Residential HVAC Momentum Savings Analysis Draft Results Memo

November 3, 2015

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Executive Summary

This memo describes the results of the research team's technical estimation of Momentum Savings from residential air source heat pumps in the Pacific Northwest region between 2010 and 2014.

Methodology

The methodology for estimating Momentum Savings follows the four question framework:

1) **What is the market?** The research team defined the market for this analysis as newly installed ducted air source heat pumps in single family and manufactured homes. The geographic scope of the market is the Northwest region comprised of counties in OR, WA, ID, and Western MT, each assigned to heating zones 1 2, and 3 by the Regional Technical Forum (RTF).

2) **How big is the market?** The research team defines the annual market size as the number of HVAC units sold per year, for each year of the analysis (2010-2014). The team determined the market size using a stock turnover model calibrated to Air-Conditioning, Heating, and Refrigeration Institute (AHRI) regional sales data.

3) **What are the total market savings?** Total market savings are equal to the difference between baseline consumption and actual consumption. The research team calculated baseline consumption using the Sixth Plan baseline, annual market size, and HVAC unit energy consumption (UEC) values from energy modeling. The team calculated actual consumption using the same approach, substituting Sixth Plan baseline efficiencies for HVAC efficiency values from sales data.

4) **What are the program savings?** Momentum Savings, by definition, exclude electricity savings achieved through efficiency programs in the region. The research team developed estimates of programmatic savings from program data provided by BPA and investor-owned utilities—recalculated to be consistent with the Northwest Power and Conservation Council's Sixth Regional Power Plan (Sixth Plan). The team subtracted this calculation of programmatic savings from total market savings to calculate Momentum Savings, according to Equation 1.

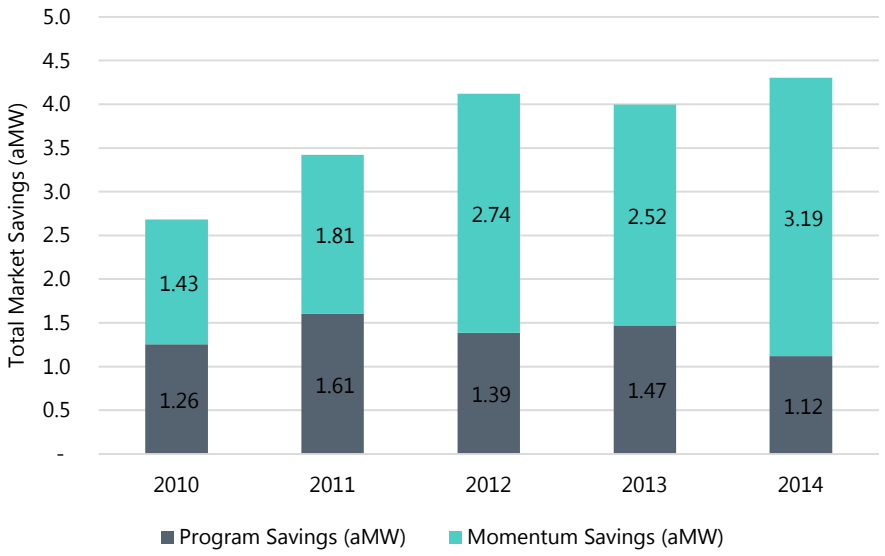
Equation 1. Momentum Savings Calculation

$$\text{Momentum Savings} = \text{Total Market Savings} - \text{Program Savings}$$

Results

Figure 1 shows the sources of total market savings, split between Momentum Savings and program savings.

Figure 1: Total Market Savings (aMW) for Air Source Heat Pumps by Source



Source: Navigant analysis

Driving Factors

From primary sales data collection efforts, the team learned that the relative proportion of efficient and inefficient air source heat pump sales did not significantly change over the analysis period. Therefore, the efficiency mix of units sold is not a main driver of the savings. The driving factors that determine Momentum Savings are:

1) **The relative proportion of conversions vs. upgrades in the market.** When an air source heat pump replaces an electric forced air furnace (a conversion) this yields much greater savings than when an air source heat pump replaces another air source heat pump (an upgrade).

2) **The market size.** Because program savings remain relatively constant over the analysis period, when the market size increases relative to program unit sales, Momentum Savings also increase.

3) **Quality installations**. For units sold into the market, the team assumes that contractors who install these units do not follow proper commissioning, controls, and sizing (CC&S) practices. If the analysis team were to find that a certain percentage of contractors in the market outside of programs actually are following proper CC&S practices, Momentum Savings could increase.

4) **Program savings.** Because the total market savings are split into two sources—program savings and Momentum Savings—the program savings calculations directly influence Momentum Savings results.

Future Research Opportunities

Acknowledging that some data gaps exist in this current analysis, the team developed recommendations for future data collection and analysis that could improve the estimation of residential HVAC Momentum Savings.

1) **Survey HVAC installation contractors.** Installation context (upgrades vs. conversions, home type, fuel switching, CC&S practices, etc.) is the primary driver of Momentum Savings results. The team could interview HVAC installation contractors in order to obtain better information regarding these factors.

2) **Enhance program savings data.** Many utilities across the Pacific Northwest provided well-documented program savings data. In some cases, however, regional energy efficiency program managers were unable to provide full detailed data on their residential HVAC programs. More detailed program data would refine Momentum Savings estimates.

3) **Enhance market data.** The team could collect more data from individual distributors and HVAC trade organizations to more precisely characterize the regional market size. Enhancing market data may involve establishing relationships with AHRI to obtain more context for their data, subscribing to other regional HVAC data acquisition services such as Heating, Air Conditioning and Refrigeration Distributors International (HARDI), dedicating time to establishing ongoing relationships with regional distributors, or some combination of these approaches.

4) **Calculate HVAC cooling savings.** This analysis concerns electric heating use. Although electric cooling is less common in the region, estimating cooling savings would likely increase Momentum Savings.

The remainder of this report explains the technical details of the methodology outlined above, and presents the analysis results that led the research team to these conclusions.

Introduction

This memo describes in detail the results of the research team's estimation of Momentum Savings from residential air source heat pumps in Bonneville Power Administration (BPA) territory and the Pacific Northwest region between 2010 and 2014.

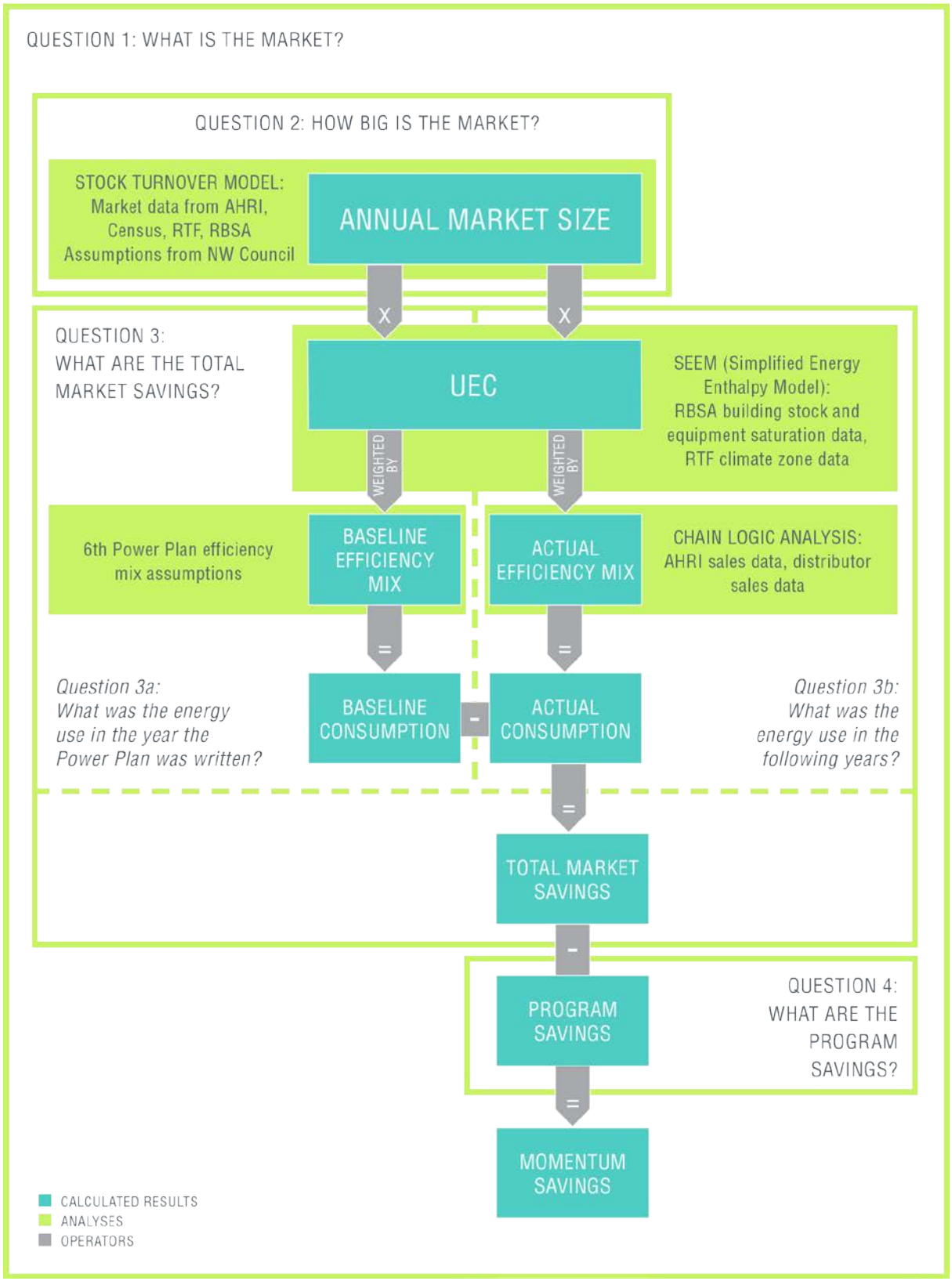
The "Methodology and Results" section presents the research team's detailed technical methods for estimating Momentum Savings using the Four Question Framework, and also documents the key technical decisions the research team made during the analysis. The "Driving Factors" section describes the steps the research team used to calculate the total energy consumption in the baseline and actual market scenarios (Question 3 of the Four Question Framework). It also defines the program savings achieved in the HVAC market (Question 4). Finally, the "Opportunities for Future Research" provides the research team's recommendations for improving future estimates of Momentum Savings in the residential HVAC market.

Methodology and Results

The Four Question Framework organizes this chapter. Questions 1 and 2 define the residential HVAC market in terms of number of units installed in the marketplace each year within the product categories covered by this analysis. Questions 3 and 4 presents the methods for quantifying Momentum Savings, including calculating the total energy consumption in the baseline and actual market scenarios and defining the program savings achieved in the HVAC market. Together, the results of the Four Questions enable the research team to estimate Momentum Savings in the residential HVAC market.

Figure 2 shows the overall calculation of Momentum Savings, including the three key components for calculating consumption for the baseline and actual market scenarios: annual market size, UEC, and efficiency mix. Note that the values for annual market size and UEC remain constant for both scenarios and the only difference will be the efficiency mix within the HVAC market.

Figure 2: Overview of Momentum Savings Methodology



Source: Navigant analysis

Question 1: What is the market?

The research team defined the market for this analysis as newly installed ducted air source heat pumps in single family and manufactured homes. The defined market excludes measures that impact energy use after heat pump installation, such as improvements to building shell characteristics, HVAC distribution systems, tune-ups of existing HVAC systems, or HVAC control systems. The geographic scope of the market is the Northwest region comprised of counties in OR, WA, ID, and Western MT, each assigned to heating zones 1 2, and 3 by the Regional Technical Forum (RTF). The market encompasses the entire four-state Northwest region as defined in the Sixth Power Plan, including areas served by utilities other than BPA.

Table 1 presents the specific set of air source heat pumps included in this analysis. These measures cover two scenarios as defined by the Council's Sixth Power Plan (Sixth Plan)[1]:

- **Conversion measures.** Air source heat pump installations replacing older technology of a different type (e.g., conversion from an electric furnace to a heat pump).
- **Upgrade measures.** Air source heat pump installations that replace an existing air source heat pump that is the same or more efficient. New construction shipments of air source heat pumps also qualify as upgrades.

[1] The analysis team defines upgrades and conversions this way to maintain consistency with how the Sixth Plan characterizes HVAC replacements. This language uses the term "upgrade" to apply to any like-for-like replacement of HVAC technology, regardless of whether the efficiency is actually being upgraded.

Table 1: HVAC Conversion and Upgrade Scenarios within Scope of Analysis

Conversion of	Converted to	In the context of	With efficiencies of
Electric forced-air furnace w/ central air conditioning **Electric forced-air furnace w/o central air conditioning**	new air source heat pumps	single family homes, manufactured homes	HSPF[2] 7.7/SEER[3] 13; HSPF 8.5/SEER 14; HSPF 9.0/SEER 14; HSPF 9.5/SEER 14; HSPF 10.0/SEER 14; HSPF 10.5/SEER 14; HSPF 11.5/SEER 14 (variable capacity)
Upgrade of	**Upgraded to**	**In the context of**	**With efficiencies of**
Retired existing heat pump	new air source heat pumps	single family homes, manufactured homes	HSPF 8.5/SEER 14; HSPF 9.0/SEER 14; HSPF 9.5/SEER 14; HSPF 10.0/SEER 14; HSPF 10.5/SEER 14; HSPF 11.5/SEER 14 (variable capacity)

Source: Navigant analysis of Sixth Power Plan data

Key Decisions

- The research team assumed that all HVAC units sold in the region are "lost opportunity" measures, or only those units sold to replace faulty or "burnt out" units.[4] This assumption is consistent with the Sixth Plan.
- The research team did not quantify Momentum Savings from ductless heat pumps, as the Northwest Energy Efficiency Alliance (NEEA) recently undertook an effort to quantify these savings.[5]
- The research team modeled the permutations of products and efficiencies where *substantial* distributor shipment data indicate that the product is applicable to the region. The research team's Sales Data Results Memo explains the details of distributor shipment data, and how the data led the team to conclude that the units in Table 1 account for a significant portion of regional electric heating consumption.

[2] Heating Seasonal Performance Factor (HSPF) is a unit of heating efficiency.
[3] Seasonal Energy Efficiency Ratio (SEER) is a unit of cooling efficiency.
[4] Lost-opportunity resources can only be technically or economically captured during a limited window of opportunity, such as when a building is built or an industrial process is upgraded.
[5] For more information on NEEA's work in this area, see https://neea.org/docs/default-source/reports/ductless-heat-pump-market-continues-to-increase-dhp-mper-4.pdf?sfvrsn=12

Question 2: How big is the market?

The research team defines the **annual market size** as the number of units sold per year, for each year of the analysis (2010-2014), for each combination of:

- HVAC unit type (as outlined in Table 1)
- Housing type (single family or manufactured homes)

The team developed a **stock turnover model** to determine annual market size for each of the combinations described above. Key data for this model includes distributor sales data collected by the research team, sales data provided by the Air-Conditioning, Heating, and Refrigeration Institute (AHRI)[6], historical and forecast housing data from the Northwest Power and Conservation Council (the Council)[7], climate zone data technology allocation data from 2011 Single Family and Manufactured Homes Residential Building Stock Assessments (RBSA)[8,9], regional stock saturation data from the 1992 Pacific Northwest Residential Energy Survey (PNRES92)[10] and RBSA, and estimated measure life data from the U.S. Department of Energy (DOE) Energy Conservation Standards Rulemaking Engineering Analysis for heat pumps and furnaces.[11]

The team's stock turnover model is similar to the stock turnover models developed to estimate market size for BPA's Appliance Standards Momentum Savings project.[12] As with the Appliance Standards Model, the HVAC Stock Model starts by using the 1992 (PNRES92) [13] and 2011 (RBSA) stock saturations to develop a linear trend for each technology[14] and housing type. Specific to the HVAC Stock Model, the team also developed an estimate of the equipment saturation in new construction over the same time period to reflect changing preferences and availability of technology.

The team applied these trends to the housing stock and new construction figures, respectively, to arrive at estimates of the installed stock and shipments to new construction in each year from 1980 to 2015. The models then estimate the replacement shipments and other new installations in each year of the

[6] AHRI represents 95% of the total heat pumps sold in the region. These data are comprehensive in market coverage, but limited to the extent that the reports present aggregated data; AHRI provides sales data in terms of units sold, not capacity (tons, kW, or BTUs), and much of the data are aggregated by unit type and efficiency level.

[7] Northwest Power and Conservation Council Sixth Power Plan Supply Curve Files: Residential Supply Curve Housing and Appliance Units

[8] '2011 Residential Building Stock Assessment: Single-Family Characteristics and Energy Use', NEEA, September 18, 2012

[9] 'Residential Building Stock Assessment: Manufactured Homes Characteristics and Energy Use', NEEA, January 30, 2013

[10] The 1992 Pacific Northwest Residential Energy Survey – Phase I, Book2: Item-by-Item Cross tabulations, Volume C: Pacific Northwest Region

[11] DOE Furnaces and Boilers 2007 Final Rule, Technical Support Document Chapter 8: Lifecycle Cost Analysis, Table 8.3.3 Furnace and Boiler Lifetimes Used in the LCC Analysis.

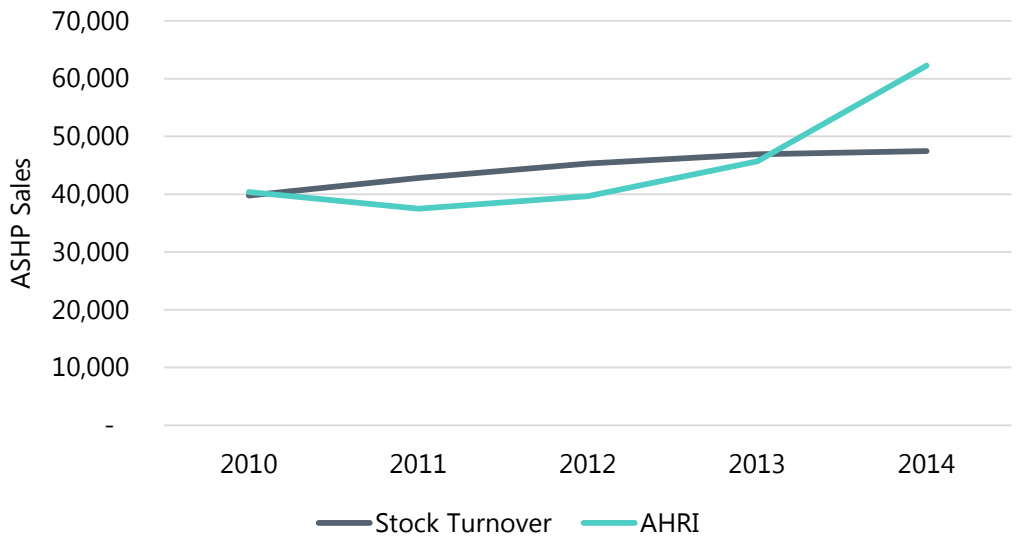
[12] Available at: https://www.bpa.gov/EE/Utility/research-archive/Documents/Appliance_Standards_Report.pdf

[13] The 1992 Pacific Northwest Residential Energy Survey – Phase I, Book2: Item-by-Item Cross tabulations, Volume C: Pacific Northwest Region

[14] This includes electric forced air furnaces, gas forced air furnaces, and ducted air source heat pumps. While the savings in this analysis are derived from air source heat pumps, both types of furnaces were modeled to estimate the portion of electric forced air furnaces that were converted to ducted heat pumps.

analysis by examining how the stock turns over and how it grows.[15] Stock turnover is a function of the estimated useful life of the equipment. For air source heat pumps, the team calibrated the model by changing the air source heat pump useful life from 21 to 23 years so the model results would match the total shipments estimated from AHRI and distributor sales data. Figure 3 presents a comparison of the AHRI market data and the stock model estimates. As shown in the figure, the stock turnover model is calibrated to the average AHRI shipments across the analysis period. Though the model does not exactly match shipments in any given year, this calibration process provided the research team a reasonable level of confidence that the stock turnover model effectively represents reality.

Figure 3: Comparison of AHRI Market Data and Stock Turnover Model Output



Source: Navigant analysis of AHRI data, using results of the Stock Turnover Model

The model assumes that HVAC equipment is shipped, put into service, and remains in the installed stock for its estimated useful life after which it is retired and replaced. Whether or not each system is replaced with a similar piece of technology is a function of the stock saturation's trajectory, with the assumption that if stock is growing, like technology is replaced with like technology, and if it is shrinking, some fraction of retired systems are replaced with a different technology.

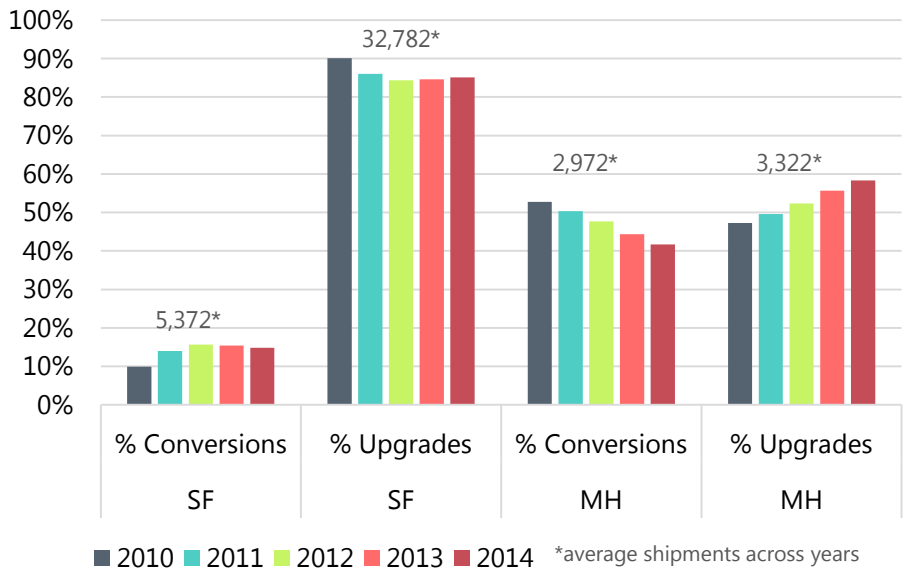
An upgrade occurs when ducted heat pumps are retired and replaced with a new ducted heat pump. A conversion occurs when electric forced air furnaces (FAF) are retired and replaced with either a ducted heat pump or a gas forced air furnace. To determine which technology is replacing electric forced air furnaces, the team determined the total electric forced air furnace conversions and subtracted out the portion that the team estimated converted to gas. The team based this estimate on the rise of gas forced air furnace saturation in existing homes, and assumes that these conversions arise from homeowners switching to gas forced air furnaces from either electric forced air furnaces or baseboard heating. The number of these conversions from electric forced air furnaces versus those from baseboard heating is tied to either technology's relative stock saturation.

[15] If, in a given year, the installed stock grows by more than the number of units shipped to new construction, the model assigns this growth in units to the existing housing stock.

The estimated number of ducted heat pump upgrades and conversions from electric forced air furnaces to ducted heat pumps in each year of the analysis period (2010 – 2014) were then imported into the HVAC Momentum Savings model where they were combined with unit energy consumption (UEC) data from the residential Simplified Energy Enthalpy Model (SEEM[16]) version 97 weighted by climate zone allocations from RBSA. See Figure 4 for the estimates of ducted heat pump upgrades and conversions in single family and manufactured homes in each year of the analysis.

The analysis results presented in Figure 4 indicate that, on a percentage basis, there are many more conversions in the manufactured home context relative to the single family context. This is primarily due to the higher prevalence of electric forced air furnaces in manufactured homes. However, in absolute terms, there are significantly more shipments in both categories in the single family sector, due to the larger market size for single family homes in the region. The number of upgrades in manufactured homes increases over the analysis period, driven by an increase in the saturation of air source heat pumps in these homes. Note that within each home type, the percentage of conversions and upgrades sum to 100% in each year, indicating that all air source heat pump shipments can be characterized as either a conversion or upgrade.

Figure 4: ASHP Installed as Conversions or Upgrades by Home Type



Source: Navigant analysis using results of the Stock Turnover Model

Key Decisions

Key decisions made by the research team while developing the stock turnover model include the following:

[16] SEEM, written by Ecotope, was developed by and for the Council and NEEA. SEEM is used to estimate conservation measure savings for regional energy utility policy planners.

- **Adjust AHRI estimates of market size to reflect a portion of ducted heat pumps sold into multifamily and small commercial applications.** The analysis team received data from AHRI representing all sales in the heat pump market, regardless of where end users ultimately installed the heat pumps. DOE analysis indicates that 93% of heat pumps are installed in residential locations, and seven percent are installed in small commercial buildings.[17] Based on discussion with regional subject matter experts, reasonable expectations from RBSA data, and calibration of the stock turnover model, the analysis team assumed that three percent of the residential heat pumps are installed in multifamily contexts (such as attached townhomes), leaving 90% of all AHRI sales installed in homes of interest (single family and manufactured homes).
- **Calibrate the ducted heat pump model shipments to the adjusted AHRI data by changing the measure life.** The overall number of shipments in a given year is the sum of shipments to new construction, system conversions, and replacements of existing stock. The number of replacements in any year is a function of the estimated useful life of the equipment – following the logic that a shorter useful life increases annual replacements as the stock turns over more frequently. The team calibrated the model by changing the useful life of ducted heat pumps from 21 to 23 years such that the total sales from 2010 to 2014 matched the total sales in the same period as estimated using the AHRI data. The team opted for one aggregate calibration in lieu of year-to-year adjustments for the sake of simplicity, recognizing the natural variability in sales data.
- **Model HVAC equipment at the housing sector level in the stock model, then allocate the stock and shipments to each climate zone in the HVAC Momentum Savings model.** When first developing the stock turnover model, the team explored developing individual stock turnover models for the equipment found in each climate zone. Housing stock allocations by heating and cooling zones are available from the Sixth Power Plan supply curves and the RBSA also offers stock saturations of primary and secondary heating and cooling equipment by heating and cooling zones. However, the team found that the resulting stock of ducted heat pumps differed depending on if the analysis categorized them as heating or cooling equipment. This difference was exacerbated by the models need to then turn this stock over. Given these challenges, the team opted to model the stock turnover of all regional ducted heat pumps and then to allocate these shipments and stock across the various heating and cooling zones. The selected approach remedies the issues outline above.
- **Include all heat pumps, regardless of primary/secondary classification.** Based on a thorough review of RBSA data, there appear to be two types of 'secondary' heat pumps: those where people assert they primarily heat with wood, and those that are 'secondary' to another heat pump (e.g. if a house has zonal heating/cooling with multiple heat pumps). The team identified 20 secondary units out of 1404 in the RBSA data set, 15 of which were secondary to wood and five of which were secondary to other heat pumps. In discussing this with David Baylon of Ecotope (a primary author of the RBSA), the team believes the latter arrangement essentially behaves like a primary heat pump and so should be counted as a separate primary unit, and the

[17] Department of Energy. 2011-06-08 Furnace and Central Air Conditioners and Heat Pump National Impact Analysis Spreadsheet (Energy Efficiency) and Furnace Installation Analysis Worksheet http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0011

former is a negligible quantity. Furthermore, the analysis is simulating the HVAC UEC values using the RTF Phase I and Phase II SEEM calibrations[18], which account for the interaction between wood heat and electric heat.

- **Develop forecasts for new construction saturations of each technology separate from the forecasts of stock saturations.** This analysis sought to improve upon previous stock turnover modeling methodologies, which made the simplifying assumption that new construction saturation was equal to stock saturation. The team knows this to not be true as the very nature of increasing stock almost assuredly requires higher saturation in new construction. The team opted to develop independent estimates of new construction saturations because this subtle change in methodology has profound impacts on the balance of upgrades and conversions.
- **Assume the electric forced air furnace conversions transition to either gas forced air furnaces or to ducted heat pumps.** Earlier iterations of this analysis assumed that retirements of electric forced air furnaces, which were not replaced by another forced air furnace, constituted a conversion to a ducted heat pump. In actuality, they may be converted to gas forced air furnaces, ducted heat pumps, or other technologies entirely. For the simplicity of modeling, the team assigned conversion of electric forced air furnaces to either gas forced air furnaces or ducted heat pumps as these represent the two dominant heating technologies, which leverage existing duct infrastructure in homes. To determine the number of conversions of electric forced air furnaces to gas forced air furnaces, the team examined the growth in stock of gas forced air furnaces in their own stock turnover model. The team assumed that the growth in gas forced air furnace stock in existing homes (i.e. not from new construction) must be attributed to the conversion to a gas forced air furnace from some other heating technology. The team assumed that these conversions arise from the replacement of electric forced air furnaces and baseboard heating in the same relative proportions as they appear in the housing stock. For details on the quantities of these conversions by year, see Figure 11.

After defining the scope of the analysis (Question 1) and estimating market size (Question 2), the research team calculated the total market savings (Question 3).

Question 3: What are the total market savings?

Total market savings are equal to the difference between baseline consumption and actual consumption. Questions 3a and 3b enable the estimation of total market savings by calculating the total energy consumption for both the baseline and actual market scenarios, respectively.

Question 3a: What was the energy use when the Power Plan was written?

The research team estimated **baseline consumption** using four inputs:

- Annual market size (estimated previously in Question 2)

[18] The Phase 1 and Phase 2 calibration multipliers were developed after extensive analysis and discussion by members of the RTF to account for observed discrepancies between residential billing analyses and SEEM outputs. These calibration multipliers "true up" the results of SEEM to be more reflective of actual residential energy consumption data in the region.

- HVAC UEC for each HVAC conversion and upgrade scenario included in Table 1
- Baseline efficiency mix (the share of total sales occurring in each efficiency level as assumed by the Sixth Plan)
- Climate zone (geographic heating zones 1, 2, or 3 as established by the [RTF])

The research team estimated the **HVAC UEC** values using the residential **SEEM**. The team modeled UEC estimates separately for each efficiency level of a given measure.

The research team used a multi-step process to develop UEC values that accurately reflect the diversity of home types and climate zones in the Northwest region. The single-family SEEM model used 192 different "characteristic scenarios" developed by the RTF from RBSA data that represent typical homes in the region.[19] Each scenario is a different energy simulation, which resulted in a new UEC output. The research team simulated all scenarios for all units listed in Table 1. The team then applied home characteristic and climate zone weighting factors from RBSA to SEEM model results in order to arrive at an estimated UEC for each HVAC efficiency in each climate zone, as well as region-wide weighted UECs. See the text box titled "Estimating Measure-Level UEC" for an illustration of how the research team used the SEEM model to estimate UEC for a specific efficiency level.

Estimating Measure-Level UEC

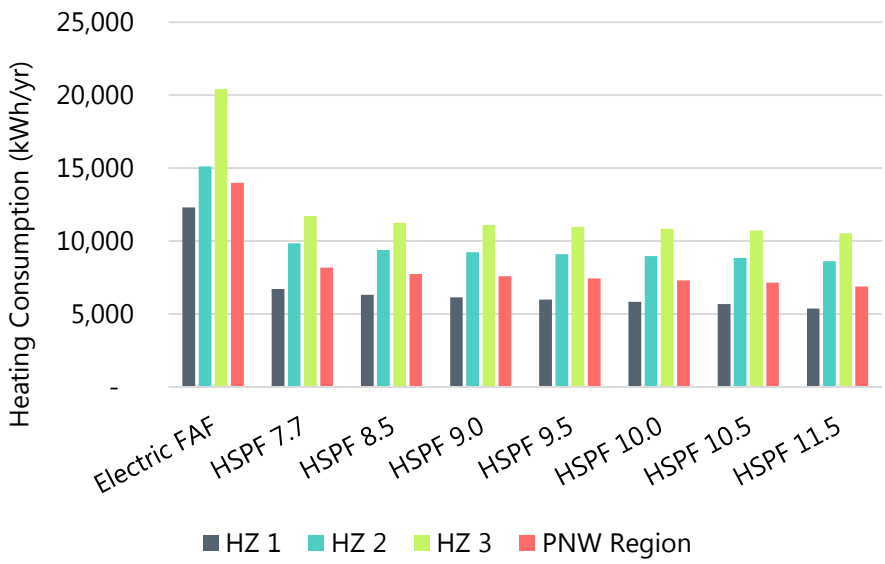
The following steps illustrate an example of the UEC modeling using an air source heat pump (ASHP) HSPF 8.5 HVAC type/efficiency combination.

1. **Set up the SEEM model.** The team assumes all ASHP units shipped in the market are installed in the typical home scenarios of the SEEM model (192 for single family homes, 321 for manufactured homes).
2. **Run the SEEM model.** The team runs a SEEM simulation for each of the applicable characteristic homes, using the same HVAC unit type/efficiency combination (in this case, ASHP HSPF 8.5).
3. **Apply characteristic home weights.** The characteristic home weights indicate the region-wide prevalence of each of the typical homes, as determined by the RBSA. This will develop a weighted UEC for ASHP HSPF 8.5 in a composite home, which is the weighted average UEC of all homes in the region.
4. **Apply climate zone weights.** The team applies the RTF established climate zone weights by home to each of the SEEM scenarios. This results in the typical UEC of an ASHP HSPF 8.5 in a single composite home in each climate zone. Subsequent application of climate zone weighting factors generates regional UEC values for the ASHP HSPF 8.5 unit.

Figure 5 shows the UEC for single family homes converting from electric FAF to air source heat pump (ASHP) as an example output from this process. Figure 5 compares the UEC values in each climate zone by unit type and efficiency and shows the relative energy consumption between unit types and climate zones. Table 2 presents the discreet UEC values displayed in Figure 5. Note that there is a large difference between FAF UEC and ASHP UEC, signifying that a conversion saves significantly more energy than an upgrade. This is a main driver of the analysis results, discussed further below. The weightings of the characteristic scenarios for upgrade and conversion cases are different, which leads to UEC values for the same system in the two cases. In other words, in the RBSA, homes that have electric FAF initially are different from homes that have ASHP initially in terms of size and shell characteristics.

[19] 192 is the maximum number of applicable models. For certain HVAC units only a subset of the models were applicable. For example, no model with electric baseboard heat was used to simulate heat pump savings, since that would imply a case of switching from decentralized to centralized heating. The same approach was used for manufactured homes, except there are 321 distinct models in that case.

Figure 5: UEC Values (kWh/yr.) for Single Family Homes Eligible for Conversions, by Efficiency Level and Climate Zone



Source: Navigant analysis using SEEM 97 and RBSA data

Table 2: UEC Values (kWh/yr.) for Single Family Homes Eligible for Conversions, by Efficiency Level and Climate Zone

Single Family Homes - Conversions				
Heating Zone	**HZ 1**	**HZ 2**	**HZ 3**	**PNW Region**
Electric FAF	12,306	15,105	20,426	**13,983**
HSPF 7.7	6,720	9,851	11,709	**8,180**
HSPF 8.5	6,307	9,391	11,244	**7,747**
HSPF 9.0	6,144	9,241	11,099	**7,590**
HSPF 9.5	5,984	9,101	10,965	**7,439**
HSPF 10.0	5,827	8,967	10,843	**7,293**
HSPF 10.5	5,673	8,841	10,730	**7,151**
HSPF 11.5	5,371	8,609	10,530	**6,881**

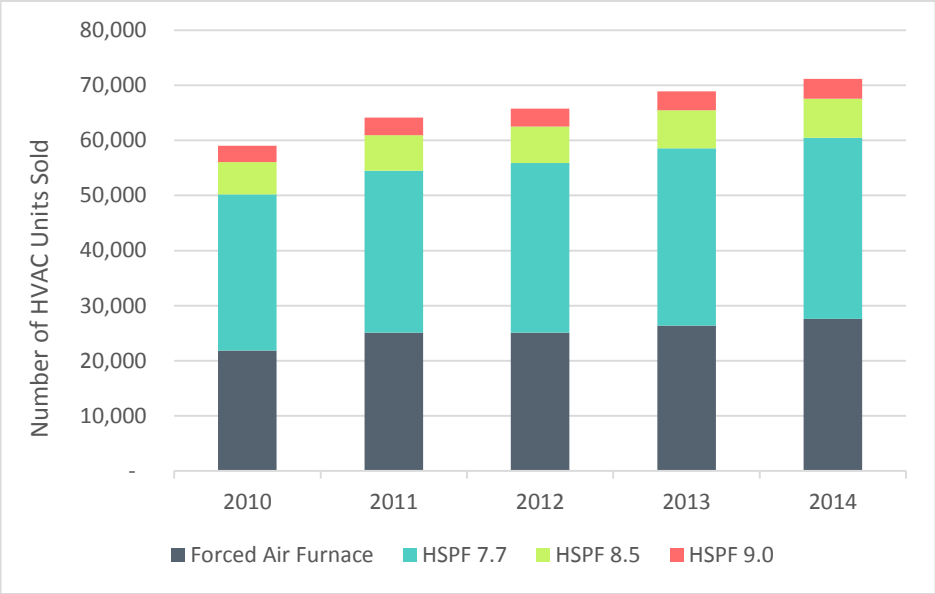
Source: Navigant analysis using SEEM 97 and RBSA data

The research team then used the UECs to calculate baseline consumption according to the assumed **baseline efficiency mix** as documented in the Sixth Plan. The efficiency mix is the distribution of sales across the spectrum of least efficient (code minimum) to most efficient (highest efficiency in the market). The Sixth Plan assumed the following baseline efficiency mixes:

- Conversions: 85% of the natural retirements of electric forced air furnaces are replaced with the same type of electric forced air furnace, 10% are converted to HSPF 8.5 air source heat pumps, and 5 percent are converted to HSPF 9.0 air source heat pumps[20]
- Upgrades: 85% of the natural retirements of air source heat pumps are replaced with HSPF 7.7, 10% HSPF 8.5, and 5 percent HSPF 9.0 (all air source heat pumps)

Using this information and the total market size from Question 2, the team calculated the number of units in each efficiency tier within the total market. These results are show in Figure 6, aggregated by housing type (single family and manufactured) and installation type (conversions and upgrades). The units sold increases over the analysis period as a function of the growth in market size. The relative portion of units in each efficiency tier (the efficiency mix) remains consistent across all years for the base case.

Figure 6: Total Units Sold by Efficiency Level – Base Case



Source: Navigant analysis of Sixth Power Plan Data

[20] In other words, the Sixth Plan assumes a "current practice" baseline where 15% of forced air furnaces are replaced with heat pumps when they wear out, but the remaining 85% are not converted to a different technology.

Finally, the research team estimated the baseline consumption for each year of the analysis by multiplying the annual market size by the weighted UEC estimate as shown in Equation 2.

Equation 2. Baseline Consumption Calculation, by Building Type and HVAC type

$$\text{Baseline Consumption} = \text{Market Size} \times \text{UEC}_{\text{Weighted by baseline efficiency mix}}$$

Using this equation, the team calculated the baseline total market consumption in each year, shown in Table 3. The baseline consumption increases over the analysis period as a function of the growth in market size.

Table 3: Baseline Market Consumption by Year (aMW)

2010	2011	2012	2013	2014
62.4	69.0	70.4	73.8	76.2

Source: Navigant analysis of Sixth Power Plan Data and results of the Stock Turnover Model

Key Decisions

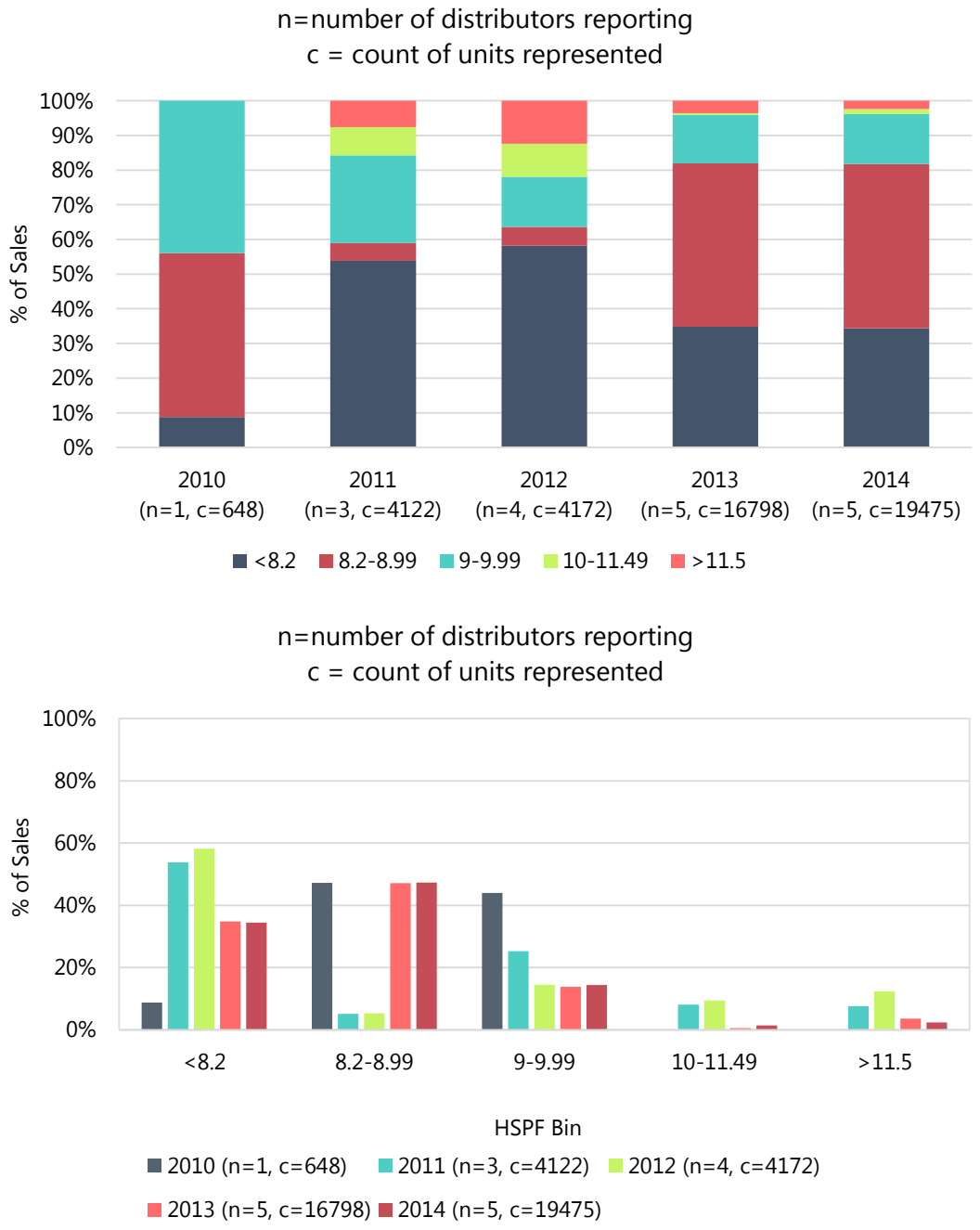
Key decisions made by the research team which impact the baseline consumption include the following:

- The team used the SEEM modeling platform to develop UEC values, as it is well-vetted by the RTF and applied widely throughout the Northwest region.
- The team followed the RTF approach for developing regional building characteristics from the RBSA as inputs to SEEM. The team also remained consistent with the RTF approach for weighting the results of these model runs, as these weights have been applied to other analyses conducted by the RTF in the region.
- The team used the RTF-approved SEEM calibration multipliers to discount the results of the SEEM models.
- The team did not use the exact UEC values from the Sixth Plan. Instead, the team applied the Sixth Plan efficiency mixes to new UEC values, which were calculated using the updated version of SEEM (SEEM 97).

Question 3b: What was the energy use in the following years?

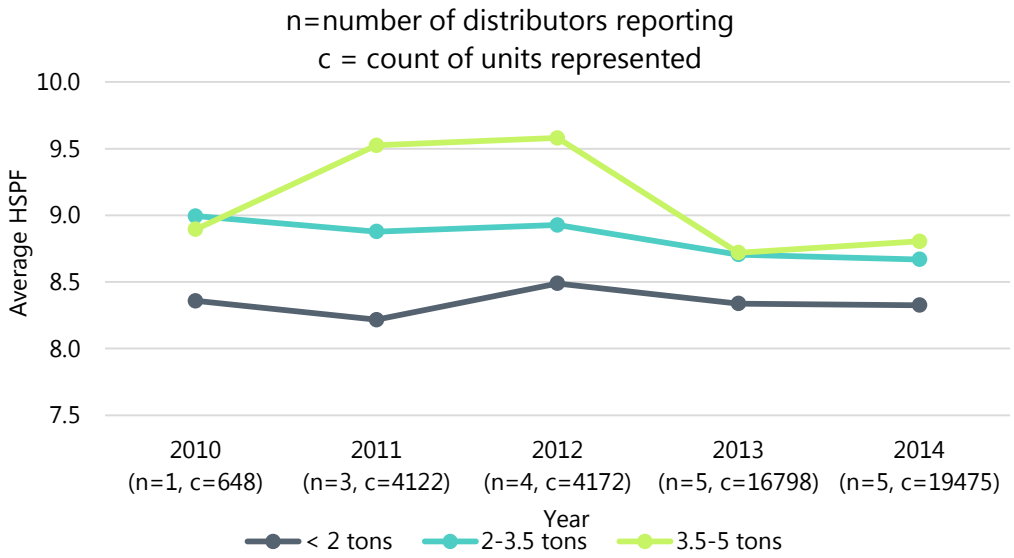
Actual consumption is calculated using the same basic equation as in the baseline consumption calculation. The only factor that varies between the two calculations is the **actual efficiency mix**, estimated using sales data from distributors. The actual consumption calculation uses the estimate of annual market size calculated in Question 2 and the UEC calculated in Question 3a. In the actual market scenario, the team weights the UEC for each measure by the actual efficiency mix as estimated in this step of the analysis. Figure 7 and Figure 8 show the relevant market data that informed this analysis, as well as the number of distributors and unit counts for each year. Note that the number of distributors and unit counts increase in recent years, due to better data availability from distributors.

Figure 7: Residential Split System Air Source Heat Pump Sales by HSPF Category



Source: Navigant analysis of distributor reported sales data

Figure 8: Average Heating Efficiency of Residential Split System Air Source Heat Pumps



Source: Navigant analysis of distributor reported sales data

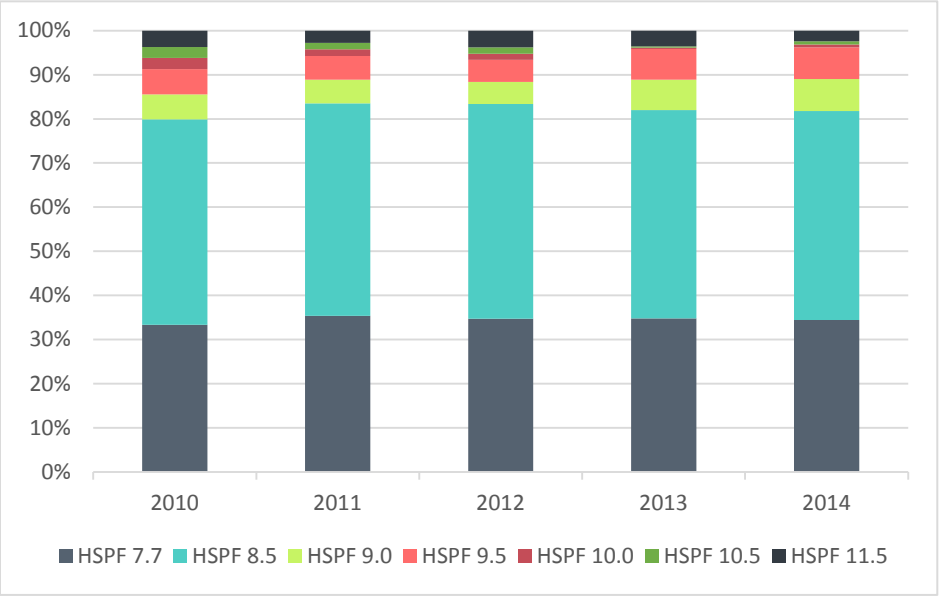
The research team estimated the actual efficiency mix for each year of the analysis using these distributor sales data. The team extrapolated information known about part of the market to the entire market. Depending on the year, the team surveyed between 2% and 45% of the total estimated market (Table 4). The results of the analysis were estimates of the percentage of all HVAC units sold at each efficiency level across the spectrum of least efficient (code minimum) to most efficient (highest available efficiency). The research team multiplied these percentages (collectively known as the actual efficiency mix) by the UEC estimation from Question 3a to create a single, weighted average UEC estimate for all HVAC units sold in the actual market scenario.

Table 4: Estimated Portion of Market Represented by Distributor Surveys

Total Units Shipped (AHRI and Stock Model)	37,140	39,012	40,650	42,478	43,504
Total Units Surveyed (Distributor Surveys)	648	4,122	4,172	16,798	19,475
Estimated Portion of Market Surveyed (%)	2%	11%	10%	40%	45%
Number of Distributor Companies Reporting	1	3	4	5	5

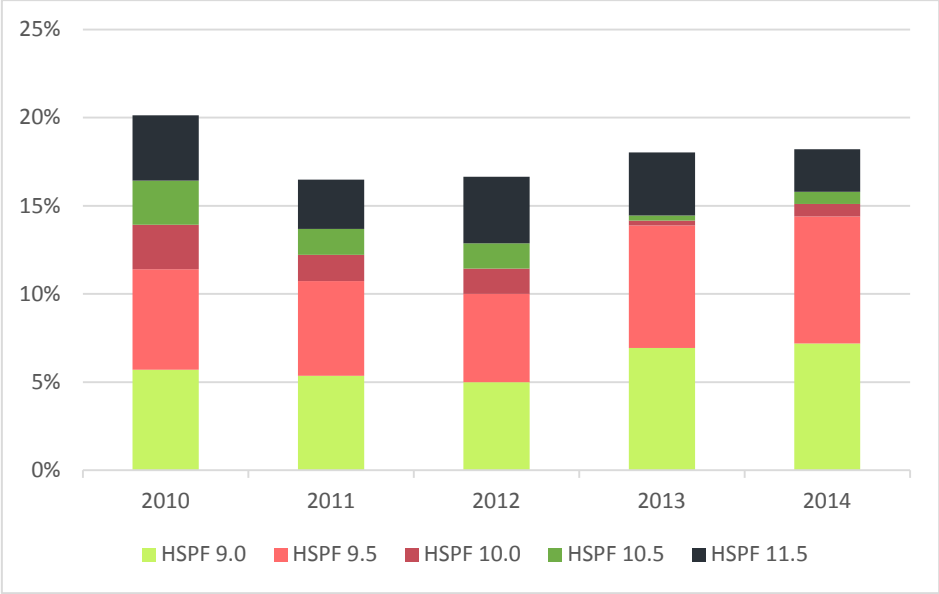
Figure 9 shows the normalized air source heat pump efficiency distributions, for all efficiency tiers, derived from distributor shipment data. The majority of units are in the two lowest efficiency tiers (HSPF 7.7 and 8.5), and the relative proportions of shipments in each tier do not vary significantly over time. Distributors reported sales data as ranges, which the analysis team converted to efficiency point estimates at the midpoint of each range, which also represent typical efficiency ratings in the market. Figure 10 shows the same data for the higher efficiency tiers at or above HSPF 9.0. While the data do show some variability at this level of detail, the research team concluded that this variance may not represent real significant market trends, as four out of five distributors surveyed were unable to provide data spanning the entire analysis period. Note that there were no significant changes to code, tax credits, or efficiency programs during the analysis period.

Figure 9: Actual Market Efficiency Mix of Air Source Heat Pumps – Upgrade Case



Source: Navigant analysis of distributor reported sales data

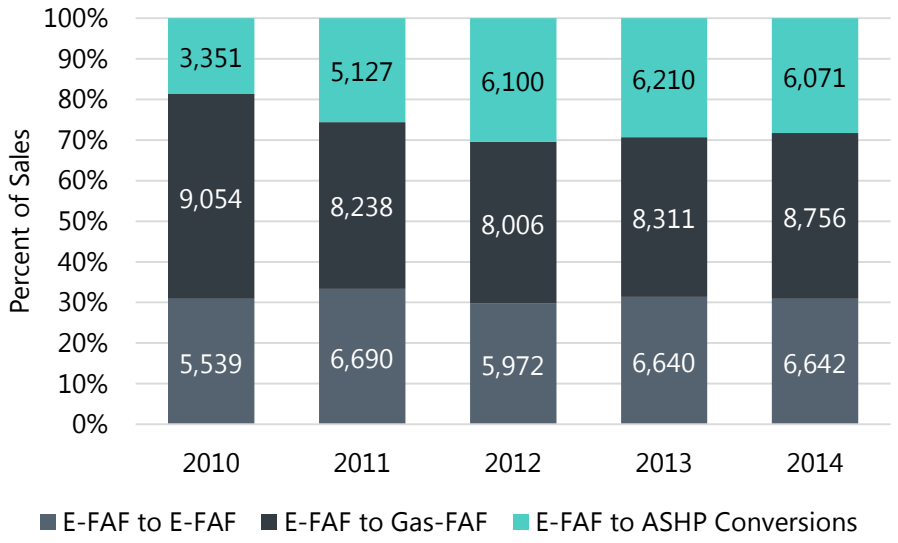
Figure 10: High Efficiency Air Source Heat Pumps as a Percentage of Total Market Shipments – Upgrade Case



Source: Navigant analysis of distributor reported sales data

The upgrade scenario represents a homogeneous market (e.g. ASHP replacing other ASHP), so the team applied the efficiency distributions to the ASHP market size at face value. To represent the efficiency distribution in the conversion case, the research team needed to estimate the size of the natural replacement market for electric forced air furnaces, and assume that a certain percentage of forced air furnaces are not being converted to air source heat pumps. Of those not being converted to air source heat pumps, they are replaced by the same type of electric forced air furnaces, or converted to gas forced air furnaces (and are removed from consideration in this analysis). The team derived these percentages by comparing the market size for electric forced air furnaces and air source heat pumps, as calculated by the calibrated stock turnover model (described in more detail under Question 2). This analysis, shown in Figure 11, indicated that 70% to 85% of forced air furnaces retiring in any given year are not converted to heat pumps.

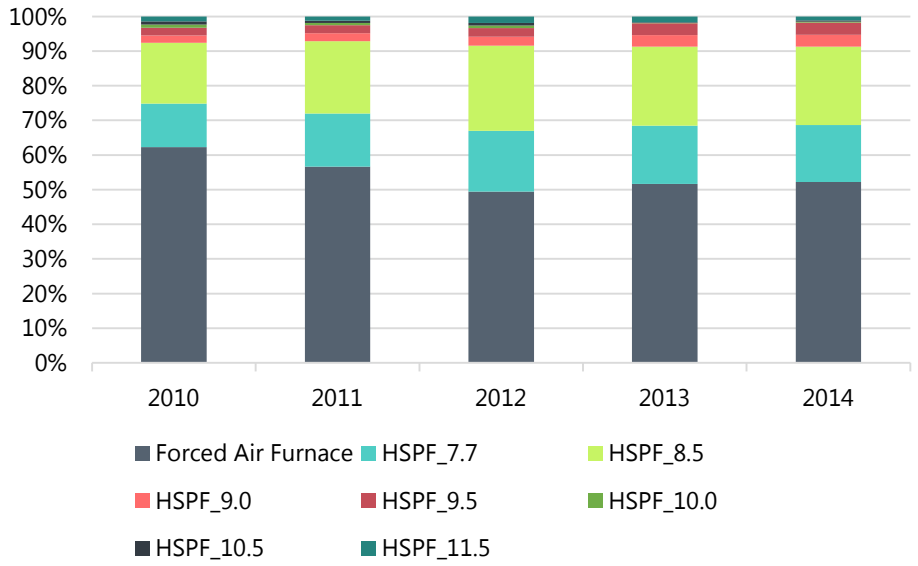
Figure 11: HVAC Unit Types Estimated to be Replacing Forced Air Furnaces in Single Family Homes



Source: Navigant analysis using results of the Stock Turnover Model

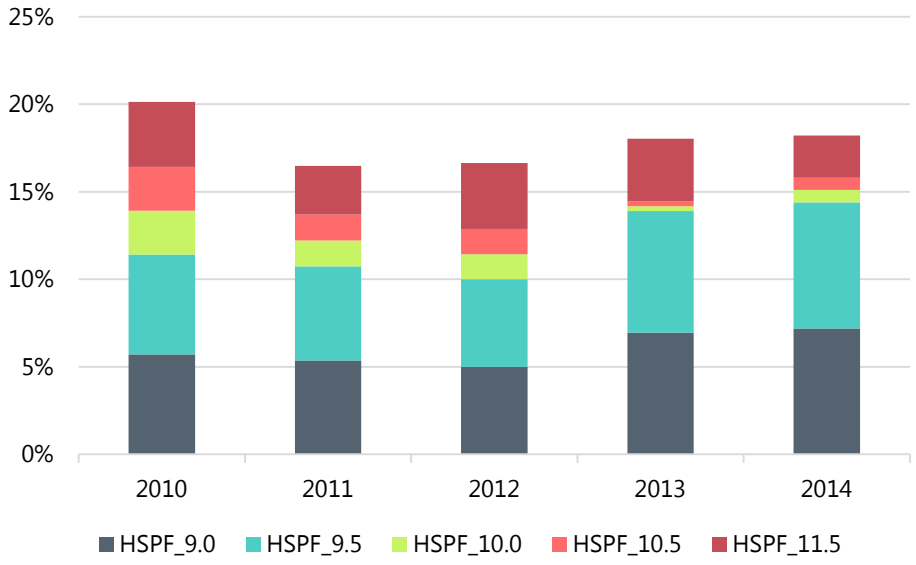
The team determined the electric forced air furnace contribution to the efficiency mix as the number of electric forced air furnaces shipped each year, divided by the total electric market size. The total electric market size is the sum of the forced air furnaces not converted to a different unit type (E-FAF to E-FAF), and those that converted to other electric heat (E-FAF to ASHP Conversions). Therefore, the gas units are not considered when developing the efficiency mix. Figure 12 shows the actual market efficiency mix for the conversion scenario, a portion of which remains electric FAF. The majority of units are replaced with new forced air furnace (i.e., are not converted). Of those that are converted, most are converted to air source heat pumps in the lower efficiency tiers (HSPF 7.7 and 8.5). The team believes that the relative proportion of conversions increases between 2010 and 2012 because of economic recovery after the 2009 recession. Figure 13 shows the same data for the higher efficiency tiers at or above HSPF 9.0. While the data does show some variability at this level of detail, the research team concluded that this variance may not represent real significant market trends, as four out of five distributors surveyed were unable to provide data spanning the entire analysis period.

Figure 12: Actual Market Efficiency Mix of Forced Air Furnaces and Air Source Heat Pumps – Single Family Conversion Case



Source: Navigant analysis of distributor reported sales data

Figure 13: High Efficiency Air Source Heat Pumps as a Percentage of Total Market Shipments – Single Family Conversion Case



Source: Navigant analysis of distributor reported sales data

Finally, the research team estimated actual consumption for each year of the analysis by multiplying the annual market size by the actual efficiency mix-weighted UEC estimate as shown in Equation 3. Table 5 shows the results of this calculation.

Equation 3. Actual Consumption Calculation, by Building Type and HVAC type

$$\text{Actual Consumption} = \text{Market Size} \times \text{UEC}_{\text{Weighted by actual efficiency mix}}$$

Table 5: Actual Market Consumption by Year (aMW)

2010	2011	2012	2013	2014
59.7	65.5	66.3	69.8	71.9

Source: Navigant analysis of distributor reported sales data and results of the Stock Turnover Model calibrated to AHRI data.

Key Decisions

The research team made one key decision when analyzing distributor sales data: some distributors only provided data for a subset of years in the analysis period. Therefore, the analysis team used the trends present in the data provided by each distributor to project sales by efficiency forward or backward to smooth trends and fill gaps in the data. Table 4 provides annual detail on the number of distributors reporting, the number of shipments reported by all distributors, and the portion of the total market surveyed.

Total Market Savings

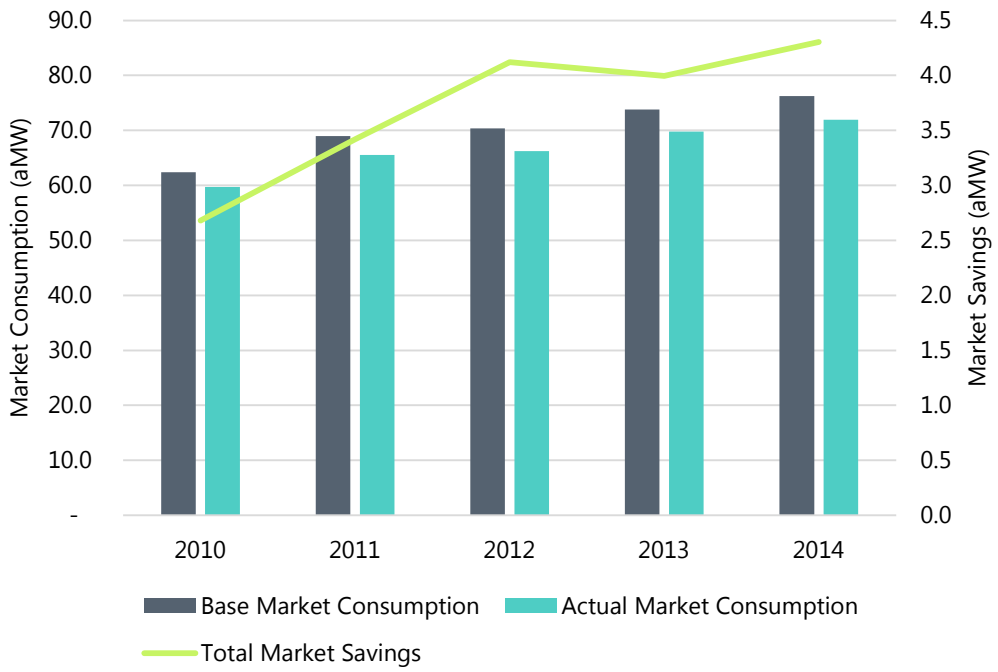
To conclude the analysis in Questions 3a and 3b and arrive at total market savings, the team calculated the difference between baseline consumption and actual consumption as shown in Equation 4.

Equation 4. Total Market Savings Calculation

$$\text{Total Market Savings} = \text{Actual Energy Consumption} - \text{Baseline Energy Consumption}$$

Figure 14 shows the baseline and actual market consumption, calculated in Questions 3a and 3b on the primary axis, and the total market savings on the secondary axis. Total savings increase over time, primarily driven by growth in the market. The relative difference between baseline and actual market consumption does not change significantly over time. The implication is that growth in the total market size, rather than increasingly efficient mix of air source heat pumps, increases total market savings over time.

Figure 14: Baseline Market Consumption, Actual Market Consumption, and Total Market Savings (Secondary Axis) in aMW



Source: Navigant analysis of Sixth Power Plan data, distributor reported sales data, and results of the Stock Turnover Model

The final step in the analysis is determining the regional program savings relative to the Sixth Plan baseline.

Question 4: What are the program savings?

Question 4 concerns the final variable in the Momentum Savings equation: program savings. Momentum Savings, by definition, exclude electricity savings achieved through efficiency programs in the region. The research team developed estimates of programmatic savings from program data provided by BPA and investor-owned utilities.

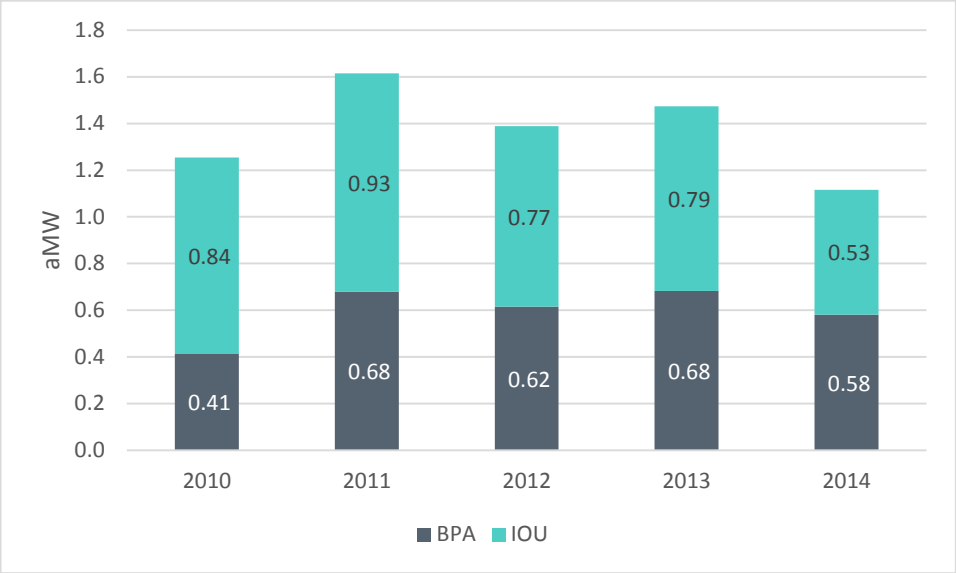
However, to subtract these programmatic savings from the total market savings, the team first measured both values against the same baseline. Regional program administrators report program savings measured against customized baselines from local evaluations or RTF deemed savings values. These baselines are constantly changing over time, and vary throughout the analysis period. In contrast, the total market savings analysis described above measures savings against the Sixth Plan baseline—a fixed baseline that often differs from those baselines used to evaluate program savings. For this reason, we cannot use program savings as-reported without first recalculating the program savings against the Sixth Plan baseline. To accomplish this, the analysis used measure counts from the program data[21] and UEC

[21] The research team requested detailed program participation data, including fields for HVAC unit type, building type, and unit quantity for units incentivized directly through regional utility programs from 2010-2014. All regional IOUs responded with the exception of Northwestern Energy, which does not have an active electric HVAC program. Where there were gaps in the program data from investor-

values as defined in Question 3 to estimate programmatic savings against the Sixth Plan baseline, consistent with the estimation of total market savings.

The research team calculated program savings for each efficiency level by subtracting the actual UEC for that efficiency level (as calculated from program unit efficiencies) from the baseline efficiency mix-weighted UEC (from the Council baseline), then multiplying the result by the total number of program measures. This is the same procedure used to calculate total market savings under Question 3, except the team substituted program unit quantities as the "market size". Furthermore, consistent with the Sixth Plan, the team assumed that any conversion facilitated by the program would have an 85% chance of not converting without the influence of the program. Figure 15 shows the results of this analysis, separated into BPA program savings and other Investor Owned Utility (IOU) program savings.

Figure 15: Program Savings by Year (MWh)



Source: Navigant analysis of BPA and IOU HVAC program savings data

Key Decisions

Key Decisions made by the research team include the following:

- Because each IOU uses a different baseline to report program savings, the team decided that the best way to measure program savings against the Council baseline would be to collect data on unit type, quantity, installation context, and efficiency level, and re-calculate program savings using the SEEM UEC values derived from Question 3.
- Lacking a reliable source of data on IOU program activity, the research team decided to survey IOU representatives to request the appropriate data to determine regional program savings. While there were still gaps in the data received from IOU program administrators, these data proved sufficient to calculate savings from this analysis.

owned utilities (IOUs), the team applied assumptions based on BPA program data to the missing IOU program data. The team structured the analysis such that new IOU data can be easily incorporated as it becomes available.

Calculating Momentum Savings—The Results

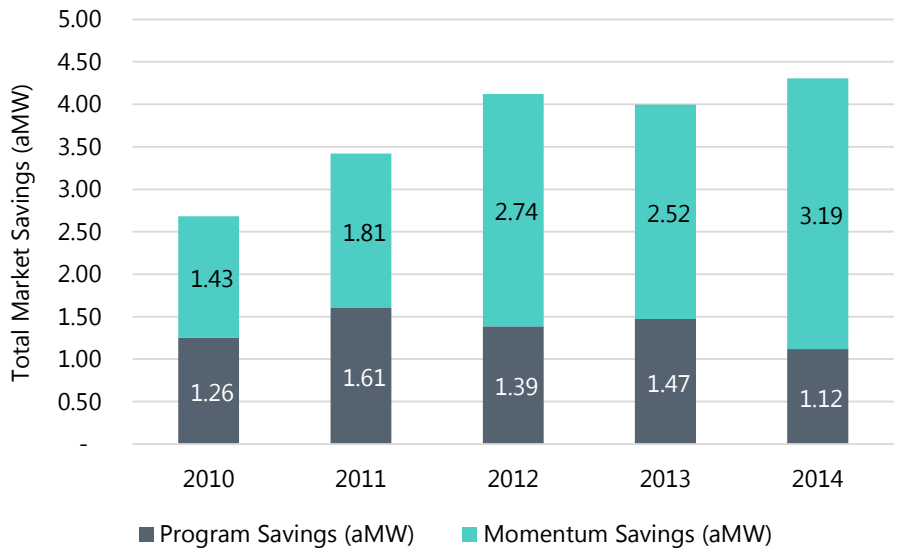
Momentum Savings are equal to the difference between total market savings and program savings as shown in Equation 5. The total market savings encompass the entire four-state Northwest region, including areas served by utilities other than BPA. Likewise, program savings include all programs in the region, not only BPA programs.

Equation 5. Momentum Savings Calculation

Momentum Savings = Total Market Savings – Program Savings

Figure 16 shows the sources of total market savings, split between Momentum Savings and program savings. Table 6 shows the two sources of total market savings in average megawatts (aMW) and as a percent of total market savings.

Figure 16: Sources of Total Market Savings (aMW) for Air Source Heat Pumps



Source: Navigant analysis

Table 6: Sources of Total Market Savings (aMW and % of Total Market Savings)

	2010	2011	2012	2013	2014
Program Savings (aMW)	1.26	1.61	1.39	1.47	1.12
Momentum Savings (aMW)	1.43	1.81	2.74	2.52	3.19
Program Savings (% of Total Market)	47%	47%	34%	37%	26%
Momentum Savings (% of Total Market)	53%	53%	66%	63%	74%

Source: Navigant analysis

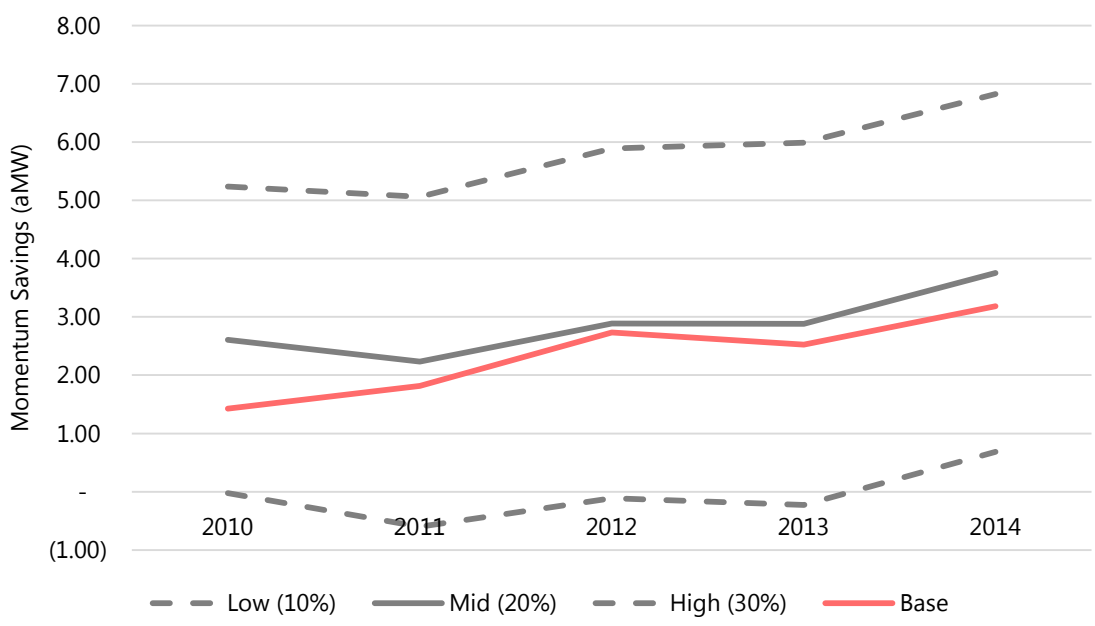
Driving Factors

Throughout the analysis, the research team identified several significant uncertainties that have a large effect on the analysis results, as well as potential future actions to address the uncertainties. This section describes the key factors that drive Momentum Savings for residential HVAC, and discusses the model's remaining uncertainties.

Conversions vs. Upgrades

The number of ASHP units installed as conversions from electric forced air furnaces, relative to upgrades from other ASHP is a main driver of Momentum Savings, and one of the largest uncertainties in the analysis. A conversion from an electric forced air furnace to a heat pump yields much greater savings than an upgrade from a less efficient heat pump to a more efficient heat pump. As shown above in Figure 5, there is a large decrease in UEC between FAF and ASHP, but only incremental decreases in UEC between lower efficiency ASHP and higher efficiency ASHP. Figure 17 shows the sensitivity of Momentum Savings to this assumption. The red "Base" line represents the best estimate of momentum savings reported in Figure 16.

Figure 17: Momentum Savings as a Function of the percentage of ASHP Units Installed as Conversions (aMW)



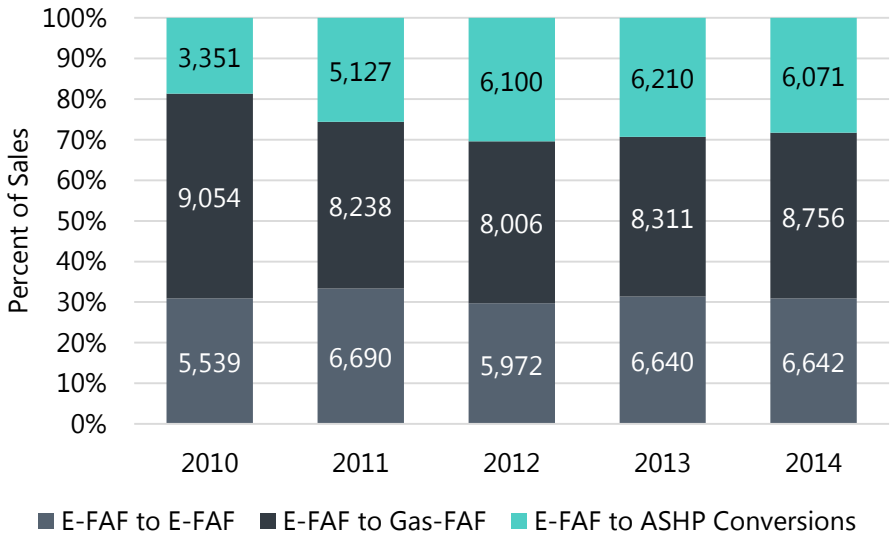
Source: Navigant analysis

The team determined the number of conversions and upgrades based on assumptions about electric FAF and ASHP stock saturations, derived from RBSA and the 1992 Pacific Northwest Residential Energy Survey (PNRES92) data. Specifically, the team assumed diminishing saturation of electric FAF indicating a

conversion to ASHP or gas FAF. This simplifying assumption does not account for scenarios of switching from decentralized to centralized HVAC systems, installing ASHP as a secondary system, or switching from gas furnaces to ASHP. Obtaining more data on the installation context of ASHP would help the research team refine this assumption.

The number of conversions from electric forced air furnaces to air source heat pump increases throughout the analysis period. This increase is a result of the increasing market size in the stock turnover model. Because electric forced air furnaces have a 21 year measure life[22], a large growth in the building stock from 1989 to 1993 yields an increasing number of natural retirements between 2010 and 2014. Figure 18 shows the number of heat pumps and electric and gas force air furnaces shipped in each year. Between 2010 and 2011, there is a 53% increase in conversions of electric forced air furnaces to air source heat pumps. The team has identified this as a key driving factor for the model results, and suggests more research is necessary to validate this increase.

Figure 18: HVAC Unit Types Estimated to be Replacing Forced Air Furnaces in Single Family Homes



Source: Navigant analysis of AHRI data, using results of the Stock Turnover Model

Market Size

The quantity of heat pumps sold in the Pacific Northwest is a key determinant of Momentum Savings. If the market size increases relative to program unit sales, Momentum Savings also increase. During the analysis period (2010-2014), the market for residential HVAC units increased, as shown in Figure 3. Historical data indicates this increase in market size is a function of the economic recovery from the housing crisis in 2008-2009. As described in Question 2, the team used a variety of data sources to inform the stock turnover model, which calculates market size. Aligning the various data sources required

[22] DOE Furnaces and Boilers 2007 Final Rule, Technical Support Document Chapter 8: Lifecycle Cost Analysis, Table 8.3.3 Furnace and Boiler Lifetimes Used in the LCC Analysis.

several assumptions outlined under "Key Decisions" in Question 2. The research team should continue to seek data to inform these considerations, and refine the estimate of market size.

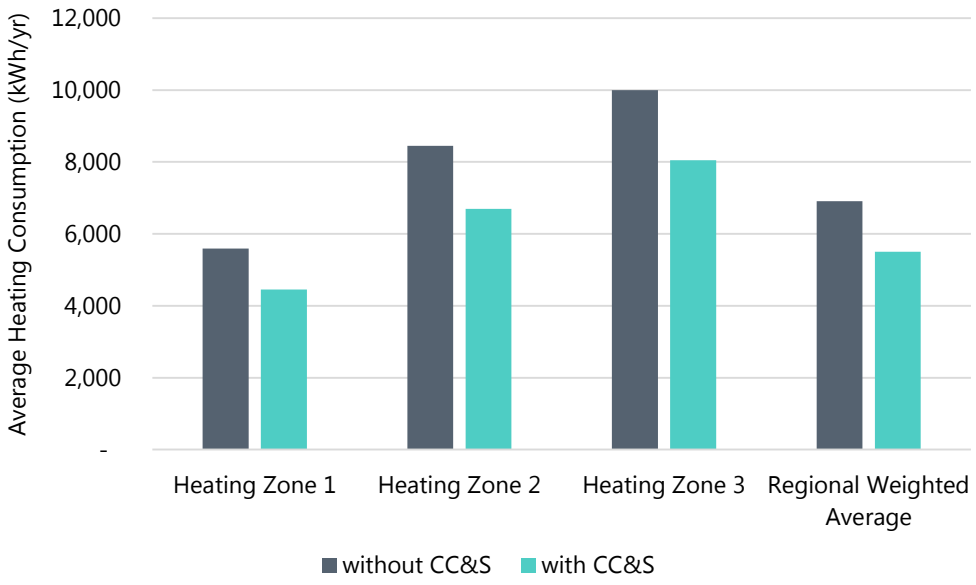
Quality Installations

Quality installation—also known as commissioning, controls, and sizing (CC&S)—is an important factor that impacts the efficiency of HVAC equipment. To calculate total market savings, the team assumes that contractors do not follow proper CC&S practices. This assumption remains consistent even for program savings, to allow for a subtraction of program savings from total market savings using consistent UEC values.

If the analysis team were to find that a certain percentage of contractors in the market outside of programs actually are following proper CC&S practices, total market savings and momentum savings would increase.

To test the significance of CC&S on the per unit energy consumption, the research team simulated two different versions of SEEM, one with and without CC&S. As shown in Figure 19, the addition of proper CC&S results in approximately a 20% decrease in annual heating consumption averaged across all HSPF efficiency levels considered in the analysis.

Figure 19: Comparison of Average per Unit Heating Consumption with and without CC&S (kWh/yr.)



Source: Navigant analysis using SEEM 97

Program Savings

As described in the methodology section under Question 4, the research team must measure all the regional program savings against the Sixth Plan baseline to enable an "apples to apples" comparison of programmatic and Momentum Savings. In order to calculate the program savings, the research team

requested detailed program tracking data from utilities across the region. While we received a lot of well-documented program data from utilities across the Pacific Northwest, including the IOUs, in some cases, regional energy efficiency program managers were unable to provide full detailed data on their residential HVAC programs.

Table 7 summarizes the data gaps in each program savings data request. In this table, "Yes" means the program data was complete and used in the analysis, "Most" means the research team interpreted portions of the data and used them in the analysis, and "No" means the data field was not obtained from the program records. In cases where gaps were present in the data, the research team projected the values from known data sources. For example, all IOUs were unable to provide the housing type (single family or manufactured homes) in which the unit was installed. The analysis team assumed that the split between single family and manufactured homes was the same as the split present in the BPA data, and applied those percentages to IOU program data accordingly.

Table 7: Summary of Program Data Completeness

Service Territory	Program Year	Measure Name Clear	Quantity	Efficiency	Housing Type	Years Data Covers
BPA	Yes	Yes	Yes	Yes	Yes	2010-2014
Avista	Yes	Yes	Yes	Most	No	2010-2014
Energy Trust of Oregon	Yes	Most	Yes	Most	No	2010-2014
Idaho Power	Yes	No	Yes	Yes	Yes	2010-2014
PacifiCorp (ID and WA)	Yes	Yes	Yes	No	No	2010-2014
Puget Sound Energy	Yes	Most	Yes	Most	No	2010-2014

Source: Navigant analysis of BPA and IOU program data

Acquisition of more detailed program data may increase or decrease Momentum Savings, depending on if the data decrease or increase program savings respectively.

Future Research Opportunities

This section presents the research team's recommendations to BPA for future data collection and analysis that could improve the estimation of residential HVAC Momentum Savings. Table 8 summarizes each opportunity according to the following criteria:

- **Impact on results:** the estimate of how the research opportunity may impact the Momentum Savings estimates, based on the highest and lowest expected outcomes from the research. Research topics with greater uncertainty generally yield a higher impact.
    - Low: likely to affect Momentum Savings results by <10%
    - Medium: could potentially affect Momentum Savings results by 10-20%
    - High: could potentially affect Momentum Savings results by greater than 20%
- **Effort:** the estimate of expected level of effort required to adequately investigate the opportunity.
- **Overall ranking:** The analysis team ranked the research opportunities according to overall importance, taking into account expected level of effort and model sensitivities.

Table 8: Summary of Opportunities for Future Research

Opportunity	Overall Ranking	Impact	Level of Effort
Survey of HVAC installation contractors	1	High	****
Enhancing program savings data from BPA and IOUs	2	Low	*
Obtaining more context for AHRI data	3	Medium	**
Calculating HVAC cooling savings	4	Medium	***
Calculating DHP Momentum Savings	5	High	***

Source: Navigant analysis

Survey HVAC Installation Contractors

Impact on results: High

Effort: ****

After developing the model, it became clear that installation context is a main driver of the results. More data on the breakdown of installations between single family, manufactured homes, conversions, upgrades, multifamily, and small commercial establishments would greatly reduce the uncertainty in the current model. The team could interview HVAC installation contractors in order to obtain more details regarding these factors. These interviews would have the added benefit of informing the team about the

prevalence of fuel switching in the market, as well as quality installation practices outside of utility programs.

The team ranked this opportunity as the first priority due to how sensitive the results of the model are to the installation context assumptions, even though the team estimates it to be the highest level of effort opportunity.

Enhance Program Savings Data from BPA and IOUs

Impact on results: Low

Effort: *

As mentioned above, the program data obtained from BPA and regional IOUs was partially incomplete. In the future, the research team could develop simple, streamlined annual data requests to specific contacts at each IOU. In return, BPA could provide HVAC market characterization data and program opportunities to participating IOUs. BPA would need to determine to what extent IOU program managers would value this market characterization, and what types of data they would be interested in.

The team ranked this opportunity as the second priority, as it requires a relatively low level of effort and will ensure that future HVAC Momentum Savings analyses use all available program data.

Enhance market data

Impact on results: Medium

Effort: **

The research team was fortunate enough to receive a summary of the entire Pacific Northwest HVAC market according to AHRI from one of the distributor interviewees. However, more context would improve these data significantly. How much of the market does AHRI really characterize? Should the stock turnover model precisely match AHRI data, or be slightly lower due to distribution of units to commercial spaces? Does AHRI collect more detailed information on heating efficiencies?

Enhancing market data may involve establishing relationships with AHRI to obtain more context for their data, subscribing to other regional HVAC data acquisition services, such as Heating, Air Conditioning and Refrigeration Distributors International (HARDI), dedicating time to establishing ongoing relationships with regional distributors, or some combination of these approaches. The team is in the process of assessing the various options to choose the best approach.

The team ranked this opportunity as the third priority. Depending on the results, this could have a substantial impact on Momentum Savings estimates. However, the level of effort required for obtaining more market data is uncertain, as it may require more primary data collection or a subscription service.

Calculate HVAC Cooling Savings

Impact on results: Medium

Effort: ***

The research team did not estimate cooling savings in this analysis for three reasons:

- Cooling savings are a small (yet growing) portion of residential HVAC electricity use in the region
- Examining heating HVAC functionality simplified development of the stock turnover model, as ASHP were only replacing FAF, not potentially replacing central air conditioners
- Homes that did not previously have cooling that install ASHP for the cooling functionality can result in reduced savings

In the future, the team could develop a methodology for estimating the cooling savings and accounting for these complications. The team ranked this opportunity as the fourth priority, as it would be relatively resource-intensive to execute.

Coordinate with NEEA to Calculate Ductless Heat Pump (DHP) Momentum Savings

Impact on results: High

Effort: **

This analysis did not estimate Momentum Savings from DHP technology. As the regional HVAC market for DHP accelerates, this will be an important market to characterize and track, both for program design opportunities and potential Momentum Savings. Subsequent analyses should coordinate with NEEA to consider DHP in residential HVAC Momentum Savings.

The team ranked this opportunity as the fifth priority, as NEEA already developed estimates for DHP Momentum Savings.

Appendix

Table 9: Single Family SEEM UEC Values by Replacement Type and Climate Zone

Single Family Homes - Conversions				
Unit Type	**HZ 1**	**HZ 2**	**HZ 3**	**PNW Region**
Electric FAF	12,306	15,105	20,426	13,983
HSPF 7.7	6,720	9,851	11,709	8,180
HSPF 8.5	6,307	9,391	11,244	7,747
HSPF 9.0	6,144	9,241	11,099	7,590
HSPF 9.5	5,984	9,101	10,965	7,439
HSPF 10.0	5,827	8,967	10,843	7,293
HSPF 10.5	5,673	8,841	10,730	7,151
HSPF 11.5	5,371	8,609	10,530	6,881
Single Family Homes - Upgrades				
Unit Type	**HZ 1**	**HZ 2**	**HZ 3**	**PNW Region**
Electric FAF				
HSPF 7.7	6,200	8,998	10,480	7,487
HSPF 8.5	5,843	8,627	10,136	7,127
HSPF 9.0	5,706	8,515	10,044	7,002
HSPF 9.5	5,571	8,409	9,958	6,881
HSPF 10.0	5,438	8,309	9,880	6,763
HSPF 10.5	5,308	8,215	9,810	6,650
HSPF 11.5	5,053	8,045	9,691	6,436

Table 10: Manufactured Home SEEM UEC Values by Replacement Type and Climate Zone

Manufactured Homes - Conversions				
Unit Type	**HZ 1**	**HZ 2**	**HZ 3**	**PNW Region**
Electric FAF	10,460	12,839	17,362	11,885
HSPF 7.7	5,712	8,373	9,953	6,953
HSPF 8.5	5,361	7,983	9,558	6,585
HSPF 9.0	5,222	7,855	9,434	6,452
HSPF 9.5	5,086	7,735	9,320	6,323
HSPF 10.0	4,953	7,622	9,217	6,199
HSPF 10.5	4,822	7,515	9,121	6,079
HSPF 11.5	4,565	7,318	8,950	5,849
Manufactured Homes - Upgrades				
Unit Type	**HZ 1**	**HZ 2**	**HZ 3**	**PNW Region**
Electric FAF	-	-	-	-
HSPF 7.7	5,270	7,649	8,908	6,364
HSPF 8.5	4,967	7,333	8,616	6,058
HSPF 9.0	4,850	7,238	8,537	5,951
HSPF 9.5	4,735	7,148	8,464	5,849
HSPF 10.0	4,622	7,063	8,398	5,749
HSPF 10.5	4,512	6,983	8,339	5,653
HSPF 11.5	4,295	6,839	8,238	5,470