$422	$109	$1,821	$3,089	$4,910	$3,051
AC (C) + AH (C)	16.0	11.0	0.0	$282	$183	$882	$422	$109	$1,769	$3,000	$4,769	$2,910
AC (C) + AH (T)	16.0	12.0	0.0	$219	$160	$226	$257	$0	$862	$1,462	$2,324	$466
AC (C) + AH (C)	16.0	12.5	0.0	$194	$135	$224	$257	$0	$810	$1,374	$2,184	$325
AC (C) + AH (C)	16.0	12.5	0.0	$331	$338	$255	$327	$0	$1,251	$2,122	$3,373	$1,173
AC (C) + AH (C)	16.0	13.0	0.0	$220	$175	$149	$292	$0	$837	$1,419	$2,256	$397
AC (C) + AH (C)	16.0	13.0	0.0	$220	$175	$169	$292	$0	$857	$1,453	$2,309	$451
AC (C) + AH (C)	16.0	13.0	0.0	$265	$183	$193	$315	$53	$956	$1,622	$2,578	$719

Air Conditioner, Air Handler System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
AC (C) + AH (T)	16.0	13.0	0.0	$237	$184	$285	$282	$90	$987	$1,674	$2,661	$802
AC (C) + AH (T)	16.0	13.0	0.0	$247	$199	$287	$292	$90	$1,026	$1,740	$2,766	$907
AC (C) + AH (T)	16.0	13.0	0.0	$224	$172	$280	$257	$90	$933	$1,583	$2,516	$657
AC (C) + AH (T)	16.0	13.0	0.0	$247	$199	$307	$292	$90	$1,046	$1,774	$2,820	$961
AC (C) + AH (T)	16.0	13.0	0.0	$292	$207	$331	$315	$143	$1,145	$1,942	$3,088	$1,229
AC (C) + AH (C)	16.0	13.0	0.0	$212	$162	$282	$282	$90	$938	$1,592	$2,530	$671
AC (C) + AH (C)	16.0	13.0	0.0	$223	$178	$285	$292	$90	$977	$1,658	$2,635	$776
AC (C) + AH (C)	16.0	13.0	0.0	$200	$150	$278	$257	$90	$884	$1,500	$2,384	$526
AC (C) + AH (C)	16.0	13.0	0.0	$223	$178	$304	$292	$90	$997	$1,691	$2,688	$830
AC (C) + AH (C)	16.0	13.0	0.0	$268	$185	$329	$315	$143	$1,097	$1,860	$2,957	$1,098
AC (C) + AH (T)	16.0	13.0	0.0	$242	$187	$233	$292	$0	$955	$1,620	$2,575	$716
AC (C) + AH (T)	16.0	13.0	0.0	$242	$187	$253	$292	$0	$975	$1,653	$2,628	$770
AC (C) + AH (T)	16.0	13.0	0.0	$287	$195	$277	$315	$53	$1,074	$1,822	$2,897	$1,038
AC (C) + AH (C)	16.0	13.0	0.0	$207	$147	$228	$282	$0	$864	$1,466	$2,330	$471
AC (C) + AH (C)	16.0	13.0	0.0	$217	$162	$231	$292	$0	$903	$1,532	$2,435	$576
AC (C) + AH (C)	16.0	13.0	0.0	$217	$162	$250	$292	$0	$923	$1,565	$2,488	$629
AC (C) + AH (C)	16.0	13.0	0.0	$262	$170	$275	$315	$53	$1,022	$1,734	$2,756	$897
AC (C) + AH (C)	16.0	13.0	0.0	$245	$238	$227	$253	$0	$963	$1,633	$2,595	$396
AC (C) + AH (C)	16.0	13.0	0.0	$259	$241	$227	$253	$0	$979	$1,661	$2,640	$441
AC (C) + AH (C)	16.0	13.0	0.0	$298	$283	$236	$327	$0	$1,144	$1,940	$3,083	$884
AC (C) + AH (C)	16.0	13.0	0.0	$248	$252	$229	$253	$0	$982	$1,665	$2,647	$447
AC (C) + AH (C)	16.0	13.0	0.0	$262	$254	$229	$253	$0	$998	$1,693	$2,691	$492
AC (C) + AH (C)	16.0	13.0	0.0	$268	$273	$230	$253	$0	$1,024	$1,736	$2,760	$560
AC (C) + AH (C)	16.0	13.0	0.0	$282	$275	$230	$253	$0	$1,040	$1,764	$2,804	$605
AC (C) + AH (T)	16.0	13.0	0.0	$260	$269	$200	$253	$0	$981	$1,664	$2,646	$446
AC (C) + AH (T)	16.0	13.0	0.0	$274	$271	$200	$253	$0	$998	$1,693	$2,691	$491
AC (C) + AH (C)	16.0	13.0	0.0	$270	$278	$202	$253	$0	$1,003	$1,701	$2,704	$505
AC (C) + AH (C)	16.0	13.0	0.0	$284	$281	$202	$253	$0	$1,020	$1,729	$2,749	$549
AC (C) + AH (C)	16.0	13.0	0.0	$262	$286	$242	$253	$0	$1,042	$1,768	$2,810	$611

Air Conditioner, Air Handler System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
AC (C) + AH (C)	16.0	13.0	0.0	$276	$288	$242	$253	$0	$1,059	$1,796	$2,855	$656
AC (C) + AH (C)	16.0	13.5	0.0	$257	$241	$280	$282	$90	$1,059	$1,797	$2,856	$997
AC (C) + AH (C)	16.0	13.5	0.0	$244	$229	$275	$257	$90	$1,005	$1,705	$2,710	$852
AC (C) + AH (C)	16.0	13.5	0.0	$312	$264	$326	$315	$143	$1,218	$2,065	$3,283	$1,424
AC (C) + AH (T)	16.0	13.5	0.0	$232	$172	$231	$282	$0	$916	$1,554	$2,470	$611
AC (C) + AH (T)	16.0	13.5	0.0	$313	$314	$209	$327	$0	$1,162	$1,972	$3,134	$935
AC (C) + AH (C)	16.0	13.5	0.0	$269	$331	$400	$290	$58	$1,309	$2,219	$3,528	$1,328
AC (C) + AH (C)	16.5	13.0	0.0	$271	$207	$314	$357	$149	$1,148	$1,948	$3,096	$1,237
AC (C) + AH (T)	16.5	13.0	0.0	$250	$208	$235	$335	$0	$1,027	$1,742	$2,770	$911
AC (C) + AH (T)	16.5	13.0	0.0	$290	$216	$262	$357	$59	$1,126	$1,910	$3,036	$1,177
AC (C) + AH (C)	16.5	13.0	0.0	$225	$183	$233	$335	$0	$975	$1,654	$2,629	$771
AC (C) + AH (C)	16.5	13.0	0.0	$266	$191	$260	$357	$59	$1,074	$1,822	$2,896	$1,037
AC (C) + AH (T)	16.5	13.5	0.0	$237	$185	$299	$285	$90	$1,006	$1,706	$2,713	$854
AC (C) + AH (C)	16.5	13.5	0.0	$212	$164	$297	$285	$90	$958	$1,624	$2,581	$723
AC (C) + AH (T)	16.5	13.5	0.0	$232	$173	$246	$285	$0	$935	$1,586	$2,521	$663
AC (C) + AH (C)	16.5	13.5	0.0	$207	$148	$243	$285	$0	$883	$1,498	$2,381	$522
AC (C) + AH (C)	16.5	14.0	0.0	$257	$242	$295	$285	$90	$1,078	$1,829	$2,907	$1,049
AC (C) + AH (C)	17.0	10.0	0.0	$332	$280	$933	$422	$199	$1,967	$3,337	$5,304	$3,445
AC (C) + AH (T)	17.0	13.0	0.0	$295	$228	$316	$357	$149	$1,197	$2,030	$3,227	$1,368
AC (C) + AH (C)	17.0	13.5	0.0	$315	$285	$312	$357	$149	$1,269	$2,153	$3,422	$1,563
AC (C) + AH (C)	17.0	13.5	0.0	$323	$323	$212	$327	$0	$1,184	$2,008	$3,192	$993
AC (C) + AH (T)	17.0	13.5	0.0	$364	$482	$355	$387	$45	$1,639	$2,780	$4,419	$2,220
AC (C) + AH (C)	17.0	13.5	0.0	$381	$518	$367	$387	$45	$1,705	$2,891	$4,596	$2,396
AC (C) + AH (T)	17.0	14.0	0.0	$284	$337	$360	$290	$58	$1,290	$2,188	$3,478	$1,279
AC (C) + AH (C)	17.0	14.0	0.0	$294	$346	$363	$290	$58	$1,312	$2,225	$3,536	$1,337
AC (C) + AH (C)	17.0	14.0	0.0	$286	$354	$403	$290	$58	$1,351	$2,291	$3,643	$1,443
AC (C) + AH (C)	17.0	14.0	0.0	$302	$362	$406	$290	$58	$1,379	$2,338	$3,717	$1,517
AC (C) + AH (C)	17.0	14.0	0.0	$302	$363	$425	$290	$58	$1,398	$2,372	$3,770	$1,571
AC (C) + AH (C)	17.5	14.5	0.0	$294	$363	$405	$290	$58	$1,371	$2,325	$3,696	$1,496

Air Conditioner, Air Handler System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
AC (C) + AH (C)	17.7	14.7	0.0	$302	$363	$418	$290	$58	$1,392	$2,360	$3,752	$1,552
AC (C) + AH (T)	18.0	11.0	0.0	$312	$220	$938	$422	$199	$1,892	$3,209	$5,101	$3,242
AC (C) + AH (C)	18.0	11.0	0.0	$288	$198	$936	$422	$199	$1,843	$3,126	$4,970	$3,111
AC (C) + AH (C)	18.5	12.2	0.0	$288	$198	$936	$422	$199	$1,843	$3,126	$4,970	$3,111
AC (C) + AH (C)	18.5	12.2	0.0	$282	$183	$882	$422	$109	$1,769	$3,000	$4,769	$2,910
AC (C) + AH (C)	18.5	12.5	0.0	$332	$280	$933	$422	$199	$1,967	$3,337	$5,304	$3,445
AC (C) + AH (C)	18.5	12.5	0.0	$307	$250	$882	$422	$109	$1,861	$3,157	$5,018	$3,159
AC (C) + AH (C)	19.0	11.0	0.0	$312	$260	$938	$422	$199	$1,932	$3,277	$5,209	$3,350
AC (C) + AH (T)	19.0	12.2	0.0	$312	$220	$938	$422	$199	$1,892	$3,209	$5,101	$3,242
AC (C) + AH (T)	19.0	12.2	0.0	$307	$208	$884	$422	$109	$1,821	$3,089	$4,910	$3,051
AC (C) + AH (C)	19.0	12.5	0.0	$312	$260	$938	$422	$199	$1,932	$3,277	$5,209	$3,350
AC (C) + AH (C)	19.0	13.5	0.0	$394	$516	$418	$387	$45	$1,767	$2,997	$4,764	$2,564
AC (C) + AH (C)	19.0	14.0	0.0	$290	$328	$384	$401	$157	$1,404	$2,380	$3,784	$1,925
AC (C) + AH (T)	19.0	14.0	0.0	$310	$338	$332	$401	$67	$1,381	$2,343	$3,724	$1,865
AC (C) + AH (C)	19.0	14.0	0.0	$285	$313	$330	$401	$67	$1,329	$2,254	$3,584	$1,725
AC (C) + AH (C)	19.0	14.0	0.0	$389	$518	$369	$387	$45	$1,715	$2,908	$4,623	$2,424
AC (C) + AH (C)	19.0	14.0	0.0	$369	$502	$455	$387	$45	$1,764	$2,991	$4,755	$2,556
AC (C) + AH (C)	19.0	14.0	0.0	$402	$533	$474	$387	$45	$1,847	$3,132	$4,979	$2,779
AC (C) + AH (T)	19.5	14.0	0.0	$315	$350	$386	$401	$157	$1,452	$2,463	$3,915	$2,056
AC (C) + AH (C)	20.0	15.0	0.0	$402	$532	$462	$387	$45	$1,834	$3,110	$4,944	$2,745
AC (C) + AH (C)	20.5	15.0	0.0	$394	$533	$460	$387	$45	$1,826	$3,097	$4,923	$2,723
AC (C) + AH (T)	21.0	15.0	0.0	$384	$507	$416	$387	$45	$1,745	$2,960	$4,705	$2,506
AC (C) + AH (C)	21.0	15.0	0.0	$402	$533	$480	$387	$45	$1,854	$3,144	$4,997	$2,798

Table 17: Manufacturing Cost and Price Estimates for Air Conditioner, Coil-Only (AC-CO) Unit Combinations (excludes non-efficiency items)

Air Conditioner, Indoor Coil System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
AC (C) + CO (C) – Baseline 1	13.0	10.9	0.0	$119	$153	$50	$261	$0	$583	$989	$1,572	$0
AC (C) + CO (C) – Baseline 2	13.0	11.0	0.0	$159	$166	$57	$243	$0	$624	$1,059	$1,683	$0
AC (C) + CO (C)	13.0	10.5	0.0	$140	$172	$50	$260	$0	$623	$1,056	$1,679	$0
AC (C) + CO (C)	13.0	10.9	0.0	$129	$167	$50	$261	$0	$607	$1,029	$1,636	$0
AC (C) + CO (C)	13.0	10.9	0.0	$134	$169	$50	$261	$0	$614	$1,041	$1,655	$0
AC (C) + CO (C)	13.0	10.9	0.0	$123	$153	$50	$261	$0	$587	$995	$1,582	$0
AC (C) + CO (C)	13.0	11.0	0.0	$135	$170	$50	$260	$0	$616	$1,044	$1,660	$0
AC (C) + CO (C)	13.0	11.0	0.0	$129	$167	$50	$261	$0	$607	$1,030	$1,637	$0
AC (C) + CO (C)	13.0	11.0	0.0	$135	$171	$50	$260	$0	$616	$1,045	$1,661	$0
AC (C) + CO (C)	13.0	11.0	0.0	$134	$169	$50	$261	$0	$614	$1,042	$1,656	$0
AC (C) + CO (C)	13.0	11.0	0.0	$140	$172	$50	$260	$0	$623	$1,057	$1,680	$0
AC (C) + CO (C)	13.0	11.0	0.0	$138	$179	$50	$261	$0	$628	$1,065	$1,693	$0
AC (C) + CO (C)	13.0	11.0	0.0	$125	$156	$50	$260	$0	$592	$1,004	$1,596	$0
AC (C) + CO (C)	13.0	11.0	0.0	$129	$156	$50	$260	$0	$596	$1,011	$1,607	$0
AC (C) + CO (C)	13.0	11.0	0.0	$132	$173	$50	$261	$0	$616	$1,045	$1,662	$0
AC (C) + CO (C)	13.0	11.0	0.0	$138	$177	$50	$260	$0	$625	$1,061	$1,686	$0
AC (C) + CO (C)	13.0	11.0	0.0	$169	$166	$57	$246	$0	$638	$1,082	$1,720	$0
AC (C) + CO (C)	13.0	11.0	0.0	$159	$176	$57	$243	$0	$635	$1,077	$1,712	$0
AC (C) + CO (C)	13.0	11.0	0.0	$169	$177	$57	$246	$0	$649	$1,100	$1,749	$0
AC (C) + CO (C)	13.0	11.0	0.0	$166	$188	$57	$243	$0	$654	$1,110	$1,764	$0
AC (C) + CO (C)	13.0	11.0	0.0	$176	$189	$57	$246	$0	$668	$1,132	$1,800	$0
AC (C) + CO (C)	13.5	11.0	0.0	$149	$221	$57	$243	$0	$670	$1,136	$1,806	$122
AC (C) + CO (C)	13.5	11.0	0.0	$159	$222	$57	$246	$0	$683	$1,159	$1,842	$159
AC (C) + CO (C)	13.5	11.0	0.0	$159	$223	$57	$243	$0	$682	$1,156	$1,837	$154
AC (C) + CO (C)	13.5	11.0	0.0	$169	$223	$57	$246	$0	$695	$1,179	$1,874	$191
AC (C) + CO (C)	13.5	11.0	0.0	$145	$201	$57	$243	$0	$645	$1,095	$1,740	$57
AC (C) + CO (C)	13.5	11.0	0.0	$155	$201	$57	$246	$0	$659	$1,117	$1,776	$93
AC (C) + CO (C)	13.5	11.0	0.0	$148	$198	$57	$243	$0	$645	$1,095	$1,740	$57

Air Conditioner, Indoor Coil System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
AC (C) + CO (C)	13.5	11.0	0.0	$158	$198	$57	$246	$0	$659	$1,118	$1,776	$93
AC (C) + CO (C)	13.5	11.5	0.0	$152	$243	$57	$243	$0	$695	$1,178	$1,873	$190
AC (C) + CO (C)	13.5	11.5	0.0	$162	$243	$57	$246	$0	$708	$1,201	$1,910	$227
AC (C) + CO (C)	13.5	11.5	0.0	$147	$222	$57	$243	$0	$669	$1,134	$1,803	$119
AC (C) + CO (C)	13.5	11.5	0.0	$157	$223	$57	$246	$0	$682	$1,157	$1,839	$156
AC (C) + CO (C)	14.0	11.0	0.0	$125	$163	$53	$257	$0	$597	$1,013	$1,610	$38
AC (C) + CO (C)	14.0	11.0	0.0	$129	$163	$53	$257	$0	$601	$1,019	$1,620	$48
AC (C) + CO (C)	14.0	11.5	0.0	$158	$204	$60	$292	$0	$714	$1,211	$1,924	$353
AC (C) + CO (C)	14.0	11.5	0.0	$135	$177	$53	$257	$0	$621	$1,053	$1,674	$102
AC (C) + CO (C)	14.0	11.5	0.0	$158	$204	$79	$292	$0	$734	$1,244	$1,978	$406
AC (C) + CO (C)	14.0	11.5	0.0	$203	$212	$104	$315	$53	$833	$1,413	$2,246	$674
AC (C) + CO (C)	14.0	11.5	0.0	$163	$206	$60	$292	$0	$721	$1,223	$1,943	$372
AC (C) + CO (C)	14.0	11.5	0.0	$140	$178	$53	$257	$0	$628	$1,065	$1,693	$121
AC (C) + CO (C)	14.0	11.5	0.0	$163	$206	$79	$292	$0	$741	$1,256	$1,997	$425
AC (C) + CO (C)	14.0	11.5	0.0	$208	$213	$104	$315	$53	$840	$1,425	$2,265	$693
AC (C) + CO (C)	14.0	11.5	0.0	$158	$204	$60	$292	$0	$714	$1,211	$1,925	$353
AC (C) + CO (C)	14.0	11.5	0.0	$135	$177	$53	$257	$0	$621	$1,053	$1,674	$103
AC (C) + CO (C)	14.0	11.5	0.0	$158	$204	$79	$292	$0	$734	$1,245	$1,978	$407
AC (C) + CO (C)	14.0	11.5	0.0	$203	$212	$104	$315	$53	$833	$1,413	$2,247	$675
AC (C) + CO (C)	14.0	11.5	0.0	$163	$206	$60	$292	$0	$721	$1,223	$1,944	$373
AC (C) + CO (C)	14.0	11.5	0.0	$140	$179	$53	$257	$0	$628	$1,066	$1,694	$122
AC (C) + CO (C)	14.0	11.5	0.0	$163	$206	$79	$292	$0	$741	$1,257	$1,998	$426
AC (C) + CO (C)	14.0	11.5	0.0	$208	$214	$104	$315	$53	$841	$1,426	$2,266	$694
AC (C) + CO (C)	14.0	11.5	0.0	$161	$215	$60	$292	$0	$728	$1,235	$1,964	$392
AC (C) + CO (C)	14.0	11.5	0.0	$161	$215	$79	$292	$0	$748	$1,269	$2,017	$445
AC (C) + CO (C)	14.0	11.5	0.0	$206	$223	$104	$315	$53	$848	$1,438	$2,285	$714
AC (C) + CO (C)	14.0	11.5	0.0	$167	$216	$60	$292	$0	$735	$1,247	$1,982	$410
AC (C) + CO (C)	14.0	11.5	0.0	$167	$216	$79	$292	$0	$755	$1,280	$2,035	$464
AC (C) + CO (C)	14.0	11.5	0.0	$212	$224	$104	$315	$53	$854	$1,449	$2,303	$732

Air Conditioner, Indoor Coil System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
AC (C) + CO (C)	14.0	11.5	0.0	$148	$190	$60	$292	$0	$690	$1,170	$1,860	$289
AC (C) + CO (C)	14.0	11.5	0.0	$148	$190	$79	$292	$0	$710	$1,204	$1,914	$342
AC (C) + CO (C)	14.0	11.5	0.0	$193	$198	$104	$315	$53	$809	$1,373	$2,182	$610
AC (C) + CO (C)	14.0	11.5	0.0	$152	$190	$60	$292	$0	$694	$1,177	$1,871	$299
AC (C) + CO (C)	14.0	11.5	0.0	$152	$190	$79	$292	$0	$714	$1,210	$1,924	$352
AC (C) + CO (C)	14.0	11.5	0.0	$197	$198	$104	$315	$53	$813	$1,379	$2,192	$621
AC (C) + CO (C)	14.0	11.5	0.0	$138	$183	$53	$257	$0	$630	$1,069	$1,700	$128
AC (C) + CO (C)	14.0	11.5	0.0	$154	$254	$57	$243	$0	$707	$1,200	$1,907	$224
AC (C) + CO (C)	14.0	11.5	0.0	$164	$254	$57	$246	$0	$721	$1,223	$1,943	$260
AC (C) + CO (C)	14.0	11.5	0.0	$233	$295	$79	$327	$0	$934	$1,585	$2,519	$836
AC (C) + CO (C)	14.0	11.5	0.0	$166	$249	$57	$243	$0	$715	$1,213	$1,928	$245
AC (C) + CO (C)	14.0	11.5	0.0	$176	$250	$57	$246	$0	$729	$1,236	$1,964	$281
AC (C) + CO (C)	14.0	11.5	0.0	$231	$233	$79	$327	$0	$870	$1,476	$2,347	$664
AC (C) + CO (C)	14.0	11.5	0.0	$220	$265	$79	$327	$0	$892	$1,512	$2,404	$720
AC (C) + CO (C)	14.0	11.5	0.0	$148	$234	$57	$243	$0	$682	$1,157	$1,839	$155
AC (C) + CO (C)	14.0	11.5	0.0	$158	$235	$57	$246	$0	$696	$1,180	$1,875	$192
AC (C) + CO (C)	14.0	12.0	0.0	$221	$289	$79	$327	$0	$916	$1,553	$2,469	$786
AC (C) + CO (C)	14.0	12.0	0.0	$217	$268	$79	$327	$0	$891	$1,512	$2,403	$720
AC (C) + CO (C)	14.0	12.2	0.0	$147	$188	$57	$282	$0	$675	$1,145	$1,819	$248
AC (C) + CO (C)	14.0	12.2	0.0	$147	$190	$72	$285	$0	$694	$1,177	$1,871	$299
AC (C) + CO (C)	14.0	12.2	0.0	$153	$190	$57	$282	$0	$682	$1,157	$1,839	$267
AC (C) + CO (C)	14.0	12.2	0.0	$153	$192	$72	$285	$0	$701	$1,189	$1,890	$318
AC (C) + CO (C)	14.0	12.2	0.0	$147	$188	$57	$282	$0	$675	$1,145	$1,820	$249
AC (C) + CO (C)	14.0	12.2	0.0	$153	$190	$57	$282	$0	$682	$1,157	$1,840	$268
AC (C) + CO (C)	14.0	12.2	0.0	$138	$174	$57	$282	$0	$651	$1,104	$1,755	$184
AC (C) + CO (C)	14.0	12.2	0.0	$138	$176	$72	$285	$0	$670	$1,137	$1,807	$235
AC (C) + CO (C)	14.0	12.2	0.0	$142	$174	$57	$282	$0	$655	$1,111	$1,766	$194
AC (C) + CO (C)	14.0	12.2	0.0	$142	$176	$72	$285	$0	$674	$1,143	$1,817	$245
AC (C) + CO (C)	14.3	11.5	0.0	$178	$189	$70	$253	$0	$689	$1,169	$1,859	$175

Air Conditioner, Indoor Coil System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
AC (C) + CO (C)	14.3	12.2	0.0	$168	$244	$70	$253	$0	$735	$1,246	$1,981	$298
AC (C) + CO (C)	14.3	12.2	0.0	$182	$246	$70	$253	$0	$751	$1,274	$2,026	$343
AC (C) + CO (C)	14.3	12.2	0.0	$164	$224	$70	$253	$0	$710	$1,205	$1,915	$232
AC (C) + CO (C)	14.3	12.2	0.0	$178	$226	$70	$253	$0	$727	$1,233	$1,960	$277
AC (C) + CO (C)	14.5	12.0	0.0	$161	$210	$60	$292	$0	$723	$1,227	$1,950	$379
AC (C) + CO (C)	14.5	12.0	0.0	$161	$210	$79	$292	$0	$743	$1,261	$2,004	$432
AC (C) + CO (C)	14.5	12.0	0.0	$206	$218	$104	$315	$53	$843	$1,429	$2,272	$700
AC (C) + CO (C)	14.5	12.0	0.0	$224	$311	$79	$327	$0	$941	$1,596	$2,537	$854
AC (C) + CO (C)	14.5	12.0	0.0	$231	$290	$79	$327	$0	$928	$1,573	$2,501	$818
AC (C) + CO (C)	14.5	12.0	0.0	$180	$251	$70	$253	$0	$753	$1,278	$2,031	$348
AC (C) + CO (C)	14.5	12.0	0.0	$239	$317	$79	$327	$0	$961	$1,630	$2,591	$908
AC (C) + CO (C)	14.5	12.0	0.0	$231	$244	$79	$327	$0	$881	$1,494	$2,376	$692
AC (C) + CO (C)	14.5	12.0	0.0	$219	$290	$79	$327	$0	$915	$1,551	$2,466	$783
AC (C) + CO (C)	14.5	12.0	0.0	$167	$221	$70	$253	$0	$710	$1,205	$1,915	$232
AC (C) + CO (C)	14.5	12.2	0.0	$147	$190	$72	$285	$0	$694	$1,177	$1,871	$300
AC (C) + CO (C)	14.5	12.2	0.0	$153	$192	$72	$285	$0	$701	$1,190	$1,891	$319
AC (C) + CO (C)	14.5	12.2	0.0	$151	$194	$57	$282	$0	$685	$1,161	$1,846	$274
AC (C) + CO (C)	14.5	12.2	0.0	$151	$196	$72	$285	$0	$704	$1,193	$1,897	$325
AC (C) + CO (C)	14.5	12.2	0.0	$172	$242	$61	$335	$0	$810	$1,374	$2,184	$612
AC (C) + CO (C)	14.5	12.2	0.0	$171	$266	$70	$253	$0	$760	$1,289	$2,049	$365
AC (C) + CO (C)	14.5	12.2	0.0	$186	$268	$70	$253	$0	$777	$1,317	$2,094	$410
AC (C) + CO (C)	14.5	12.2	0.0	$226	$321	$79	$327	$0	$953	$1,617	$2,571	$887
AC (C) + CO (C)	14.5	12.2	0.0	$178	$246	$70	$253	$0	$747	$1,266	$2,013	$330
AC (C) + CO (C)	14.5	12.2	0.0	$192	$248	$70	$253	$0	$763	$1,294	$2,058	$374
AC (C) + CO (C)	14.5	12.2	0.0	$233	$321	$79	$327	$0	$960	$1,628	$2,588	$905
AC (C) + CO (C)	14.5	12.2	0.0	$178	$199	$70	$253	$0	$700	$1,187	$1,888	$204
AC (C) + CO (C)	14.5	12.2	0.0	$192	$202	$70	$253	$0	$717	$1,216	$1,932	$249
AC (C) + CO (C)	14.5	12.2	0.0	$239	$256	$79	$327	$0	$900	$1,527	$2,427	$744
AC (C) + CO (C)	14.5	12.2	0.0	$166	$245	$70	$253	$0	$734	$1,244	$1,978	$295

Air Conditioner, Indoor Coil System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
AC (C) + CO (C)	14.5	12.2	0.0	$180	$247	$70	$253	$0	$750	$1,273	$2,023	$340
AC (C) + CO (C)	14.5	12.2	0.0	$220	$302	$79	$327	$0	$928	$1,574	$2,502	$819
AC (C) + CO (C)	14.5	12.5	0.0	$173	$277	$70	$253	$0	$772	$1,310	$2,082	$399
AC (C) + CO (C)	14.5	12.5	0.0	$187	$279	$70	$253	$0	$789	$1,338	$2,127	$444
AC (C) + CO (C)	14.5	12.5	0.0	$185	$272	$70	$253	$0	$780	$1,323	$2,103	$420
AC (C) + CO (C)	14.5	12.5	0.0	$200	$274	$70	$253	$0	$797	$1,351	$2,148	$465
AC (C) + CO (C)	14.5	12.5	0.0	$180	$276	$70	$253	$0	$779	$1,321	$2,100	$417
AC (C) + CO (C)	14.5	12.5	0.0	$194	$278	$70	$253	$0	$796	$1,349	$2,145	$462
AC (C) + CO (C)	14.5	12.5	0.0	$202	$257	$231	$290	$58	$998	$1,693	$2,691	$1,008
AC (C) + CO (C)	14.5	12.5	0.0	$167	$257	$70	$253	$0	$747	$1,267	$2,014	$331
AC (C) + CO (C)	14.5	12.5	0.0	$181	$260	$70	$253	$0	$764	$1,295	$2,059	$376
AC (C) + CO (C)	15.0	12.5	0.0	$192	$312	$231	$290	$58	$1,044	$1,770	$2,813	$1,130
AC (C) + CO (C)	15.0	12.5	0.0	$204	$318	$231	$290	$58	$1,062	$1,801	$2,863	$1,180
AC (C) + CO (C)	15.0	12.5	0.0	$185	$211	$70	$253	$0	$719	$1,220	$1,939	$256
AC (C) + CO (C)	15.0	12.5	0.0	$200	$213	$70	$253	$0	$736	$1,248	$1,984	$301
AC (C) + CO (C)	15.0	12.5	0.0	$188	$292	$231	$290	$58	$1,019	$1,728	$2,748	$1,064
AC (C) + CO (C)	15.0	12.5	0.0	$191	$289	$231	$290	$58	$1,019	$1,729	$2,748	$1,064
AC (C) + CO (C)	15.0	12.7	0.0	$202	$314	$231	$290	$58	$1,055	$1,790	$2,845	$1,162
AC (C) + CO (C)	15.1	12.5	0.0	$202	$267	$231	$290	$58	$1,009	$1,711	$2,720	$1,037
AC (C) + CO (C)	15.1	13.0	0.0	$209	$279	$231	$290	$58	$1,028	$1,743	$2,771	$1,088
AC (C) + CO (C)	15.2	12.7	0.0	$195	$334	$231	$290	$58	$1,069	$1,812	$2,881	$1,198
AC (C) + CO (C)	15.2	12.7	0.0	$197	$345	$231	$290	$58	$1,081	$1,834	$2,915	$1,231
AC (C) + CO (C)	15.2	12.7	0.0	$204	$344	$231	$290	$58	$1,088	$1,845	$2,932	$1,249
AC (C) + CO (C)	15.2	12.7	0.0	$190	$313	$231	$290	$58	$1,042	$1,768	$2,810	$1,127
AC (C) + CO (C)	15.2	12.7	0.0	$191	$325	$231	$290	$58	$1,056	$1,791	$2,846	$1,163
AC (C) + CO (C)	15.2	13.0	0.0	$209	$340	$231	$290	$58	$1,089	$1,847	$2,936	$1,252
AC (C) + CO (C)	16.0	12.5	0.0	$225	$355	$159	$401	$67	$1,140	$1,934	$3,074	$1,502
AC (C) + CO (C)	16.0	12.5	0.0	$231	$357	$159	$401	$67	$1,147	$1,946	$3,093	$1,522
AC (C) + CO (C)	16.0	12.5	0.0	$229	$366	$159	$401	$67	$1,155	$1,958	$3,113	$1,541

Air Conditioner, Indoor Coil System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
AC (C) + CO (C)	16.0	12.5	0.0	$235	$367	$159	$401	$67	$1,161	$1,970	$3,131	$1,559
AC (C) + CO (C)	16.0	12.5	0.0	$229	$361	$159	$401	$67	$1,150	$1,950	$3,099	$1,528
AC (C) + CO (C)	16.0	12.5	0.0	$302	$427	$286	$387	$45	$1,453	$2,465	$3,918	$2,235
AC (C) + CO (C)	16.5	12.5	0.0	$233	$371	$159	$401	$67	$1,164	$1,974	$3,138	$1,566
AC (C) + CO (C)	17.0	13.0	0.0	$292	$482	$286	$387	$45	$1,499	$2,542	$4,041	$2,357
AC (C) + CO (C)	17.0	13.0	0.0	$295	$504	$286	$387	$45	$1,524	$2,584	$4,108	$2,425
AC (C) + CO (C)	17.0	13.0	0.0	$297	$515	$286	$387	$45	$1,536	$2,606	$4,142	$2,459
AC (C) + CO (C)	17.0	13.0	0.0	$302	$484	$286	$387	$45	$1,511	$2,562	$4,072	$2,389
AC (C) + CO (C)	17.0	13.0	0.0	$304	$489	$286	$387	$45	$1,517	$2,573	$4,090	$2,407
AC (C) + CO (C)	17.0	13.0	0.0	$309	$510	$286	$387	$45	$1,544	$2,619	$4,163	$2,480
AC (C) + CO (C)	17.0	13.0	0.0	$304	$514	$286	$387	$45	$1,543	$2,617	$4,160	$2,476
AC (C) + CO (C)	17.0	13.0	0.0	$302	$438	$286	$387	$45	$1,464	$2,483	$3,947	$2,264
AC (C) + CO (C)	17.0	13.0	0.0	$309	$449	$286	$387	$45	$1,483	$2,515	$3,999	$2,315
AC (C) + CO (C)	17.0	13.0	0.0	$288	$462	$286	$387	$45	$1,474	$2,500	$3,975	$2,291
AC (C) + CO (C)	17.0	13.0	0.0	$290	$483	$286	$387	$45	$1,498	$2,540	$4,038	$2,354
AC (C) + CO (C)	17.0	13.0	0.0	$291	$459	$286	$387	$45	$1,474	$2,501	$3,975	$2,292
AC (C) + CO (C)	17.0	13.0	0.0	$291	$496	$286	$387	$45	$1,511	$2,563	$4,074	$2,390

Table 18: Manufacturing Cost and Price Estimates for Heat Pump, Air Handler (HP-AH) Unit Combinations (excludes non-efficiency items)

Heat Pump, Air Handler System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
HP (C) + AH (C) – Baseline 1	14.0	11.5	8.2	$214	$168	$147	$343	$0	$872	$1,479	$2,351	$0
HP (C) + AH (T) – Baseline 2	14.0	12.2	8.2	$246	$228	$139	$320	$7	$933	$1,582	$2,514	$0
HP (T) + AH (C)	14.0	11.7	8.2	$274	$293	$154	$330	$7	$1,051	$1,783	$2,834	$0
HP (T) + AH (T)	14.0	11.7	8.2	$270	$279	$152	$330	$7	$1,032	$1,750	$2,782	$0
HP (C) + AH (C)	14.0	11.7	8.2	$258	$269	$154	$330	$7	$1,011	$1,715	$2,726	$0
HP (C) + AH (T)	14.0	11.7	8.2	$255	$255	$152	$330	$7	$992	$1,683	$2,675	$0
HP (C) + AH (C)	14.0	11.5	8.5	$214	$168	$147	$343	$0	$872	$1,479	$2,351	$0
HP (T) + AH (T)	14.2	11.7	8.2	$267	$287	$142	$330	$7	$1,026	$1,741	$2,767	$253
HP (C) + AH (C)	14.5	12.0	8.2	$267	$319	$224	$415	$8	$1,226	$2,079	$3,304	$790
HP (T) + AH (C)	14.5	12.2	8.2	$271	$307	$243	$330	$7	$1,151	$1,952	$3,103	$589
HP (C) + AH (C)	14.5	12.0	8.2	$212	$155	$228	$351	$0	$947	$1,605	$2,552	$201
HP (C) + AH (T)	14.5	12.5	8.2	$237	$180	$231	$351	$0	$999	$1,694	$2,692	$341
HP (C) + AH (C)	14.5	12.0	8.2	$217	$171	$282	$351	$90	$1,021	$1,731	$2,752	$401
HP (C) + AH (T)	14.5	12.5	8.2	$242	$192	$285	$351	$90	$1,069	$1,814	$2,883	$532
HP (C) + AH (T)	14.5	12.0	8.2	$209	$181	$168	$357	$0	$915	$1,551	$2,466	$115
HP (C) + AH (C)	14.5	11.5	8.2	$217	$171	$282	$343	$90	$1,013	$1,717	$2,730	$379
HP (C) + AH (C)	14.5	12.0	8.2	$212	$155	$228	$343	$0	$938	$1,591	$2,530	$179
HP (C) + AH (T)	14.5	12.0	8.2	$237	$180	$231	$343	$0	$990	$1,680	$2,670	$319
HP (C) + AH (T)	14.5	12.0	8.2	$242	$192	$285	$343	$90	$1,061	$1,800	$2,861	$510
HP (C) + AH (C)	14.5	12.2	8.2	$256	$282	$243	$330	$7	$1,111	$1,884	$2,995	$481
HP (C) + AH (C)	14.5	12.0	8.5	$229	$173	$170	$357	$0	$929	$1,575	$2,504	$153
HP (C) + AH (C)	14.5	11.5	8.5	$212	$155	$228	$343	$0	$938	$1,591	$2,530	$179
HP (C) + AH (T)	14.5	12.0	8.5	$237	$180	$231	$343	$0	$990	$1,680	$2,670	$319
HP (T) + AH (T)	14.5	12.0	8.5	$209	$182	$168	$359	$0	$917	$1,556	$2,473	$122
HP (T) + AH (C)	14.5	12.0	8.5	$229	$174	$170	$359	$0	$931	$1,579	$2,511	$160
HP (C) + AH (C)	14.5	12.0	8.5	$214	$168	$147	$343	$0	$872	$1,479	$2,351	$0
HP (C) + AH (C)	15.0	12.5	8.5	$282	$185	$290	$403	$61	$1,159	$1,966	$3,126	$775

Heat Pump, Air Handler System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
HP (C) + AH (C)	15.0	12.0	8.5	$287	$200	$344	$403	$151	$1,234	$2,093	$3,326	$975
HP (C) + AH (C)	15.0	12.0	8.5	$285	$198	$208	$403	$61	$1,093	$1,854	$2,947	$596
HP (C) + AH (C)	15.0	12.0	8.5	$231	$193	$306	$357	$90	$1,087	$1,843	$2,930	$579
HP (C) + AH (C)	15.0	12.5	8.5	$229	$191	$170	$357	$0	$946	$1,605	$2,551	$200
HP (C) + AH (T)	15.0	12.0	8.5	$242	$192	$285	$343	$90	$1,061	$1,800	$2,861	$510
HP (T) + AH (C)	15.0	12.5	8.5	$229	$191	$170	$359	$0	$949	$1,609	$2,558	$207
HP (C) + AH (C)	15.0	12.0	8.5	$217	$171	$282	$343	$90	$1,013	$1,717	$2,730	$379
HP (T) + AH (C)	15.2	12.7	8.7	$304	$337	$249	$330	$7	$1,221	$2,071	$3,292	$778
HP (T) + AH (C)	15.2	12.7	8.7	$288	$329	$246	$330	$7	$1,193	$2,024	$3,217	$703
HP (T) + AH (C)	15.2	12.7	8.7	$284	$323	$155	$330	$7	$1,092	$1,852	$2,943	$429
HP (C) + AH (C)	15.2	12.7	8.7	$289	$313	$249	$330	$7	$1,181	$2,003	$3,184	$670
HP (C) + AH (C)	15.2	12.7	8.7	$273	$305	$246	$330	$7	$1,154	$1,956	$3,110	$596
HP (C) + AH (T)	15.5	11.2	8.5	$279	$337	$195	$415	$8	$1,225	$2,078	$3,304	$789
HP (T) + AH (C)	15.5	12.5	8.5	$271	$282	$230	$330	$7	$1,114	$1,889	$3,002	$488
HP (C) + AH (T)	15.5	12.5	8.5	$307	$210	$292	$403	$61	$1,212	$2,055	$3,266	$915
HP (C) + AH (T)	15.5	12.5	8.5	$312	$222	$346	$403	$151	$1,282	$2,175	$3,457	$1,106
HP (C) + AH (T)	15.5	12.5	8.5	$256	$215	$308	$357	$90	$1,136	$1,926	$3,062	$710
HP (C) + AH (C)	15.5	12.5	8.5	$256	$257	$230	$330	$7	$1,074	$1,821	$2,895	$381
HP (T) + AH (C)	15.5	13.0	8.7	$304	$338	$268	$330	$7	$1,241	$2,104	$3,345	$831
HP (C) + AH (C)	15.5	13.0	8.7	$289	$314	$268	$330	$7	$1,201	$2,037	$3,237	$723
HP (T) + AH (C)	15.5	13.0	9.0	$304	$338	$261	$330	$7	$1,234	$2,093	$3,327	$813
HP (T) + AH (C)	15.5	13.0	9.0	$297	$338	$248	$330	$7	$1,213	$2,057	$3,271	$756
HP (C) + AH (C)	15.5	12.5	9.0	$226	$178	$252	$357	$0	$1,013	$1,717	$2,730	$379
HP (C) + AH (T)	15.5	12.5	9.0	$251	$203	$255	$357	$0	$1,065	$1,806	$2,870	$519
HP (T) + AH (C)	15.5	12.5	9.0	$226	$178	$252	$359	$0	$1,015	$1,722	$2,737	$386
HP (T) + AH (C)	15.5	12.5	9.0	$231	$194	$306	$359	$90	$1,089	$1,848	$2,937	$586
HP (C) + AH (C)	15.5	13.0	9.0	$289	$314	$261	$330	$7	$1,194	$2,025	$3,219	$705
HP (C) + AH (C)	15.5	13.0	9.0	$282	$314	$248	$330	$7	$1,173	$1,990	$3,163	$649
HP (T) + AH (C)	15.7	13.2	8.7	$284	$432	$316	$386	$58	$1,437	$2,438	$3,875	$1,361

Heat Pump, Air Handler System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
HP (T) + AH (C)	15.7	13.2	9.0	$276	$432	$314	$386	$58	$1,427	$2,420	$3,848	$1,333
HP (T) + AH (C)	16.0	12.0	8.5	$377	$454	$371	$478	$45	$1,731	$2,936	$4,667	$2,153
HP (T) + AH (C)	16.0	12.0	8.5	$368	$454	$369	$478	$45	$1,721	$2,919	$4,640	$2,126
HP (C) + AH (C)	16.0	12.5	8.5	$297	$362	$252	$415	$8	$1,327	$2,250	$3,577	$1,063
HP (C) + AH (C)	16.0	12.0	8.5	$297	$362	$259	$415	$8	$1,334	$2,262	$3,595	$1,081
HP (C) + AH (C)	16.0	12.0	8.5	$297	$361	$241	$415	$8	$1,314	$2,228	$3,542	$1,028
HP (C) + AH (C)	16.0	12.5	8.5	$289	$346	$197	$415	$8	$1,247	$2,115	$3,362	$848
HP (T) + AH (C)	16.0	13.5	9.0	$296	$322	$206	$330	$7	$1,154	$1,957	$3,111	$597
HP (T) + AH (T)	16.0	13.5	9.0	$287	$312	$203	$330	$7	$1,132	$1,921	$3,053	$539
HP (T) + AH (T)	16.0	12.5	9.0	$251	$203	$255	$359	$0	$1,067	$1,810	$2,877	$526
HP (T) + AH (T)	16.0	13.0	9.0	$256	$215	$308	$359	$90	$1,138	$1,930	$3,068	$717
HP (C) + AH (C)	16.0	13.5	9.0	$281	$297	$206	$330	$7	$1,114	$1,890	$3,004	$490
HP (C) + AH (T)	16.0	13.5	9.0	$271	$288	$203	$330	$7	$1,093	$1,853	$2,946	$431
HP (C) + AH (C)	16.5	12.0	8.2	$282	$184	$880	$578	$109	$1,924	$3,264	$5,188	$2,837
HP (C) + AH (T)	16.5	12.0	8.2	$307	$209	$882	$578	$109	$1,977	$3,352	$5,329	$2,978
HP (C) + AH (C)	16.5	12.5	8.5	$281	$353	$237	$415	$8	$1,286	$2,182	$3,468	$954
HP (C) + AH (C)	17.0	12.5	8.5	$290	$362	$239	$415	$8	$1,306	$2,215	$3,521	$1,007
HP (T) + AH (T)	17.0	13.0	9.0	$371	$443	$418	$478	$45	$1,762	$2,988	$4,749	$2,235
HP (T) + AH (C)	17.0	14.0	9.0	$297	$447	$427	$386	$58	$1,576	$2,673	$4,249	$1,735
HP (T) + AH (T)	17.0	14.0	9.0	$279	$421	$363	$386	$58	$1,468	$2,489	$3,957	$1,443
HP (T) + AH (C)	17.0	13.5	9.0	$285	$317	$333	$485	$67	$1,420	$2,408	$3,827	$1,476
HP (T) + AH (T)	17.0	13.5	9.0	$310	$342	$336	$485	$67	$1,472	$2,496	$3,968	$1,617
HP (C) + AH (C)	17.0	13.0	9.0	$285	$317	$290	$481	$67	$1,373	$2,329	$3,702	$1,351
HP (C) + AH (T)	17.0	13.0	9.0	$310	$342	$292	$481	$67	$1,425	$2,417	$3,842	$1,491
HP (C) + AH (C)	17.0	13.0	9.0	$290	$332	$344	$481	$157	$1,447	$2,455	$3,902	$1,551
HP (C) + AH (T)	17.0	13.0	9.0	$315	$354	$346	$481	$157	$1,496	$2,537	$4,034	$1,682
HP (C) + AH (C)	17.0	13.0	9.0	$233	$317	$259	$447	$0	$1,255	$2,129	$3,385	$1,034
HP (C) + AH (T)	17.0	13.0	9.0	$258	$342	$261	$447	$0	$1,308	$2,218	$3,525	$1,174
HP (T) + AH (C)	17.0	14.0	9.5	$297	$447	$421	$386	$58	$1,569	$2,662	$4,231	$1,717

Heat Pump, Air Handler System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
HP (T) + AH (C)	17.0	14.0	9.5	$297	$446	$409	$386	$58	$1,556	$2,640	$4,196	$1,682
HP (T) + AH (C)	17.0	14.0	9.5	$289	$447	$407	$386	$58	$1,548	$2,626	$4,175	$1,661
HP (T) + AH (C)	17.0	14.5	9.5	$289	$431	$365	$386	$58	$1,489	$2,526	$4,015	$1,501
HP (C) + AH (C)	17.0	11.0	10.0	$312	$261	$936	$578	$199	$2,087	$3,540	$5,628	$3,277
HP (T) + AH (C)	17.5	14.5	9.5	$280	$438	$405	$386	$58	$1,529	$2,593	$4,122	$1,608
HP (T) + AH (C)	17.5	13.5	9.5	$290	$332	$387	$485	$157	$1,494	$2,534	$4,028	$1,677
HP (C) + AH (C)	17.5	11.5	10.0	$287	$199	$934	$578	$199	$1,999	$3,390	$5,389	$3,038
HP (C) + AH (C)	17.5	11.0	10.0	$287	$199	$934	$578	$199	$1,999	$3,390	$5,389	$3,038
HP (T) + AH (C)	18.0	13.0	9.0	$389	$469	$476	$478	$45	$1,863	$3,160	$5,023	$2,509
HP (T) + AH (C)	18.0	13.0	9.0	$389	$469	$483	$478	$45	$1,870	$3,171	$5,041	$2,527
HP (T) + AH (C)	18.0	13.0	9.0	$389	$468	$464	$478	$45	$1,850	$3,138	$4,988	$2,474
HP (T) + AH (C)	18.0	13.0	9.0	$373	$460	$460	$478	$45	$1,823	$3,091	$4,914	$2,400
HP (C) + AH (C)	18.0	12.5	10.0	$312	$261	$936	$578	$199	$2,087	$3,540	$5,628	$3,277
HP (C) + AH (T)	18.0	12.0	10.0	$312	$221	$936	$578	$199	$2,047	$3,472	$5,520	$3,169
HP (C) + AH (T)	18.0	11.0	10.0	$312	$221	$936	$578	$199	$2,047	$3,472	$5,520	$3,169
HP (T) + AH (T)	18.0	13.5	10.0	$315	$354	$390	$485	$157	$1,543	$2,616	$4,159	$1,808
HP (T) + AH (C)	19.0	13.0	9.0	$381	$453	$420	$478	$45	$1,783	$3,024	$4,808	$2,294
HP (T) + AH (C)	19.0	14.5	10.5	$340	$371	$946	$622	$217	$2,279	$3,866	$6,145	$3,794
HP (T) + AH (C)	19.2	13.5	9.2	$382	$469	$462	$478	$45	$1,842	$3,125	$4,967	$2,453
HP (T) + AH (T)	19.5	15.0	10.5	$365	$392	$948	$622	$217	$2,328	$3,948	$6,276	$3,925
HP (T) + AH (C)	20.0	15.0	12.0	$365	$432	$948	$622	$217	$2,368	$4,016	$6,384	$4,033

Table 19: Manufacturing Cost and Price Estimates for Heat Pump, Coil-Only (HP-CO) Unit Combinations (excludes non-efficiency items)

Heat Pump, Indoor Coil System Combo (C)=Catalog, (T)=Teardown	AHRI Ratings			Sub-Systems				Non-Efficiency Costs (excluded)	Total MPC	Markup	System Price	Incremental System Price
	SEER	EER	HSPF	Shell	Heat Exchangers	Electricals	Sealed System					
HP (T) + CO (C) – Baseline 1	14.0	11.0	8.2	$170	$226	$81	$359	$0	$836	$1,417	$2,253	$0
HP (C) + CO (C) – Baseline 2	14.0	11.7	8.2	$194	$279	$73	$330	$8	$877	$1,487	$2,363	$0
HP (C) + CO (C)	14.0	11.5	8.2	$235	$370	$119	$481	$67	$1,205	$2,044	$3,249	$0
HP (C) + CO (C)	14.0	11.5	8.2	$229	$369	$119	$481	$67	$1,198	$2,033	$3,231	$0
HP (T) + CO (C)	14.0	12.0	8.5	$235	$370	$162	$485	$67	$1,252	$2,123	$3,375	$1,122
HP (T) + CO (C)	14.0	12.0	8.5	$229	$369	$162	$485	$67	$1,245	$2,112	$3,357	$1,104
HP (T) + CO (C)	14.0	12.0	8.5	$231	$360	$162	$485	$67	$1,238	$2,099	$3,337	$1,085
HP (T) + CO (C)	14.0	12.0	8.5	$225	$359	$162	$485	$67	$1,231	$2,087	$3,318	$1,065
HP (T) + CO (C)	14.0	12.0	8.5	$231	$360	$162	$485	$67	$1,237	$2,099	$3,336	$1,084
HP (T) + CO (C)	14.0	12.0	8.5	$225	$358	$162	$485	$67	$1,230	$2,087	$3,317	$1,064
HP (T) + CO (C)	14.2	12.0	8.2	$212	$315	$73	$330	$7	$931	$1,579	$2,511	$148
HP (C) + CO (C)	14.2	12.0	8.2	$197	$291	$73	$330	$7	$891	$1,512	$2,403	$40
HP (T) + CO (C)	14.5	12.0	8.5	$216	$344	$162	$485	$67	$1,207	$2,046	$3,253	$1,000
HP (T) + CO (C)	15.0	12.7	8.2	$185	$397	$233	$386	$58	$1,220	$2,069	$3,290	$926
HP (T) + CO (C)	15.0	12.5	8.2	$199	$428	$233	$386	$58	$1,265	$2,146	$3,412	$1,049
HP (T) + CO (C)	15.0	12.7	8.2	$190	$418	$233	$386	$58	$1,246	$2,114	$3,360	$997
HP (T) + CO (C)	15.0	12.5	8.5	$186	$410	$233	$386	$58	$1,234	$2,092	$3,326	$963
HP (T) + CO (C)	15.0	12.5	8.5	$204	$424	$233	$386	$58	$1,267	$2,148	$3,415	$1,052
HP (T) + CO (C)	15.0	12.5	8.5	$192	$429	$233	$386	$58	$1,259	$2,135	$3,394	$1,031