BONNEVILLE POWER ADMINISTRATION

Executive Summary

Northwest HVAC Sales & Trends 2016 – 2020

April 2022

Bonneville Power Administration

PREPARED BY:
Cadeo Group

Report Overview

This report describes the method Cadeo (the research team) used for analyzing full-category Northwest HVAC supplier sales data for 2016-2020. 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. The sales data represent submittals from 11 suppliers and are the result of a data collection project conducted by Northwest Energy Efficiency Alliance (NEEA) and their contractors: CLEAResult and Energy Solutions.

BPA and NEEA support this sales data collection effort with the goal of obtaining robust information on the regional HVAC market by leveraging NEEA and CLEAResult's existing relationships with regional HVAC suppliers. This effort has been ongoing for four years. NEEA augments the data set by contracting with Energy Solutions to match equipment model numbers to equipment efficiency attributes from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) certification database.

The resulting analyses provide regional efficiency mix information for major residential heating and cooling equipment, help the region understand year-over-year trends in sales volume, and inform standard practice baselines. BPA uses the analysis results to inform market modeling efforts, specifically to estimate total market sales for the residential HVAC markets and efficiency levels for residential HVAC technologies installed in Northwest homes. The dataset also provides limited regional insights into commercial HVAC sales.

This report marks the culmination of HVAC sales data collection supporting updates to BPA's residential HVAC market model for the Seventh Power Plan Action Plan Period (2016-2021). This also marks the first year of tracking and reporting variable capacity heat pump sales in addition to examining emerging ductless heat pump configurations.

Data collection will be ongoing, supporting analyses related to the 2021 Power Plan Action Plan Period (2022 – 2027). Starting in 2022, NEEA is partnering with D+R International on recruitment and sales data collection of 2021 supplier sales. Based on D+R's experience implementing the HARDI Unitary Report, this partnership will continue to improve data collection of residential HVAC sales and support a larger focus on the collection of commercial sales data.

Data Sources

- Full category HVAC sales data covering five years of sales from a subset of Northwest HVAC suppliers, collected by NEEA and its contractors to support regional market analyses.
- Regional HVAC sales data from the Heating, Air Conditioning and Refrigeration Distributors International (HARDI), accessed through NEEA's subscription.
- Interviews conducted in 2021 with 27 Northwest HVAC market participants and observers.

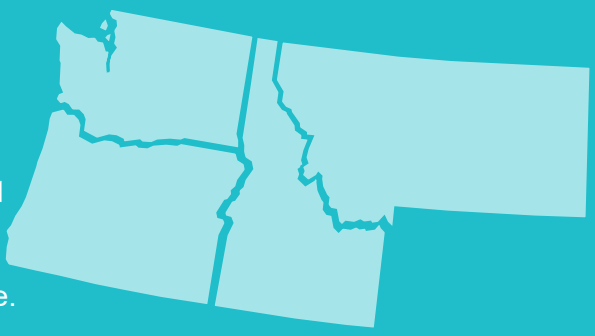
Market Coverage

Sector Coverage

The regional HVAC supplier dataset is a mix of regional and national suppliers, and includes the general supply house sales that supply the residential sector. The majority of known residential suppliers provided sales data and those reported sales encompass approximately 25% to 45% of residential sales for each of the four main residential technologies: gas furnaces, air source heat pumps (including variable-capacity heat pumps), ductless heat pumps and central air conditioners.

In contrast, commercial-sized equipment accounts for 2% of reported sales and is likely a small portion of the overall commercial HVAC market. The commercial sector has more variation in HVAC equipment types and a greater presence of manufacturer-direct sales compared to the residential sector.

Geographic Coverage



For the residential market, there is a persistent under-representation of Idaho and Montana in the reported sales, which is discussed in the appended memo. Information is provided for all states through the 11 reporting suppliers, and coverage of Idaho and Montana has imvproved over time from less than 10% of reported 2016 sales to nearly 20% of 2020 reported sales. Additionally, there are at least four reporting suppliers for each of the four main residential technologies in each state.

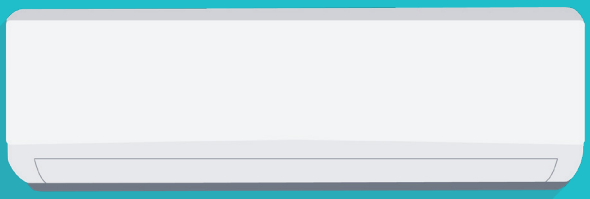
Manufacturer Coverage

While a comprehensive assessment would require market sales for all regional suppliers, a qualitative review of reported sales by manufacturer for each of the major residential HVAC technologies against internet lists of top-10 manufacturers indicated most major manufacturers of residential equipment are represented in the dataset.

Technology Coverage

For the four key technologies, ductless heat pumps have the best coverage with nearly all suppliers reporting sales for that technology and the highest number of reporting suppliers for each state. Reported ductless heat pump sales represent approximately 45% of the overall Northwest market, likely the result of NEEA's longstanding engagement with ductless heat pump suppliers.

Gas furnaces are similarly well-represented at approximately 37% of the overall Northwest market. Reported sales for air-source heat pumps and central air conditioners represent between 25% and 30%, respectively, of the overall Northwest market.



Market Channel Coverage

Big-box retail and online sales are not included in the dataset and could be a gap, particularly for ductless heat pumps. Market actors interviewed in 2021 indicated installers and homeowners could increasingly be turning to retail and online sales channels over traditional HVAC suppliers. In addition, some interviewees estimated online ductless heat pump sales as "low" while others estimated sales at between 10% and 20% of the overall sales.

Reported Sales Data

The sales data presented in **Table 1** is based on supplier-reported sales data, extrapolated to fill temporal and geographic gaps. For a more in-depth discussion of analysis and extrapolation processes, please see the HVAC Sales Data Analysis Memo, appended to this document. The data presented in this table can be used to review the total volumes of reported sales by technology and by year as well as to assess year-over-year change in reported sales volumes. This table is not, however, an indication of total market sales. BPA's Residential HVAC Market Model produces technology-specific product flow estimates for the main residential technologies using a stock turnover model and various data sources. Results will be published later in 2022 on https://www.bpa.gov/energy-and-services/efficiency/market-research-and-momentum-savings/hvac-market-research.

TABLE 1 - Reported Sales Volume by Technology

Technology	2016	2017	2018	2019	2020
Central Air Conditioning - Condenser	31,188	38,634	47,889	55,587	66,340
Gas Furnace	51,289	57,499	62,663	63,075	72,588
Heat Pump - Air Source, Single & Two-Stage	18,785	21,616	21,988	23,843	27,750
Heat Pump - Ductless	18,271	22,433	25,395	25,399	29,405
Heat Pump - Air Source, Variable Capacity	-	3,234	3,325	3,469	4,760
Heat Pump - Air Source, Single Packaged	548	655	796	726	759
Electric Furnace	989	1,376	1,581	1,614	1,549
Variable Speed Mini-Split & Multi-Split Air Conditioning	1,257	1,261	952	1,101	1,264
Gas Packaged Unit	1,982	2,374	2,904	2,756	3,193
Heat Pump - Packaged Terminal (PTHP)	Excluded	621	1,260	1,289	Excluded
Central Air Conditioning - Packaged Terminal (PTAC)	296	268	266	Excluded	Excluded
Variable Refrigerant Flow	Excluded	Excluded	170	137	Excluded
Unitary Large Equipment	889	1,070	1,996	2,072	2,421

COVID Impact

No clear pattern related to COVID emerged from the sales data for the four main residential technologies. HVAC sales continued to increase as they have in the years leading up to the pandemic. The 2020 increases were more significant than 2019 increases (approximately 16% versus 6%) but in line with earlier years (e.g., 2017: 20%; 2018: 13%) making it difficult to attribute the increases to COVID over other possible market influences.

Efficiency continues to improve for the main residential HVAC technologies. These improvements are discussed in more detail in the next sections.

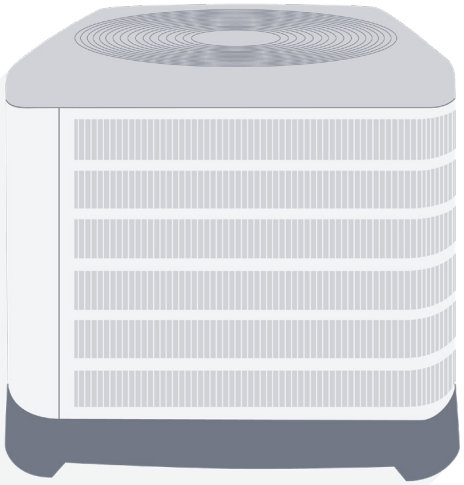
Residential Insights

In this section we will review insights specific to five technologies. The insights focus first on air source heat pumps which are an important technology for energy efficiency efforts as they can provide high efficiency electric heating along with centralized cooling. We start with single- and two-stage air-source heat pumps which we generally refer to in this report as ASHP. Next, we discuss air source heat pumps with a variable compressor, which are referred to as variable capacity heat pumps or VCHP. The discussion then moves to ductless heat pumps (DHP) including emerging configuration trends. Finally, we discuss insights regarding central air conditioners and gas furnaces.

Single and Two-Stage Air Source Heat Pump

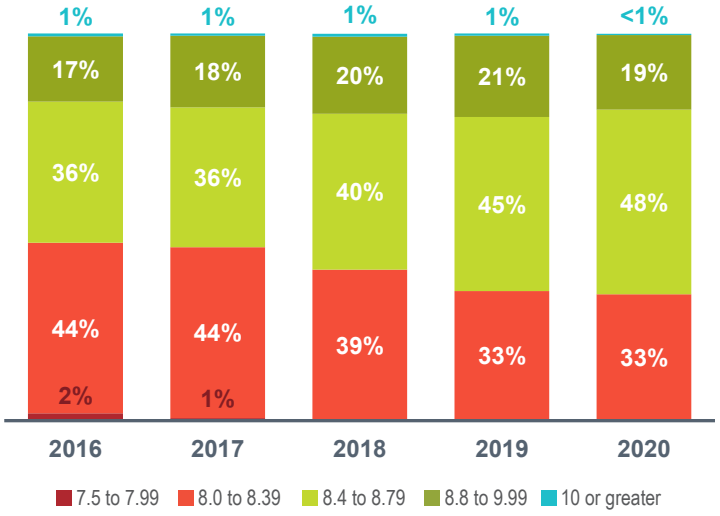
Reported sales of ASHPs increased in 2019 (nearly 10%) and 2020 (15%).

The efficiency of single- and two-stage ASHP sales have slowly and steadily increased in efficiency. The largest heating efficiency gains have been from the lowest tiers to HSPF 8.4 to 8.79. Nearly 12% of sales in 2020 were SEER 16 or higher cooling efficiency.



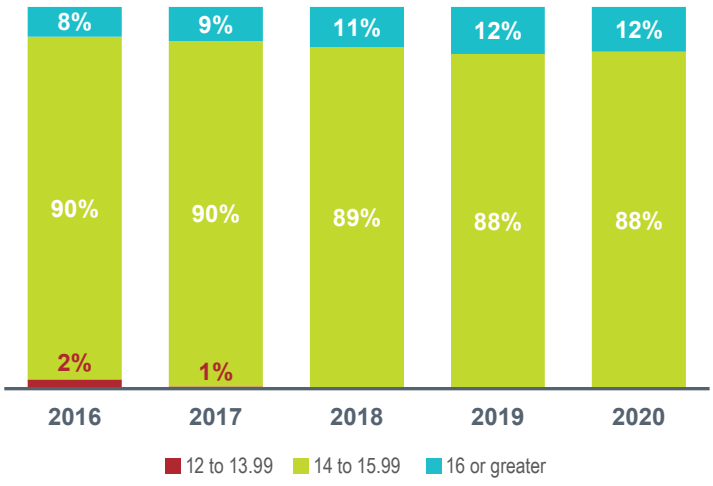
The efficiency mix is from analysis of supplier sales data. Single- and two-stage ASHP continue to show a continued trend toward higher efficiency.

Heating Efficiency Mix (HSPF)



Please note graph totals may not add to 100% due to rounding.

Cooling Efficiency Mix (SEER)

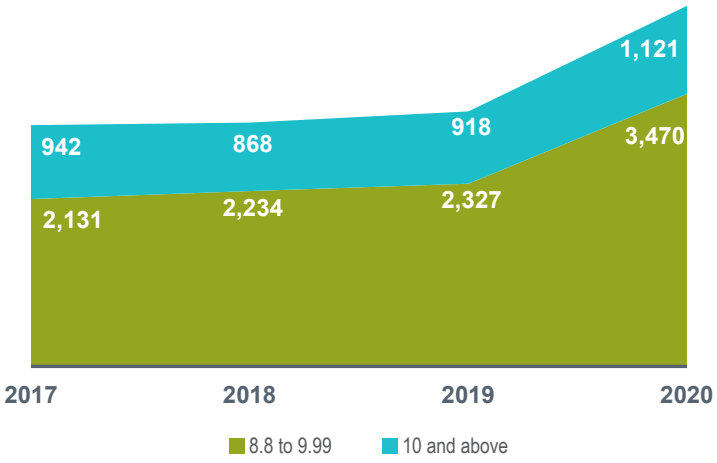


Variable Capacity Heat Pump

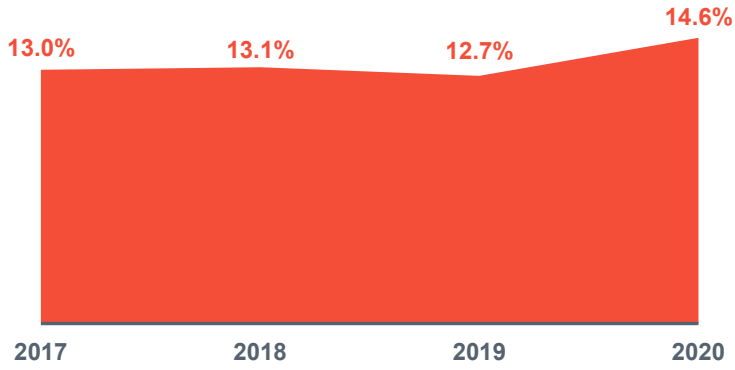
Variable Capacity Heat Pumps (VCHPs, but also referred to as variable speed heat pumps and inverter-driven heat pumps) are air source heat pumps with a variable speed compressor. The inverter-driven compressor allows the heat pump to vary its capacity, typically making them more efficient than single- and two-stage ASHPs. Nearly all regional sales of VCHP are SEER 16 or above cooling efficiency. HSPF efficiency is discussed in more detail below.

VCHP sales were low volume in 2020, but they are making up an increasing share of heat pump sales. Respondents to market actor interviews conducted in 2021 unanimously confirmed that sales of VCHPs had increased over the past few years and were expected to continue increasing. This technology now represents nearly 15% of ducted heat pump sales in the region.

VCHP Sales Volume



VCHP Share of Ducted ASHP Sales

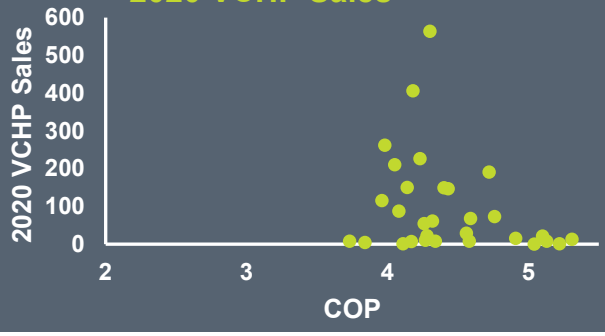


Identifying VCHP in the Sales Data

Previous analyses of this data to support BPA's market model used the heating-based HSPF metric as an indicator of inverter-driven heat pumps: ASHPs with HSPF higher than 10 were assumed to be VCHP. However, this study found that HSPF is not a good indicator of variable capacity: this year's analysis of the sales data reveals the majority of 2020 VCHP sales were below HSPF 10.

For this round, we identified VCHP sales by referencing model numbers in reference lists from BPA, the Energy Trust of Oregon, and the Northeast Energy Efficiency Partnerships (NEEP). The team identified additional units through text searches of ASHP model descriptions (e.g., VSP or VAR) followed by verifying model information. The reference lists were also used to analyze coefficient of performance (COP) - an important non-HSPF performance metric, which showed that 2020 VCHP sales had an average COP (at min. capacity 47F) of 4.28. However, as the scatter plot below shows, there is variation in how efficient VCHPs are during mild climate hours.

COP at Min. Capacity 47°F - 2020 VCHP Sales

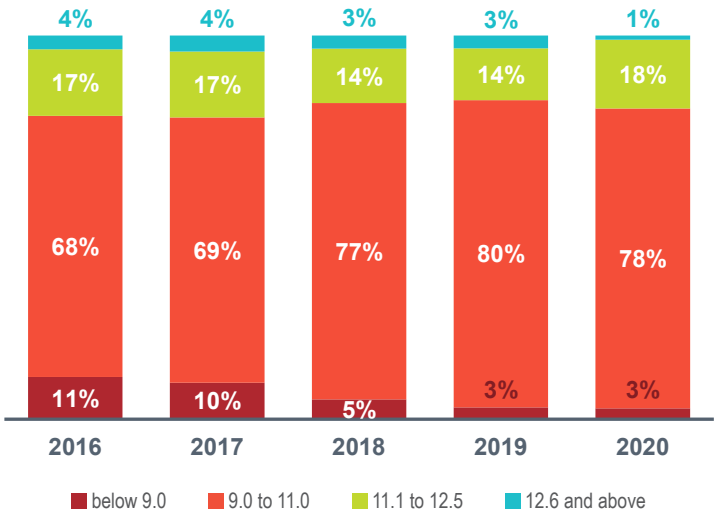


Ductless Heat Pump

Ductless Heat Pumps (DHPs), or "minisplits," use the same variable speed compressor technology as VCHPs. DHPs, however, do not distribute air through ductwork. Each indoor unit ("head") contains a variable speed fan that blows air directly into the conditioned room. They are broken out separately because they are often used in different, typically smaller, applications. DHPs can be sold with one or more indoor units. DHPs provide heating and cooling, but use refrigerant piping to transfer heat instead of relying on duct work. DHP sales increased by approximately 15% in 2020 (the average year-over-year increase between 2016 and 2020 is 13%).

Market actors interviewed in 2021 mentioned an increasing interest in mixing and matching equipment to meet specific home needs. Below are some typical system configurations that are emerging in addition to the traditional DHP with indoor heads.

Efficiency Mix (HSPF)



Code minimum sales are decreasing (both in volume and percent of total sales), but we are not seeing a corresponding increase at the highest efficiency tiers. Nearly 80% of sales are in the HSPF 9.0-11.0 bin.

Ducted Minisplits

DHPs that use indoor ducts are also referred to as concealed ducted, short duct, ducted ductless, or medium static units. The indoor unit is an indoor coil with short ducts. This might be found in an attic space where one indoor coil could supply two to four upstairs bedrooms, an alternative to placing an indoor unit in each bedroom.

Hybrid DHP with Fancoil

These are also referred to as high static units. They comprise an outdoor DHP unit paired with an indoor coil on an existing indoor furnace (gas, electric, or oil). These allow for backup heat if the DHP cannot meet demand and are typically sold with a 24V interface that controls when to use the DHP coil versus the existing furnace.

Multizone DHP with Fancoil

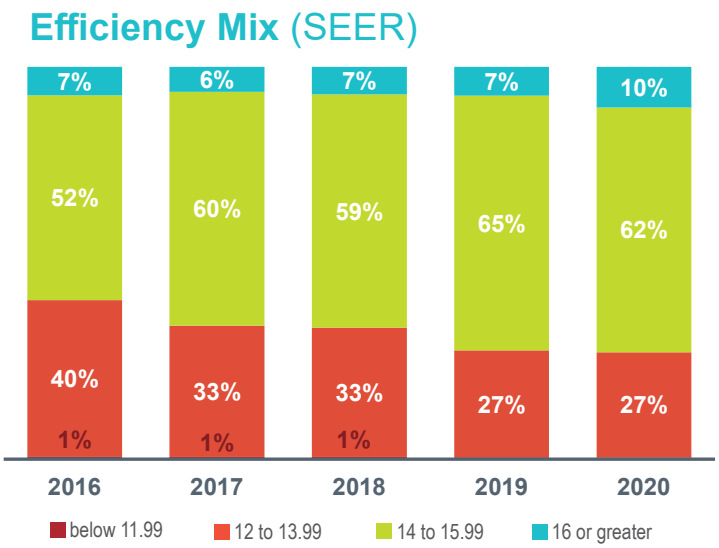
These system configurations are similar to the hybrid DHP, but allow for multiple zones with an outdoor DHP that provide conditioning to previously unconditioned non-ducted areas. These include one or more indoor DHP units, which could be high wall heads, low floor heads, or even "ducted minisplits."

Identifying DHP Installation Trends in the Sales Data

The sales data include DHP outdoor and indoor units, however, outdoor and indoor unit sales are not linked to one another. Most of the system configurations discussed above are unidentifiable in the sales data. As an indicator of ducted minisplit systems, sales for short-duct units were identified through model number searches. There are insufficient reporting suppliers and overall volume for a robust analysis, however, the identified units showed a rapid increase in sales between 2018 and 2019. Tracking 24V control interfaces could be a more accurate way to understand ducted minisplit system sales. These controllers are included in the sales data, but lack the sufficient number of reporting suppliers and overall volume to support reporting or analysis. Future rounds of analysis will continue efforts to identify sales of these system configurations.

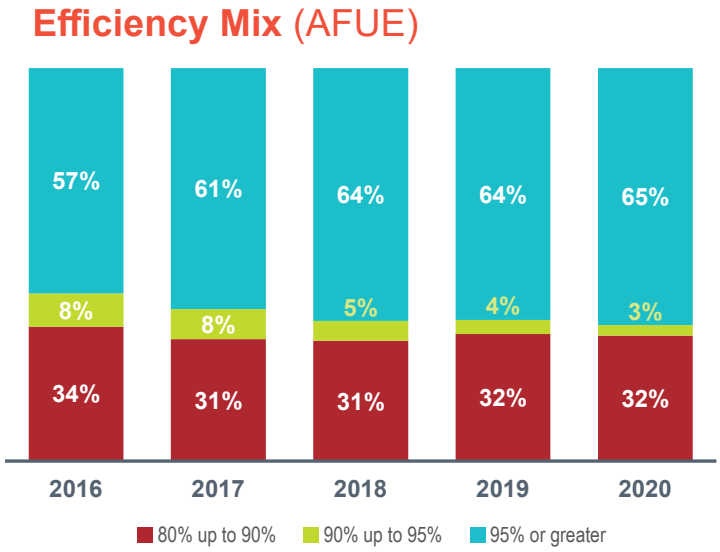
Central Air Conditioning

CAC systems provide cooled air to an entire building or home using the vapor compression refrigeration cycle to transfer heat energy from indoor spaces. Estimated sales are increasing at a rate between 15% and 20% for 2019 and 2020, respectively. Efficiency mix trends for CAC show an encouraging shift toward higher efficiency products.



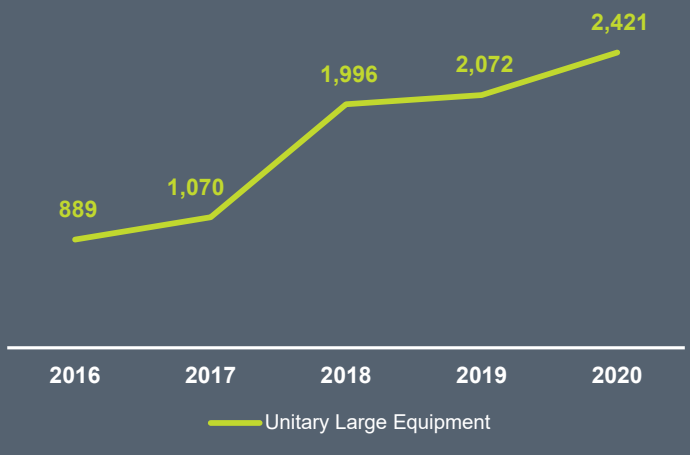
Gas Furnace

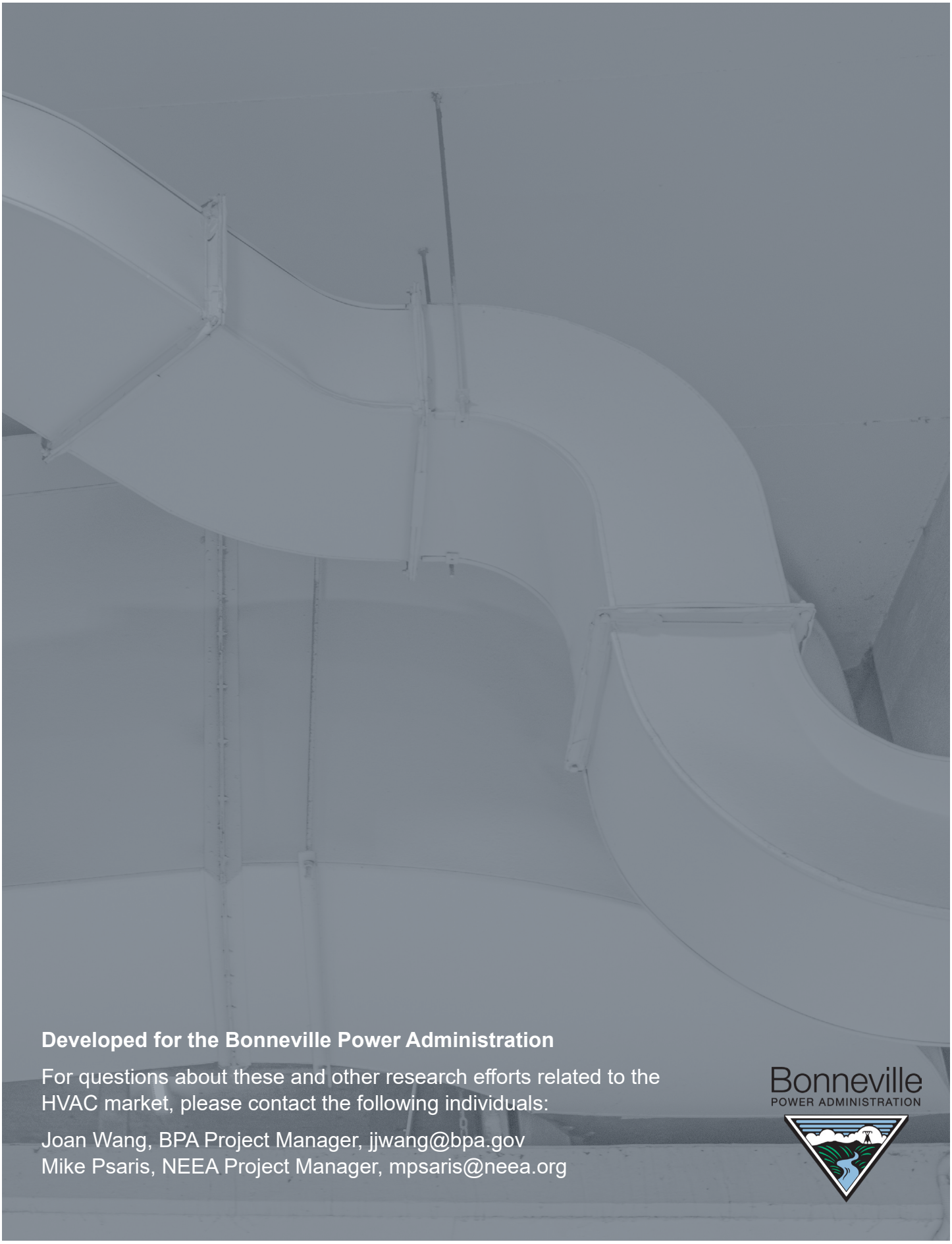
Gas furnace sales continue to increase (15% between 2019 and 2020). A bifurcated market is visible with most sales above 95% AFUE and nearly a third consistently below 90% AFUE. Anecdotally, suppliers report the lower efficiency units are installed as back up heat for heat pump installations.



Commercial Sector

While the dataset is not representative of the commercial sector, it suggests continued increase in sales of refrigerant-based packaged HVAC systems over 65,000 Btu/hr (unitary large equipment, which does not include VRF systems).





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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Memorandum

To: Joan Wang, Bonneville Power Administration

From: Elizabeth Daykin and Isaac Schultz, Cadeo

Date: April 27, 2022

Subject: 2016–2020 HVAC Sales Data Analysis

Introduction and Context

This memorandum describes analysis conducted by the Bonneville Power Administration (BPA) and Cadeo (the research team) on full-category Northwest HVAC supplier sales data for 2016–2020. These supplier sales data are the result of an annual data collection project conducted by the Northwest Energy Efficiency Alliance (NEEA) and their contractors: CLEAResult and Energy Solutions. The memo includes the team's approach to developing estimates of annual efficiency mix and technology mix for four key residential heating and cooling technologies sold in the Northwest region: central air conditioners, air-source heat pumps, gas furnaces, and ductless heat pumps.

BPA and NEEA initiated this sales data collection effort with the goal of obtaining regional full-category sales data for HVAC equipment by leveraging NEEA and CLEAResult's existing relationships with regional HVAC suppliers. This effort has been ongoing for four years. In early 2019 BPA completed an analysis of the first round of data (covering sales for 2016 and 2017) and used the results to characterize the regional residential HVAC market and to estimate total market energy consumption and Momentum Savings from the adoption of efficient HVAC equipment.

In the subsequent rounds of data collection, NEEA continued to leverage the relationships that they and CLEAResult had with regional HVAC suppliers 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 database.[1]

This document presents analysis results of the fourth round of data collection, covering sales occurring during the years of 2016 and 2020. Analysis results will be used in BPA's Residential HVAC Market Model to estimate final Momentum Savings for the Seventh Power Plan Action Plan Period (2016-2021). The analysis also builds on prior years by identifying variable capacity heat pumps (a subset of air source heat pumps), assessing emerging ductless heat pump configurations, and leveraging updated product flow[2] estimates.

This memo begins with an overview of the analysis methodology followed by assessments of data quality and data gaps. The team then discusses the approaches used to address temporal and geographic gaps, final adjustments, and product flow estimates. Finally, the memo describes additional gaps and sources

[1] Details of NEEA's data collection or model matching are not part of this analysis and memo.

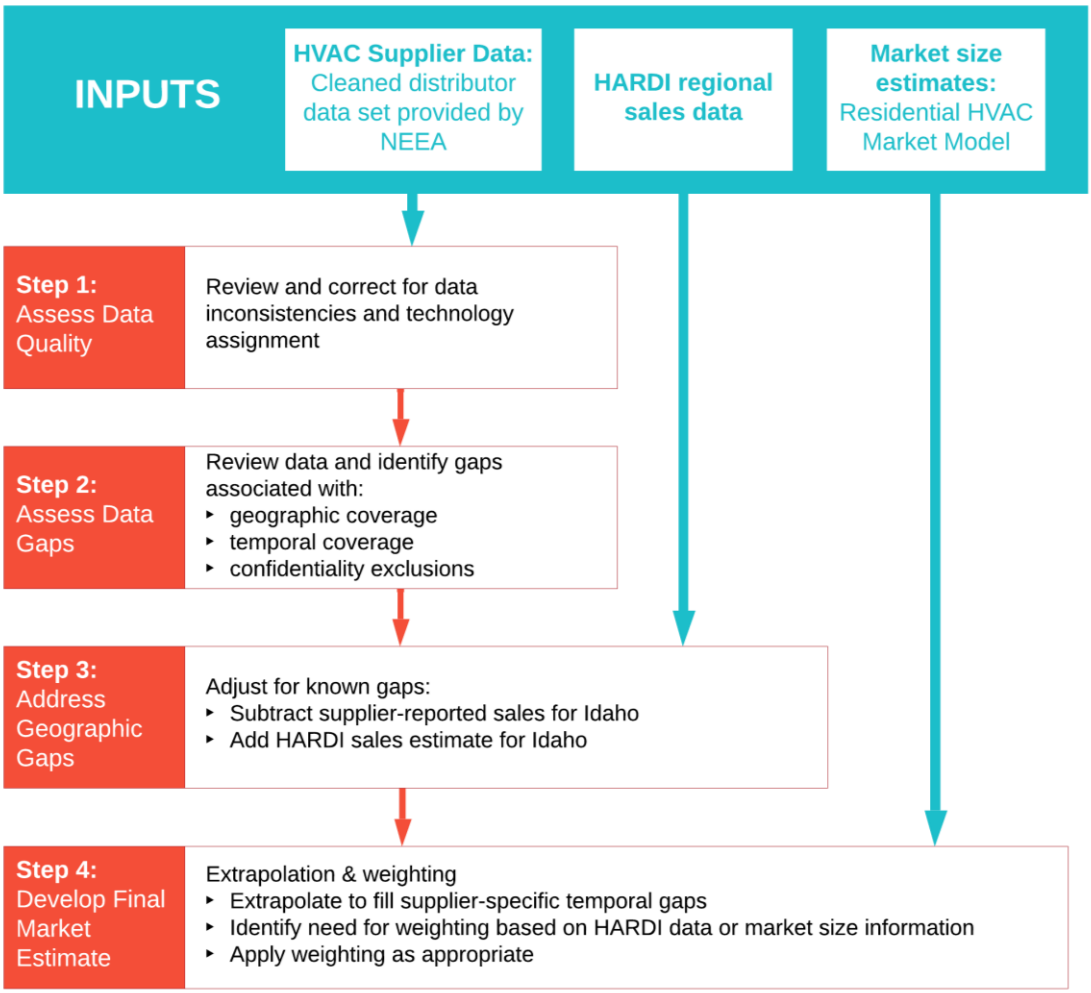
[2] Product flow is defined as the total number of units entering the stock via sales each year. BPA's Residential HVAC Market Model produces technology-specific product flow estimates using a stock turnover model and various data sources. Results will be published later in 2022 on https://www.bpa.gov/energy-and-services/efficiency/market-research-and-momentum-savings/hvac-market-research

of uncertainty followed by Appendix A, which outlines the relationship between this effort and BPA's Residential HVAC Market Model. This memo is accompanied by a spreadsheet that contains aggregated and anonymized results of the sales data analysis.

Overall Methodology

This section describes the methodological steps that the team used to analyze NEEA's sales data. The analytical approach and methodology for this round largely follows the prior rounds of analysis completed for BPA. 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:

1. The HVAC supplier sales data collected and processed by NEEA's contractors and provided to BPA by NEEA.
2. Regional HVAC sales data from the Heating, Air Conditioning and Refrigeration Suppliers International (HARDI), accessed through NEEA's subscription.[3] 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 supplier data.
3. Product flow estimates developed by BPA's existing Residential HVAC Market Model, which was published in 2019[4] and is undergoing updates in 2022. Background on the development of those estimates will be available with published Residential HVAC Market Model updates midyear of 2022.

The latter two inputs are used to provide context and enable adjustments to address known gaps in the supplier data and calibrate the efficiency mix to an existing estimate of product flow. The application of these data is detailed in the discussion below.

The resulting dataset provides total reported volumes of sales by technology and year from participating suppliers (in Table 5) which is extrapolated (Table 7). These data are useful for assessing year-over-year changes in sales volumes within a given technology. On its own, however, this data is not a complete view of the overall residential HVAC market, subregions, or the commercial HVAC market. Data gaps and uncertainties are discussed further in the remainder of this memo.

Step 1: Assess Supplier Data Quality

In 2021, ten suppliers submitted datasets to NEEA including one new participant, which expanded the data available for analysis to eleven total suppliers.

It is encouraging to have additional supplier data to work with and the newest supplier represents approximately 9% of reported sales for the four key residential technologies included in this analysis.[5]

In its raw form, these data include model numbers, quantity sold, and the calendar month in which the equipment was sold for each supplier. NEEA's contractor Energy Solutions supplemented this raw data with efficiency and capacity attributes by matching the reported model numbers through publicly available sources (including the AHRI Directory of Certified Product Performance).[6]

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

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 technology mix and efficiency mix of the overall HVAC market (nor are they used as

[3] In this document the term HARDI refers to a data product that D+R International has developed in partnership with HARDI. These data contain HVAC sales data for the Northwest region.
[4] https://www.bpa.gov/EE/Utility/Momentum-Savings/Documents/190601_Res_HVAC_Model_Methodology_Report.pdf
[5] Central air conditioners, air source heat pumps, gas furnaces, and ductless heat pumps.
[6] AHRI maintains a directory of equipment performance data. It is available online at https://www.ahridirectory.org.

inputs to the BPA market model). For this analysis, the research team focused on the attributes listed in Table 1.

Table 1: Relevant HVAC Database Description Fields

Field Name	Description
Technology	The HVAC technology type such as variable refrigerant flow (VRF) systems and packaged terminal heat pumps (PTHP)
Fuel Type	The type of fuel used for heating, water heating, or some packaged units (electric, natural gas, propane, oil)*
Heating Capacity, MBH	MBH is a measure of the size of a heating system, representing the maximum amount of energy the system can provide, measured in millions of British thermal units (MMBtus). One MBH is equivalent to 1000 British thermal units per hour, or kBtu/hr.
Cooling Capacity, MBH	MBH (Tons) is a measure of size of the cooling system, representing the energy the system can provide, measured in millions of British thermal units (MMBtus) or tons. One ton equals 12 MBH.
SEER	The Seasonal Energy Efficiency Ratio (SEER), an energy efficiency rating for air conditioners and other cooling equipment.
Median SEER	Median SEER for the listed configurations of 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**

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

**Some HVAC technologies are composed of a combination of indoor and outdoor units. In these instances, the AHRI product directory 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 supplier-specific data is protected. The team reviewed the NEEA-provided supplier dataset to identify the need for any additional data cleaning. This step includes checking for incorrect value types, consistency of technology assignments, relational inconsistencies, and formatting issues.

Consistent with prior years, the team found the data to be well organized and complete. The adjustments required to use the data for BPA's analyses were minor and reflected the specific categorization required to align with BPA's market model categorizations, including a sector categorization 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 identified 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 suppliers with gaps in their submittals associated with a specific time period. Filling in supplier-specific temporal gaps is important given the limited number of suppliers in the 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. (The specific approach to filling temporal gaps is discussed in more depth in *Step 4: Final Market Estimates*.)

NEEA asked suppliers to submit five years of sales (2016, 2017, 2018, 2019, and 2020); however, some of the 11 participating suppliers did not provide complete data for the full time period. Table 2 displays the number of supplier submissions by year.

Table 2: Supplier Data Submissions

Submission Types	2016	2017	2018	2019	2020
Complete sales data	6	8	10	9	8
Partial sales data	2	1	0	1	1

Geographic Gaps

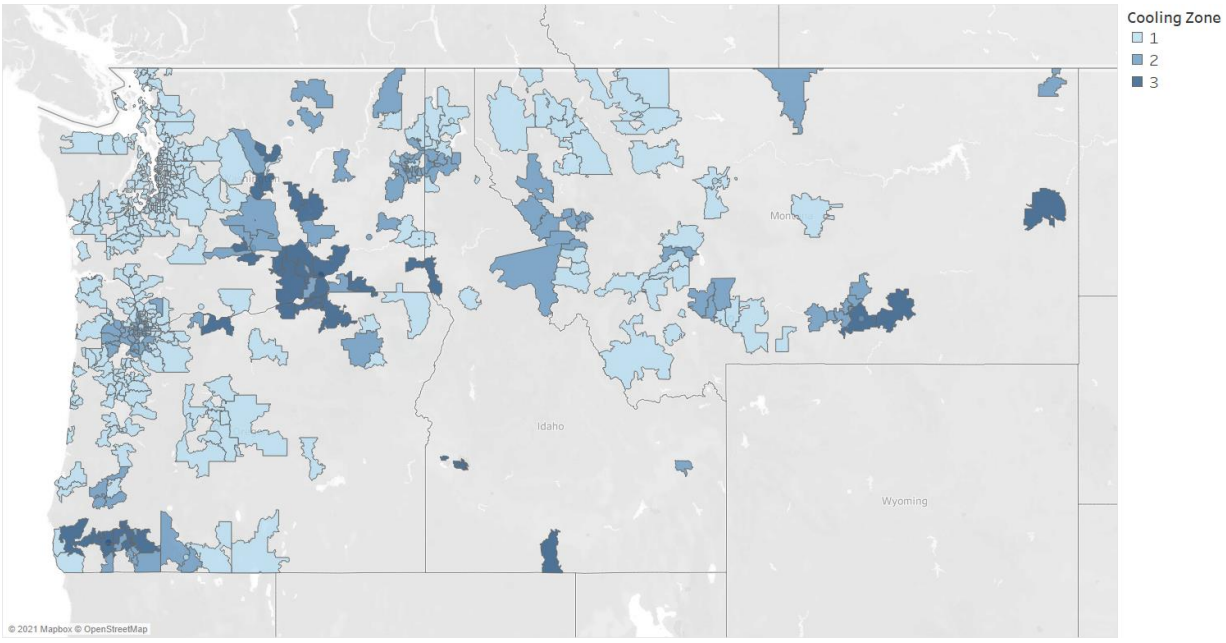
Geographic gaps refer to any states substantially underrepresented in the existing dataset. Because the objective is to derive regional inferences from these data, the team must build a dataset that is as representative as possible of the entire region. The team defines "region" consistent with the definition used by the Northwest Power and Conservation Council: Washington, Oregon, Idaho, and western Montana. However, the team assumes that the sales mix in western Montana is the same as the sales mix for the entire state, and includes sales occurring in eastern Montana in the calculations that establish the efficiency mix for Montana (shown in *Step 4: Final Market Estimates* below). This efficiency mix is only applied to the in-region portion of the state's building stock in the Residential HVAC Market Model.

To identify geographic gaps in the 2020 data, the team mapped the spatial distribution of the 2020 reported cooling equipment in the dataset (Figure 2) by ZIP code. The team used a two-step approach to determine the sales location for the HVAC units sold and reported in this data collection effort:

- Use ship-to ZIP code if available (65% of sales)
- If ship-to ZIP code is not available, use ship-from ZIP code (adding this step increased the known geographic assignment to 100% of reported sales)

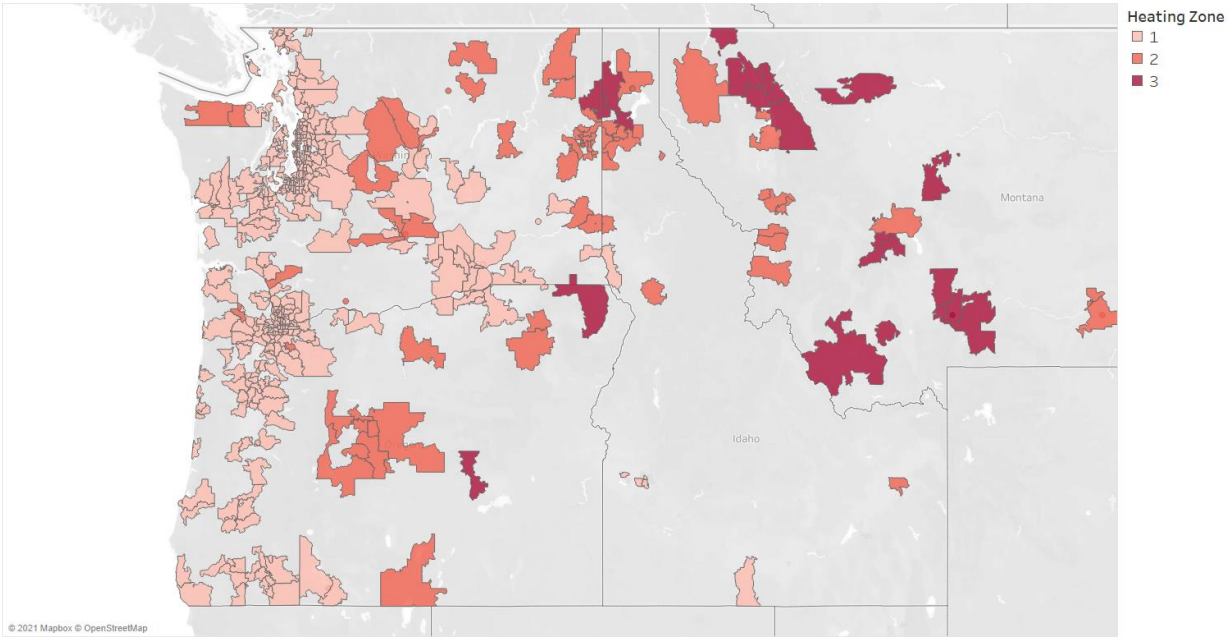
ZIP codes where cooling equipment was sold by one or more suppliers are shaded, with lighter blue shading indicating cooling zone 1 and the darkest shading indicating cooling zone 3. ZIP codes not represented in the sales data are not shaded. Perhaps unsurprisingly, the shading largely aligns with population centers. This map shows that southern Idaho, where Boise is located, is very sparsely shaded – indicating a geographic gap for cooling equipment.

Figure 2: Reported 2020 Sales of Cooling Equipment, by Climate Zone



Similarly, Figure 3 displays the distribution of 2020 reported heating equipment by ZIP code. Each ZIP code with heating equipment sold by one or more suppliers 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 in southern Idaho.

Figure 3: Reported 2019 Sales of Heating Equipment, by Climate Zone



These maps illustrate the limited coverage of reported sales in the southern Idaho region, consistent with geographic gaps the team identified in the prior rounds of analysis.

Subsequent adjustments to improve geographic coverage are discussed in *Step 3: Address Geographic Gaps* below.

Technology Gaps

Identifying technology gaps requires 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 supplier confidentiality issues by identifying and removing any technologies with fewer than three suppliers and any technologies with fewer than 100 units in annual sales across all suppliers. While this process preserves anonymity of participating suppliers, it can create gaps in coverage for some technologies.

Table 3 and Table 4 present all the technologies represented in the data. Technologies that do not meet the three supplier and 100 units sold criteria are noted. These are removed from further analysis to preserve supplier confidentiality.

Note that air-source heat pumps, which are one of the four key residential technologies, are represented by two subcategories in Table 3: Heat Pump – Air Source, Single- and Two-Stage which encompasses single-stage and two-stage air source heat pumps, and Heat Pump - Air Source, Variable Capacity which encompasses variable-capacity (or variable speed) heat pumps.

Table 3: Residential HVAC Technologies in Supplier Dataset

Technology	Included in Analysis	Excluded: Too Few Units	Excluded: Not Enough Supplier Submissions
Central Air Conditioning – Condenser	Yes		
Gas Furnace	Yes		
Heat Pump – Air Source, Single- and Two-Stage	Yes		
Heat Pump – Ductless	Yes		
Heat Pump – Air Source, Variable Capacity	Yes	For 2016	
Heat Pump – Single Packaged	Yes		
Electric Furnace	Yes		
Variable Speed Mini-Split and Multi-Split Air Conditioning	Yes		
Gas Packaged Unit	Yes		
Boilers	No		Yes
Oil Furnace	No		Yes
Central Air Conditioning – Single Packaged	No	For 2016 and 2017	Yes
Direct Heating Equipment	No		Yes
Water heaters	No		Yes

Table 4: Commercial HVAC Technologies in Supplier Dataset

Technology	Included in Analysis	Excluded: Too Few Units	Excluded: Not Enough Supplier Submissions
Central Air Conditioning - Packaged Terminal (PTAC)	Yes		For 2019 and 2020
Heat Pump – Air Source, Variable Capacity	Yes	For 2016 and 2020	Yes
Heat Pump – Packaged Terminal (PTHP)	Yes	For 2016 and 2020	Yes
Variable Refrigerant Flow	Yes	For 2016, 2017, and 2020	
Unitary Large Equipment	Yes		
Heat Pump – Air Source, Single- and Two-Stage	No	Yes	Yes
Central Air Conditioning - Single Packaged	No	Yes	Yes

Technology	Included in Analysis	Excluded: Too Few Units	Excluded: Not Enough Supplier Submissions
Heat Pump – Single Packaged	No	Yes	Yes
Single Packaged Vertical AC & HP	No	Yes	Yes
Heat Pump – Ductless	No	Yes	Yes
Boilers	No	Yes	Yes
Gas Furnace	No	Yes	Yes
Water Heaters	No		Yes
Heat Pump – Water Source	No		Yes
Water heaters	No		Yes

Table 5 presents the annual reported sales volume for the technologies that pass the reporting criteria. The team's experience, informed by stock turnover, market research, and prior access to confidential product flow estimates, suggests that the sales data from the eleven suppliers in the database encompasses approximately 25% to 45% of the residential sales for each of the four main residential technologies: gas furnaces, air source heat pumps (including variable-capacity heat pumps), ductless heat pumps and central air conditioners. This estimated coverage is consistent with prior rounds of data collection. 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 5: Reported Supplier Sales Volume by Technology (Unextrapolated)

Sector	Technology	2016 Reported Quantity	2017 Reported Quantity	2018 Reported Quantity	2019 Reported Quantity	2020 Reported Quantity
Residential	Central Air Conditioning – Condenser	16,359	28,023	43,181	51,429	27,080
Residential	Gas Furnace	36,121	46,858	58,737	62,315	38,957
Residential	Heat Pump – Air Source, Single- and Two-Stage	11,897	17,332	21,739	23,696	16,413
Residential	Heat Pump – Ductless	13,348	20,829	25,380	25,360	24,916
Residential	Heat Pump – Air Source, Variable Capacity	NA	2,248	3,102	3,245	3,007
Residential	Heat Pump – Single Packaged	460	649	796	726	156
Residential	Electric Furnace	989	1,330	1,581	1,614	1,549
Residential	Variable Speed Mini-Split & Multi-Split Air Conditioning	845	1,241	952	1,101	313

Sector	Technology	2016 Reported Quantity	2017 Reported Quantity	2018 Reported Quantity	2019 Reported Quantity	2020 Reported Quantity
Residential	Gas Packaged Unit	1,806	2,369	2,904	2,756	470
Commercial	Heat Pump – Air Source, Variable Capacity	NA	161	223	224	NA
Commercial	Heat Pump – Packaged Terminal (PTHP)	NA	621	1,260	1,289	NA
Commercial	Central Air Conditioning - Packaged Terminal (PTAC)	296	264	266	NA	NA
Commercial	Variable Refrigerant Flow	NA	NA	170	137	NA
Commercial	Unitary Large Equipment	746	1,069	1,996	2,072	350

Step 3: Address Geographic Gaps

In *Step 2: Assess Data Gaps*, the team confirmed the need to address the underrepresentation of Idaho in the reported supplier data. To do so, the team integrated data from HARDI,[7] which the research team received through a non-disclosure agreement with NEEA.

Though the HARDI report helps to fill a geographic gap, the suppliers that contribute to it are anonymized, making it difficult to determine the extent of overlap between the NEEA supplier data and the HARDI data. For this reason, the team subtracted Idaho sales from the NEEA supplier data and replaced it with HARDI data for Idaho for three technologies: central air conditioners, air source heat pumps (including variable capacity heat pumps), and gas furnaces.[8] This approach leverages both data sets for a more complete view of the region while relying more heavily on the NEEA supplier data that has greater transparency and detailed equipment information.

The team summarized the effect of replacing the NEEA data with HARDI data for Idaho (limited to the three specified technologies) by comparing the distribution of each technology's reported sales by state to population distribution pre-HARDI (Figure 4) and post-HARDI (Figure 5). The team used each state's share of population as a rough proxy for understanding the regional coverage of the reported supplier data[9] 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). The comparison shows that using HARDI data to fill the Idaho geographic gap resulted primarily in increasing reported sales for central air conditioning in Idaho; coverage of the other technologies (air-source heat pumps and gas furnaces) improved slightly. Figure 4 and Figure 5 illustrate the results of the analysis for 2020 sales. The team has performed this analysis for prior years with similar results.

[7] Data prepared by D+R International.
[8] Although NEEA's HARDI license includes ductless heat pumps in addition to these three technologies, reported ductless heat pump quantities are greater in the NEEA data compared to HARDI so they are excluded from this step.
[9] The team also conducted a comparison of sales to housing counts (sourced from the American Community Survey) with near-identical results.

Figure 4: Reported 2020 Sales by Equipment and State Pre HARDI-Integration

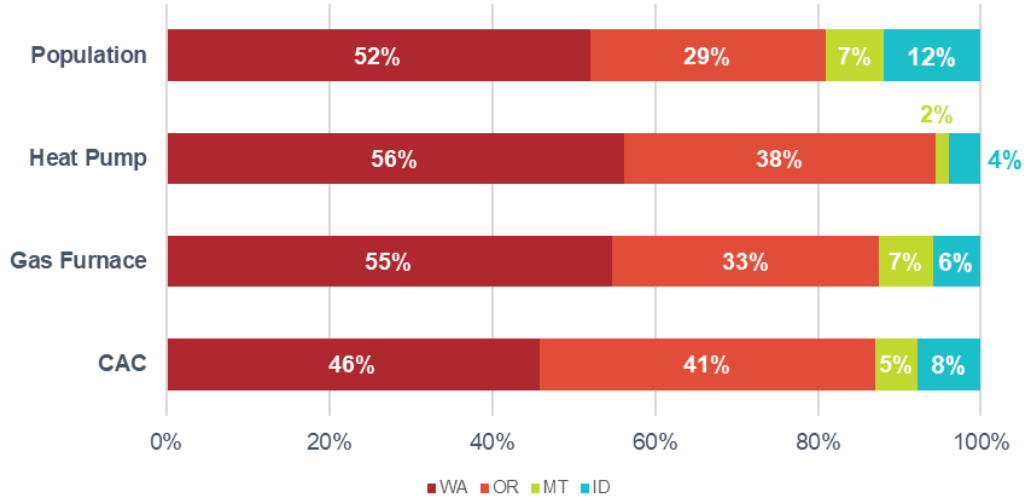
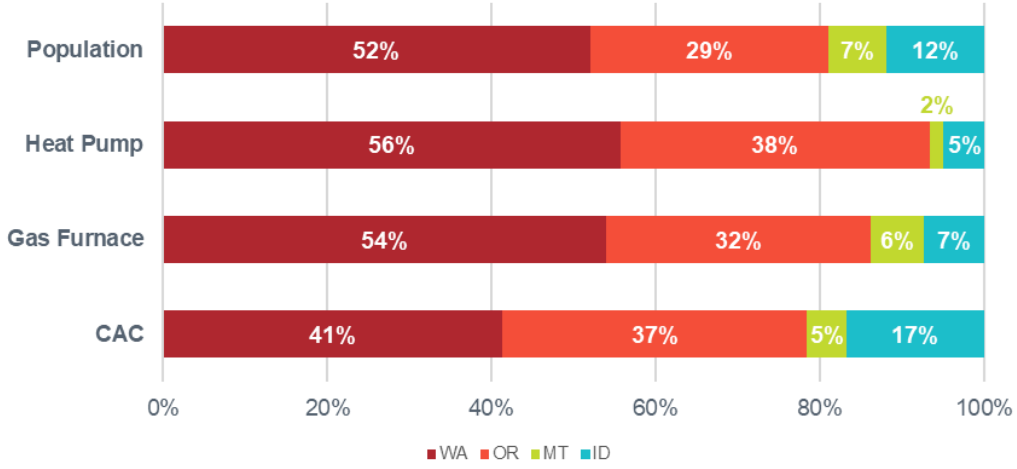


Figure 5: Reported 2020 Sales by Equipment and State, Post HARDI-Integration



Step 4: Final Market Estimates

The last step involves two primary analytical components required to prepare a final full market estimates of annual efficiency mix and total sales volume for key residential heating and cooling technologies. The intent of both components is to fill data gaps.

- **Extrapolation** fills temporal gaps in supplier submissions, and
- **Weighting** fills market coverage gaps from other regional suppliers who did not submit data

Address Temporal Gaps

Following the integration of HARDI data for Idaho, the team extrapolated to fill temporal gaps in sales data from reporting suppliers. Extrapolation is important because the efficiency mix for HVAC equipment

varies from supplier to supplier. Creating a complete time-series dataset for each supplier in the sample through extrapolation mitigates the impact of data gaps on the calculated efficiency mix.

The team's approach rests on two key assumptions:

- **A supplier's market share remains relatively constant over time.** For example, if a supplier's sales represented 25% of all reported HVAC sales in 2017, then the team assumes that supplier will represent 25% of all reported HVAC sales in 2018.
- **The mix of technologies is, on average, similar for that supplier across years.** For example, if ductless heat pumps accounted for 5% of a supplier's total reported sales in 2017, then the analysis assumes ductless heat pump sales would similarly account for 5% of this supplier's total reported sales in 2018.

The team confirmed these assumptions are reasonable by reviewing the sales patterns for suppliers who submitted at least two complete and consecutive years of data. Specifically, the team plotted supplier-specific market share across years and supplier-specific technology mix across years. The results of these analyses are protected by confidentiality agreements, but the team's analyses confirmed both assumptions are reasonable.

As visible in Table 2, the overall temporal coverage of the data is good. It is important to note, however, that the temporal gaps differ between suppliers. For example, one might be missing an entire year of data, whereas another might be missing only a month. To address these differences, the team applied different extrapolation processes in the order listed:

1. For data submissions missing a month or less of sales data, the team:
    a. Relied solely on the supplier's submitted data to ensure the most accurate prediction, rather than using other suppliers' data to extrapolate sales.
    b. Extrapolated sales for the missing weeks or month assuming that the relative volume and mix of those sales is the same as that month in the prior or subsequent year.

2. For the data submissions missing more than a month, the team:
    a. Estimated an overall market share for each supplier based on the most complete, recent year of data.
    b. Applied these market share estimates to the reported data to extrapolate the total sales for the missing period.
    c. Allocated those extrapolated sales to the same technology and efficiency mix as reported in either the prior or subsequent year for that supplier (e.g., 5% of total sales are SEER 18 or higher air source heat pumps).

This methodology ensures the team leverages the information gathered for each year to fill data gaps. Table 6 presents the portion of sales data extrapolated for each year. There were no temporal gaps to fill in 2018 and 2019. Extrapolated sales vary based on the completeness of submitted supplier sales data, relative market share of missing supplier data, and reported sales growth for each technology. The team cannot discuss specific suppliers or their participation status for any given year, even in an anonymized fashion, in order to protect study participant confidentiality.

Table 6: Proportion of Sales Data Extrapolated*

2016 Percent Extrapolated	2017 Percent Extrapolated	2018 Percent Extrapolated	2019 Percent Extrapolated	2020 Percent Extrapolated
24%	12%	0%	0%	43%

Table 7 presents the estimated annual sales for the eleven participating suppliers, by technology, after extrapolating to fill temporal and geographic gaps.

Table 7: Reported Supplier Sales Volume by Technology (Extrapolated)

Technology	2016 Extrapolated Quantity	2017 Extrapolated Quantity	2018 Extrapolated Quantity	2019 Extrapolated Quantity	2020 Extrapolated Quantity
Central Air Conditioning – Condenser	31,188	38,634	47,889	55,587	66,340
Gas Furnace	51,289	57,499	62,663	63,075	72,588
Heat Pump – Air Source, Single- and Two-Stage	18,785	21,616	21,988	23,843	27,750
Heat Pump – Ductless	18,271	22,433	25,395	25,399	29,405
Heat Pump – Variable Capacity	NA	3,234	3,325	3,469	4,760
Heat Pump – Single Packaged	548	655	796	726	759
Electric Furnace	989	1,376	1,581	1,614	1,549
Variable Speed Mini-Split & Multi-Split Air Conditioning	1,257	1,261	952	1,101	1,264
Gas Packaged Unit	1,982	2,374	2,904	2,756	3,193
Heat Pump – Packaged Terminal (PTHP)	NA	621	1,260	1,289	NA
Central Air Conditioning - Packaged Terminal (PTAC)	296	268	266	NA	NA
Variable Refrigerant Flow	NA	NA	170	137	NA
Unitary Large Equipment	889	1,070	1,996	2,072	2,421

After addressing geographic and temporal gaps in the reported supplier sales data, the team used the post-extrapolated data in Table 7 to calculate the final heating and cooling efficiency mix of four key residential technologies: central air conditioners, air source heat pumps, gas furnaces, and ductless heat pumps. This efficiency mix, as presented in Table 8 and Table 9, is an input to the BPA Residential HVAC

Market Model for the model update. With this information, the team can better estimate how the efficiency trends in equipment sales are affecting regional HVAC energy consumption during 2016–2021.

Table 8: Final Heating Efficiency Mix – Residential

Technology	Heating Efficiency		2016	2017	2018	2019	2020
Gas Furnace	80% up to 89.99% AFUE		34%	31%	31%	32%	32%
	90% up to 94.99% AFUE		8%	8%	5%	4%	3%
	95% AFUE or greater		57%	61%	64%	64%	65%
Heat Pump – Air Source	Single- or Two-Stage	HSPF 7.5-7.99	2%	1%	0%	0%	0%
		HSPF 8-8.39	44%	39%	34%	29%	28%
		HSPF 8.4-8.79	36%	32%	35%	40%	41%
		HSPF 8.8-9.99	17%	16%	17%	18%	17%
		HSPF 10 or above	1%	1%	1%	0%	0%
	Variable capacity		NA	12%	12%	12%	14%
Heat Pump – Ductless	Below HSPF 9.0		11%	10%	5%	3%	3%
	HSPF 9.0 to 11.0		68%	69%	77%	80%	78%
	HSPF 11.1 to 12.5		17%	17%	14%	14%	18%
	HSPF 12.6 or above		4%	4%	4%	3%	1%

Table 9: Final Cooling Efficiency Mix – Residential

Technology	Cooling Efficiency		2016	2017	2018	2019	2020
Central Air Conditioning – Condenser	SEER 10-11.99		1%	1%	1%	0%	0%
	SEER 12-13.99		40%	33%	33%	27%	27%
	SEER 14-15.99		52%	60%	59%	65%	62%
	SEER 16 or above		7%	6%	7%	7%	10%
Heat Pump – Air Source	Single- or Two-Stage	SEER 12-13.99	2%	1%	0%	0%	0%
		SEER 14-15.99	90%	79%	78%	77%	76%
		SEER 16 or above	8%	8%	9%	11%	10%
	Variable capacity		NA	12%	12%	12%	14%

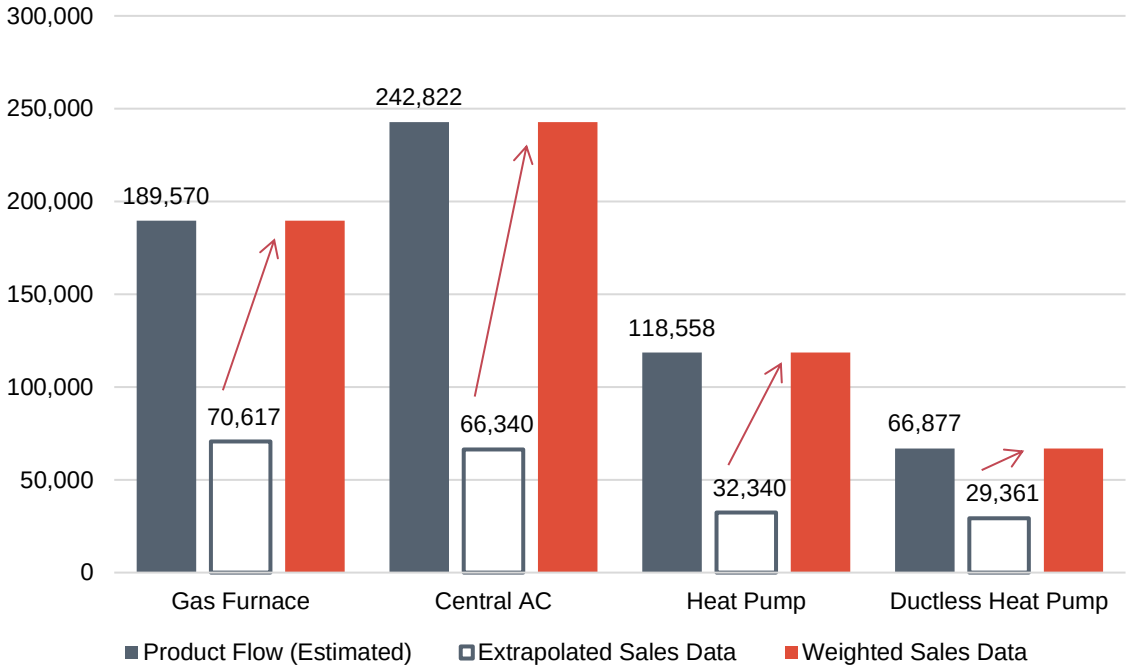
Weighting

Weighting is important for understanding the full product flow of annual equipment sales in the region. 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 dataset with the estimated

regional product flow for each technology. The weighting process described below does not impact the efficiency mix within a given technology type (e.g., the percent of ASHP sales that are HSPF 9.0).

After extrapolation, the team applied a scalar weight to the extrapolated sales quantities to match estimated regional sales totals. Figure 6 illustrates how the extrapolated sales data are weighted up so the efficiency mix in the supplier data is scaled to match the estimated sales quantity for each technology.

Figure 6: Weighted 2020 Sales Data: Scaled Extrapolated Data to Estimated Product Flows



The team considered other sources for estimating annual technology-specific product flows, but elected to use the Residential HVAC Market Model for four reasons:

- The market model is publicly available and contains annual sales estimates for a wide set of technologies;
- The market model is calibrated to align with the equipment stock and efficiency mix in the 2016 Residential Building Stock Assessment;
- The market model estimates for years 2017 through 2021 are aligned with a wide range of best-available data sources; and
- There is no known comparably reliable, transparent, and sufficiently detailed annual product flow source.

The Residential HVAC Market Model product flow estimates are reported as the number of households with the equipment type.[10] The team translates those estimates to individual equipment units using average equipment type per home estimates from the 2016 Residential Building Stock Assessment. For

[10] As mentioned earlier, background on the development of those estimates will be available with published Residential HVAC Market Model updates midyear of 2022, on https://www.bpa.gov/energy-and-services/efficiency/market-research-and-momentum-savings/hvac-market-research

example, the Residential HVAC Market Model estimates that central ACs were sold into 232,303 homes in 2020. Based on the 2016 Residential Building Stock Assessment, the typical home in the region has 1.045 central AC units per home. The product flow estimate for 2020, therefore, is 242,822 central AC units.

Remaining Data Gaps and Uncertainties

The regional HVAC supplier dataset is a mix of regional and national suppliers, and includes the general supply house sales that supply the residential sector. The majority of known residential suppliers provide data and most major manufacturers of residential HVAC equipment are represented in the dataset. Given that and the stability in efficiency trends, the team has confidence that the efficiency mix of the supplier dataset (as presented in Table 8 and Table 9) are representative of the region and can serve as an input to the Residential HVAC model.

There are, however, gaps beyond those discussed in Step 2 and Step 3 that cannot be fully assessed or addressed and create additional uncertainty with the overall dataset.

Commercial Equipment

The regional HVAC supplier dataset is a mix of regional and national suppliers, with the majority of known residential suppliers providing their sales data. In contrast, none of the known suppliers focused on commercial sales participate in the study and commercial-sized equipment accounts for only 2% of reported sales. The team estimates the dataset represents a small portion of the overall commercial HVAC market and therefore cannot support meaningful insights about commercial HVAC equipment.

System Configurations

Market actors interviewed in 2021[11] mentioned increasing interest in mixing and matching equipment to meet specific home needs. The supplier dataset provides detailed information for each unit sold, but does not provide a way to identify units sold together to serve the same home. The dataset also does not have enough information to characterize how HVAC systems are configured at each site (i.e., ducted minisplits or air-source heat pumps with gas furnace back-up heat). The team recommends pairing future sales data collection efforts with market actor interviews that focus on in-situ HVAC system trends and configurations, interpreted alongside the region's residential building stock assessments (RBSA).

Retail and Online Sales

Big-box retail and online sales are not included in the dataset and could be a significant gap for some technologies. Market-actor interviews conducted in 2021[12] reflected consensus that online and retail sales are increasing; however, the precise volume may be unknowable without access to sales data from retail and online channels. Online sales for HVAC equipment are flowing directly to contractors and, to a lesser extent, homeowners. While estimates are difficult to make, market observers report these sales could be as high as 10-20% for ductless heat pumps.

The team believes that this gap applies to some technologies included in this memo (such as ductless heat pumps and central air conditioners). Additionally, other technologies like room air conditioners, smart thermostats, and zonal heating equipment (baseboards and wall heaters) are not well represented

[11] https://www.bpa.gov/-/media/Aep/energy-efficiency/momentum-savings/bpa-hvac-market-actors-interview-findings-2020-2021.pdf
[12] Ibid.

in the NEEA sales data as the sales channels for these products include electrical suppliers and retail channels not reflected in the HVAC supplier dataset.

Future data collection should consider capturing sales of ductless heat pumps and other HVAC equipment through online and retail channels.

COVID-19

Market actors interviewed in 2021 indicated 2020 sales were impacted by stay-at-home orders and supply-chain issues.[13] The team reviewed the sales data to identify these or other impacts from the global COVID-19 pandemic, but no clear pattern emerged. While sales continued to increase in 2020 and the increases were more significant than 2019 increases (approximately 17% versus 6%), the increase was in line with earlier years (e.g., 2017: 20%; 2018: 13%) making it difficult to attribute the increases to COVID over other possible market influences. Some suppliers showed slight changes in how monthly sales were distributed throughout 2020 compared to prior years, but there was no clear indication of COVID impacts to overall sales trends.

Additionally, there was no discernible impact on efficiency related to COVID. All technologies show a steady trend toward higher efficiency, year over year.

[13] https://www.bpa.gov/-/media/Aep/energy-efficiency/momentum-savings/bpa-hvac-market-actors-interview-findings-2020-2021.pdf

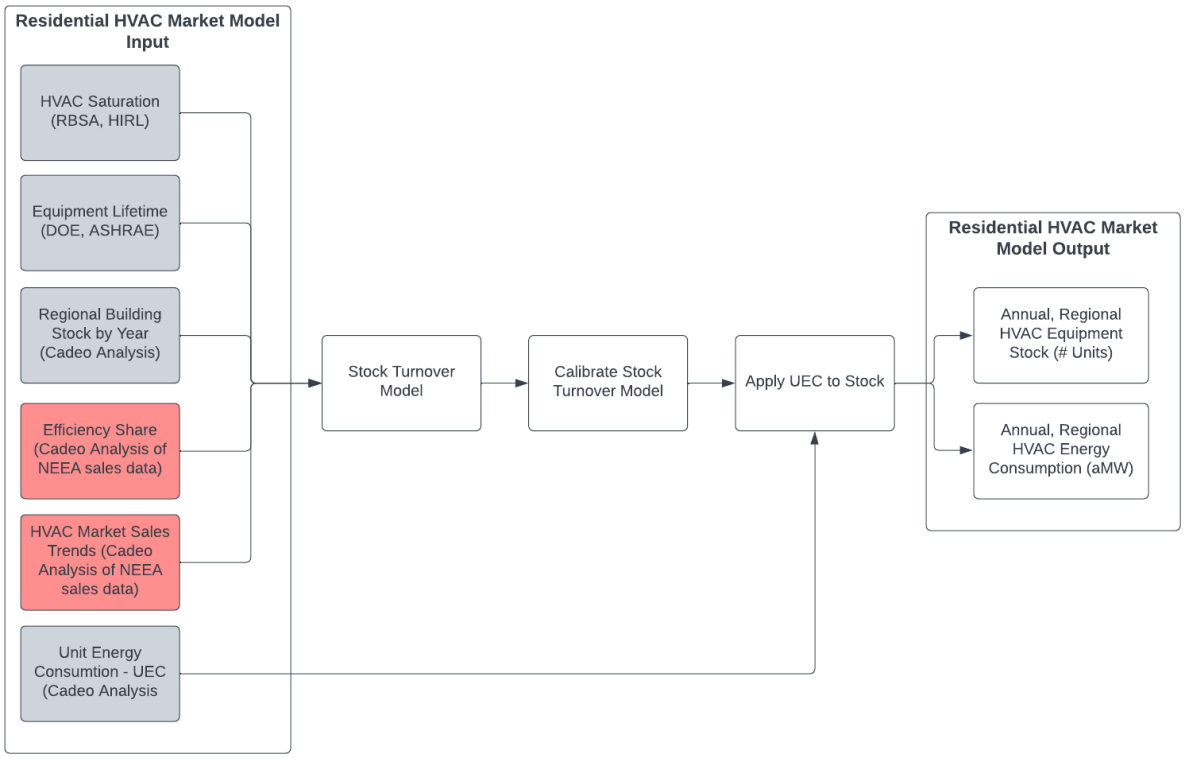
Appendix A: Relationship to the BPA Residential HVAC Market Model

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[14] action plan period (calendar years 2016–2021).

Figure A1 shows the architecture of the Residential HVAC Market Model.[15] The team uses the efficiency shares obtained in this sales data analysis as one of the inputs to its market model (see Table 8 and Table 9 above). The model produces:

- an estimate of regional HVAC stock (number of HVAC units per dwelling unit, 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

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

region. Second, the annual regional sales estimate is used to weight the supplier data up to a regional sales estimate.

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,[16] 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.[17]

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

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

[17] 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.

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 RBSA and align with *past* federal standards.

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
Variable Capacity**	NA	NA

* Denotes efficiency below current federal standard

** Applicable only to Air Source Heat Pumps

The team 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.

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
Variable Capacity**	NA	NA

* Denotes efficiency below current federal standard

** Applicable only to Air Source Heat Pumps