## Executive Summary

# HVAC Sales Data 2016-2018

May 2020

Bonneville Power Administration

PREPARED BY:
Cadeo Group

Bonneville
POWER ADMINISTRATION

# Report Overview

This report describes the research team's method for analyzing full-category Northwest HVAC distributor sales data for 2016-2018. Included is the team's approach to developing estimates of annual efficiency mix and technology mix for heating and cooling equipment sold in the Northwest region as a whole. These distributor sales data are the result of a data collection project conducted by NEEA and their contractors: CLEAResult and Energy Solutions.

BPA and NEEA initiated this sales data collection effort with the goal of obtaining full category sales data for HVAC sales within the region. The project leverages existing relationships with regional HVAC distributors. This effort has been ongoing for two years. In the first year this effort garnered sales data from five regional HVAC distributors, covering sales occurring during the years of 2016 and 2017. In 2019 BPA completed an analysis of these data and used the results of that analysis to characterize the regional residential HVAC market and to estimate total market energy savings and Momentum Savings from the adoption of efficient HVAC equipment.

In this second round of annual data collection, NEEA continued to leverage the relationships that they and CLEAResult had with regional HVAC distributors while also contracting with Energy Solutions to match equipment model numbers to equipment efficiency attributes from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) certification databases. The second round garnered sales data from seven regional HVAC distributors, covering the years 2016-2018.

This project also included developing an accompanying Excel workbook displaying regionally extrapolated sales data useful for understanding the total reported volumes of sales by technology and year for the aggregated distributor population and for assessing year-over-year changes in sales volumes within a given technology. These data can also be used to confirm HVAC standard practice baselines or inform baseline adjustments. On its own, this data is not, however, a complete view of the HVAC market, regional submarkets, or the commercial HVAC market.

This annual data collection effort is ongoing, and NEEA attempts to recruit new distributors every year. As the resulting dataset grows, BPA will continue to use this data to inform its Market Modeling efforts, including estimating total market sales and stock by technology for the residential and non-residential HVAC markets and efficiency level for the residential HVAC market in the Northwest.

# Process Overview

STEP 1

## Data Collection and Processing

NEEA and its contractor CLEAResult, collected distributor sales data for the HVAC market in the Northwest. This effort involved:

- Collaborating with regional stakeholders to execute a process for requesting full-category HVAC sales data for residential and non-residential equipment.
- Coordinating outreach effort to 26 regional distributors.
- Successfully receiving confidential sales data submissions from seven distributors.
- NEEA engaged Energy Solutions to supplement the raw data with efficiency and capacity attributes.

STEP 2

## Data Analysis for Market Modeling

BPA and its contractor, Cadeo, analyzed the sales data and assessed its utility as an input to BPA's Residential HVAC Market Model, which quantifies regional energy consumption for the residential HVAC end use during the Northwest Power and Conservation Council's 7th Power Plan period (2016-2021). This process included:

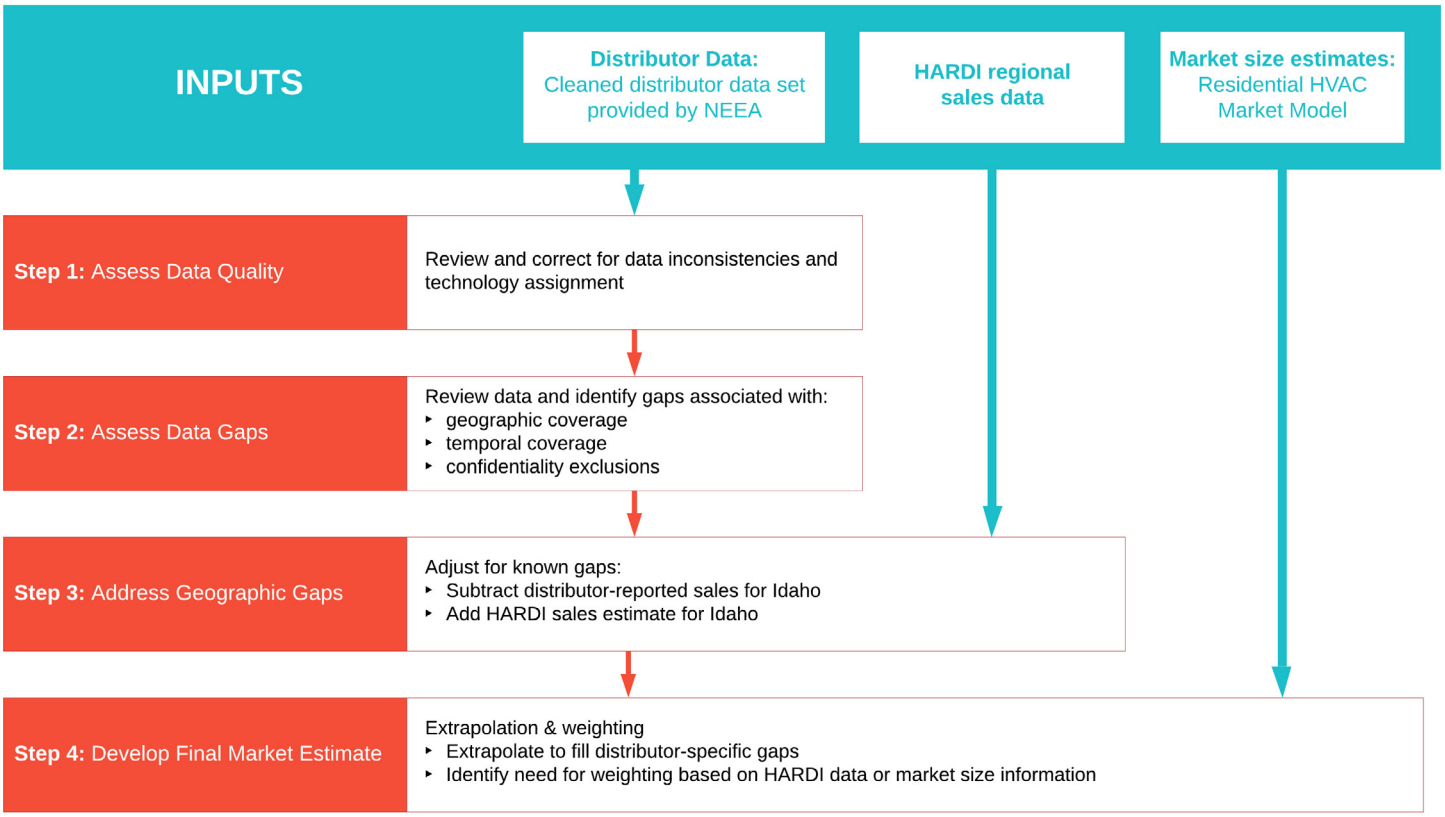
- Assessing distributor data submissions for gaps and representativeness.
- Extrapolating to fill gaps.
- Applying scalar weights to obtain a regionally representative efficiency mix.

# Data Analysis Methodology

## Focus on Residential Technologies

The analysis focused on the four key residential technologies covered in the Market Model: ductless heat pumps (DHPs), ducted air-source heat pumps (ASHPs), gas forced-air furnaces (FAFs), and central air conditioners (CACs). Those technologies also had the most robust data so a more detailed analysis was feasible. In future iterations of this effort, the analysis may include additional technologies as better data become available.

# Analysis Steps




As shown above, there are three key inputs into the analysis:

1. The HVAC distributor sales data provided by NEEA. These are the distributor data discussed above and the result of efforts by NEEA and their contractors to collect.
2. Regional HVAC sales data from the Heating, Air Conditioning and Refrigeration Distributors International (HARDI), accessed through NEEA's subscription. These data have sales by year, state, technology, and efficiency bin for key residential technologies, but at a much lower level of detail than that provided by the NEEA distributor data.
3. Market size estimates from BPA's existing Residential HVAC Market Model, developed in 2018 and published in 2019. It uses a stock turnover model to predict residential HVAC stock and sales from 2016 to 2021. This model provides a transparent, calibrated projection of overall regional HVAC sales.

These inputs are used as appropriate to provide context and enable adjustments to address known gaps in the distributor data and calibrate the efficiency mix to an existing estimate of market size. The precise application of these data is detailed in the discussion below.

# Market Coverage

The aggregated 2016-2018 data set includes sales from distributors covering all four states in the Northwest region (Idaho, Montana, Oregon, and Washington). Each state's coverage varies. While the collected data could not be anonymized sufficiently to support reporting of sales at the state level, this year's effort is a substantial expansion of the HVAC data the NEEA/CLEAResult team obtained in its previous effort, resulting in:

- **Inclusion of three additional distributors (increasing the distributor population from five to eight)[1]**
- **An additional year of sales for all eight distributors**
- **Additional data for 2016, which addressed a data gap present in the last round of analysis**

*1 While only seven distributors submitted data for 2018, the analytical team was able to extrapolate and weight sales for eight distributors based on prior submittals.*

**Table 1** presents the reported sales volume, by year for the technologies that pass the reporting criteria (more than three distributors reporting and more than 100 units in each year). Based on previous research and the Residential HVAC Market Model, the team estimates the sales data from the eight distributors in the database encompasses approximately 35% to 45% of the residential market for gas furnaces, air source heat pumps, ductless heat pumps and central air conditioners. In the commercial sector, where there is more variation in HVAC equipment types and a greater presence of manufacturer-direct sales, the team estimates that the database represents a small portion of the market.

## TABLE 1 - Extrapolated & Weighted Distributor Sales Volume by Technology

| Technology | 2016 Reported Quantity | 2017 Reported Quantity | 2018 Reported Quantity |
|---|---|---|---|
| Central Air Conditioning – Condenser | 88,491 | 83,400 | 76,471 |
| Gas Furnace | 106,440 | 105,207 | 104,134 |
| Heat Pump | 61,737 | 61,776 | 61,193 |
| Heat Pump – Ductless | 40,859 | 40,188 | 39,703 |
| Variable Speed Mini-Split & Multi-Split Air Conditioning | 1,764 | 1,742 | 1,702 |
| Gas Packaged Unit | 652 | 782 | 816 |
| Central Air Conditioning - Packaged Terminal (PTAC) | 336 | 275 | 274 |
| Unitary Large Equipment | 846 | 1,021 | 1,892 |

# Cooling Efficiency

The raw sales data are augmented to fill in geographic gaps and extrapolated to fill in temporal gaps.[2] The adjusted data provide a critical input into the Residential HVAC Market Model: the estimated efficiency mix in technologies of interest. These are provided in **Tables 2 and 3.**

## TABLE 2 - Final Cooling Efficiency Mix – Residential

| Technology | Cooling Efficiency | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Central Air Conditioner (Condensing Units) | SEER 10 | 1%* | 1% | 1% |
| | SEER 13 | 42% | 35% | 35% |
| | SEER 14.5 | 51% | 58% | 58% |
| | SEER 18 | 7% | 6% | 7% |
| Air Source Heat Pump | SEER 13 | 3% | 1% | 0% |
| | SEER 14.5 | 83% | 82% | 82% |
| | SEER 18 | 15% | 17% | 18% |

** percentages for each technology may not sum to 100 due to rounding*

*2 For a more in-depth discussion of the adjustment processes, please see the HVAC Sales Data Analysis Memo, appended to this document. For more information, visit BPA's website: https://www.bpa.gov/EE/Utility/Momentum-Savings/Pages/HVAC.aspx*

# Heating Efficiency

### TABLE 3 - Final Heating Efficiency Mix – Residential

| Technology | Heating Efficiency | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Gas Furnace | 80% up to 90% AFUE | 34%* | 30% | 30% |
| | 90% up to 95% AFUE | 9% | 8% | 5% |
| | 95% AFUE or greater | 57% | 62% | 65% |
| Air Source Heat Pump | HSPF 7.7 | 2% | 1% | 0% |
| | HSPF 8.2 | 43% | 42% | 38% |
| | HSPF 8.5 | 29% | 29% | 33% |
| | HSPF 9.0 | 20% | 23% | 25% |
| | HSPF 12.0 | 5% | 5% | 5% |
| Ductless Heat Pump (Outdoor Units) | Below HSPF 9.0 | 13% | 12% | 7% |
| | HSPF 9.0 to 11.0 | 65% | 65% | 74% |
| | HSPF 11.1 to 12.5 | 18% | 18% | 15% |
| | HSPF 12.6 and above | 4% | 4% | 4% |

** percentages for each technology may not sum to 100 due to rounding*

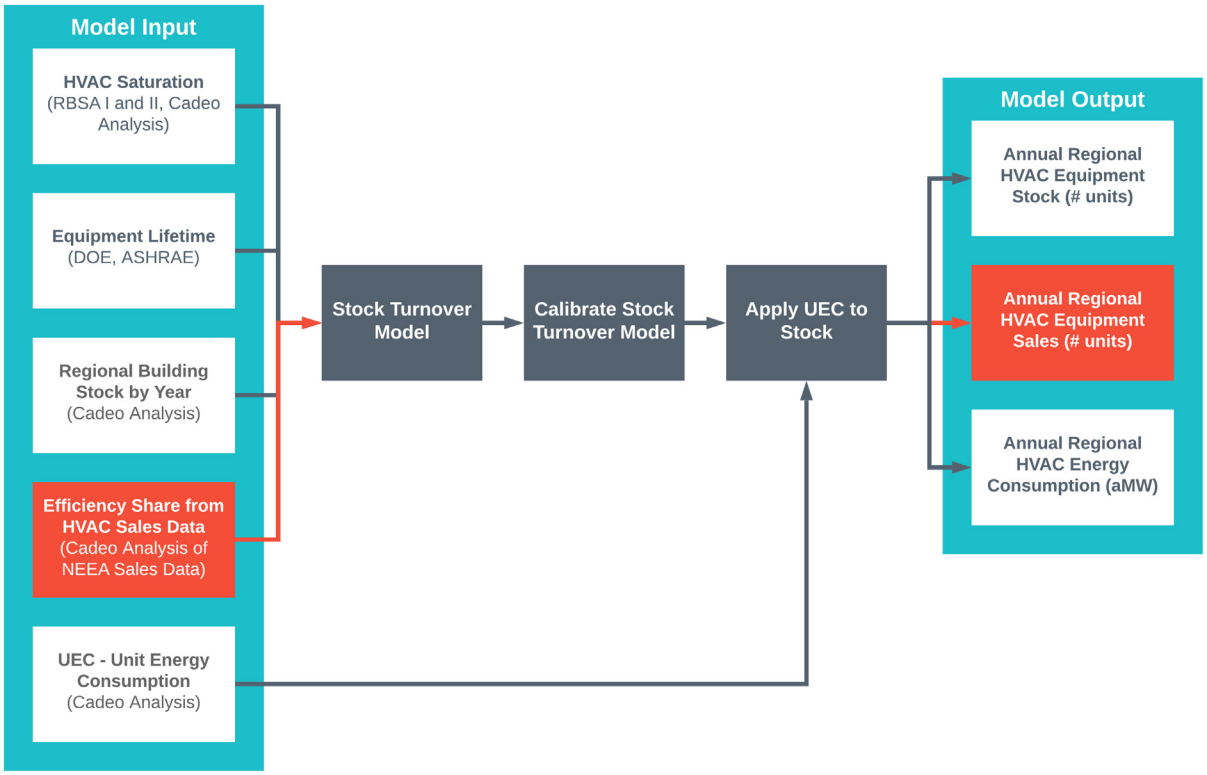
## Relationship to the Regional Residential HVAC Market Model

Prior to this round of sales data collection and analysis, the BPA research team developed a regional Market Model for residential HVAC equipment that estimates total regional electric consumption, total market savings, and Momentum Savings for the Seventh Power Plan action plan period (calendar years 2016–2021).

**Figure 1** shows the architecture of the Residential HVAC Market Model. The team uses the efficiency shares obtained in this sales data analysis project as one of the inputs to its Market Model (see Table 7 and Table 8 above). The model produces three outputs:

- **an estimate of regional HVAC stock (number of dwelling units, by year),**
- **an estimate of regional HVAC sales (number of HVAC units sold, by year), and**
- **an estimate of regional HVAC energy consumption (aMW, by year).**

## FIGURE 1 - BPA Residential HVAC Market Model Architecture



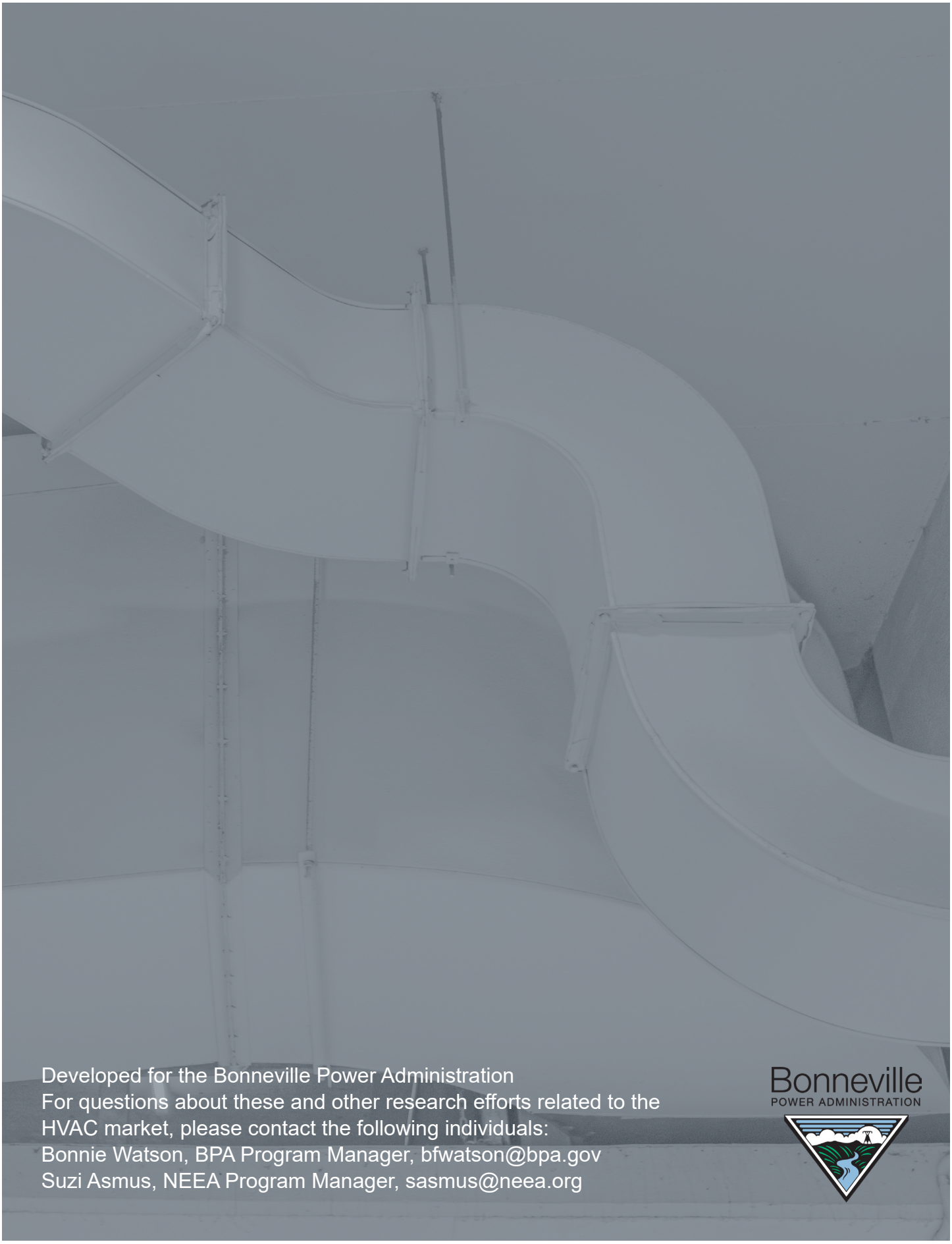

The red boxes in **Figure 1** are the two elements of the Market Model related to this analysis. First, the efficiency shares derived from this work are used as an input to reflect the overall efficiency mix in the region. Second, the annual regional sales estimate is an output of the model, and is also used as an input into the sales data analysis to weight the distributor data up to a regional sales estimate.

# What's Next in HVAC Sales Data Research?

NEEA has already launched the next wave of distributor outreach and will be collecting additional sales data from participating distributors. This data will improve the coverage and comprehensiveness of the current dataset. With sufficient volume and coverage, it may be possible to:

- Estimate sales and efficiency mixes for additional technologies
- Estimate sales and efficiency mixes by state
- Develop year-over-year trendlines

BPA and its contractors are already planning for an expanded effort to augment and analyze the data being collected through NEEA's distributor outreach and address specific questions that emerged from stakeholder review. The results of this work, planned for the second half of 2020, will inform an update to the Residential HVAC Market Model, expected in 2021.



Developed for the Bonneville Power Administration
For questions about these and other research efforts related to the HVAC market, please contact the following individuals:

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Bonneville
POWER ADMINISTRATION

# Memorandum

To: Ben Mabee and Bonnie Watson, Bonneville Power Administration

From: Dulane Moran, Elizabeth Daykin and Fred Shaefer, Cadeo

Date: May 29, 2020

Subject: Final Memo: HVAC Distributor Data Market Analysis

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## Introduction and Context

This memorandum describes the research team's method for analyzing full-category Northwest HVAC distributor sales data for 2016-2018. Included is the team's approach to developing estimates of annual efficiency mix and technology mix for heating and cooling equipment sold in the Pacific Northwest region as a whole. These distributor sales data are the result of a data collection project conducted by NEEA and their contractors: CLEAResult and Energy Solutions.

BPA and NEEA initiated this sales data collection effort with the goal of obtaining full-category sales data for HVAC equipment within its service territory by leveraging NEEA and CLEAResult's existing relationships with regional HVAC distributors. This effort has been ongoing for two years. In the first year this effort garnered sales data from five regional HVAC distributors, covering sales occurring during the years of 2016 and 2017. In 2019 BPA completed an analysis of these data and used the results of that analysis to characterize the regional residential HVAC market and to estimate total market energy savings and Momentum Savings from the adoption of efficient HVAC equipment.

In this second round of annual data collection, NEEA continued to leverage the relationships that they and CLEAResult had with regional HVAC distributors while also contracting with Energy Solutions to match equipment model numbers to equipment efficiency attributes from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) certification databases. The details of NEEA's data collection or model matching processes are not part of the scope of this task order.

The memo is organized in the following sections:

- Overall methodology and approach to analysis
- An assessment of the distributor data quality
- An assessment of the data gaps
- Approaches used to address geographic gaps
- Final adjustments and market estimates
- Data applicability
- Next steps
- Appendix A: Relationship to the BPA Residential HVAC Market Model

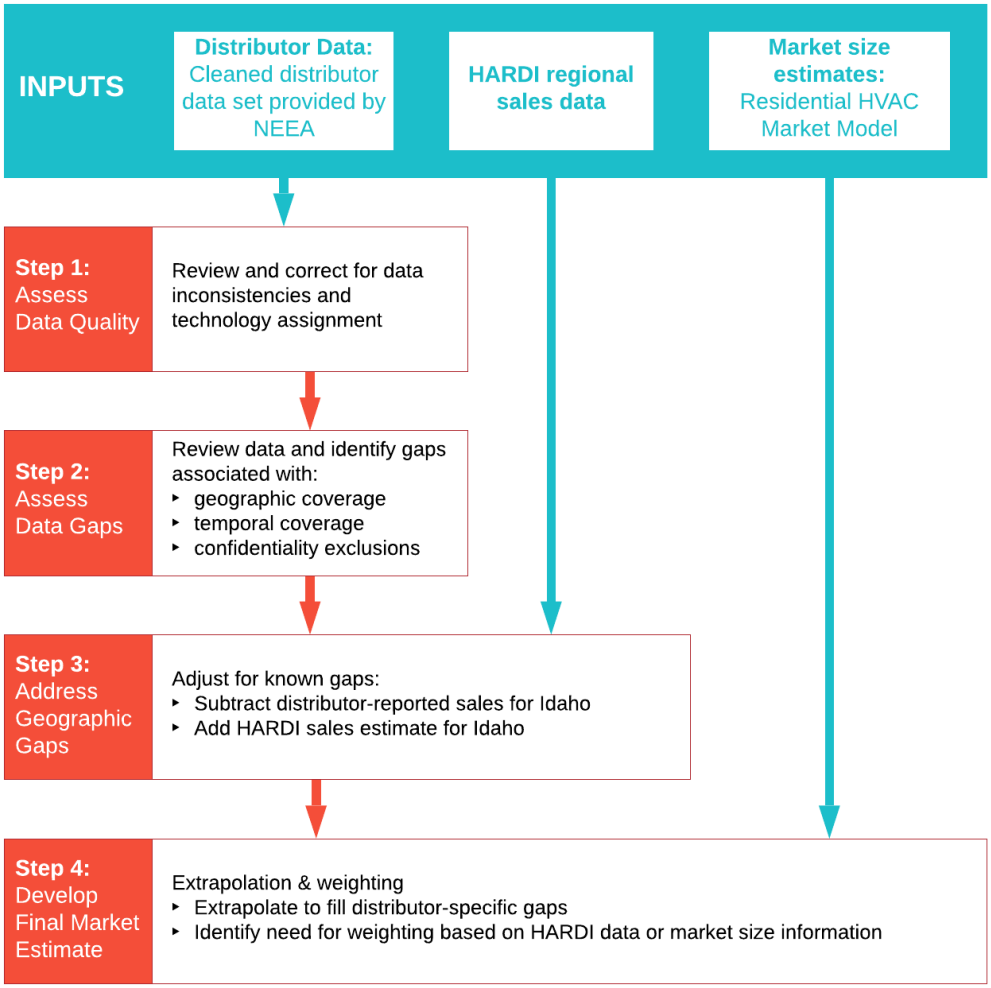
## Overall Methodology

This section describes the methodological steps that the team uses to analyze NEEA's sales data.

The analytical approach and methodology for this round largely follows the prior round of analysis that BPA completed in March 2019. The team does introduce small changes to the proposed analytical approach, which are driven by the differences in data availability compared to the prior round.

Figure 1 presents an overall map of the analytical steps undertaken in this round of analysis, each of which are discussed in more detail in this memo.

Figure 1: Analysis Process



As shown in Figure 1, there are three key inputs into the analysis:

1. The HVAC distributor sales data provided by NEEA. These are the distributor data discussed above and the result of efforts by NEEA and their contractors to collect.
2. Market size estimates from BPA's existing Residential HVAC Market Model. The Residential HVAC Market Model was developed in 2018 and published in2019. It uses a stock turnover model to predict residential HVAC stock and sales from 2016 to 2021. This model, published in 2019, provides a transparent, calibrated projection of overall regional HVAC sales.[1]
3. Regional HVAC sales data from the Heating, Air Conditioning and Refrigeration Distributors International (HARDI), accessed through NEEA's subscription.[2] These data have sales by year, state, technology, and efficiency bin for key residential technologies, but at a much lower level of detail than that provided by the NEEA distributor data.

These inputs are used as appropriate to provide context and enable adjustments to address known gaps in the distributor data and calibrate the efficiency mix to an existing estimate of market size. The precise application of these data is detailed in the discussion below.

## Step 1: Assess Distributor Data Quality

The team received sales data for the years 2016 through 2018 from eight regional HVAC distributors in a relational database. This year's effort is a substantial expansion of the HVAC data that the NEEA/CLEAResult team obtained in its previous effort, resulting in:

- Inclusion of three additional distributors (increasing the distributor population from five to eight)
- An additional year of sales for all eight distributors
- Additional data for 2016, which filled in a previous data gap present in the last round of analysis

The inclusion of the new distributors expands the regional market coverage and increases our overall confidence in the representativeness of the data. The additional distributors are of a similar volume to most of the first-round participants, and together represent less than 20% of the overall reported sales for the residential technologies included in our analysis.[3]

In its raw form, these data include, for each distributor, model numbers, quantity sold, and the calendar month in which the equipment was sold. NEEA's contractor Energy Solutions supplemented this raw data with efficiency and capacity attributes by looking up the reported model numbers in publicly available sources (including the AHRI Directory of Certified Product Performance).[4]

The NEEA HVAC sales data is housed in a relational database consisting of nine tables composed of confidential raw and post-processed data (i.e., efficiency and capacity information for each model number in the raw data). The NEEA/Energy Solutions team created detailed tables and views for each HVAC technology that included model information and sales.

[1] For additional information on the market model, see Appendix A.
[2] In this document the term HARDI refers to a data product that D+R International has developed in partnership with Heating Air-conditioning & Refrigeration Distributors International (HARDI). These data contain HVAC sales data for the Pacific Northwest region.
[3] The technologies included in this analysis are central air conditioners, air source heat pumps, gas furnaces, and ductless heat pump. The team was able to identify electric forced air furnaces in the distributor sales data, but at a very low volume (approximately 1,000 a year) and nearly all designed for manufactured homes.
[4] AHRI, the Air-Conditioning, Heating, & Refrigeration Institute, maintains a directory of equipment performance data. It is available online at https://www.ahridirectory.org.

The database contains over 1,000 attributes across all the tables, though most are ancillary to this analysis. For example, attributes such as model number, input ratings, high-heat ratings are not essential to understanding the overall HVAC market (nor are they used as inputs to the BPA market model). For this analysis, the research team focused on the attributes listed in Table 1.

Table 1: HVAC Database Description Fields

| Field Name | Description |
|---|---|
| Technology | The HVAC technology type |
| Fuel Type | The type of fuel used for heating, water heating,[5] or some packaged units (electric, gas, propane, etc.) |
| Heating Capacity, MBH | The measure of energy units needed to heat a given amount of space, measured in millions of British thermal units (MMBtus) |
| Cooling Capacity, MBH | The measure of energy units needed to cool a given amount of space, measured in millions of British thermal units (MMBtus) |
| SEER | The Seasonal Energy Efficiency Ratio (SEER), an energy efficiency rating for air conditioners |
| Median SEER | Median SEER for the listed configurations for an outdoor central air condenser or heat pump* |
| AFUE % | The Annual Fuel Utilization Efficiency (AFUE), a measure of a furnace's heating efficiency |
| Median HSPF | Median Heating Seasonal Performance Factor (HSPF), the heating efficiency rating for heat pumps for an outdoor heat pump unit* |

*Some HVAC technologies are composed of a combination of indoor and outdoor units. In these instances, the AHRI source data lists the efficiency and capacity of each possible indoor/outdoor unit combination. The sales data do not enable analysis of specific indoor/outdoor equipment combinations; rather, the team defined the HSPF and SEER value for each outdoor unit as the median of the HSPF and SEER values for all of the indoor units that it can be paired with.

All data are anonymized for reporting to ensure that distributor-specific data is protected. The team reviewed the NEEA-provided distributor data set to identify the need for any additional data cleaning. This step includes checking for the following items:

- incorrect value types,
- consistency of technology assignments,
- relational inconsistencies, and
- formatting issues

Overall, the team found the data to be well organized and complete. The adjustments required to use the data for these analyses were minor and reflected the specific categorization required to align with BPA measures.

[5] The data request included water heating equipment at the request of the stakeholders to support market transformation activities.

To align the analyses with prior BPA studies and to categorize equipment into its appropriate sector, the team applied sector categorizations consistent with BPA's definitions for residential and commercial equipment:

- Air Source Heat Pumps, Ductless Heat Pumps and Central Air Conditioners:
    - Residential: capacity of less than or equal to 5 tons (60 kBTU/hr).
    - Commercial: capacity of greater than 5 tons (60 kBTU/hr).
- Furnaces:
    - Residential: capacity less than 225 KBtu/hr.
    - Commercial: capacity greater than or equal to 225 KBtu/hr.

## Step 2: Assess Data Gaps

After receiving the sales data and assessing data quality, the team found notable temporal, technology and geographic gaps in the dataset. The specific findings for each of these gaps are discussed in this section.

### Temporal Gaps

Temporal gaps refer to any distributors with gaps in their submittals associated with a specific time period. The team believe that filling in these distributor-specific gaps is important given the limited number of distributors in our data and the unique product mix represented by each one. Moving forward without filling in the missing data could affect the accuracy of our estimate of regional HVAC efficiency.

NEEA asked distributors to submit three years of sales (2016, 2017, 2018), however, the team found that some distributors did not provide complete data for the full time period. Figure 2, displays the temporal gaps in the submissions of four distributors.

- Distributor A: submitted partial sales data for December 2017
- Distributor C: submitted partial sales data for December 2017 and did not submit sales data for calendar year 2018
- Distributor F: submitted partial sales data for calendar year 2016
- Distributor G: did not submit sales data for months between January 2016 through November 2016.

## Figure 2. Temporal Gaps in HVAC Sales Data

| | 2016 | | | | | | | | 2017 | | | | | | | | 2018 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Distributor | | | | | | | | Distributor | | | | | | | | Distributor | | | | | | | |
| | A | B | C | D | E | F | G | H | A | B | C | D | E | F | G | H | A | B | C | D | E | F | G | H |
| January | ✓ | ✓ | ✓ | ✓ | ✓ | ~ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| February | ✓ | ✓ | ✓ | ✓ | ✓ | ~ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| March | ✓ | ✓ | ✓ | ✓ | ✓ | ~ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| April | ✓ | ✓ | ✓ | ✓ | ✓ | ~ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| May | ✓ | ✓ | ✓ | ✓ | ✓ | ~ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| June | ✓ | ✓ | ✓ | ✓ | ✓ | ~ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| July | ✓ | ✓ | ✓ | ✓ | ✓ | ~ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| August | ✓ | ✓ | ✓ | ✓ | ✓ | ~ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| September | ✓ | ✓ | ✓ | ✓ | ✓ | ~ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| October | ✓ | ✓ | ✓ | ✓ | ✓ | ~ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| November | ✓ | ✓ | ✓ | ✓ | ✓ | ~ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ |
| December | ✓ | ✓ | ✓ | ✓ | ✓ | ~ | ✓ | ✓ | ~ | ✓ | ~ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ |

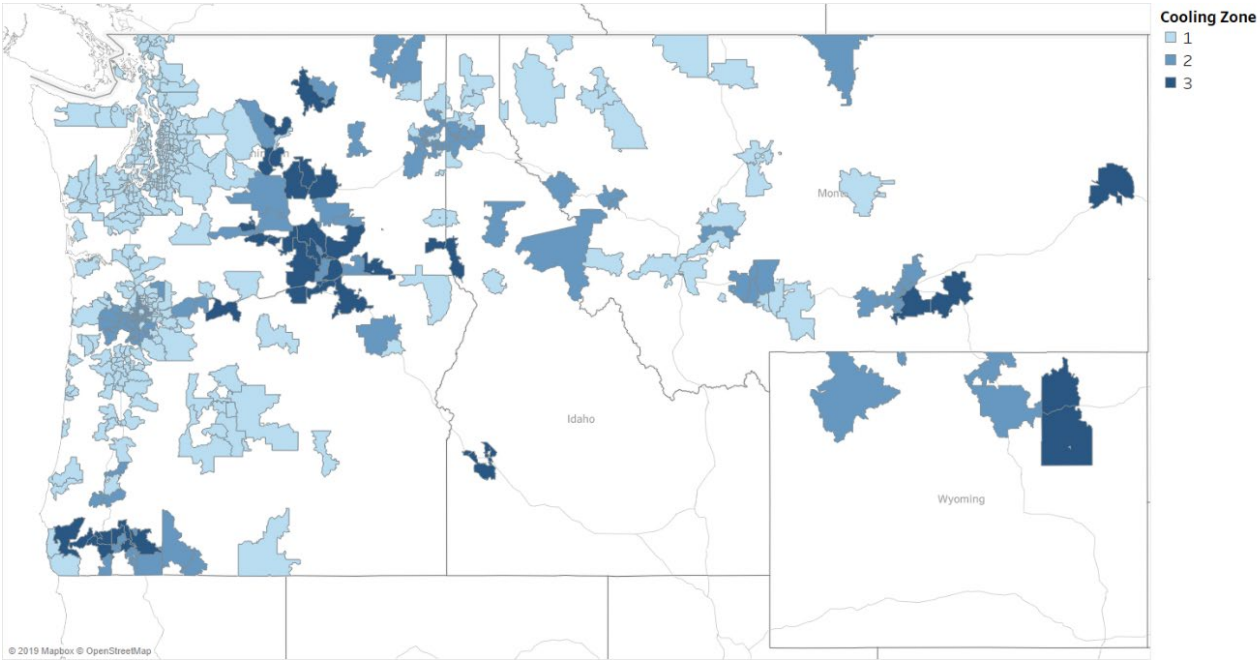
| | |
|---|---|
| Data Submitted | ✓ |
| Not Submitted | × |
| Partially Submitted | ~ |

## Geographic

Geographic gaps refer to any states substantially underrepresented in the existing dataset. Because the objective is to derive regional inferences from these data, the team must build a data set that is as representative as possible across the region.

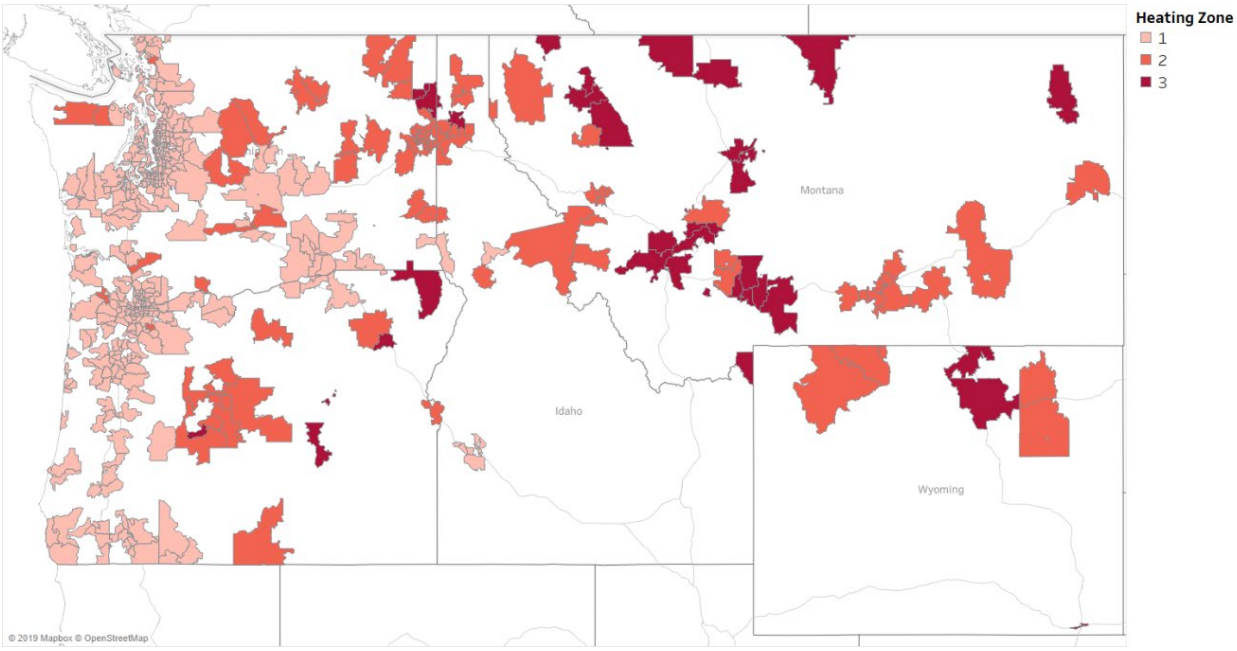
To understand the geographic gaps in the data set, the team mapped the spatial distribution of the cooling equipment in the dataset (Figure 3) by ZIP code. ZIP codes where cooling equipment was sold by one or more distributors is shaded, with lighter blue shading indicating cooling zone 1 and the darkest shading indicating cooling zone 3. ZIP codes that are not represented in the sales data are not shaded. Perhaps unsurprisingly, the shading largely aligns with population centers. This map shows that southern Idaho, where Boise is located, is very sparsely shaded – indicating a geographic gap for cooling equipment.

Figure 3. Reported Sales of Cooling Equipment, by Climate Zone




Similarly, Figure 4, displays the distribution of heating equipment, again by ZIP code. Each ZIP code with heating equipment sold by one or more distributors is shaded, with lighter red shading indicating heating zone 1 and the darkest shading indicating heating zone 3. ZIP codes that are not represented in the sales data are not shaded. This map also indicates a similar geographic gap for heating equipment.

Figure 4. Reported Sales of Heating Equipment, by Climate Zone



These maps illustrate the very limited coverage of reported sales in the southern Idaho region, which remains a major geographic gap that the team also noted in the prior round of analysis of 2016-2017 data. Figure 3 and Figure 4 also illustrate that a small percentage of reported sales are associated with Wyoming; the team will exclude these[6] units from the analyses in this document and in subsequent deliverables unless otherwise noted.

To further quantify geographic gaps in the reported sales data, the team sought to compare reported sales by state to population by state. Population is a good comparison metric since one would expect HVAC equipment sales to be approximately correlated to population. (i.e., a state with a higher population would likely have higher HVAC equipment sales.)

To conduct this comparison, the team used a two-step approach to determine the sales location for 99% of the HVAC units sold and reported in this data collection effort.

- Use ship-to ZIP code if available (69% of sales)
- If ship-to ZIP code is not available, use ship-from ZIP code (adding this step increased the known geographic assignment to 99% of reported sales)

The results of this analysis and the subsequent adjustments to improve geographic coverage are discussed in *Step 3: Address Geographic Gaps* below.

## Technology

Identifying technology gaps included the team assessing the comprehensiveness of the technologies in the data relative to the residential HVAC equipment stock in the region. During this step, the team screened the data for distributor confidentiality issues by identifying and removing any technologies with fewer than three distributors and any technologies with fewer than 100 units in annual sales across all distributors. While this process preserves anonymity of participation distributors, it can create gaps in coverage for some technologies.

Table 2 presents all of the technologies represented in the data. Technologies that do not meet the three distributor and 100 units sold criteria are noted. These are removed from further analysis to preserve distributor confidentiality.

### Table 2. Residential HVAC Technologies in Distributor Dataset

| Technology | Included in Analysis | Excluded: Too Few Units | Excluded: Not Enough Distributor Submissions |
|---|---|---|---|
| Central AC – Condenser | Yes | | |
| Gas Furnace | Yes | | |
| Heat Pump | Yes | | |
| Heat Pump – Ductless | Yes | | |
| Heat Pump – Single Packaged | Yes | | |
| Gas Packaged Unit | Yes | | |

[6] For the purposes of this analysis, the team defines "region" consistent with the definition used by the Northwest Power and Conservation Council, and includes Washington, Oregon, Idaho, and western Montana.

| Technology | Included in Analysis | Excluded: Too Few Units | Excluded: Not Enough Distributor Submissions |
|---|---|---|---|
| Variable Speed Mini-Split and Multi-Split Air Conditioning | Yes | | |
| Boilers | No | | Yes |
| Electric Furnace | No | | Yes |
| Oil Furnace | No | | Yes |
| Central Air Conditioning – Single Packaged | No | | Yes |
| Direct Heating Equipment | No | | Yes |
| Water heaters | No | | Yes |

Table 3. Commercial HVAC Technologies in Distributor Dataset

| Technology | Included in Analysis | Excluded for Too Few Units | Excluded for Not Enough Distributor Submissions |
|---|---|---|---|
| Central AC - Packaged Terminal (PTAC) | Yes | | |
| Heat Pump – Packaged Terminal (PTHP) | Yes | (2017 & 2018) | |
| Heat Pump | Yes | | |
| Unitary Large Equipment | Yes | | |
| VRF | No | Yes | |
| Boiler | No | Yes | Yes |
| Central Air Conditioning - Single Packaged | No | Yes | Yes |
| Heat Pump - Single Packaged | No | Yes | Yes |
| Single Packaged Vertical AC & HP | No | Yes | Yes |
| Heat Pump – Ductless | No | Yes | Yes |
| Boiler | No | Yes | Yes |
| Gas Furnace | No | | Yes |
| Water Heaters | No | | Yes |
| Heat Pump – Water Source | No | | Yes |
| Water heaters | No | | Yes |

Table 4 presents the reported sales volume, by year for the technologies that pass the reporting criteria. The team's experience suggests that the sales data from the eight distributors in the database encompasses approximately 35% to 45% of the residential market for gas furnaces, air source heat pumps, ductless heat pumps and central air conditioners. In the commercial sector, where there is more variation in HVAC equipment types and a greater presence of manufacturer-direct sales, the team estimates that the database represents a small portion of the market.

Table 4. Unextrapolated Distributor Sales Volume by Technology

| Sector | Technology | 2016 Reported Quantity | 2017 Reported Quantity | 2018 Reported Quantity |
|---|---|---|---|---|
| Residential | Central Air Conditioning – Condenser | 17,945 | 28,549 | 33,646 |
| Residential | Gas Furnace | 37,234 | 46,515 | 47,271 |
| Residential | Heat Pump | 13,768 | 18,355 | 18,152 |
| Residential | Heat Pump – Ductless | 13,817 | 21,591 | 23,441 |
| Residential | Variable Speed Mini-Split & Multi-Split Air Conditioning | 786 | 1,831 | 1,840 |
| Residential | Gas Packaged Unit | 686 | 800 | 824 |
| Commercial | Heat Pump | 107 | 216 | 294 |
| Commercial | Central Air Conditioning - Packaged Terminal (PTAC) | 336 | 271 | 467 |
| Commercial | Heat Pump – Packaged Terminal (PTHP) | 133 | -- | -- |
| Commercial | Unitary Large Equipment | 778 | 1,042 | 1,953 |

Some technologies that are common in the regional residential HVAC market, like room air conditioners, smart thermostats, and zonal heating equipment are not represented in the NEEA sales data as the sales channels for these products include retail channels not reflected in the distributor dataset. The team expected this gap; integrating sales data for this equipment would require integrating retail and perhaps online sales estimates.

## Step 3: Address Geographic Gaps

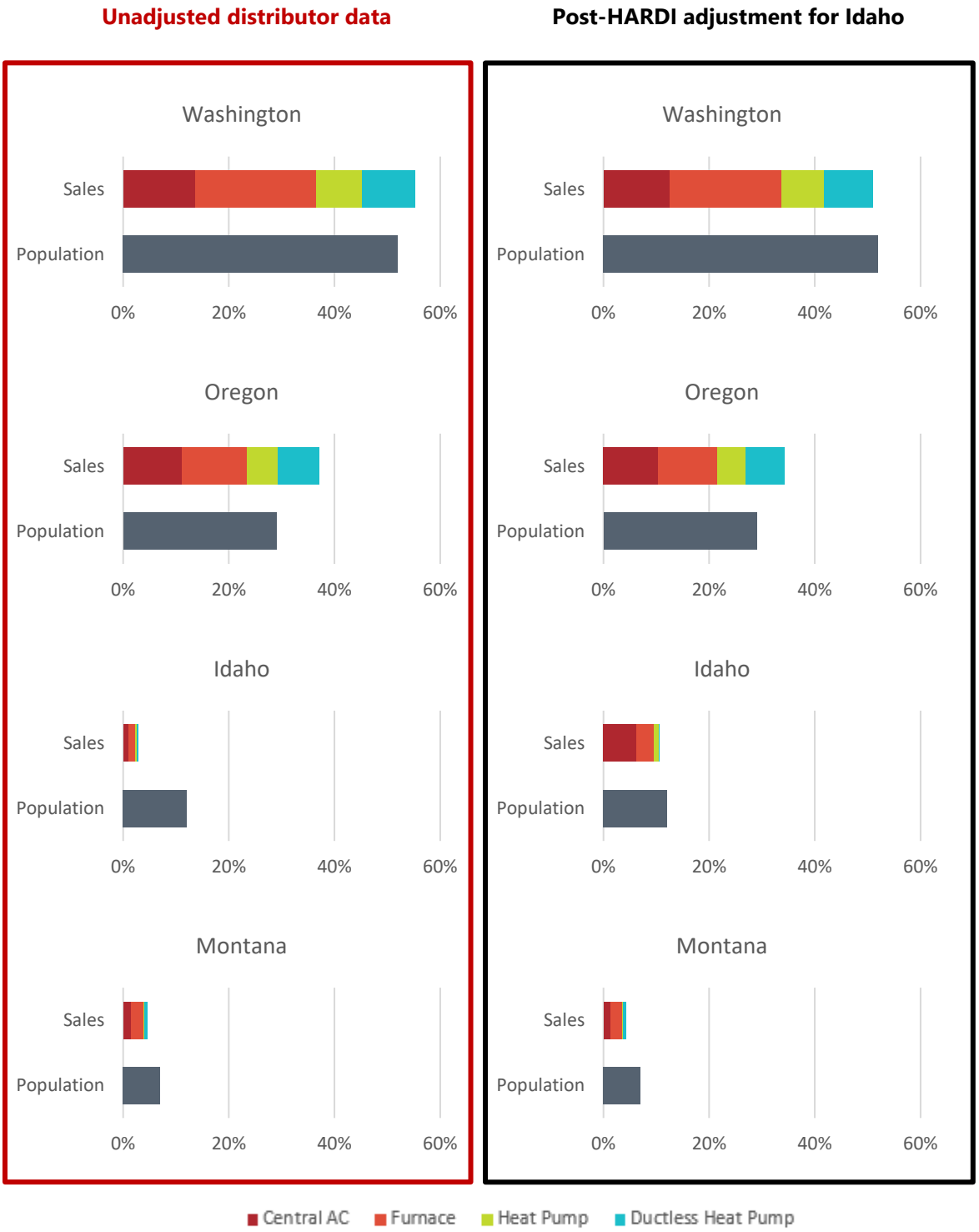
Step 2 (above) discusses the value of using state population as a proxy for understanding the regional coverage of the raw distributor data. The team's analysis confirmed the need to adjust for the underrepresentation of Idaho. To address the identified gap in Idaho sales data and make the underlying dataset more representative, team integrated data from the HARDI market data report. The research team received these data through a non-disclosure agreement with NEEA, as in the previous round of analysis. Though the HARDI report fills a geographic gap, the distributors that contribute to it are anonymized, making it difficult to determine the extent of distributor overlap between the NEEA-reported distributor data and the HARDI data product. For this reason, the team subtracted Idaho sales from the NEEA-provided distributor data and replaced it with HARDI data for Idaho for four technologies: central air conditioners, ductless heat pumps, air source heat pumps, and gas furnaces.[7]

As shown in the left set of graphs in Figure 5 below, sales for Washington, as a percent of total regional reported sales, were roughly proportional to Washington's population as a percent of total regional population. This indicates that the dataset provides good coverage for Washington. Oregon sales relative to population indicate that Oregon appears was overrepresented in the original dataset. While the sales in Montana and Idaho indicate both states are underrepresented in the dataset, the difference for Idaho (3% of sales, 12% of population) is substantially higher than that for Montana (5% of sales, 7% of population). As is visible in the graphs on the right, integrating HARDI data adjusts Idaho's share of

[7] NEEA's HARDI license includes only these four technologies.

regional HVAC sales to align more closely with its share of regional population, which also corrects some of the overrepresentation of Oregon or Washington HVAC sales.

Figure 5. Total 2018 Reported Sales by Technology by State: Original and Post-HARDI Integrated



## Step 4: Final Market Estimates

The last step involves two primary analytical components required to prepare a final market estimate. The intent of both components is to fill data gaps.

- **Extrapolation** fills temporal gaps in distributor submissions, and
- **Weighting** fills market coverage gaps

### *Extrapolation*

Following the integration of HARDI data for Idaho, the team extrapolated to fill in temporal gaps in sales data from reporting distributors. Extrapolation is important because the efficiency mix for HVAC equipment varies from distributor to distributor making it imperative that the we have a complete time-series dataset for each distributor in our sample to avoid introducing bias to the regional efficiency mix calculated from these data.

**Process**

Our approach rests on two key assumptions:[8] (These values are illustrative examples only, not actual distributor market shares.)

- **Distributors' market share remains relatively constant over time.** For example, if Distributor A sales represented 25% of all reported HVAC sales in 2017, then the team assumes Distributor A will represent 25% of HVAC sales in 2018.
- **The mix of technologies is, on average, similar for that distributor across years.** For example, if participating distributor's sales showed that heat pumps accounted for 5% of all reported unit sales in 2017, then the analysis assumes that this distributor had heat pumps accounting for 5% of total reported sales in 2018.

Prior to continuing with the extrapolation process, the team confirmed both assumptions through analyses that plotted: 1) distributor-specific market share across years; and 2) distributor-specific technology mix across years. The results of these analyses are protected by confidentiality agreements, but the team's analyses confirmed that both assumptions are reasonable.

As visible in Figure 2 on page 6, the overall temporal coverage of the data is good. In most cases the team only needed to make minor extrapolations to fill in missing data. It is important to note, however, that the temporal gaps differ between distributors, for example: one might be missing an entire year, another might be missing only a month. To address these differences the team applied different extrapolation processes (applied in the order listed):

[8] In previous analyses, the team confirmed these assumptions by reviewing the sales patterns for distributors that submitted at least two complete and consecutive years of sales data to ensure that assumptions of consistency were warranted. We repeated that effort this year.

1. For the two cases in which data submissions were missing a month or less of sales data, the team:
    a. Extrapolated for the missing weeks to create a complete set of data for the full year.
    b. Relied solely on the distributor's submitted data to ensure the most accurate prediction, rather than using other distributors' data to extrapolate sales.
    c. Calculated the extrapolated sales for the full month assuming that the relative volume and mix of those sales is the same as that month in a proximate year.

2. For three cases in which data submissions were missing more than a month, the team:
    a. Calculated an estimated overall market share for each distributor in which a full year was submitted, (for example: the percent of all reported unit sales in 2016).
    b. Applied these market share estimates to the reported data to extrapolate the total sales for the missing period.
    c. Allocated those total sales to the same technology and efficiency mix as reported in either the prior or subsequent year, e.g., 5% of total sales are SEER 18 air source heat pumps.

This methodology ensures the team leverages the information gathered for each year to extrapolate for data gaps and uses the market shares from the reported sales data to inform the extrapolated sales. Table 5 presents the portion of sales data for each technology that are extrapolated for each year. In general, level of extrapolation, particularly for 2017 and 2018, is quite low. In 2016, variable speed mini-split and multi-split air conditioning required extrapolating more than 50% of the sales. This reflects a specific gap in 2016 submittals. Unextrapolated sales volume for this product category indicate that in 2016 fewer than 1,000 units were reported, in 2017 and 2018 this jumped to more than 1,800.

Table 5. Proportion of Sales Data that are Extrapolated

| Technology | 2016 Percent Extrapolated | 2017 Percent Extrapolated | 2018 Percent Extrapolated |
|---|---|---|---|
| Central Air Conditioning – Condenser | 10% | 0% | 3% |
| Gas Furnace | 8% | 1% | 2% |
| Heat Pump | 11% | 1% | 3% |
| Heat Pump – Ductless | 21% | 1% | 0% |
| Variable Speed Mini-Split & Multi-Split Air Conditioning | 56% | 1% | 0% |
| Central Air Conditioning - Packaged Terminal (PTAC) | 0% | 1% | 3% |
| Heat Pump – Packaged Terminal (PTHP) | 0% | 0% | 0% |
| Gas Packaged Unit | 0% | 0% | 0% |
| Unitary Large Equipment | 10% | 0% | 1% |

Finally, the critical information that the team obtained from these data is the efficiency mix in the technologies of interest. We present these next.

## Table 6. Final Heating Efficiency Mix – Residential

| Technology | Heating Efficiency | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Gas Furnace | 80% up to 90% AFUE | 34% | 30% | 30% |
| | 90% up to 95% AFUE | 9% | 8% | 5% |
| | 95% AFUE or greater | 57% | 62% | 65% |
| Air Source Heat Pump | HSPF 7.7 | 2% | 1% | 0% |
| | HSPF 8.2 | 43% | 42% | 38% |
| | HSPF 8.5 | 29% | 29% | 33% |
| | HSPF 9.0 | 20% | 23% | 25% |
| | HSPF 12.0 | 5% | 5% | 5% |
| Ductless Heat Pump (Outdoor Units) | Below HSPF 9.0 | 13% | 12% | 7% |
| | HSPF 9.0 to 11.0 | 65% | 65% | 74% |
| | HSPF 11.1 to 12.5 | 18% | 18% | 15% |
| | HSPF 12.6 and above | 4% | 4% | 4% |

## Table 7. Final Cooling Efficiency Mix – Residential

| Technology | Cooling Efficiency | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Central Air Conditioner (Condensing Units) | SEER 10 | 1% | 1% | 1% |
| | SEER 13 | 42% | 35% | 35% |
| | SEER 14.5 | 51% | 58% | 58% |
| | SEER 18 | 7% | 6% | 7% |
| Air Source Heat Pump | SEER 13 | 3% | 1% | 0% |
| | SEER 14.5 | 83% | 82% | 82% |
| | SEER 18 | 15% | 17% | 18% |

### *Weighting*

Weighting is important for understanding the full market size of annual equipment sales. It preserves the efficiency mix obtained from the sales data but scales the data to represent the full market. The purpose of this weighting process is to align the final sales data set with the regional market size for each technology. The weighting process that we describe below does not impact the efficiency mix within a given technology type (e.g., the percent of ASHP sales that are HSPF 9.0).

#### Process

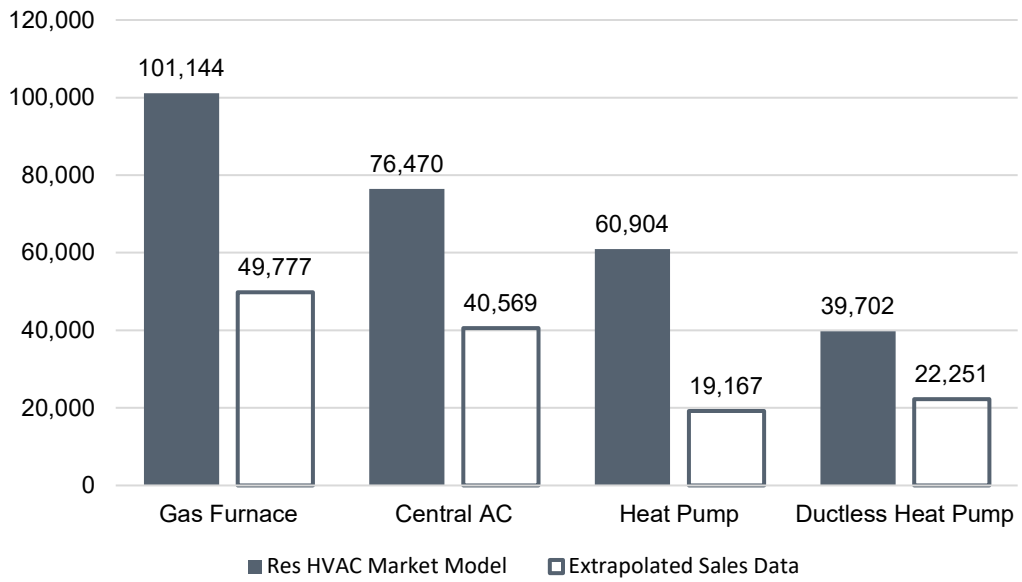
After extrapolation, team applied a scalar weight to the extrapolated sales quantities to match regional sales totals as estimated by the BPA Residential HVAC Market Model.[9,10] The figures below provide an illustration of this process. Figure 6 compares the sales volume predicted by the Residential HVAC Market Model to the extrapolated sales data in the distributor data set. Figure 7 illustrates how the extrapolated

[9] The efficiency mix of ASHP and CAC equipment are the only inputs to the Residential HVAC Market Model that derived from sales data analysis. The team does not use annual sales volume as an input; the primary driver for the model's annual sales estimate is the change in regional HVAC equipment stock between the 2011 RBSA and the 2016 RBSA. See the appendix of this document for additional detail on the model's architecture.

[10] For more information on the method and data behind the Residential HVAC Market Model, please see https://www.bpa.gov/EE/Utility/Momentum-Savings/Documents/190601_Res_HVAC_Model_Methodology_Report.pdf

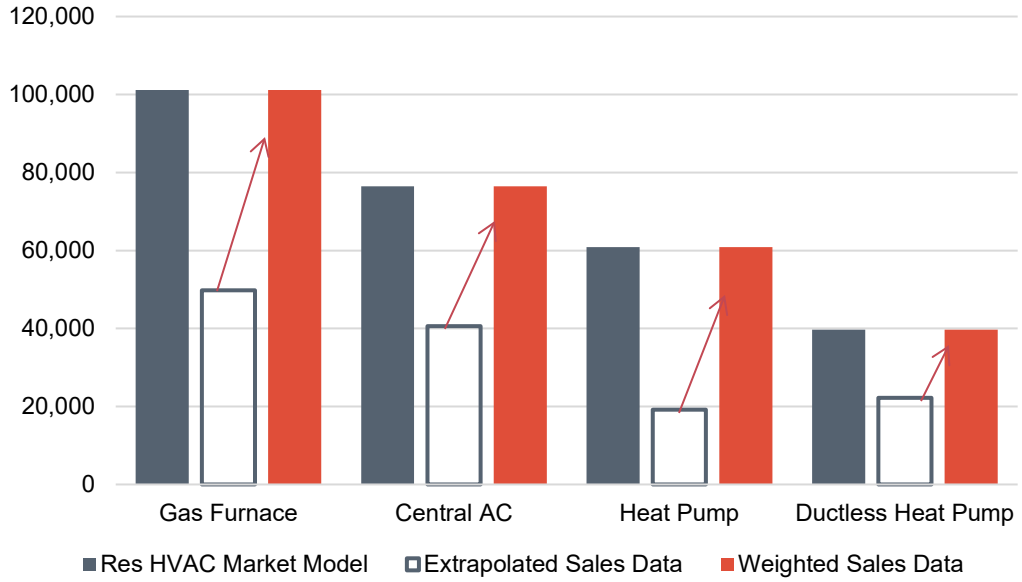
sales data are weighted up so that the efficiency mix in the distributor data is scaled to match the sales quantity for each technology expected from the Residential HVAC Market Model. In the end, the solid grey and solid red bars are identical – indicating that the final market size matches that predicted by the Market Model.

Figure 6. Unweighted Sales Data: Market Model and Extrapolated Sales Data




To preserve the efficiency mix and coverage in the extrapolated sales data and apply that mix to the entire regional market, the team scaled the extrapolated data to match the volume as predicted in the Residential HVAC Market Model (Figure 7).

Figure 7. Weighted Sales Data: Scaled Extrapolated Data to Predicted Volume



The team considered other sources for annual market sizing, but elected to use the Residential HVAC Market Model for three reasons:

- The market model is publicly available and contains annual sales estimates for a wide set of technologies,
- The model's output is already calibrated to align with the equipment stock and efficiency mix in the 2016 RBSA,
- An alternative annual market size source is confidential and lacks technology-level detail present in the Market Model and distributor data.

## Data Applicability

This dataset is useful for understanding the total reported volumes of sales by technology and year for the aggregated distributor population and for assessing year-over-year changes in sales volumes within a given technology. These data can also be used to confirm HVAC standard practice baselines or inform baseline adjustments. On its own, this data is not, however, a complete view of the HVAC market, regional submarkets, or the commercial HVAC market.

The final heating and cooling efficiency mixes that the team calculates as part of this project are an input to its Residential HVAC Market Model. The team will use the results of this analysis when BPA does its next model update, which is currently planned for 2021. With this information, the team can better estimate how the current efficiency trends are affecting regional HVAC energy consumption for the remainder of the region's Seventh Power Plan action plan period that ends in 2021. When the Residential HVAC Market Model is updated again, the model outputs will be vetted again by incorporating program and other market data.

## Next Steps

This analysis reports on sales trends for many key residential HVAC technologies, but does not seek to understand why each distributor's sales trends look the way that they do. As such, the team recommends that NEEA consider including brief distributor interviews to accompany future sales data submittals. Ideally these interviews would provide more context for understanding the sales trends observed in distributor data and identify potential events affecting sales volumes (such as mergers, acquisitions, or branch closures). Alternatively, BPA could consider updating the 2018 distributor market characterization prepared to guide the planning and initial years of the regional HVAC distributor data collection effort.

Idaho remains a persistent geographic data gap. The NEEA team is aware of this and working with their contractors and stakeholders to improve the coverage for Idaho. Although the HARDI market data report allows the team to fill that gap, the HARDI data set does not contain the same level of resolution as NEEA's sales data. BPA should provide support to any efforts to expand Idaho distributor participation.

The analyses and stakeholder discussions that have supported this project also identified several persistent gaps that should be considered for future data collection:

- **Adding retail or online sales channel investigation.** Technologies that are commonly sold through retail channels (such as room air conditioners, smart thermostats, even some types of zonal heating equipment) are not represented in the distributor sales data. If the region seeks

better understanding of the sales trends and installation volumes for these technologies, the team recommends adding retail channel data into future sales data projects. [11]

- **Augmenting this data with electrical component distributors**. Zonal and DHP equipment can also be obtained from some electrical component distributors. To understand the volume and verify this sales channel, the team recommends NEEA and the HVAC sales data stakeholders consider augmenting the existing effort with outreach to these distributors.
- **Elevating the focus on air-source heat pumps.** ASHP equipment has relatively low coverage in the current dataset and is an important component for achieving regional electrical efficiency targets. Increasing the overall focus on obtaining data on ASHPs could involve more direct distributor targeting, additional secondary research, or even focused primary research.
- **Considering the addition of heat recovery/energy recovery ventilation (HRV/ERV) equipment**. HRV/ERVs are technologies of interest and could be included in the next update planned for the Residential HVAC Market Model. Achieving good coverage for these technologies could require targeting specific distributors or secondary market research to gain a better understanding for the overall market size.

[11] NEEANEEA's Retail Product Platform provides comprehensive sales data for room air conditioners and could provide information on smart thermostats in the future.

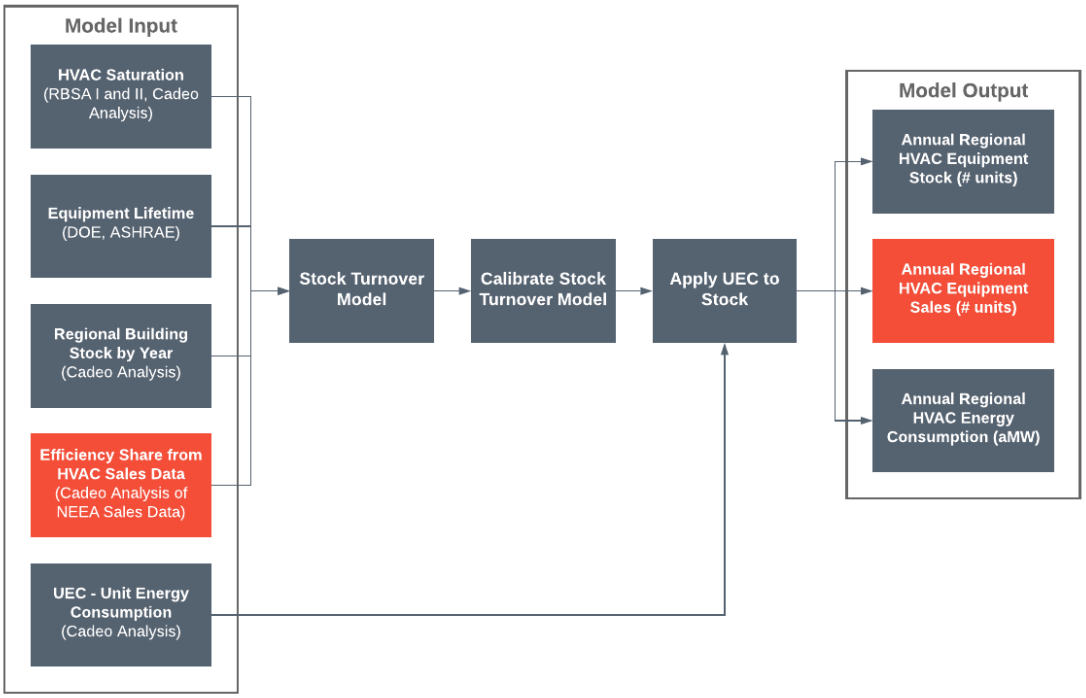
# Appendix A: Relationship to the Regional Residential HVAC Market Model

Prior to this round of sales data collection and analysis, the BPA research team developed a regional market model for residential HVAC equipment that estimates total regional electric consumption, total market savings, and Momentum Savings for the Seventh Power Plan[12] action plan period (calendar years 2016–2021).

Figure A1 shows the architecture of the Residential HVAC Market Model.[13] The team uses the efficiency shares obtained in this sales data analysis project as one of the inputs to its market model (see Table 7 and Table 8 above). The model produces three outputs:

- an estimate of regional HVAC stock (number of dwelling units, by year),
- an estimate of regional HVAC sales (number of HVAC units sold, by year), and
- an estimate of regional HVAC energy consumption (aMW, by year).

Figure A1. BPA Residential HVAC Market Model Architecture




The red boxes in Figure A1 are the two elements of the market model related to this analysis. First, the efficiency shares derived from this work are used as an input to reflect the overall efficiency mix in the region. Second, the annual regional sales estimate is used to weight the distributor data up to a regional sales estimate.

[12] Available at https://www.nwcouncil.org/reports/seventh-power-plan
[13] Full methodological details are available at https://www.bpa.gov/EE/Utility/Momentum-Savings/Documents/190601_Res_HVAC_Model_Methodology_Report.pdf

To ensure the validity of its result, the team calibrated its stock turnover model to match the equipment stock observed in the 2016 RBSA by setting the model's saturation and efficiency share inputs such that the model's equipment stock aligned with the 2016 RBSA (i.e., are within the statistical error band). In addition to the 2016 RBSA comparison, the team used other regional market data and reports, like NEEA's Northwest Ductless Heat Pump Initiative: Market Progress Evaluation #7,[14] to ensure that the model's annual sales volumes aligned with accepted regional values.

## Technologies and Efficiency Levels in the Residential HVAC Market Model

In the market model, the team segmented some technologies—Air Source Heat Pumps (ASHP) and Central Air Conditioning (CAC) systems—into efficiency tiers. Other technologies in the market model, such as ductless heat pumps and furnaces have a spectrum of efficiency ratings, but the market model has only the average energy consumption and the total equipment stock across all tiers.[15]

### Table A1. Residential HVAC Market Model Technologies

| End Use | Technology | Efficiency Tiers in Market Model |
|---|---|---|
| Heating | Air Source Heat Pump | Yes |
| | Ductless Heat Pump | No |
| | Forced Air Furnace: Electric | No |
| | Electric Zonal | No |
| | Ground-Source Heat Pump | No |
| | Forced Air Furnace: Gas/Other Fuel | No |
| | Other | No |
| Cooling | Central Air Conditioning | Yes |
| | Air Source Heat Pump | Yes |
| | Room Air Conditioning | No |
| | Ductless Heat Pump | No |
| | Packaged Terminal Air Conditioner | No |
| | Ground-Source Heat Pump | No |
| | Other | No |

The team has divided the ASHP heating efficiency spectrum into six tiers (Table A2), as determined by the heating seasonal performance factor (HSPF) of the system. Broadly, these tiers are driven by the regional equipment stock as measured by the 2016 Regional Building Stock Assessment (RBSA) and align with *past* federal standards. The sales data presented in this document reflects *current* federal standards, and as such, is heavily weighted to ASHP units with an HSPF of 8.2 or higher.

[14] Available at https://neea.org/img/documents/DHP_MPER_7_Report_FINAL_CC.pdf

[15] Broadly, this is due to low regional equipment saturation (<5% of homes), uncertainty in energy consumption, or relatively small differences in energy consumption between efficiency tiers.

## Table A2. Residential HVAC Market Model ASHP Heating Efficiency Tiers

| Efficiency Tier | Low HSPF Value | High HSPF Value |
|---|---|---|
| HSPF 7.2* | Low | 7.49 |
| HSPF 7.7* | 7.50 | 7.99 |
| HSPF 8.2 | 8.00 | 8.39 |
| HSPF 8.5 | 8.40 | 8.79 |
| HSPF 9.0 | 8.80 | 9.99 |
| HSPF 12.0 | 10.00 | High |

* Denotes efficiency below current federal standard

The also divided cooling efficiency for both CAC and ASHP, into four tiers, as determined by the seasonal energy efficiency rating (SEER) of the system. Similar to the heating system efficiency tiers described above, the cooling tiers are driven by the equipment stock and *past* federal efficiency standards. The sales data presented in this document reflects *current* federal standards, and as such, does not include any CAC or ASHP systems with a SEER less than 13.0.

## Table A3. Residential HVAC Market Model CAC and ASHP Cooling Efficiency Tiers

| Efficiency Tier | Low SEER Value | High SEER Value |
|---|---|---|
| SEER 10* | Low | 11.99 |
| SEER 13 | 12.00 | 13.99 |
| SEER 14.5 | 14.00 | 15.99 |
| SEER 18 | 16.00 | High |

* Denotes efficiency below current federal standard