2022-2027 Residential HVAC Interim Market Model Expert Panel Activity Summary

June 2025

This summary documents the activities, process, and participants of the expert panel for BPA's 2022-2027 Residential HVAC Interim Market Model and related market research. Panel activities described in this summary took place between June 2023 and November 2024.

Residential HVAC Market Research and Purpose of Expert Panel

Accurately estimating total regional energy consumption for HVAC systems is challenging due to the many highly variable factors that influence HVAC energy consumption. BPA pursues research in the residential HVAC market because of its large energy consumption and potential for new technology adoption. In its continued market research efforts to improve the regional body of knowledge about energy consumption and savings, BPA built and maintains a quantitative market model representing the regional residential HVAC market.

In 2024, BPA updated the market model to produce an estimate of energy consumption and Momentum Savings for BPA's current Energy Efficiency Action Plan period of 2022 to 2027. BPA refers to this current model iteration as the 2022-2027 Residential HVAC Interim Market Model and intends to update it in 2028 to finalize results for 2022-2027. Because of uncertainty around forecast results, BPA has not published materials related to the 2022-2027 Residential HVAC Interim Market Model. For more information on BPA's residential HVAC market research, please contact Masumi Izawa, the BPA project lead, at mrizawa@bpa.gov or visit https://www.bpa.gov/energy-and-services/efficiency/market-research-and-momentum-savings/hvac-market-research.

BPA contracted with DNV to facilitate a panel of independent experts and regional stakeholders to review and provide feedback throughout the development of the 2022-2027 Residential HVAC Interim Market Model and related market research. The goal of the expert panel process is to provide BPA with independent expert review and advice on their market research, methodologies, market model, and results. Additionally, the expert panel process ensures continuous engagement in BPA's market research from its stakeholders representing the Northwest Power and Conservation Council (Council), the Northwest Energy Efficiency Alliance (NEEA), the Regional Technical Forum (RTF), and internal BPA staff.

Overview of Panel Engagement Activities

This section summarizes panel activities that took place between June 2023 and November 2024 throughout the development of the 2022-2027 Residential HVAC Interim Market Model and related market research. A more detailed catalog of specific panelists engaged in each activity and meeting minutes for each working session are accessible at the end of this document.

Residential HVAC Model Expert Panel Kickoff Working Session on June 6, 2023: BPA engaged with the full panel to kick off the model development process and asked the panelists to respond to questions related to the following topics: forecasting new construction rates with housing starts data, forecasting product flow and efficiency mix, fully-ducted mini-split consumption, and unit energy consumption updates. The panelists provided BPA with additional sources of data and recent studies to review.

New Construction Saturations Desk Review from Nov. 3-10, 2023: BPA engaged the panel to review new construction saturations and asked the panel which data sources BPA should rely on to forecast new construction trends. The panel recommended BPA use its existing data sources but to rely on NEEA's code compliance study for WA activity for years without other data sources . The panel also suggested BPA weight each state by construction activity. BPA agreed with these suggestions and adjusted the model inputs accordingly using data from Dodge Analytics to weight construction activity in each state.

Residential Building Stock Assessment (RBSA) III Air Source Heat Pump (ASHP) Heating Seasonal Performance Factor (HSPF) Data Gaps Desk Review on Feb. 22, 2024: BPA asked a targeted group of panelists to review RBSA HSPF missing values and the team's methodology to fill missing HSPF values. The panelists generally agreed with BPA's methods used to fill the missing HSPF gaps and thought the resulting HSPF distribution were reasonable.

RBSA III HVAC Equipment Analysis Working Session on Mar. 21, 2024: BPA presented an overview of the RBSA III and how BPA uses it in the model, BPA's analysis of the single-family HVAC equipment saturations and the ASHP efficiency saturations, and an initial summary of trends between the different RBSA reports. Panelists provided feedback on the following topics: RBSA weights, HSPF, RBSA regions vs. states, primary system alignment, equipment saturation trends, variable speed heat pump configuration, and filling ASHP HSPF gaps. As a result, BPA calibrated the model so that 2022 equipment and efficiency saturations fall within the error bounds of the RBSA.

Building Shell Inputs Working Session on May 7, 2024: BPA engaged the panel on a review of how the model tracks changes in the building shell model inputs for the 2022-2027 interim model, and the RBSA building shell data. BPA specifically asked the panelists to provide a high-level reality check on the building shell market, share other data sources or recommendations for future research, and think about how BPA can best extract information from available data. Based on the panel's consensus, BPA revised its 2023-2027 projection of the single-family insulation market activity from an increasing trend to a flat projection fixed at 2022 levels.

Single-Family Stock Saturations and Product Flow Desk Review from May 20-24, 2024: BPA asked panelists to respond to a series of questions about single-family primary heating and cooling equipment product flow. Panelist feedback focused on HVAC product flow (sales) trends, expectations for total sales volume, code influences, and residential HVAC stock saturation forecasts. The panelists recommended that BPA consider a

number of variations on product flow projections into future years and the resulting trends in equipment saturations. BPA used the feedback to bolster projections and reviewed their impacts in a sensitivity analysis.

Interim Market Model Draft Results Working Session on Nov. 18, 2024: BPA engaged the full panel to discuss future research and review model results, which included high-level findings, market trends, consumption trends, and energy savings trends. Panelist feedback confirmed the reasonableness of BPA's interim model forecast results and highlighted a number of areas to conduct additional research prior to updating the final model. Feedback on future research primarily focused on three areas: addressing heat pump supplemental heat, characterizing different ductless heat pump configurations, and tracking early replacement trends.

Expert Panel Process

For each panel engagement, DNV first met with BPA to understand the research of modeling needs and identified the appropriate panelists. Then DNV scheduled the working session meeting or review, distributed materials, and facilitated the discussion and feedback response. Panelists were responsible for showing up to the working session, completing their desk review on time, and contributing critical feedback in a professional and respectful manner.

BPA and its research contractor documented all panelist feedback in a comment tracker and provided responses to the feedback received including any follow-through actions taken. For transparency, panelists received a copy of the comment tracker and meeting notes in a thank you email that DNV sent after activity completion.

Expert Panelists

The panel included both experts and stakeholders with a diverse range of residential HVAC knowledge and capacities. DNV recruited the independent expert panelists while BPA recruited regional stakeholders as appropriate for this market. BPA requested DNV to recruit independent experts that provide expertise on all elements of the market research.

- **Market/Industry Expert:** A market/industry subject-matter expert (SME) has a strong understanding of residential HVAC market dynamics in the Northwest including who the market players are, what the market trends are, and how the supply chain typically works for residential HVAC equipment. In addition, the market/industry SMEs is up to date on current and any potential future federal or state codes and standards impacting the residential HVAC market and ideally has past "boots on the ground" experience working within the residential HVAC market (e.g., have worked with/for a manufacturer, distributor, installer, etc.). BPA requested the expert panel to include market/industry SMEs with expertise on the smart thermostat and insulation markets. A market/industry expert helps BPA ground its research and analysis in reality and makes sure BPA is not missing any important aspects of the regional market when trying to model annual full-market stock and sales.
- **Technology Expert:** The technology SME has engineering expertise and a strong understanding of how residential HVAC technologies – including air-source and variable speed heat pumps, ductless heat

pumps, central air conditioners, gas furnaces, electric furnaces, electric resistance heating, boilers, smart thermostats, and insulation – work, and preferably know how to model energy consumption for these technologies using Simplified Energy Enthalpy Models (SEEM) and other residential building engineering models. Technology experts are up to date on technology trends and issues, emerging technologies, and current and any potential future federal or state codes and standards impacting the residential HVAC market. A technology expert understands how different technical specifications and installation conditions (such as presence of advanced smart thermostats and insulation levels) affect the equipment's performance and energy consumption, which technologies are appropriate for which applications and can explain tradeoffs in efficiency, cost, and performance across numerous technology categories. BPA prefers technology experts that also understand the supply chain and current market trends.

- **Market Analysis Expert:** A market analysis expert is someone with experience using a mix of datasets such as sales data, regional building stock assessment data, utility program data and census data, and analyzing them for the broader regional market/population. A market analysis expert is well versed in assessing the representativeness and uncertainties of a sample dataset to determine whether and how to use it to make inferences on the population. A market analysis expert has knowledge of inputs, methods and outputs of stock turnover models and is preferably familiar with the Council's power plans and baseline methodologies.
- **Sampling/Statistical Expert:** A sampling/statistical SME has a strong understanding of sampling methods and techniques. They can review and provide feedback to BPA on sampling plans for primary data collection in a way that ensures the data are robust and representative of the population. They help inform BPA on the appropriate use of primary and secondary data sources, including appropriate uses of weights.
- **Regional Stakeholder**: Regional stakeholders are those from the Council, NEEA, RTF, or BPA that participated on behalf of their organization.

Table 1 shows the independent experts and regional stakeholders in the Residential HVAC expert panel.

Table 1. Residential HVAC Expert Panelists

Panelist Name	Expert Classification	Affiliation during Panel
Mark Jerome	Market/Industry Expert	CLEAResult
Chris McKinney	Market/Industry Expert	Ferguson
Jonathan Moscatello	Market/Industry Expert	Daikin Comfort Technologies
Abram Conant	Technical Expert	Proctor Engineering
Bob Davis	Technical Expert	Ecotope
Kevin Madison	Technical Expert	Lawrence Berkeley National Laboratory (LBNL)

Panelist Name	Expert Classification	Affiliation during Panel
David Baylon	Market Analysis Expert	Independent
Mitt Jones	Market Analysis Expert	Cadmus
Jonathan Belmont	Regional Stakeholder	BPA
Nathan Kelly	Regional Stakeholder	BPA
Christian Douglas	Regional Stakeholder	Council
Tina Jayaweera	Regional Stakeholder	Council
Ryan Brown	Regional Stakeholder	NEEA
Christopher Dymond	Regional Stakeholder	NEEA
Havala Hanson	Regional Stakeholder	NEEA

Catalog of Panel Activities

The panel kicked off in June 2023 and ended in November 2024, completing a total of seven engagement activities. Table 2 shows the full list of panel engagements, topics covered, and panelists involved. Appendix A provides the detailed meeting minutes to the working sessions. A copy of the comment tracker with panelist feedback and BPA's responses is available upon request.

Table 2. Residential HVAC Expert Panel Completed Activities

#	Review Type	Panel Engagement Period	Topics Reviewed	Independent Experts	Regional Stakeholders
1	Working Session	June 6, 2023	Interim model panel kickoff including model updates, planned panel engagements, and continuous market research.	Mark Jerome, Abram Conant, David Baylon, Mitt Jones, Bob Davis	Ryan Brown, Christian Douglass, Christopher Dymond, Havala Hanson, Tina Jayaweera
2	Desk Review	Nov. 3-10, 2023	New construction HVAC saturations.	Mark Jerome, David Baylon, Mitt Jones, Jonathan Moscatello	Christian Douglass
3	Desk Review	Feb. 22, 2024	Suggestions to improve methodology for filling HSPF gaps.	None, targeted panel	Christian Douglass, Laura Thomas, David Bopp, Mike Psaris, Brandon Giatti
4	Working Session	Mar. 21, 2024	Model overview, how RBSA data were used, RBSA single-family HVAC equipment analysis, equipment saturations, mapping to model cells, efficiency saturations, filling data gaps.	Mark Jerome, David Baylon, Mitt Jones, Jonathan Moscatello	Ryan Brown, Nathan Kelly, David Bopp, Christopher Dymond

#	Review Type	Panel Engagement Period	Topics Reviewed	Independent Experts	Regional Stakeholders
5	Working Session	May 7, 2024	Building shell model inputs and RBSA single-family insulation data analysis.	Mark Jerome, Abram Conant, Bob Davis, David Baylon	Nathan Kelly, Ryan Brown, Christian Douglass, Christopher Dymond, Amy Burke, Blake Ringeisen, Mike Psaris, Jonathon Belmont
6	Desk Review	May 20-24, 2024	Single-family stock and product flow.	Abram Conant, Bob Davis, Mark Jerome, David Baylon	Nathan Kelly, Ryan Brown, Christian Douglass, Christopher Dymond
7	Working Session	Nov. 18, 2024	Interim model draft results including high-level findings, market trends, energy consumption trends, and energy savings trends.	Mark Jerome, Jonathan Moscatello, Abram Conant, Bob Davis, David Baylon, Chris McKinney	Ryan Brown, Christian Douglass, Christopher Dymond, Aaron Ingle, Jonathon Belmont

Appendix A: Working Session Meeting Minutes

The following contains the meeting minutes to all working sessions.

Working Session: Residential HVAC Expert Panel Kickoff – June 6, 2023

ACTION ITEM – This highlights an action item for a panelist.

ACTION ITEM – This highlights an action item for BPA and/or Cadeo.

Attendees

BPA: Joan Wang, Erik Boyer, Bonnie Watson

DNV: Tyler Mahone, Lorre Rosen, Bridget Ransford

Cadeo: Courtney Dale, Bretnie Eschenbach

Panelists: Mark Jerome (CLEAResult), Abram Conant (Proctor Engineering), David Baylon (Independent), Mitt Jones (Cadmus), Ryan Brown (NEEA), Christian Douglass (Council, RTF), Christopher Dymond (NEEA), Havala Hanson (NEEA), Tina Jayaweera (Council), Bob Davis (Ecotope)

Unable to attend: Jonathan Moscatello (Daikin Comfort Technologies), Chris McKinney (Airefco), Kevin Madison (LBNL)

Introductions

Tyler reminded everyone that this call is a re-kickoff to the residential HVAC (Res HVAC) market model for BPA. Many of the panelists were involved in the last round that wrapped up in the summer of 2022. This time we have a new modeling lead from Cadeo, Courtney Dale. Tyler then walked through the agenda and had the panelists introduce themselves.

Working Session Agenda

- Introductions
- Background
- Model Context
- Interim Model Plan
    - Model Updates
    - Planned Panel Engagements
    - Continuous Market Research
- Questions

Background

Joan presented some background information about the model. The last time this panel met was in the spring of 2022 when BPA presented model results from the past 6 years. Fast forward a year, we are now ready to update the model for the next iteration. Today is really a kickoff; we are not going to dive deep into any particular topic. This meeting will give the panel an idea of what to expect over the next 12 months in terms of the topics we will discuss, key model inputs we are trying to update, and how we plan to engage with the panel.

Meeting Goals

Joan reviewed the goals for the meeting with the purpose of re-engaging the panel for the next iteration of the ResHVAC market model. Throughout the slide deck, we will introduce questions and get the panelists thinking about the model. Follow-up requests for panelists are indicated by **Green Shaded Boxes** throughout the presentation notes.

Future panel engagements are indicated by a star (★) throughout the presentation notes.

Purpose of the Expert Panel

Joan reminded the panel that the Res HVAC model is a resource to the region. The model uses best available data and vetted methods and produces a lot of different results. It quantifies momentum savings. It estimates regional total energy consumption in the Res HVAC end use and how that might change over time. It also produces insights into different HVAC markets in terms of saturation and product flow and how that changes over time.

This model would not be where it is today without the guidance and expertise the panel has provided throughout the last few years. Joan thanked the panelists for their past commitment and participation; we look forward to engaging with the panel over the next few months.

Dave Baylon asked a question. I realize that momentum savings has become a watchword over the last decade or so. Historically, we have distinguished utility programs from market transformation somewhat. Although it is not clear where that line gets drawn.

What I want to know is - how is momentum savings distinguished from regular commercialization such as codes, or is it? If it isn't, what is the purpose beyond having a sort of shorthand that allows you to take credit for conservation that is not actually happening as a result of your programs or anyone else's programs?

Bonnie replied, the purpose of the panel is to give BPA technical advice for the scope of the models. There is a white paper that BPA wrote about the purpose and principles of momentum savings. I encourage you to check that out. It has the answers to a lot of the questions that you asked. It details why are we doing this, and how do we get there.

The BPA's formal definition of momentum savings is energy savings that are occurring in the marketplace for select markets — so, it is not a conceptual representation of all savings happening in the market — It is for select areas that are cost effective, above the baseline, and not double-counted with any kind of codes and standards, NEEA market transformation, or utility programs. We have made a lot of effort to make sure that there is no double-counting happening. The theoretical basis for momentum savings and where this came about is looking at momentum savings as part of the NW region's resource. When you look at energy efficiency as a resource, say you're looking at the NW and it needs "X" amount of energy efficiency to meet demand, and it is the most cost-effective resource out there. (The Power Plan, as well as BPA's, planning efforts are agnostic as to who pays for that resource and where it comes from as long as it's truly happening out there.) Our policy, and the region's policy, is that we count momentum savings as part of the resource. It is a much smaller piece of the pie than it used to be. For the next 6-year period, we are only forecasting to report 30 aMW of momentum savings. If you compare that to our previous models, it is a smaller chunk of the overall pie. If you have any additional questions, we should take that offline. Bonnie said Dave can email her directly and she will send the white paper for his review after the call if he wants to read any further.

Tyler will follow-up with a copy of the white paper and will send to Dave. He also reminded everyone that the expert panels are really focused on the market model more than the actual momentum savings calculations that come out of it. The exercise in creating these market models has a lot of inputs that go

beyond just the momentum savings. The purpose of these expert panels is to make sure that the assumptions going into the market models are the best that they can be.

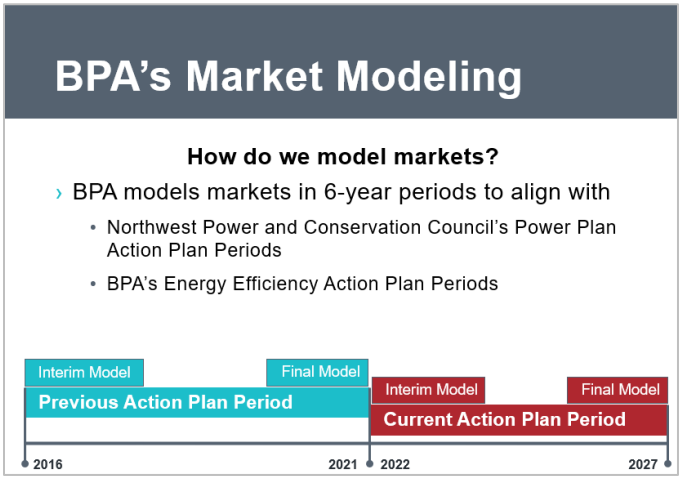
Joan thanked Dave for the question and noted that it is good to be reminded of the definition of momentum savings since it might have been a while for some of the folks on the call. She thanked Bonnie for the context and Tyler for moving the discussion along.

BPA's Market Modeling

Joan continued to discuss how we model the markets. We model markets in 6-year periods. That aligns with both the Council's Power Plan action plan periods and the BPA's energy efficiency action plan periods.

The blue area in the slide shown below is the previous action plan period that spanned from 2016-2021. Our final model from that period is what we worked on with this panel last year. Moving forward, the next action plan period is from 2022-2027. This will be the period where we focus on analysis. We will be working on the interim model for the next 12-18 months. The purpose of the interim model is to provide a good forecast for how the market is changing during the 2022-2027 period.

What we want to get out of this interim model is the best forecast that we can come up with. Towards the end of this action plan period, we will pick up the model again and update it with the newer, more available data and we will call that the "final model."



The outputs we want from the interim model is a forecast of energy consumption and savings for the entire action plan period. At the end of next year, we want to know what we do not currently know about the market and what additional research we must do so that we have all the data that we need to produce robust results from our final model. Not only do we want a forecast from this effort, but we also want a plan to continuously conduct market research to get what we need to know about this market.

Same Model, New Data

Joan continued. We already have a well-established model and well-vetted methodology. A lot of the Res HVAC model and the success of it comes from several very strong, recurring regional data collection activities. This model relies heavily on the Residential Building Stock Assessment (RBSA) and NEEA. And we also update the model with new sales data collection done by NEEA every year.

These are important data sources that make the model successful and reliable. What we need from the panel over the next few months is your guidance on helping us forecast into the unknown — the years that have not occurred yet. We have new data that we can use to update the model already. But what we will figure out with your help is how we can best forecast into the future. We also want you to tell us where we don't know a lot about the market, and what data we can incorporate into the model.

What's new for the Interim Model?

Joan discussed what is new about the interim model and what we are excited to update this round.

The 2021 Power Plan was released, and our model will need to be updated with new baselines for different equipment. We are very excited that the RBSA III will be released very soon and that will give us a much better and more recent look at the ResHVAC stock as of 2022, which is when the site visits occurred. We will spend time analyzing and discussing this information with you on future calls.

RBSA III will be released (Early fall 2023):

- Even newer baseline HVAC saturations
- New building shell conditions
- New billing data results

What we are really looking to explore further is how different Res HVAC technologies are being adapted. The Res HVAC market is experiencing significant changes from all angles, and it remains the biggest end-use in the Residential sector. I think the market model has an important job to do to quantify and track these changing trends for the region.

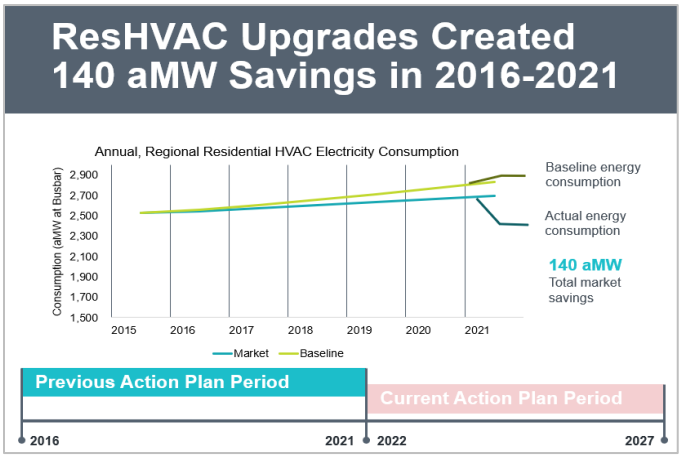
Technologies evolving:

- Variable speed heat pumps (VSHPs) are entering the market
- Ductless heat pumps (DHPs) are seeing new configurations
- Demand for cooling are changing market conditions

Christopher noted that in the past, the market model was a momentum savings model, but it seems like you are more interested in using it for forecasting and program tweaking. Can you comment on what is the highest/greatest value you see using the model for?

Joan responded that the model serves multiple purposes. It quantifies momentum savings, but also comprehensively quantifies how the entire ResHVAC market is changing. Those insights provide information for program strategy and help the region capture the total energy efficiency resource that the ResHVAC market provides including program investments, NEEA initiatives, and momentum savings. The model provides all of these things, and they are all important.

Model Context



Bretnie provided some brief reminders to set us up for Courtney talking about what we are going to update in this model period. As a refresher, where we left off with the last model is that the model reported baseline energy consumption increasing, which is another model output about how the market is changing. Energy consumption was increasing because of increased new construction activity and increased adoption of cooling. We also saw some savings against the baseline (the green line in the chart above). The market model produced or reported 140 aMW of market savings. We will be looking to update both consumption and savings in the next action plan period. In the next slide, we will talk about where those savings came from. The market savings came from several technologies. A couple of the outputs tell us what some of these market trends are, what the technologies that are impacting changes in consumption, and what technologies are producing energy savings for the region. Two of the big hot topics were air source heat pumps and ductless heat pumps. Both of which saw a big increase in NEEA sales data. We also saw gas furnaces holding fairly flat. So that is something we will look at going forward in the current action plan period (if the growing adoption of heat pumps impacts that). That is something we will be looking for in the stock assessment as well. Some of these trends were recently corroborated by a study that the Energy Trust of Oregon did on HVAC technologies in the region, or in Oregon, specifically.

Dave asked to what extent that BPA is trying to corroborate the regional numbers, have you looked at what is happening in Washington where there has been considerably more activity than in Oregon on the question of how you convert gas furnaces?

Bretnie replied that there will be something we look for in this current action plan period. I think that what we found from the end of the last model was that these new policies were not hitting the stock just yet since they were introduced in codes that will only influence new construction and stuff that is built once the new 2021 WA code gets adopted, which I recently heard was pushed out. So, I think what we saw in the model is that we did not see evidence of those policies yet, even though there has been a lot of adoption. But I think that is something we can pay attention to in this current action plan period.

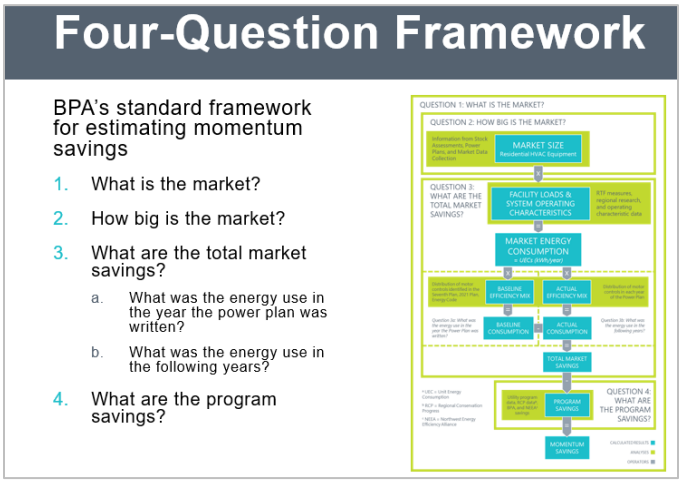
Dave pointed out that the actual change in the Washington new construction is a result of the 2018 code, not the 2021 code. All this new construction is influenced by that. Even if nothing happens and we never get a new 2021 code, that has already occurred.

Bretnie said that is true and we talked about that in the last model, that some of the heat pump adoption was associated with code requirements and those are part of our baseline or taken out of the model in terms of reported savings for technologies going through to construction. Bretnie thanked Dave for that reminder. One of the other interesting trends that came out of the last model was insights into what is happening with cooling. At the beginning of the plan period, we had less than 50 percent of homes with a form of cooling. By the end of the plan period, 75 percent of homes had some form of cooling including room air conditioners and portable air conditioners. This was corroborated by a recent Energy Trust of Oregon study that saw really high adoption of cooling technologies. The 2021 Plan expects to have very high adoption of cooling technologies within the plan period. That is something that we will be updating and paying close attention to in this current plan period —changes in both whole home cooling solutions and those portable room air conditioners.

Interim Model Plan

Bretnie continued. First, we will talk about some of the model updates, the planned engagements we will have over the plan period, and some next steps. This is very similar to what Joan presented earlier. We are right at the beginning of this action plan period and starting this interim model. There will be two outputs to the interim model: energy consumptions and savings forecast for 2022-2027 and a plan for future continuous market research. So that when we end this interim model, we will start collecting and analyzing data looking for other opportunities to improve the model so that when we get to the final model, we will have new data that we can update and finalize.

Model Updates



Bretnie continued. To get us started on some of the model updates, we will be talking about the model updates in terms of our four-question framework which includes the market size, energy consumption, and program savings. This is just a refresher, this is all in the methodology memo, but the standard framework that BPA uses for market models is the four-question framework, which is outlined below.

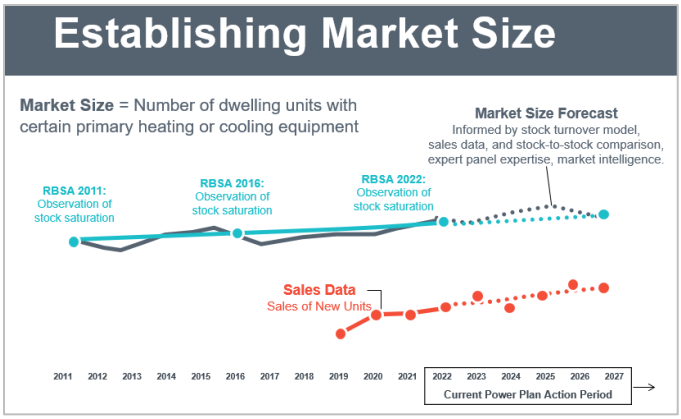
We are going to run through our market model updates with these questions in mind. **Bretnie** handed the presentation over to Courtney.

Question 1: What is the Market?

Courtney said that we have been working on this model for a couple of iterations now because we have a well-established scope for this model. We have very limited change to the market scope. It is limited only to the analysis period, which previously was 2011 to 2021 and will now extend through 2027. The baseline year will now be 2021 and results will be calculated for 2022-2027.

Question 2: How Big is the Market?

Courtney discussed why this question is a little more interesting. When we are establishing the size of the market, we are thinking about two factors. The first is the total number of dwelling units in the northwest. The second is the primary heating and cooling equipment of each of those dwelling units. What we do, especially looking backwards, is review the stock saturations found in the RBSAs from 2011-2016. Soon, we will be doing 2022 when that RBSA comes out. That shows us the trend in the market size up to the current period. Our next task is to forecast the market size. This is what the stock turnover does, it helps us with various inputs. We can look forward, without the benefit of 2027 RBSA, and get a strong estimate of what the market is going to look like for the Power Plan action period. That forecast comes from several different data sets and information sources. The first is the trend in the RBSA. We will project that out into the future. But that trend is going to be adjusted by our analysis of NEEA's HVAC sales data collection activity. The sales data shown at the bottom of the chart (below) informs us of the product flow coming into the market. It's not comprehensive sales data, but it is representative and so we are doing some analysis to adjust our forecast of the market size. We will also use some market research that provides intelligence into what the market is doing and rely heavily on this expert panel's expertise and feedback to help guide those forecasts into the future.



Courtney said that this is where we will start asking the panelists some questions. One of the questions we have for this group is about the number of total dwelling units in the region. We rely on housing starts data from the census to estimate new construction along with other similar pieces of data. We will project that recent census housing starts through 2027. However, we understand from conversations with various market actors that the new construction market has experienced some change recently. We had supply chain issues that made everything that is required to build a house more experience and harder to get. More recently, we had interest rate hikes that are affecting the market for new construction homes and the appetite for building. So, our question for the group is: Do you know of any additional sources that suggest a changing of residential new construction trends or forecasts regional residential new construction?

Tyler jumped in and reminded the group that he will be sending the slides as well as a follow-up spreadsheet to ask these specific questions so you can provide your responses to us after the meeting.

Dave asked if we are relying strictly on census data for these estimates or do we have other sources for estimating new construction in the region. If so, what are they?

Bretnie replied that our past model relied solely on the census data. At the end of the plan period, we updated it with past starts. So, now we are at the beginning of the plan period we are about to forecast, and that is what we are looking for from the panel.

Dave said that in Washington and Oregon, the census is fine. The nature of our permitting process more or less guarantees that we get everything except cabins in the woods. That is less true in Idaho, but it is not a huge bias…maybe 10 percent. Then you get to Montana where it is hopeless. In Montana, the census data is at best approximate because it covers the markets where there are permits. Only about a dozen large municipalities have their own building departments. Everybody else must report to the state and the state does not issue residential permits. Only the utility issues hook-up permits, which might not be much help to you. There are other data sources, but the census in Montana is hopelessly biased.

Bretnie asked Dave if he knew of any other data sources.

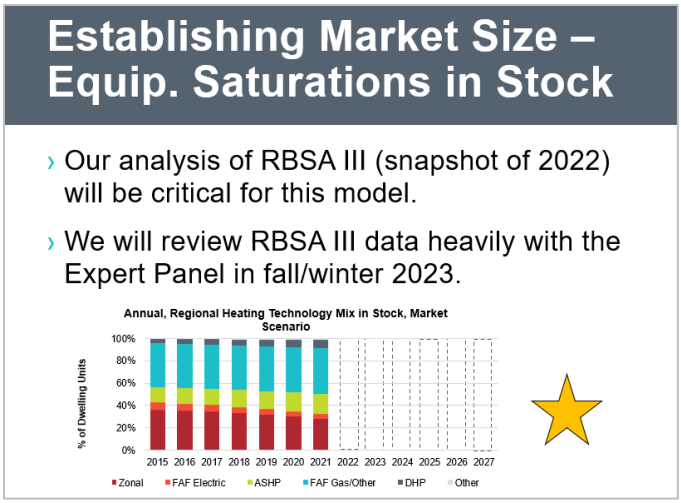
Dave said there is something called the Western Construction data, and it actually reports in the same way that Dodge does for new commercial construction. It uses informants and phone surveys to survey builders and find their residential construction. The last time he used it, a decade or two ago, it was 60 percent of the housing stock was identified through this system. It may be better now, but probably not a lot better.

Bretnie asked Dave if he could remember the exact name of the dataset, and Dave said that he would find the reference. He said that it also reports on Idaho, but only in the weeds.

Tyler asked the group if NEEA or Tina from the Council had started looking into this and had any potential data sources.

Tina replied that they also use Dodge new construction data.

Ryan said that they also use the census data for building starts. Every time there is a new code, we do a code compliance study that does not do forecasting but potentially helps with some of the assumptions that might be a layer down from what we are talking about right now.



Tina noted that it could help understanding the differences in patterns in new technologies going into new construction and existing.

Bretnie said it's on the list of documents to review in terms of new construction saturation and technologies.

Tina said she would reach out to Massoud, who is the Council's forecaster on the data sources that he relies on.

Courtney returned to the discussion about establishing market size. He mentioned that the other side of the market size coin is the equipment saturations in the stock. We were just talking about only the number of dwelling units, now we need to know what the primary heating and cooling system of each of those dwelling units is. The slide above is a reminder of what is coming to this group of panelists. We will rely heavily on the RBSA III, which is a snapshot of 2022 for the analysis of the equipment saturations. We intend to engage with this group multiple times in the winter of 2023 to review the analysis that we have done on the RBSA to help us think about how to look forward with that data.

Product Flow and Efficiency Mix Forecast

Courtney continued. In addition to RBSA, we use NEEA's HVAC sales data to inform changes in efficiency mix and volume of product flow from year to year. Unfortunately, it is 2023 and we do not have the benefit of all that data, we only have the data through 2022. We have the sense that the market for Res HVAC equipment is changing a little bit. We have the Inflation Reduction Act of 2022 (IRA) out there providing some big tax credits. The technologies are changing, we are seeing new equipment configurations, and we see new/changing preference toward more efficient equipment. We are hoping to leverage this panel's expertise for new data sources that project trends in the HVAC market, or maybe even forecasts of the efficiency mix and volume of product flow.

Do you have any data sources for projected trends in the regional HVAC market that could support how we forecast efficiency mix and volume of product flow?

Courtney asked David specifically if he had any data sources to share in the meeting.

David said that the only ones that he knows of that are not easily quantified outside of what NEEA does is the manufacturer's estimates of their sales of certain kinds of equipment which is hard to come by. Although, it is possible to talk to informants that are sworn to secrecy and find some of that information. David mentioned that he was happy to see representatives from Daikin and Airefco on the committee.

Bretnie agreed and said that maybe we could have some side conversations with them. It may be worth some conversations where if BPA shows them the trend line, they could help refine the forecast.

Joan also commented that BPA also attends the AHR Expo and talk to manufacturers. We did that earlier this year and plan to attend next year. Hopefully when we attend next year, we will have some estimates that we could share with manufacturers.

Christian mentioned that every once in a while, Energy Star will report their percent of market share. You could see what percent of Energy Star that is, which could be at least a point of triangulation that you could use. He added that sometimes there is a lag with that, so he is not sure how current it is.

Mark agreed that there are some trends that are changing. There are going to be some refrigerants change in the near term. He does not have any ideas for where other data lives that would be useful. But there will be big market shifts that are going to happen during this forecast period.

Joan agreed with Mark. She added that she thinks we are thinking in the right direction. When we have the latest sales data for 2022 later this year, the BPA will have to come up with a forecast and bring it to the panel to potentially adjust the forecast using your best judgement and assumptions about what might happen because of the upcoming changes.

Mark asked if NEEA is still collecting HVAC sales data. That last he heard, CLEAResult was part of that for a while. But he knows that they are not doing that anymore.

Joan replied that yes, NEEA is still collecting HVAC sales data, and it is getting better every year.

Christopher mentioned that the refrigerant change really hits hard in 2028/2029 when we start restraining against the Kigali Amendment requirements that the Biden administration aligns itself with. It might be that the forecast looks just great until 2027, and then it all goes crazy.

Mark added that he has seen where the EPA has projected that they want to have some hydrofluorocarbons like R-410A out of the manufacturers ability to put them in as early as 2025. California is changing with California Air Resources Board's (CARB's) rules that aligns with CARB 2025. So, there may be some shifts there, maybe later. It's still proposed, so we are waiting to hear what the final ruling will be.

Christopher added that the Washington state legislature has been trying to get legislation that parallels California, but he does not know how it finally turned out. The original rules were not timely, but they may still be in progress. If that happens, then a set of goals similar to California's will probably materialize sometime in the next year.

Tyler reminded the panel that this is a future topic and thanked everyone for their great ideas.

Question 3: What are the total market savings?

Question 3a. What was the energy use in the year the plan was written?

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

Courtney said that question 3 is very interesting and everyone has a lot of strong opinions on this one. The calculation of the unit energy consumptions (UEC) estimates for the interim model will remain mostly unchanged. The UECs are the estimate of the heating energy consumption and cooling energy consumption for a dwelling unit in a certain configuration with ,for example, a ductless heat pump that has or has not been weatherized, has a thermostat or not.

Courtney continued. There are about 3,000 UECs covering all different configurations of homes that the model includes or covers. Our expectation at this point for the interim model is that those UECs are going to remain relatively unchanged. We did this model less than a year ago. We have not changed our thinking about those UECs tremendously since that time. There will be a time when we decide to look more closely at the UECs. We know the RTF is changing the building simulation software they use to calculate the energy savings. The third RBSA is going to come out and change and the RTF will also look at calibrating to the building data in the RBSA. That work has not been done yet, and our intent is to wait until the region has done that work on those energy savings estimates and then leverage it in our final model. Of course, in the short-term, if we do make any changes or add new UECs, we are going to talk with this expert panel on those topics, which is why we have a "star" here.

David said that he thinks it will be unlikely that UECs remain unchanged. Leaving aside the question of what happens with changes in simulations, he thinks that it will change. It will change noticeably because of better efficiency.

Tina said that the RTF is planning on revisiting the heat pump, both upgrades and conversions, at the end of this year. She was not sure of the timeline of the Interim Model, but like Dave said, we will be looking at this at the end of the year. She agrees with David that there will be changes coming, although we do not know how significant they will be.

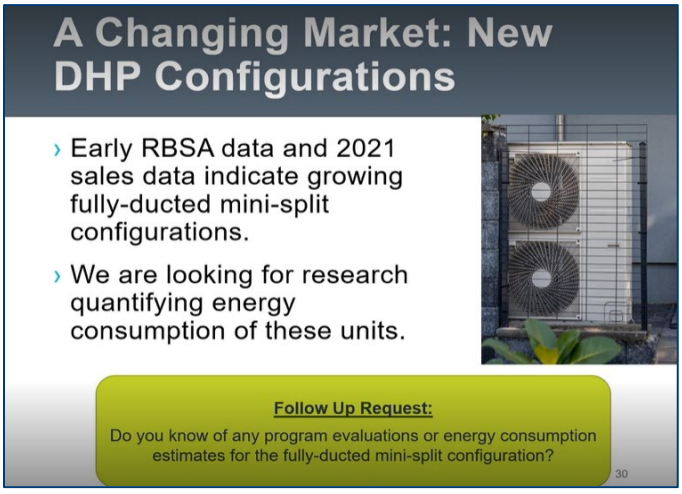
Courtney clarified that, of course, the BPA will track what is going on with the RTF the whole way through. The timing may be difficult, but the BPA is open to making adjustments to the heat pump UECs if required by the update. There will be a series of updates that affect the UECs, and the BPA does expect to comprehensively address those by the final model.

Christian said that this largely looks ok, but we should look at how the market model was done. Our air source heat pump conversion measure at the RTF has been based directly on billing analyses that is not modeled. There was a recent Energy Trust evaluation that showed half the savings of most historic billing analyses. He thinks they weighted it in with the other ones. So, it is not like our savings were cut in half, but that would be the only thing to perhaps look at.

Bretnie said that was a good reminder. The timing of that study was toward the end of the last model and the conversion savings from air source heat pumps the market model was estimating was lower than the RTF estimate. When we presented those results at the end of the model, that study had just come out and there were a lot of conversations about the future of air source heat pump savings. Right now, we are anticipating that our market model will align with some of the updated estimates because it was lower than what some of the regional estimates were at that time. This is something we will pay attention to and make sure we are aligning where we can. Between lowering the energy consumption use of electric furnaces and increasing the consumption of air source heat pumps, it decreased the savings from air source heat pump consumption in the model to something lower than what the rest of the region was reporting at the time. Hopefully, it means that we are in a nice place right now, but we will keep tracking it.

Courtney said that we took a quick look at that as part of our planning work to get to this point. But that is the “more analysis required” part of what you see on the slide. That is what we were thinking about when we wrote those words. So, we will do something more in-depth on that topic.

A Changing Market: New DHP Configurations



Courtney moved on to the next topic. The Res HVAC market is changing and offering new pieces of equipment and doing new stuff with equipment that we thought we already understood. What we see in the preliminary RBSA data and NEEA’s 2021 HVAC sales data is that we see fully ducted mini-split configurations. That is the compressor unit that we would expect to be hooked up to a ductless heat pump head is now actually connected to a whole home ducted system, whether that is electric or gas furnace or simply an air handler that pushes the air through a whole home duct system. For the first time, this is a configuration that we see in the data.

We are talking to programs about this configuration. It has been interesting to hear opinions. Some programs categorize this as a variable speed heat pump — part of a broader category where the direction of the discharge (horizontal or vertical) does not matter, it’s a variable speed compressor, so we will treat it as a variable speed heat pump. Others consider it to be a ductless heat pump but with

duct losses and fan energy consumption. So, we are going to be looking more closely at this configuration of equipment to find utility program evaluations for other energy consumption estimates. But we want to start with this group.

Do you know of any program evaluations or energy consumption estimates for the fully-ducted mini-split configuration?

Tina asked for clarification about what we mean by fully ducted mini split configuration.

Courtney said that we are trying to be very specific about these categories of equipment. The outdoor unit, the compressor, is a horizontal discharge compressor like you see on the slide below.

It is variable speed, but it is distinct from the vertical access/vertical discharge systems that we traditionally see hooked up to a whole home ducted system. What we see now is that these horizontal discharge units are being connected to the whole home duct system, and that is a configuration we do not have a UEC for.

Bretnie added that it could be the slim ducts that has got a fan so that it is almost non-ducted but it still sends it to different spaces in a home. It could be that you are replacing an electric furnace and a gas furnace and taking that outdoor unit and ducting it through a fully ducted home with an air handler. This is something we came to this panel two years ago at the beginning of the last model, and people said, "is this really happening?" People said yes, it's coming. But now it's here, so we are trying to understand how these systems actually operate in the field.

Tina commented that it is not really a mini-split configuration. That is what is bothering her.

Bretnie replied that the mini-split is still the outdoor unit, but it is ducted in the home, so it is different from the traditional air source heat pump.

Courtney and **Christian** noted we may need terminology alignment.

Joan said that we have to marry the granularity and categorization we see in stock data and sales data with our UECs, and we have to match those. What we've been doing with the sales data is we would just categorize these as ductless heat pumps (DHPs); we would not categorize them as variable speed, centrally ducted air source heat pumps. She does not think that is adequate anymore.

Bob Davis said that he does not think the horizontal discharge terminology is helpful. In doing very recent fieldwork, most of the major manufacturers have a horizontal discharge heat pump with a DC compressor and a variable capacity compressor (e.g., Trane, Daikin, Mitsubishi) and that goes with a ducted system. He thinks that the system we discussed earlier is a ductless outdoor unit, similar to what he has at his house, with flare fittings and is connected to a fan coil that has raised fittings. You can pair it with a gas furnace; you can pair it with a different fan coil. It actually has what appear to be ratings for different indoor coils and furnaces. He does not think the ratings are any good, but it has ratings. What the main divide is, is does it have a DC compressor in it, does it have ducts? Yes or no. Because the duct effects, in real life, will overwhelm even the most nominally, the most earth-shatteringly efficient system ever sold. That is what really matters.

Bretnie added that what we want is data on that.

Bob said he has it at his house and he is extremely disappointed.

Courtney added that we appreciate that feedback. To provide some clarification about the mini-split, we were trying to get away from ducted/ductless mini-splits, which is an even worse set of terminology. We were trying to move towards horizontal discharge because that is a little clearer. He said that Joan's point is really important. We are not just doing stock-to-stock where we know what the duct system is connected to, we are seeing this equipment in the sales data, and we have to assign it to a configuration for the model. We do not necessarily know if this specific piece of equipment is going to

be connected to a ductless or ducted system. That is why we need the saturations of this and a separate UEC for the consumption.

David added that most of what Bob said is what he was trying to get to, and he has actually been doing the work. The main thing is, when we get to these fully ducted systems, we also have to get to a fully sealed duct system. If we don't, as we saw in variable speed equipment that was evaluated 20 years ago, it's a 50 percent reduction in the coefficient of performance (COP).

Mark said that he had the same comment as Dave and Bob. There is a lot of different applications out there and it is a growing trend. He thinks he saw the first one in 2017. It was a fully ducted outdoor mini-split unit that replaced an electric forced-air furnace indoor unit. They are out there, and they are growing.

Bretnie added that if anyone has data about performance or energy consumption of these types of systems, that is what we are looking for here.

A Changing Market: Increasing VSHP Adoption

Courtney moved onto the next topic. We continue to see an increasing level of adoption in variable speed heat pumps (VSHPs). We know there is a lot of research on the benefits of VSHPs and we will do work to inform the UEC and work with this panel to come up with the best UEC for this equipment.

 We will discuss any changes to UECs with the panel.

Question 4: What are the Program Savings?

Courtney continued with question #4. This falls back into the category of "same model, new data." Because we have an established model, there is no change to program savings approach. We will update with the most recent savings data available.

Planned Panel Engagements

Courtney began to wrap up the meeting with an overview of the upcoming planned panel engagements. Internally, we break up the plan into three work periods. The first is before we have access to the RBSA. We are going to take care of as much non-RBSA business as we can like making decisions on UEC structure and other non-RBSA factors such as housing, new dwelling units, etc. We will engage with the panel on all new and altered UECs, and we expect to have additional targeted engagements with specific individuals about detailed topics on which they are experts and conduct various desk reviews on their work.

When the RBSA arrives in late summer/early fall, we will begin RBSA analysis, determine stock-to-stock progression of equipment saturation to determine baseline equipment saturation and project forward. We will also look at the history of weatherization activity. And we will also update the model code. We expected at least two expert panel sessions on our RBSA analysis and other targeted engagements and desk reviews.

Finally, we get into the modeling period where we actually generate Interim Model forecast results. That will result in an expert panel session in spring of 2024. The next 12-15 months is when most of our engagements are expected. We will still be working on documentation, QA/QC, and there may be some more documentation reviews and desktop reviews at that point. Our work will be wrapping up the Interim Model at that point.

Joan added she thinks it is safe to say that we want to do all the work to update model inputs and update the model code to receive those inputs before the end of this calendar year. The rest of this year, the next 6 months, will be a pretty heavy workload for the BPA. Towards the last quarter of this

year, we will be reaching out to the panel quite a bit. If you have any concerns about that time period or bandwidth, please be proactive and reach out to Tyler and Lorre and we will work around your schedules.

Bretnie asked Christian if he had any early data on RTF measure updates for air source heat pumps that he wants to share before the RBSA.

Christian said that he does not, and that he does not think he will be working on that data either.

Continuous Market Research

Courtney briefly mentioned that in addition to a savings forecast for 2022-2027, the other goal is the plan for continuous market research. In the previous iteration of the model, the three research topics that we addressed are shown below:

Joan mentioned that we threw out these three topics that were already on our minds in terms of market research that we are considering planning to conduct over the next few years. We welcome your feedback and if you have any additional ideas for other areas of the market, we would love to hear them.

Next Steps

Tyler reviewed next steps. After this meeting, we will email the slide deck along with a workbook that includes the questions we highlighted throughout the panel today. If you have written feedback or ideas or comments, we would love to have that feedback so we can document them and follow-up.

There will be future engagements and a few targeted desk reviews over the summer and another panel like this late/summer early fall and another one towards the end of the year.

Your input and feedback and guidance is valuable and really does make the process better. Thank you for joining us today.

Working Session: RBSA III HVAC Equipment Analysis – March 21, 2024

ACTION ITEM – This highlights an action item for a panelist.

ACTION ITEM – This highlights an action item for BPA and/or Cadeo.

Attendees

BPA: Joan Wang, Bonnie Watson

DNV: Tyler Mahone, Lorre Rosen

Cadeo: Courtney Dale, Bretnie Eschenbach

Panelists: Ryan Brown (NEEA), Mark Jerome (CLEAResult), David Baylon (Independent), Mitt Jones (Cadmus), Nathan Kelly (BPA), Jonathan Moscatello (Daikin Comfort Technologies), David Bopp (RTF), Christopher Dymond (NEEA)

Unable to attend: Christian Douglass (Council), Mike Psaris (NEEA), Chris McKinney (Airefco)

Introductions

Tyler walked through the agenda and introduced the panel.

Working Session Agenda

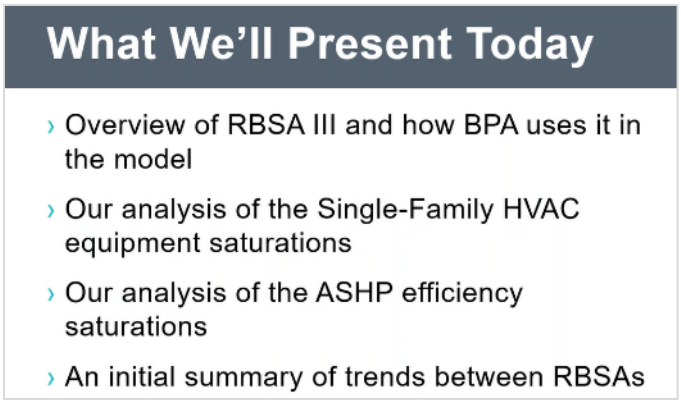
- Introduction (5 min)
- Today's Session Goal (5 min)
- Model Overview (20 min)
- How we use RBSA data
- RBSA SF HVAC Equipment Analysis (45 min)
- Equipment saturations
- Mapping to model cells
- Efficiency saturations
- Filling data gaps
- Zoom Out & Next Steps (5 min)

Joan discussed the purpose of the panel and reviewed the goals for today's working session. The Residential Building Stock Assessment (RBSA) is a regional study that is conducted by NEEA every 5 years. It is one of the most important resources that the Northwest region has tracking of how the residential building stock changes over time and how that impacts energy consumption. The RBSA will be published in April. Our team has been engaged with NEEA throughout the study, along with other funders of the study, to review and provide guidance on how the study is running and review the dataset along the way. We are using the draft final data for today's analysis and presentation.

Dave Baylon asked if Joan could summarize what the constraints were, what years are you looking at, and how were you stratifying or dividing up the sample across the region? **Joan** replied that the latest RBSA is based on site visits conducted in 2022 and covers all of the Northwest region and is divided

into seven geographic regions. There is also a layer that separates between BPA and non-BPA. We also had a stratification of between urban and rural. The study includes single- and multifamily. The study does not include a separate manufactured home study. BPA's analysis of the RBSA study is at the regional level. **Tyler** added that the RBSA is a bigger study that this modeling effort is using. The RBSA report is coming out in a month or so and that is where we can dive into that methodology.

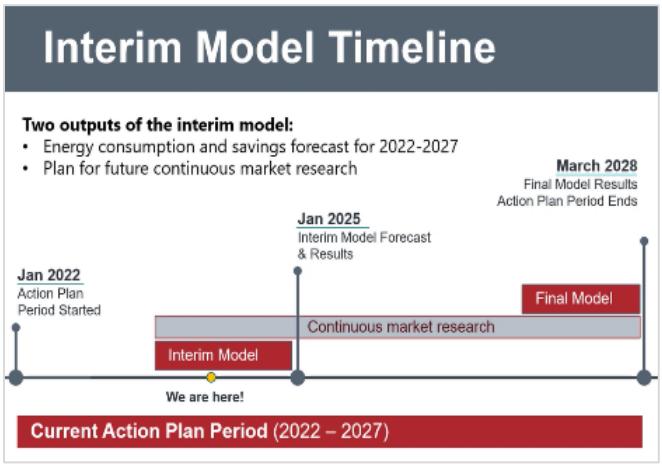
Joan continued. Because the RBSA is such an important input to our model, we want to show you everything we did with the data and then we can look at some interesting results together.

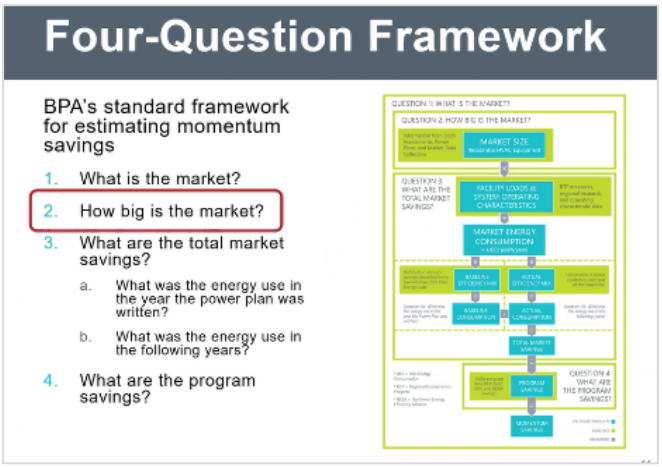


Joan reviewed the specific items that will be presented. Today, we are just going to talk about single-family data today, no multifamily or manufacturer homes data. What we will see in the results is the comparison of results between RBSA 2022 and RBSA 2016/2017 and RBSA 2011/2012.

David Bopp said I'm assuming that in the database there are identifiers for multifamily manufactured homes that you used for the screening. **Joan** replied, yes.

Overview of ResHVAC Model





Joan explained the interim model timeline and reviewed the four-question framework. We are currently updating the existing model for the new Action Plan, which is from 2022 to 2027. Our current model phase is called the Interim Model. We are updating the model so that we can get a forecast of model results for the 2022 to 2027 plan. After 2027, we will finalize the model. Keep in mind that everything that the interim model is doing is developing that energy consumption and savings forecast. The four-question framework is the framework that our market models follow to produce energy consumption and savings estimates. The RBSA data helps us determine how the Res HVAC market is segmented.

Overview of the RBSA

NEEA conducts regular building stock assessments

- RBSA conducted by NEEA every 5-6 years.
  - 2011, 2016, and 2022
- 2022 Assessment Scope:
  - Single family
  - Multifamily
  - No manufactured home study
- Current Status
  - Data reviewed by RBSA Workgroup
  - NEEA plans to publish in April
  - **Not final; do not share**

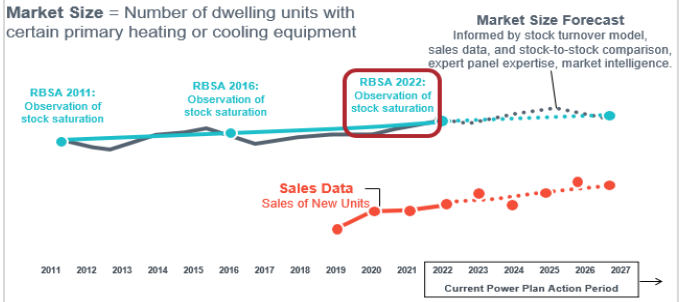
RBSA III is a critical data set for the model

We use the RBSA III to:

- Update 2021 baseline HVAC saturations
- Calibrate the 2022 HVAC stock saturation to RBSA III
- Update building shell conditions (not covered today)
- Potentially use new billing data to calibrate UECs (in future model update)

Courtney discussed how the RBSA provides critical data for the model. We use the RBSA for a number of different things. In our calibration process, sales data from NEEA shows us changes in HVAC equipment coming into the market. It is helpful to have a data source in 2022 where we have a picture of that stock. We also use this to set the baseline of the model. We are tracking energy consumption changes relative to 2021, the baseline of the power plan action period. At a later date, we will also dig into the building shell analysis that is captured in the RBSA. And then further in the future, we will potentially look at the RBSA billing data and consider changes to our UEC values.

RBSAs guide the stock turnover model



Courtney continued. I talked quickly about calibrating the stock turnover model and this is an illustrative chart that shows RBSA 2011 that set the starting point of the stock saturation. As we take equipment in through the sales data, take equipment out through retirements, we track the market through the years to 2016. We make sure that we hit the 2016 RBSA saturations and then we do that again with the 2022 stock saturations. From that point, we will make a forecast.

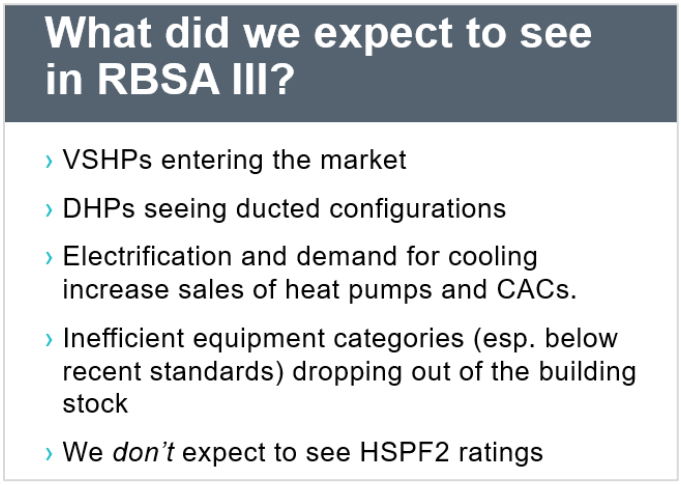
What's new in RBSA III?

Related to single-family HVAC equipment data:

- Structure of the data – primary system designation
  - In RBSA 2016, NEEA did not use a technology hierarchy for assigning a single primary system
- Large percentage of "unknown" HSPF values
- *Some* manufactured homes are included in the single-family sample, but were not specifically recruited

Courtney covered a few observations of what is new in the RBSA that is relevant to our model. NEEA's report will discuss other observations and nuances in the data, but we will cover some that are relevant to our own model. The structure of the data is a little bit different in terms of the primary HVAC system designation. In this round, NEEA used a technology hierarchy that matches the way that we have done in our analyses of previous RBSAs. Another finding for this RBSA is that there was a large percentage of unknown heating seasonal performance factor (HSPF) values for centrally ducted heat pumps. Also, there were some manufactured home observations in the single-family data that we have filtered out.

Dave Baylon said that the large percentage of unknown HSPF values is fairly concerning. Does that level of unknown reflect our ability to understand any details about the heat pump, like variable versus single-speed, or about the controls or anything like that? Unknown for HSPF can be recovered from, but unknown from a lot of those things you cannot. **Courtney** replied that we do not use RBSA data in that way to calculate UEC of heat pumps. We do not have to model the number of tons or control the number of stages for the purposes of the model. But the RBSA data does have good coverage on indicating whether the heat pump was variable speed or not. **Bretnie** added that the RBSA collected a range of values associated with each equipment type. Some are very robust in what information they provide, variable speed or not, and others, when you get more granular like HSPF, have more missing values.



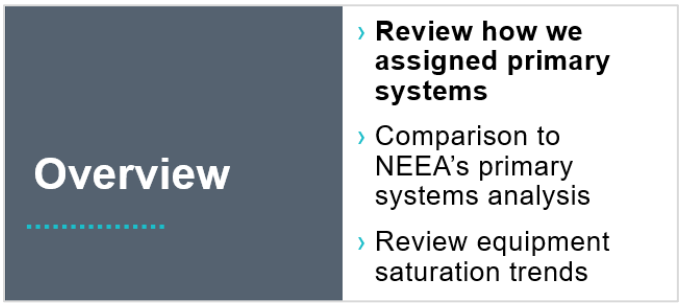
Courtney continued. I want to talk about what we expect the RBSA to tell us about what's happening in the market. [See slide]. Somebody always asks us how are you dealing with HSPF2? And in this case, we are not because this data was pulled in 2022 before HSPF2 was law.

David Bopp asked a question. The ductless heat pump piece you have on there, you're not talking short duct on ductless, right? You are talking horizontal axis heat pumps that are going to the full duct setup. **Courtney** said, yes.

Mark added that they do not publish the HSPF numbers on indoor and outdoor units, and it varies based on indoor and outdoor unit combinations. And we are never going to get that number without doing a significant deep dive into model numbers of indoor and outdoor units. We do not have a lot of package units in residential homes. **Joan** added that what is cool about the RBSA stock data is that we do get to know the combination of indoor and outdoor, which we do not get from the sales data that we also use in the model. There are a lot of unknown HSPFs in the RBSA data, but the RBSA captured a lot of model numbers and so it is a matter of finding the additional information using the model matching. **David Baylon** asked a question. So, you actually do have the model numbers? **Joan** said yes.

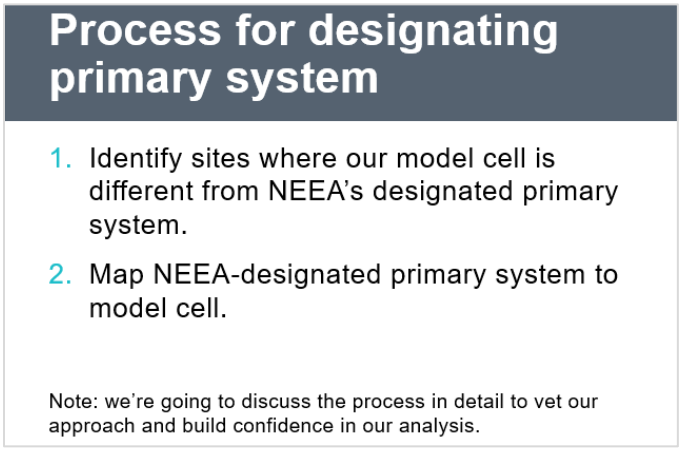
RBSA SF Analysis on Equipment Saturations

Primary System Assignment

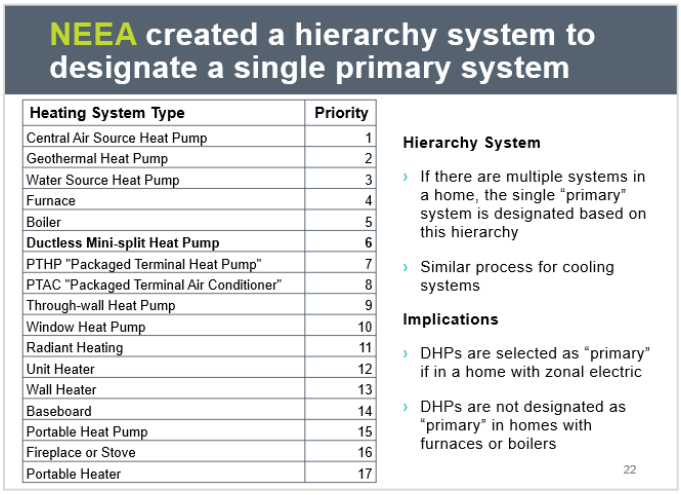


Courtney continued. In this section, we are going to talk about how we assigned the primary system, which is important because our Res HVAC market model only tracks the primary system and models energy consumption of the primary system in at home. It is important that we have a robust methodology to determine which is the primary system. A lot of homes have multiple HVAC systems, and it can get confusing. **Joan** clarified that the model estimates the heating and cooling energy consumption for the entire home including secondary systems. But the way we estimate that energy consumption is based on the assigned primary system. We are not only looking at the

consumption of the primary system, but also for the whole home. **David Baylon** asked if we also have an estimate of off grid heating either in the RBSA or in the model? **Bretnie** asked if you mean, for example, fireplaces? Yes, that is accounted for in the model. It is factored into the total home consumption. **Courtney** continued. Our UEC considers non-electric heating that occurs in the home. After we talk about assigning primary systems, we will compare our primary systems to the NEEA primary systems and then we will talk about what is going on in the market through time.



Courtney continued. The process here starts with looking at NEEA's designated primary systems and seeing where our model has a different designation.



Here is NEEA's system or logic for designating the primary system. Basically, if a home has two HVAC systems, the one that occurs highest on the list is the primary system. Air source heat pumps are at the top, then you have the furnace boilers, DHPs, and then it gets into more of the zonals towards the bottom. For example, in a home with a ductless mini-split, if that home has baseboards, NEEA has designated that as a ductless mini-split home. If that home has a furnace, NEEA has designated that as a furnace primary system. I'll just add that this is a new process compared to the last RBSA (2016) where you could have multiple systems in a home, and they are all designated as a primary system. **David Baylon** asked a question about NEEA's process developing this hierarchy. **Tyler** replied that there is a working group on the RBSA, and we won't dive into detail there. **Joan** added that this is an improvement on NEEA's part in trying to designate that primary system. NEEA worked with the RBSA worker group, which is composed of technical experts from funders of the study.

ResHVAC Model equipment bins

We need to sort RBSA sites into ResHVAC model cells because:

- NEEA's categories do not always align with the model cells
- We split DHPs into
  - DHP w Zonal
  - DHP w eFAF
  - Full DHP
  - VSHP-H (ducted minisplit)
- Sometimes we aggregate multiple HVAC types into a single model cell

End Use	Equipment	Efficiency Tier
Heating	DHP	DHP eFAF
		DHP Zonal
		DHP Full
	ASHP	
	FAF Electric	
	FAF Gas/Other	
	GSHP	
	Zonal	

Courtney continued. We need to sort the RBSA sites into the model cells for many different reasons. NEEA's categories do not always match with the model cell, and NEEA's logic does not always match with the model's designation logic. We want a higher degree of visibility into what type of equipment DHPs are installed with for our market model. In a number of other instances (like for some non-electric zonal heat equipment), we aggregate multiple of NEEA's primary systems into a single primary system.

The ResHVAC model has higher resolution on DHPs

- For DHPs, the ResHVAC model includes multiple configurations.
  - 13 (of 1,910) RBSA sites were recategorized. They do not meaningfully change saturations.

NEEA Designated Primary Heating System	NEEA Secondary Heating System	ResHVAC Model Primary Heating System
Furnace – Electric	Ductless Mini-split Heat Pump - Electric	DHP || DHP eFAF
Ductless Mini-split Heat Pump - Electric	None	DHP || DHP Full
Boiler – Electric	Ductless Mini-split Heat Pump - Electric	DHP || DHP Zonal
Ductless Mini-split Heat Pump - Electric	Electric Baseboard	DHP || DHP Zonal

25

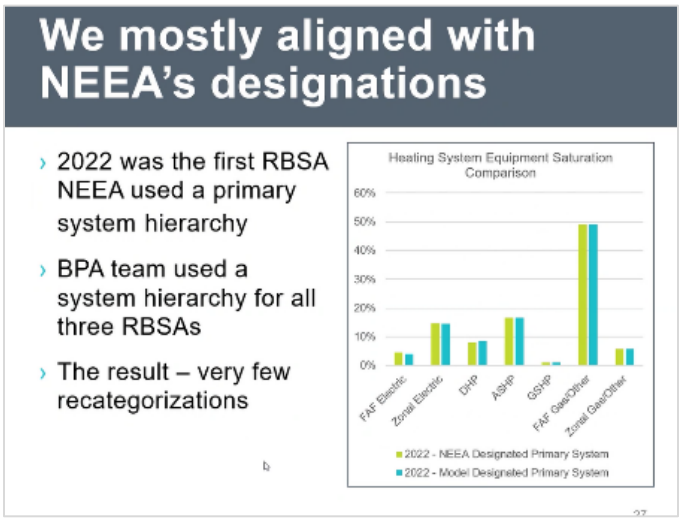
Courtney continued. For DHPs, the Res HVAC model has a higher level of resolution in terms of what the primary system, or multiple pieces of equipment, are part of the primary system designation. The model likes to differentiate between DHP that have an electric force air furnace, DHPs with zonal, and DHPs with no backup or secondary electric fuels. As we saw in the NEEA designation above, when a home has a DHP and an electric forced air furnace, NEEA will identify the furnace as the primary system. So, we recategorized that as DHP with an eFAF. The same process goes with an electric boiler that had a DHP installed as well: NEEA designates the electric boiler as the primary, but we changed it to DHP with zonal electric heat. The last example is a mini-split with no secondary heating system, so that it becomes DHP full.

Nathan asked about the first line on the table. That could be a system, like the whole house has an air source furnace, or air source heat pump, or just an electric furnace and then maybe an upstairs bedroom has a mini-split heat ductless heat pump. Does that fall under that first category And if so, would that really be a primary ductless heat pump heating system? **Joan** said that this "Furnace – Electric" is NEEA terminology. That is an eFAF. It does not include an air source heat pump. In that case we are assuming, if a house has an eFAF and a ductless heat pump, then we assume that the ductless heat pump is the primary system, and the UEC captures both. **Bretnie** added that this is where there is an RTF measure that is DHP with eFAF that tries to capture these homes that have an eFAF and the DHP offsets some of that electric use depending on where it is put in the home. And it still has pretty high energy consumption, but it is a little bit lower than what it would be with just an electric furnace. It is tricky to say the DHP is the primary system because it is pairing them together, and we are trying to capture the energy consumption associated with both of those systems. **Nathan** said that he understands and would say that the eFAF still would be the energy driver of the house in those situations, right? And DHP would be there also. **Bretnie** added. Our UEC does reflect how much energy that home uses. It is still pretty high consumption from the electric furnace, and the DHP with electric zonal is similar. It is a little bit less than it would be without the DHP because it is displacing some of that electric resistance heat.

David Bopp said that I am assuming that the location of the DHP was not in the database. You could not rule out ones where the DHP was in a bedroom in these scenarios. **Courtney** said that we did not

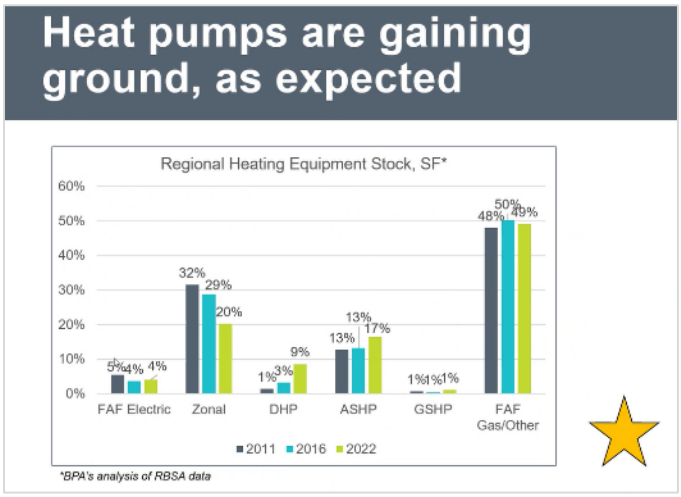
do that. **Joan** said that she thinks the data is there, but we did not go into that detail. **David Baylon** said that we actually looked at this early on in the DHP process, maybe 10 years ago. When this case occurs, there is somewhere between a 30 and 40 percent chance that the DHP is primary always. And there is a mix of conditions thereafter about 30 percent that it is never primary, and then there is a mix for the for the remainder. I think that given we do not care about what the saturation of electric furnaces is except that there is a historic curiosity that doing it this way is a more reasonable way for purposes of this model to understand the DHP. **Bretnie** added that it has historically been a program measure. That is one of the reasons it is a segment in the model. **David Baylon** added. If that is the reason, it is a program measure because it often turns out to be primary.

Comparison to NEEA's Primary System Assignment



Courtney continued. Compared to NEEA's original primary system assignments, we made 13 recategorizations. Our reassignments in the 2022 RBSA did not result in very different saturations of equipment or designations of primary equipment compared to NEEA's original data. It has not always been true with previous analysis of the RBSAs, but we were very happy that it is true in this round.

Review Equipment Saturations Trends



Courtney continued. The trends from comparing across the 2011, 2016, and 2022 RBSA are what we expect to see when programs are trying to increase adoption of air source heat pumps and ductless heat pumps. We see both of those categories gaining ground. The combined gas and electric zonal systems are decreasing over time. Gas forced air furnaces are decreasing slightly. Electric forced air furnaces remain a small part of the region's heating systems and are decreasing a little bit.

Chris Dymond said I would love to know total numbers as well. I think eFAFs are 300,000 and gas FAFs are 2.5 million. Does that sound right? **Courtney** said 2.5 is about right. We used percentages in the model. **Bretnie** added that the final output will include quantities.

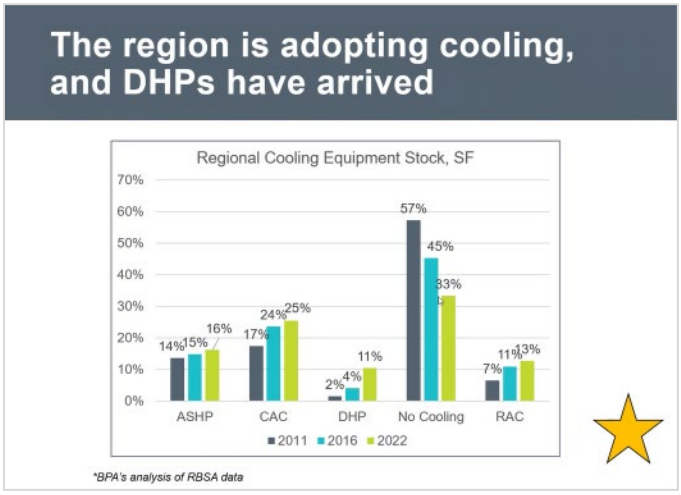
David Bopp added. I was just curious to see a breakdown of newer homes versus older homes over the last five or seven years in the sample versus previously and see how it looks different. But that may not be necessary for your model, in which case, I will see it eventually.

Mark added that this is slightly looking backwards but looking forward I can see that this is going to be an ever-changing slide as we progress through the years. Air source heat pumps are going to continue to grow, gas is going to go down a little bit, DHPs will go up a little bit, and hopefully eFAFs will go down. No real big surprises here.

David Baylon added. What we are doing is playing with the electric heat margin. Thus far, there is no impact on the selection of gas furnaces or the use of gas furnaces in the region irrespective of our attention to heat pumps and DHPs and whatnot. I will be interested if it ever does change. That is interesting and probably driven a lot by programs. It is reassuring that you can be effective. It would be more reassuring if it changed something in the gas furnace, but it did not. **Bretnie** added that maybe we will see that in the next RBSA.

Mark added. It is so hard to determine what someone would call a water source heat pump versus a geothermal or ground source heat pump. I assume that we are dropping all those together in the same bucket. **Courtney** replied yes, and that is the ground source heat pump that includes geothermal and water source.

Jonathan said that he would like to see dual fuel as a heating product category. I am looking ahead to the future, and I think a lot of the manufacturing community wonders what the role of dual fuel is going forward. Some people see the Northwest region as a place where there is a good presence of dual fuel gas and heat pump heating. But it would be great to see some data to support that and track it over time. **Bretnie** said that is a great point. Something that we have thought about each time we update this model is if it needs to be a separate designation. And we have not done that yet, but if we think that is changing over time, it might be interesting. **Joan** added that is definitely something that we can track separately in the model, starting now and look at in the RBSA. Currently, dual fuels would be included in the first category, labeled air source heat pump (ASHP) . But we can consider separating it out in the model and also just how we produce results. **Mark** commented. With the dual fuel piece, we are not going to have an RTF measure for that in the foreseeable future. We will see what happens as the next power plan gets put together. **David Baylon** commented. The heat pump with gas backup is in the Washington code and it gets a little more credit than any other gas system that might be in the Washington code elsewhere. In effect, there is a bit of an incentive to use that, especially if you are going to make a system that would otherwise trash the heat pump.



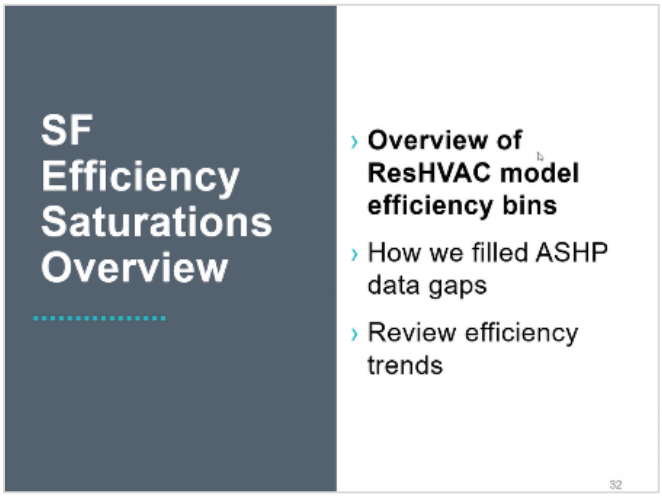
Courtney continued. On the cooling side, we expected the region to be adopting and adding cooling and that is what we see from 57 percent in 2011 down to just a third of homes do not have cooling in the region in in 2022. And then all the other technologies are increasing across the board because they are being added as the no cooling is dropping off.

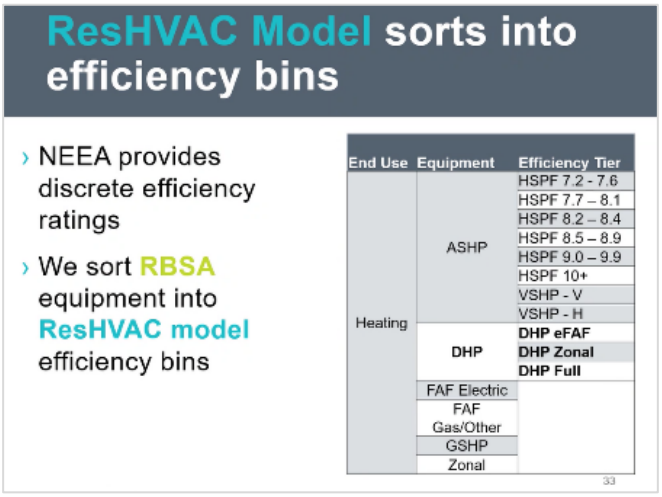
Jonathan added. A similar comment on the cooling slide would be there are regulations coming that, in the manufacturing community, are going to drive greater sales of something that looks like a ductless heat pump, but it is really a central variable capacity heat pump. I think they would not even show up today. But I think in the years ahead there will be more of those. It might be something to watch for future iterations or maybe begin to start thinking about how you would track that separately and report it. It might be interesting, especially if there are found to be different savings or characteristics of that product. **Courtney** asked if that would be like a mini variable refrigerant flow (VRF) or an outdoor unit that has a top discharge

variable speed heat pump but then has refrigerant piping to a bunch of different high wall heads throughout the home. **Jonathan** replied. I think that it would still be a DHP, but I think we are talking about an air source heat pump or a central air conditioner. But it has got the technology of the DHP, the variable capacity nature. It would still hook to duct work and be a central system, but it is a blend of technology. **Courtey** asked. So, it looks like a DHP on the outside of the home? **Bretnie** said. That is one of the topics that we came to the panel about last year, about exactly how we should structure that. So, that will be something that we can report on. **Joan** added that we did not used to track those in the data and now we have separated out those horizontal discharge mini-split units that are used in whole home heating and cooling. We have actually recategorized those from DHP to air source heat pump because that is what they are used for. We are separately tracking that as an efficiency level. **Mark** said that once you get some ducts attached to it, it acts more like an air source heat pump than it does a DHP.

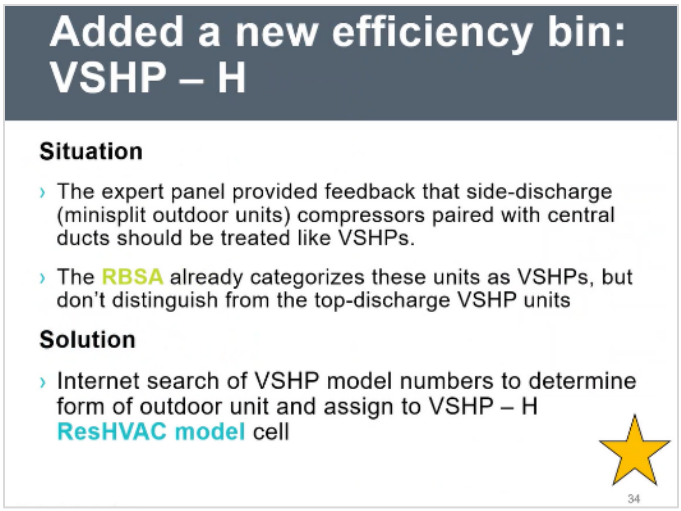
RBSA SF Analysis on Efficiency saturations

Overview of ResHVAC Model Efficiency Bins





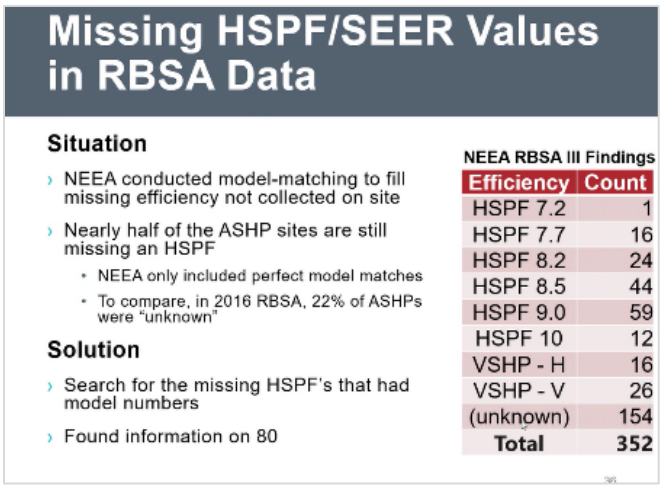
Courtney continued. The ResHVAC model efficiency bins are shown here. For air source heat pumps, there are a handful of different efficiencies. We do have an efficiency bin for variable speed heat pumps, which have now been split out into “V” meaning vertical or top discharge and “H” meaning horizontal or side discharge. The RBSA has data on HSPF rating and SEER rating on the cooling, and we throw that into the appropriate bin and create efficiency bins.

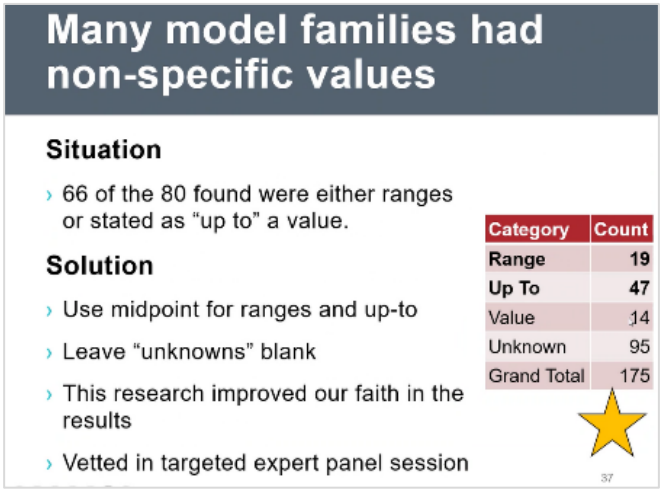


Courtney continued. Digging into the detail on the VSHP-H model segment in the sales data that we intake and in the RBSA, we saw that there were some outdoor units that look like what we have historically thought of as a DHP, but the mini-split outdoor unit would be connected to a coil in an air handler that goes through like a whole home duct system. NEEA categorized these simply as variable speed heat pumps. We searched through all of the identified variable speed heat pumps and figured out which ones look like mini-splits, and then we categorized them as "H". The energy consumption level is identical to the VSHP-V category. We are using these two different model segments so that we can appropriately sort the sales data that we see in the future. And we think it is interesting to see this emerging configuration. **Joan** added that if further research shows that we should be using a different UEC estimate between horizontal and vertical discharge variable speed units in the future, then we have the ability to do that. For right now, we are using the same energy consumption estimate for both of these. **Mark** added that there are some differences. I think that one thing that is not well known about these vertical versus horizontal discharges is the big separation between what we would consider a conventional type of system, whether it be variable speed or not and a ductless system is the location of the outdoor expansion device, which is not something we can like look at and determine right away. But the location of that expansion device is really what dictates whether it is the mini-split variety or a conventional type of variety regardless of variable speed. On a mini-split variety, the indoor expansion device is in the outdoor unit; on a conventional system, the indoor expansion devices on the indoor. So, there is a definite separation there. The compressors could be slightly different, which might give you some variation of efficiencies and UEC. But it is like trying to determine this and setting it up as V versus H, you may have some that do not perfectly line up, but I think this is like a good attempt to try to get to something that's extremely difficult to figure out. **Jonathan** added. The technology does not have to be side discharge outdoor unit. I think the differentiator is that these are digitally controlled variable speed systems. Mark brings up a good point that some manufacturers locate some components in different places. But I think one thing they all have in common is that there is an inverter program that varies the speed of all the various components in it. NEEA has settled in on variable speed heat pumps. **Chris Dymond** noted that the vertical / horizontal is getting muddled. I think it is informative, but we are starting to see the term mini-split no longer really applying when it is a gargantuan mini-split. It is no longer mini at all, and we are starting to see vertical discharge having behaviors a lot like mini-splits.

David Baylon said that I thought we were talking about the nature of the ducting system, not the nature of the discharge. I think that these are largely irrelevant to the actual outdoor unit discharged. But the indoor unit is a fairly relevant point because the minimum low-volume air handlers are usually buried in soffits and places like that, and without exterior ducts. With variable speed heat pumps, but especially the DHPs, they typically continue to operate at very low speed and pressure despite the status of the thermostat. Which means that if you have outdoor leaky ducts, they are continuously operating as essentially a leaky system. Chances are good that we are not going to do anything about that unless we bring the ducts inside. And I do not know if they are or not, but it is the relevant point to overall efficiency. **Courtney** replied. That is reflected in the variable speed heat pump energy consumption. The variable speed UEC is higher than an unducted configuration of a DHP. If they are all inside, it should not make a difference to the overall UEC. It is only when you actually have conventional duct systems running through the attic and crawl space.

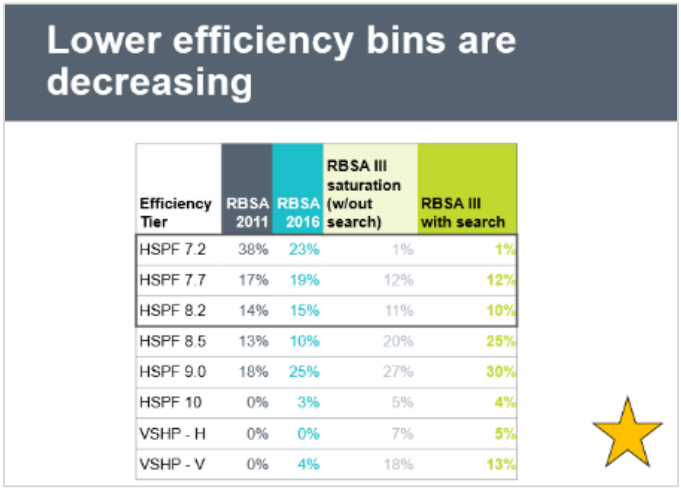
How we filled ASHP data gaps





Courtney continued. Here is the number of sites that were sorted into the different bins, and 154 of these sites had an unknown HSPF value in the raw data. Compared to the 2016 RBSA, only 22 percent of the HSPFs were unknown. So, we searched the model numbers online to attempt to fill the missing HSPFs, which was challenging because some model numbers were not recorded correctly. They did not match to the AHRI database entry. We only found information on 80 of the 154 sites. Fourteen of the 80 that we found had a discrete value listed that we could identify and match to that model. For the rest, we found a bunch of different sizes of model and then different HSPFs depending on the indoor equipment. So, these were either ranges or more commonly "up to" values, e.g., up to an HSPF of 9.3. We solved that for the range by choosing the midpoint. It is probably the most representative of the different models that are being installed and different configurations of indoor equipment. For the "up to" values, we used that same delta between the high point and the midpoint of the range to decrement the "up to" values. We talked about this with a subset of this panel (Christian Douglass from Council, Laura Thomas and Dave Bopp from RTF, and Mike Psaris and Brandon Giatti from NEEA), and they agreed with our methodology. We did some additional work to vet our approach, really running down some of those "up to" value models. Ultimately, we feel good about our approach and that this research really improved the results that we are seeing. **Mark** said that sounds right. I've seen the nice little yellow label on the side with ranges and "up to" points. I tried to make some determinations at one point in time: Is it variable speed that does this or is it two stage or what? I never came to a consensus of what it meant. It may be just digging through AHRI and figuring out if there is a different test procedure that leads to this. **Jonathan** added. I think the only way you can ever know is through looking at AHRI and finding those model combinations there. Otherwise, there are a lot of publications that even we put out as manufacturers that use that "up to" value. And the only way you can get that definitive answer is through AHRI. Is the RBSA used at all in creating baseline for saving any measures anywhere? I cannot remember if the RBSA serves more understanding the market and how transformation takes place. **Bretnie** replied yes, I think so. **David Baylon** replied. We do not have plan B, RBSA is where the baselines come from. **Mark** added. It is basically what is happening in the marketplace, which is kind of what this is getting to. Our baseline is not necessarily the federal minimum. It is what is being sold in the marketplace, and that is what dictates where our baseline sits. **Jonathan** added. I just get a little anxious when I see the kind of methodology that isn't going to the AHRI database because I think you don't know unless you go there. In other markets, manufacturers are under a tremendous amount of pressure to increase efficiencies very quickly. When we have assumptions in some of the foundational research, it opens up a lot more questions and uncertainty. **Ryan** added in the chat: The efficiencies from the sales data does reference the AHRI tables. **Joan** added. The RBSA site auditors directly noted down what the efficiency was if they could see it on the unit when they go do the audit.

So, that is very accurate. Sometimes they did not do that, and NEEA did a huge model matching exercise to get that information using the AHRI database by matching to model numbers. The result of all of that is that we are still left with half of the heat pumps with unknown HSPF. We did not want to leave it there, we wanted to see if we could fill any additional ones by doing a more robust Internet search. There are layers of how we can get the real truth. This is as far as we are comfortable taking it, in terms of what we are presenting here today. What I think is great about doing this exercise was we wanted to see if the unknown bucket is somehow biased towards older models or if they are creating some sort of bias that would make us not confident about using the rest of the data at all. I think the conclusion is that actually there was not a lot of bias in the unknown category.



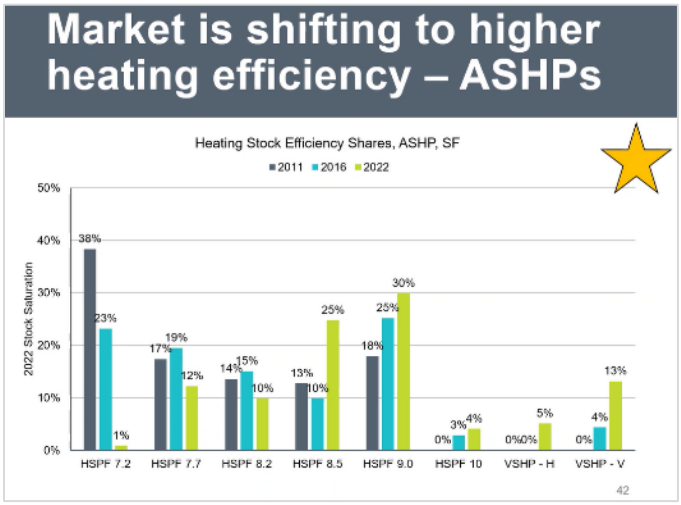
Courtney continued. The results here indicate that the search makes us feel even better about the saturations within each of these efficiency bins, and we continue to see the effect that we would expect in the market. The lower efficiency bins are decreasing, the mid-tier bins are increasing steadily, and the variable speed heat pumps are coming quickly. **Joan** added. If you look at the difference before filling the missing gaps and after, the results do not change that much. This makes me feel really good about our understanding of the stock using RBSA 2022. **Mark** added. I would see 9.0 HSPF as a pretty high percentage. This does give me faith that what we have been trying to accomplish with momentum savings in this market model shows that we have actually influenced what has happened in the marketplace. Otherwise, I would not be seeing 9.0 be the top tier you as far as percentage.

Chris D. said I wonder if we can slice this with an eye on the federal tax credit threshold for HSPF. It is the equivalent of 10.6, which is an HSPF2 of 9. Can you speak about the ducted versus ductless split on this? **Courtney** said that we do not calculate DHP savings based on the HSPFs. We just focus on the backup secondary. **Joan** said that we are just focused on ducted units. **Chris D.** replied. So, all these models were ducted, even the, the horizontal discharge? Interesting.

David Baylon added. Looking at this table, I am a little concerned about the biases that you missed by not getting all of the heat pumps or at least not have been able to be unbiased about how you did that selection. One percent looks like a small number for HSPA 7.2. My guess is that many of the ones you did not get were actually in that category. Those almost 20 years old or older, so there is a good chance that half of them went away by themselves or just wandered off. But the degree to which it dropped between RBSA II and III looks a little bigger than you would expect. And that would change how these saturations would go as you move into the model. Hopefully there is a way to recover some of that. But if you have a model that you cannot figure out because it is so old that the last RBSA or the last AHRI isn't available to you, maybe there is another solution. **Courtney** said that was one of the reasons we did that Google search to fill missing gaps, to see if there were a bunch of those models that have been illegal since 2006 that had missing HSPF. And we couldn't fill them all, but we did not find very many of those older units [in the ones we filled], and certainly not nearly as many as the 9.0 category. **David Baylon** replied. I guess the question then is, so when you did that, did you actually assign 7.2? If you came to a heat pump that was installed and you did not know anything else about it, but was installed before 2005? **Bretnie** said RBSA typically did not include the install date. Sometimes it has manufacturer year, but that is as equally unknown as the HSPF value. So, the answer is no. **David Baylon** asked if you had the manufacturer's date. **Bretnie** said in some cases, but not all. And we were able to get the unknown values down from 50 percent down to 22 percent, which is the same

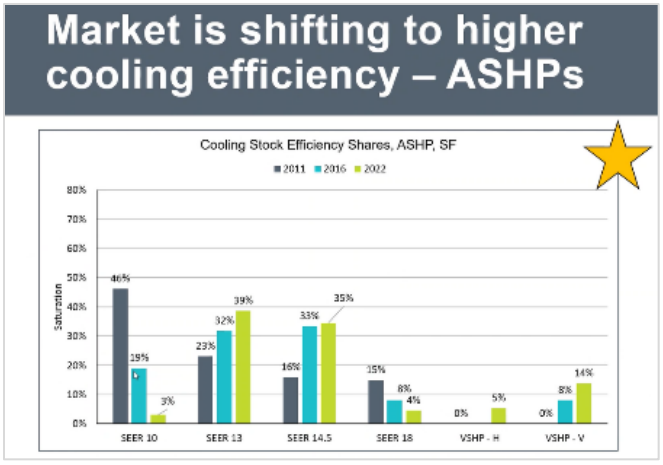
as what the RBSA II was. We feel pretty good that we are not missing a huge chunk of HSPF 7.2, and that number did not increase by doing our search. We felt good that we were not biasing the data towards that. **David Baylon** said still, that is a surprising drop. **Bretnie** responded. That was our biggest concern as well before we did this search, that we were missing a lot of those. But like you said, those have not been available for sale for almost 20 years. It makes sense that there are not many of them left in the in the stock.

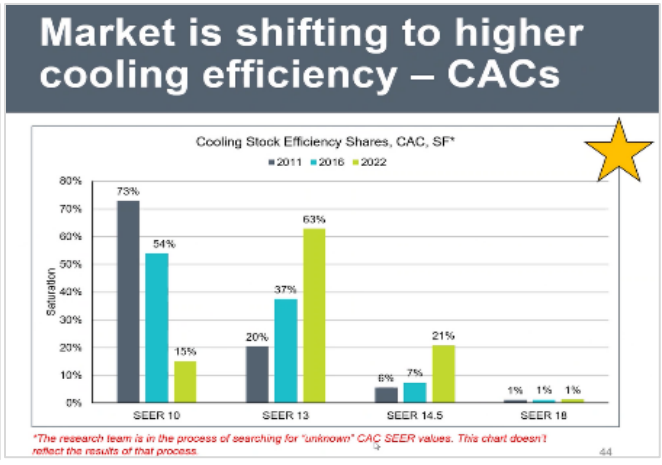
Nathan asked in the chat if these were HSPF or HSPF2. **Joan** replied HSPF. This is looking at what's in homes as of 2022, so HSPF2 is not yet in the homes.



Courtney continued. You see here the efficiency through time. That category of 7.2 is illegal in 2006. You would really expect it to fall off. There are some still out there, but those are 20 years old almost at this point. And then you see some of those higher HSPF increasing as those products are more available and people select them, hopefully through the encouragement of their utility programs. The other thing to highlight here is that variable speed products are really emerging in force.

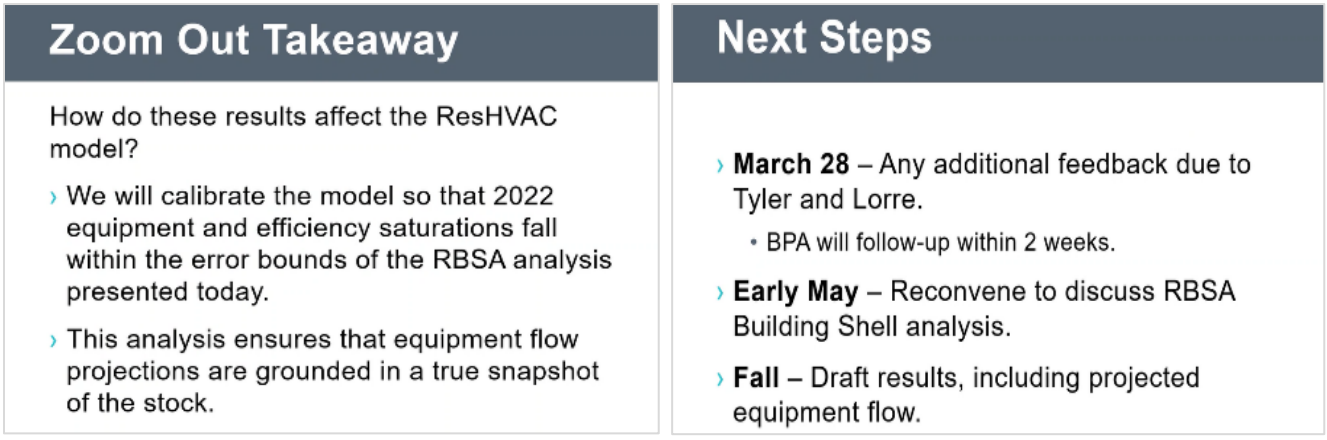
In the chat: **Christopher Dymond:** HSPF 10 = HSPF2 8.5 for ducted. Tax credit will likely be HSPF2 of 8.0 for ducted and ductless split systems**. Bretnie:** That's something we could report on in the final model results or maybe in the next round of sales data analysis - what percent of the stock is above the tax credit threshold. **Christopher Dymond:** 19 percent of current listed products meet or exceed the tax credit HSPF2 target of 8.0. Like number of unique listings, not sales.





Courtney continued. Looking at the cooling efficiency for air source heat pumps, you see the lower efficiencies are falling out of the market, the mid and higher efficiencies are increasing especially in the variable speed category. This CACs chart does not yet present the results of attempting to fill missing SEER values, but you see similar things from the air source heat pumps cooling efficiencies.

Zoom out and Next Steps



Courtney reviewed key takeaways. **Tyler** discussed the next steps.

Working Session: Building Shell Model Inputs – May 7, 2024

ACTION ITEM – This highlights an action item for a panelist.

ACTION ITEM – This highlights an action item for BPA and/or Cadeo.

Attendees

BPA: Joan Wang

DNV: Tyler Mahone, Lorre Rosen

Cadeo: Courtney Dale, Bretnie Eschenbach

Invited Panelists	Affiliation	Attended	Did Not Attend
Mark Jerome	CLEAResult	☒	☐
Abram Conant	Proctor Engineering	☒	☐
Bob Davis	Ecotope	☒	☐
Kevin Madison	PNNL	☐	☒
David Baylon	Independent	☒	☐
Nathan Kelly	BPA	☒	☐
Ryan Brown	NEEA	☒	☐
Christian Douglass	Council	☒	☐
Christopher Dymond	NEEA	☒	☐
Amy Burke	BPA	☒	☐
Blake Ringeisen	NEEA	☒	☐
Mike Psaris	NEEA	☒	☐
Jonathon Belmont	BPA	☒	☐

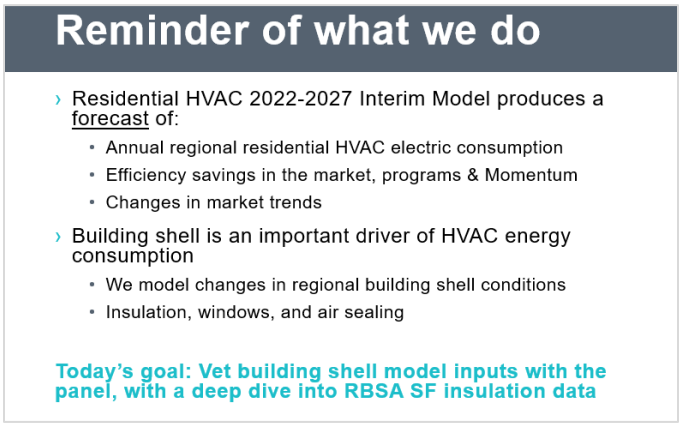
Working Session Agenda

- Introduction (5 min)
- Today's Session Goal (10 min)
- Building Shell Model Inputs (45 min)
- RBSA SF Insulation Data Analysis (45 min)
- Wrap-up and Next Steps (15 min)

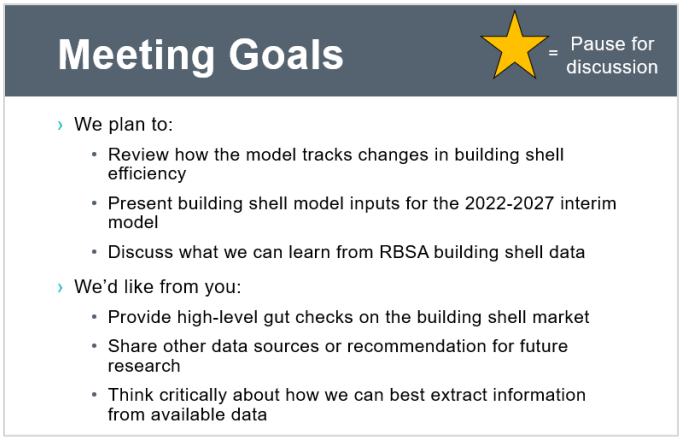
Introductions

Tyler walked through the agenda and introduced the panel.

Today's Session Goal

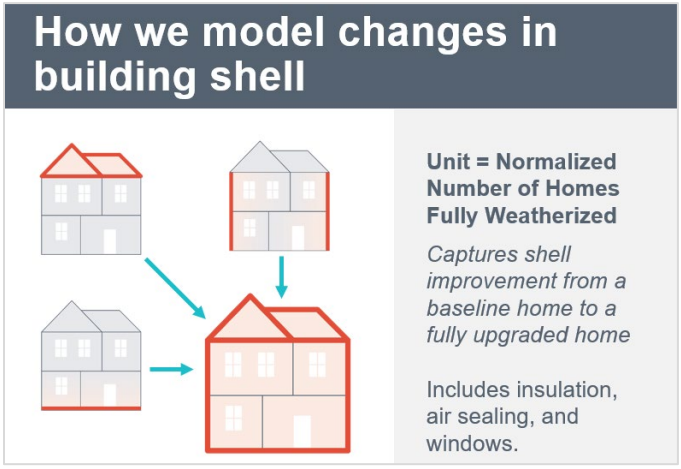


Joan started with a quick recap. Our team is currently working on the Res HVAC 2022 to 2027 interim model. With this model, we are trying to produce an accurate forecast of annual regional Res HVAC electric consumption. We are also curious about the savings that we get from making energy efficiency changes in the market as a whole, the part that is driven by program incentives, and then the remainder being momentum savings. A lot of the actual data we have only goes up to 2022. So, this is really a forecast and that is why it is important to get these forecasts in front of the experts to give us a high-level gut check. In 2027, we will update the model with as much actual data as we can and turn it from a forecast to actual savings estimates. Today, we want to discuss our model's building shell conditions of residential homes in the region because it is an important driver of HVAC energy consumption. We want to accurately model building shell conditions so that we can account for the impact on HVAC energy consumption. We want to accurately model the changes that are happening in regional building shells over time, from 2022 to 2027. The kinds of upgrades in building shell that we model include insulation, windows, and air sealing. Our primary goal today is to vet the building shell model inputs for this interim model with the expert panelists. As a part of that, we are going to do a deeper dive into what we were able to glean and analyze from the newest RBSA data that just got published. We are actually not using the newest RBSA data as a direct input into our building shell model inputs. But it is a very important data source, and we took the time to try to understand as much as we could from the new RBSA about regional building shell conditions. **Chistopher** asked a question. When you say model, do you mean building energy simulation or are you just saying forecasting model? **Joan** responded. The way we model HVAC equipment is what we call UEC. I think that some of that is based on building energy simulation modeling. What we are going to focus on today is our building shell and model inputs, which is separate from the energy consumption estimates. **Bretnie** chimed in. The entire market model is a combination of market data and energy consumption estimates.

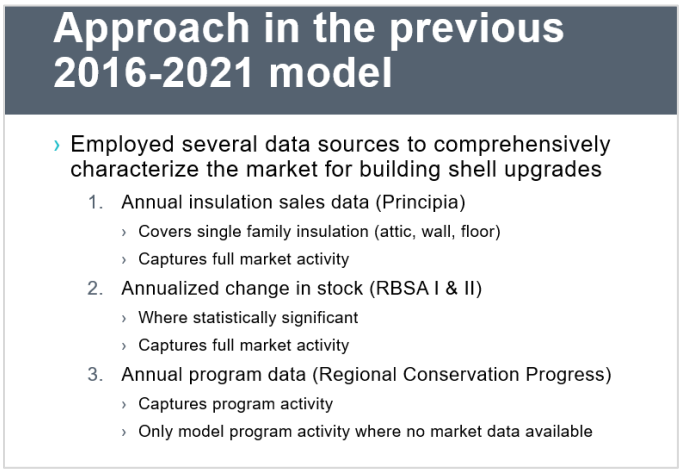


Joan continued. We want to show you how we are tracking changes in building shell efficiency and what they look like in terms of actual inputs to the model for this 2022 to 2027 forecast. We also want to show you what we think we can learn from the RBSA building shell data even if it did not end up serving as a direct input to our model. What we would like to get from you is a high-level gut check on what we are saying about the building shell market for the next 6 years and where you think our biggest data gaps are. We do have a couple of years to do more research on the biggest and most important data gaps. Also, if you think of any data sources that already exist or are going to be published in the next few years or you have a recommendation for how we might fill data gaps, that is another thing we are looking for from you today. Lastly, we would like you to consider how we can best extract data from the RBSA.

Building Shell Model Inputs



Courtney started with a quick discussion about how we model changes to building shell in the region. We collect a lot of data on building shell upgrades, and we convert them to what we call a "fully weatherized home". We know that individual homes do not often receive a full upgrade or go from totally unweatherized to totally weatherized. We aggregate those different installations across the region to a fully weatherized home; a normalized unit. And then we track the number of baseline homes, which we define through previous RBSA residential building stock assessment databases, and then a fully weatherized home, which is determined by an energy building energy simulation software.

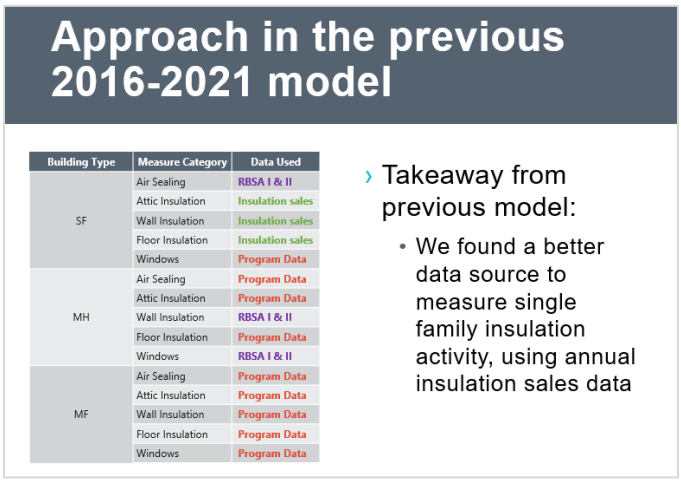


Courtney continued. From 2016 to 2021, we employed multiple data sources and created a hierarchy. The best quality data we received was annualized insulation sales data. Principia, a market research firm that specializes in the construction industry, provided market data that covered single-family insulation including attic, wall, and floor. That market data was the source of our model inputs for those measures in single-family homes. Next, we have annualized change between RBSA I from 2011 and RBSA II from 2016. Where those changes in heat loss rate were statistically significant for each component and each building type, we use the RBSA trends annualized as the model input. We will talk about which components where we use the RBSA trend. Finally, if we did not have another data source, we used regional program data from the Regional Conservation Progress report. This captures program activity only, which we do not expect to represent the full market. We all know that weatherization activity (building shell upgrade activity) occurs outside of programs as well.

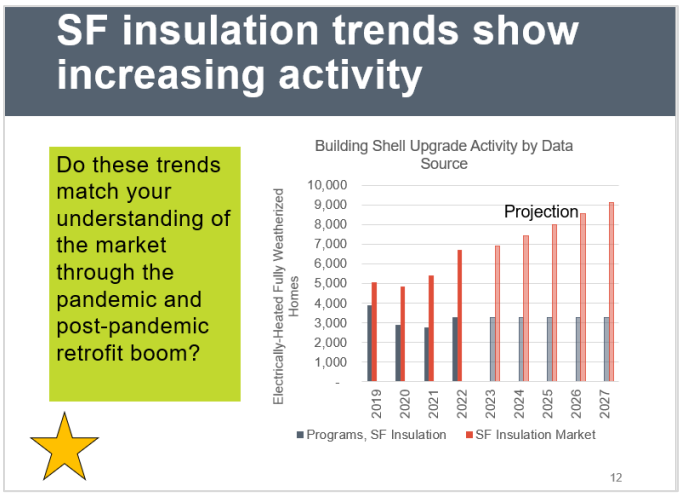
David asked a question. Regarding Principia, insulation is sold for a number of reason, most of which are new construction. How did you adjust that so that you could find the insulation market that actually reflects existing buildings. **Courtney** responded. In addition to collecting quantitative sales data from manufacturers, Principia performs qualitative research with regional distribution networks to determine the share of sales going to retrofit applications versus new construction as well as the building type. **David** added. Do they report that? **Courtney** replied. Yes, they tell us the result of that work. **David** added. So, it is a percentage of all the insulation that is in the original data set? **Bretnie** replied. Yes, we are able to differentiate insulation going into new construction versus existing homes. **David** added. And you care mostly about existing houses? There are a lot of other reasons why there might be insulation. But if you have that as an adjustment— good, bad, or indifferent—but it is an adjustment. **Courtney** replied. I think so.

David asked. The other question I have is about the annualized stock of RBSA I and II. There have been adjustments made, largely by the RTF. Are you using those adjustments based on the efforts to correct for the inadequacies of the data collection system or are you using the data collection system as

was presented by the consultants. **Courtney** asked. You mean for RBSA II? **David** added. Well, RBSA II is the worst one, but RBSA I has some of the same issues. **Joan** responded. Several years ago, we did a very detailed analysis of RBSA II compared to RBSA I in collaboration with lots of stakeholders, including the RTF. And we vetted our approach with this panel. We are just reviewing it with you as a jumping off point for the work we are currently doing. We only captured market activity from the RBSA comparison where statistically significant. **David** added that this is an important adjustment. So, if you did it, that is fine. **Christian** added. Yes, I think we shared all that analysis with BPA, and I think that it has all been integrated into the model.



Courtney continued. This is the previous model inputs' data sources. As a reminder, we looked at the RBSA I to II trend and part of the reason that we purchased the insulation sales data, which is what David was just talking about, was the complications of using the RBSA data. So, insulation sales were the data source for the single-family attic, wall, and floor. We did have a statistically significant trend from RBSA I and II in single-family air sealing and manufactured home wall insulation and window upgrades. Part of the takeaway was that we chose to purchase additional sales data to make the model more robust in the most significant model categories.



Courtney continued. Here, we have programs in gray and insulation market data in red. We see programs decreasing in the previous few years and we see a steady increase in the single-family insulation market data. In 2020, because of COVID, it was a down year for programs and a flat year for the market. And then in 2022, we see an increase and maybe a post-pandemic retrofit boom. What we have done for the market data is a linear extrapolation of the previous years. I am curious if this looks different from what you would expect from your knowledge of the market for building shell activity. **David** replied. I am a little skeptical of your projection. It implies that we are taking off finally after decades of inaction. I do not think that is true. I think I would be a little more conservative about what you thought was going to happen in the future, especially since you are only targeting existing electrically heated homes, which is not exactly a big group anymore. **Christian** asked. I tend to agree with Dave, but I just want to make sure I understand. Is this incremental homes every year? Do we have pre-pandemic data? **Courtney** said yes, we do have that from the previous model. But we refreshed the data, which is why I am showing it here. Principia adjusted their expectations downward from the previous data purchase a couple years ago. They still had it increasing, but from a lower point than what we had from them for the previous model. It is not an apples-apples comparison. **Christian** added. Given current conditions and costs, I have a hard time imaging that this trend is going up. Interest rates are high; costs have doubled post pandemic. I do not see people with a lot of expendable cash right now for something like this. Even heat pump sales are slowing. I tend to agree with Dave, I would probably be more conservative and maybe flatline it at best. **Bob** added. I have to agree, especially since this is electrically heated. The largest number of houses out there are still gas heated

homes, and a lot of those houses do not have wall insulation. That is the big divide whether you have it or whether you do not; it is all so expensive to do it. It is expensive to do it correctly so that homeowners do not damage their property. I am also skeptical about that 2022 number. Even with IRA things coming in, I would flatline it or even think it might trend down. I would not project it upward with a ruler on the page with a positive slope. **Nathan** added. I tend to agree. I am always skeptical when I see a linear line like that for projection. But I am just trying to understand the graph. The program bars, that is how many programs are implementing these each year and if so, why is that flat? **Courtney** replied. There is a regionally reported data source from effectively all of the utilities operating energy efficiency programs in the Northwest. We take that and convert it to electrically heated fully weatherized homes. It is just the electric portion of utility programs. Generally speaking, we consider 2022 to be representative of what we expect programs to do in the future, which is not exactly what they have done in the past. We have heard allusions to decreasing program activity in weatherization for a while now. We have program data going back to 2016 that shows a drop off to 2018 and flat activity after that. **Nathan** added. If the graph says program activity stays the same but installs increase, that does not sit right with me. **Tyler** added. I think there is a general consensus that the projections might be a little too high.

David added. I think that the situation in 2019 is a great deal more representative of how the electric heated market relates to the program market. They are different by what, 15 percent? Maybe that is what makes this look weird. You have a flat program and then somehow all the insulation is getting put in outside of the program in electrically heated houses with winterization programs. This does not seem realistic at all to me. I would be more inclined to decide on what you are going to assign to the utility and leave the forecast at the 2019 level, which is probably the closest thing we have to reality. In effect, you only get this 50 percent or 75 percent difference with what you have now represented here. Get it back down to something a lot closer to 15 percent or 20 percent. **Courtney** added. Flatten it out is what we are hearing. **David** added. Flatten it out and lower the projection. I do not know exactly what is included here. Usually, this spread has to do with windows, but my recollection of the window situation is that it has been fairly saturated across the whole region. There is not that much spread in the windows anymore.

Bob added (in the chat). Also, just for clarity, are manufactured homes included in the singe-family category? **Joan** replied that this chart is just focused on single-family installation. It does not include windows or air sealing. It also does not include manufactured homes.

Christian added (in the chat). I guess the IRA could change things. I did not think about that. Could make things more complicated. **Bob** replied (in the chat). I also wonder how many electrically heated homes in the region are not already close to fully weatherized (meaning wall insulation and at least moderate ceiling insulation). Maybe windows are the main thing left? I am unsure what “fully weatherized” means in terms of windows. Maybe 2x glazing with thermally broken frame? **Mike** added (in the chat). If you are using average for programs, maybe use average for insulation market too. **Joan** added. It does seem that the consensus is we should keep single family-insulation market activity flat to something. There are a couple options there I see such as to 2022 to 2019 or an average of 2019 to 2022, which we will definitely consider.

Approach in the 2022-2027 Interim Model: SF other

- RBSA II-III trends were not statistically significant
- Use program data to model improvements in air sealing and windows

RBSA II-III Trends

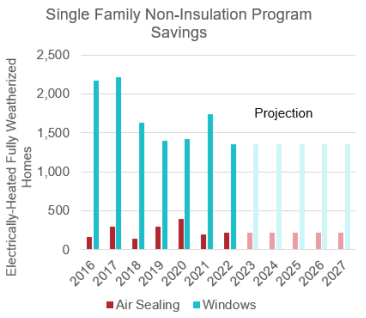
Component Value	RBSA II Average	RBSA III Average	Difference	P-Value
ACH_{50}	9.454	9.436	0.018	0.927
Window U-Value	0.482	0.473	-0.010	0.158

Courtney continued. We are now talking about single-family windows and air sealing; we reviewed the trend from RBSA II to III and then to program data. I am going to show the RBSA trend first. The trends were not statistically significant. The P-values were not below .05, so we will not use the RBSA trend. The trend showed for a slight improvement in the heat loss rate for windows, which is going from a U-value of .482 to .473 or about a .01 improvement. It shows a little bit of weatherization activity, but not statistically significant. For air sealing, it was functionally the same number as ACH_{50}.

Approach in the 2022-2027 Interim Model: SF other

What is the relative size of non-program to program window upgrades now and in the next few years?

Data/future research recommendations?



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Courtney continued. Since the RBSA trends were insignificant, we are going to use program data for single-family windows and air sealing. Here is the program trend going back to 2016. Interestingly the RBSA trend that I just showed you, when converted to fully weatherized homes, is about double the program activity. We see about 3,000 fully weatherized homes per year in the RBSA trend compared to 1,500 or so in the program data. One of the things that we need to consider across all these different components is which data gaps we want to fill over the next few years. Maybe you all have information we could use, market data we should purchase, or other research we could do. We do not need to figure out how we are going to collect data at this point. But we do want to get your sense of whether or not the projection looks reasonable and what is the priority of things the market research team should look at in the next couple of years. I consider windows to occur outside of programs more commonly than most other weatherization activity. So that is something that we could pursue. Anybody else have opinions there?

Christian asked (in the chat). Is this prime window replacements only or does it include things like adding insulating storm windows? **Courtney** replied. Prime windows only; does not include storm windows.

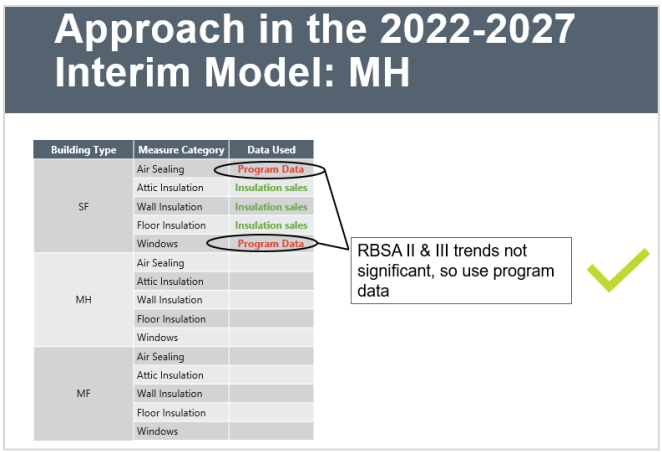
David added. The main issue with windows is that we have not really supported window upgrades. The utilities have always been nervous about cost effectiveness and cost; they are expensive. This is based on what I saw in RBSA I; I have not looked at RBSA III at all. We saw saturations of windows with u-value .47 in about 75 to 80 percent of all houses, including electric, gas, etc. So, you say that you are roughly at 7,000 houses with new windows and that you will start running out of existing houses in the next 5 years. All the houses that have happened since RBSA I have had windows that were at least .47. The code requires numbers more like .3 now, even in the slow group. And Home Depot has obligingly made it so that it's pretty much the only window they sell. I do not see how we have that much upside in window saturation. 7,500 extra houses in windows are a significant amount of what is left over after what we saw in 2010, and my guess is that most of that has already been taken up. **Courtney** replied. We definitely saw in RBSA III inefficient widows, the single pane or metal frame double pane. There is still some remaining stock out there that could be eligible for replacement. It might be diminishing returns for those houses if you still have a single pane metal frame window at this

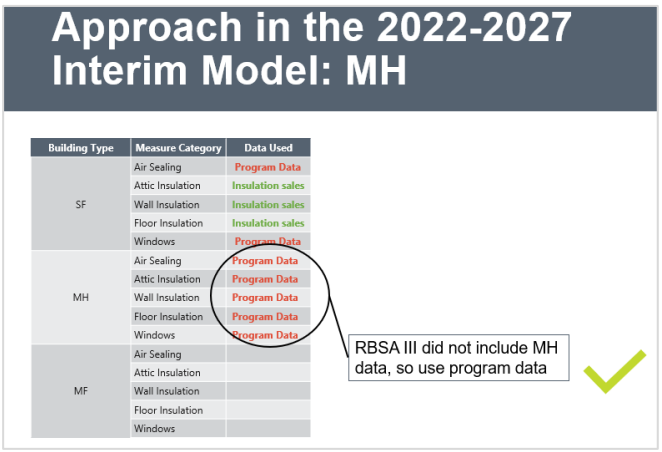
point, it is probably going to stay there for a little bit longer. We can definitely compare the implied number of window replacements in the data that we are projecting forward against the remaining percentage of homes. **David** added. Keeping track of the total number of houses you have got to work with will probably help this projection. Because of the way you have defined fully insulated, you are going to start running out of houses. Even if there is a strong upward pressure on insulation for IRA or some other reason, at some point you are going to run out of houses. They will turn up as something else, but not as insulation or windows. Maybe infiltration, but that is a different question. That has been neglected mercilessly for most of the last 40 years, and it is just as bad now, especially with existing housing.

Christopher asked. How many electric heated houses do we have? In eFAF, we have 200,000-300,000, right? **Courtney** replied. Yes, there are a significant number of zonal and air source heat pump and ductless heat pump. **Bretnie** added. There are about 4 million single-family homes in the region, and at least half of those are electrically heated. **Courtney** added. Yes, there are about 1.5 million houses that are electrically heated. **Christopher** added. There are 2,000 participating in programs and maybe two or three times that and still seems like a lot of houses that are electrically heated. What fraction of those still have a single pane? I do not know. Do we know how big is the remaining market there? I am more familiar with HVAC than I am with building shell measures. **Courtney** replied, yes. I can look that up when we get to the break.

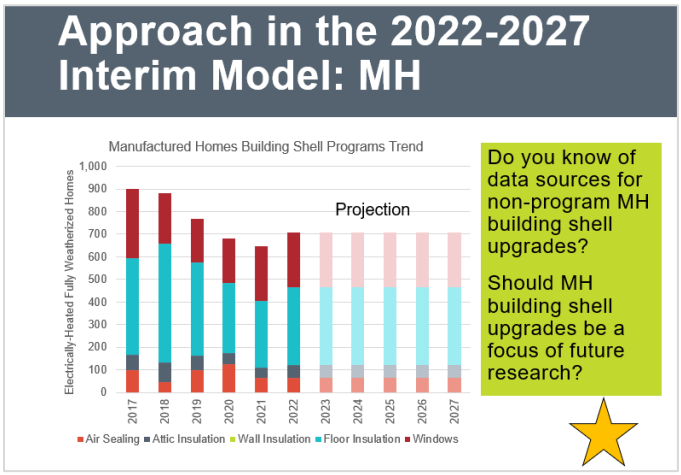
Bretnie added. I think that is the question to everybody today. What you know of how much is really left and how much is happening outside of programs. If we have data gaps or if the RBSA is leaving us with questions, is this an area that is worth pursuing more data? **David** said that if you do not have electric resistance heat, you are very concerned about the overall heat loss rate. If you are trying to replace those with heat pumps, it is a serious issue in the performance of heat pumps. If you have a large heat loss rate, you cannot match it very well with the heat pump. That is how you get lots of electric resistance back. **Courtney** replied. Hopefully, the HVAC installers of the region know that as well.

Amy added (in the chat). I would advocate for decreased focus on single-family and more focus on manufactured homes and multifamily buildings. There is a ton of national funding that will be rolling out later this year, with a lot of focus on single-family HVAC and weatherization. **Courtney** replied. I really appreciate Amy's comment, and we are going to jump to the manufactured homes and the multifamily data in a minute.





Courtney continued. We propose to use program data for all manufactured home components. We think the RBSA I-to-II data is dated, and it is probably a better representation of the market to use just the program data, which we think is more reliable. RBSA III did not include a manufactured home survey, so we could not analyze that for a trend.



Courtney continued. Here is what the manufactured home program data looks like broken out by component. The projections, based on 2022 levels, are functionally the average of the more recent years. I do not want to use 2017 or earlier. I think this is a very interesting opportunity for future research and specifically, for low-income weatherization programs that receive weatherization assistance program funding from DOE. As long as they do not use utility funding, the weatherization activity that is funded through those programs is not being captured in the Regional Progress Report (RCP) program data and so is not represented here. And those could potentially address a large portion of the manufactured homes in the region.

Bob asked. What does "program" mean for manufactured homes. A lot of the work is cap agencies; I assume that is included, right? **Courtney** replied. Not, not necessarily. Those CAP agencies receive a mix of funding. We presume that if they were funded through like BPA's Energy Efficiency Incentive (EEI) funding or other utility funding that has to report to the RCP, it would be included. But for projects that are not even partially funded by utility program funds, but through DOE federal funds or state bonds or grants, those would not be captured here. **Bob** added. I think those are important. One thing that is not on this list is duct sealing. My question is, mobile homes are almost all electrically heated, but how many are left that need it done correctly? And it is a sort of a double counting measure because it has effects on the HVAC system but also on other things in the house, but I do not know if that is included. Insulation is rightfully left out because it is almost impossible to do in manufactured homes, at least without destroying everything. Floor insulation is probably the one that has the most potential. It is a specialized thing, but there is lot of potential for that one. I would try to find what the cap numbers are with this because it is a significant chunk of the picture for manufactured homes. **Courtney** agreed.

David asked. What do we mean by existing? Where do we draw the line for the vintage of existing? **Courtney** replied. Anything prior to 2011 exists, and anything post 2011 is new for the purposes of the model. **David** added. So, manufactured home or any other home that was built or sited before 2011 is considered existing, correct? **Courtney** replied. Yes. The building shell condition of those homes is represented in the baseline home. I think your point is a home that is built or sited in 2010 has effectively new construction levels of insulation. But that is baked into the baseline home. **David** added. In manufactured homes, at least for the last 30 years, the insulation levels required in the manufacturing track pretty well. The single-family residential code tracks it because of activities of Department of Housing and Urban Development (HUD) and others. For example, you might think that windows were important if you thought that the average windows in manufactured homes were the average of all the windows that ever got put in manufactured homes. But for purposes of the fraction that has been built since 1990, which is not a trivial fraction, you are wrong. Those windows were class 35 windows. **Courtney** replied. I see your point. Manufactured homes are also going to be younger and more newly built than single-family homes. **Christopher** added. But there were so many built in the 70s and 80s. **David** added. In RBSA I, there were 60 percent before 1982-1983. Are they still there? This was 40 years ago.

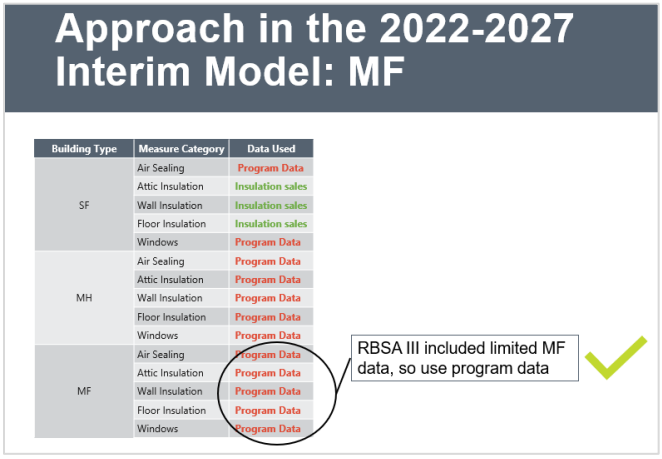
Jonathon added (in the chat). It would be interesting to know what moving the "new" vs "existing" line does to your analysis. **Bretnie** replied (in the chat): Jonathan, the new construction differentiation is mostly a way for us to differentiate how much energy a home uses, since a new home will use less on

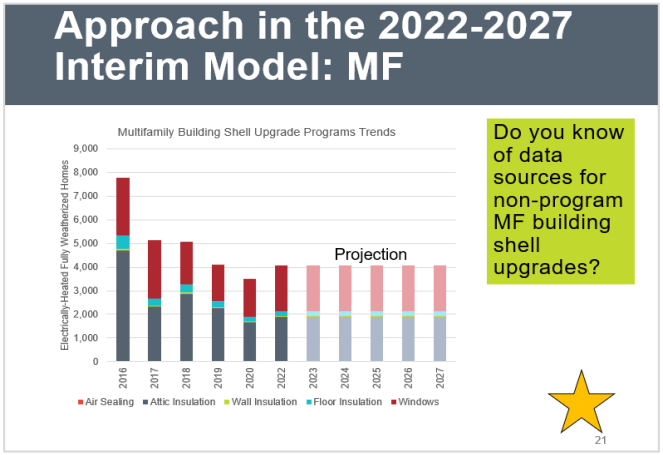
average than an existing home. Moving the line up or down just puts more homes into one bucket vs the other. So, if we make new construction newer, we just move more homes to the existing category. They are all included in the model.

Christopher added (in the chat). Approximately $330 million in IRA funds spread across four states equals approximately 42,000 homes at $8k/home. It is not that significant. Even if we assume this funding is leveraged 2:1 we still only get <2 percent of homes will be impacted. **Amy** added (in the chat). IRA will have less influence than anticipated, but there are a half dozen other federal programs rolling out as well. **Jonathan** added (in the chat). Tax credits probably will not help folks with multifamily too much. **Christopher** added (in the chat): This table is RBSA II.

Application	E-Zonal		EFAF		ASHP		Gas	
	#	ft2	#	ft2	#	ft2	#	ft2
Site Built SF Homes	670,181	775,064,349	150,374	315,900,619	666,464	1,471,843,419	2,399,165	5,116,376,078
Manufactured Homes	16,692	17,490,489	180,660	230,701,024	116,116	170,247,388	62,685	81,834,381
Low-rise Multifamily	622,348	427,343,264	22,127	18,669,276	36,071	25,487,667	71,393	63,470,654
Small Office	17,902	73,645,144	-	-	16,431	124,505,999	31,398	226,903,199
Small Retail	11,610	63,516,067	-	-	4,935	19,574,215	28,451	394,988,979
Commercial (Education)								

Christopher added. We should not get too enamored with this IRA funding. If you took the $8 billion and you spread it across the per capita, you end up with $330 million in the four-state region and only two states are currently going to pursue this. At $8K each, that is only about 42,000 homes—less than 1% of our housing stock being influenced by IRA. Even if that is leveraged two to one, we are still not going to see the IRA funding as a huge incentive for weatherization. **Courtney** said. That is a fair point; thank you for giving us that scope. **Bob** added. Tax credits will do more, but it is not as big as people think.

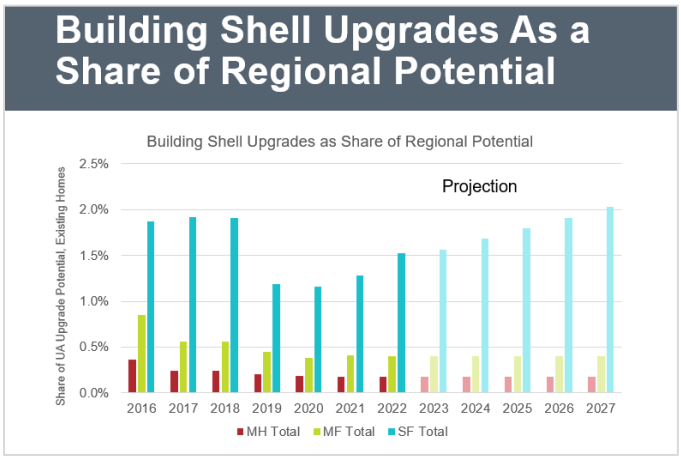




Courtney continued. We had limited multifamily data from the RBSA III. We did not try to make a trend line between RBSAs. What we are reporting here is program data, which is more units than manufactured home. This is a little weird because the conversion to fully weatherized homes uses a dwelling unit. For multifamily, that is an apartment or a condo, which is smaller/consumes less energy than a single-family home. We will show you an apples-to-apples comparison in just a minute that shows a representation of the UA or of the building shell activity. But this data shows that multifamily program activity is still significantly lower than single-family and is concentrated in attic insulation and window upgrades. How would you prioritize multifamily homes versus manufactured homes in terms of research for us to perform over the next couple years?

David replied. Multifamily is a lot more important in terms of the number of buildings, the amount of energy consumed, and the trend. The question is, what is it? The characterization of multifamily, especially at a building level, has been more or less ignored by RBSA except for RBSA I. And that is

because that is the only one I did. It is much more cost effective to not worry about that sort of thing in the multifamily sector. It is much harder to do the sampling and the analysis if you try to do buildings and units together. We do not know much about multifamily, relatively speaking, and that is too bad. **Christopher** added. There are 700,000 multifamily, low rise multifamily out there, right? **David** replied. Yes, it is big. Luckily, they are getting torn down pretty quick in the urban areas because they can be replaced by six-story buildings. That definitely is a trend. **Bob** added. I am surprised that multifamily did not get more attention in RBSA III. I thought that was part of the plan and the sampling strategy, what happened there? **Bretnie** added. I do not know if we want to get too deep into the RBSA. **David** added. It matters in this case because if there is more data collected, that will make a big difference in what you think about multifamily. **Mike** said that our current plan (which could obviously change later) is that multifamily data collection is going to be split: the new RBSA will continue collecting units, and we did collect units in this RBSA III. We did also collect building-level data where we could, but we basically scrapped recruiting the buildings first and then the units in the middle of this study and just went to the units and then collected available building data as we could. The central systems for multifamily buildings will be collected through Commercial Building Stock Assessment (CBSA) and that study is underway now. I can pull up some numbers and share it out to the group later. But multifamily building is a small sector relative to all single-family homes and relative to commercial buildings. Square footage wise, it is a bit more substantial. We are basically oversampling multifamily buildings in the CBSA that is underway now. **David** asked. That oversample is for all multifamily buildings, correct?



Courtney continued. I'm jumping ahead to this slide because it shows a more apples-to-apples comparison of the single-family versus multifamily versus manufactured home in terms of savings activity. This shows UA upgrade as share of UA potential. **Christopher** asked. Are you saying this is a percent of market or percent of the UA increase? I am confused by the graph. **Courtney** replied. It is the UA increase for building shell activity compared to a denominator of the amount of UA upgrade remaining in the region from RBSA. The UA upgrade remaining (denominator) is the remaining amount of area in the region that could be weatherized if we were to bring every home up to perfectly weatherized, which is the ambition of all programs. For example, a building would have UA of about 300 and currently the average building UA in the region is about 650. **David** asked. This is all buildings or is this just electric heat? **Bretnie** added. A certain percentage of homes are already weatherized and that is out of the equation/this graph. And then another percentage remains that we could still upgrade (the denominator). We are saying that this percent of the total potential excludes the stuff that has already been upgraded. That is baked into the baseline. **Christian** said. I am still confused. What is the denominator, is it the baseline of all of the buildings? **David** added. And we are only talking about the percentage improvement in the aggregate? **Courtney** replied. The denominator is the total remaining upgrade available in the region. The numerator is the building shell activity that we saw in all of the data that we just presented. **David** added. Some noticeable fraction has been removed because they are already insulated. **Courtney** replied. Yes. This is the activity. This 1 percent of the building shell upgrade potential is whether a building receives a building shell upgrade and is now fully weatherized and is out of the potential category. You are taking potential upgrades and upgrading them.

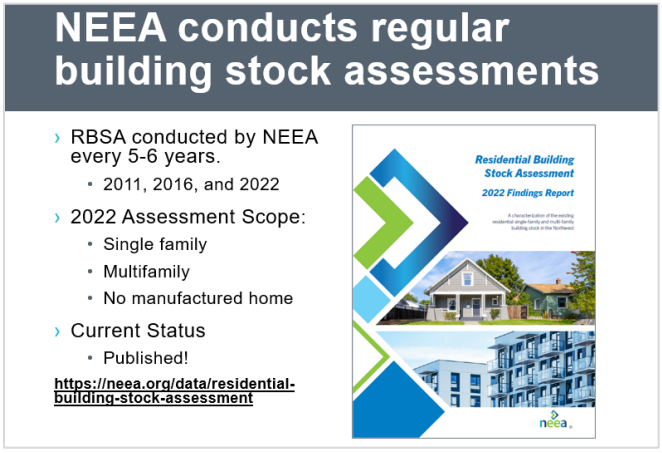
Joan added. I know it is really hard digest all of these with different units. The goal of presenting you this particular chart is to compare the size of the upgrade that we are projecting by building type. We are essentially summarizing all the previous charts that we have shown you before that were separate

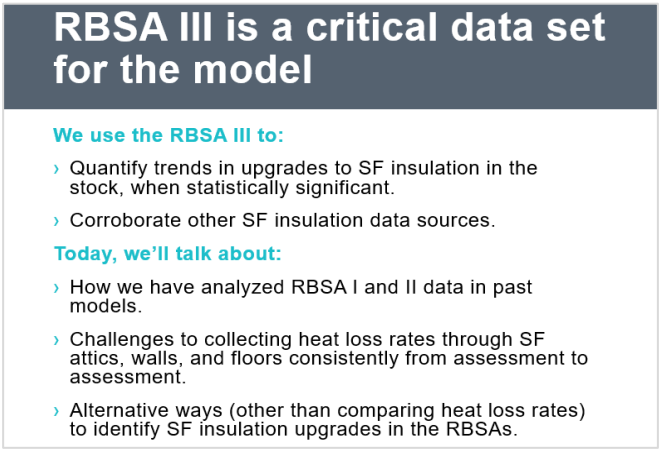
for single-family versus manufacture homes versus multifamily, and we are putting them all together. What I am hoping you can focus on is the comparison of the relative size of the upgrades that we are projecting in each building segment and knowing that, for single-family insulation, we have data that covers the total market. For single family air sealing and windows, we only have program data right now; we are not capturing non-program window activity. That is a gap we have in single-family. For manufactured homes and multifamily, these lines are only representative of program activity and our projection based on program activity. The question we asked you is where are we potentially missing the biggest upgrades in savings because we do not have data beyond program data? We are asking this question so that we know where we should focus our research for the next couple of years. We also want to capture momentum savings in that market. But on the other hand, I am really curious about where we are missing the biggest amount of building shell upgrades that would actually impact our estimates of HVAC energy consumption to a degree that we are potentially overestimating energy consumption. If we are under-capturing a large portion of building shell upgrades, then we may be over-estimating energy consumption. Thinking about it from that perspective might help you give us more direction on where we should prioritize research and where we should get market data in that area.

Amy added. We just went through a low-income process evaluation that included a demographic analysis. We looked at the regional breakdown by housing type and then also by income level, which is defined federally using the 200 percent of federal poverty line. We can provide that to you. There is definitely significant potential left for multifamily; there are a lot of multifamily in Oregon, way more than I was expecting. I was expecting more up in Washington. Also, we have heard from other organizations like Habitat for Humanity and Vital Housing, who are really going after upgrading and retrofitting existing multifamily buildings. Not just building new but also doing a deep dive into making sure that those buildings are all set up. There is a renewed focus on that, which I thought was interesting. But in terms of data too, there are so many other organizations that are working on this. Also, we are updating how we track data that is completed through our grants. All homes that are weatherized, we have that. We can provide that to you if that would be helpful. It is small compared to a lot of our other EEI programs.

RBSA SF Insulation Data Analysis

Background

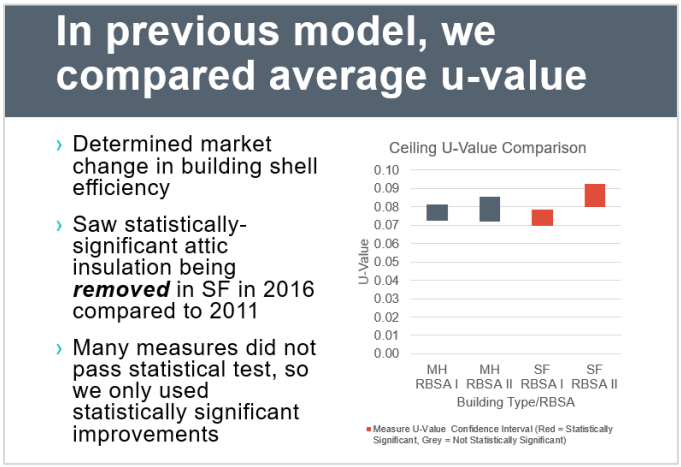




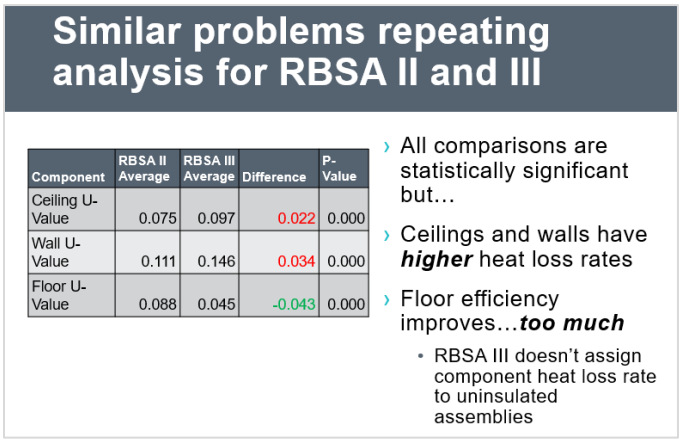
Courtney continued. NEEA conducts very useful and extensive building stock assessment databases and reports every 5 to 6 years. We have 2011, 2016, and 2022. We thank Mike and the NEEA team for giving us an advanced copy so that we could push this work ahead. We used the RBSA-to-RBSA trend to quantify building shell upgrades in the past. We want to use this RBSA III data to quantify trends

compared to RBSA II and to corroborate our other single-family insulation data sources. We like to triangulate our model inputs as much as possible, especially when we have a database like this one. We will talk about some challenges in analyzing the heat loss rates through these single-family insulation measures. And then we will discuss an alternative way we developed to identify the weatherization and corroborate our data sources using this RBSA II to III trend.

Average U-value Trends



Courtney continued. In the previous model, we compared the RBSA I to II trend. Here we have single-family and manufactured homes from RBSA I to II where we were comparing the U-value for heat loss rates. In this graph, the center of the box is the average, and the box is defined by the 95 percent confidence intervals. We see that that for single-family ceilings, there was a trend of increasing heat loss rates from 2011 to 2016. It was statistically significant. This implies that insulation is being removed from homes, which I do not think we believe.



Courtney continued. I did not make a fancy graph for the heat loss rates in the RBSA II to III range, but we see the same thing for ceilings and walls, an increasing trend in heat loss rates. Floors see an improvement in U-value, a half of the heat loss rate. That is because in the RBSA III database, the U-value is not defined for some uninsulated asset floor assemblies where there is no heat loss or U-value rate. I think they assigned it to the crawl space walls. I am not going to talk about that as much, but I do want to talk about the increasing trends.

Christopher asked for clarification. When you say U-value, you are referring to a calculated U-value based on what was found in the field, right? Not a measured U-value? **Courtney** replied yes, calculated U-value. I want to point out that we could actually do measured U-values if we do it with gas-heated homes because we can easily see the slope of the heat loss line versus outdoor temperature. And there are some folks that are exploring that. Then you could actually have a true thing. For example, we calculated it to be X at least in gas-heated house. It is really hard with heat-pump-heated houses. You could do it with all electric-heated houses, but then you have to ask if there is wood heat in the house. But it is something to think about and maybe as a research objective for the future. **Courtney** replied. That is a very interesting suggestion.

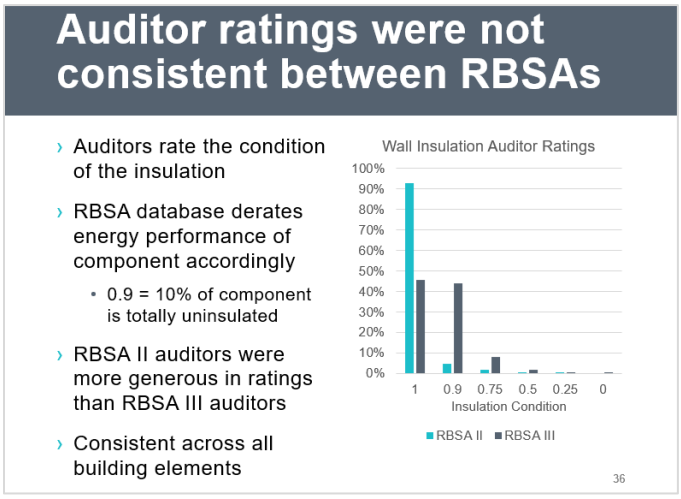
David added that there is a very important difference between RBSA I, II, and III. RBSA I was a building-level analysis. It was done so when we talk about ceiling insulation, somebody looked in the ceiling and when we talk about wall insulation, somebody looked in the walls. When you do unit-level, you are not likely to have that flexibility. The ceiling of any particular unit that you selected might or might not be part of the actual ceiling of the actual building. So, if I were going to say anything about the comparison there, it is not a question of taking out insulation. It is a question of missing lots of insulation because of the study design. **Courtney** added. Hold on; we are going to talk about why this trend

exists, we do not have to hypothesize quite so much. **David** replied. This is not a hypothesis. This is actually what happened in these two studies. I do not know what happened in III. **Courtney** added. But this is for single-family only (not multifamily), and we are not showing RBSA I here so let's stay focused on the RBSA II to III trend.

Christopher added (in the chat). Ownership is key to decisions for weatherization. I can see multifamily getting window upgrades as that can improve curb appeal and rental rates. Other weatherization is not likely.

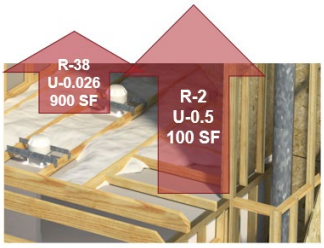
Auditor Uncertainty

Courtney continued. I want to talk about what is causing this trend. It is worth noting what the auditing process looks like. We have an auditor out in the field; they measure the insulation, record the type, and offer the condition rating and other things associated with what is physically in the house. Then the RBSA database calculates a U-value, which is the heat loss rate and then the R-value, which considers the insulation condition. That is a more complete representation of how the heating and cooling systems are performing and what they have to overcome in terms of heat loss in the home.



Courtney continued. What we see is that the condition ratings were not consistent between the RBSAs. The auditor is noting the condition of the insulation that they see, and it is assigned to either a 1, .9, .75, .5, .25, or a zero. It is pretty clear that the RBSA II auditors assigned a 1 much more frequently than a .9, whereas in RBSA III we see a more even distribution between a 1 and a .9 condition rating. I am showing walls here, but it is also consistent across all building elements such as attics and floors. Assigning a .9 condition may seem pretty innocuous in terms of what we think of in the region. I agree, there is very little perfect insulation in the world, especially in attics and floors. But the reason it is a big deal is because the way that U-value for heat loss is calculated is hugely impacted with the insulation condition rating.

How rating affects heat loss calculation – 0.9 example



	Area 1	Area 2	Total
Sq. ft.	900	100	1,000
R-value	38	2	-
U-value	0.026	0.5	-
Heat loss (UA)	24	50	74
Area-Weighted U-value			0.07
Area-Weighted R-value			13

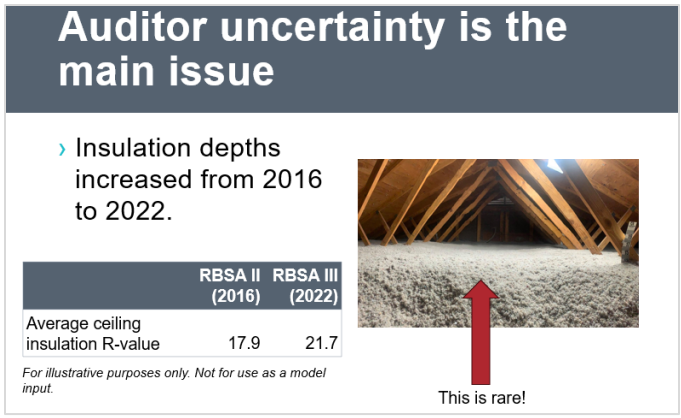
Courtney continued. With a .9 rating, the heat loss calculation assumes that 90 percent of the component is perfectly insulated and then effectively no insulation in the remainder 10 percent. If you have 10 percent of a 1,000-square-foot attic that is totally uninsulated, you will have an R-value of 2 and a U-value of .5, so the UA of that component, which only has 100 square feet, is 50 BTU per degree F per hour, whereas the perfectly insulated 900 square feet has about half of that. When you add those two things together and then average them over 1,000 square feet of home, the area-weighted U-value jumps to .07, which is effectively an R-value of 13. In this case, the auditor comes into the attic and measures 13 or 14 inches of blown cellulose in a home. But something happened to damage the insulation. Now, what we are saying is that the whole attic space is losing heat at the same rate as an R-13 consistent insulation level. We do not have a better way of doing this that we are recommending for NEEA. We do not want to solve that problem right now in this meeting. We want to focus on finding the weatherization activity in the in the database. Are there any questions about why that .9 rating is so impactful in terms of the heat loss U-value? **David** replied. When the auditor says .9, does that mean it is essentially no insulation in 10 percent of the building or 10 percent of the component? Is that what the auditor meant or are they just estimating the quality of the insulation they observe? Is there some way for us to know if they used infrared cameras. It was not in RBSA II, but was it in RBSA III? **Courtney** replied yes. **David** added. Well, that is an improvement, which is probably why we see some different rating conditions. I think we should just toss all RBSA II data out altogether.

Auditor uncertainty is the main issue

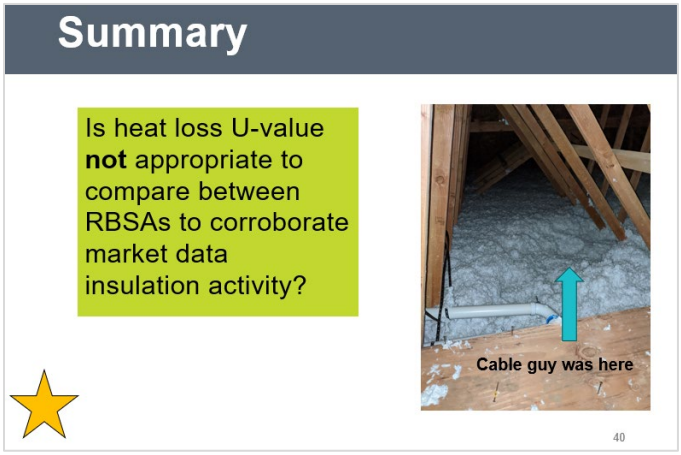
		Heat loss rate		Informational	
Component (RBSA III)	Example Insulation R Value	Heat loss U-value (Condition = 1.0)	Heat loss U-value (Condition = 0.9)	Heat loss R-value (Condition = 1.0)	Heat loss R-value (Condition = 0.9)
Ceilings	45	0.030	0.079	**33**	**13**
Walls	12	0.095	0.114	**11**	**9**
Floors	20	0.047	0.064	**21**	**16**

Uninsulated share increases heat loss rate significantly, particularly for ceilings.

Courtney continued. Here is another way of looking at the information we have. Again, we just have the u-values calculated in the RBSA database. I found some examples of ceilings, walls, and floors that had an R-value and then found effectively identical instances of that insulation being installed in a different home with a different condition rating. So, with the condition set to 1, this R-45 has a U-value, a heat loss of .03. At .9, it is .079. When you convert to R-value, it is a 33 versus a 13. The system is most punitive in ceilings. Floors are thicker, they have more layers. There is a lot more barrier than just a thin piece of sheet rock.



Courtney continued. That difference in condition rating between RBSA II and III is causing the heat loss rate to go in a direction we do not believe, indicating more heat loss across the region in RBSA III compared to II. If you look at the average depth of insulation in open attics between RBSA II and III, you actually see more depth of insulation in RBSA III. So, the average ceiling R-value before the condition de-rating is deeper now than 6 years ago, which we would expect to see. I have been in a lot of attics and done a lot of energy audits around the region. It is rare to see perfectly insulated components. But it is difficult to assign a heat loss rate or an average R-value to a component where the insulation is damaged or incomplete. It is one of the things that makes energy auditing so difficult, RBSA is difficult, and it is difficult to assign savings to programs.



Courtney continued. Our opinion is that there are methodological differences between the two RBSAs and the impact of those methodological differences is very important in terms of calculating the heat loss U-value. Do you agree that the heat loss U-values can really not be compared in the RBSAs? **Christian** replied. It was not an omission that this was not shown in the report. That was a recommendation from the working group for a lot of the same reasons you show here. I strongly made this recommendation that it is too difficult for so many reasons to do this. You are showing one of them, and I could probably name three more. When you compare widgets, that is much easier to do. How many heat pump water heaters? But this is complicated and there are so many sources of signal relative to the noise. **Courtney** replied. I totally agree. Recording a model number is one thing. Figuring out what the heat loss of this attic here would be is different.

David added. In response to the fact that we are getting infrared cameras into the audits, that is a big improvement, especially where we have actual houses. It would be a less big improvement if you did the audits in the summertime, but you still can see things that give you a hint about what the insulation levels are. The percentage numbers you might see with infrared cameras might be more reliable. Secondly, let's say you have a .75 and you say, well, 25 percent is R-0. That probably is not true ever. At least not in attics. It might be true in walls, because the obvious problem is that you did not insulate the cavity. You often know that in RBSA III, apparently. And you do not know in RBSA II or I, because neither of those had that kind of quality control. To the extent that we have a big improvement in auditing in RBSA III, it is probably more reliable in every sense except for the fact that the trend is unknown. It is not a trend; it is a different data set and there is no way to compare them. I am pretty confident that that is true between RBSA II and RBSA III. I am also pretty confident that it is maybe less true to RBSA I, but not that much less.

Mike added. To add to what Christian said, even at the start of the study we talked with the work group about whether we should even try to do this given that even with the infrared sensing, it is still difficult for reasons that Dave just mentioned. For example, if you are doing it this summer, the signal is harder to see even with the infrared sensor. It is extremely challenging data to collect, but we decided to do it.

We showed graphs; we did work with the work group and looked at comparisons from one study to the next. We decided not even to show that in the report, but to only show things that we could reliably say had a change. I agree that it is probably not useful to show a change from one study to the other. I do not know if there are any other ways to track changes in in this type of information.

Alternative Building Shell Analysis

Is it Weatherization?

Goal for this analysis

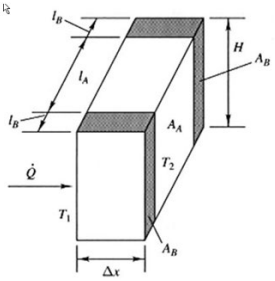
- Use an alternative approach to quantifying how much the stock is being upgraded.
  - Demonstrate that upgrades are not NOT happening.
- Use RBSA Results to corroborate insulation sales data and program data.
  - Since we already have sales data, this is just a comparison point.

Courtney continued. We did an alternative analysis. We want to look at a line in the database and be able to say is this weatherization, yes or no. The point is that for our analysis, we do not really need the RBSA to tell us what the heat loss rate is. We need the RBSA to tell us if there is insulation in the home. We can do the rest on our own. The insulation condition is important, and I do not want to downplay that. That is why we ended up not going all the way to making model inputs from this alternative analysis. But we wanted to take this alternative approach to demonstrate that building shell upgrades are not happening. When we took our first cut at the heat loss U-value from the RBSA data, we could not show a trend of improving building shell condition. This new analysis at least demonstrates that upgrades are happening and corroborates our model inputs.

Mike asked. Can you clarify that you want to know the existence of insulation, not the condition. **Courtney** replied. Yes, that is exactly what we ended up doing. We did not get into the insulation condition. We tried; it was messy. We ended up pulling back and just seeing how much building shell activity is occurring in the region. Are we seeing that there are greater levels of insulation in existing homes than in 2016?

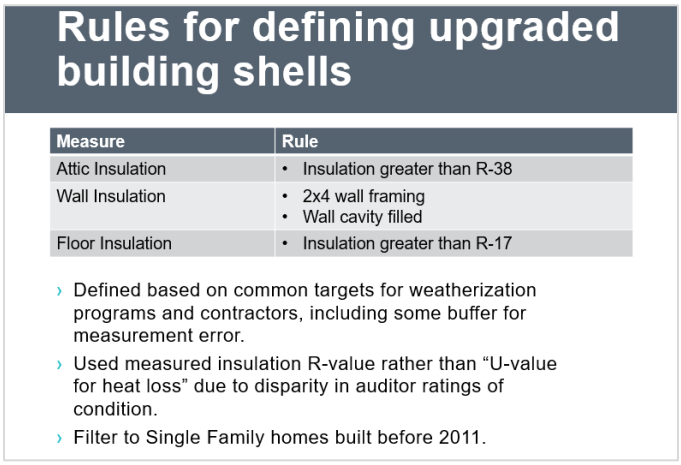
Use the RBSA to identify upgraded building shell

Calculating heat loss rate is hard

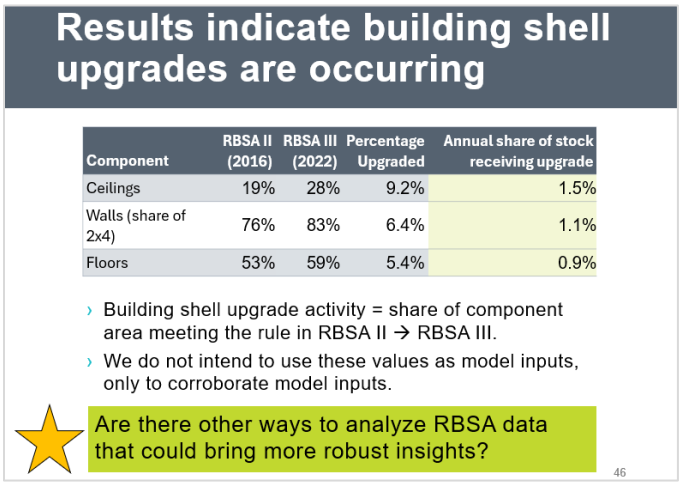


Identifying upgraded building shells is easy

Courtney continued. The point is calculating heat loss is really hard. It is very challenging data to collect, and the calculations are hard to get right. But ultimately, identifying upgraded building shell area is pretty easy, especially for something like walls where it is as simple as “is the cavity insulated, yes or no.” Then you can compare the square footage of insulation in the region that is insulated longitudinally through time.



Courtney continued. What we did here is defined what the upgraded building shell is by choosing common weatherization program targets. For attics, it is an R-38. Anything that is an R-38 counts as an upgraded home. That might include some code homes, but that is going to be consistent between the two RBSAs because we are filtering down to just existing homes (built before 2011), which should not change too much between RBSAs conducted in 2016 and 2022. For walls, we filtered down to just the 2x4 cavity walls because code started requiring 2x6 walls after it started requiring insulation. There are almost no 2x6 walls in the RBSA that are uninsulated, that do not have the cavity filled. For floor insulation, we chose R-17, which is not a real amount of insulation that can be purchased because they do not really sell R-17 batts. It is the number that is between R-15 and R-19, which is why I chose it. If you say R-19, the percentage of square footage in the region that is weatherization goes down, but it stays relatively the same between the two RBSAs.



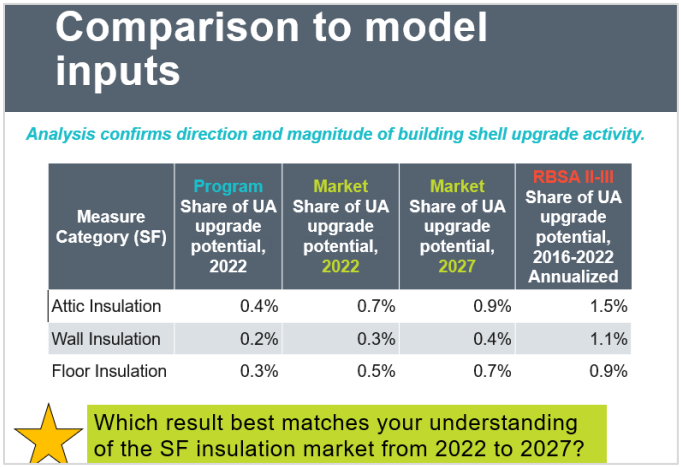
Courtney continued. Here are the results of this analysis. We calculated the total percentage of regional square footage that meets that definition in 2016 and 2022, calculated the difference between the two years and then divided by six to get the annual percentage of total regional area of this component that is receiving an upgrade that is weatherization. That amount is 1.5 percent for ceilings, 1.1 percent for walls, and .9 percent for floors. Again, we do not intend to use these as direct model inputs. But what I am happy to see is an increase in the amount of total insulation in the region between the six years.

Christian asked. Can you explain how these percentages are calculated a little more? For example, you are looking at the square footage for walls that have the 2x4 cavity filled? **Courtney** replied, yes. **Christian** added. Are you decrementing the condition or the percent that is in good condition because we still do not get out of that issue, right? **Courtney** replied. It does not consider the condition rating. And we tried a number of ways to assign a U-value both accounting for and not accounting for the condition rating. Ultimately, it did not seem sound. **Christian** said, I think that makes sense. You are trying to normalize. I think it is not perfect, but I think what you are doing here makes sense.

David added. When we say 76 percent from RBSA 2016 to 83 percent, what we are saying in this definition is that whatever we decide the insulation value of the 2x4 wall is, 76 percent of the walls were that in 2016 and 83 percent were that in 2022. It is a single U-value that you are just carrying around as though you knew what the insulation levels or what some kind of corrected value of insulation levels were for R-11 walls. Right? **Courtney and Bretnie** both replied, right. **David** added. The way we got that number, the one where we say this is what U-value in R-11 wall is not the R-11 U-value, but U-value with the R-11 wall on average across everybody that has one. The way we got to that was the preheat loss U-value. **Courtey** replied. Right, so it is not accounting for the condition rating. We are looking to see what is written on the batt of insulation. What the rating is of the depth of insulation. We

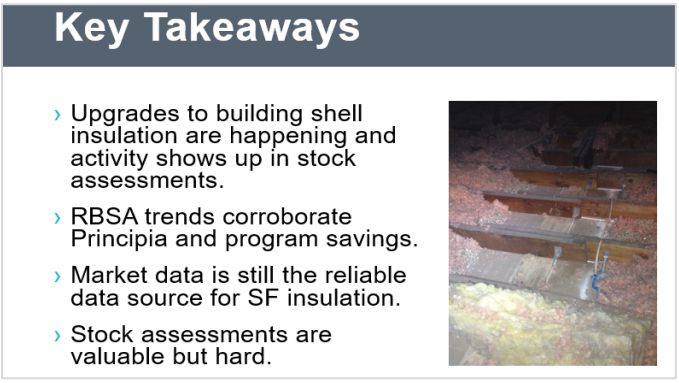
are not calculating fully weatherized homes here because we did not want to assign a representative heat loss U-value to the not weatherized and the weatherized homes. There are a number of things you could do. You could use average ratings from RBSA III or average the U-value for heat loss from RBSA III for homes that were counted as the weatherization homes versus those that did not. You could assign RTF savings for these measures to account for imperfect conditions. But what we are doing here is saying that the total volume of insulation in each of these components is increasing over time.

David added. That is good detail. But I think the question I was trying to ask is on the assumption that we somehow normalized our way out of this problem as far as the individual walls are concerned. This analysis shows there has been a 7 percent point increase in walls that are insulated that are in the existing building category between 2016 and 2022. And while I think the 83 percent looks pretty solid, the 76 percent does not because of the way RBSA II collected that kind of data, which was at best different than RBSA III. It is this change that I am more concerned about. Do we think that 76 percent was all that we had or if we actually went to RBSA II with the same equipment in the same direction, would we have got the same 83 percent? What do you think are the biases associated with data collection in RBSA 2016 versus 2022, and did we take into account for those methodological differences in the data collection? It is a big difference, but it is the standard. I mean all of the stuff we did up until RBSA III has that problem. Auditors are guessing, they have to. Or somebody else was guessing if the auditor did not, and both of those things did happen. But everybody is guessing. **Courtney** asked. Do you have any ideas for how we should address that bias? **David** replied. I probably can think of some having been one of the main people that did guessing here, but the question is what would my guess have been had I had data? The other part of this is that since a fairly noticeable fraction, 15-20 percent, of your existing buildings were built under a code over the last 2-3 decades, those all had insulated walls. You can just discount all that because they could have been bad in the 80s. But after that, people were getting inspected, there was a code, there was an inspector, and he took it seriously. **Bretnie** added. The data that we are looking at is just homes that were built in 2011 or earlier. **David** replied. But 30 years of that had a code. **Courtney** added. Yes, when we looked at that, we filtered down to homes that were built before 1973. And many of them had some insulation because they had been weatherized. But ultimately, that is not a consistent way to do it because states implement codes at different times. It becomes just increasingly challenging to do that. **David** replied. Apart from Montana, that is not really relevant. The codes were in place in some form or another by 1990 and were enforced.



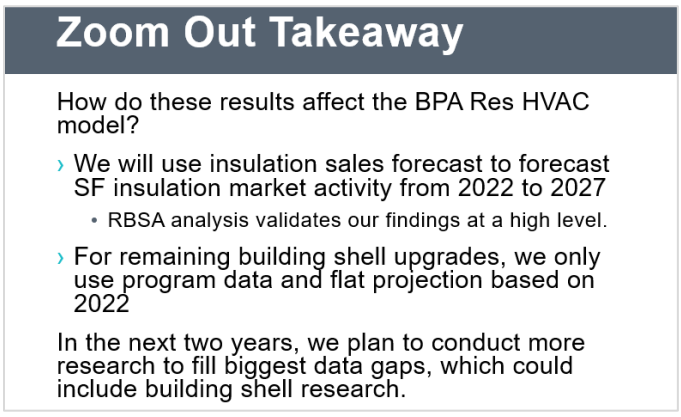
Courtney continued. Let's look at these different insulation data: the program data, market data we collected in 2022 here with linear projection to 2027. With programs, for example, we see .4 percent of the UA upgrade potential is being upgraded in attics every year and then .2 for walls and .3. We see that being much higher in each case in the insulation sales data represents the total market. It is closer with the RBSA II-III trend from the alternative analysis we just showed you. We expect the market data to be higher than programs because not all of the market activity is only occurring in programs. The RBSA trend that we have identified here is in fact higher than the insulation sales data in all components. It is directionally in agreement, which I think is an important finding. And it is not an order of magnitude different. It is just a couple of percentage points. To me, this validates the model inputs that we are using based on insulation sales data, but it is not necessarily a model input I want to use in the model.

Bretnie added. This approach is another way of looking at the RBSAs and trying to pull out anything that we can feel more confident in comparing between RBSAs. We still do not want to use them as model inputs. We are comparing it to other market data to help us understand how weatherization is changing over time. This is telling us that we are at least in the ballpark; that the RBSA and the market data and the program data are all pointing towards buildings getting better over time. **Christian** asked (in the chat): Can you remind me - is market based on insulation sales? **Bretnie** replied. The market data for insulation in single-family is the Principia sales data.

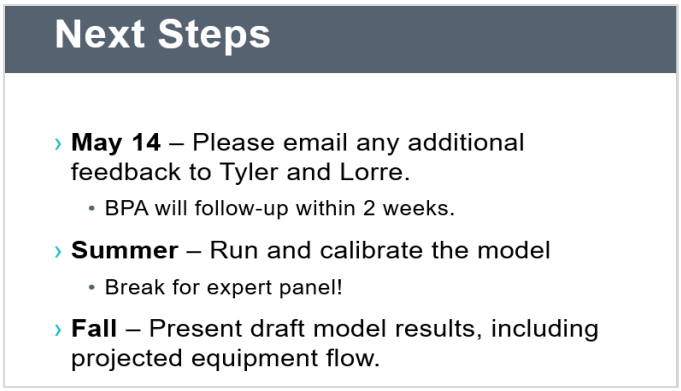


Courtney continued. We do believe that building shell insulation upgrades are occurring in the region, and we think that the RBSA agrees with us and validates our trend of positive increase in the number of fully weatherized homes in our model inputs. We still think that the market data that we purchased is the most accurate representation for single-family insulation and intend to continue to use that model input. The final takeaway is that stock assessments are valuable but difficult.

Wrap-up and Next Steps



Bretnie added. But I think the other thing that is helpful in that comparison is looking at it in a different way, which is, what is left? I think the RBSA, looking at it from this perspective, tells us that there is still a lot of ceiling insulation potential and that opportunities may be decreasing for walls. I think this alternative way of looking at it gives us some different perspectives than we would if we just said nothing is usable in the RBSA. **Courtney** added. We are going to be sending you a request for feedback on this presentation's analysis. We really want feedback on the projections we discussed and the recommendations for future research. We intend to use the insulation market data to forecast that forward. Based on today's feedback, we will probably make that adjustment to flatten out the forecast. We plan to do a lot more research in the next coming years. We want to know what is valuable for people for the region and what is most impactful on the market model.



Tyler reviewed the next steps.

Working Session #4: Interim Market Model Draft Results – Nov. 18, 2024

ACTION ITEM – This highlights an action item for a panelist.

ACTION ITEM – This highlights an action item for BPA and/or Cadeo.

Attendees

BPA: Joan Wang

DNV: Tyler Mahone, Lorre Rosen

Resource Innovations (formerly Cadeo): Courtney Dale, Sarah Widder

Invited Panelists	Affiliation	Attended	Did Not Attend
Mark Jerome	CLEAResult	☒	☐
Jonathan Moscatello	Daikin Comfort	☒	☐
Abram Conant	Proctor Engineering	☒	☐
Bob Davis	Ecotope	☒	☐
Kevin Madison	PNNL	☐	☒
David Baylon	Independent	☒	☐
Ryan Brown	NEEA	☒	☐
Christian Douglass	Council	☒	☐
Christopher Dymond	NEEA	☒	☐
Aaron Ingle	NEEA	☒	☐
Jonathon Belmont	BPA	☒	☐
Chris McKinney	Ferguson	☒	☐
Mark Jerome	CLEAResult	☒	☐

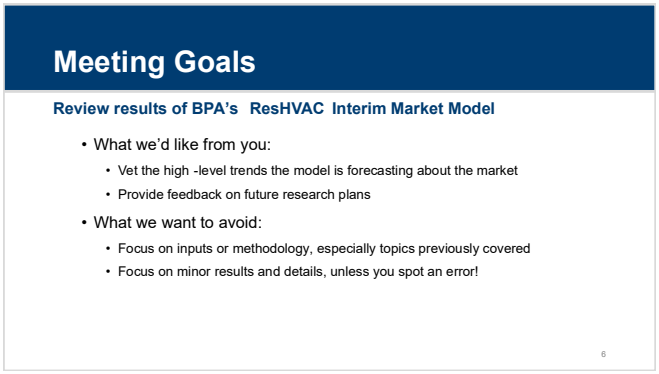
Working Session Agenda

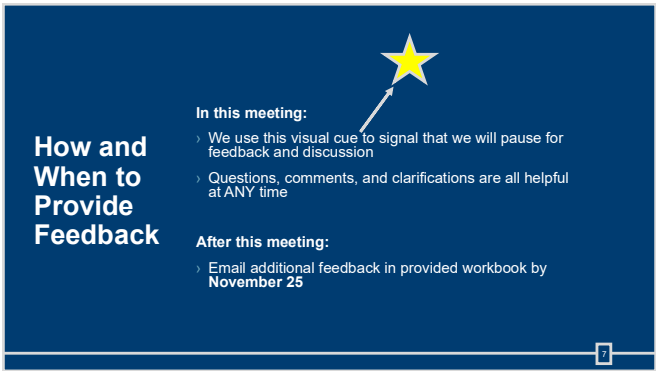
- Panel Objectives and How-To (5 min)
- Model Methodology Refresher (15 min)
- Model Results (75 min)
    - High level findings
    - Market trends
    - Consumption trends
    - Energy savings trends
- Future Research (20 min)
- Next Steps (5 min)

Introductions

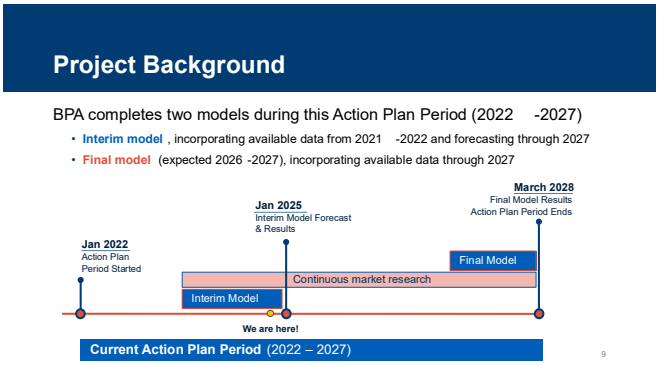
Tyler walked through the agenda and introduced the panel.

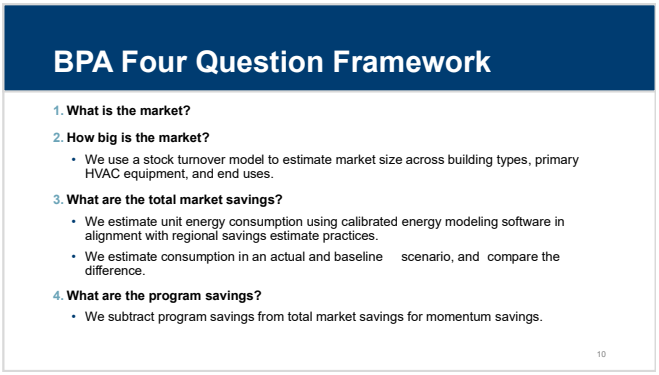
Panel Objectives and How-To

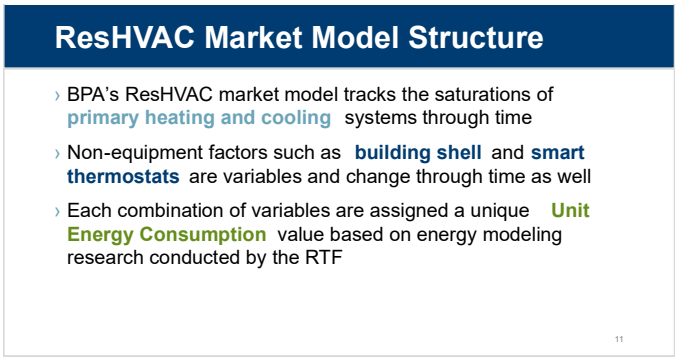




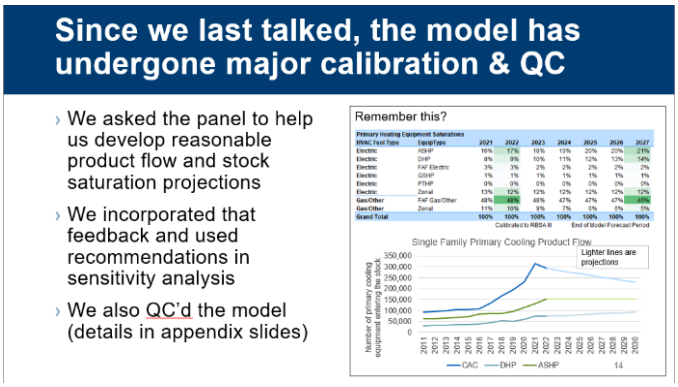
Model Methodology Refresher







David asked. I was not completely clear about how you are handling secondary heating. The three categories where this matters a lot: electric resistance, zonal and electric furnaces, and "other." It seems to me that a single UEC would have to include some kind of correction for the amount of secondary heat that is typically present in those groups. I do not understand whether we were getting a single number that covered everything coming out of SEEM for example, or whether there was an actual correction for the possibility or probability of secondary heating. **Courtney** replied. Every UEC has an element of accounted for secondary heating. We do not track if house A has secondary heating and house B does not. Every single heating system accounts for that secondary heating, which is done the same way that the RTF for RBSA 2016. And I am sure there will be a new calibration that we will have to account for in the final model as well. **David** added. Does this end up being a correction to what would be otherwise predicted as the total heating load or reduces the total heating load? **Courtney** replied. The SEEM calculates total heating load, which if it were electric resonance, would be 12,000 kWh and then knocks it down by 10 percent. It depends on the heating zone. **David** asked. What happens to the 10 percent? **Courtney** said that it was removed. **David** added. It is not removed, of course, right? It is actually somewhere else. It is just that you are not counting for it. **Courtney** added. We are counting electric heating only. So, if it is a gas furnace or if it is a wood stove, then it is not electric heating.

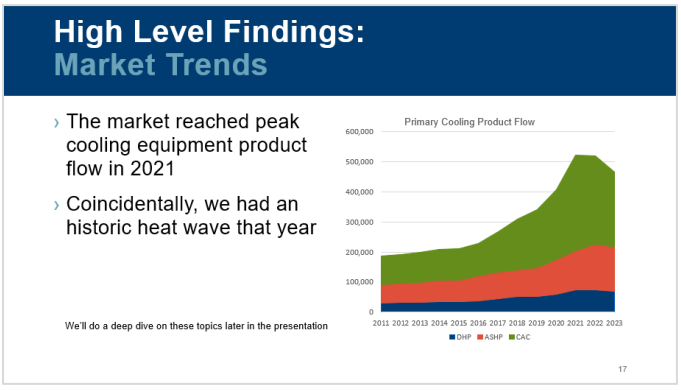


Christopher Dymond asked. What do you mean by saturation? **Courtney** replied. We use saturation two ways. One is stock saturation. Forty percent of the homes that existed in the Northwest in 2023 use gas furnaces, 10 percent of them used air source heat pumps, 15 percent of them used ductless heat pumps. That is stock saturation. Then there is also the saturation in the product flow, the percentage of that product flow that is air source heat pumps, gas furnaces, and other different equipment types. **Joan** added. We usually call the distribution of what is in the product flow or sales as the technology mix of the sales. We do not use saturation much in describing product flow or sales. We use saturation to describe what is happening in the stock. **Christopher** added. The next slide shows that ductless heat pumps (DHPs) are primary heating, but we do not actually know what fraction of the load they are actually carrying. **Joan** added. Yes, the fraction of the energy load is something that our model outputs. We do look at how the model is forecasting in terms of energy consumption and consumption of different homes that have different primary heating and cooling equipment. **Courtney** added. I do not break out consumption by technology type in this presentation, but we definitely can do it if you are interested in future model outputs.

David asked. The slide basically says that there is almost a doubling of the DHP saturation, but virtually no impact on electric furnaces or electric zonal that does not square with the programs. In effect, what you are saying is that DHPs are becoming primary relative to gas zonal, which I presume means zonal stoves, wood, gas, or propane. I do not think you are right. I am concerned about the fact that you do not seem to be impacting the electric heat sector with it. **Courtney** replied. We are just showing you results from 2021-2027. The model actually starts in 2011 with the first RBSA. The stock turnover model starts running in 2011 and runs through 2027, and we calibrate it to the two subsequent RBSAs. Those two subsequent RBSAs show that the biggest downward trend that is being replaced by other equipment occurs in the non-electric zonal category. So, we continue that trend through 2027.

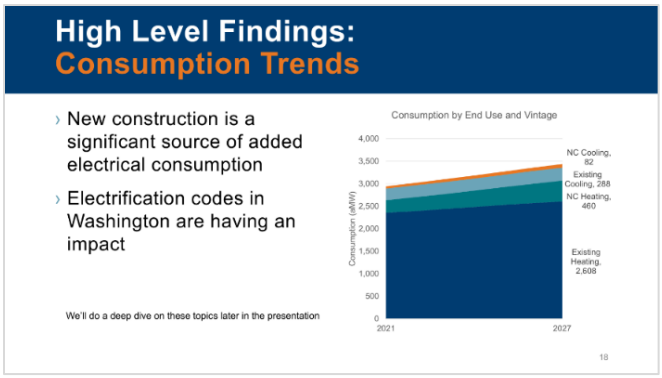
Model Results

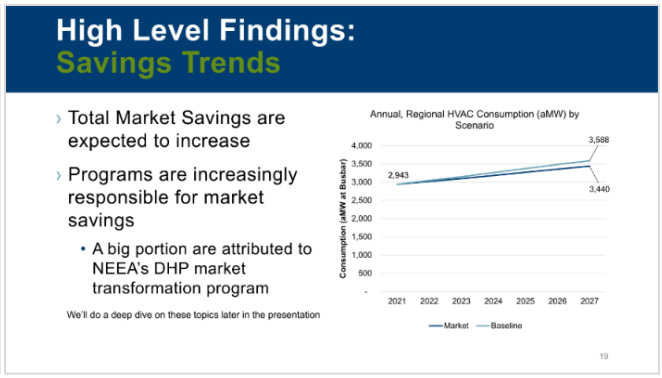
High-level Findings



Tyler asked Jonathan Moscatello and Chris McKinney (market actors) if this high-level trend makes sense. **Chris** said yes, this definitely makes sense.

Christopher asked in the chat window: What is the primary heating in a dual fuel system? What fraction of heating load is carried by the heat pump? **Joan** replied. It depends on the combination. Biggest combination is ASHP with gas backup, so ASHP is the primary heating and gas furnace is secondary. The split of heating load is taken care of in the SEEM calibrated/modeled UEC, I don't know the answer we can get you more details offline. But this model did not do updates of that while we await new data. We will revisit more in the final model.



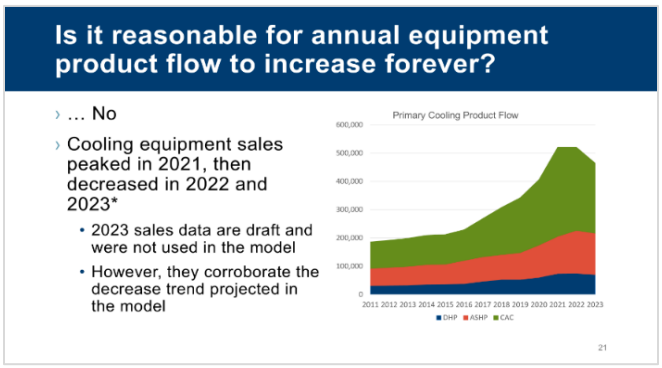


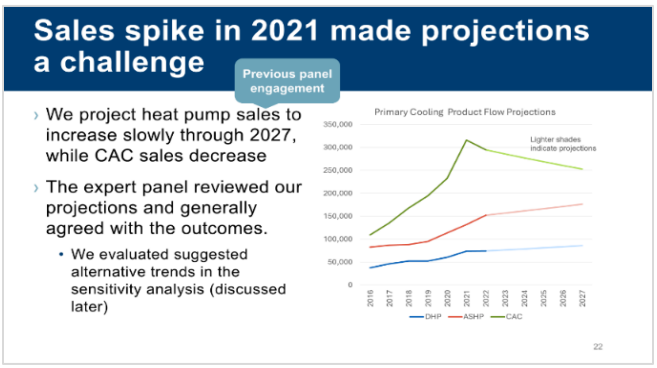
Jonathan said. Some of the trends do not seem right to me based on the code changes in Oregon and Washington. For instance, hearing that electric zonal and really all electric resistance heat is becoming very difficult to achieve. Therefore, we are seeing continued year-over-year growth in ductless. Back on those previous slides where you show the market share that shows an increase in these product categories and then the decrease in the ones that are gas zonal. That is a surprise to me. **Courtney** replied. We do not add any electric zonal into the stock. It is just legacy. This is a good time to point out that this includes multifamily and virtually all of multifamily still has electric resistance.

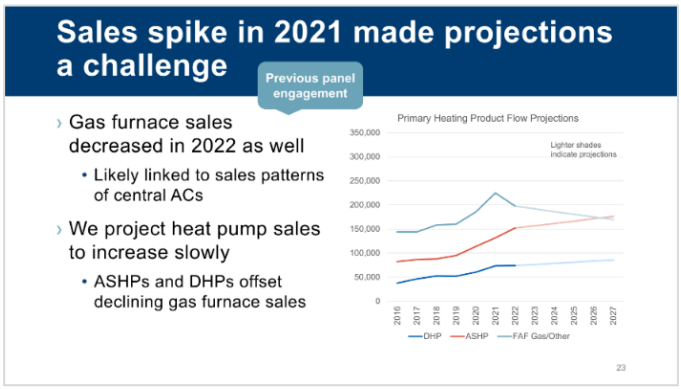
David asked in the chat window: The DHP saturation almost doubles but has almost no corresponding decrease in EFA or ER, all of the adjustment is to gas/other. Experience suggests that the DHP is often associated with the electric heat. Hopefully so does the programs. **Joan** responded to David and Jonathan. I think your feedback is on point. And I think what is hard about what we are showing here is looking at the universe and diving deeper into particular segments and differentiating sales in stock. So, we are talking about the whole region that includes our giant existing home as well as new construction, versus if we just look at new construction or single family. We will try to describe the results cut different ways and then we can come back to your feedback and see if we are on track.

David asked for an explanation of what is meant by residential sector. Multifamily gives a rather critical change in the nature of that sector. **Courtney** replied. The scope of the model is all residences with in-unit heat. A multifamily building's central system is not included, but we do include high rise with in-unit heat. **David** added. Really. I do not see how you lost so much electric resistance if that is the case. Because that is a lot, if not most, of the apartments that are being added at rates like 10,000 units a year in in Seattle and probably pretty close to that in Portland. And that does not even count what goes on elsewhere in the region. And those are all electric resistance. **Courtney** replied. Multifamily is only about a sixth of the total stock. It is all blended in that number. **David** replied. Yes, but you lost saturation of electric resistance in spite of the fact that a sixth of them are being added. **Courtney** replied. Not added. I mean, that is the sixth of the total stock. We are adding 10,000. There are 20,000 new multifamily units and 50,000 new single family units in the region.

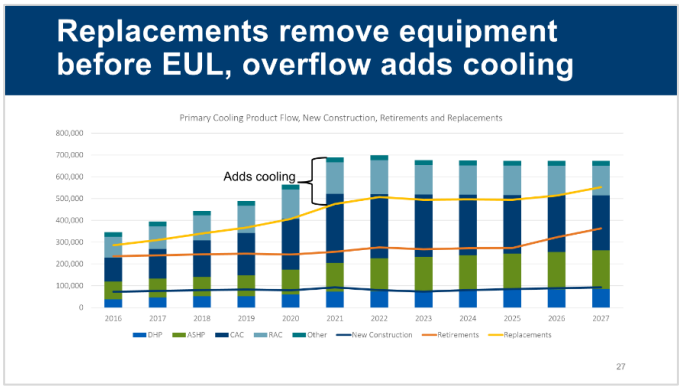
Market trends (sales and stock saturations)







David said, really? But it looks like you have a decline in cooling. **Courtney** replied. *(Jumping to slide 24.)* This is the cumulative incoming product flow. We come up to 2022, had a minor decrease in 2023, and then continue forward. *(Jumping back to slide 22.)* When we look at these technologies separately from each other, AC sales are decreasing and being replaced by air source heat pump sales. **Jonathan** added. Yeah, I see something that is off here. You show this enormous trend and increase in cooling overall and then you show this dramatic decrease in the AC portion, and then the somewhat increasing heat pump options. But I do not think you have accounted for the overall trend and in your total units. But I agree that I think you will see a tapering of AC over time, but I think it will be made-up by much more aggressive heat pump options that would result in the continuing dramatic increase in the addition of school infrastructures. That makes sense. **Courtney** replied. We will show you how that comes out in the model. I think it is really interesting how this dramatic increase in overall product flow affects the stock. But you are right, the region is adding cooling and there is a reason for that.



Aaron asked in the chat window: Can we explain the difference between replacements and retirements? **Tyler** replied. Replacement = early retirement.

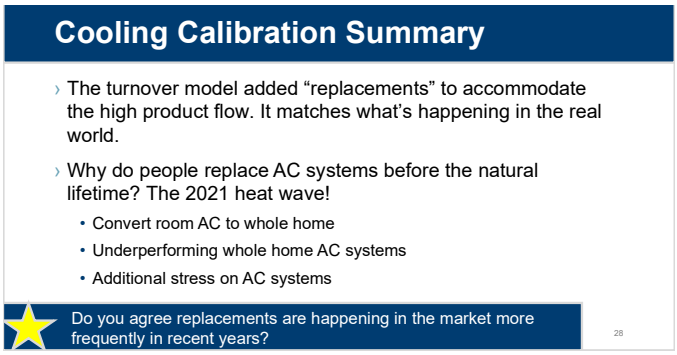
Bob asked in the chat window: I need quick clarification on what “new construction” means here. **Joan** replied: New homes added to the home stock. Or do you mean something else? **Bob** replied. I mean in context of this graph. Maybe all it is saying is how many new construction units have some sort of mechanical cooling. Overall effect through 2027 is that houses with mechanical cooling are staying flat. **Joan** replied. I think it is saying that the rate of new homes being added to the stock is stable and sizable every year. And we give cooling to new homes (maybe not all, but most? based on new construction data we have). **Bob** replied. I also think the “other” category here most likely applies to multifamily. I assume thru-wall units (PTHPs) are part of this. **Bob** added. I am glad Jonathan mentioned the disruptions in the supply chain (and consumer demand) caused by impending refrigerant changeover and (also) big price bumps. Also, I am still unclear how the IRA effect will play out, especially given

administration changeover in 2025. **Bob** added. I was wrong. Dave's question clarified what I was wondering about. I think a cumulative graphic (which I'm sure exists somewhere close by) would help.

Christopher asked. Is the vertical axis “homes” or “systems”? **Courtney** replied. It is homes. This is sales. **Christian** added. Yes, but sales is “systems.” **Courtney** replied. Yes, systems. But we assign one primary system per home, right? We have already accounted for secondary systems. You see DHPs, we know that some of DHPs are secondary and those are not on this graph. **Christian** added. So, the fact that you might have three DHPs sold into one home, you have a sales number that says three, but you have only one home served? **Courtney** replied. Yes. **Christian** said. These are homes. OK, that is good. **Courtney** replied. Yes, you are right, it is a little confusing. It is primary systems. They are basically the same. DHPs are confusing. That might be something we want to look even more closely at. People are changing and I think we might need to account better for number of systems they are putting in their home.

David asked. The difference between the yellow line and the top of the bar chart is unaccounted for in the existing residential sector and it is assumed to be added cooling that is actually primary cooling because it was not there before. This number, 200,000 unit sales, is the amount of new cooling being added to the region more or less annually correct? **Courtney** replied. I would not say it is unaccounted for. We are accounting for it. We track the number and the saturation of no cooling homes. That is effectively a technology category in the model. **David** added. Right, but what you see here is that it is 200,000? Is that supported in the market? **Courtney** replied. Yes. We had 3 million homes with no cooling in 2016. And the research that the Council did expects a significant reduction in the “no cooling” homes in the region. **David** added. But 15 or 20 percent of that is actually multifamily where cooling is a non-trivial addition. **Courtney** said that sector adds cooling more slowly than the rest.

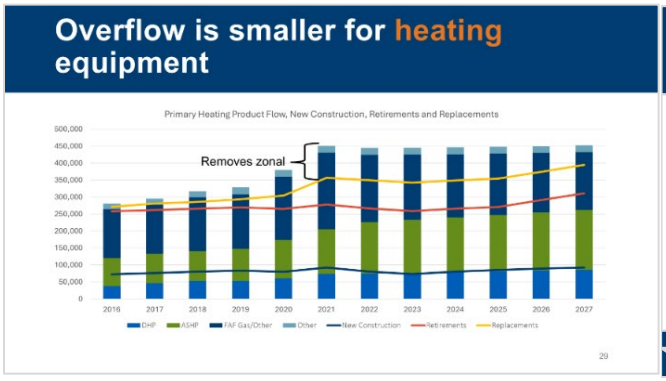
Aaron asked in the chat window: Does the replacement category include expansion of cooling within homes (e.g., a home going from RAC upstairs to a CAC?)

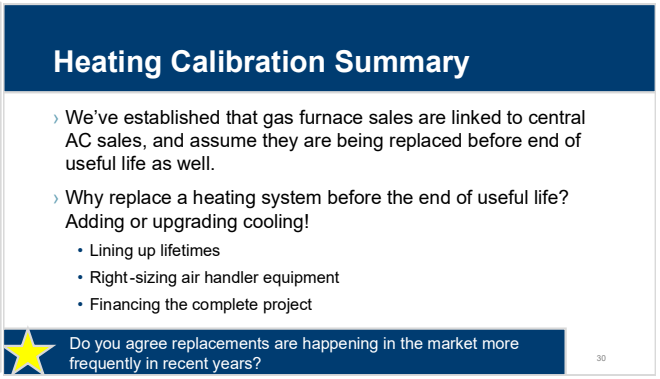


Jonathan asked. It looks like you have got the leveling off of the annual system sale or home system change. How would what I am about to share influence that conclusion? As manufacturers, we saw that the change in our rating systems and the whole turnover of inventories related to that, and now with refrigerant transition, it is just a big disruption in the market. I think it started in 2021, and those two disruptions were continuous. As manufacturers, we saw a series of flat years regarding those changes in addition to some softening from consumers for a variety of reasons. Right around 2021-2022 where you show leveling, I think that is consistent with the data. But I think that sales data is classic disruption related. If we had not had those disruptions, I think you would see an increasing rate change from 2021 to 2024. With that being said, would you still show the leveling that you show on this graph in the years 2021 onward if we had not seen these disruptions in the market? **Courtney** replied. That is interesting, I had not tracked those two disruptions. It sounds like that is consistent with what we have modelled here. The projections are uncertain. We turn the incoming product flow into effectively a stock saturation. We probably just turn down the number of replacements if the incoming product flow was lower in order to match our expectations of added cooling. **Jonathan** replied. I think that makes sense. I am right, this is conservative, but that is okay too. The other factor I will share is that with those disruptions, stocks and sales are generally more affected because many of the manufacturers invested in those changes and quickly did their refrigerant transition on the product lines that are most attractive in the Northwest. So unfortunately, we are seeing the disruptions on things, such as, we are able to get more than we are with low minimums here.

Bob added. I am really glad Jonathan put that in there because, I think in the last meeting, we agreed with being a little conservative on these increases because of the price changes we were seeing. And part of that certainly had to do with impending refrigerant changeover. There are other factors like the IRA incentives and tax credits. I am not even sure what is going to happen with that now. It is going to continue to be a factor for many consumers, but given the completely unknown direction that DOE was going to head in February, it is going to have an effect. But installers are businesspeople, and they are trying to do their best to remain in business. I think that the conservativism may not be totally warranted. Given the general pricing and all these other factors, I think it is going to put a damper on things overall for some time, which is consistent with your chart.

Christian added in the chat window. In response to the question with the star - I would assign the uptick to "added cooling". It's very hard for me to imagine - with prices the way they are - that people have been increasingly replacing systems early. I would think the opposite - people are doing whatever they can to keep their systems running and will only replace them if absolutely necessary (end of life). **Courtney** replied. I will point out that new air conditioners have not changed that much through time, maybe a little bit of an increase, but they made up a pretty significant portion of the stock going back. Those are a lot of the ones that we removed because we assumed they would be retired early compared to an air source heat pump or a central AC system. **Christian** replied. Just talking to people, and seeing quotes on new systems, I cannot imagine anyone retiring a big central system early because they are so expensive right now. **Courtney** added. I am with you. It would be like you are adding something to the second floor.





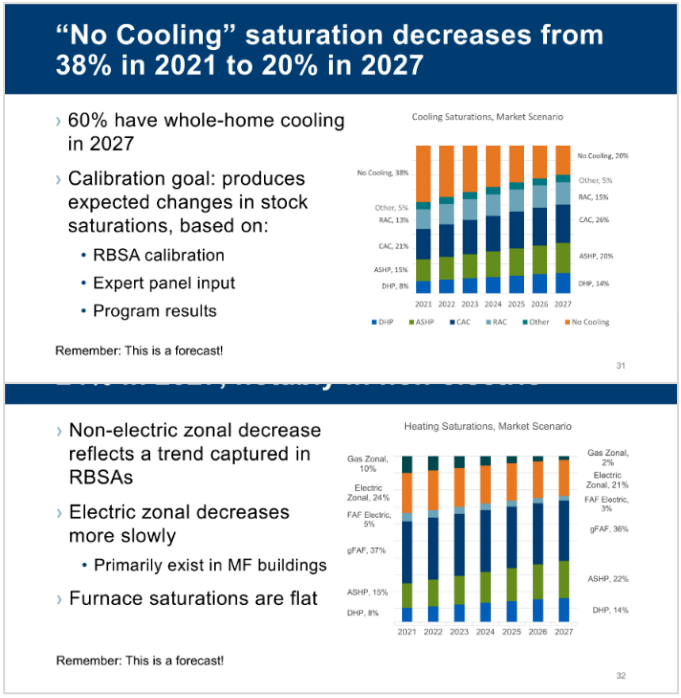
Christopher Dymond commented. I just want to point out that we are missing a whole product category that I think is emerging that we should pay attention to and that is dual fuel. It is not a heat pump, and it is not a gas furnace. The amount of the electric load with a heat pump can range from 20 percent to 80 percent. We have to consider adding to your model here is that this is not a primary and secondary because that implies something different. We are going to see this become its own product category. I think you should add that. **Courtney** replied. I appreciate that feedback. We see a trend in the RBSAs that is increasingly occurring. I think you are right that we should add that. **Christopher Dymond** added. It is not just that you are changing it to an air source heat pump as primary. **Courtney** replied. Hopefully, someone will do some research on energy consumption related to those systems. **Chris McKinney** added. Christopher, 100 percent agree with this. This will be a big trend moving forward.

Joan asked Courtney if we got enough feedback on the product flow. Did we get enough feedback on the rate of what we are calling replacements (which is a big category of anything that is not new construction or retiring equipment at the end of their useful life, or adding cooling)? That is probably our biggest area of uncertainty. **Courtney** replied. We explained that spike in product flow with early retirements or replacements, which we associated with adding cooling because you are lining up the lifetimes, you are right sizing the air handler. Maybe You are financing a really expensive project, and you want to roll your furnace into it. **Joan** added. For the sake of model simplicity, it is a hodgepodge of

things. But I would love to ask the panel if this makes sense. We do not know what is happening precisely, but there is a portion of what is happening in the stock to accommodate all this incoming product flow. How do we research that? At a high level, we have these stock assessments that give us a really great snapshot in time every 5 years. So, we can model to the stock assessments, but what is happening in between the years? **Christian** replied. I have a couple of thoughts. Based on the previous slide, you said your hypothesis is those electric zonal homes are going to DHPs, is that right? **Courtney** replied. Yes, all zonal. **Christian** continued. The two places where I see a lot of those DHPs going, 1) It is added load. It is load building. I do not know if that is captured in your new construction or not. Maybe this goes back to the earlier question of what is truly new construction, right? Because if it is only new builds, then I think DHPs are going there. But a lot of it is room additions. And I do not know really where that falls in some of this math. 2) I suspect that that a lot of them are going into these flips. Homes that had electric zonal and then, when they are flipped, you almost always see DHPs in those houses. I see those as being the two bigger markets where I see them going. **Courtney** replied. I tend to agree with you. It is hard to say exactly why people are adding them, but we do anticipate that a lot of these homes are becoming DHP homes. We account for the added load in the calculation of the energy savings so that we are not subtracting from the savings. But home flips is a good point. **David** added. It does suggest that your earlier explanation about how you are handling DHPs, and the overall saturation may need to be adjusted. Especially if this graphic is any indication, because that means the DHP will become a primary in a really large number of homes. If all you are doing is just tossing a few DHPs into an electric resistance home, which we have done in many thousands of cases, then the primary system is going to be DHPs. And then at that point, that number is going to be completely different than the one you have now. **Joan** replied. Home flips! Yes, good case for “early replacements.”

Mark added in the chat window: I think Christian is on to something, commercial home buyers vs individual buyers could be driving DHP and Furnace w AC installations.

Aaron commented in the chat window: I'm not sure the definition of replacements is quite clear - it mixes some different buckets. I think we need to differentiate the fact that the increase in cooling is partially an increasing percent of home sq ft that is fully conditioned, and partially an increase in number of homes with any conditioning.

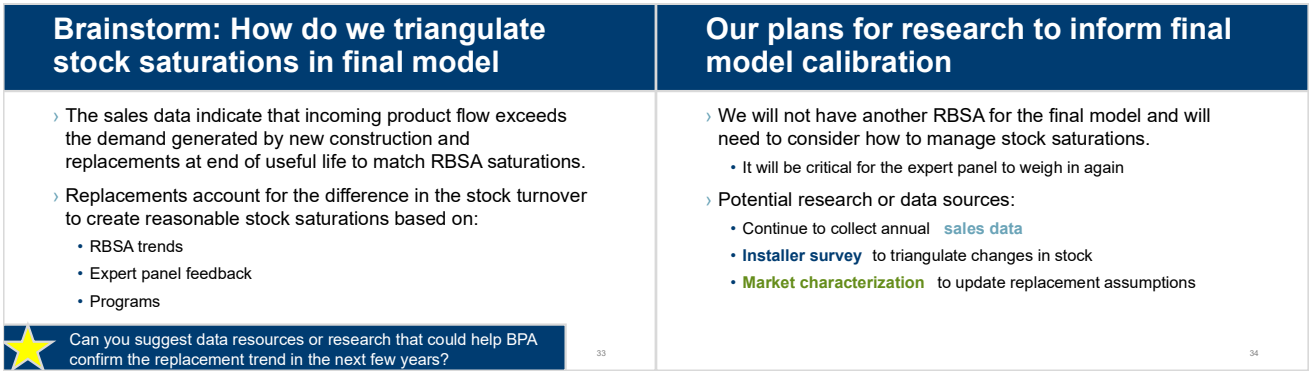


Christian commented. This looks good to me. DHPs is the hardest one I think. But in terms of overall trends, this looks reasonable.

Christian asked. Unfortunately, I have not had a chance to look at RBSA 3 yet. Is a fifth of the region still electric zonal? **Courtney** replied. It is frustrating. Most of that is within multifamily. Eight percent of multifamily is still zonal electric.

Aaron asked in the chat window: ASHP for cooling is 20 percent in 2027, for heating is 22 percent? **Courtney** replied. Cooling and heating differed just a little bit because of how we consider primary systems. I think it is more prominent in the ductless where we have some configurations where the ductless is the primary cooling but not the primary heating system. That is why you have slight variations in the system percentages. For example, if there is a gas

furnace in the home, the ductless heat pump is going to be not the primary heating system. There are slight variations, but it should not be major.



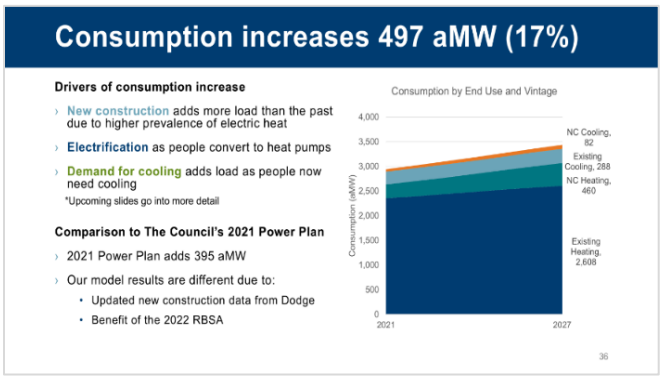
Joan added to the chat window. To be clear, there will be a new RBSA in 2027/28 but just not in time for our final model for this plan period. We will definitely use the new RBSA in future model iterations.

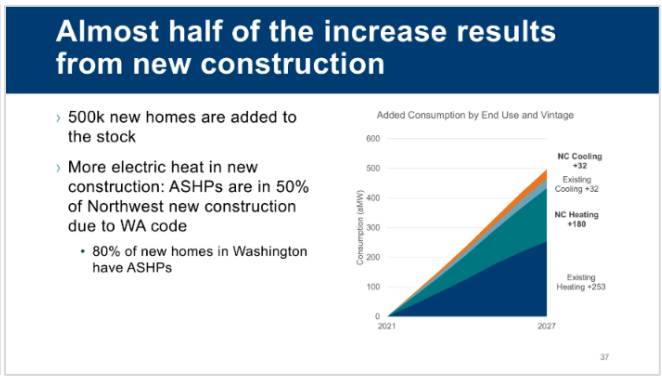
Ryan added. As part of NEEA's long-term monitoring and tracking efforts DHPs, we also do some installer surveys periodically. They are pretty targeted to understanding things about DHPs through the lens of this displacement-focused program that NEEA has worked on for a number of years. But there might be some information we could pull out of that to help refine our assumptions about product flow. As you are thinking about an installer survey, I wonder how to make sure we are consolidating efforts there and not necessarily overwhelming our market actors. **Courtney** replied. That is a great call out. We will definitely need to coordinate. I should have a fourth bullet point which is reading NEEA's reports on the DHP market. **Joan** added. The next one should be available in mid-year next year, second quarter of 2025. I agree with you Ryan, we will definitely work with you and hopefully collaborate where we can. On the DHP-specific questions we could work with you through the existing survey that you already do and so that we can right size our other research questions for the other installer survey. Either way, it sounds like we should definitely consult with Dave Baylon for anything DHP related. We will do that too.

Christian added. I do not know how much of this is being driven by Washington. Their new construction went from 80 percent gas, 20 percent electric, pretty much flipped on its head. And I am sure we all know that a proposition was just passed that could reverse that. **David** replied. No, it can't. **Christian** continued. If it is true that Washington has spurred a lot of this, then I think it would be good for someone to track what is going to happen after that legislation. **Bob** added. The effects of that measure are still somewhat TBD. **Courtney** added. I 100 percent agree. **David** added. It is not correct that the initiative that passed actually changes the code. The code does not restrict gas. This exchange was because the efficiency of the gas furnace is so abysmally less than the efficiency of a heat pump. And Washington's performance goals are energy based, not fuel based. What does that means in terms of the current initiative, I'm not sure. But the one that really counts is the one that does the cap and trade and that won by two thirds. **Courtney** replied. We have not accounted for those results. We will have plenty of time to digest the impacts in the future. **David** added. In the olden days, utilities found out things about saturations with phone surveys. A phone survey at regional level is about an order of magnitude cheaper than an RBSA. And if we really have an interest in a lot of these saturation details, we do not need a full audit to do that. We just need to be able to do a phone survey. I would suggest reviewing that as a possibility because it certainly could be done within the interims between the 5-year RBSA, which are extremely expensive and require field work. **Joan** said that is a good point. Energy Trust does a lot of these surveys for Oregon and maybe we need a targeted phone survey to just capture the rest. But I also just want a caveat that given that we are BPA, we are a little more constrained in direct end-user research efforts. But we should definitely rethink that and work with our regional partners on that.

Bob added in the chat window: Consumers are increasingly worried about the cost of heating their homes and electricity costs do seem to be increasing faster than gas costs. So, even with Coefficient of Performance (COPs) of 2.5-3, the cheap gas wins out in many parts of the region. By “many parts” I mostly mean cities and the 'burbs (that is, where 75 pct of the region's people live).

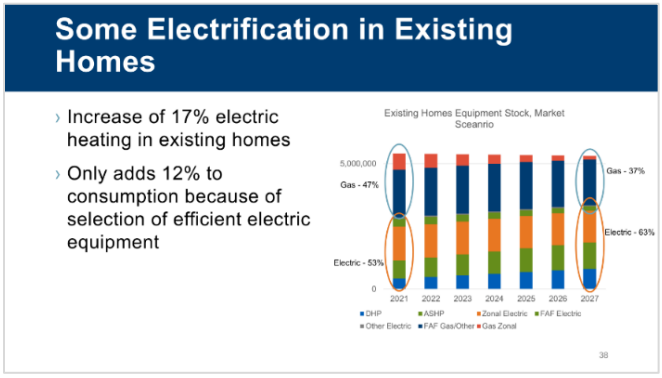
Consumption trends

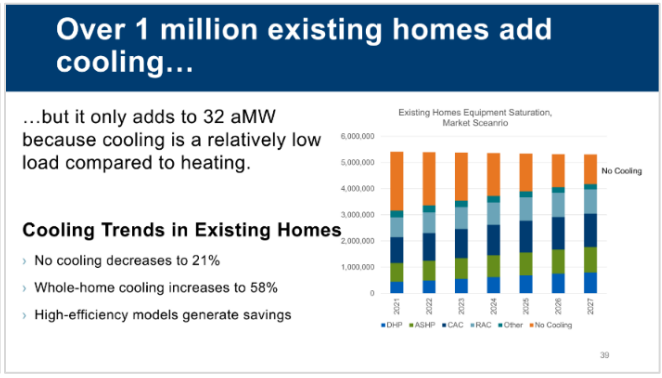




Christian added in the chat window: Is this in addition to demolitions or are demolitions not taken into account? **Courtney** said, yes, they are in a small portion of homes each year.

Christopher asked. When you were looking at existing heating growing by 253 average megawatts, is it mostly from fuel switching or fuel shifting? **Courtney** replied. We do not see a trend where we are moving backwards in efficiency, away from increasing electric resistance. I imagine that most of that is from fuel switching, but it is slightly less than the baseline, slightly less than the counterfactual because the added heating load is slightly more efficient. **Christopher** added. If you had 253 average megawatts and call it roughly 303,000 kilowatt hours of a dual fuel system that is using electric. That is roughly 3/4 of a million homes shifting to dual fuel. By 2027, that is a lot. It feels like a pretty steep increase in dual fuel to me if that is where the primary source of that existing heating gain comes from. **Courtney** replied. A lot of that comes through nonelectric zonal too. **Christopher** continued. So, you are saying it is existing heating increased, not new construction? **Courtney** replied. It is gas zonal, which is really not electric zonal. **Christopher** asked. Are these wall units? **Courtney** replied. These are wall units or wood stoves or boilers. **Christopher** commented. Still, that is 3/4 of a million homes switching over to heat pumps. That's a lot. **Joan** added. We are trying to make this discussion about product flow and sales and put them into the stock. **Courtney** added. This is a key question for us moving forward. That is extending the trend of the RBSAs forward. We will want to look hard at that number. That is why we are engaging with the expert panel now to help us make a plan for research to triangulate that number.

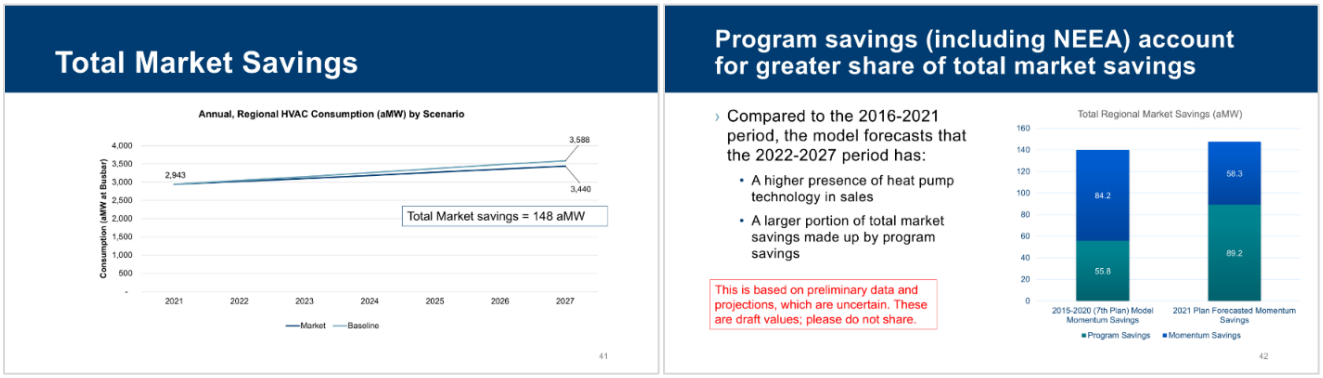




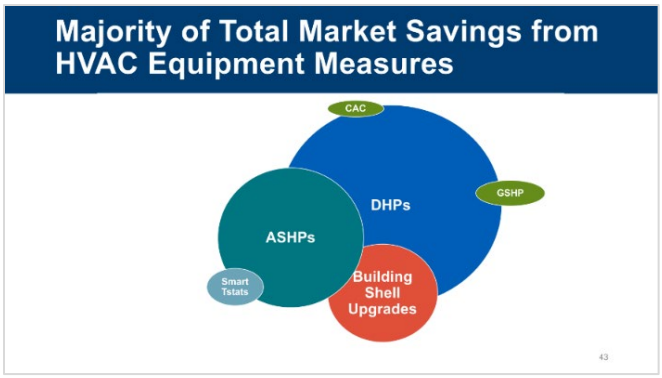
Courtney continued. Again, we see 1,000,000 existing homes adding cooling. But it only adds 32 average megawatts because the relative load of cooling is pretty small compared to the heating load.

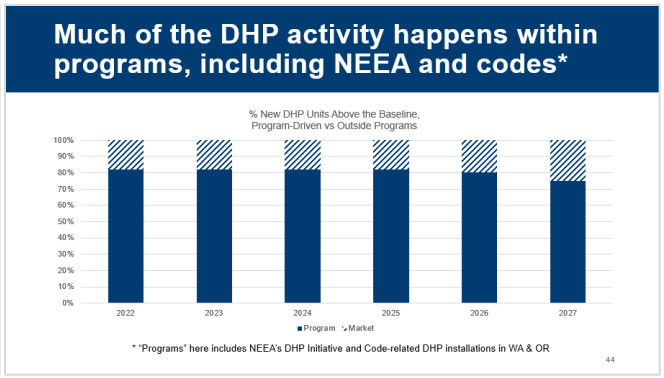
"No cooling" decreases to 21 percent. Whole home cooling, which does not include room air conditioners, increases to 58 percent. And we see a lot of high-efficiency models generating savings. **Christian** asked. How are you calibrating those cooling UECs? We have been looking at a lot of Home Energy Management Systems (HEMS) data and a lot of those cooling loads look quite a bit higher than we have modeled in the past by a factor of two or three sometimes. **Courtney** replied. We have not looked at that in a while and that might be something we need to look more closely at in the future. I think it is roughly a tenth of the amount of energy consumption of a heating load. **Christian** added. Out of HEMS, we are seeing significantly higher cooling loads in the model in the past. If there are kind of places where you are looking at improving the model, that might be one to look at in the future. It is still quite a bit less than heating. But it is becoming a bigger fraction for sure. **Courtney** replied. That will be something interesting to look at. We did these UECs in 2021 and I think we probably did not have the benefit of knowing what summers are now looking like. **Joan** added. It is definitely on our list to refresh in the next couple of years. **David** added. We should remember that what is also happening is warmer temperatures in the winter. Even if we get cooling at this level, we might or might not have a total increase in consumption. New homes built after 2011 count as new construction. **Courtney** replied. At the start of the model, we have some new home energy consumption.

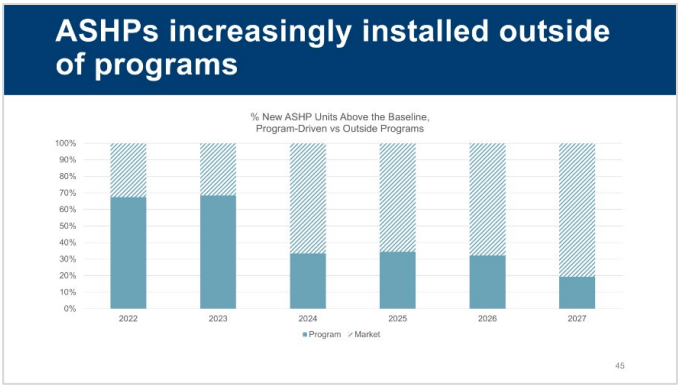
Savings trends



David asked. Why are they assigned to program homes? **Courtney** replied. They are program homes because they are associated with NEEA's DHP initiative. **David** added. Not NEEA's code initiative? **Courtney** replied. We also account for NEEA's code initiative on air source heat pumps and DHPs, I think. **David** added. So, in effect, all the progress and code is being counted as a program. **Courtney** replied. We do not really get savings from new construction anyway. **Joan** added. I think calling all of those things program savings might not be very helpful. For the purpose of what we are trying to do here, we use the model to look at what is happening in the market in total. Then, we need to quantify the momentum savings. In order to not overcount momentum savings, we try to take account of everything else that is program directed, like direct incentive, as well as NEEA's efforts including those related to code. Specifically, NEEA's DHP savings were very conservative in doing that. NEEA's DHP target markets are specific target markets, whereas our model is just saying all DHP savings count as NEEA savings. We are very conservative in counting everything in that program bucket. We are not breaking it out right now. **Tyler** reminded the panel that these are preliminary results draft values. Please do not share these numbers outside of this panel at this point.

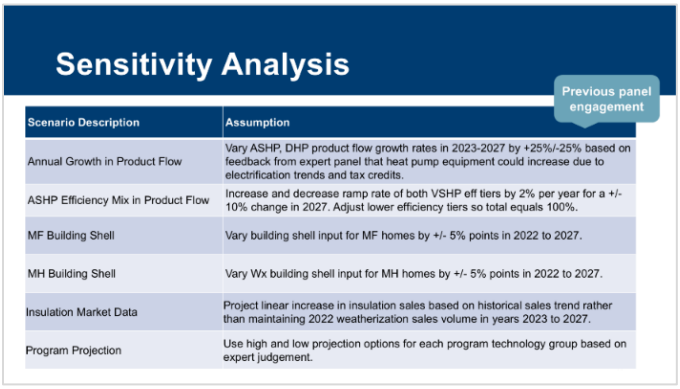




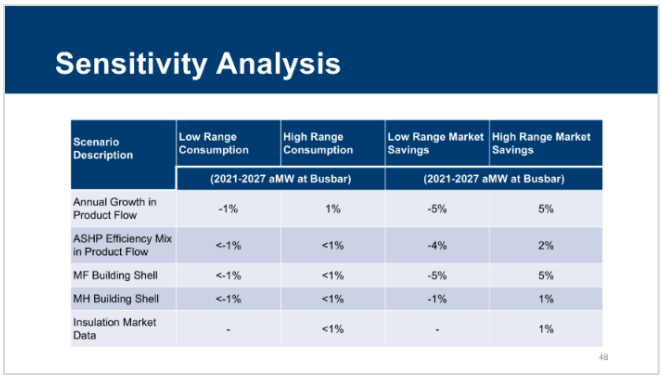


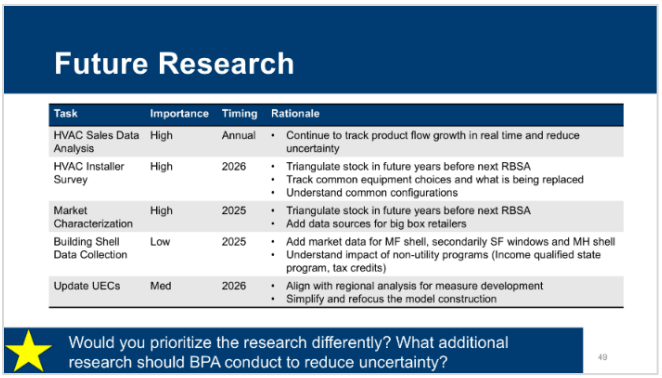
David said. I am pretty skeptical of that drop. **Courtney** replied. Me too but would imagine it would be just a steadier drop instead of the significant one that happened in 2024. But it is difficult to extract this specific data from the model and attribute savings. **Christopher** added. We have a pretty substantial change in the tax credit occurring in 2025. Utility funds are pretty small. **Courtney** replied. Variable speed are increasingly part of programs, but air source heat pump adoption has been pretty stagnant for quite a while in programs.

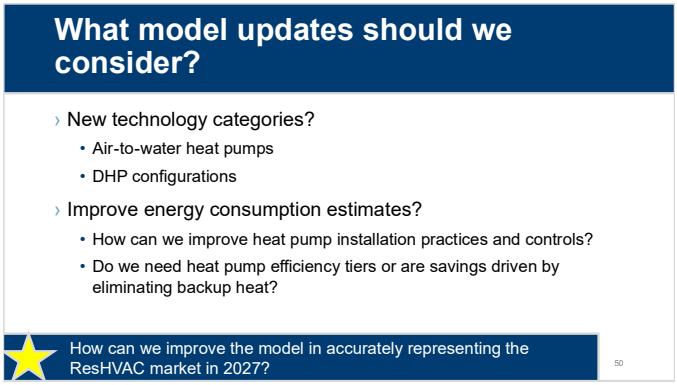
Uncertainty and Future Research



Christopher commented. All of those take a bite out of the existing heating gain. I want to point out that when we are talking about the bulk of them coming from switching to a heat pump from some kind of a fossil or wood source, which could be 4000 kilowatt hours a year, depending on the type of dual fuel system. It is a very wide range, and we need to think about what we know about that. There is an opportunity there, when people do switch to a heat pump, to get them into a good heat pump because it is a far bigger swing in energy consumption than going from a variable speed to a very good variable speed. **Courtney** replied. That is a good point. I always think that the feedback we get from this group is related to electric resistance backup of a heat pump. But you are mentioning non-electric resistance supplemental heat, which is something I think the region will want to look at more closely in the coming years. **Christopher** added. If they use this gas furnace for setback recovery, you are not going to get much heat pump out of it.

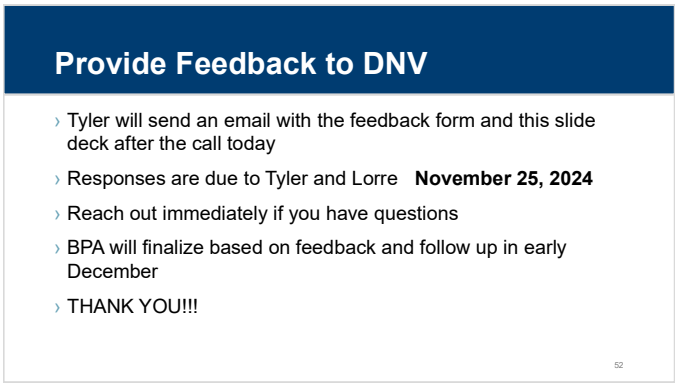






Christopher replied. The first thing that comes to mind is DHP configurations. We are talking about either a single-zone displacement without ductwork or a whole home with and without ductwork because a lot of these ductless are blurring into whole home multi-head, even tri-mode systems that also do domestic hot water. **Courtney** replied. I agree. We did add a configuration, the horizontal discharge, the traditional DHP outdoor unit connected to a duct system with a central air handler. And we've assigned that to the variable speed heat pump category. **Christopher** added. One more I think that might be worthwhile is something that minimizes the use of supplemental heat. When we look at the setback recovery, the defrost, or even just the crossover temperature —to electric or to a fossil — that kind of control is actually as impactful as the efficiency of the equipment, if not more. **David** added. For the most part, the efficiency of the modern heat pump is probably secondary to the controls simply because we lose so much efficiency adding electric resistance because of variation in controls that is not neither justified nor particularly important, but certainly historically has some significance. This is not exactly the installer's problem in the sense that we can and should be focusing our heat pump programs on this controls problem and its ongoing maintenance. It is probably a factor of 2 in the efficiency of the heat pump itself on average. **Courtney** replied. I agree, we should all look very hard on it. I expect the RTF to look hard at this when they review the air source heat pump measures. And we can certainly be a part of that conversation as well. **David** added. To the point that the utilities are involved in heat pumps at all, it is more important that they are involved in the controls of heat pumps than in whether or not the heat pump is there or its marginal efficiency.

Next Steps



Joan asked in the chat window: Here's a prompt for everyone: given this presentation, can you each type in the chat the one research question or model improvement that we should try to do in the next 2 years? And why? **Christian** responded: Better calibrating UECs (and UESs) using newer data sources (e.g., HEMS). **Christian** added. The BPA high performance high capacity research group (Tony Koch, et al.) also has some great data and insights. **Mark** responded. Big items that might impact the model: 1) Political changes (Upcoming sales trends), 2) UEC and UES data from HEMS 3) Dual Fuel and DHP new applications. **Christopher** responded. 1. What is current installation practice (ducts, controls, sizing, system choice)? Look at utility program cohort and non-program participant cohort. 2. What is the impact of different control strategies to reduce supplemental heat (electric resistance (ER) or fossil)? 3. Do we get the most out of a room Air Conditioner replaced with Room Heat Pump?