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

June 2025

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

Commercial 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 commercial 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 commercial HVAC market.

In 2024, BPA developed the first iteration of this 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 first model iteration as the 2022–2027 Commercial 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 Interim Market Model. For more information on BPA's commercial HVAC market research, please contact Joan Wang, the BPA project lead, at jjwang@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 Commercial 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 November 2022 and August 2024 throughout the development of the 2022-2027 Commercial 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. A copy of the comment tracker with panelist feedback and BPA's responses is available upon request.

Controls Data Availability Working Session on Nov. 2, 2022: BPA engaged with the full expert panel to obtain feedback on its evaluation of data availability for the commercial HVAC controls market and its approach for filling identified data gaps. In addition to the presentation slides, the panelists were asked to review the following materials: commercial HVAC methodology memo, controls data availability memo, and controls data summary workbook. BPA asked panelists to respond to questions regarding the following market inputs: market scope, equipment stock, equipment sales, and energy consumption. Based on panelist feedback, BPA made updates to the memos and workbook reviewed by the panelists and provided the updated information to the expert panel.

Model Development Kickoff Working Session on March 28, 2023: BPA engaged with the full expert panel to kick off the model development process and asked the panelists to respond to questions related to market trends, Commercial Building Stock Assessment (CBSA) data, ductless heat pumps, packaged terminal heat pumps, and variable refrigerant flow refrigerant-based heat recovery. The panel's feedback helped inform BPA's model development plan.

Permit Data Memo Desk Review from June 12-26, 2023: BPA requested the expert panel to review the commercial HVAC data collection findings memo from 2020 regarding the typical variation in HVAC equipment information found in Approved Permit Documents compared to the As-Installed Final conditions in constructed buildings. Panelists were asked if they have any data that either confirms or conflicts with the findings in the memo. In general, the panelists agreed that the findings in the memo were consistent with their experience.

Market Model Forecasting and CBSA Review Working Session on Sept. 8, 2023: BPA engaged the expert panel to review its analysis of CBSA data and asked panelists opinions on a forecast of floorspace and HVAC technologies from 2023-2027. Panelist feedback on the floorspace forecast confirmed that the existing data source was best for the market model. However, feedback regarding the forecast of HVAC technologies were varied. BPA acknowledged that HVAC technologies were an area of uncertainty that would improve through future permit data collection.

Building Simulation Inputs Working Session on Nov. 16, 2023: BPA discussed with panelists the building simulation inputs related to weather files and climate zones and building types. Based on panelist discussions, BPA provided follow-up slides to the panel and provided a list of items and approaches that BPA could conduct including removing Colville, WA as a weather file location and adding Medford, OR, running simulations using

TMYx 2004-2018 weather data, using the medium office prototype to represent all office buildings in the permit data, and using the retail standalone prototype to represent all retail buildings in the permit data. Additionally, BPA investigated the presence of economizers in the permit data for each HVAC type, as well as the impact economizers have on total and cooling energy use and provided the panelists with the results of that analysis.

Building Simulation Results Working Session on Apr. 4, 2024: BPA presented the building simulation results and asked for feedback regarding energy recovery ventilator (ERV) and dedicated outdoor air system, unit energy consumption results, and simulation validations. Panelists were asked if they knew of a different source for identifying ERV heating fuel type, if commercial buildings were selecting more efficient equipment than 5-10 years ago, and what other comparison data sources they would suggest for simulation validation. BPA used the feedback to finalize the simulations for the model.

Interim Market Model Draft Results Working Session on June 14, 2024: BPA shared the draft results of the commercial HVAC model with the panelists and discussed future research. The main comments about the draft model results focused on the relatively small estimated momentum savings, which panelists attributed to the limited scope of the model (only permitted construction projects above $200,000, representing about 1 percent of the total commercial HVAC market), aggressive baseline codes, and the exclusion of existing buildings and certain technologies such as hydronic systems and ground source heat pumps. Panelists highlighted that most savings came from above-code efficiency improvements and the use of ERVs, particularly with variable refrigerant flow systems, and expressed interest in seeing future models expand to include more of the market, especially rooftop units with ERVs, and to account for technology shifts like the adoption of heat pumps over electric resistance in existing buildings. There was a general sense that, while the savings captured in the current model are modest, the commercial HVAC market is important and rapidly evolving, warranting ongoing research and potential expansion of the model's scope.

Research Planning Working Session on Aug. 22, 2024: BPA met with the panel to discuss commercial HVAC Momentum Savings, general market research, and BPA program planning. BPA received feedback around where Momentum Savings are already happening and where opportunities exist for future savings.

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 commercial 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 commercial 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 commercial HVAC equipment. In addition, the market/industry SMEs are up to date on current and any potential future federal or state codes and standards impacting the commercial HVAC market and ideally has past "boots on the ground" experience working within the commercial HVAC market (e.g., have worked with/for a manufacturer, distributor, installer, etc.). 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 commercial HVAC technologies — variable refrigerant flow systems, ductless heat pumps, air source heat pumps, chilled water systems, rooftop units, direct expansion cooling, and dedicated outdoor air systems — work, and preferably know how to model energy consumption for these. 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 commercial HVAC market. A technology expert understands how different technical specifications and installation conditions (such as system capacity, efficiency ratings, heat recovery, building envelope, ductwork design, climate zone) 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 Commercial HVAC expert panel.

Table 1. Commercial HVAC Expert Panelists

Panelist Name	Expert Classification	Affiliation during Panel
Cassandra Beck	Market/Industry Expert	Trane
Peter Kramer	Market/Industry Expert	Trane
Jesse Dean	Market/Industry Expert	Edo Energy/McKinstry
Mark Lessans	Market/Industry Expert	Johnson Controls
Albert Rooks	Market/Industry Expert	Small Planet Supply
Mike Wolf	Market/Industry Expert	Greenheck
Brandon Adams	Technical Expert	Vector Energy Solutions
Pete Jacobs	Technical Expert	Building Metrics
Eric Mullendore	Regional Stakeholder	BPA
Christian Douglass	Regional Stakeholder	Council
Kevin Smit	Regional Stakeholder	Council
Lauren Bates	Regional Stakeholder	NEEA
Chris Wolgamott	Regional Stakeholder	NEEA

Catalog of Panel Activities

The panel kicked off in November 2022 and ended in August 2024, completing a total of eight 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. Commercial HVAC Expert Panel Completed Activities

#	Review Type	Panel Engagement Period	Topics Reviewed	Independent Experts	Regional Stakeholders
1	Working Session	Nov. 2, 2022	Controls data availability and summary including market scope, equipment stock, equipment sales, and energy consumption.	Brandon Adams, Peter Kramer, Mark Lessans, Jesse Dean, Albert Rooks, Kandice Cohen, Mike Wolf, Pete Jacobs	Lauren Bates, Eric Mullendore
2	Working Session	March 28, 2023	Commercial HVAC market model kickoff meeting including background and current status, review of the model scope, possible scope expansions, and next steps.	Albert Rooks, Jesse Dean, Cassandra Beck, Christian Douglass	Kevin Smit, Lauren Bates, Eric Mullendore
3	Desk Review	June 12-26, 2023	Memo regarding HVAC equipment permit data.	Albert Rooks, Brandon Adams, Mike Wolf, Mark Lessans	Kevin Smit, Lauren Bates
4	Working Session	Sept. 8, 2023	Market model timeline, segmentation and principal technologies, CBSA review, forecast of floorspace, and forecast of HVAC technology.	Christian Douglass, Peter Kramer, Cassandra Beck, Brandon Adams	Kevin Smit, Eric Mullendore, Lauren Bates
5	Working Session	Nov. 16, 2023	Building simulation inputs including weather files, climate zones, and building types.	Christian Douglass, Peter Kramer, Brandon Adams, Mark Lessans	None (targeted panel)
6	Working Session	April 4, 2024	Building simulation results and comparisons.	Albert Rooks, Brandon Adams, Peter Kramer, Mark Lessans, Pete Jacobs	Eric Mullendore, Chris Wolgamott, Kevin Smit, Christian Douglass
7	Working Session	June 14, 2024	Interim model draft results, interesting findings, and future research questions.	Albert Rooks, Brandon Adams, Peter Kramer, Jesse Dean, Mark Lessans, Pete Jacobs	Chris Wolgamott, Christian Douglass
8	Working Session	Aug. 22, 2024	Goals of research planning, what we learned, brainstorming, next steps.	Brandon Adams, Peter Kramer, Pete Jacobs	Eric Mullendore, Christian Douglass

Appendix A: Working Session Meeting Notes

The following contains the meeting minutes to all working sessions.

Working Session: Controls Data Availability – Nov. 2, 2022

Began recording meeting

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

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

Attendees

BPA: Juan Carlos Blacker, Eric Mullendore

Cadeo: Bretnie Eschenbach, Rick Huddle

DNV: Brielle Bushong, Tyler Mahone, Andrew Wood

Panelists: Kandice Cohen, Peter Jacobs, Albert Rooks, Jesse Dean, Mark Lessans, Mike Wolf, Kevin Smit (Regional Technical Form (RTF))

NEEA Representative: Lauren Bates

Trane Experts: Peter Kramer, Cassandra Beck

Working Session Agenda

1. Background and Context
2. Panel Objectives and How-To
3. Modeling Context
4. Data Availability Methodology
5. Data Availability Findings and Gaps

Project Background and Context

BPA's Market Models:

- Estimate market energy consumption
- Quantify Momentum Savings as a regional power resource
- "Momentum Savings" are electrical energy savings above baseline (= code for new construction) and outside of incentive programs
- Use the best information available to accurately characterize market trends
- In this project:
    - "Building simulations" = energy modeling
    - "Market model" = regional energy use
- Non-residential lighting and commercial HVAC are large sources of electricity consumption and, therefore, are high-priority markets for BPA to track
- BPA is planning to build a commercial HVAC market model in 2023
    - BPA is investigating the feasibility of including controls to this market model

Project Objectives

- Characterize the controls markets for the commercial HVAC market
    - Develop a segmentation of the controls market (how each controls technology maps to an HVAC technology, understand operational variation, etc.)
- Evaluate data availability and known data gaps for controls in this market
    - Determine what data is needed to answer key research question related to modeling feasibility
    - Identify where there are data gaps and which of them can be filled through future efforts
- Assess the feasibility of including controls in the commercial HVAC market model for 2022-2027 (2021 Plan Period)
    - Determine opportunities to leverage best available information to model the market
    - Understand how including controls would impact the planned model methodology
        - The 2021 Plan Period refers to the Northwest Power and Conservation Council Plan

Definitions

For the purposes of this study:

- Controlled equipment – HVAC equipment
- **Integrated controls, or manufacturer-based controls** – controls that come packaged with equipment that cannot be altered by the end user
- **Controls strategy** – adjustable technology & components used to change equipment behavior

Discussion

Cassandra Beck asked if they are trying to understand the market size in the market model.

- Rick responded that this is part of what they are trying to understand through the model, and that he would describe this in further detail later in the presentation.

Panel Objectives and How-To

Expert Panel Session Purpose

BPA and Cadeo need feedback on their evaluation of data availability for the commercial HVAC controls market and their approach for filling identified data gaps. BPA and Cadeo are open to any feedback, questions, or comments from the panelists, such as:

- Would you characterize data availability differently from what the team asserts?
- Do you see any data gaps beyond what the team has already identified?
- Can you offer alternative approaches to filling the data gaps the team identified?

Modeling Context

For all of BPA's market modeling efforts, the research team follows BPA's Four Question Framework for estimating Momentum Savings as a basis for model methodology. Each of these questions is tethered to model inputs that, when taken together, answer the Four Question Framework with a complete model methodology.

The Four Questions are:

1. What is the market?

2. How big is the market?
3. What are the total market savings?
    a. What was the energy use in the year the plan was written?
    b. What was the actual energy use in the following years?
4. What are the program savings?

For the purposes of this panel session, the research team focused on Questions 1 and 2 of the Four Question Framework and conducted a preliminary assessment of data availability for Question 3. In upcoming research, the research team will explore Questions 3 and 4 in more detail.

Key Model Inputs for Data Availability Assessment

There are four main model inputs that we used to guide our data availability assessment for modeling controls:

1. **Market Scope:** The specific controls strategies, controlled equipment, applications, geographic boundaries, and other dimensions that define the scope of the controls market the research team will ultimately model.
2. **Equipment Stock:** The total saturation of all controls strategies installed as a percentage of the total specified non-residential lighting stock (i.e., what percent of lighting stock has controls?); and the saturation of each control strategy installed on controlled equipment in the stock (i.e., what is the mix of controls strategies in the stock?).
3. **Equipment Sales:** The new control strategies installed on new or existing controlled equipment in a given year.
4. **Energy Consumption:** The amount of energy savings (energy consumption reduction) as a percentage of non-residential lighting consumption (kilowatt-hours or average megawatts) associated with the overall controls market and from each control strategy on each controlled equipment technology.

Data Availability Methodology

Data Availability Research Questions

The team broke out research questions by model input to guide the data availability assessment in the following table.

Table 1 Data Availability Research Questions by Model Input

Model Input	Question#	Research Question
Market Scope	**RQ1**	**What controls technologies can be installed with which equipment types, and in which installation contexts? (i.e., controls technology mapping and segmentation).**
Equipment stock	**RQ2**	**What portion of commercial HVAC installed stock is affected by controls, and how is that portion changing over time? (i.e., controls stock size).**
	RQ3	**What is the stock saturation of controls technologies of interest, and how has this saturation changed over time? (i.e., characterization of controls installed stock mix).**
Equipment sales	**RQ4**	**What mix of controls technologies is installed in a given year? (i.e., characterization of controls sales) .**
Energy consumption	**RQ5**	**What is the energy impact of controls technologies on various corresponding equipment, and how does this impact vary according to operating settings (i.e., characterization of controls savings)?**
	RQ6	**To what extent do controls savings persist over time (i.e., persistence of controls savings)?**

Discussion

Cassandra asked for clarification on energy consumption model inputs. She asked if RQ1 is asking what is the potential savings out there for the technology, and if the second one asks what is the actual savings being seen in the field.

- Rick responded that RQ5 includes both the potential and the actual. But then RQ6 is more like does it last over time? Do people go in and change strategies? Do they change set points? And again, you can probably imagine that one is the first kind of basic question is yes, they do and then how much. So how much as people tweak things, Overtime. How does that affect our savings? So the first one is really both how much is potential and what's actually happening.

Pete Jacobs asked if they are only looking for savings above Code.

- Rick responded that they are looking to characterize what is actually being installed, and how much is happening above and beyond Code.
    - **Pete** then asked if they are considering code compliance. Rick confirmed that this is another big question they are trying to answer through this model.
    - **Pete** asked if BPA has a new construction stock forecast by building type. Bretnie responded that the Council provides new construction forecasts to them—not by building type— and that they also further inform that forecast with their permit data collection, which was up to date through 2021. She also explained that they use those two data sets to project that forward to create a new construction forecast by building type.

Peter Kramer asked what the end goal of this project is. Juan Carlos explained that at the most basic level, we are trying to understand the market and the way the market is broken out by the different product types throughout the Northwest. In this specific case, we are determining how controls play into the HVAC products that are that are being sold here and we're trying to see if adding controls to our market model, that we start building in January, is feasible. Is it something that is a separate characteristic for the HVAC market or is it something that's included in all products, and how should we include controls as an aspect to HVAC products in the commercial market?

- **Peter** then asked if the model will inform programs. Juan Carlos responded that at this point, the model will not inform programs beyond determining how much energy is being used by commercial HVAC in the Northwest.
    - **Lauren Bates** responded that NEEA does use the results of BPA's models to inform program design

Lauren Bates asked for clarification on "affected by controls" in #RQ2 because anything with controls is going to be affected by them. Rick responded that they wanted to confirm that it is true that all com HVAC installed stock is controlled.

Data Availability Assessment

In its market research work, BPA also adheres to the principle of utilizing the best available data for modeling. The characteristics outlined in the following table are intentionally flexible to allow the team to leverage the best available data across multiple sources.

Table 2 Data Availability Assessment Framework

Level	Description	Data Characteristics
High	**There are no barriers to modeling, and any data gaps can be tolerated.**	• There are empirical data available, where appropriate. • Modeled or engineering calculations follow industry standards. • Sample sizes are adequate. • Northwest regional specific data are available, where appropriate. • Data are available at a level of granularity compatible with proposed model mechanics.
Medium	**There are some barriers to modeling, but the research team identified strategies to address these barriers.**	• Limited reliability due to sample sizes or statistical approaches. • Data from national studies can be reasonably adjusted to represent the Northwest, where appropriate. • Multiple data sources or incompatible granularity can be aggregated or leveraged to make informed assumptions. • Gaps in data can be addressed through market actor interviews, planned data collection, or emerging research.
Low	**There are insurmountable barriers to modeling.**	• No applicable data exist. • The necessary data are not reasonably collectible.

Data Availability Findings

Market Scope: Controls technology mapping and segmentation

- The team has mapped controls sequences to HVAC equipment type in the Controls Mapping HVAC tab of the workbook.

Equipment stock: Controls stock size

- All commercial HVAC equipment has least basic controls: basic on/off operation and control of refrigerant/ heating/ cooling cycles. This means 100 percent of commercial HVAC equipment is affected by controls.

Equipment stock: Controls stock mix

- This information is limited but not required for new construction. The next row examines new construction sales.

Equipment sales: Characterization of controls sales

- Since the planned commercial HVAC market model focuses on installations that require meeting energy code, to understand "sales", the team investigated which strategies are required by code. The team found ample information on code-required control strategies, but data is limited on actual *compliancy* of code requirements.

Energy consumption: Characterization of Controls Savings

- The team has determined that it is feasible to estimate and/or model the energy savings associated with most control strategies. However, there are some data gaps. The team can likely find a way to estimate energy savings for those strategies.

Energy consumption: Persistence of Controls Savings

- The research team found several sources that may indicate whether, and to what extent, controls savings persist over time. The data did not provide a conclusive "answer" to savings persistence, but by triangulating sources, the team believes we can arrive at a reasonable and defensible estimate.

Scope of Market Model: Where are Efficiency Gains?

Table 3 Summary of Market Model Scope

In scope	Not in scope	Reasoning
• New construction • Major remodel (triggers code/permit)	• Existing buildings • Retrofits • Replacement on failure	• Building permit data is accurate/thorough. Lack of data on not-in-scope items • Majority of energy efficiency appears in permits
• ASHP • DHP (mini-splits) • VRF + Ventilation • Unitary AC (packaged DX equipment, incl. gas-packs) • Heat recovery, when part of any of the above systems	• Gas usage • Hydronic systems • Chillers • Boilers • Custom-built AHUs	• The scope of the 2021 Power Plan is electricity use • Hydronic systems cannot be reliably modeled • Custom-build AHUs typically use hydronics

Discussion

Pete Jacobs asked if they consider unitary AC to include split systems that you might see in small retail or small offices. Bretnie responded that air source heat pump (ASHP) and ductless heat pumps (DHPs) would fall under most of the split systems and then the unitary AC is really other systems that include a compressor. So, it's focused on more on the cooling side that we don't capture in the other systems.

Identified Controls Strategies

Expert Panel Questions: Control Strategies

- Are we missing any important controls strategies?
- Are supply air temperature (SAT) reset, static pressure reset, (variable air volume) VAV box minimums applicable to ASHP?
- Are there any strategies that you recommend removing based on your experience?

Discussion

Albert noted that economizer and heat recovery don't intersect in the table, but that controlling heat recovery with an economizer would be a normal course. He asked if he understood the table correctly. Rick responded that the table does not show heat recovery as its own technology and clarified that the column identifies if heat recovery is on these other systems.

> **Albert** then asked if heat recovery ventilator (HRV) is paired with an air source heat pump in the table. Rick confirmed this. **Albert** followed up recommending that this be included because there's a lot of applications going forward with HRVs paired with air source heat pumps and there's a great temperature band, especially in the northwest climate, where we can operate the building without any input from the air source heat pump, just the HRV. And there's control to. To keep that running in the optimum band. Especially as the building gets better, maybe in the next code cycle.

Peter Jacobs commented that Supply Air Temp Reset, VAV box minimums, and duct static pressure reset generally would apply to VA system-type, package VAV system and that a package VAV system is going to send cooling out. It's not really going to send heating out at the level of the equipment—it will do it at more of a zone level. He would say those do not apply to air source heat pumps. I do not know of any package VAV air source heat pumps. It doesn't make much sense.

Peter Kramer noted in the chat: ASHP, typically are small, packaged units (5 tons and less). So usually that means they are single zone units, so items like SAT reset, duct static reset, VAV box mins would not apply.

Jesse Dean in the comments: For heat recovery / energy recovery - are you focusing on dedicated outdoor air systems (DOAS)?

Controls Stock Size

- Commercial Building Stock Assessment (CBSA) data gives breakdown of control type (e.g., direct digital control (DDC), manual controls, programmable t-stat) for 12 different building types
    - (Office and Schools are shown to the right)
- Data is well segmented

Controls Stock Mix

- Data is incomplete and/or not granular enough
- Commercial buildings energy consumption survey (CBECS) is national, incomplete, and not segmented
- CBSA has virtually no information
- All commercial HVAC equipment has least basic controls: capability of basic scheduling and control of refrigerant/ heating/ cooling cycles.
    - 100 percent of commercial HVAC equipment is affected by controls.

Discussion

Pete Jacobs commented that a lot of these building stock assessments look at the entire market, so he is curious if the data holds up when you take away existing buildings. He mentioned CBECS probably gets really thin if you take away existing buildings, and asked if CBSA has a segment dedicated to new construction where those kind of breakouts are shown for new construction only? Rick responded that they don't have that breakout and that they are not really taking them to be direct model inputs. This is more to inform if everything in the stock has controls on it, and if they can assume all new construction has controls on it, and to determine how much of the market is affected by controls.

Controls Sales

- For new construction, sales can be inferred from code requirements
- Roughly 84 percent of new construction happens in Washington and Oregon, so the team focused on those requirements. Generally Wyoming and Montana have similar requirements

Discussion

Lauren Bates in the chat: NEEA is going to be working on the next CBSA data collection soon, and it may be possible to gather more data on this for next one. TBD. There are many trade-offs.

- Bretnie responded in the chat: That's great to hear Lauren! Controls data would be a great addition!

Controls Sales (Installation Practices)

Data Gaps:

1. Percentage of control strategies that are installed
    a. Opportunities to Address Data Gaps: Market actor interviews conducted as part of this study will help verify code compliance.
2. Percentage of control strategies that are installed properly
    a. Opportunities to Address Data Gaps: Market actor interviews conducted as part of this study will help verify the installation practices. (e.g., What percent of the time does the installed configuration differ from the designed configuration, and why?)
3. Compressor lockout temperatures for commercial ASHP
    a. Opportunities to Address Data Gaps: Market actor interviews conducted as part of this study will help verify if compressor lockout is used and the actual settings.

Expert Panel Question : Controls Sales Data Gaps

Can you think of any additional data sources we should leverage for controls sales?

- Any sources on code compliance? (Code compliance studies sponsored by NEEA did not examine controls.)
- Any sources on actual installation practices vs. design?
- Any sources on compressor lockout temps for commercial ASHP?
- Any sources on installed deadband of setpoints?

Discussion

Pete Jacobs asked for clarification on standard heat pumps versus cold climate heat pump distinction. Rick responded that they have not captured data on this yet, and requested any information be provided.

Controls Savings

Very incomplete savings estimates are available from existing sources, but the team found that they can use building simulation models to fill the gaps.

Expert Panel Question: Controls Savings Data Gaps

- Do you have any alternatives to modeling to determine savings for a combination of control strategies?
- Can you think of any other data sources we should leverage for controls savings?
    - (Specifically, that includes combinations of control strategies/ interactive effects. Not single-strategy studies.)

Persistence of Controls Savings

This is the area with the most uncertainty in the data.

Data Gaps:

- Persistence of energy savings specific to the control strategies of interest (Exception: one data source was found specific to economizer and scheduling savings).
    - Opportunities to Address Data Gaps: Use the available sources to develop general estimates of savings persistence and apply these estimates to all, or a subset, of controls strategies.

Expert Panel Question: Controls Savings Persistence Data Gaps

- Given the wide variance in values from the data, do you have suggestions on how to improve on our persistence approach?
- Can you think of any other data sources we should leverage for controls savings persistence?

Discussion

Peter Kramer noted that a big challenge with HVAC savings is the human element creating variability. The challenge I think that always exists with savings especially in the HVAC world is you're touching a lot of human factors here, which creates an enormous amount of ability with driving savings. He commented that you can install the most efficient product that can have fantastic economizer use solutions and everything else, but the second that operator or building occupant makes a change and runs that equipment around the clock for whatever the reason, the great ideas or savings that existed there just went out the window. He thinks that will forever be the challenge in trying to get confident and that's why that LBNL study was really high level and showed a lot of variability all really showed a lot of variability.

Kevin Smit followed up with what Peter commented, saying it is, a difficult thing and it's highly variable. He noted that the RTF has been looking at heat pumps for decades and they see very little difference between heat pumps with and without controls in their customer use data. He suggested that looking into strategic energy management (SEM) data may provide better data on the savings persistence data gaps.

- **Kevin** will look into what kind of specific data on SEM programs and evaluations he can provide and put them in the comment tracker.

Andrew asked how persistence of savings plays out in the market modeling

- Bretnie responded that what she is envisioning it is, let's say you account for 5 percent savings associated with controls when you install them on equipment. And the first thing people say

when you talk about controls is, well, are they still going to be in the same condition by the end of the plan. Or in five years or in three years or in one year? We want to build in a methodology to account for that, which could play out in a few different ways. But right now, we are thinking of using these data sources to estimate over a period of time how will those savings basically degrade and that could take the place in like a haircut at the end of the savings, or it could be an annual methodology to account for persistence of savings in the model that looks like savings degradation.

Pete Jacobs noted that all the studies they cited are retrocommissioning studies and asked if they should consider commissioning studies instead as they are mainly focused on new construction in this model.

- Rick agreed but responded that those studies represent the best data available to them at this time.

Kandice commented that she immediately thought of persistence of savings and retrocommissioning when they asked RQ6. There's a layer here that she feels like is a macro trend that we're seeing a lot of that adds some context—there are customers who have control systems and you're going to get a certain level of persistence over time for those savings. And then you have customers who have "intelligent services contracts" where we're coming in on a quarterly basis (for example) and meeting with that customer and consistently doing energy models on their building to see how they're building is actually running in reality. And I think you're going to have a very different persistence of controls in that situation. And so maybe that should be something that would be worth considering and incorporating.

- **Rick** agreed and asked if she knew of any data sources that might have that?

Albert asked about what time scales they are looking for in terms of persistence.

- Rick responded that any level of data would be helpful.

Recommendations

Upcoming study work and market actor interviews will give insight into:

- Code compliance
- Control installation practices
- Incentive program savings

Expert Panel Question: Modeling Feasibility

- Do you know of data sources that show HVAC controls are saving energy:
  - Above code and
  - Outside of utility incentive programs?
- Do you think it's important to consider controls strategies when determining commercial HVAC energy use?

Next Steps

- Ongoing
  - In-depth review of 2021 Power Plan baselines, load forecast, and savings potential
  - Market actor interviews with controls contractors, commissioning agents, manufacturer reps/distributors, and ESCOs
- Upcoming
- Review of regional incentive program documentation

Expert Panel Review

- Review all data availability materials and submit comments by 11/18
    - Presentation (slide deck)
        - Please use the questions from the slides to guide your review
- Workbook (Excel)
    - "Expert Panel Questions_HVAC" is the main tab that the panelists can use to provide their review of the materials
    - The other tabs provide extra context and background, BPA/Cadeo aren't requesting that the panelists review everything in them
- Memo

Final Discussion

Kandice asked if they would like information on non-HVAC controls integration and sent over a link (https://www.designlights.org/resources/reports/report-energy-savings-from-networked-lighting-control-nlc-systems-with-and-without-lllc/)

- Juan Carlos replied that the panelists should feel free to provide any and all information related to controls integration, as they are also working on lighting controls integration into their market models.

Working Session: Model Development Kickoff – Mar. 28, 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: Juan Carlos Blacker

DNV: Tyler Mahone, Bridget Ransford, Lorre Rosen

Cadeo: Bretnie Eschenbach, Rick Huddle

Panelists: Albert Rooks (Small Planet Company), Jesse Dean (Edo Energy/McKinstry), Cassandra Beck (Trane), Kevin Smit (NW Power Council), Lauren Bates (NEEA), Christian Douglass (RTF/Ptarmigan Consulting), Eric Mullendore (BPA)

Unable to attend: Michael Wolf (Greenheck Fans), Mark Lessons (Johnson Controls), Peter Kramer (Trane), Brandon Adams (Vector Energy Solutions), Peter Jacobs (Building Metrics)

Panel Objectives

The purpose of the expert panel is to help BPA determine the best market model for commercial HVAC. The expertise of the panel will help BPA identify key drivers in the market and develop preliminary estimates about what is happening in the market.

Working Session Agenda

The presentation will cover the following agenda:

- Introductions
- Background & current status
- Review current scope
- Possible scope expansions
- Summary of scope
- What's next

Background and Current Status

Juan Carlos noted that the purpose of the expert panel is to help BPA determine the best market model for commercial HVAC. This is the first time that BPA is building a model for commercial HVAC. Over the next year, BPA will be building the first part of the market model to develop preliminary estimates on what is happening in the market and identify the key market drivers.

BPA is trying to estimate market energy consumption for commercial HVAC and quantify momentum savings as a regional power resource. Momentum savings are electrical savings above baseline (code for new construction) and outside of incentive programs, both from the utilities and NEEA. BPA will use the best information available to accurately characterize market trends in commercial HVAC. Currently, BPA has minimal data for commercial HVAC product sales and current stock. BPA is looking to the

panelists to help identify the best data for additional market information. For this project, BPA will focus on building simulations (i.e., energy modeling) and the market model for regional energy use. BPA will continue these workshops every 3 months. The panel includes stakeholders from BPA and NEEA, but also industry experts. We are looking to industry professionals to tap into their expertise.

Momentum savings are all the savings generated by efficient products that are not claimed by utility incentive programs or from NEEA's market transformation programs. Any product that is sold or used in the market that has not been influenced by these two programs, BPA can claim savings and use to generating projections for power needs. This is very important for BPA's planning purposes. We need to understand the full market picture to determine momentum savings. For more information, anyone can reach out to Juan Carlos.

Rick discussed the screening questions to determine if BPA should create a market model.

Screening Question	Information Needed to Answer	Additional Notes
Can we accurately model it?	• Do we have data that tells us quantity/ saturation of technologies? • Do we have building simulation strategies?	
Included in the 2021 Power Plan?	**Council Plan** • Did the Council consider the technology/ measure? • Was it deemed cost-effective?	**Juan Carlos mentioned that throughout the 2021 Power Plan, BPA will continue to build out and iterate on the market model. BPA will finalize the model and release the model at the end of the Plan to demonstrate the momentum savings. The market model will be in lock step with the Plan.**
What's the saving potential?	**2021 Plan Period savings:** • New construction • Retrofit	
Can we determine Program Savings?	**Regional Conservation Progress report** • Can we determine how much utility programs saved?	
Is it important to the region?	**BPA** • Utility websites • RTF measures	

For all the screening questions above, there are different levels of "yes" for the different technologies. For principal technologies, BPA will collect the following detailed data to determine momentum savings:

- Saturation
- Facility type
- Size of units
- Efficiency

For ancillary technologies, BPA will collect the following basic data:

- Saturation
- Facility type

There is no momentum savings associated with the ancillary technologies.

Rick discussed the commercial HVAC work completed by Cadeo during the last 5 years.

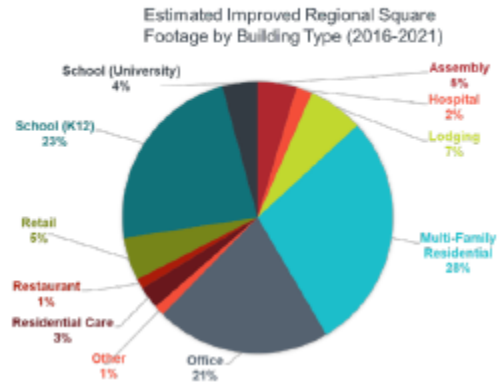
- 2019 - Cadeo Team conducted pilot study into the plausibility of gathering commercial HVAC market data via building permits.
- 2020 - Permit vs Installed Investigation.
- 2021 - Permit data collection begins, and the team concluded data collection.
- 2022 - Final data set, lessons learned memo, and analysis.
- 2023 – Completed the Controls Feasibility Study and began to build the market model

Juan Carlos discussed BPA's permit data work over the last few years. Anyone who is interested in that permit data, or the associated work, can reach out to him or check the BPA website. This permit data will be used as primary data sources for the market model.

Juan Carlos mentioned that the "light bulb" icon will indicate when BPA is looking for feedback from the panel experts. He noted that a post call questionnaire will also be sent to collect detailed responses.

Rick explained that the following chart is a breakdown of the different facility types from 170 different facilities covering over 317 million square feet in 2016-2021.

1. Do you expect construction work to still be high in Office, Schools, and MF-Res?



Cassandra asked if "assembly" is industrial. Rick clarified that assembly refers to religious buildings. Cassandra noted that the industrial market seems to be missing from the list of building types. Rick said that we are trying to focus on commercial as opposed to industrial.

Sarah asked Cassandra if "industrial" means commercial buildings or office space/warehouse on an industrial site, or industrial HVAC for an industrial application or process? Cassandra and Rick said "both." Cassandra continued said that warehouse and data center space will be a large portion of industrial space especially with the CHIPS Act. Sarah noted that the information available about industrial spaces is very limited, but it is worth considering the commercial aspects of industrial sites.

Christian asked if this is brand new construction plus major renovations? Rick said "yes," new construction, additions to existing buildings and renovations large enough to go through permitting are all included. Christian said that multi-family and new schools are booming.

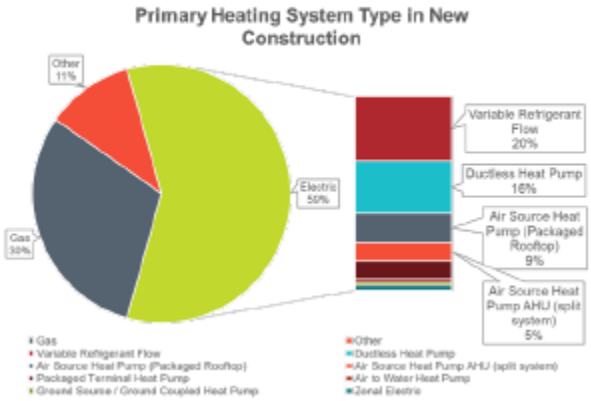
Jesse mainly works within the existing building space and noted that within the commercial real estate (CRE) market, interest rates and vacancy rates have doubled. People are repurposing office space into

multi-family residential. The CRE market is still scrambling to determine what to do with office space post Covid.

Bretnie said that BPA may do another data collection effort post-pandemic (in the next few years).

Albert sees a slight bump in residential care as the population ages. Nobody knows what is going on with retail, could be going up or down.

1. Do you expect any change in technologies for heating?

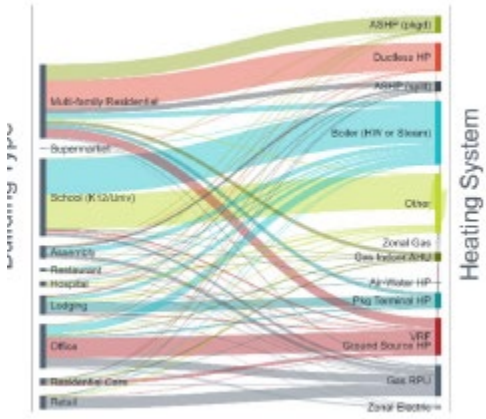


Christian noted that Washington state codes and other policies will be taking a huge bite out of gas. He doesn't know if the same will be true for Oregon.

Jesse added that air source heat pump will take up a larger percentage and variable refrigerant flow (VRF) will go down over time. He sees more claimed cold climate air source heat pump technology in Washington right now in the commercial sector.

Rick clarified that the chart above shows percent of square foot.

1. Do you expect schools, offices, or multifamily to install different systems?



Christian asked what is "other" that half of schools are using? Rick answered, district heating. 80-90 percent of schools are boiler systems. Washington state is nixing gas. It is hard to predict whether they will go VRF or something else.

Albert thinks we are going to see a change because cooling in schools should change. We see that in multi-family and schools operate during the day when it is hot. Boiler percentages should decrease over time as the need for cooling becomes more necessary. As the building envelope gets tighter and

ventilation becomes for efficient, heat tends to stay in the building. If the building is occupied during the day, the need for cooling becomes more important and boilers won't provide that. Rick clarified that this chart is focused on heating; but Albert noted that if the need for cooling increases, heat will decrease.

Review Current Scope

Screening Question	Big Picture Answer	
Can we reasonably model it?	**Yes** • Permit data provides all the detailed info we need • We have modeling strategies	☑
Included in the 2021 Power Plan?	**Yes**	☑
What's the saving potential?	2021 Plan Period savings: • **New construction 1.1 aMW** • Most savings are for solely for equipment efficiency above code • Exception: VRF includes ASHP -> VRF + DOAS	☑
Can we determine Program Savings?	**Maybe** From 2015-2021, **5.1-19.3 aMW** of Program savings*	?
Is it important to the region?	**Yes** • At least 4 out of 9 large utility programs have offerings*	☑

* "DX cooling" is included in "RTU" that have 14.1 aMW of reported savings

Rick provided an overview of the current scope. Current principal technologies include:

- VRF - variable-refrigerant flow
- DHP – ductless heat pumps: aka mini splits
- ASHP – air source heat pumps, heat recovery
- Direct Expansion Cooling (DX Cooling)
- DOAS – systems associated with VRF and DHP, includes heat recovery

The permit data doesn't include detailed data on other technologies, like water source heat pump (WSHP), Chillers, packaged terminal heat pump (PTHP), gas units, other packaged systems. Potential for future inclusion if permit data is expanded. BPA has tracked these technologies in its permit data and can calculate consumption from these technologies.

Current ancillary technologies that failed the screening questions include:

- Hydronic systems
- District heating and cooling
  - Steam or hot water
  - Chilled water
- Ground source heat pumps
- Air-to-water heat pumps
- PTHP
- Gas usage

Possible Scope Expansions

Rick discussed possible scope expansions.

Ideally this model would calculate the energy consumption and momentum savings of the entire market, but we do have a data problem. Two-thirds of the permit data is just new construction, but we do have existing buildings in the permit data. One-quarter of the data are retrofits for existing buildings, 7 percent is a mix of new and retrofit.

Technologies

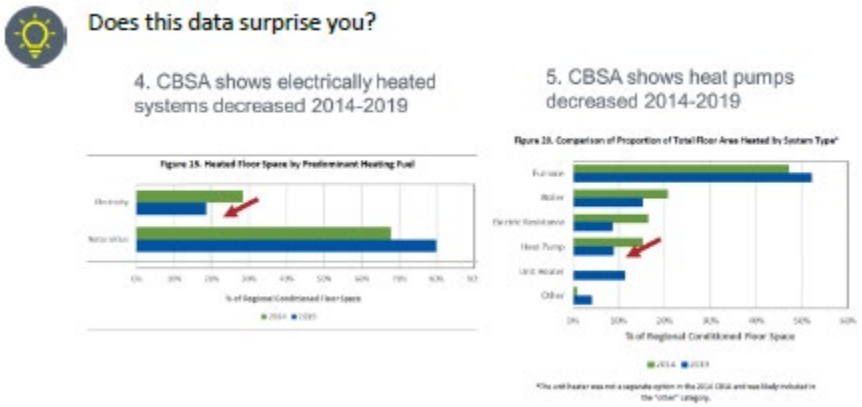
Are permits capturing most of the market change? We looked to the following four technologies and the number of systems in the permit data compared to the number of systems in the CBSA data to try to answer this question.

Number of Systems Serving as Primary Heating System

Primary Heating System	Permit Data (2016-2021)	2019 CBSA (total stock, through 2018)
VRF	701	24
DHP	691	402
RTU HP	674	290
PTHP	192	2,340

Permit data shows more systems- except PTHP

Bretnie: we are trying to understand if the permit data is the best data for full market characterization of existing and new buildings, understanding that it is a very large, complex model. Different data can tell us different things about the market. We are trying to find the most impactful and robust data. The CBSA data confirms that the permit data captures most of the "market change".



Christian noted that knowing a lot about CBSA data and the problems associated with it, he would not read into any directional changes from this.

Bretnie asked if we can build a stock-to-stock model like we have done in the past like the residential HVAC market model and the non-residential lighting model? This CBSA data told us a stock-to-stock model was not going to work, does that sound right?

Christian and Kevin both agree with Bretnie. There is a lot of error in this data regarding what is electric, what is gas, etc.

Sarah asked a follow-up question for the panelists to consider and maybe provide written responses. How valuable is it to understand the rest of what's going on out there? Is there a lot of change happening that we are not seeing in the permit data for the commercial HVAC market? What other data sources would we be able to leverage? How much should we focus on that in the future, given we have limited data right now.

Christian responded that there is likely a lot of activity that we're missing in this process, but it is probably like-for-like activity, and it is not where the savings are coming from. You are capturing the savings in the permit data.

Full Market Summary

Recommendation: Ancillary & Future Possibility

- Track full market through CBSA
- Characterize square footage, facility type, HVAC type
- Do not determine energy use
- Helps prepare the model for future inclusion

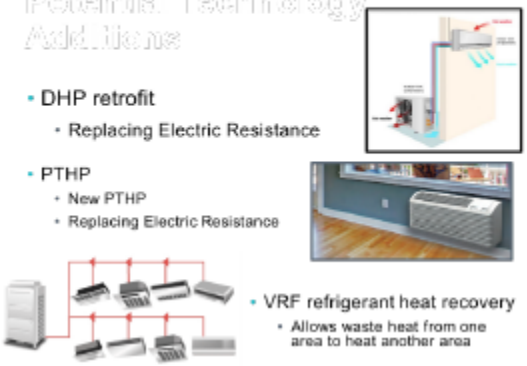
Rick continued the discussion by providing a full market summary:

- Permit data includes existing buildings that undergo significant renovations
- Permit data potentially capturing most of market change
- If we decided to model consumption of Full Market, we'd need significantly more building simulations (= longer time to develop)
- Also a consideration: the next CBSA is coming…

Potential Technologies Additions

Ductless Heat Pump (DHP) Retrofits

6a. How often do you see electric resistance heat in commercial buildings?
6b. How often do you see ER getting replaced with DHP?
6c. Do you know of a difference depending on type of building or size?
6d. Do you know of a data source to quantify this information?



None of the panelists responded to these questions, so **Rick** reminded the group that we will send a questionnaire to the panelists to complete after the meeting.

Screening Question	Big Picture Answer	
Can we reasonably model it?	**Possibly:** either now, or in the future • Need to catalogue any projects that are retrofit • Current permit data shows NO ER -> DHP	?
Included in the 2021 Power Plan?	Yes	☑
What's the saving potential?	2021 Plan Period Retrofit savings: • Retrofit 13.6 aMW	☑
Can we determine Program savings?	Yes • From 2015-2021, 2.4 aMW of savings	☑
Is it important to the region?	Yes • 8/9 Utility programs have DHP offerings	☑

PTHP New and Retrofits

Rick provided overview of the slide below.

Screening Question	Big Picture Answer	
Can we reasonably model it?	**Probably**- either now, or in the future • Need to re-catalogue any NC with primary PTHP heat • Current permit data doesn't show any ER -> PTHP • RTF is developing a measure, but controversial savings	?
Included in the 2021 Power Plan?	Yes	☑
What's the saving potential?	**2021 Plan Period savings:** • New construction **0.1 aMW** (above code) • Retrofit **5.4 aMW** (ER -> PTHP)	☑
Can we determine Program savings?	**Yes** • From 2015-2021, 0.3 aMW of savings	☑
Is it important to the region?	**Somewhat** • 3 out of 9 Utility programs have PTHP offerings • Is BPA programs team interested?	?

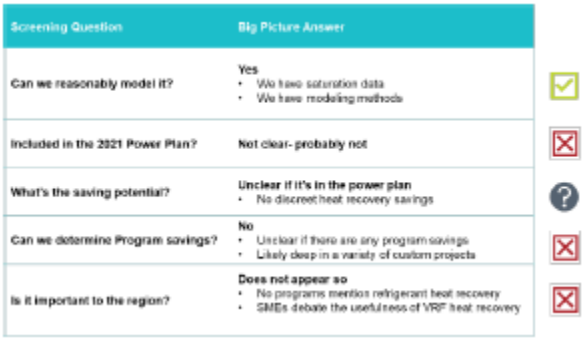
Kevin asked a question about the categories. We usually have three categories of savings (new construction, natural replacement, and retrofit) but we only show two categories here (new construction and retrofit). Rick replied that only these two categories are captured in the permit data.

7a. How often do you see PTHP in commercial buildings?
7b. Is this in a particular facility type?
7c. Do you expect to see that grow in next 5 years?
7d. How often do you see electric resistance heat getting replaced by PTHP?
7e. How often do you see PTAC w/ ER getting replaced by PTHP?
7f. Do you know of a data source to support this information

Christian noted that PTHPs will have a huge blind spots in permits. It's a direct replacement for Packaged Terminal Air conditioners (PTACs) and building maintenance can do it, so this will not show up in permit data. Unfortunately, there is a huge number of PTACs in lodging and residential care. The potential to replace the PTACs with PTHPs is huge, but the PTHPs tend to buy bad products, so we don't like them. We wish they were installing DHPs. In new construction, there will be more DHPs. But in the retrofit market there is huge potential for PTHPs.

VRF Refrigerant Heat Recovery

Rick provided an overview of the following slide:



Screening Question	Big Picture Answer	
Can we reasonably model it?	Yes • We have saturation data • We have modeling methods	☑
Included in the 2021 Power Plan?	Not clear- probably not	☒
What's the saving potential?	Unclear if it's in the power plan • No discreet heat recovery savings	?
Can we determine Program savings?	No • Unclear if there are any program savings • Likely deep in a variety of custom projects	☒
Is it important to the region?	Does not appear so • No programs mention refrigerant heat recovery • SMEs debate the usefulness of VRF heat recovery	☒

8a. How often do you see VRF with heat recovery?
8b. Do you see heat recovery in particular building type or size?
8c. Do you have insights on the magnitude of savings from heat recovery?
8d. Do you have data sources of the information?

Cassandra noted that we are talking about simultaneous heating and cooling. With refrigerant, you can have a two-pipe system that has only heating or cooling, or simultaneous heating and cooling where you can recover heat in the loop. There is potentially savings from that simultaneous heating and cooling.

Rick asked if the panel has seen anyone putting in refrigerant heat recovery systems in VRF systems, or do they think it's a sham?

Albert hasn't seen it. But he thinks this will be a challenge in future modelling as the refrigerants start changing and the technical operation of equipment becomes more challenging. For example, Vancouver, BC is writing a lot of by-laws that make the refrigerant choice a challenge. Rick noted that building simulations may need to change to address this issue.

Cassandra also sees this at Trane, but Peter might know more about this topic, but it is coming up more and more. We do see it with Mitsubishi.

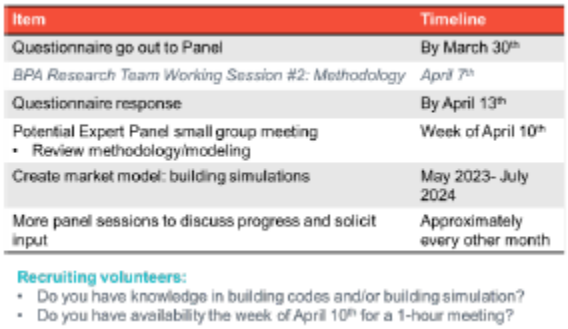
Juan Carlos and Tyler noted that we will be sending the questionnaire to Peter and any other panelists that were unable to attend today's session. Juan Carlos noted that we included those three technologies here so that the panelists can weigh in on whether these should be moved into the primary technology category, rather than remain ancillary technologies.

Sarah noted that with VRF heat recovery, it is a design choice that people are making. The question is, how much does it influence the energy consumption of a VRF system. It could be that everybody loves heat recovery from a comfort or load management perspective, but it may not have a huge influence on consumption or energy savings potential. There is a possibility for energy savings in the right applications, but to what extent is this an energy efficiency opportunity? Is energy efficiency an equipment attribute, and how much should we care about that aspect of VRF systems?

Rick noted that we should add Sarah's question to the questionnaire.

What's Next

Juan Carlos reviewed the following action items and deadlines.



Item	Timeline
Questionnaire go out to Panel	By March 30th
BPA Research Team Working Session #2: Methodology	*April 7th*
Questionnaire response	By April 13th
Potential Expert Panel small group meeting • Review methodology/modeling	Week of April 10th
Create market model: building simulations	May 2023- July 2024
More panel sessions to discuss progress and solicit input	Approximately every other month

Recruiting volunteers:
- Do you have knowledge in building codes and/or building simulation?
- Do you have availability the week of April 10th for a 1-hour meeting?

Tyler will email everyone with the request for volunteers and will coordinate the April 10th meeting. Anyone should reach out to Tyler or Juan Carlos with any questions or suggestions for upcoming topics or additional experts to add to the panel workshops.

Juan Carlos is very excited to get this model started. It is the first of its kind at BPA for commercial HVAC. It's a very challenging market. Potential volunteers for the April 10th meeting include:

- Peter from Trane
- Lauren is not available, but will check with Havala

Working Session: Market Model Forecasting and CBSA Review – Sep. 8, 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: Juan Carlos Blacker

DNV: Tyler Mahone, Lorre Rosen

Cadeo: Rick Huddle, Sarah Widder

Panelists: Christian Douglas (Ptarmigan/RTF), Kevin Smit (Council), Eric Mullendore (BPA), Peter Kramer (Trane), Cassandra Beck (Trane), Lauren Bates (NEEA), Brandon Adams (Vector Energy Solutions)

Unable to attend: Albert Rooks, Mike Wolf, Pete Jacobs, Jesse Dean

Introductions

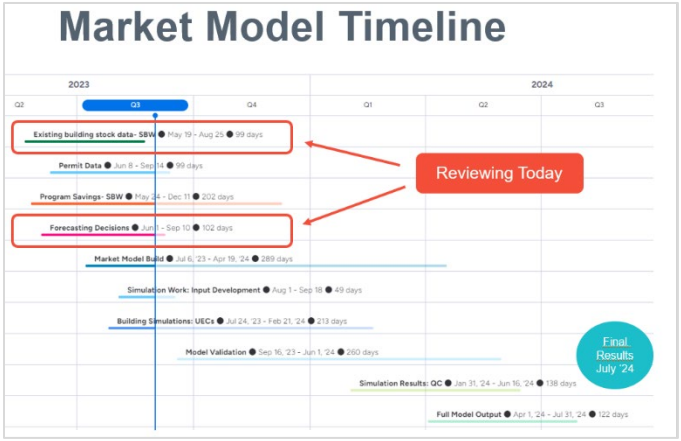
Tyler started the recording and led the panel through brief introductions. This is our first panel session since we kicked this panel back off in March. So, since we have not all met since March, I do want to just let go quickly around the room and let everybody do a short introduction, remind people of your name and affiliation.

Juan Carlos reviewed the agenda topics and thanked everyone for attending. As you all know, the panels are really important to the market research that we are doing on commercial HVACs and really look at you guys for your expertise, your knowledge, and your market savvy in commercial HVAC. First, we are going to go over the model, our market model timeline, where we are at in that timeline, and where you guys are going to punch into that timeline. We are going to talk about the segmentation and principal technologies and give you guys some context around that. We are going to talk about our review of the CBSA and how we are using it in our model. And then we are going to discuss the forecast of floorspace that we have put together, get your thoughts on what we have done, and then finish with a forecast of the HVAC technology where it is going.

Working Session Agenda

- Market Model Timeline
- Segmentation & Principal Technologies (Context)
- CBSA Review
- Forecast of Floorspace
- Forecast of HVAC Technology

Market Model Timeline

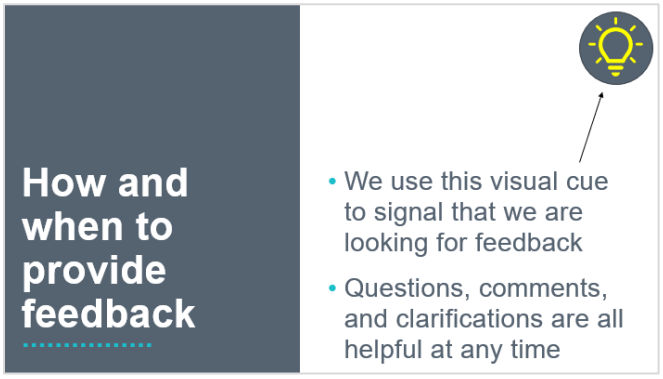


Juan Carlos continued. This is the timeline of the work that we have been doing and will be doing. You can see it goes all the way through Q3 of 2024. At that point, we will have the full intern model output. But for today, we are looking at the existing building stock data that we have been researching and the forecasting decisions that we have been looking at. In concert with those two, we have also been looking at permit data and program savings. Where we are at now is deep in the initial development and research for this model. Your input here is important.

We are also doing some building simulation work which, should be very interesting. But we are not ready talk about that at all today. We are going to do some model validation later in Q4. In Q1 2024, we will do some simulation results in the early part of next year. And then we will have that final model up.

We are relatively at the beginning of the timeline, and that is why this is our first real full panel meeting, but you will see more and more activity as we go along. Again, we appreciate you guys being here.

Panel Objectives and How-To



Juan Carlos continued. Our big goal today is to update you guys on our CBSA studies and our existing building analysis. Most importantly is to get your panel feedback on both the forecasting of floorspace and the forecasting and the saturation of the HVAC technology.

Juan Carlos provided some instructions on giving feedback throughout the presentation. Most everybody here has been on these panels before, but the way that we want to get your feedback as we are going along, if you have questions, you are welcome to chime in. There's the raise hand function within teams that you can use that.

Tyler added: I also encourage you to ask questions in the chat if you have small clarifying questions that you want to put in there. Both me and Sarah will be monitoring the chat as we go along.

Segmentation & Principal Technologies

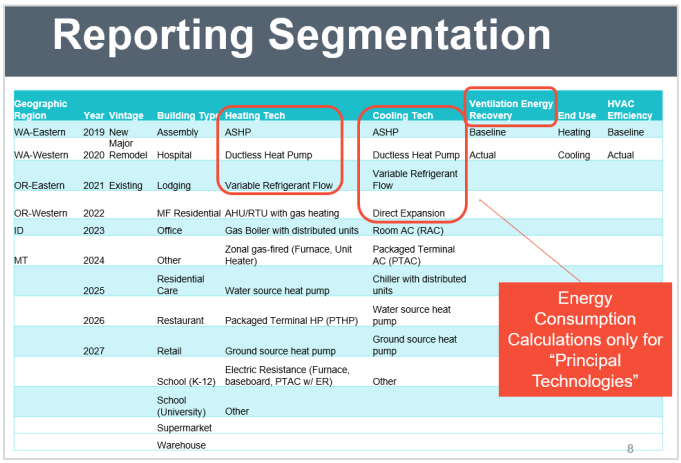
Sarah began with a reminder that it had been a while since we have all met and we should warm up to what we are talking about with the commercial HVAC model. We are going to focus on how we are

breaking down the commercial HVAC market in the model into a number of different subsegments in which we can reasonably and accurately estimate unique energy consumption signatures with those building simulations that Juan Carlos talked about.

I will review how we are breaking down the existing stock and what those variables and dimensions look like. And that will be a great prelude to the CBSA information that Rick will talk about that will inform how big each of those pieces of the pie are. And then I'll also review the principal technologies.

Among that segmentation there are pieces of the pie that are we are going to care about more and characterize more than the entire pie. And for those, we will estimate energy consumption.

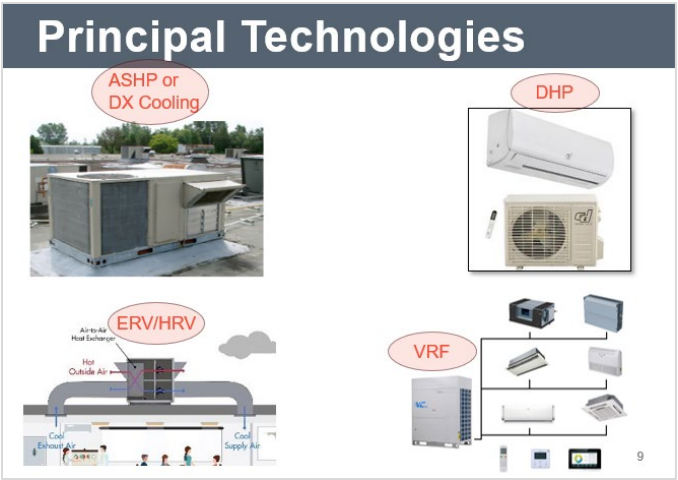
For the remainder, we will look at floor space saturations and how those change over time but not necessarily quantify energy consumption of the entire market at least at this juncture.



Sarah continued. Here is the detailed table that breaks down our big commercial HVAC market into unique subsegments. We have got geographic regions that we are looking at that is important for code baselines, also the year is important for code baselines. We have a number of them that we are considering in the model.

And then we have vintage, "new construction" and "major remodel,", which would both be permitted projects and then "existing," which is what the CBSA will inform. We have got a number of building types there. Heating and cooling technologies are next. There are a number of different technologies that we are going to characterize in the model, but the ones in the red boxes, those are our principal technologies that we are going to model energy consumption and look at energy consumption trends over time.

We have air source heat pumps, ductless heat pumps and variable refrigerant flow. We are basically focused on heat pumps and then also on the addition of direct expansion cooling on the cooling side. That would be like in a rooftop unit (RTU) paired with gas heat most typically. We will also look at energy recovery, heat recovery ventilation (HRV), energy recovery ventilator (ERV) when that occurs in addition to an existing principal technology, not necessarily on its own. And we will look at a baseline and actual efficiencies for all of those technologies. A baseline efficiency level and an actual efficiency level, that is going to be our only driver of savings in the model, is more efficient versions of those principal technologies, including the HRV and ERV.



Sarah continued. This is a visual picture that is easier to relate to than a detailed table. This is what we care about in this model, what the primary focus is going to be in terms of things we are tracking. We are going to track a lot of things, but these are our main focus: air source heat pump or cooling. That is a picture of a single-packaged RTU. That is predominantly what we're talking about, although not exclusively, HRV, ERV, ductless heat pumps, and variable refrigerant flow (VRF), which are both versions of zonal technologies.

Kevin asked a question. On the previous slide, I was curious why you are not looking at the PTHPs or PTACs, the package terminals.

Rick responded that we did consider, especially the PTHPs. But in our permit data that we collected from 2015 to 2019, we did not see enough of those, especially as primary heat, some supplemental heat, but not as much primary.

Sarah added that some information about saturations and where those technologies are occurring will likely come out of the model. It will just mean that we are not quantifying savings for them, at least at this point in this interim model. And as we will talk about later when Rick talks about forecasting, we are just in the first phases of model development. We have still got a long road and things could change.

Eric added a clarification point he heard earlier about the ventilation energy recovery. Am I correct in saying that the presence of ventilation energy recovery itself is not considered a measure, simply a higher efficiency above baseline is considered the source of savings?

Rick responded. I think the distinction that Sarah was explaining was that if there is HRV that are packaged or that are paired with non-principal technologies, we are not going to characterize those savings. But when they are paired with our DHP's or VRF or air source heat pumps, that is when we will characterize that.

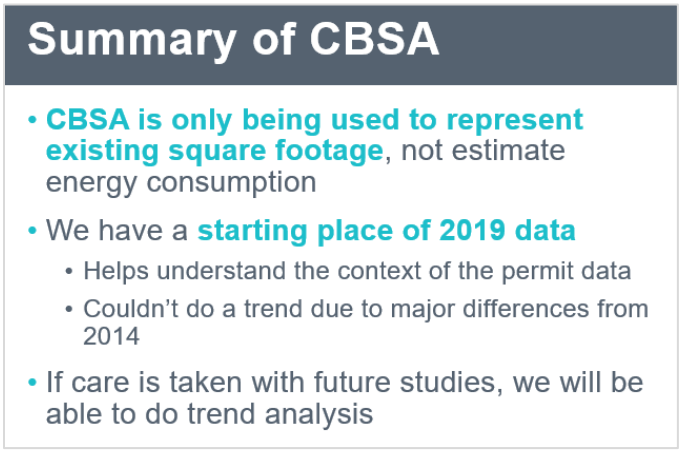
Sarah added that it might have got confused when I was talking about HVAC efficiency. The improvement in HVAC efficiency is going to be our predominant or our only driver of savings, and we are going to characterize kind of a baseline in actual case of ventilation energy recovery. But maybe Rick you could speak to what the baseline is in, in that case, if that's a less efficient HRV, ERV or not one.

Rick added that it is very complicated. For ERVs, the code is very complicated depending on the amount of outside air versus design. And we are just parsing that out exactly how it is going to look right now. But there are cases where it is required, and it is going to be compared against when it is required and the efficiency above code. So, I think there are two possibilities there.

Sarah added that for the baseline case, it depends. And that is actually an excellent segue to this slide. Because, in addition to just those principal technologies, the other thing that limits the scope of what we are characterizing in terms of energy consumption and our building simulations is that we are only looking at permitted projects, projects that are subject to code. And so that means code is our baseline. So, if it requires an HRV then it is a code-required HRV. If it does not, then there are different assumptions. So, it depends. It is a very complicated baseline, but it is a code-driven baseline. We are not looking at cases where someone is just adding an HRV that are not permitted projects. We do have that “existing vintage” where existing HVAC systems are existing or making tiny tweaks to them that

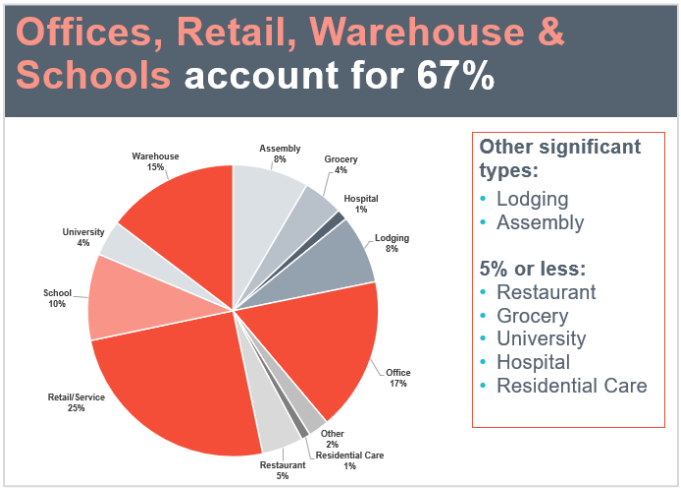
would not trigger code requirements. And those certainly occur, but we are not going to characterize the energy consumption associated with that at this point.

CBSA Review

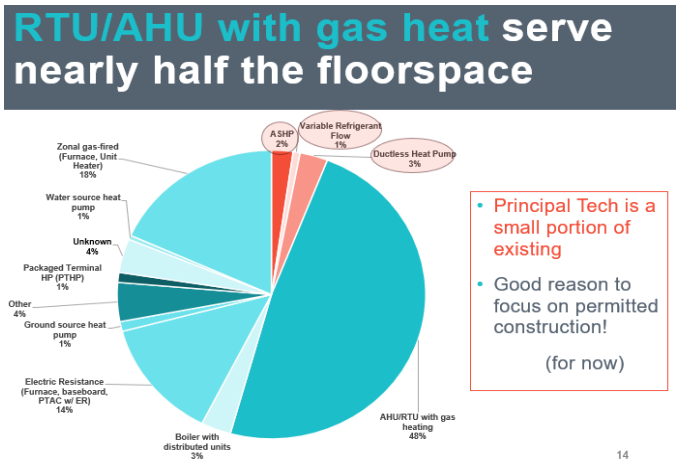


Rick began the discussion about CBSA review. The next few slides talk about CBSA and what we saw in. We are really only using the CBSA and analyzing that to understand what is in the existing building. We are not going to calculate energy consumption on it, but it does help give some context for our permit data that we are going to look at briefly here in in a few slides and how it interacts with the forecast.

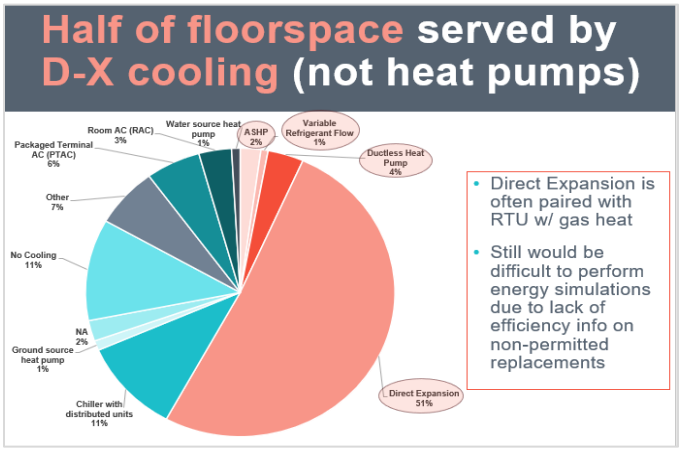
We use 2019 CBSA. I think in our previous expert panel we talked about potentially doing a trend analysis between 2014, and the panelists generally said that was not a good idea. We did look at it and agreed with the panelists. So, all the data that you will see is based on 2019, but there is a new CBSA in the works. Depending on how that lines up, we may or may not be able to do a trend analysis based on that.



Rick continued. We have three or four slides that show some of the highlights from what we found. Probably not a big surprise to anybody, but offices, retail, warehouses, and schools account for two-thirds of the building space, the floorspace. That is especially important because in our permit data, schools and offices were a big portion. We wanted to see how that compared in our permit data. We excluded warehouses because they are generally gas heated, and we are interested in electrical consumption. So, you will not see any warehouses in our permit data. The big players are school, office, and retail. But then how are they heated?



Rick continued. Again, this is probably no surprise to the folks here, but gas heat for rooftops or air handlers makes up essentially half of the floorspace. I wanted to point out that our principal technologies, air source heat pumps, VRF and ductless heat pumps, make up a really small portion of the existing stock. And so again, it is a good reason to focus on the permitted construction for now, and we will see how that potentially changes over time. That's for heating.

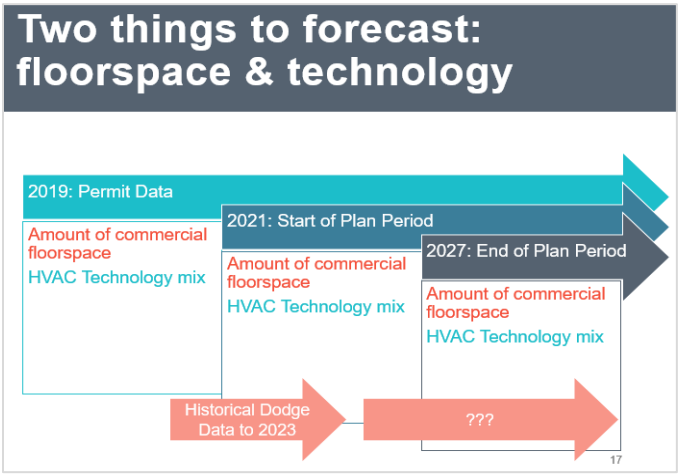


Rick continued. For cooling, direct expansion accounts for nearly half or a little over half of the floorspace. They are often pair RTUs with gas heat. But even if we were able to or wanted to calculate energy consumption on those, the tracking of baseline and efficient case would be really difficult because we do not have insights into the efficiency for those one-to-one or non-permanent replacements. A lot of the floorspace is cooled by one of our principal technologies, but tricky to calculate the consumption.

Eric asked a question. On both of these last two slides, is this half of the floorspace of the building types that we are looking at or half of all of the floorspace including the not included building types? **Rick** replied that this is for CBSA, which includes everything that was in the CBSA. **Eric** said that is what he was trying to figure out, whether we were kind of descending a funnel or whether we were looking at the whole the dataset here.

Rick confirmed that this is the whole dataset for CBSA.

Forecasting to 2017



Rick continued. There are two things we need to forecast for the floorspace, how floorspace is going to change or over time and how the technology is going to change over time. And from our permit data, we have this starting point of 2019. We have the floorspace by building type and we have the technology mix there. Our plan period that we are going to be calculating consumption is from 2021 to 2027. We need to know how those things are changing over time.

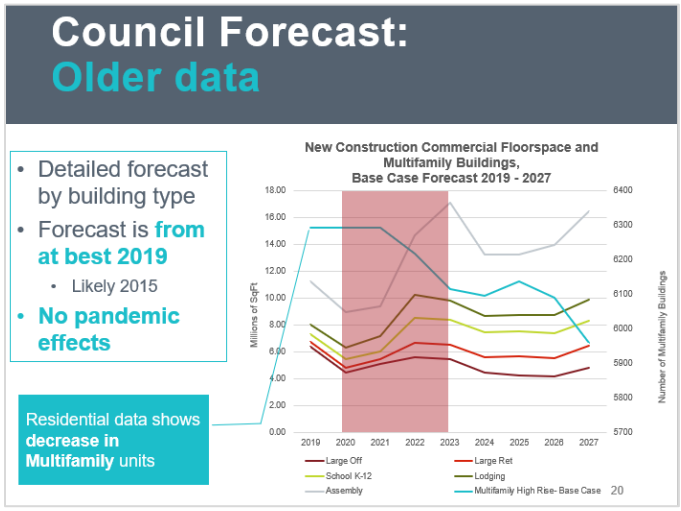
We have some historical Dodge data that we purchased just recently, a few months ago. So, we actually have historical data to take us from

2019 to 2021 and that will help us account for the floorspace, but then we have to figure out what is going on after that. So that's a big question mark.

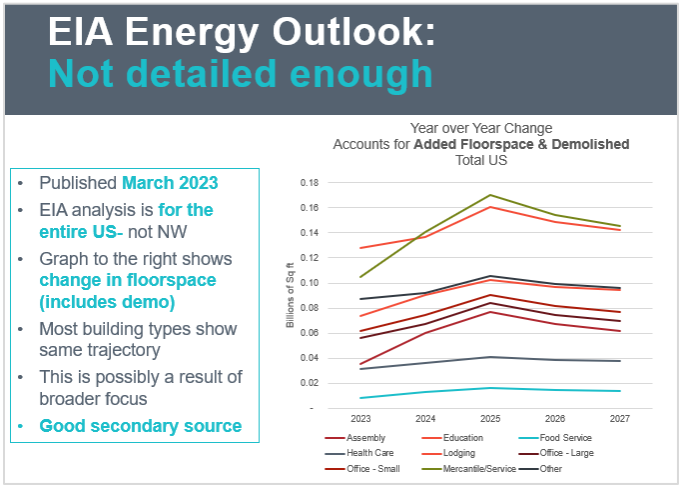
For the technology mix, we do not have good insights into how that has changed recently, but we will talk about that later. This is just to really emphasize that we have these two things, we are looking for floorspace and the technology.

Forecasting Floorspace

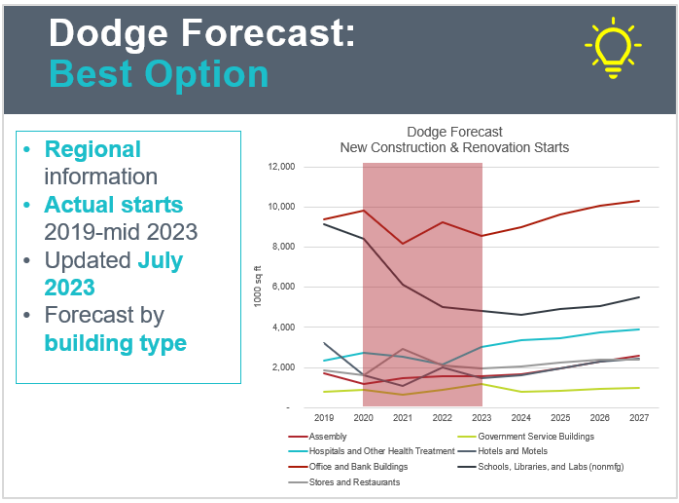
Rick continued. First, we are going to talk about some floorspace, and we looked at these three data sources: the power plan from the Power and Conservation Council, US Energy Information Administration (EIA), and a forecast that we bought from Dodge.



Rick discussed the Council forecast, which is by building type here. These different lines are different building types. They have forecasts 2019 to 2027. Normally, the plan is really our "go to" data source. But in this case, the plan was developed quite a while ago. Our takeaway here is that it was from 2019 pre-pandemic. When we looked through the data sources and then documentation, it looked like the floorspace part was actually created in 2015. In any case, it was created well before the pandemic, which is here in this pink block. You can see that the projection at that time was that floorspace would grow except for multifamily units. The multifamily units would drop, and we know that is not the case because we found we have this Dodge data, which we will look at in a second. Generally, this is just older data, and it does not match what we know. So, we did not think that was a good choice for us.



Rick discussed the EIA energy outlook, which was recently published in March. The EIA comes up with this outlook for the entire United States; it is not regional. They don't have a regional floorspace prediction. But by doing some calculations, we can show what they project to be the change in floorspace here. And you see everything kind of follows the same line. It is not very detailed, and it is not regionally specific. We considered it but did not think it was great. It is a good secondary source.



Rick continued. So, that led us to Dodge. We bought this forecast from them, and it looks to us to be the best option. Dodge has this regional breakdown; they actually have it broken down by state and we combined it here for the region. It starts in 2019 and goes up to mid-2023. It was just recently updated, and it is very clear. It is broken out and very specialized by building type.

So, I thought I would just pause here, and we will look at these individual building types and I have a little bit on the methodology if you are interested in it. They have this top-down and bottom-up approach, but I'll pause here and just see what your first takes are on that.

Peter asked a question. This data set and that first one, are kind of similar regions from a geographic perspective. Are we thinking we kind of captured most of Oregon, most of Washington, Idaho, and Montana or something like that?

Rick said yes, 57 percent of Montana.

Peter continued. The data on this one looks quite a bit different than the first one as far as square footages. I remember we are off by a factor of 100 or 10 aren't we, or no? That was in the single millions, and this is in the 10s of millions? Is that right?

Rick replied. I have not looked at the actual numbers and how they compare specifically. The region is the same, but I'm not sure the building types line up exactly. There might be some differences in those definitions too. The Dodge forecast is trying to show the entirety of the building types that exist today. This is not just what was new construction permitted or anything like that. This is what exists; this is permitted. They are looking at not the entire stock but just construction starts for new construction and renovation.

Rick added. I scratched my head a little bit; I got to think that office has to dominate a lot more than what it is showing. But if it is what has actually been in construction, I guess that makes more sense.

I have a couple more slides on diving into the building type, so we can look at that a little bit more clearly.

Christian has a few quick comments/questions. The top red line, is that assembly or is that office and bank?

Rick replied that it is an office and bank.

Rick added that, if we could, let's save building analysis for later when we can look at it a little bit more clearly.

Christian said, the other question is, are these numbers being used in an absolute sense? Are they being used as like a relative percentage, like off of the CBSA, relative percentage off of the permit data that we collected?

Rick replied, yes.

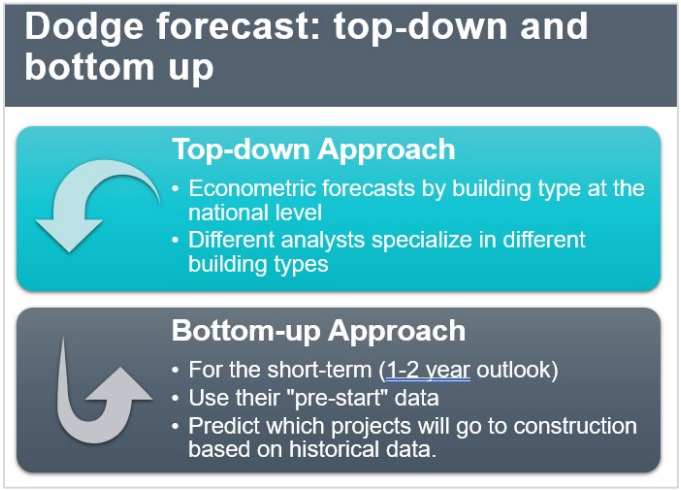
Kevin said his question is similar to Christian's. I think there should be some calibration with the CBSA and with the regional data because the totals we found in the Dodge data are really lacking in the past, in terms of the total square footage in the region. There are building types missing and things like that. I don't know if you have talked to Aaron James at NEEA at all, but he has been deep in the weeds and we have gone around and around with him quite a bit on the totals, the regional square footage, and

that kind of thing. I do not disagree why you are using the Dodge data here, and that the regional forecast is pre-COVID, But I am a little concerned relying too strongly only on the Dodge.

Rick replied. Let's go ahead and look at how we were expecting to use the Dodge data.

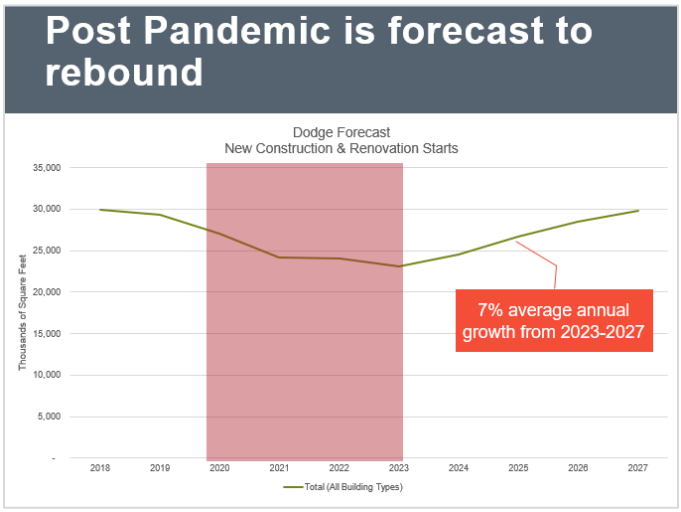
Lauren added in the chat that she can ask I can ask Aaron James and Mike Psaris to weigh in as part of NEEA's feedback.

Juan Carlos said yes, please do.



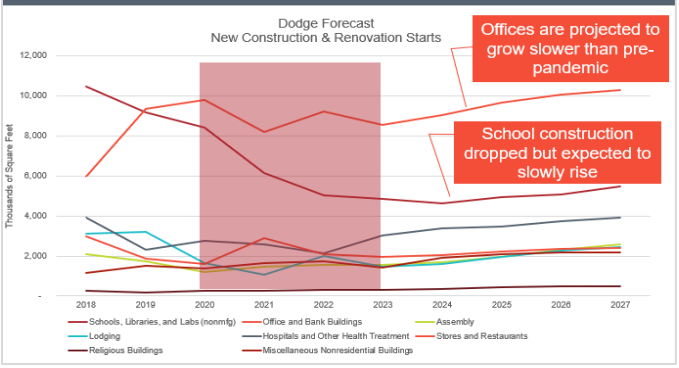
Rick continued. I will just quickly go over the Dodge forecasts top-down and bottom-up approaches again. They have these econometric forecasts for the entire nation against buying building type. And they do have these analysts that specialize in different building types, which I think gives some more credibility to how they are looking at it and their expertise in it.

For their short term, they use this bottom-up approach where they look at their restart data that they have been collecting all along, and predict which projects will go to construction, especially in that that one or two years upcoming. That is the methodology.



Rick continued. I think this answers a couple of the questions. We are not looking necessarily at the absolute values here, but we are using this average annual growth. We are going to look at it by building type in just a minute. But this is one thing to know to see that they have seen new construction, and all permitted construction, drop since 2018, which I do not think would be a big surprise to everybody. But they do predict that the 7 percent average annual growth will continue to grow across all building types.

Both schools & offices are forecast to rebound



Rick continued. And then a couple of things by building type. Offices are projected to grow, which you know might come as a surprise. It did to me, but it is quite a bit less than it did overall from 2018 to 2019. We will look at those specific numbers in a minute. School construction has been dropping for a while, but they predict that it will slowly, pretty slowly rise.

Dodge Average Annual Growth in construction starts aligns closely with EIA Nationwide projections

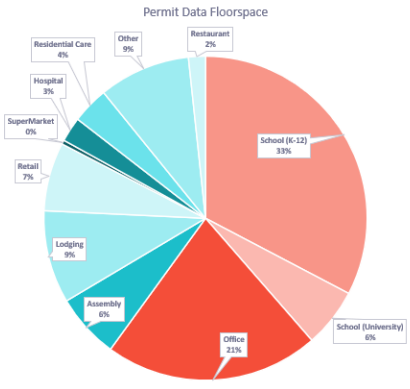
Facility Type	Dodge Historical 2018-2022	Dodge Projected 2023-2027	EIA Projection (Nationwide) 2023-2027	Notes
Schools, Libraries, and Labs	-13%	3%	3%	**Small growth,** but a significant change from recent history.
Office and Bank Buildings	14%	5%	6%	**Significantly less growth than historical** and less growth than overall total.
Assembly	-6%	16%	18%	**Significant growth**, and a large change from recent history.
Lodging	-9%	17%	7%	**Significant growth,** which is a large change from recent history.
Hospitals and Other Healthcare	-11%	7%	5%	**Average growth,** which is a change from recent history.
Stores and Restaurants	-8%	6%	10%	**Average growth**, but a significant change from recent history.
Total	-5%	**7%**	**7%**	The total change is on-par with the nationwide average change, but a significant change from recent history.

Rick continued. Here is the table that shows, by building type, historically over the past five years, four years how things have changed from 2018 to 2022 and then how Dodge predicts them to change. For reference, we have also provided the nationwide EIA projection. As you see, the Dodge projection lines up pretty well with EIA, which is, for me, comforting. For lodging, it is quite a bit different, which I could easily understand. Lodging might be different here in the Northwest as compared to the nation, a little different in stores and restaurants also. But the thing that gave me some good comfort is that from 2018 to 2022, they saw 14 percent change in increase in offices, but it is going to be a lot slower coming up and that matches the EIA.

Permit Data Floorspace

Facility Type	Dodge Projected 2023-2027
Schools, Libraries, etc.	3%
Office and Bank Buildings	5%
Assembly	16%
Lodging	17%
Stores and Restaurants	6%
Hospitals, etc	7%
Total	**7%**

60% of permit data



Rick explained the data on the graph. As I mentioned before, this is our permit data and it shows that schools, both K12 and university, and offices make up 60 percent of the permit data. We really wanted to pay close attention to those. This is the Dodge projected growth rate. Again, not using their actual numbers, but we could apply a 3 percent growth rate, average annual growth rate to what we actually see in the permit data. That is what we are proposing to do and apply these numbers to the other building types also. Does that make sense, how we are proposing to use the data at this point?

Christian asked if this is net of buildings being demolished, tons of vacant floor space already existing, etc.?

Rick replied that we do have in our market model — a spot for demolition to kind of take away from existing. But for our energy consumption data, we are going to look at this permit data and then use this projection minus the demolition. I'm sorry if that did not make sense, it is complicated.

Christian added that picking a source is fine. Crystal balls are never very good, right? In this particular area, they are probably worse than normal just given all these post-pandemic effects. I think a straight line is as defensible as anything in that practical regard. And it makes sense that there are still permits and we are still building things, but I guess there is also a lot of vacant space. I guess just to the extent that we are also taking that into account, I think makes sense.

Rick added that we would not be calculating the energy consumption of the vacant space.

Peter commented with a general question or topic for discussion. I do not see it specific on this slide, but I think if we go on back two slides, the title talked about Dodge forecast new construction and renovation starts. I'm not sure what they mean by renovation starts. I was curious if any of this data is reflective of major work that is being done with an existing facility.

So, is this major renovation work? Even though they might show growth, — there is work being done in millions of square feet — but is that already part of some percent of existing building stock that is already there? In which case we, would want to add that too, right?

Rick replied that there is the accounting of floorspace and then we are calculating energy consumption change in energy consumption for it. If it is remodeled, we would want to know what renovated. We want to know what that kind of change in energy consumption would be from a base case. It still has to meet code because it is a major renovation and what the efficient units are installed in.

Sarah added that if you remember that detailed table, we said this model is characterizing in terms of square footage, new construction, major remodel and existing. And the existing we are characterizing with CBSA and at this point really holding it constant. And then this percentage would be used to understand how much of that total commercial HVAC pie is new construction or major remodel. And that is going into those pieces of pie that we care the most about and are characterizing energy consumption for. They have to meet code, and they might be more efficient than code. They go from our overall bucket into our now into the energy consumption details bucket. To your point Peter, not all of them are adding total square footage to the market. And that is something that we are going to have to work out in terms of how we are applying this number and what our model is saying both now in this interim time when we are forecasting and, in the end, when we have hopefully more real data to rely on permits and an additional CBSA. But that annual growth rate is not added square footage, but it is added square footage that we are characterizing consumption for. Rick, I do not know if you can speak to how much of that we think is new construction or how we are going to apply that to how much is the square footage really, really growing or not. Maybe we can come back to this group once we have more information on that.

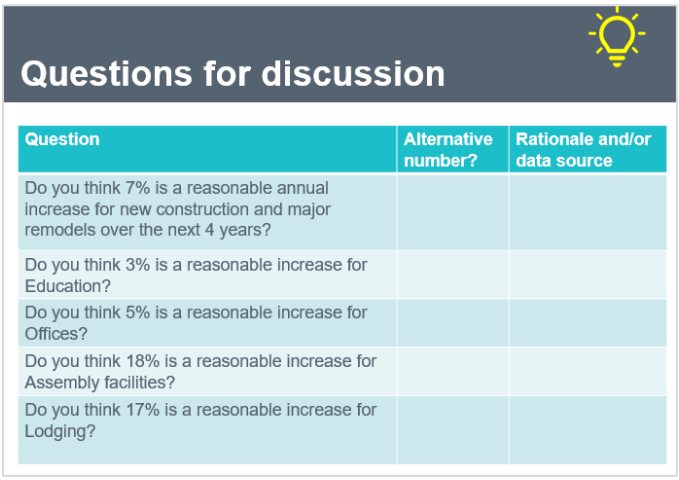
Peter thanked Rick and Sarah for that answer.

Sarah continued. To Christian's point about a straight line being as good as anything and you know the limitations of the data we have here, I totally respect that. Actually, this is a prelude to some questions we have for you all about how we are going to use this data and if there is better information or better assumptions that we could make. But this is a reminder that this is a forecast, and it is going to be important because we are going to finalize and publish this data and use it to explain to the best of our knowledge what is happening both right now and in the future. It is just chapter one of a two-part series when we are going to be able to add another round of permit data collection, hopefully CBSA information, and finalize what actually happens in the full 2021 plan. So, while the forecast is important and we want to be as right as possible, it is anybody's guess what is going to actually happen.

Brandon asked in the chat if we think the feds will have data on the projects funded by IRA? For future consideration?

Rick said that in the EIA outlook, they have several different cases: base case, high adoption of IRA incentives, one is low, etc. They do not change the floorspace on that, they only change the technology. The EIA predicts that those are not going to have an effect on floorspace, only on technology.

Tyler added that my thoughts on this right now from what we see, a lot of the IRA-funded stuff is very decentralized and still being set up. So, it is going to be a long time before any of that is consistent, before we get consistent data from IRA-funded things. But maybe that is just me being pessimistic.



Sarah walked the panel through the question for discussion. We are going to pause here and get any additional feedback you all have about using the Dodge data in the way we are talking about the annual percentages that we would apply to the different building types. And, like Peter clarified, that would be square footage that enters our permitted bucket both new construction and major remodel.

We have on the slide here just a couple numbers called out in particular that Rick spoke to. The 7 percent over the next four years and then percentages for education and offices that we are particularly interested in, that is the majority of the floorspace that we see in permitted projects. And then assembly, where we saw an especially high percentage. And lodging, which we saw an especially high percentage and unique for the Pacific Northwest.

We are interested in any feedback on those in particular both right now. You can out specific recommendations in the spreadsheet, or discuss them now, if there is something better that we should do. It is fine to acknowledge the limitations of the data that we have and that there is uncertainty, and that is inherent in any projection. But, if there is an alternative value you have and then especially that rationale, if it is data-driven, that is excellent. Then we can say this is better than Dodge. But even if it is an intuition or a gut feeling, we can take that into consideration. But we need to weight that subject matter expert opinion against citable project information. The more robust you can be in your rationale, the better and the easier it is for us to incorporate.

Branded added one thought on schools, in terms of data collection. Going to each state and looking at what school districts have successfully passed bonds for major renovation or new construction might be an additional data source to determine whether or not that 3 percent number is realistic or not. That is the only real value-add comment I have: the bottom two categories, the 18 percent growth for assembly and 17 percent growth for lodging, just seem really high to me. Looking at what infrastructure is doing, and it comes wobbly. We have an election year coming up.

Kevin agreed. I think almost all those numbers seem too high to me, especially offices. I think that is plenty high and the last two seem high and the overall 7 percent in the next year. That just seems really high. I was looking at our forecast for offices, for example, and it actually shows a decline over that time frame rather than an increase.

Sarah asked Kevin to speak a little bit to what your projections are based on.

Kevin responded that the projections are from the 2021 plan. It is the historical data forecast. But you are right, the baseline numbers were from pre-COVID. But it still shows that offices have a big dip in 2022 in construction and then it rebounds starting in about 2026 or 2027 it starts to go up again. That is what our forecast is showing, which is quite different than what you are.

Rick asked how do you all come up with your forecasts?

Kevin replied that it is a big process and a lot of data, but we have the forecasting model called Energy 2020. We are actually switching to a different one now, but there is a lot that goes into that load forecast. It is all part of our load forecast and use load forecast that we build up for each power plan. We are looking at early to mid-next year to have a new one out, but that might be a little bit late for what you are doing here. For every plan, we do a detailed square footage forecast by building type and for both residential commercial, well actually all sectors. But for commercial, it is building square footage and that's econometric. I do not know all the details that go into it, but that is what we have done.

Eric asked a question. Could one major just difference between those two be the major renovation question?

Kevin said it could be.

Eric continued. Because if the Council is truly looking at additional square footage, that is a very different conversation than percentage, percentage of building stock that sees major turnover in building systems.

Kevin said that was a good point.

Eric continued. I think that is what we are trying to capture here, right? How often do we revert to a code baseline? It is the percentage reflected here, which is different than how much square footage is added at on a net basis.

Kevin, Sarah, and Rick all agreed that this was a good point.

Kevin added. how much of that, how much of this is renovation versus new construction? I think would be good to have some idea of…

Rick added that we do have that broken out in our permit data, but I do not have it for you today. It also gets messy because there is a lot of new construction and some major renovation, and a lot of it gets mixed together. But we have an estimate of that breakdown.

Tyler reminded everyone that these questions will be in the feedback workbook, and that we do want written feedback on these questions and topics.

Eric asked if the workbook includes the breakout of new construction, like true new construction, versus major renovation.

Rick replied. No, it does not have in there. But I think we will make a note of that, and we can provide an update after the call or on the next panel.

Tyler added that Rick would have to do a little bit of work to get those numbers broken out that way.

Eric added. I totally get that. I just think it would, for myself, and it sounds like maybe a few other people, help us feel more or less comfortable with the percentages shown.

Rick said that he thinks we have it already done. It would just be a matter of putting it in a presentable format and send it out. We could do that next week.

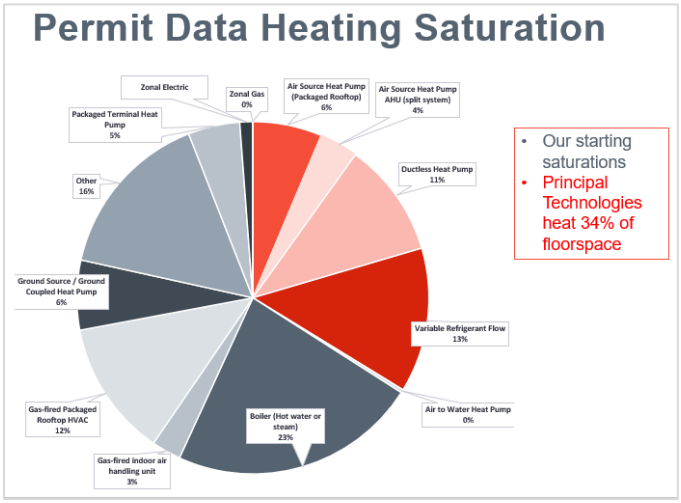
Juan Carlos said, let's make that happen.

Rick agreed and then said that he would move on to technology forecasting, which is even more difficult.

In the chat window, **Lauren** noted that regarding bonds, Washington has a website that tracks this for schools: Election Results for School Financing | OSPI. She added that NEEA was just talking about looking into school construction from bonds a couple of days ago.

Forecasting Technology

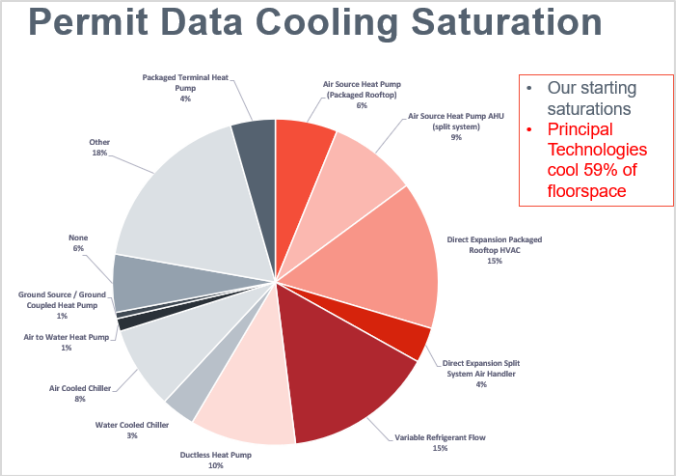
Rick continued. I just want to lay out what we are talking about when I say technology forecasting. We are trying to develop a saturation, which is the percentage of floorspace that is served by each HVAC type, and we are trying to develop that over time. We do have this starting place with our permit data, but our big question is how will it change, or will it change? Will the saturation of technologies change over time. And I will show you our permit data to give you kind of our starting saturations here.



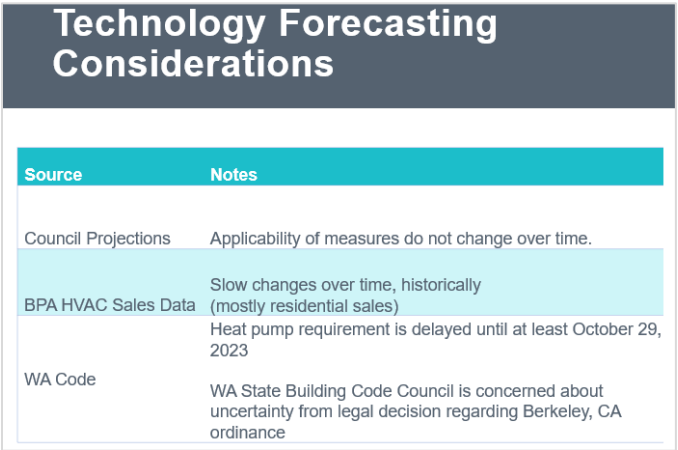
Rick continued. This is for heating only, and this is all of the floorspace in our permit data, which includes new construction and major remodels. The big take away is that about one third of the floorspace is heated by one of our principal technologies.

I am just going to point out one thing because I was really shocked by this one. The ground source heat pump of 6 percent seemed really large to me was surprising. It is based on one elementary school up in Redmond, WA. But the Lake Washington school district does have 10 schools that have ground source heat pump. So, I think there are some of those projects that are happening and have been happening.

Lauren confirmed in the chat that what Rick is saying is consistent with what she has seen in ConstructConnect: more ground source heat pumps than expected, and they are going into schools. But there are still not huge numbers of ground source heat pumps going in.



Rick continued. We have the same breakdown, but for cooling. Since we are interested in direct expansion cooling in addition to the heat pump cooling. Sixty percent of the floorspace is cooled by our principal technologies.



Rick continued. Then the question is, how do we project those saturations over time? We had trouble finding data sources. One thing that we looked at again was the Council projections, which is our go-to resource, and I couldn't find a saturation for new construction floorspace or permitted construction floor space. Kevin, please correct me if I'm wrong. But what they do have is individual measures like ductless heat pumps and air source heat pumps and VRF that align with our technologies. And there is an applicability that they assign to each of those measures, and that applicability is the percentage of floorspace that the technology is connected with. The applicability for each individual measure does not change over time. That was one data point we looked at.

The other one is the BPA does an annual HVAC sales data collection, which is mostly residential sales. There is a small portion that is commercial, but mostly residential. We historically see that kind of saturation; technologies change pretty slowly over time.

The other thing that was a big consideration is that the Washington code has a requirement for commercial buildings to be heated by heat pumps, generally speaking. But that requirement has been delayed recently until at least fall of this year, while the Washington State Building Code Council figures out what they are going to do.

There was a Berkeley ban of gas and that got thrown out by the courts, so the Washington code is a big one that just makes me think that something will happen soon. But it is very much up in the air.

Kevin commented. We do have our saturations frozen, like you said. But, if there is an efficiency measure involved, we have a ramp rate that changes over time and that could be applied to the number of units being added over time, assuming the efficiency programs are following those trends. I'm not sure if that is helpful at all, but there are ways to get those forecasts from those ramp rates.

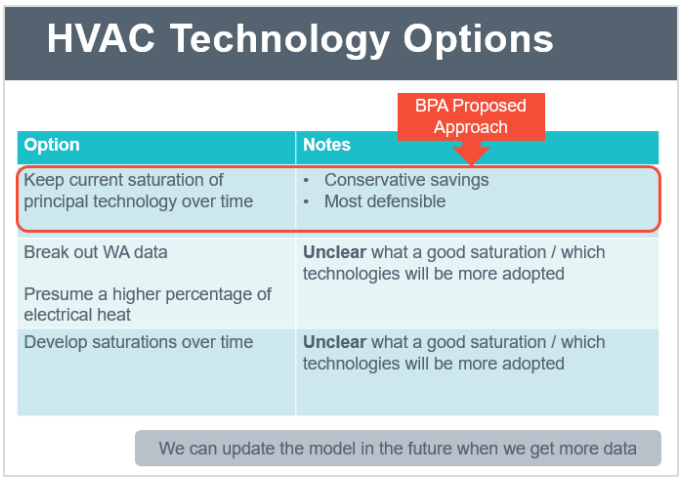
Rick said okay. I was thinking of those ramp rates as the adoption of the measure. Does that change technology or is it the adoption of the more efficient technology?

Kevin said yes. I think in most cases it is just the more efficient ones. That's a good point. There are a few instances I would have to double check. We do have some conversion.

Rick added: the VRF, right?

Kevin said he thinks that is pretty minor. It probably will not impact what you are doing too much. But I can double check. The VRF is one, but I think that you are probably OK with what you're doing.

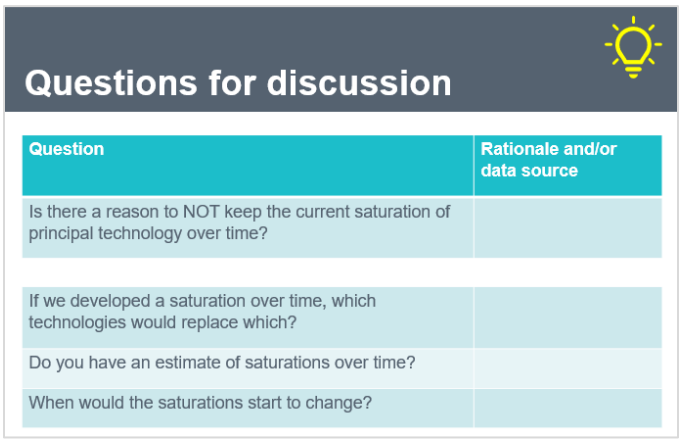
Rick said, if you find anything else, I'll take a look. It would be great to align with the Council's work.



Rick continued. We have three different options, maybe you all will come up with some other ones as we go. But one would be just to keep the current saturation of the principal technology overtime. We think Washington is going to change soon. So maybe we break that one out. The most complicated option would be to develop saturations for all states over time.

The approach that we are leaning towards now, and would like to run by you all, is just to keep that current saturation, keep it constant. It likely leads to more conservative momentum savings, some more consistent consumption over time. At this point, we believe it is the most defensible without some other data sources. The big problem with the other two options is that it is unclear what is going to get changed and when is it going to happen. There are just a lot of unknowns that we do not have good information about. It is all a kind of crystal ball. It is hard to come up with anything that we can really hang our hat on. This is another good reason potentially to keep it constant over time. Like Sarah pointed out earlier, we are going to update the model in the future based on another round of permit data. Potentially the CBSA will give us some other insights.

So that is where we are landing at this point, and where we would like to have a little discussion.



Rick continued. The main question is, is there a reason not to keep the saturation constant over time? The sub questions here are if we do some sort of develop a saturation, what replaces what and then when would it happen?

Christian had a comment. I think flat is fine with floorspace. Here though, I actually think we at least know the direction. Unlike the other question, I don't even think we know the direction. So that's why I said flat there. Here, I think we know the saturations are going up. How much up? I do not know. I do not know if we have any kind of sales data that can give us any kind of hint at that. Flat is fine. I do think we know the direction. Other than that, I don't have any really detailed answers.

Peter added. A couple of slides prior, we had permit data for cooling technology and permit data for her heating. I assume you guys capture that. So that's a snapshot in time, right?

Rick said yes.

Peter continued. Do we have multiples of those snapshots in time? If you had permit data from 2018, 2020, 2022, you could use that as a projector. Here is the piece of the pie that rooftops were and that VRF was, and here is how that's been evolving over the last next years.

Rick said yes, the permit data was collected from 2015 to 2019. We do have some starts over that period. But the sampling plan was not designed to be annual. So, we cannot really make a comparison.

Sarah added. But to Rick's point, we are going to collect permit data again, and then we will have that. Where this is chapter one, the very first time we are building this model for this market, and then we will have the follow up where I think we will be able to have a lot more robust information.

Peter said that seems like probably one of the better sources of information to do some level of projecting going forward.

Kevin added that he will take a look. The Council forecasted some of the gas systems switching over in the new construction. The saturation of the technology would change a little bit based on that. But I again I don't know if I can actually get the numbers. I think it would be fairly small, but I will see what I can do.

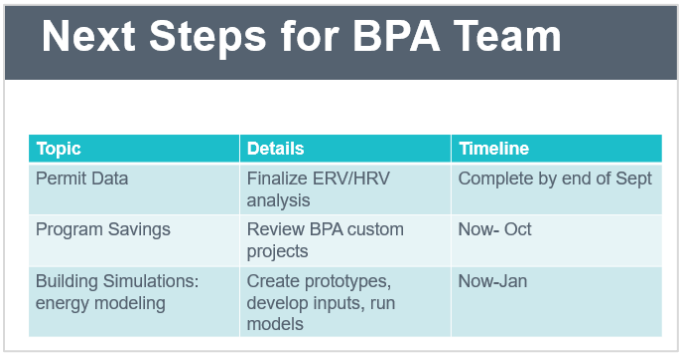
Rick added that we did look a little bit at the forecast and could not tease out anything.

Kevin added that it is very deep. It is very hard to figure that out. And with Masood retired, I am not sure, I mean it is even more difficult. But I'll see if I can figure out where that is.

Lauren added in the chat that the sales data that BPA and NEEA collect is currently lacking in commercial systems, but NEEA is working aggressively to get more commercial sales data so it may get better over time.

Tyler reminded everyone that these are the questions that we will be circulating in the workbook. If you have additional thoughts as we move forward or suggestions or places where additional exploration could be warranted, please provide that in the written comments.

Next Steps

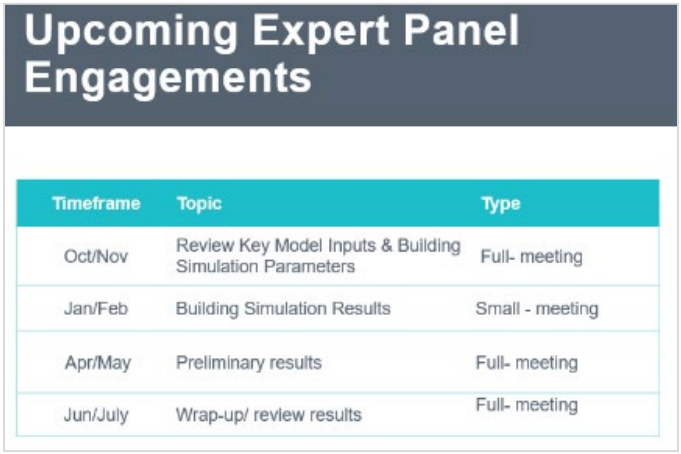


Rick talked about next steps with the panelists. On our side, we have these three major topics that we are looking at currently and in the near- to long-term future. Right now, we are in the permit data, where we are finalizing this analysis of the heat recovery. It gets really complicated there. We talked about comparing to code. We should be done with that by the end of this month. That will finalize all the permit data analysis. We have already looked at heating and cooling technologies and how those efficiencies, how they match up against code. Everything is a little bit above code. There is some momentum savings there, some difference in in consumption.

We are working on the program savings to understand what and how much of the permit data is influenced by programs. We have a list that we are going to send over to BPA soon to ask for some custom projects and look at those.

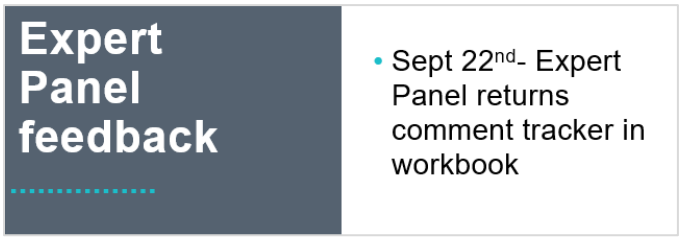
And then we will start our building simulation, actual energy modeling, creating prototypes, tweaking the permit data, and looking at other inputs like building characteristics. We will develop all the inputs that we need to have for the models. And that is going to go out all the way till January of next year.

Lauren added in the chat that she not sure if this will actually be helpful or not, but NEEA is surveying HVAC contractors, system designers, and supply chain re: sales of some the target systems this fall. I am hoping to repeat at least some of the surveys in fall 2024, but that's TBD. Recruiting will be hard but we will try to get representative samples of survey respondents. Juan Carlos, let's check in again so I can give you the latest info on our data collection for Market Progress Evaluations.



Juan Carlos thanked the panel for all the questions, conversation, and messages in the chat. Appreciate all that all this goes a long way to us helping figure out our models. We will be coming back to you guys pretty regularly. The first thing is for you guys to give us written feedback on what we presented today. We are giving you two weeks to get that back to us and then we are going to engage you in late October, early November for another full meeting to review key model inputs and building simulation parameters. That should be fascinating; I'm super interested in that. Then we will let you have the holidays off, but we'll tap you again late January, early February to do the building simulation results. That is going to be a smaller meeting. We may not ask all of you to join. If it is something you are particularly interested in or think you have a particular expertise in, please let us know and we will make sure that you are included in that meeting.

A couple months after that in April or May, we will present to you some preliminary results. That will be a full meeting. In June or July, we will give you a review of our results and our first interim model. In between those engagements, there may be some desk reviews or some data that we want you to just look at without a meeting involved. But these are the next full panel engagements that we have listed; so put those on your calendar so that when we tap you for it, you're not surprised.



Tyler reminded everyone that we are going to recirculate the slides from today along with a workbook where we're asking you to provide some written feedback on some of the questions that we've gone over today. And we're asking for those to come back in two weeks on September 22nd. You will hear from me and Lorre on scheduling the next full panel session to go over model inputs in the building simulation parameters. We are shooting for late October, early November for that meeting. When you get a Doodle poll, please fill it out and we will get that on everybody's calendar as soon as we can.

As many of you know, forecasting is difficult. It is hard and the research team here is really just trying to get the best available data and the best possible inputs to come up with reasonable forecasts to make these models better and that is what this panel is here for. So, please provide some comments, thoughts, and places where people can do additional exploration. We really, really appreciate everybody's participation.

Sarah suggested that we hold off on sending the workbook until after Rick is able to make the updates to break out the new construction versus remodel. It sounded like people really wanted that in order to be able to provide more robust information. Rick and Juan Carlos, would it affect the timeline too much if we pushed it until the end of September. That would give people an extra week.

Rick replied that he did not think that would affect our timeline.

Juan Carlos asked the panel if it would be comfortable if we held on sending the workbook for another week until we get that fixed. In about a week, look for that workbook and these slides and we will look for your response. We will still give you two weeks to respond. I think with that we might actually be able to include the meeting notes as well if we.

Everyone agreed that this was a good idea.

Once the feedback workbook has been updated, **Lorre** will send the revised workbook, slides, and the meeting notes to the team with a deadline of September 29th.

Working Session: Building Simulation Inputs – Nov. 16, 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: Juan Carlos Blacker

DNV: Tyler Mahone, Lorre Rosen

Cadeo: Rick Huddle, Will Gorrissen, Marcus Dimeo

Targeted Group of Panelists: Christian Douglass (Ptarmigan/RTF), Peter Kramer (Trane), Brandon Adams (Vector Energy Solutions), Mark Lessons (Johnson Controls)

Introductions

Tyler started the recording and led the panel through brief introductions. We specifically asked the experts here today to join this panel due to your knowledge about building simulation. Today should be more of a discussion. Feel free to jump in and ask questions to Rick or the Cadeo team as we are going through it.

Juan Carlos thanked everyone for coming and asked everyone to participate as there would not be any homework after this panel session. We are really looking forward to getting all the necessary feedback during this meeting so that Cadeo and the BPA can make decisions without further follow-up.

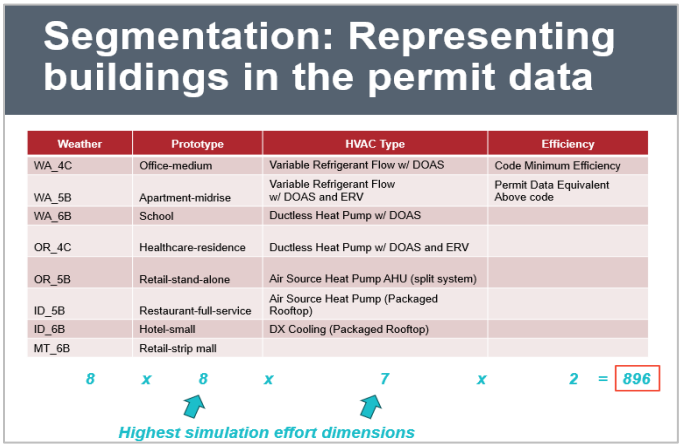
Rick walked through the following discussion topics/agenda for today's call.

Discussion Topics

- Weather Files & Climate Zones
    - Locations to use for simulations
    - Aggregating simulations into the Market Model
    - Weather files for simulations
- Building Types
    - Directly simulated buildings
    - Assigning buildings with multiple prototypes
    - Assigning buildings with no prototypes
        - Proxy simulations

Rick continued. I think the first topic is relatively light, the weather files in the climate zone. There are kind of three subtopics. First, the cities that we want to use as inputs to the building simulations. Then we are going to aggregate those building simulations into the market model. Lastly, we will look at the weather files that were used. Those are relatively straightforward, and we can probably go through them quicker. The building types are more complicated. You will see that 83 percent of the buildings are going to be directly simulated. There are buildings that do not have multiple prototypes and so we

are choosing which prototypes to use for them. And then there are buildings that do not have a prototype. We are proposing proxy simulations for those. When you see the lightbulb icon on a slide, we will be asking questions for open discussion. But of course, feel free to chime in if you have clarifying questions as we go.



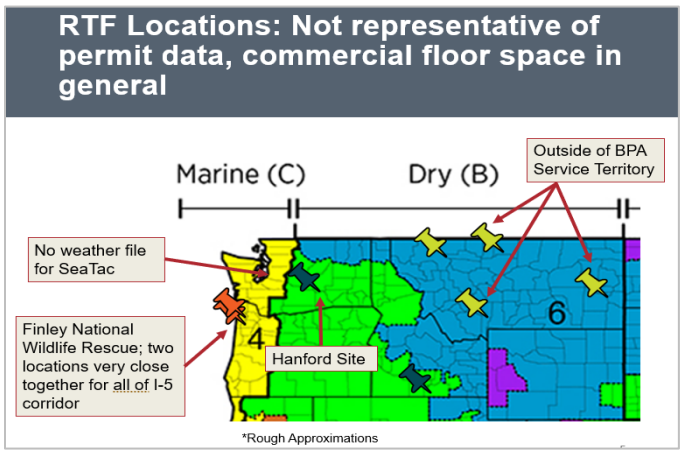
Rick discussed segmentation. One thing to note here is that we are trying to represent all the permitted construction that is happening in the region. Since there are so many different building types and locations, we need to segment them out into discreet building simulations. This is how we propose to do that. We will talk about the weather files in a minute.

You already know that where the buildings are located makes a big difference in energy use. So, we have representative cities or locations throughout the region. And then there are the buildings themselves. We have prototypes for all the buildings as you can see office, apartments, schools, etc.

For HVAC types, you know that different buildings are going to have different HVAC types for most or all of the building types. The last key part is what is the efficiency. “Code minimum” or code is our minimum or baseline efficiency. In the permit data, you might remember from way back that the average efficiency for all permanent construction is above code by a certain amount depending on the HVAC type. That is going to be our efficient case, and we will take the difference of those to get the savings. A couple of other things to note here is that you can see that there are almost 900 different building simulations that we will be running. This is a pretty big project. But those two middle columns, the building and HVAC types, are the ones that take the most effort to figure out. Once we get those parts done, plugging in a different city or a different efficiency is relatively straightforward.

Rick handed the presentation over to Marcus to discuss weather files.

Weather Files and Climate Zones

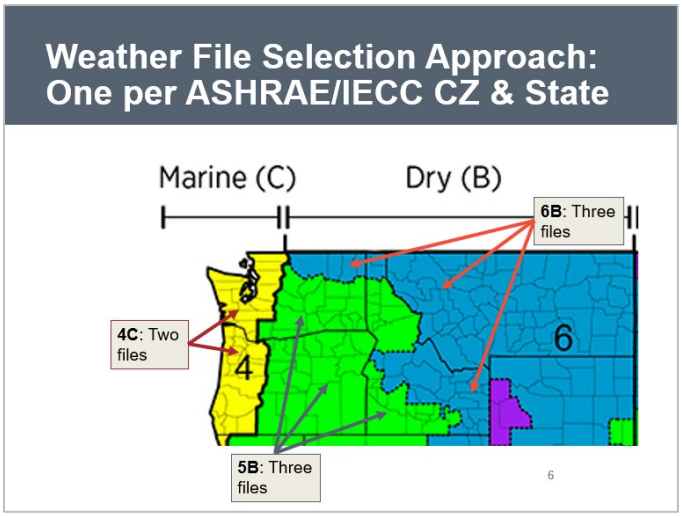


Marcus introduced himself and began to walk through the weather files and building types that we are proposing and mentioned that Will is going to jump in to provide color and commentary as needed.

For weather files and climate zones we are going to be simulating, there are really two options that we were considering. One of which was using the locations that the RTF uses for their simulations to represent the region and energy send. Thankfully, we have some folks on the call that are more familiar with these RTF locations and how they are chosen. To sum it up, the RTF chose these locations based on variation of heating degree days, including degree days in the region, and tried to make them representative of residential and commercial locations as well.

The bottom line of why we did not choose this option was that we did not feel it was representative of our permit data or commercial floor space in general, particularly for BPA's service territory. So, what I did here is pin the different RTF locations on top of the American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE) map of the region, which shows the climate zones. Please note that we do have three locations that are actually outside of BPA's service territory and so they are not any use to us.

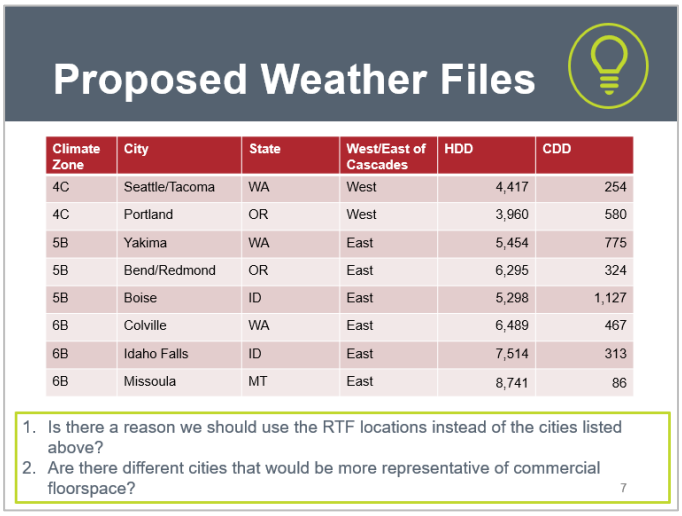
There also is no weather file in the archive location for Seattle/Tacoma. Given that this is a commercial model for the region, we feel we would be remiss not to include Seattle/Tacoma weather files in our building simulations. There are two locations that are a little bit further away from where we would expect commercial floor space to be. We have Finley National Wildlife Rescue and Hanford Site. Hanford Site is pretty close to the tri-cities area. So, maybe that is a good location. In that case, we would just Redmond weather file. Next, I want to draw attention to these two pins that are in climate zone 4C. They are bunched close together. And we would rather have a nice spread for all locations, but particularly for 4C since that part of the region has the highest population density.



Marcus continued. To show you our preferred approach, I think of this as a simpler approach in terms of how we would assign unit energy consumptions (UECs) by location as well as trying to represent commercial floor space.

So, what this approach is, is just taking one weather file per ASHRAE zone and state. For example, for ASHRAE zone 4C, we would take a weather file in 4C Washington and 4C Oregon, particularly locations that will have high amounts of commercial floor space.

Similarly, for 5B, we would have three weather files, one for Washington, one for Oregon, and one for Idaho. And then three weather files for 6B1 for that sliver in Northern Washington that is in the 6B climate zone, Idaho, and then a location in Montana that is within BPA service territory.



Will continued. Here is our list of proposed weather files, again based on commercial floor space and trying to represent climate zones and states. I will not go through these in too much detail, but I will say that we chose locations that had high amounts of commercial floor space, and we are also cognizant of cities that were on the border of two different climate zones. For example, Spokane WA is on the line of 5B and 6B, and that was not a great representation of Eastern Washington. So, we chose Yakima for that instance.

Will asked the first question. Does anyone have a reason or things we are not thinking about on why we would choose the RTF locations instead of an approach such as the one I just walked through? And then if we want to stick with this approach, are there other cities that we think would be more representative of commercial floor space in BPA service territory?

Peter Kramer said that in general, the logic seems spot on. We are focused on BPA territory. 99.9 percent of all Portland is covered by PGE, not a BPA utility. So, is the analysis supposed to still capture buildings in these metro areas that are served by BPA utilities?

Will said that we do want to represent cities that will have commercial floor space that are representative of these ASHRAE zones. So, when I talk about BPA service territory, I am mostly referring to not Eastern Montana. But you are right, as you said, Portland is 90 percent PGE, but we still want to use that as a location to kind of represent our building simulations.

Tyler added that the market models are for all of the Pacific Northwest, not just BPA territory.

Juan Carlos said that PGE is a BPA utility; they do buy power from the BPA. They are considered a utility. They are an investor-owned utility (IOU). So, they have a different sort of focus. But basically, everything in the Columbia watershed is our territory. It includes the states of Oregon, Washington, and Idaho, and then Montana West of the continental divide. And there is a tiny sliver in northern Nevada and a tiny sliver in western Wyoming that count, but we do not consider those. If you are 100 miles from a tributary to the Columbia, you are in BPA territory. We do not provide less services to areas that are mainly IOU focused.

Peter thanked Juan Carlos for the details. He continued. You guys know you cannot only get so granular, it is just going to go crazy with the amount of analysis you are going to do if you try and really break these climate zones down even tighter. But certainly, using Portland to represent that whole 4C for Oregon. As you go south, you know in Medford and Grants Pass, that area does see quite a bit more sun. I think their summers are quite a bit warmer and I think their winters are noticeably cooler. I do not know how much you need to be concerned about that, but just as an FYI there.

Marcus added. That is good, and we are considering locations further south such as Eugene.

Peter said Portland is probably not terrible for Eugene. There are a handful utilities that are still within that BPA territory that go all the way to Southern Oregon. And there is enough of a metro; there is enough of a built environment down there.

Marcus said that when we looked at Eugene and a few other places around that area, the heating degree days and cooling degree days really looked more like Seattle. So, that is just something to keep in mind if we do want to have a little bit more variation in our building simulations. I have not thought about exactly how that would affect our market model, but I am just pointing out that those locations do look pretty similar to Seattle in terms of heating degree days and cooling degree days.

Peter agreed. Eugene especially is going to see a bit more moderate temperatures and a little bit more cloud cover. But if you go further South, things tend to open up in Southern Oregon. That is where I would say it differs quite a bit. Seattle would not be representative of that southern part of Oregon. Nor would probably Portland. Portland is not bad, but there is certainly enough difference there.

Will added. I do think that is great input. One challenge here. I do think Medford would be representative of a certain part of Western Oregon much better than Portland. But currently, the market model is going to think about things in terms of state and either east or west of the Cascades. That is the granularity the market model is dealing with, and we are rolling up from these simulation climate zones or regions up to those market model regions. If we just moved Portland to Medford for example, that is fine, then we would not have to change our process at all or think about it differently. If we had Portland and Medford, we would have to come up with some way of dividing Western Oregon into spaces more similar to those two. So, this is one potential wrinkle.

I guess the third approach would be to use buildings simulated to the Seattle/Tacoma weather and apply that to Northern Oregon. But we would still have to come up with some dividing line between this part of Eastern. Does the group here think it is important to reassess that Western Oregon location.

Tyler jumped in to get to Christian and Brandon's comments really quick because they both had their hands up.

Christian added that he does not have a problem deviating from the RTF locations. I do not think we have ever thought of the RTF locations as being sector specific. We were thinking of the whole region. I think if we did look at only a commercial building space, we probably would come up with different cities. I do think some of the points that have been made are good, and I think it is one of the reasons that RTF cities are maybe the ones you do not expect. Because even in climate zone 4C, you have areas of elevation that have weather that look like 6B. That is one of the reasons why we get some of the cities we do. All that being said, I do not have a problem with this. I do think given the issue that just came up, you are probably not getting much by having three cities and 6B. I have never even heard of Colville, WA. And I do know that the smaller the city, the higher the probability that there are issues with the weather data. It might be worth taking out Colville and adding in another 4C that is further south. That might do a much better job of representing the population of floor space.

Brandon echoed Pete's sentiment on Southern Oregon. You addressed that articulately. I just also want to remind you, there is another relatively medium-sized city in Oregon called Klamath Falls that is on the east side and sits at 4,100-4,300 feet, which we found has a significant impact on our sizing for HVAC equipment. I would just be curious whether it is western Oregon or the southeast section. It would be interesting to look at the weather data for Klamath Falls for example and see if there is a big enough delta compared to the other cities east of the Cascades that might warrant it getting special consideration. Or if it is similar to these other 6Bs that we have in here, then I think it is covered. The other question I had is what is the source of the heating degree day and cooling degree days? How far back in time does this look? The reason I ask that is I have stopped designing, and when I am guiding the engineers who work under us, I guide them to design to the last five years average for peak cooling and peak heating. I think that is critical and probably something we are going to see more of. I do not know how often engineers, at least if they are doing their due diligence or using 30- or 20-year data, because it is just not representative of what we have seen recently.

Will proposed that the group can accept first and then move on to the next topic. Will suggested that we switch Colville for Medford. That way, we will have two Eastern Oregon, and we will use the RTF Climate Zone apportionment workbook. They have to decide which sections of Western Oregon go to Medford and which go to Portland. everyone agreed that it was fine.

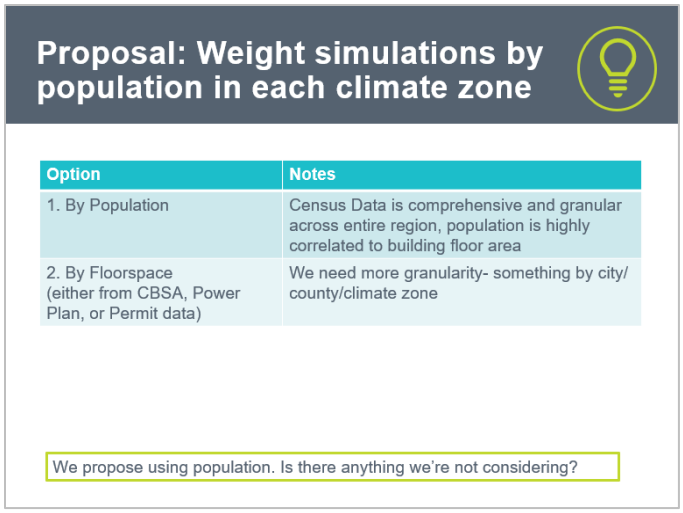
Proposal: Weight simulations by population in each climate zone

Some simulation results need to be aggregated to model segments

Sim Case	Population	Weighting	Model Segment
WA_4C	5,773,147	100%	Western WA
WA_5B	1,191,325	93%	Eastern WA
WA_6B	84,746	7%	Eastern WA
OR_4C	3,455,981	100%	Western OR
OR_5B	554,443	100%	Eastern OR
ID_5B	1,610,157	71%	ID
ID_6B	672,628	29%	ID
MT_6B	904,152*	100%	MT

*MT Population is not filtered for BPA service territories

Will mentioned that we need to roll the simulation regions up to the scale that the market model thinks about. When we have two climate zones east of the Cascades in Washington for example, we need to weight the simulation results up to Eastern Washington. We proposed to do that just based on county-level population data because it would have a high level of granularity.



Will continued. It was relatively simple to overlay it between the market model geography and the building simulation geography. Basically, the ASHRAE climate zones are defined at the county-level as well. We just wanted to see what folks thought about that. Other options would be looking at various data sources for commercial floor space in the region, which is a perfectly fine approach. But that mapping process is potentially slightly more complicated, depending on if the data is available at county level or overlaps with the ASHRAE climate zones. We may have to do some work on that front. Does anyone have immediate thoughts on using human population as sort of a proxy for commercial floor space.

Brandon said to be careful with rural areas. That is the only word of caution I would exercise there, because your correlation is going to be different there than it is going to be in Portland.

Will said that a sampling study looking at commercial buildings floor area might actually miss those rural areas, and we might have more comprehensive data on the census side of things. So, do we expect we will be overweighting the more rural market models of geographies?

Brandon responded. I am just saying that for institutional buildings, you are going to have city, county administration, schools, etc. But in a rural community like Klamath Falls, there are a lot of employees here that aren't working in commercial offices, you know, and so the amount of the employee base that's working in commercial offices in a rural community versus a metropolitan area, I think is going to be different. And so that ratio probably needs to be accounted for.

Tyler added that whenever I am developing weights, you want to consider the population you are expanding to, which in this case, you are expanding to commercial floor space. So, if you have a data set that uses commercial floor space to create your population that you are going to expand to, then I think that makes sense. I know the CBSA did a lot of work on their weighting system. So, if you had used their expansion weights and then had that as your population of floor space, you would probably get something similar in terms of census data, in terms of population, for your weighting and it is going to be more of a correlation of what you are trying to expand to.

Will added that I am happy to move towards floorspace from CBSA if folks think that is a better solution.

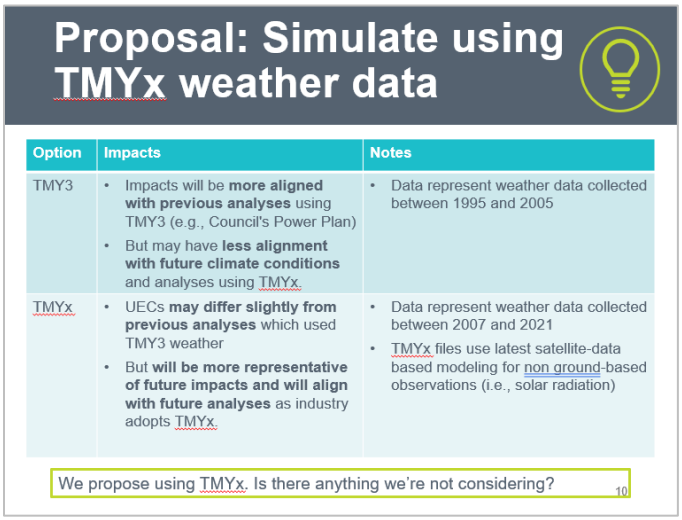
Christian said that he does not have a strong opinion because they both have their pros and cons. I think in a perfect world you use floor space. But I know the limitations of our floor space studies and I think the population data is probably of much higher quality. Those balance each other out and make me kind of indifferent.

Marcus added that our thinking was population given the given the amount of data we have there. It sounds like there are no big problems with population and the results might be the same anyway.

Will said I know we need to move on but, to alleviate some of the concern about the rural urban divide, we are aggregating between east of the Cascades and west of the Cascades up to that level. I feel like we may capture some of that urban rural divide anyway. We are not breaking Eastern Washington from two and combining it to one. I think that the general change in density as you cross the Cascades should hopefully mitigate some of that concern because, in the end, we will then map it to our floor area from the permit data and that will be the market model. This is just apportioning it around.

Brandon added that Tyler made a perfect point. The population growth will be going into commercial space because that is the direction that these communities are going. So, I think that addresses it.

Marcus added that we can move on to what weather files we are going to be using.



Marcus continued. To answer a previous question, the heating degree days and cooling degree days we were looking at on previous slide I think were TMY3. TMY3 is a typical meteorological year data from 1995 to 2005. Previous analysis, in particular the RTS energy models, use TMY3 data. But ww are proposing to simulate using TMYx weather data which covers 2007 to 2021. The pro there is that we are using more representative to current and future time weather data. And we have seen the industry moving towards using TMYx recently. Having our models use TMYx weather data would be more a prospective approach to compare against future analysis. Whereas the only con is we would not be able to compare our models to previous analysis, particularly the ones that the RTF has done. We are proposing to use TMYx data, but I want to open the floor to see if there is anything that we are not considering or any reasons that we may want to reconsider using TMY3.

Peter added in the chat that TMYx data sounds good to him.

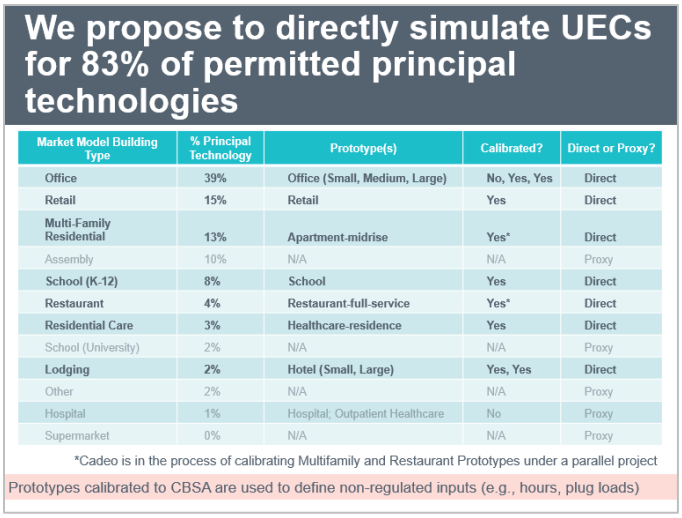
Christian said that, in general, he thinks TMYx is definitely better than TMY3. It looks as you would expect that there is a lot more cooling and TMYx and TMY3. There are different flavors of TMYx, and we did a pretty big study on this. We hired a couple of outside people, Ben Larson and this other climatologist / meteorologist, they looked into this for us. There is the more recent TMYx that I think you are referring to here. We were advised not to use the most recent data because some of the really recent stuff, even the temperature data is derived from really big grids. And that is okay for solar data, but not weather data so much. But there is a slightly older data set, it is TMYx 2004 to 2018. It is not quite as recent, but we were told that the weather data is much higher quality than some of this recent data in the newer TMYx. So, we have decided to use TMYx 2004 to 2018.

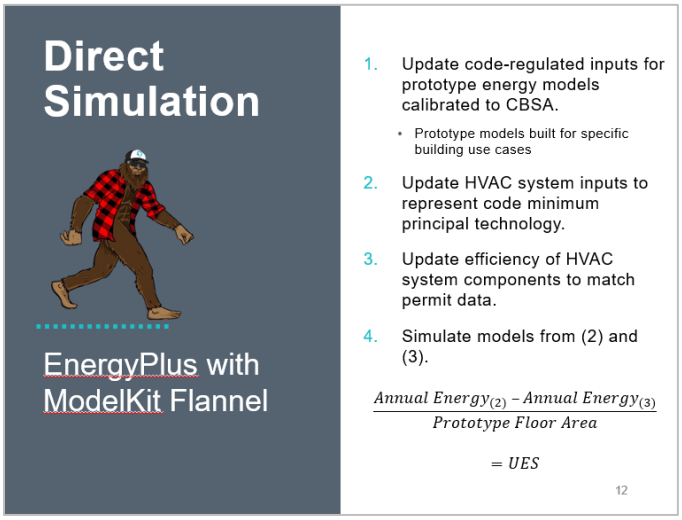
Will said that is great, that is perfect. That is exactly what we are looking for.

Tyler added that as Christian Yeah, yeah, we can make that just as Christian pointed out we want to check whichever weather station you are pulling the TMYx from that it has a good calculation. Not all weather stations are created equal.

Will added that was another benefit of moving to the more urban locations as we expect them to have larger airports and have more consistent historical weather data. But we will definitely review that. It sounds like everyone is comfortable with TMYx of some flavor. I do remember that they had something about an update. But if we dig into it and it looks like they have improved the surface temperature data to at the same level as the 2004 to 2018, would folks suggest we move to 2007 to 2021 or just stick with 2004-2018? This is a hypothetical situation, but I thought I saw something about updating. But it may have been the cloud model.

Brandon suggested looking at a few data sets, see if they are relatively close, and stick with what you got.





Christian said if that is the case, please let us know. I can also reach out to my contact just to see if that is his understanding as well. We were pretty heavily cautioned against using it if that is the case, and we can confirm that, then the more recent the better for sure.

Will said, okay, sounds good. Sounds like we will use TMYx definitely most likely 2004 or 2008 through whatever the numbers you said. But if we get some other information, we will use the most recent of the best quality. Sounds like a good decision.

Building Types

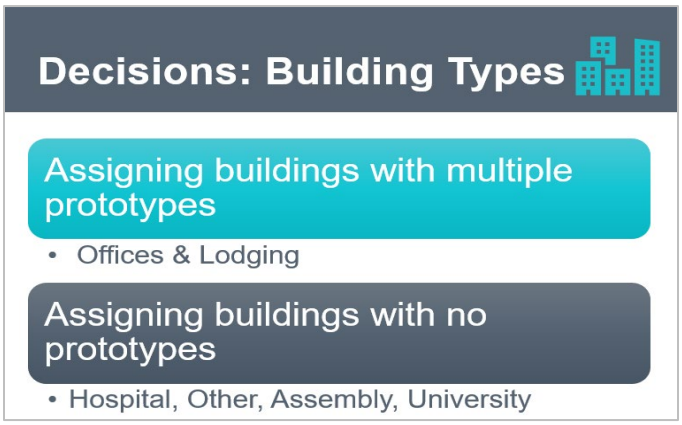
Marcus started the discussion on building types. Rick broached this concept of direct simulation versus proxy simulation. I want to describe what direct simulation means really quick. The Pacific Northwest Laboratory and the Department of Energy (PNNL DOE) developed these commercial prototype models to be representative of certain building use cases and a software development firm developed this tool called ModelKit Flannel for the RTF that uses EnergyPlus as the background that incorporates these commercial prototypes. And then we and the RTF are in the process of calibrating these commercial models to CBSA data.

So, for direct simulation, what that means is using those calibrated models for the specific use cases that we are finding in permit data. For example, office buildings that were seen in permit data are going to be represented by a calibrated office prototype that is direct simulation. The difference in approach for direct simulation is that we are going to be updating the code-regulated inputs for those calibrated models to represent new construction buildings. And then we will be updating the HVAC system inputs to again represent code minimum.

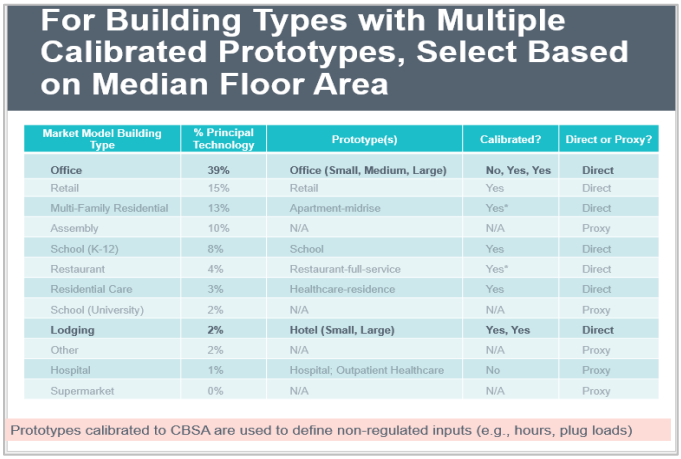
Rick also explained the efficiency tiers that we are going to be simulating. The baseline will be code minimum for the principal technologies and then we will have a second segment of the efficient case, which is the efficiencies that we are seeing in the permit data. And then we will be simulating models with both of those efficiency tiers to eventually calculate our UES.

Marcus continued. In terms of which buildings will be directly simulated and the percent of install capacity that we see in our permit data, we are going to be directly simulating offices, retail buildings, and multifamily buildings. Those three have the largest installed capacity that we see in the permit data, and all three have calibrated prototypes. We will also be directly simulating schools, restaurants, residential care, and lodging. And again, all of those have directly simulated prototypes. And if I did not already mention this, that would cover 83 percent of installed capacity. Just to just to reiterate, these prototypes that are calibrated already have defined non-regulated inputs that really have the most uncertainty, e.g., schedules or plug loads. An advantage of using the calibrated models is we do not have to worry about those kind of inputs. I mentioned that the prototypes were already calibrated by us,

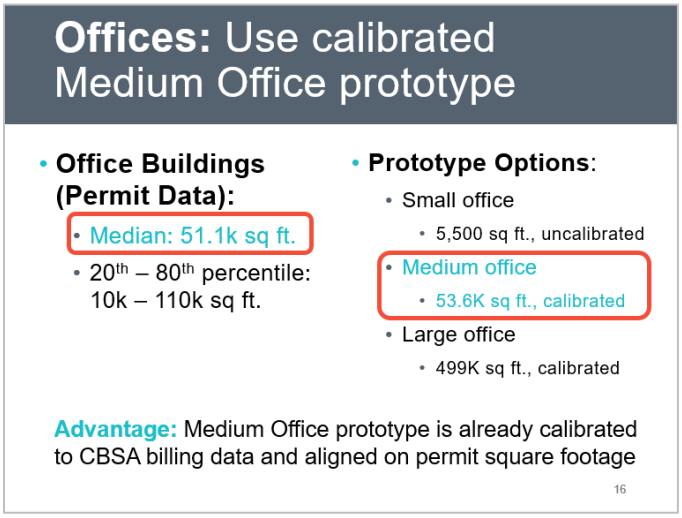
but that the multifamily and restaurant models are currently in the process of being calibrated in a parallel project right now. As Rick also mentioned, there are two more things we have to think about when trying to assign these building types to prototypes that we are going to be simulating.



Marcus continued. There are buildings in the permit data that have multiple prototypes, specifically, offices and lodging. We need to figure out how we are going to be representing those buildings. And then there are buildings in the permit data that have no prototypes, specifically hospitals, assembly buildings, university buildings, and the "other" category.



Marcus continued. First, we will talk about the buildings that have multiple prototypes. The office building has a small, medium, and large prototype. The small prototype is not calibrated; the other two are. Lodging also has a small and a large prototype. What I will be doing next is walking through what we know about each of these buildings and our permit data and our methodology for assigning them. Basically, we selected the prototypes that are most representative in terms of square footage.



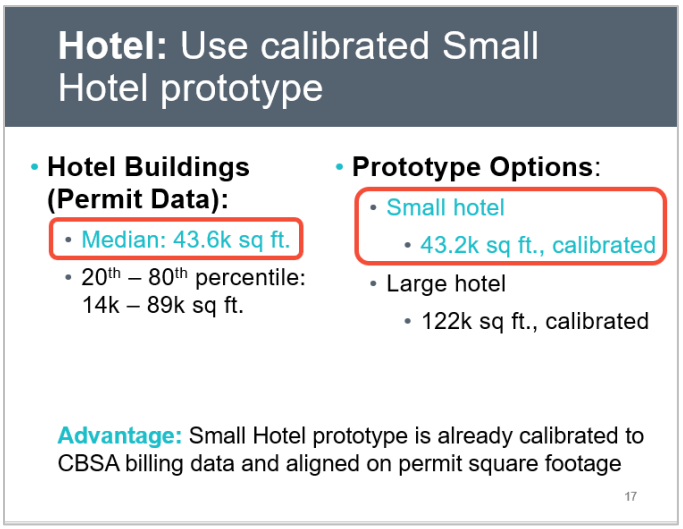
Marcus continued. To start with the office buildings, again looking at what we know about these buildings and our permit data, the median square footage for these buildings is 51,000 square feet. We use a range of 20th to 80th percentile for square footage to get rid of some of the outliers that we see in our permit data. And we see a square footage range of 10,000 to 110,000 square feet. Looking at our prototype options, small office prototypes are 5,500 square feet. When you have buildings that are that small, using them to represent a 10,000-square-foot building may not be as representative if we are trying to compare a 75,000- to 85,000-square-foot building, for example.

And then on the other side of the spectrum, there are the large office buildings that are calibrated, but they are about 500,000 square feet. So, that is quite a bit out of the range of the buildings that we see in our permit data, which turns into a Goldilocks situation where we feel that the medium office building prototype will do well enough to represent buildings in our permit data.

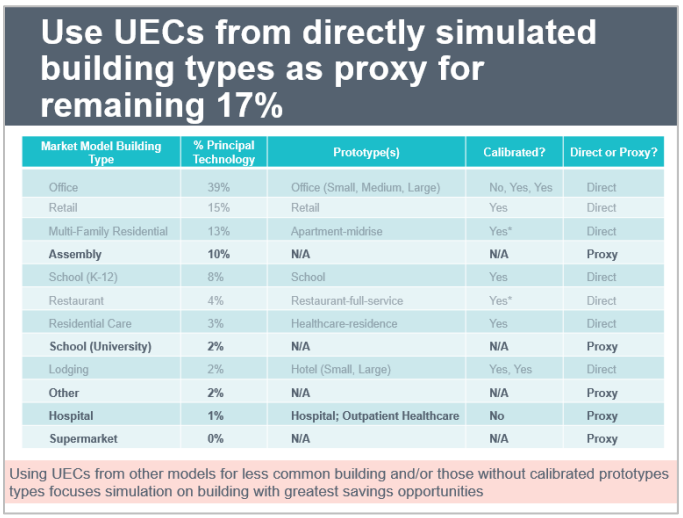
A medium office building is 53,000 square feet, which is aligned with our median square footage in the permit data. And it is actually calibrated to buildings in CBSA between 10,000 square feet and 75,000 square feet. So, the calibration does not quite get to our 80th percentile of 110,000 square feet, but it is representative of a pretty large square footage in CBSA.

Note: Peter had to drop off the call at this point in the presentation. But Peter followed up after the presentation and said that he reviewed the remaining slides (but was unable to access the meeting recording). In general, he said the assumptions on those slides made sense.

Tyler mentioned that we only have 45 minutes left in the presentation and Marcus said that he would just hit the high points of the next few slides.

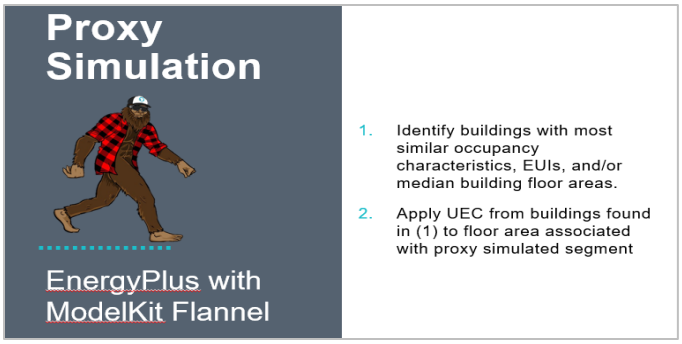


Marcus said that we used the same process for hotels. We just looked at the median square footage and 20th and 80th percentiles and found that small hotel prototype, which is 43,000 square feet aligns with the median in our permit data of also 43,000 square feet and is calibrated. Whereas large hotels is also calibrated, but they are beyond our 80th percentile.



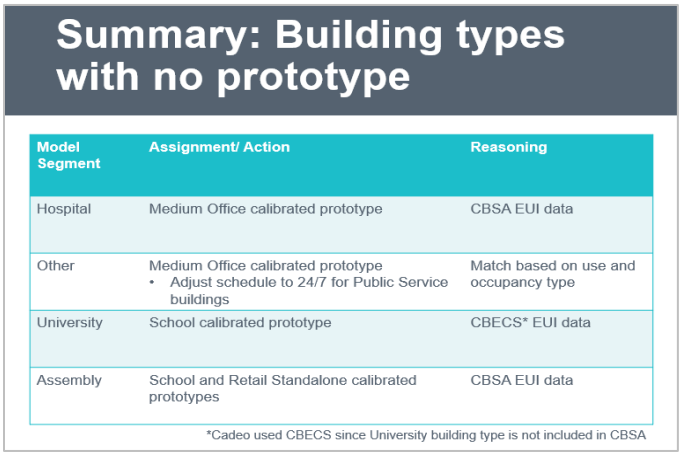
Marcus said that we are now moving on to buildings that do not have prototypes and, therefore, we need to figure out some way to represent them. This method is called proxy simulation. Just to touch on the percent installed capacity that these buildings represent, altogether they represent 17 percent of our permit data. A relatively small portion is assembly buildings. Assembly buildings come in all sorts of shapes and sizes, so that 10 percent number will get broken down a little bit smaller here in a second.

Brandon added in the chat that university campuses have multiple, different building types.

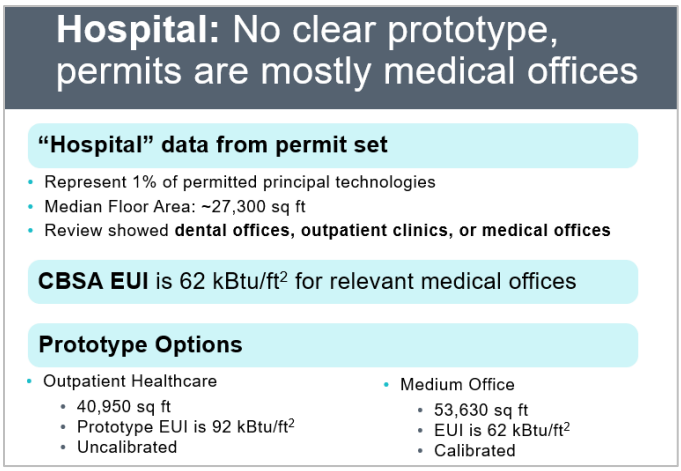


Marcus described what proxy simulation is. Whereas direct simulation uses prototypes that are designed for a specific use case, proxy simulations represent buildings by some other characteristic, which could be square footage, it could be EUI, it could be kind of diversity in zones that are included in a certain building.

Again, since we are representing a relatively small portion of installed capacity through proxy simulation, we think that we are hitting a good balance between precision and level of effort here. An alternative approach would be to just create new models for these buildings, which does not seem very feasible or necessary. The approach for proxy simulation is to identify buildings that are most similar in terms of the characteristics I described to a prototype and then apply the UEC from those buildings to the floor area associated with the proxy simulated segment.

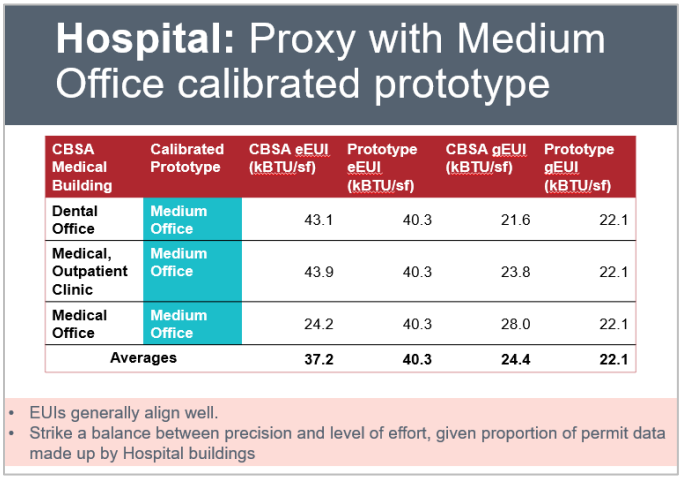


Marcus continued. To give a summary of what this looks like for our buildings that do not have prototypes, I'll go through each of these in in greater detail and get some discussion going. The hospital buildings we are proposing to proxy simulate using the medium office calibrated building, and this is based on the CBSA EUIs for the buildings that are seen in our prototype. For the other buildings, we are also going to be proxy simulating using medium office calibrated prototype. There is an option to adjust the schedules for a specific kind of other building known as public service, e.g., police departments, fire stations, etc. That is based on the use types that we are seeing. For university buildings, we are proposing to proxy simulate using school calibrated building. The source for that is Commercial Buildings Energy Consumption Survey (CBECS) data because university data is not available in the CBSA. And then the last building is assembly, which we looked at a little bit more granularly and we are going to assign to school or retail standalone calibrated prototypes based on CBSA EUIs.



Marcus continued. The bottom line with the hospital buildings that we have seen in our permit data is that there is no clear prototype that we are seeing. Although these are called hospitals, these mostly look like medical offices. For example, the median floor area for these is about 27,000 square feet. The prototypes that we have are for whole huge hospital buildings, smallest of which being outpatient health care at about 41,000 square feet. When we actually look at the permits, we find that these hospital buildings actually have characteristics that are closer to offices. These are dental offices or medical offices or outpatient clinics that are much smaller than what we have prototypes for. And we actually looked at the CBSA and filtered out for these kind of medical office type

buildings and found that they have an average EUI of 62 kBtu per square foot. I will show you a graph or a table in the next slide that breaks this out in more detail, but that is about the average. And so, we come to our two options. The first option is the outpatient healthcare model, which is the smallest healthcare facility that we found. However, this prototype is not calibrated, and it has an EUI of 92, which is substantially higher than what we are seeing in the CBSA. Compared to the medium office, larger in terms of square footage, the EUI actually is right on with what we are seeing in the CBSA.



Marcus continued. This is the table I mentioned earlier, which I will describe in more detail. This table provides in the third column the electric EUI from CBSA for each of these different medical buildings that the permit data are assigned to. And then the prototype electric EUI is in the fourth column. In the fifth and sixth columns, we have the CBSA gas EUI and prototype gas EUI.

For dental offices, we are pretty spot on for using a medium office in terms of electric and gas EUI, and same thing with medical outpatient clinic. Medical offices are a little bit lower on the electric EUI. Maybe those buildings typically have gas heating systems, but when you average it all, you know we are really aligned in terms of electric and gas EUIs.

Marcus continued. I will ask our first question. Are there things that we are not considering when assuming that measure impacts per square foot are similar in these medical offices versus generic office buildings. I will say that we did consider an alternative approach, which is calibrating that outpatient healthcare prototype to the CBSA data. But that might get us to the same point as just using a medium office which is calibrated and has the same EUI already.

Rick added a clarification. The reason we have this measure per impacts by square foot in a different color is to show that we are not trying to exactly represent every clinic that is in the permitted projects with our building simulations. We are trying to figure out what are the measure impacts per square foot, what is the consumption and savings per square foot? And that is why I really like this EUI analysis. It would be great to hear what you all think. Is there anything we are not considering, or we should consider?

Christian said that he thinks this sounds fine. I think you are right that if you calibrated outpatient healthcare, you would probably just get to the same place. And yeah, these are mostly outpatient. They look more like offices than hospitals. So, this does not bother me. I think one bigger issue on the previous slides is by sort of picking a single size in the middle, there are some things we are going to miss there even on a per square footage basis. Because with the smaller buildings, they are going to be more skin-load dominated, they are probably going to have much higher heating with much bigger buildings. They are going to have bigger cores, much more cooling. It is sort of peanut buttering that all into one building. I think that is a much bigger trade off than this trade off that we are talking about here.

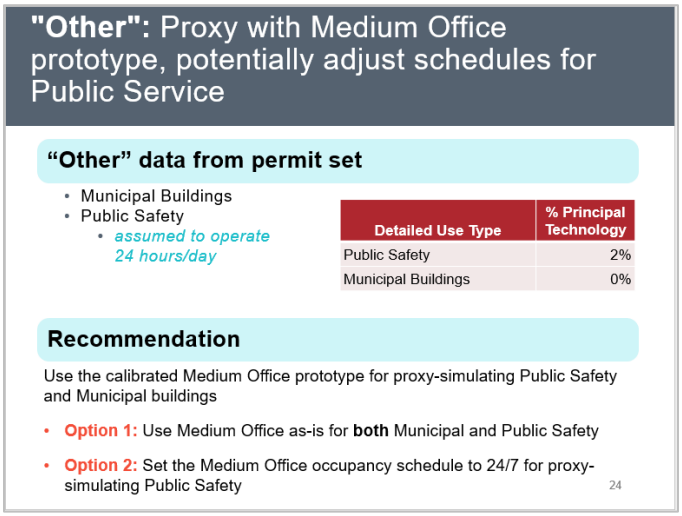
Rick said it would be great to hear other people's thoughts on this one and maybe we can circle back to the other building types in a few minutes.

Brandon said that he agrees with Christian. I had kind of the same thought on the “peanut butter spreading” on the office building definition. I thought that the medical office and hospital EUI is that CBSA data looks like really low numbers. I understand a medical office building can be pretty similar to a commercial office, but they are also different. 24,000 Btus per square foot per year seems very low, even 60,000 square foot or 6,000 Btus per square foot year also seems kind of low for a medical office building. But that said, I think that the key is, as Rick just pointed out, what we are really looking for is measure savings by square footage. So, I do not know that the baseline EUI is that critical as long as your analysis is not showing more than 100 percent savings.

Will said that touches on for another important point. I think the decision is the actual relative role that these building types play in the overall permit data set. As you mentioned, they add up to 17 percent, so they are not insignificant. But then if you are 20 percent wrong on all the proxy mappings in the same direction, then your total error is going to be some percentage of 17 percent. And that percentage varies by building type.

Tyler added that hospitals are 1 percent.

Will said that the biggest one is going to be assembly, which we will talk about later. That one is 10 percent overall. All the other unmatched building types make up that remaining 7 percent.



Marcus said the “other” category is based on use type. When we looked at the other buildings in our permit data, we found that these are just two buckets, municipal buildings/government buildings and public safety. As I said earlier, fire stations and police stations are probably more similar to an office. The exception is that public safety is going to have different schedules and so we could adjust the schedules for proxy simulating those. The percent installed capacities for public safety represents 2 percent of our installed capacity; municipal buildings are less than 1 percent.

So, we have come up with two options. We think we want to represent these buildings using the medium office prototype. Do we want to use the medium office prototype as it is for both municipal and public safety buildings or do we want to make a separate segment that adjusts the schedules to 24/7 for proxy simulating public safety buildings?

Are there things we should consider when assuming that measure impacts per square foot are similar in *municipal buildings and generic office buildings?*

Should we update the operational schedules in the office prototype to better represent the assumed *24/7 occupancies of fire halls and police stations?*

Marcus continued. Is there anything that we should consider when trying to represent municipal buildings to generic office buildings?

Christian responded. I would guess that most of the floor space and public safety is still nine-to-five workers with some small subset that is truly 24/7. So, it does not give me a lot of heartburn to try to account for that. There is far bigger fish to fry, let's put it that way.

University: Small portion of data, small buildings

University data from permit set

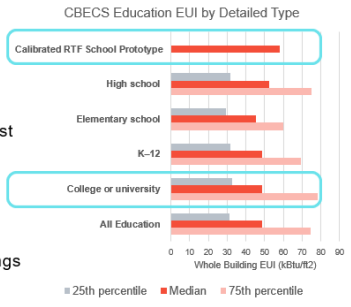
- ~3% of principal technologies in permit data
- **Median: ~38,000 sq ft**
- Buildings have a **mix of classrooms, study rooms, dining, conference rooms, trade schools, etc.**
- **No clear re-classification** of individual buildings on campuses based on permit review or detailed use types

Detailed Use Type	% Principal Technology
Colleges/Universities Except Community	2.3%
Community Colleges	0.2%

Marcus moved on to the university buildings. The approach here is to look at the permit data to see what we know. Looking at these university buildings, they represent a small portion of our data, about 2.5 percent of installed capacity. The median square footage for these buildings is 38,000 square feet, which is relatively small compared to our education prototypes that we have available. What is unique about university buildings is they have a diverse mix of zones, for example, classrooms and study rooms. There is one building that has a trade school involved and another building that has a flour milling shop. So, there is a diverse mix of schools and therefore, there is not a clear reclassification by looking at these university buildings in more detail because they are pretty mixed, and we do not have a prototype that matches them exactly.

University: Proxy with School calibrated prototype

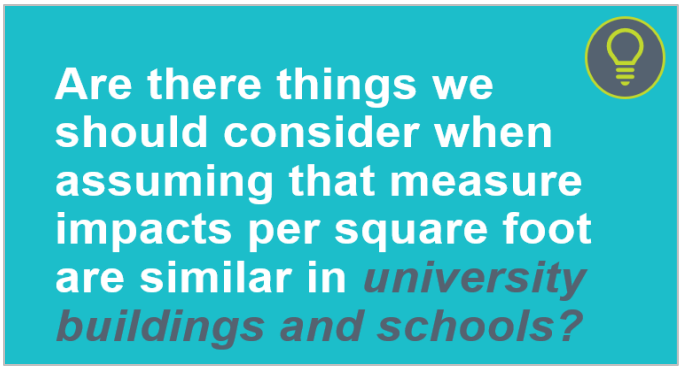
- Pros:
  - Similar median EUI
  - School prototype has been calibrated to CBSA data
  - School prototype has the most diverse set of zones (e.g., classrooms, dining, etc.)
- Cons:
  - May not fully capture unique elements of university buildings in permit dataset (e.g., flour milling shop)



Strike a balance between precision and level of effort, given proportion of University buildings served by Principal Technology in permit data

Marcus continued. However, we did look at the EUIs for these university buildings and CBECS data because CBSA data for university buildings is not available. And when we do that, in the graph to the right, we see that the EUIs for all education buildings for the most part have really similar median EUIs as well as a similar range of 25th percentile to 75th percentile.

We do have the school prototypes at our disposal, which are the most diverse building types that we have prototypes for. They have a mix of classrooms, gyms, dining rooms, etc. When we look at the EUIs for our school prototype compared to what we see in CBECS, it is certainly in the range close to that median EUI.



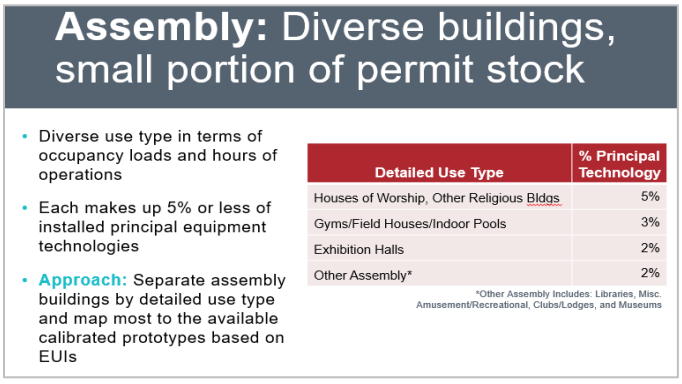
We recommend to proxy simulate using the school prototype for these university buildings. It hits on a per square footage basis. School prototypes have a diverse mix of zones as well. The only con that we see is it may not capture some of the unique elements of university buildings such as different schedules or that flour milling shop I mentioned. We think proxy simulating with the school prototype strikes a good balance.

Marcus asked are there any things that we should consider that were not already for using school to proxy simulate universities?

Brandon said that he was surprised to see that the general school EUIs match college and university EUIs. I think maybe the data that's informing the college and university EUI. You have captured the fact that the university campus has a lot of different types of buildings, and I've spent a lot of hours evaluating. I wrote the Climate Action Plan for the University System in Oregon, which we published in 2010, and it was very insightful. I have learned about how all these different buildings perform on a campus. The only thought I had was that this is not a large enough percentage of capacity. I think that would warrant additional analysis. But if you wanted to not do a proxy-based analysis at the university level, but rather take existing data related to universities you have in the prototypes buildings, that would match each of the individual building types on a campus. I have the percentages of different building types for all seven universities in Oregon. That could be easily used as a weighted method to figure out what that EUI is. But I think you are going to land right here where you are at as an average.

Will said that is a great point. And actually, that was our initial plan to deal with universities. We figured that we would identify which building type this is, and if it is a residence for example, it is going to go to multifamily. So, we did a deeper dive into the actual permits to go look at the buildings and that is where we identified this mix of use types within the individual buildings. It is not as cut and dry as we hoped in terms of, for example, this is administrative and that is a platform building. So that is another reason we decided to go this route.

Rick added. Like you said, Brandon, we are talking 2.5 percent of capacity. So, close is good, I think, personally, but I agree totally.



Marcus moved on to discuss assemblies. As I mentioned previously, assemblies are very diverse. It is kind of a catch-all term for a bunch of different kinds of building use types. What are the most prevalent assembly buildings that we are finding in permit data? What we are looking at in this table to the right are the four highest install capacity use cases for assembly buildings. All the rest are less than 1 percent install capacity. So, we did not feel it was necessary to look into those more granularly. But the four assembly building types that we have to figure out how to represent through building simulation are houses of worship or other religious buildings; gyms, field houses, indoor pools; exhibition halls; and other assembly. Other assembly is kind of the mix of all the other assembly types that are less than less than 1 percent that we figure out how to deal with. Our approach here was to break these up into four and then assign based on the CBSA data.

Assembly : Proxy simulate based on CBSA EUIs

Permit Building	Calibrated Prototype	CBSA eEUI (kBTU/sf)	Prototype eEUI (kBTU/sf)	CBSA gEUI (kBTU/sf)	Prototype gEUI (kBTU/sf)
Houses of Worship	School	20.3	22 to 33	32.6	31 to 40
Exhibition Halls	Retail	47.0	42 to 45	55.4	33 to 35
Gyms/Field Houses/Indoor Pools	Retail	49.7	42 to 45	226.6	33 to 35
Other Assembly	School	23.2	22 to 33	52.3	31 to 40

Note: No principal heating technologies in *Gyms/Field Houses/Indoor Pools* limits impact of poor gas use mapping

- EUIs generally align well.
- Strike a balance between precision and level of effort, given proportion of the permit data and challenge of representing diverse Assembly space types without a prototype

Marcus continued. In this table, we are looking at the electric and gas EUI from the CBSA and for the prototypes. I will go through these one by one. The house of worship building we are recommending using the school prototype again based on the EUI is that we are seeing in CBSA. And for the prototype exhibition halls, we are proposing to use the retail standalone prototype for gyms, field houses, and indoor pools.

We are pretty close in terms of electric EUI. But if you look at the gas EUI, that is pretty far off. We believe that is due to pool heating, which does not affect us for our model since we are only focusing on principal heating and cooling technologies or HVAC. These other assembly buildings, because those have a diverse mix of zones and because we line up pretty well in terms of electric and gas EUIs, we are recommending using school prototype to proxy those.

Are there things we should consider when assuming that measure impacts per square foot are similar between religious and *"other" assembly buildings and schools?*

Alternative Approach: Recalibrate School and Retail prototypes to better align with Assembly EUIs

Does anyone have concerns with assuming that measure impacts per square foot are similar in *exhibition halls, gyms, and retail buildings?*

Alternative Approach: Recalibrate School and Retail prototypes to better align with Assembly EUIs

Marcus asked are any things that we should consider when proxy simulating religious and other buildings with schools. Again, the alternative approach here would be to recalibrate these prototypes for these specific use cases. Again, we are talking about really low install capacity.

We do want to look at all four of these. For the houses of worship and "other", we are proposing to use schools and then the other two are retail.

Christian asked a question. Can you remind me, you said cumulatively this is 10 percent or 17 percent?

Marcus replied 10 percent.

Christian continued. Do you know what the breakdown is within these?

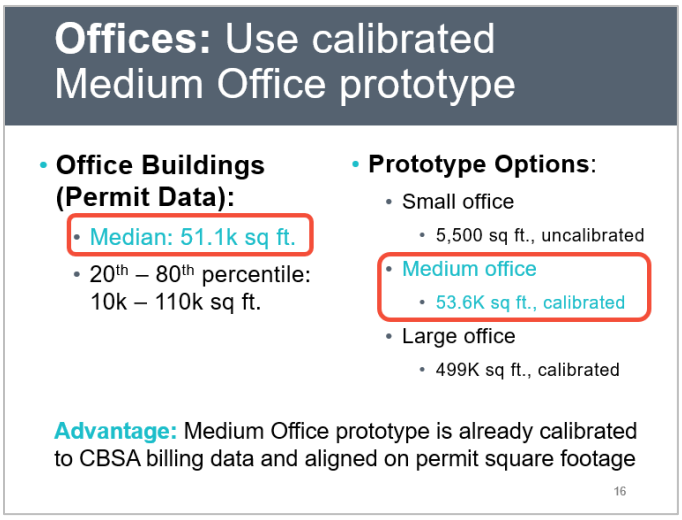
Marcus said yes, if you scroll back one slide, the breakdown is in the table.

Christian said yes, it strikes me as fine. I think your time is probably better spent doing other stuff. I mean, we don't have prototypes that even come close to being able to model most of these building types. Our options are to spend time building a prototype from scratch at the Superdome or something or just pick something because it is such a small percent. Once you put it that way, I think your decision is obvious.

Will added. I do feel like at the at the top there, the most prevalent of the assemblies is the houses of worship and, to me, mapping to a school makes sense. Often times, buildings are used during the week as community buildings and so that seems reasonable.

Marcus said that maybe we should go back to the offices and to the other "peanut butter spread" buildings.

NOTE: At this point in the presentation, we jumped back to discuss Slide 16 in more depth.



Christian asked, is it going to be part of this meeting, or maybe a future meeting when we talk about how the technologies are going to be modeled? Because that is what matters, right? At least to me, that is what matters. This stuff matters a little bit. But most of this stuff is just making sure that we are getting the right size pie, the right kind of potential. So, it has got to be close enough, but not perfect. But once we start talking about how to model the technologies and their savings, that is where the details are.

Will added. We are not specifically going to talk about that this time, but we are putting together our approach internally for a future panel. Are there specific decisions that we are going to need to make that you think would be useful to focus on and bring to the panel? Performance curves is one. Ventilation rate assumptions are another. Specifically, what elements of how to model the systems are of greatest concern to you to nail down?

Christian responded. I will say that I am less well versed in commercial HVAC in terms of this. Although, I suspect there are a lot of similarities. I know with residential HVAC, when you have something like a heat pump that has a compressor and it also has a backup resistance element, if you just model it with EnergyPlus out-of-the-box, you are going to get a far, far rosier picture of the savings than reality. Again, I do not know how a rooftop unit that has a compressor and a resistance element operates in the field, but I know how residential systems operate in the field and, unfortunately, it is very suboptimal. And so, that is the kind of thing we need to think about in our modeling because if our EnergyPlus model is assuming that the compressor is meeting all the load and the resistance is never coming on, then that sounds great. That would be a nice world to live in. But at least on the residential side, that is far from reality. Those things are my main concern.

Will said. It is more of a control strategy and capturing real human behavior more than which object we put into the model.

Christian replied. Yes, realistic controls and, for example, what coil is actually meeting the load.

Marcus asked if Brandon had insights into that. We did a little bit of research into different controls market actors and had trouble getting any insights into that. Do you have any?

Brandon said yes. My basic answer to Will's initial question is yes to all the things you said plus a whole bunch of other stuff we do not have time to talk about today. And commercial buildings, systems, and equipment are going to operate totally differently than a residential application. For example, anecdotally, you are more likely to find gas back-up in a commercial heat pump versus electric resistance. But one of the big differences I am seeing is putting in variable refrigerant flow (VRF) and dedicated outdoor-air system (DOAS) units, hybrid systems. We did two elementary schools last summer, and we are doing two more this summer. How these systems are controlled is quite a bit

different than how we have controlled traditional central plant-based systems. One example of that is we are not going to see typically as aggressive of night setbacks and occupied setbacks for a VRF system as compared to a chiller central plant, a hydronic or steam boiler plant. So, these buildings are going to idle more than the traditional design would.

The other thing that you will want to look at as you are getting outside of the defaults and hopefully making some zone adjustments in the model programming in your model is, in these schools, I have put fan cool units in every single room and every room has its own thermostat. We are trying to account for what level of autonomy these users will have and how that is going to affect the zone performance. The overall building performance deserves some thought because the systems behave a lot differently than what you would expect with a hydronic radiator or a variable air volume (VAV) system.

And then you have listed this out, so you recognize that when you are putting in VRF, a lot of times you are putting in a ventilation component. We are two months into operation with these systems that we installed last summer, and we are still going through start up and testing on the DOAS and an inverter RTUs. So, I have a lot of insight now, but by spring, I will know a lot more about how these DOAS are working because these DOAS are not just ventilating with heat recovery. They have a heating and cooling element as well. I do not know how much of the load those DOAS are going to carry as opposed to the VRF. Right now, my VRFs are solid. We sized them right. They are covering the load even on the few cool days we have had. But there is going to be offset a little bit once we plug these DOAS in and start operating them formally.

So, and I do not know if that is going to wash on the EUI. I do not think it is because your coefficient of performance on the VRF versus the efficiency on your DOAS, which is going to have a direct expansion (DX) system for cooling, gas for heating is going to be different. So, it is not going to be a one-for-one wash.

Will added. I really look forward to coming back and discussing this as we refine the control strategies and things that we are simulating. I am looking forward to talking more in depth about how these systems are performing in the wild. I do not know if someone else had a comment, but I would like to talk about the building size question that Christian brought up just because that one I think is more a critical path for the decisions we are making right now. But I am looking forward to having those other discussions.

So, I totally agree with capturing the internal versus external load balance for two smaller buildings. One of the reasons I think large office seems not representative of very much of our permit data set. Small office, on the other hand, I think there are some good arguments we made for including it. One of the reasons we did not is because there is no calibrated prototype.

I guess the question is do you expect the impact of size to be “worth the juice to work the squeeze” on calibrating that small office or is there another approach we could do to break out our office buildings and permit data to two different prototypes. Office and retail are the main, the largest building types we have in our permit data set. Those are the two things I would like to focus on if we wanted to expand our prototypes. Again, for retail it is a bit weirder because they do not have a large and a small prototype. They have got the strip mall, which I understand is not currently calibrated.

So similar questions for both. Though I could see strip mall being more representative of smaller retail, especially if you look at the unit level where the strip mall prototype has like 10 separate stores, single zones. That was a long way of saying do you have thoughts between the impact versus effort of calibration.

Tyler asked. What is the cutoff for the bottom range of medium office? Because you have got the mean square foot there. From what we were just doing recently with the commercial energy metering study off of CBSA, there is an amount of small office buildings in the region compared to the medium and large categories. It is pretty significant. There are a lot of them, and they do behave very differently. A

lot of them actually tend to have more residential-type HVAC systems. You will see a lot of small office buildings that just have one rooftop unit or mini splits, things like that. And so, I think it would be worth digging into what it would take to calibrate that prototype and be able to use it and also look at what the split your data has in terms of how many small versus medium offices there are.

Will replied. For the split of small versus medium, we looked at the 20th and 80th percentile of office sizes in our permit data and found that the 20th percentile is at the 10,000-square-foot mark.

Rick added. Didn't you say the prototype was calibrated 10 to 70,000?

Marcus said yes, the medium office prototype is already calibrated to buildings from 10,000 square feet to 75,000 square feet in the CBSA. We are capturing that bottom line. If we want that bottom line to be the 20th percentile…

Tyler added. I think if you went and looked at the CBSA just in terms of total floor space that is coming from office buildings that are less than 10,000 square feet, it is going to be a comparable amount. There is a lot of floor space from the total number of buildings that are under 10,000 square feet in the small office space.

Marcus said, but we are not looking at existing buildings though, we are trying to represent the new, permitted construction.

Tyler added. Yeah, that is different, it is not our best data source, I guess.

Christian added. Yeah, that is hard, because I kind of agree with both of you. I think Tyler's point is well taken that to the extent that there are smaller buildings, those are different systems than what we would have. Fifty thousand square feet is going to be largely multi-zone stuff, VRF, where your smaller buildings are going to be residential-style mini split. It is going to be very different kinds of equipment. It is probably at least worth looking into.

For what is it worth, I think I do have calibrated versions of the small office and small retail that I did myself early on for some RTF measures. Actually, it was for a residential mini split in a technically commercial building. I would have to find it, but that might save you a lot of time and I can direct you to the RTF presentations I gave on it.

Will added. Another option is we could report savings at the zone level and ignore the core zone because medium office prototype is a core and shell, you know, four perimeter zones and one core zone. We could just use the perimeter zones to represent smaller offices because they would be more influenced by the shell gains or losses. It would save us a simulation but add to some complexity in terms of the post-processing. I am just throwing out an option. But I think if there are calibrated models, that may change this conversation a decent amount.

Are there additional data points that we could put together that would help identify the overall importance or impact of this decision?

Christian responded. I feel like I would almost want to look at the distribution, a histogram of this data, and see how much of the distribution lands in that bucket where the systems are going to be really different. If it is 1 percent, or I don't know, less than 10 percent, then maybe this peanut buttering is fine. But if it is a pretty big chunk, then you are talking about very different systems.

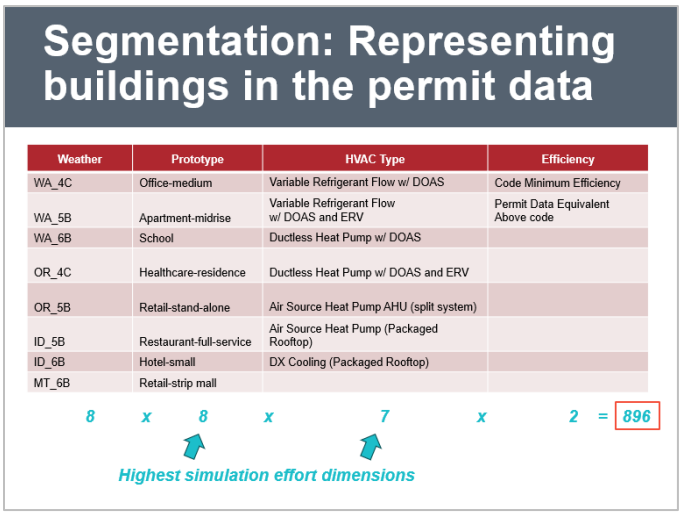
Marcus added. It seems like that would be something we could do fairly easily.

Will agreed. Yeah, it seems like it is worth it.

Brandon added that this is a pretty big slice of the pie. The office work we do, that 50,000-square-foot office is going to have a totally different system than the 5,500-square-foot standalone building or the commercial/light industrial strip with two end caps that might be 4,000 to 5,000 square feet each. And when we are doing projects in 5,500-square-foot standalone buildings, we are putting a commercial

Daikin inverter heat pump system, ducted fan coil type system in when we are taking out concentric units, taking out traditional RTUs. And that kind of model is a lot different than the VAV in a 53,000-square-foot building, obviously.

NOTE: At this point, we jumped back to an earlier slide.



Will said. To be clear, we are going to model all the typical system characteristics we see in the permit data. In general, I think there are going to be a lot of split heat pumps. It is going to be the system we will see in smaller offices, the more residential-style ducted split air-source heat pumps. So, we are going to apply the system characteristics from the permit data to the prototypes. We will not be using the prototype default system, which is a packaged VAV with reheat, to represent a small office. We will use a medium office where each zone would have a split air source heat pump if that was the case. All of these different dimensions will be combined into segments. We will have medium office with VRF, but also medium office with each zone served separately by a more residential-style system.

Brandon added. I was just curious on the school HVAC type, why did we go with ductless heat pump versus VRF?

Tyler said. No, it is not a map like that. This is just a list of the different variables. Think of it as a 900 map list.

Will said that these are all independent. We will have all these same HVAC types that we see here.

Tyler added that each column is independent, mutually exclusive. That actually brings up a good point. I think Rick and Marcus, a good follow up after you have taken in the feedback from today. If you wanted to do another deep dive, you could resend this table out to the group to show where you decided to go with some of the building simulation models. Because I think you were going to update the weather ones, right? I think generally we got consensus on the prototypes, other than maybe small office. You could send that mapping plus the mapping that you have on slide 13 to show here is where we settled and provide a good follow up for the group. That way, we would know where you are moving forward based on today's discussion.

Marcus and Rick both agreed that it made sense and was a good idea.

Marcus said that they can provide those histograms along with what we just talked about.

Tyler said we are out of time here and I want to be mindful of people's time. This was a really great discussion. Christian and Brandon, thank you guys for really engaging here and diving in. I think everybody will look forward to once we get in a little bit more and dive into the HVAC pieces and types and see how that goes. Maybe we can do another smaller panel for that.

Working Session: Building Simulation Results – Apr. 4, 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: Juan Carlos Blacker

DNV: Tyler Mahone, Lorre Rosen

Cadeo: Rick Huddle, Will Gorrissen, Marcus Dimeo, Bretnie Eschenbach

Invited Panelists	Affiliation	Attended	Did Not Attend
Albert Rooks	**Small Planet Supply**	☒	☐
Brandon Adams	**Vector Energy Solutions**	☒	☐
Cassandra Beck	**Trane**	☐	☒
Peter Kramer	**Trane**	☒	☐
Jesse Dean	**Edo Energy/McKinstry**	☐	☒
Mark Lessans	**Johnson Controls**	☒	☐
Pete Jacobs	**Building Metrics**	☒	☐
Eric Mullendore	**BPA**	☒	☐
Chris Wolgamott	**NEEA**	☒	☐
Kevin Smit	**Council**	☒	☐
Christian Douglass	**Council**	☒	☐

Introductions

Juan Carlos introduced the presenters.

Tyler introduced the panelists.

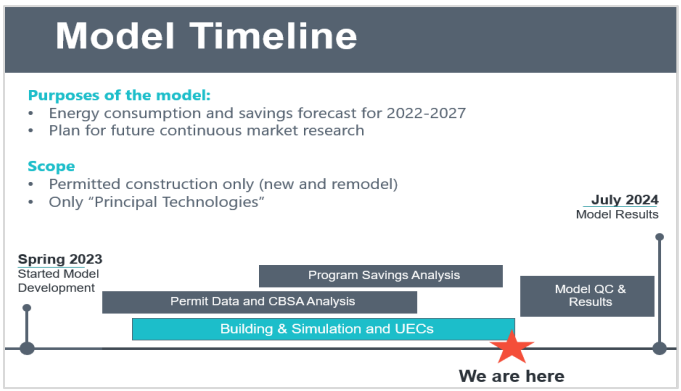
Agenda

- Background and Context
- Simulation Results
- Simulation Comparisons
- Next Steps

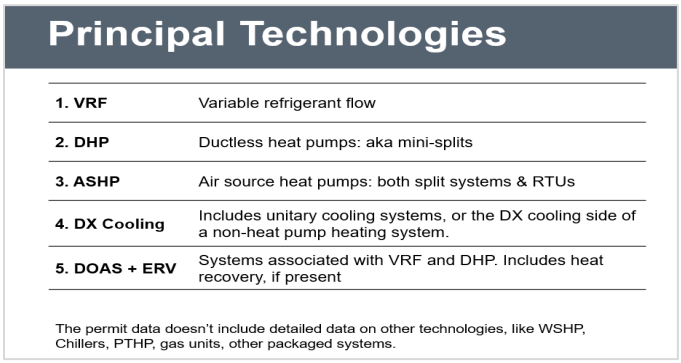
Key Topics for Feedback

- Energy Recovery Ventilator (ERV) and Dedicated Outdoor Air System (DOAS)
- UEC Results
- UEV Validations

Background and Context



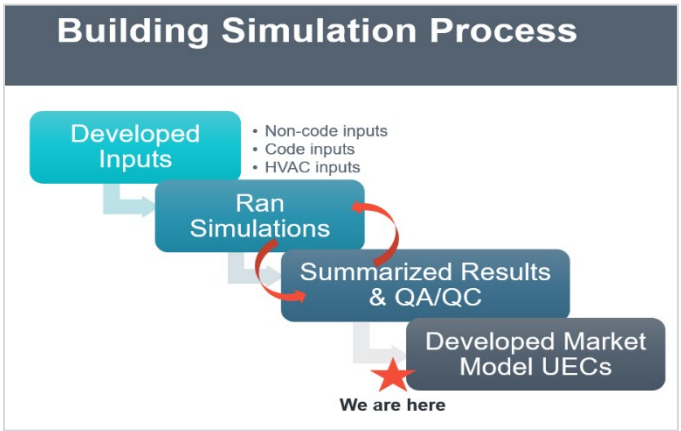
Will reviewed the model timeline. The purpose of the model is two-fold. One purpose is to understand the energy consumption and savings between 2022 and 2027 in in the commercial HVAC market. The second purpose is to get some insights and help BPA plan for some future research. A reminder about the scope is that we are not looking at existing buildings; this is just permitted construction. We started about a year ago developing all the inputs. We analyzed our permit data and then looked at the Commercial Building Stock Assessment (CBSA) to see how our inputs fit in with the existing buildings. We looked at utility programs and got some great information from them. The bulk of the work during the past two or three months has been on these building simulations. We ran more than 1,200 different building simulations and developed these unit energy consumptions (UECs), which are consumption per square foot. Now that we have all those, they will go into a Python-based market model, which will allow us to answer questions about the consumption savings for the whole region for our particular scope.



Will reminded the panel about the principal technologies.

Peter asked. Are the VRFs with and without heat recovery?

Will replied no, all our simulations were not modeled with refrigerant heat recovery. We did not see a lot of prevalence of that in the system. One of the pieces of feedback we received previously from this panel is that it was not very common and maybe not particularly useful.



Will continued. For the building simulation topics, we have three types of inputs: non-code (e.g., plug loads and infiltration) code, and HVAC. Then we ran our simulations; I think we were up to about 1,200 or 1,250 the last time I checked. Then we looked at the results and made some comparisons. We decided to tweak some things to ensure there were not any unmet loads and then revised the simulations. We did that a handful of times or so and now we have these market model UECs as consumption per square foot.

Non-code inputs are based on calibrated models

Input	Unit	Category	Source for specifying
DHW heater fuel	N/A	Water heating	Calibration
Electric equipment load	W/ft2	Plug loads	Calibration
Electric equipment schedules	Hours	Plug loads	Calibration
Exhaust fan flow rate	CFM/ft2	Ventilation	Calibration
Exterior lighting power	W	Lighting	Calibration
Foundation type	N/A	Insulation/fenestration	Calibration
Gas equipment schedule	Hours	Gas equipment load	Calibration
Gas equipment load	W	Gas equipment load	Calibration
HVAC schedule	Hours	Heating/cooling	Calibration
Infiltration schedule	Hours	Infiltration	Calibration
Lighting schedule	Hours	Lighting	Calibration
OA fraction schedule	Hours	Ventilation	Calibration
OA schedule	Hours	Ventilation	Calibration
Operation schedule	Hours	Occupancy	Calibration
Roof base type	N/A	Insulation/fenestration	Calibration
Thermostat heating & cooling schedule	Hours	Heating/cooling	Calibration
Thermostat heating & cooling setpoint	F	Heating/cooling	Calibration
Wall base type	N/A	Insulation/fenestration	Calibration

Will reviewed the non-code inputs. We used information from RTF calibrated models. The RTF has calibrated models for offices, schools, lodging, retail, residential care, and restaurants. We used that information for specific inputs of how many watts per square foot the plug load is.

Ventilation requirements based on calibrated models

Input	Category	Input	Source for specifying
DHW heater efficiency	Water heating	90%	Minimum thermal efficiency (Et) according to ANSI/ASHRAE/IES 2021
Fan pressure rise	Ventilation	Varies by HVAC configuration	ASHRAE 90.1 2019
Infiltration area	Infiltration	Varies by building type	ASHRAE 90.1 2019
Lighting area	Lighting	Varies by building type & space	ASHRAE 90.1 2019
OA economizer max temp	Ventilation	75 F	ASHRAE 90.1 2019
OA economizer type	Ventilation	Varies by HVAC size	ASHRAE 90.1 2019
Ventilation rates	Ventilation	Calibrated values	RTF Calibration
Sub-heating efficiency	Heating/cooling	100%	Electric resistance back-up heating
Roof cavity/continuous insulation	Insulation/fenestration	Varies by CZ	ASHRAE 90.1 2019
Wall cavity/continuous insulation	Insulation/fenestration	Varies by CZ	ASHRAE 90.1 2019
Window SHGC	Insulation/fenestration	Varies by CZ	ASHRAE 90.1 2019
Window U-value	Insulation/fenestration	Varies by CZ	ASHRAE 90.1 2019

Will reviewed the code-based inputs. For the code based inputs, we generally used ASHRAE 90.1. The one thing to point out here is that the ventilations rates are a little bit higher than code and so we went back to the RTF calibration values to inform the numbers that we use for the ventilation rates and for the HVAC inputs.

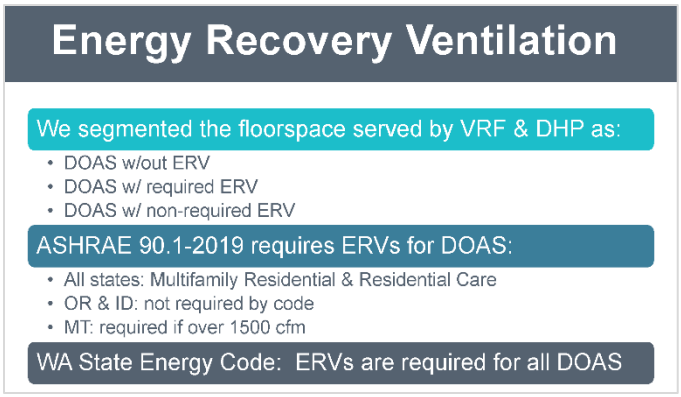
HVAC Inputs defined via codes, experience, & permit data

Input	Unit	Category	Input	Source for specifying
AHU type	N/A	Ventilation	CAV	Engineering judgement (for ASHP units only)
AHU flow minimum fraction	None	Ventilation	1 for CAV; 0.3 for Large DX	Engineering judgement
Heating/cooling coil COP	COP	Heating/cooling	Varies by HVAC type and size	ASHRAE 90.1 2019/ Permit data
Cooling sizing factor	None	Heating/cooling	1.15	ASHRAE Appendix G
DX compressor speed	N/A	Heating/cooling	CONSTANT/TWO SPEED/VARIABLE	Varies by HVAC type/efficiency level
DX type	N/A	Heating/cooling	PNNL	Default PNNL performance levels
Fan efficiency	%	Ventilation	65% for CAV; 59% for VAV	Prototype defaults
Fan motor efficiency	%	Ventilation	85% for CAV; 91% for VAV	Prototype defaults
Fan type	N/A	Ventilation	CAV for small DX; VAV for large DX	Varies by HVAC type
OA ER sensible efficiency	%	Ventilation	0.5	ASHRAE 90.1 2019
OA ER latent efficiency	%	Ventilation	0	Assume HRV only
Maximum/Minimum SAT	F	Heating/cooling	104 F/55 F (varies by system type)	Engineering judgement
DOAS preheat/VAV reheat fuel	None	Heating/cooling	Electric	Permit data

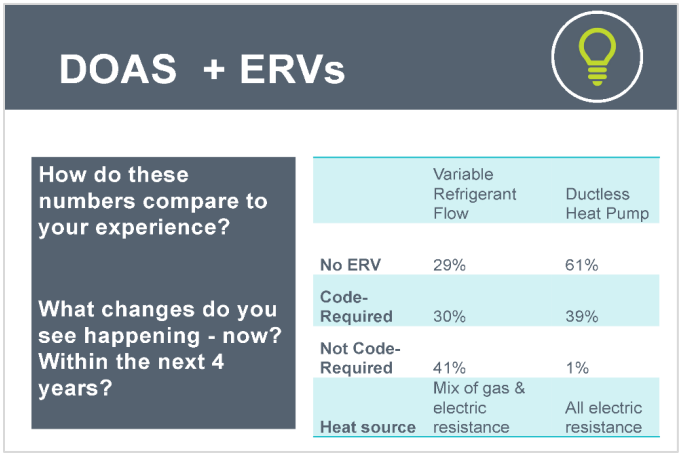
Will continued. HVAC inputs were a mixture of some things required by code, some things are from the permit data, and we also have a couple that were informed by our experience and engineering judgment. I know sometimes ears perk up when we hear “engineering judgment,” so I want to point those out. The first one is for heat pumps, which were all constant volume systems. For other kind of ventilation systems, most of them were also constant volume. But for the large DX systems, they can modulate down to as low as 0.3. And we used 104° and 55 for the maximum minimum supplier temperature. I do not think there are any big red flags on those.

Peter Karmer said that he is curious about the rooftop heat pump. Some of the larger systems require a two-speed fan, by code. Do you consider that? **Rick** replied. I think we found that there were not that many big ones. Will or Marcus, do either of you remember the details on that in our permit data?

Will replied. I would have to revisit the permit data, but I think we have modelled the larger systems as two-speed and the smaller ones with the compressor speed. I think we had a cut off, but I can look into that and follow up if that as needed a compressor or a fan. I know we discussed this, and I can follow up after this call. As Rick was saying, there is a whole workbook on these modeling inputs that we can provide, if you are curious.



Will continued. For the ERVs, previously we had talked about looking at the ventilation systems for ductless heat pumps and VRF modeling either DOAS with an ERV or without an ERV. As we looked at our permit data a little bit more, we realized that a significant portion of the ERVs that are installed were not code required. Because DOAS is such a big load, we decided to break this out into three different segments: DOAS without ERV, DOAS with a code-required ERV, and DOAS with a non-code-required ERV. But Washington State Energy code requires ERVS for all DOAS. The numbers that I will show you next take out all of the Washington ones and assume that they are all code required. For all states, multifamily residential and residential care, ERVs are required. Per ASHRAE 90.1, Oregon and Idaho do not require ERVs and then Montana does, but only if it is over 1,500 cfm.



Will continued. So here for our systems, we have VRF on the left. This is from the permit data we collected between 2015 and 2019. We saw about 1/3 of the systems for VRF systems had no ERV, almost 2/3 of the ductless heat pumps had no ERV. About 1/3 of each type had code-required ERVs. The ductless heat pumps had virtually no non-code-required ERVs. But for VRF, there were quite a few building owners that put in ERVs when they were not required. Please note that for the ductless heat pumps DOAS systems, all of these were heated by electric resistance. For the VRF systems, there was a mix of both gas and electric resistance. How do these numbers compare to your experience? And do you think that has changed recently or is going to change over the next four years of our market model?

Eric said that this feels intuitively right. It definitely seems like the ERVs have become a part of the sales process for a DOAS system regardless of whether it is just one of the options that are presented and often seems to be assumed that it is going to go in and then people opt out. That is my experience.

Brandon added that over time, we are going to see more electric resistance backup being installed just with the curtailment of gas. Right, wrong or indifference, that is the direction we are going, especially in the region. All the air handling unit (AHU) and inverter heat pumps I have installed have VFDs on the fans, and all the VRF I have installed have heat recovery. It is kind of an anecdotal and maybe I am the outlier, but all the DOAS I have designed and sold have heat recovery.

Bretnie asked. Is that regardless of whether it is required by code or not?

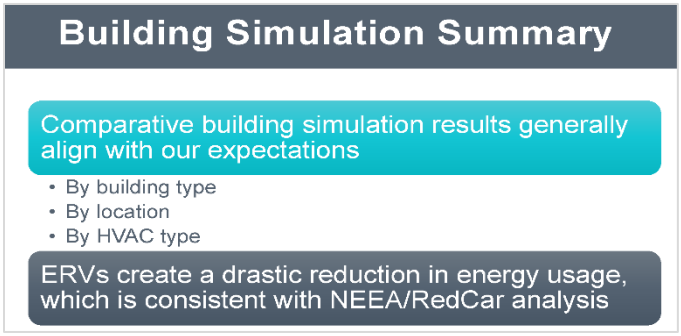
Brandon replied. Yes, we are doing it because we feel like we get the best system that way. But one of the reasons why I would advocate for heat recovery in the DOAS is I am finding that the DOAS system is pretty handy, redundant system when your VRF goes down and vice versa. That heat recovery just helps, especially when you have more extreme temperature conditions, cold or hot, it limits the energy and cost impact if it is carrying a load. It is also a factor of safety from a design standpoint.

Rick asked. Do you ever get any pushback on the cost of ERVs?

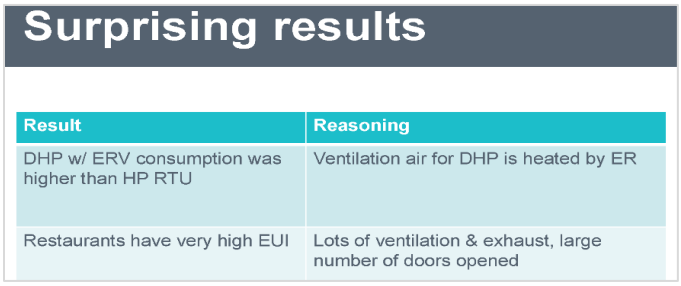
Brandon replied. I haven't yet, but that could be a function of how we talk to them. It is very common for us to put together a pro forma comparing a proposed versus baseline (code). Our model is primarily an owner direct negotiated business. If we are doing a good job of finding the right customers for us, then it is a pretty easy sale. We are not racing to the bottom on cost.

Albert added. It seems like that fuel mix seems right and maybe the ERV and the push back has to do with building type and mechanical system. The ductless with electric resistance is a very simple system with low capital cost. Whereas the VRF is much more of a mechanical design trying to hit a number of points. Maybe the fuel mix changes over time.

Building Simulations

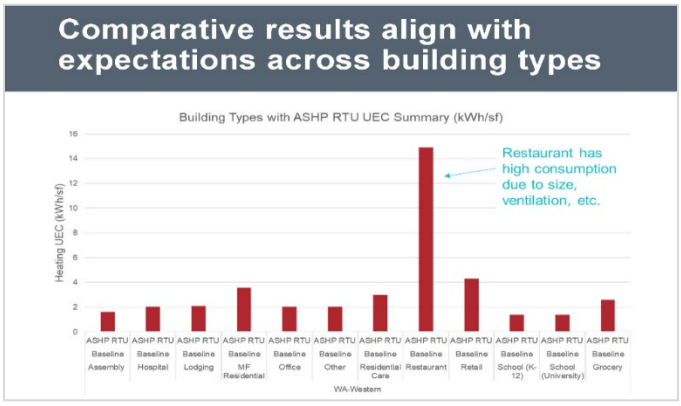


Marcus provided a summary of building simulation results. We compared the results by building type, location, and HVAC type. The findings matched up with our expectations, so that is good. We found that the installation of ERVs creates a drastic reduction in energy usage. And when we look at other simulation results such as those created by NEEA and RedCar for their very high efficiency (VHE) DOAS they find very similar results. We both find that ERVs create a drastic reduction in energy usage.



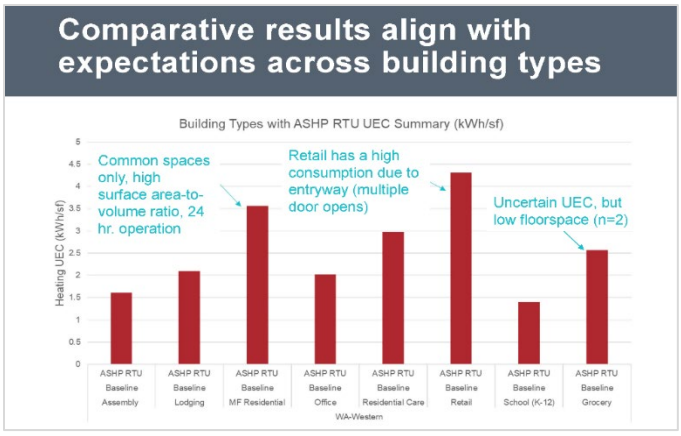
Marcus continued. But there were some things that were surprising with our results. We want to dig a little bit deeper into why we are seeing those results, one of which was that DHP with ERVs had higher consumption than heat pump rooftop units because the ventilation air is being treated by the electric resistance in the DOAS. The other one that stood out to us was that restaurant buildings have a really high EUI compared to other building types. There could be a lot of reasons for that; there is a lot of ventilation and exhausts in restaurants and a large number of doors opening and closing. Restaurants also have the lowest square footage of all the building types that we simulated. We have high energy load with low square footage. These results make sense, and they align with what we see in the CBSA as well.

UEC Results



Marcus continued. We compared our simulation results to each other a in few different ways. This first graph shows the simulation results in Western Washington. This is climate zone 4C. Here we are looking at air source heat pump, rooftop units, and all the different building types just to see how they compare to each other. Restaurants consume the most per square foot. That stands out quite a bit compared to the other models, but it also makes sense given the high consumption due to the different characteristics of the restaurant buildings and what we see in

CBSA. If we look at this more granularly, the restaurant results drown out the noise from the other models.



Marcus continued. This graph takes away the restaurant model so we can look at the other building types more granularly. For residential multifamily buildings, we are only accounting for common spaces and multifamily buildings. It is about 4,300 square feet in this prototype, and these zones have high surface area to volume ratios and 24-hour operations. We expect the energy usage on a per square footage basis to be a bit higher than the average for the rest of these, which is what we see here. Retail buildings also have relatively higher consumption, and that is in large part due to entryway zones. Doors are constantly opening and closing with these models. The building type that we have the most uncertainty about is grocery stores; we only had a couple in our sample. Given the characteristics of these buildings, we felt that there was not a strong need to simulate these directly and we can use an average of the other building types to proxy simulate these buildings. But it is a point of uncertainty because we did not directly simulate these buildings.

Albert asked a question. Is the baseline lodging also just common area or is that actually units?

Marcus said yes.

Will confirmed. It was just the multifamily residential where we broke out the dwellings from the common area.

Albert replied that efficiency makes sense then.

Pete Jacobs asked a question. So as far as the groceries go, they are somewhat unique in that there are all those interactions with casework that you would not have with any other buildings. Also, groceries tend to be almost identical from one store to the next and I would not be too concerned about a small sample size because groceries are actually fairly consistent across building types. Regarding the restaurant, are you assuming that the make-up air for the hoods is coming through the rooftop unit or is there a separate make-up air system?

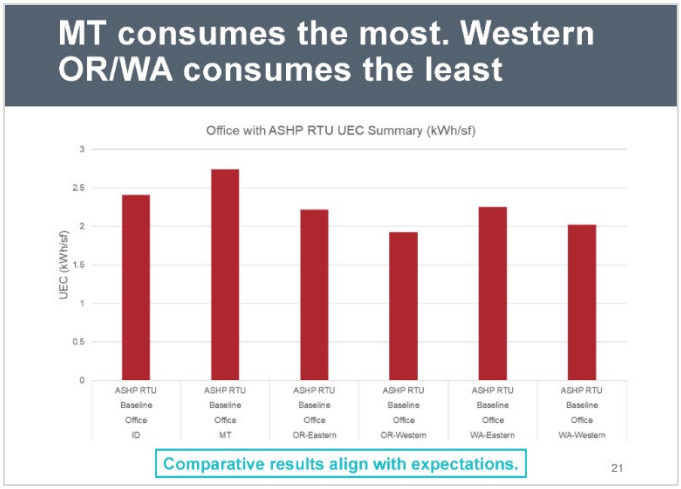
Will replied. I believe we are modeling a separate make up air system. The principal technology would just be meeting the comfort conditioning loads.

Pete Jacobs added. It depends. A lot of the fast food places will run make-up air through the rooftop units. But if that is the way your prototype is set up, that seems reasonable.

Eric added. I had the same comment about the restaurant that depending on the use of the makeup air unit, you could see they are extremely high or more typical loads for your roof units, for the grocery. I cannot imagine a grocery store having a lower heating load than your baseline retail. Grocery stores are just in heating mode all year. It can be 80° outside and you are still running heat because of the internal load regardless if they have doors on the cases or not.

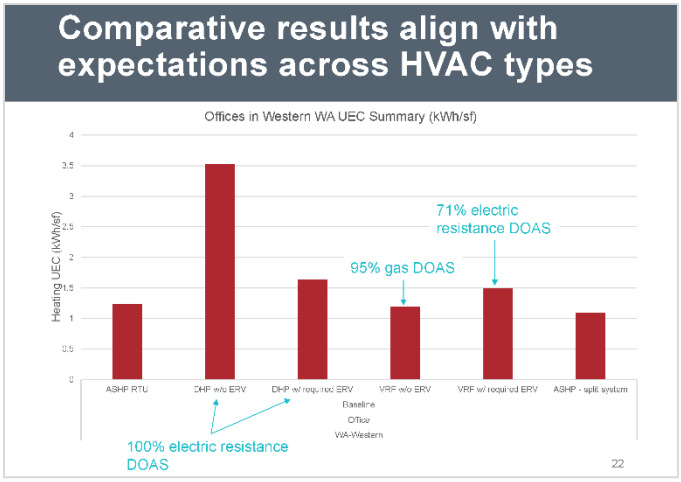
It helps a little bit if you put doors on the cases. But if it is a small enough percentage of square footage, we wrap it up in with the retail and do not try to it as distinct because they also do a lot of dehumidification even in zones that you would not typically think of. A grocery store in Seattle probably has some dehumidification equipment because of the sensitivity of the refrigeration system to that additional load and that creates a lot of maintenance issues.

Will replied. That is very much in line with what we expect and see in in other modelling projects. This was a decision we made early on based on the overall impact on the final model results due to the low square footage that we had in our in our sample. We chose to prioritize those that had a higher representation overall. Almost all building types had significantly more square footage than we saw in groceries. I agree with everything that was said, but we had to balance the impact versus the focus on that one.



Marcus continued. For this example, we are looking at office buildings with air source heat pumps and rooftop units. We are looking at Idaho on the far left, which is a mix of climate zone 6B and 5B. Montana, which is exclusively 6B, Eastern Oregon being climate zone 5B, and Western Oregon being 4C. Eastern Washington is 5B, and Western Washington is 4C. The results aligned with what we expected. With Montana being in climate zone 6B exclusively, we see the highest heating load. Then Idaho being the mixture is the second highest. Eastern Oregon and Washington being in climate zones 5B, they are next in terms of heating load. The lowest load is in the regions that are in 4C.

These are not surprising results.



Marcus continued. This last comparison of HVAC systems is perhaps the most interesting. In this example, we are looking at offices in Western Washington. We are looking at air source heat pump rooftop units and then ductless heat pump units without energy recovery. Just a reminder that the DHP units' DOAS systems are in our permit data, and we found that 100 percent of them are electric resistance. We see a really high heating load with the DHP without ERVs and then a drastic reduction in the DHP unit consumption with the installation of ERVs. On the VRF side, we do not see a similar relationship here because in the permit data for VRF systems without ERVs, the DOAS units are predominantly heated by gas, and we have a high weighting towards gas. We do not see that electrical heating load show up quite as drastically as we do on the DHP side. For VRF units that do have ERVs, we see a high signature of electric resistance though as about 71 percent of those are electric resistance. That is why you see the flip and electric heating usage even though the first VRF does not have an ERV, and the second one does.

Rick added. I will point out that this is heating UEC. So, it is not total building, it is just heating and only electric. Those are key things to remember as we are looking at these weird results here.

Christian asked a question. Does the air source heat pump RTU have a backup resistance element in it?

Marcus said I do think it does have electric resistance backup.

Will confirmed. Yes, we have modeled with electric resistance.

Christian added. It is a little interesting how low that air source heat pump RTU is relative to a DHP with ERV. It is a little hard to see through that especially if the RTU has resistance backup.

Will replied. Our thought on that was that the ventilation load is still being met with a heat pump. With the DHP, that ventilation load is being met even with an ERV. The remaining ventilation load is still being met with electric resistance. We will see some interesting results in a minute looking at the actual breakout by end use. But it was surprising to us as well that moving that load away from the heat pump seems to cause very high consumption rates.

Pete Jacobs asked a question. On the air source heat pump RTU, do you know if those systems are sized for heating or cooling? Also, do you have some sense of what the relative magnitude of the peak heating versus peak cooling load is?

Will replied that they are sized for heating in terms of the relative magnitude of cooling versus heating in different climates or in Western Washington specifically. I would have to pull those numbers, but we certainly can. We have the data.

Pete added. If it is sized for heating, then that is probably going to minimize the amount of stripping you would have to use.

Eric said that he thinks the air source heat pump is very low. I would think that it would be at least as much as a DHP considering the efficiencies that we normally see them rated at. NEEA has a lot of case studies showing roughly 70 percent energy reduction when they move to a VRF from packaged RTUs. To me that suggests that the issue is likely with the air source heat pump modeling rather than with the DHP or VRF.

Christian added. Maybe this applies to air source heat pumps and DHPs, but sometimes with EnergyPlus heat pumps they are a little realistic on the interplay between the compressor and the resistance. If you use the default heat pump, as long as the heat pump has enough nameplate capacity, it will always let the compressor take it. Whereas real heat pump controls are far more complicated than that and far more likely to use that resistance like crazy. That is probably underlying some of this. But I would think that would affect both the air sourcing pump RTUs and the DHPs. That is something we have certainly seen in our work.

Rick asked. Do you see that in commercial as well as residential?

Christian replied. Not specifically, but knowing what I know, they should behave the same way whether it is a commercial or residential building. You can get around it if you add an on/off controller to the HVAC unit, which actually makes the unit cycle like a real heat pump. It is far more likely to switch on that resistance. Where with EnergyPlus' default controller, it is literally always running. It is okay, but it can be a little unrealistic especially with heat pumps and compressor heat.

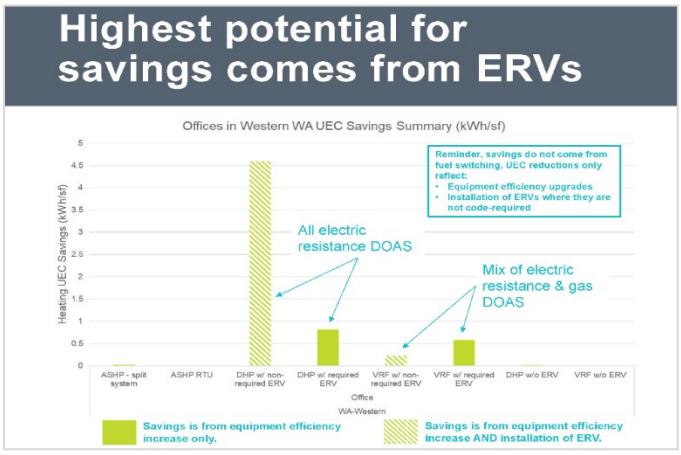
Pete Jacobs asked a question. Are you are sure on that sizing for heating? Is that common practice in the Northwest or would you typically just size for cooling and get whatever you get out of the heating side before you go move the strip heat.

Will said that is a great question for the panel.

Pete Jacobs said that in his experience, it is probably more likely that you would size the equipment for cooling and then get whatever you get out of the heating side and supplement with strip heat.

Brandon said that he generally agrees, although we have been doing projects in areas where the heating load is definitely much more extreme than the cooling load. With schools, for example, you are definitely going to focus more on the heating load than the cooling load if they are not operating in the summer. One of the things that drives that is policy changes on gas. But another thing that drives the electric resistance back up is that people get scared about increasing gas service. Oftentimes, lines are long enough where it drives you into a new permitting level. It is common for designers and contractors

to try to avoid gas in the structure upgrades with these kinds of projects, which would inform that backup.



Marcus continued. The highest saving potential comes from installation of ERVs in regions where ERVS are not code required. We are calculating any savings from fuel switching. These savings are only coming from UEC reductions due to equipment efficiency upgrades for both the principal HVAC equipment and the ERV sensible effectiveness upgrades and the installation of ERVs where they are not code required. In these bar graphs, the solid bars are just segments where we are only looking at savings from equipment efficiency increases, whereas the striped bars are savings from equipment efficiency and the installation of ERVs. The one that jumps out is the DHP with non-required ERV. The baseline there is the DHP units with no ERV electric resistance DOAS going to DHPs within the ERV still electric resistance DOAS. We see high savings potential there. For the VRF units, which have same baseline as VRF, no ERV. The DOAS fuel in those cases is 95 percent gas. It is heavily weighted to the gas side, which is why we do not see as much savings on the VRFs.

Brandon asked if you are modeling set-back temperatures.

Marcus said yes.

Brandon asked. How aggressive are they on the heat pump model?

Marcus replied. I don't have the exact setbacks in in front of me. I would not characterize them as aggressive, but they are calibrated set back temperatures from the RTF calibrated models.

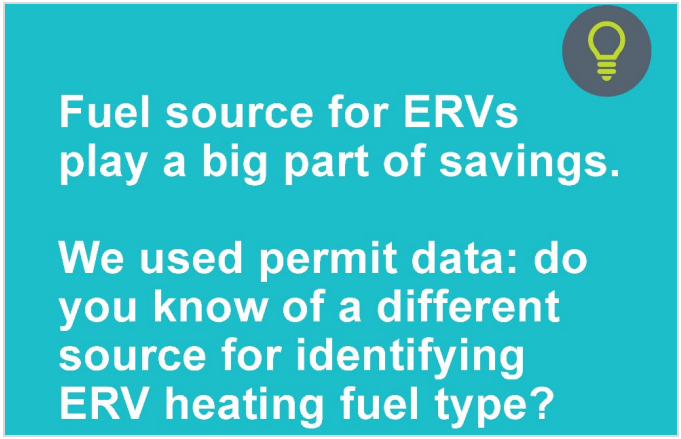
Brandon added. Seeing us not tend to set back the VRF systems as aggressively as we traditionally set back.

Rick added. Was that just VRF or maybe you do not do as much on the DHP and other heat pumps.

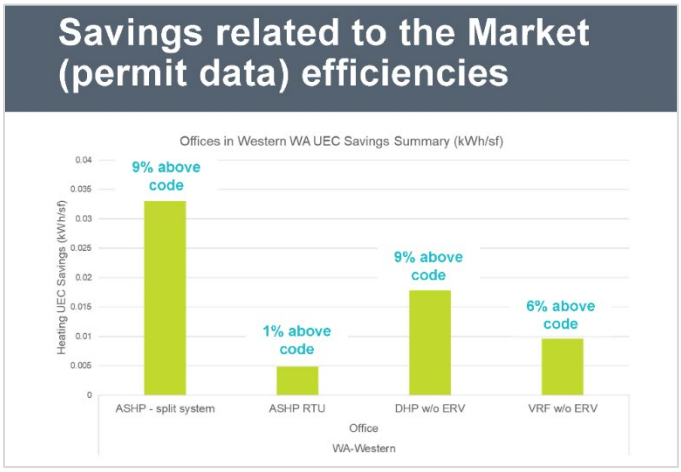
Brandon replied. I would say with the inverter heat pumps we tend to see more of a traditional set back. But I have done most of that work in an industrial space. A lot of times, they run 24/7. They are too cheap to meter.

Will asked a question. Would you expect that the motivation behind that change strategy is for energy savings or for longevity? Would you expect that to have a significant impact on savings from a heat pump?

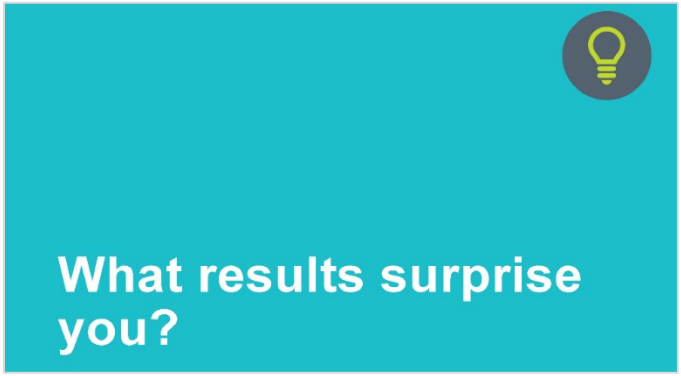
Brandon replied. I would say that the top priority is equipment preservation. We are not throttling these heat pumps too much in the mornings, especially in the winter. But it is a case-by-case basis, and I would say that we have to learn every building individually and then tailor the controls programming for how we see that building behaves, especially when we are replacing a traditional system or even in a new build. These are relatively new systems, and they do not behave the same as what people are used to working with. With the seasonal changes of the building, you have to learn that and then educate the customer on what they need to do to maximize efficiency as they transition through those shorter months.



Marcus continued. Fuel source for these ERVs does play a big part in the savings that we are seeing. As a reminder, we use the permit data to produce the weighting of gas or electric DOAS units that we use for our simulation results.



Marcus continued. On this last savings slide, we zoom in on the HVAC types that were influenced by the installation of ERVs. Here, we are looking at air source heat pump split systems, RTUs, and DHP and VRF units without ERVs. We wanted to show that the savings that we are seeing are related to the efficiencies above code that we are also seeing. For the air source heat pump split systems and DHP without ERVs, we are seeing in the permit data that they have efficiency levels that are about 9 percent above code. For the VRF units, it is about 6 percent above code. For the RTUs, it is 1 percent above code.



Christian asked Marcus to explain the last chart a little bit more. What are we calling efficiency here? Is it nameplate efficiency model deficiency? What does it include? What is an air source heat pump split system in this case? That makes me think of a residential style unit, but maybe I am not quite sure how to contextualize that.

Marcus replied. It is nameplate efficiencies. And I think you are right in terms of the air source heat pump split system; it is kind of a residential style split system for smaller buildings.

Christian added. Maybe there is something I am missing, but how is an air source heat pump split system as big of an efficiency? Is it because this is all relative to its own category?

Marcus replied. Yes, the baseline is dependent on the HVAC type, and we are using code as the baseline. In the market data, we are seeing that the nameplate efficiencies for air source heat pump split systems, for example, are 9 percent above code on average.

Christian added. Relative to other split systems, but then the DHPs, that's relative to other DHPs, is that right?

Marcus said yes.

Christian said that makes sense.

Rick added. It is relative to the code for DHPs or federal standards.

Will added. They probably fall under the same bucket in the federal standards because they are both smaller split systems more or less. But we see different outcomes based on the buildings they are installed in and the regions that they are located in, etc.

Christian added. I guess it also depends on if you know that the air source heat pump is a single speed, right? I guess it depends on the baseline.

Will replied. I believe we modeled the baseline as single-speed and the efficient case as two-speed speed for the split systems thinking that they are going to be residential. We definitely did discuss what changes would happen between what we were seeing in permit data versus minimum.

Eric asked if this was preceding the increase in federal efficiency requirements for the smaller units.

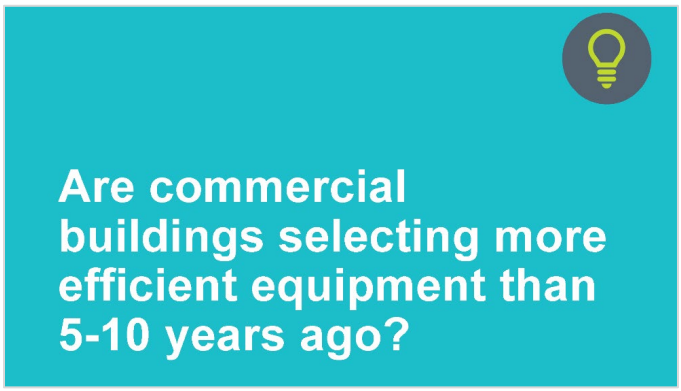
Rick responded. With the HSPF2 permit data, we saw that units were 9 percent above code at that time. Then we translated that into the current federal standard and then went 9 percent more efficient than that.

Eric said that would definitely be a point I would want to check with more current data.

Will said that part of the challenge was that the permit data spans the trend; we had to put everything to the same basis. We had some projects permitted under different regimes. Do you have a sense that the latest transition was a significant improvement in actual performance or was it mainly the transition from the HSPF to HSPF2 and SEER to SEER2?

Eric replied that we have seen some variation. We use conversion factors to change our requirements. But when you look at actual units and how they performed in the two tests, there was actually a fair amount of variation. Some units were more sensitive to that increased static pressure in the HSPF2 rating. As I understand it, the biggest difference between the two tests is the higher static pressure being modeled.

Pete Jacobs added. In terms of air source heat pump split systems being more likely to be above code, which makes sense to me. In general, there are more options for higher SEER equipment for split systems versus rooftops. Similarly for ductless and presumably for VRF too. There are more options above code. The rooftop units are generally fairly constrained in terms of the options above code efficiency.

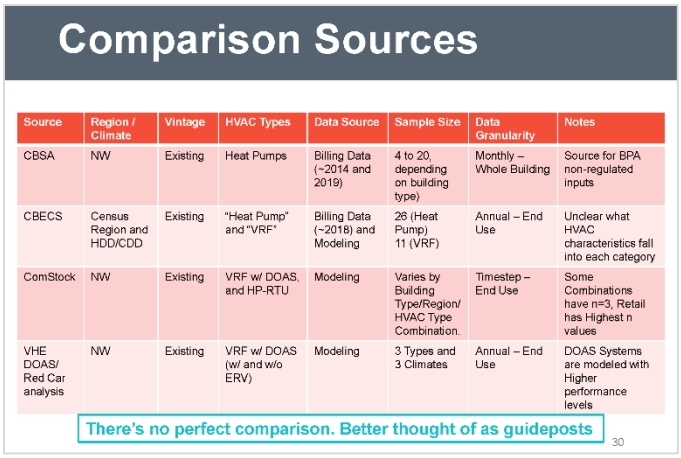


Pete Jacobs asked for clarification. Are you saying in terms of margin above code?

Rick replied, yes.

Pete Jacobs added that code is dragging everything along.

Simulation Validations



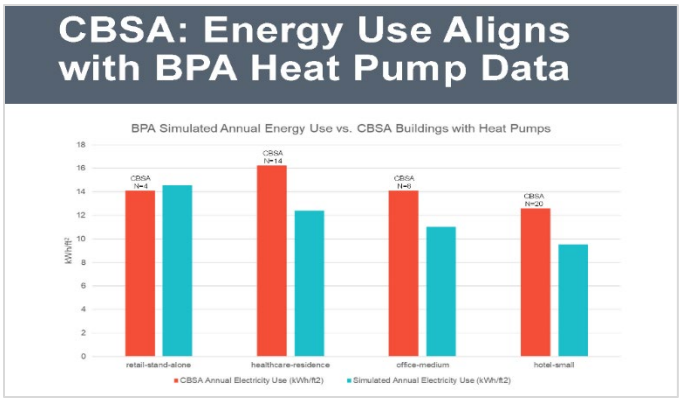
Will reviewed comparison sources. We wanted to both look at the models relative to each other and try to pull in external comparison points to get a check on the results we are seeing. This is super straightforward because we are representing new construction and major remodels. We tried to grab everything and do as many comparisons as we could so we could use this as both a way to identify issues to that we should investigate and to try and get a sense of what kind of behaviors we were capturing.

This table walks through the four sources that we have looked at so far. First, we looked at the CBSA and leveraged both 2014 and 2019 data. We took some of the values that were used to calibrate the RTS models. There are some specific to heat pumps and we combined those data into some comparison points. It is relatively low Ns on CBSA existing buildings, Ns ranging from 4 to up to 20 depending on building type. So, we have a generic category of heat pumps for that comparison. We do not have a lot of granularity in terms of system type. We lumped everything together to try and maximize the value of those Ns. This is obviously Northwest specific. We wanted to find regionally applicable comparison points. We also looked at CBECS, which is definitely not specifically Northwest focused. But we subsetted the micro data by census region, so the West census region, and then we took the data points from the CBECS data set that had heating degree days (HDDs) and cooling degree days (CDDs) that aligned with the Northwest climate zones.

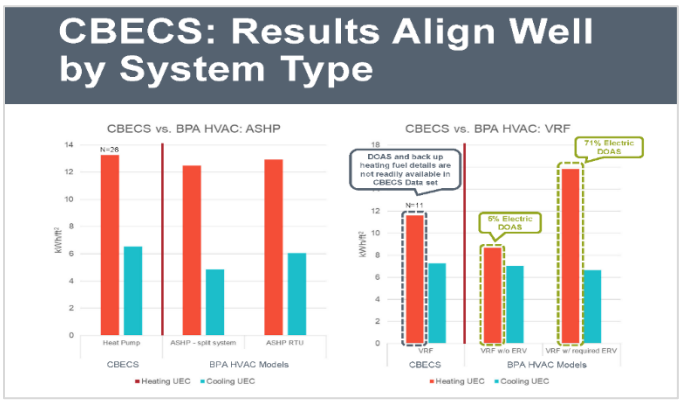
For HVAC types, we looked at buildings categorized as heat pumps that did not have significant gas heats. It is very difficult in CBECS to determine buildings that are solely heated by system X or system Y. We tried to balance getting buildings that were reflective of what we were trying to represent, but that also had sufficiently high N values to be a worthwhile comparison. These are based on the 2018 CBECS billing data likely captured a year or two before that. This left us with 26 generic heat pumps and 11 VRFs. That gave us annual values. But CBECS also does some modelling to break out end uses so we can look at heating load and cooling load. That is modelling that is not based on actual billing data.

The commercial building sector stock model (ComStock™) is a large data set of models that were built by the National Renewable Energy Laboratory (NREL). In most cases, this gives us lots of end uses and they have models that represent the VRF with DOAS and heat pump RTUs. The challenge with ComStock is that the building characteristics vary by climate zone and by system. We will see some of the impacts of that when we look at the numbers. Because of how it is put together, there are actually some fairly low N values in the Northwest for some systems and building types. We wanted to look at it as granularly as possible, but some buildings, like retail, had Ns in the 300+. But that compares two theoretically calibrated models that were calibrated on a national level.

Lastly, we looked at the VHE DOAS analysis done by NEEA and Red Car Analytics, which was modeling VRF with DOAS under a couple different scenarios. This is with and without ERV and fuels and how much consumption happens in those systems. That analysis looked at a few different configurations: DOAS with no energy recovery, DOAS with energy recovery, DOAS with the whole VHE DOAS measure specifications. But we are not looking at that. We are looking at a VRF modelled with an ERV and DOAS and one modelled without. System wise, this is a very apples-to-apples comparison, and it is modelling as well. They did a pretty comprehensive analysis to develop those models.



Will continued. The red bars are the CBSA values by building type, and the blue bars are the simulated values. It is hard to draw conclusions from just looking at these comparisons. This is meant more as a gut check to see if anything is really out of order. This gave us a place to look for further investigation. This aligns with what we expect with those higher end systems. We see lower consumption, which makes sense from a model representing a new building versus an existing building. For retail, it is very close. But with the N=4 retail systems having heat pumps and CBSA, it was hard to be certain about what conclusions to draw from that. We are also dealing with the limited number of buildings because we had to work with what was in the CBSA.



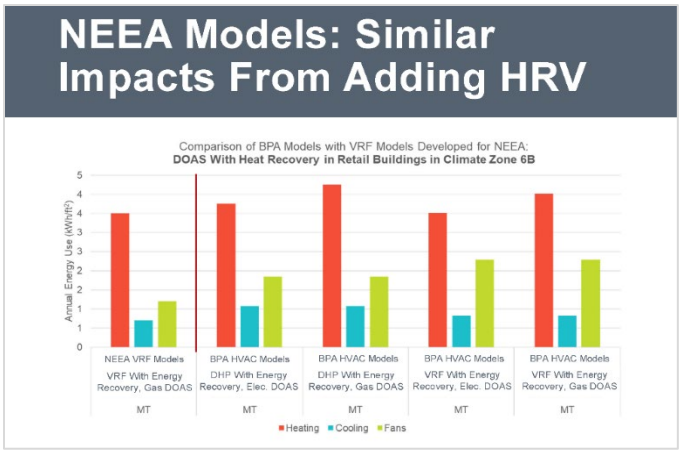
Will continued. On the left, we look at the generic air source heat pump in CBECS broken out by end use. CBECS does do a bit of a modeling disaggregation of the billing data to calculate end use. We compared those looking at the two air source heat pump configurations. The graph on the left has CBECS on the farthest left, and then the two on the right are the split system and rooftop unit. This is an average across the region to try and keep the number of comparison data points high. We have an N of 26 there and the VRF system on the right. The left most bars on the right graph are CBECS showing N of 11 and the comparison with and without ERV. Again, it is unclear what that fuel mix is in CBECS. This would be any DOAS systems or backup heat that are installed with those systems are a mixture of fuel types. On the two BPA HVAC models, there is a definite bifurcation where those without ERVs tend to be gas DOAS and with ERVs tend to be electric. It makes sense that the CBECS data would lie somewhere in between those two.

Christian added. I realize you are probably sample-size-limited, but did you filter any of these data sets for newer buildings because the blue bars are new construction, and the red are largely existing?

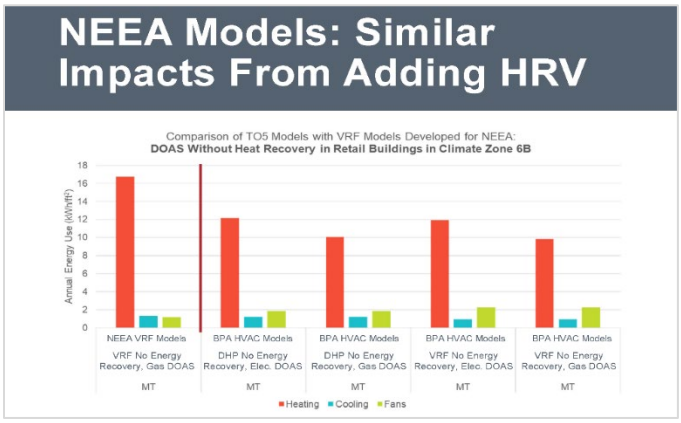
Will said no, blue is cooling and red is heating. I tried to subset by date or vintage, but it quickly made the comparisons meaningless. You do not see a clearer trend, like the CBSA, where the results made sense and we were getting less consumption with the new construction in the model than we saw in CBSA. **Will** jumped back to the previous slide. In this case, red is CBSA, blue is BPA HVAC simulations, and that trend is in line with what we expect. We would see a less clear trend with CBECS. I think the impact of that auxiliary or DOAS fuel is so huge that it is hard to draw significant collisions.

Will moved back to the current slide. From the graph on the left, we see slightly lower consumption. I wanted to try and find a new reference source, but unfortunately that is why we are doing modelling, because new data does not exist. Even with the ComStock values, with hundreds of buildings, I could not get any new data. If I tried to subset anything newer than 1980, the Ns would just fall out to nothing. It is a challenge we have come up against.

Peter Jacobs added in the chat: I do not necessarily trust the CBECS algorithms for disaggregating end uses. I imagine what they are calling the heating end use will also include ventilation fans, while the E+ models I presume is just heating.

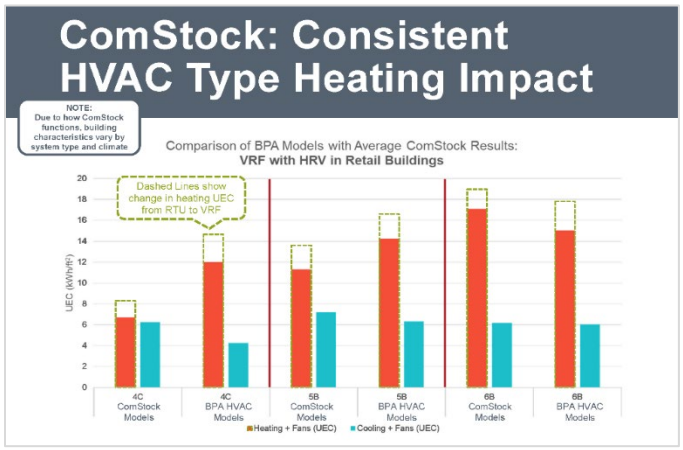


Will continued. On the left is the model that was developed by Red Car for NEEA, for the VHE DOAS program. But it is not the VHE DOAS, it is just a VRF with a standard DOAS unit with an ERV. You can see the breakdown between heating, cooling, and fans. This is for retail building and 6B climate zone. The VHE DOAS analysis had three building types and three climate zones, and we think this compares well with what we are seeing. We are comparing our DHP with electric and gas and I have combined the fuel consumption here. So, we are looking at all the energy used for heating both, because the VHE DOAS model had gas in the DOAS unit. I was trying to understand where the energy consumption happens in systems without ERVs. Does it make sense that we are seeing this huge consumption in in the DHPs with electric resistance DOAS and no ERVs?



Chris added in the chat: I am not sure the NEEA model has gas.

Will responded. NEEA modelled four different systems, and some had no heating coil in the DOAS, and some had gas, and some had electric. To make it a fair comparison, I combined all the heating consumption. That is what we are looking at here. I know there are a bunch of different analysis that were done for VHE DOAS, so it is possible that other system types were looked at. For DOAS without ERV, we are seeing a ton of consumption happening at the DOAS. So, whatever you have doing your space comfort conditioning in the zone, is really never seeing a big chunk of this load. We are putting in really efficient equipment with a DOAS and we are not seeing a lot of savings. It is because efficient equipment is not seeing a lot of load. That is what we are seeing. Our models align with the results from the report that we were comparing against. It was initially surprising to us that the more we looked into it and found other reference cases, this is something that is a big impactor and really adds to the value of energy recovery.



Will continued. Within ComStock, there is going to be a different mix of building characteristics. There will be different sizes, and some are going to have broken economizers. It is a great resource, but it is intended to be a nationally applicable project. Sometimes when you break it up into smaller subsets, you end up with weird results because you have gone from all your buildings having functioning economizers to all your buildings not having functioning economizers.

It is not an apples-to-apples comparison, but what we took from here is that we have air source heat pump and then the next one is our VRF. On the heating side, we see a consistent

difference between their air source heat pump model and their VRF model and our air source heat pump and our VRF model.

Cooling is a bit inconsistent, and I think that is driven by the variation and assumptions about economizing going into that model. One of the downsides of having that many models is it can be hard to identify one individual source. Ideally, we would have more data sources to look at.

Pete Jacobs added in the chat. You could wade into the data lake and pull out the models that are more comparable.

Eric said he was confused by the last slide. I thought when you presented before BPA's models, it seemed in air source heat pump compared to VRF, that the air source heat pump had lower energy consumption for heating. Here you seem to be suggesting that BPA's models are showing lower savings for the VRF.

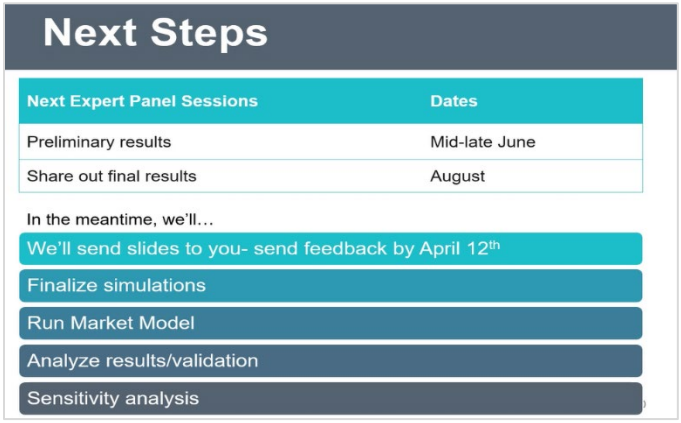
Will replied. In the previous slide, was it VRF with HRV that we were comparing against?

Eric replied. I thought it was both, because the one without VRF was so heavily gas and with VRF was so heavily electric, but both of them showed lower heating energy consumption kWh/ft^2 than either of the VRF models.

Marcus asked Will. Is this graph looking at electric heating or both fuels?

Will said this would be VRF with HRV electric, so it is comparing electric to electric. I will make a note to double check as there is a lot of data behind these. But it is electric and electric; I know with the ComStock VRF measure, they assume an electric resistance in the DOAS.

Christian added in the chat: Big cities like Seattle are now publishing EUIs publicly for commercial buildings, but 1) it is probably whole building EUIs and 2) I do not know if they have information on things like HVAC type—but it might be worth just checking.



Juan Carlos thanked the panelists and reviewed the next steps.

Working Session: Interim Market Model Draft Results – Jun. 14, 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: Juan Carlos Blacker

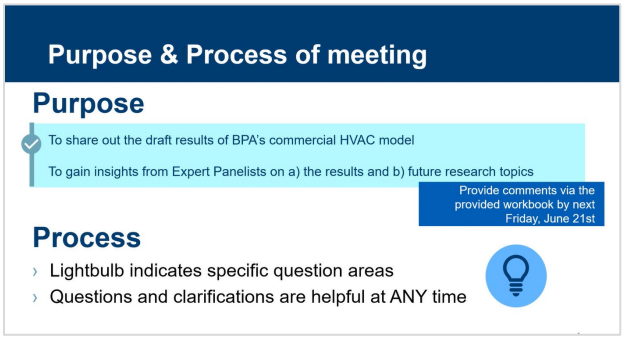
DNV: Tyler Mahone, Lorre Rosen

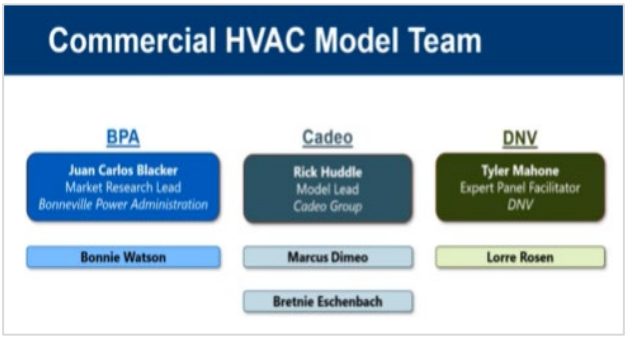
Cadeo: Rick Huddle, Marcus Dimeo, Bretnie Eschenbach

Invited Panelists	Affiliation	Attended	Did Not Attend
Albert Rooks	Small Planet Supply	☒	☐
Brandon Adams	Vector Energy Solutions	☒	☐
Cassandra Beck	Trane	☐	☒
Peter Kramer	Trane	☒	☐
Jesse Dean	Edo Energy/McKinstry	☒	☐
Mark Lessans	Johnson Controls	☒	☐
Pete Jacobs	Building Metrics	☒	☐
Eric Mullendore	BPA	☐	☒
Chris Wolgamott	NEEA	☒	☐
Kevin Smit	Council	☐	☒
Christian Douglass	Council	☒	☐

Introductions

Tyler and Juan Carlos introduced the presenters and panelists.



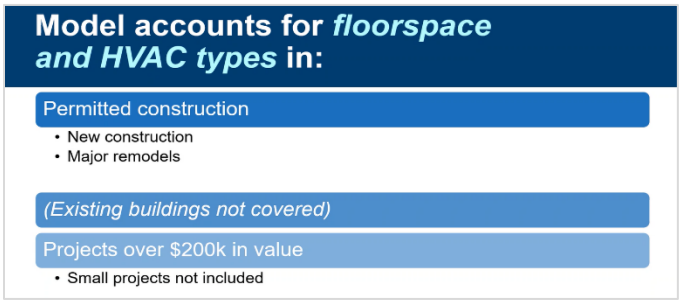


Juan Carlos discussed the purpose of the meeting and discussed the agenda for today's meeting. As you know, this is the first time we have done a market model for commercial HVAC and there has been a lot of work done on it. Many of the iterations we have done have come from your suggestions and advice. And we really appreciate that. In this meeting, we are going to show you those results and then talk about next steps and get some more of your ideas and thoughts on what we have done.

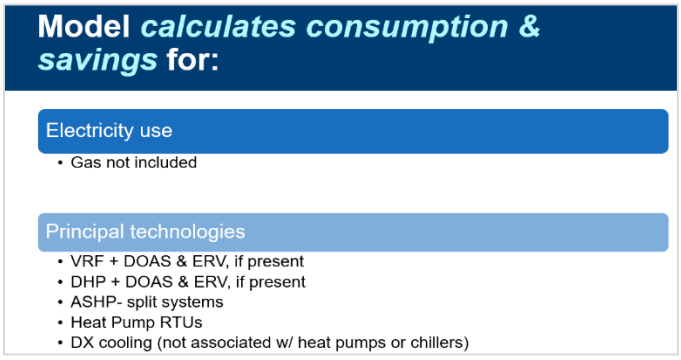
Agenda

- Model scope
- Model results
- Interesting findings
- Future research questions
- Next steps

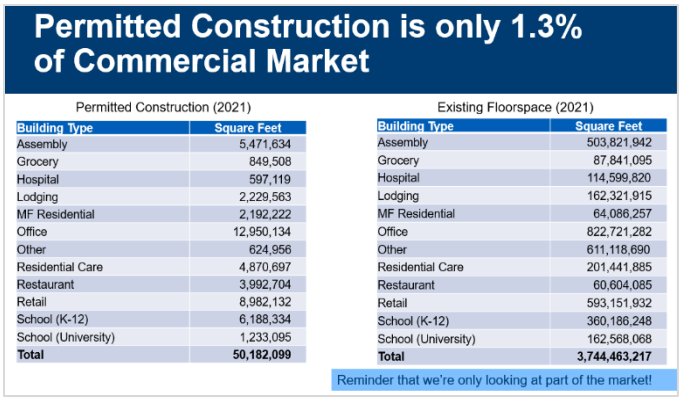
Model Scope



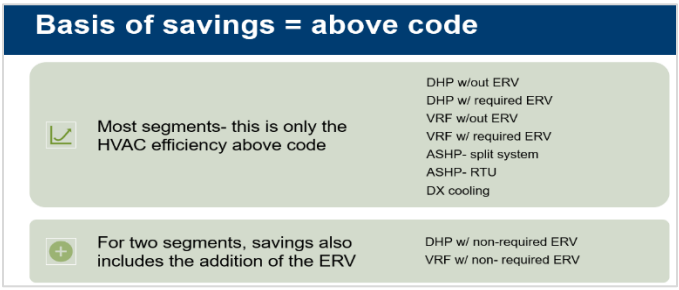
Rick began with a reminder about the scope of the model to help frame the discussion. Ideally, we would cover the entire commercial HVAC market in the whole region, but we do have some limitations. As you probably remember, we did a big data commercial permit data collection process and looked at 300 permits throughout the region. For all those permits, we accounted for the floorspace served and the HVAC type. That is for permitted construction, which covers both new construction and major remodels. Existing buildings are not in our current market model. Another limitation is that we only looked at projects that had $200,000 of construction value or higher. That was our attempt to limit small projects that would not have HVAC systems.



Rick continued. For all of those projects, we calculated consumption, energy consumption and savings for electrical use only, no gas systems. Regarding our principal technologies, these are variable refrigerant flow (VRF) systems that are paired with dedicated outdoor air systems (DOAS) and then energy recovery ventilation if it is present, ductless heat pumps or mini splits also with DOAS and an energy recovery ventilator (ERV) if it is present. Then we have smaller split system heat pumps, larger heat pump rooftop units (RTUs) and then any direct expansion (DX) cooling that is not associated with heat pumps or chillers, e.g., gas packs or built up air handlers that have maybe hydronic heating and DX cooling. We did not calculate consumption and savings for hydronic systems, water source heat pumps, packaged terminal air conditioners (PTACs), packaged terminal heat pumps (PTHPs), or ground source heat pumps.

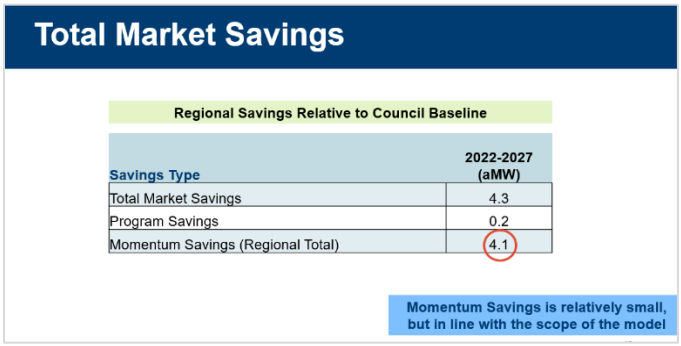


Rick continued. One of the things we want to note here is that permitted construction is really a small portion of the entire commercial market, about 1 percent. When you account for all of the existing buildings, we are just looking at a small portion.



Rick continued. The other big thing to keep in mind when we are looking at these results is that all of the savings are above code. This is the Northwest Power and Conservation Council (Council) baseline code. For most of our equipment, that means it is just the efficiency of the equipment above code. So, if mini splits have a heating seasonal performance factor (HSPF) of 9.4 instead of 9, that small efficiency difference is where the savings come from. That includes most of the technologies here. It is just this efficiency technology above code that does include ERVs. If it was 60 percent efficient versus 50 percent efficient, we captured savings for that. The two different also above code segments here are if ERVs were not required, but someone installed them anyway. Washington state requires ERVs for all DOAS systems. But in Oregon, Idaho, and Montana, it depends on the climate zone and the cubic feet per minute (CFM) airflow volume of the DOAS. So, we segmented all those out and accounted for those. But if somebody put in an ERV that was not required, that is where we get some extra savings.

Model results



Rick continued. This is our big picture wrap up. Between 2022-2027, we are calculating that there's 4.3 average megawatts (aMW) of savings from the market. This is above code for those technologies in permitted construction. You can see that program savings is a small portion of that. The momentum savings that BPA can account for is 4.1 aMW. And while this is relatively small, it does make sense when you consider the scope of the model. Those momentum savings are what fund this research. So that is one of the big reasons we want to note that here. The other big reason is that we are trying to learn about the market and see what we can influence in the future.

Christian asked a clarifying question about the baseline. I think on the last slide you said the Council baseline is code and typically the Council baseline is either code or current practice, whichever is more efficient. I just wanted to make sure that was the way you looked at things. Codes are so aggressive these days, especially in Oregon and Washington. For those states, it is probably pretty close to code. My main concern would be in Idaho and Montana, you can still build with electric resistance, but the

market is still 20 percent heat pumps. I would want to make sure we catch that 20 percent heat pump. Not everyone is building electric resistance.

Rick asked for clarification on the last part of the question.

Christian added. With the Council, our baseline is either code or current practice, whichever is more efficient. In Idaho and Montana, for example, you can still use as much electric resistance heating as you want per the code. But in sales, we see that even in those states, 20 percent of the market is heat pump and 80 percent is resistance. I would just want to make sure that we are calculating savings versus that sales baseline, and not a full resistance baseline.

Rick replied. That is one thing that I think could be included in a future model. I am not sure how we would account for that kind of technology shift.

Bretnie added. We are not getting any savings from going from an electric resistance to another technology. We looked into this quite a bit when we were starting the model. We wrote in our baseline memo that we were engaged with the Council just to make sure we were interpreting the Plan's baseline correctly.

Christian replied. Thank you. I think I forgot that we have already discussed that.

Peter Kramer asked. I know we have talked about momentum savings in the past and maybe there are some standards that are in that definition, but can you remind me within the context I'm looking here, are you talking 2022 to 2027? Is that the period you are talking about?

Rick replied. Yes, 2022-2027.

Juan Carlos added. Momentum savings is a resource that the BPA uses to determine how much energy savings we can estimate based on efficient technologies going into the market. We take the total market savings and remove any program savings, because those are already being claimed to BPA. And then the remainder of that is what we call momentum saving. It is the un-incented, un-programmatic savings that we estimate will not be needed for generation. Because what we do at BPA is plan for the generation we are going to need over the next power plan. This is our estimate of what will be saved by the use of these efficient technologies in this very limited market that we are looking at right now. That is the momentum savings.

Peter Kramer added. So, it is an aggregated total over a particular time period, 5 years?

Juan Carlos replied. It is tied to the 2021 Power Plan, which goes from 2022 to 2027. For every Power Plan, we need to develop an estimate for the momentum savings of certain markets, Commercial HVAC being one of them. We also do it for non-residential lighting, residential HVAC, and motors and drives. It is a way for BPA to do some planning based on savings by the use of efficient technologies. However, we also use this market model to develop future programs. Just to remind everybody, this model and the results, this is just our interim model. We are halfway through the plan; there is a lot more to do. We will do a final model to produce that final number, which may be different than the 4.1 that we have here. We will start that in about a year.

Albert asked a question. For my own edification, I guess the momentum savings is considered relatively small. I am curious, in your prior experience, how that compares to other initiatives, like lighting and or anything else you might have experience with? I think it was a really good note that that we are in a very aggressive code, and I am just trying to gauge the future and what momentum means.

Juan Carlos replied. The regional total of momentum savings, 4.1, is actually pretty small for our other models. We made a decision when we started this that commercial HVAC was too important a market not to be investigated. We knew initially, and have confirmed, that the savings would be small, but that does not diminish the importance of the market. In the period between this model and the final model, we are going to really evaluate this market and see if this small potential for momentum savings makes

sense to continue to do with these market models. It is just because the market is so important and there is so much change happening so quickly. But yes, relative to what we have seen in the past in lighting, this is quite small. We have seen numbers in the 40s and 50s in lighting.

Albert replied. I would imagine lighting is really heavily influenced by the consumer's availability to get product at the at the retail outlet. And there you can pick up a lot of momentum. HVAC is maybe a heavier lift because it is design based and has high capital expense. I actually thought it would be bigger, so I am a little disappointed.

Juan Carlos added. Do not be too disappointed because remember, we are looking at 1.3 percent of the market, right? This is just new construction and retrofit. For lighting, we looked at the whole market, stock and sales. This is just permitted projects because we do not have the data to do that full analysis. I am sure it would be bigger if we looked at the whole market and not just 1.3 percent of the market.

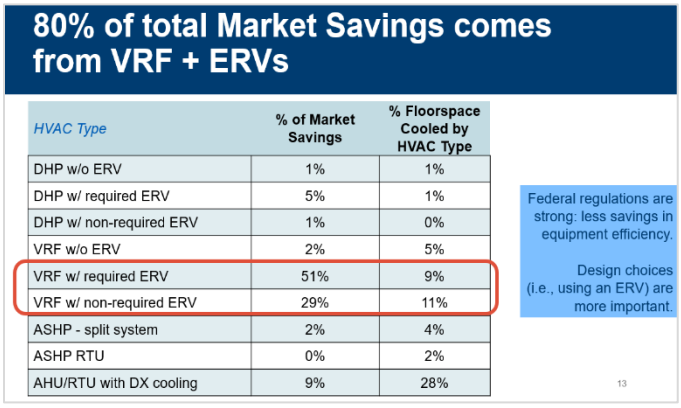
Bretnie added. It is also a factor of the baseline too. Since we are not looking at the existing building, we are looking at what code requires for the baseline. That really shrinks the available savings. But it certainly does not mean that there is not big savings out there in the market to be had, just means that what we are capturing in this slice is relatively small.

Brandon echoed Albert's comments. This is a lot smaller than I thought, but considering it is such a small sample set, it makes sense. I am wondering if you are thinking about developing an extrapolation methodology to expand these numbers out or if you are thinking you are going to expand this into a more comprehensive study.

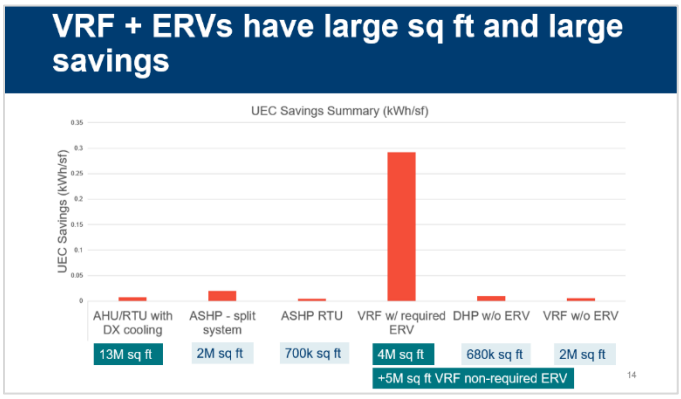
Tyler replied. I think that is what they are going to get towards the end of this meeting.

Christian asked in the chat window, "program" here is just BPA programs, correct? Not IOUs?

Bretnie replied to Christian. Programs equal all regional programs, including NEEA initiatives.



Rick continued. These are our principal technology types, and this is the percent of market savings. And then to gauge how present the technology is, it is the percent of floorspace that is cooled by that HVAC type. For VRF, both with the required and non-required ERVs, the total comes to 80 percent. The only thing that really comes close is the DX cooling at 9 percent. And that is because it is 28 percent of the floorspace. Federal regulations are already strong. There is not huge savings going from HSPF 9 to 9.4, but design choices using an ERV are really more important.



Rick continued. The Y axis is savings per square foot that we calculated through the building models that we ran. Just looking at the magnitude of savings for the VRF with required ERV, and then if you do not have an ERV, you can see how big that drops. At the bottom of the slide, we show the different technologies and the square footage that is served by those technologies. You can again see that the DX cooling, because it serves 13 million square feet in permitted construction, is where the savings

comes from. For VRF with ERVs, you get the savings per square foot and then it also has 9 million square feet total with required and non-required ERVs. This is where so much of our 80 percent of savings comes from.

Chris asked a question. On the air handler RTUs, are you only looking at the cooling savings or are you looking at gas packs with just the DX cooling or are you looking at heat pumps? Are there any heating savings or is it all cooling saving?

Rick replied. We do not account for gas savings. If it is a heat pump, it is in this heat pump RTU, which has a similar amount of savings. There is just not much floorspace that is served by heat pumps.

Chris added. So that is just cooling savings? **Rick** replied. Yes. **Chis** added. Did you look at any of this with the RTUs having the ERVs on them?

Rick replied No, in the permit data, we saw a really small portion. And this may be changing, but in 2015 to 2019 where we collected the permit data, there was just a small portion of air handlers RTUs with ERVs.

Bretnie added. We decided not to include that in this model, but that could be something that we change in the future if we find that more RTUs have ERVs, which we want to see.

Mark asked. Is it fair to say that the bulk of the savings, at least on a per square footage basis, is the presence of any of the ERV. **Rick** replied. Yes. When you look at the graph, without ERV, you are down here. But when you add the ERV, it is a big jump.

Mark replied. That is very illuminating. I would second the desire to see what this looks like if we looked at RTUs with ERVs too. Recognizing that is a smaller share of the market, it would still be helpful to have an understanding of what the savings per square foot potential is that we are modelling. Overall, this could help drive faster adoption of ERVs and integrated with RTUs as well.

Bretnie added. This is really speaking to why NEEA's very high efficiency (VHE) DOAS program sees such big savings potential.

Juan Carlos added. The DHP with ERV, which is not shown on this chart, is super high. They are massive, but it is such a tiny part of the market that we did not put it on this slide.

Bretnie added. One of the drivers behind that is the baseline for an air source heat pump RTU is only slightly less efficient than the efficient version of the air source heat pump RTU. So, it is not that there is no savings from an air source heat pump RTU, it is just that the baseline is more efficient. Whereas the VRF with or without the ERV, if you do not have an ERV, it can use a lot of energy. We tend to think of VRFs and DHPs as really big energy savers, but that means there are some really inefficient ways of doing the ventilation. It is really important to consider that when people are designing a building.

Albert noted in the chat window. Yep, that would be the impact that I would predict — unrecovered ventilation/conditioning losses really add up.

Brandon added. My brain goes to dollars pretty quickly. For the VRF with required ERV, if we round up to .3 kWh per square foot is about 30,000 kilowatt hours for 100,000-square-foot building, 8 cents a kWh, which is $2,400 a year. Is there a next step that is going to look at the incremental cost from going from VRF to the ERV. Looking at that return on investment and considering the energy savings, is there a gap there? That is where the incentives come into play. Is that in the future?

Juan Carlos replied. I would say yes, but I cannot guarantee that. Findings like this are what help drive some of our program developments. I imagine that when we go into this interim period of reevaluating the work and the research and start doing more research, this will be one of the things we look into. I am not going to promise that, but I think it is very likely that we will look at the cost effectiveness calculations and all the cost information and see where there may be programmatic potential there.

Brandon added. I would say that for someone in my world, having these metrics is incredibly helpful for having the energy benefit and financial conversation with the customer. This is awesome.

Pete Jacobs said. In the vein of inefficient ways to bring in ventilation air, I am curious if on any of the major remodel projects you looked at, was ventilation air brought in through repurposing an existing system as opposed to installing an engineered DOAS?

Rick replied. I do not think we would have insights.

Brandon added. Can I jump in on that, as an implementer? I am dealing with this in Klamath schools right now. We have found that it makes way more sense 95 percent of the time to put in new ductwork. That may not always be the case with newer buildings, but when you start dealing with older facilities, you have dirty ductwork that is not in good condition. You are really lucky if you have ductwork that is sized correctly for the new building that they are going to put in. So, we have a small amount of ductwork that we are able to repurpose for a couple of schools, but that is a very small percentage compared to the total. Newer retrofits are probably going to have a better chance of that.

Albert added in the chat window. There are better bricks studies by NEEA that did that study.

Pete Jacobs added. The reason I asked that question is if an existing ventilation system was repurposed to provide ventilation air and did minimal or no conditioning, it really affects the load that is imposed on the VRF system. The DOAS takes away all that ventilation load and then the VRF only has to do whatever sensible loads are going on inside the space. Simulation modeling is affected by how you set that up. Is that a common case or not?

Rick replied. I do not think we captured that in the permit data. We did not look at how things were demoed.

Bretnie added. There is usually not that much information about what was there before.

Chris asked one more question about VRF ERV. When you modeled it, did you model it fully decoupled, or did you model it after what NEEA is suggesting? Or did you model it as if the ventilation is partially decoupled? How did you model the VRF and ERV.

Rick replied. It was modeled decoupled.

Bretnie added. We actually worked with Neil Bulger at A2 Efficiency to make sure we were modeling it in a way that is consistent with how VHE DOAS has done it in the past.

Chris added. On the ERV, what efficiency level did you model it at?

Rick replied. The baseline was 50 percent and then the efficient case or the market case was a weighted average from the permit data which was about 60 or 62 percent.

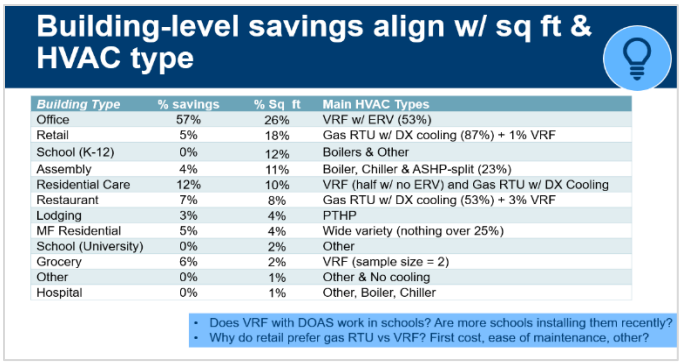
Bretnie added. So not quite VHE DOAS.

Chris confirmed. So, it was modeled fully decoupled and with about 62 to 65 percent.

Rick replied yes.

Brandon added in the chat window. Based on the condensation I see coming out of FCUs in classrooms and offices, I would say there is a fair amount of latent load being managed by the VRF/FCU. That is, with a DOAS/ERV also providing ventilation to those spaces.

Albert added in the chat window. If anyone wants a local retrofit VRF with ERV case study there is one here: https://betterbricks.com/case-studies/portland-firm-engineers-thermal-comfort-and-hvac-efficiency.



Rick continued. One other way to look at the savings here was by building type. We looked at HVAC type previously, and this is what it is by building type. The list here is by the floorspace that is covered in that building type in descending order. Not surprisingly, offices are the biggest portion of permitted construction. One of the more surprising things is that it is 57% of the savings that we calculated in the model. They were putting in a lot of VRF with ERVs. 53 percent of the floorspace in offices was served by VRF with ERVs. A couple of other things to look at are that the retail space is a pretty big percentage of the floorspace, not a huge chunk of savings. That is because there are still gas RTUs with DX cooling. DX cooling has some savings, but not nearly the order of magnitude of the ERVs. We did not see any, maybe 0.2 percent, but essentially no savings in schools even though it is a good chunk of the market. That is mainly because it is heated by boilers and other central systems. About 30 percent of the floorspace we saw was cooled by DX. The other thing to note is that residential care had a good chunk of savings because there was a good bit of VRF with the ERV.

Brandon replied. Yes, I do think that they do work in schools. There are some things that the operators need to learn. These are very different systems than they are used to, especially for replacing hydronic boiler systems or steam systems and less sophisticated or handling equipment. Making sure that they are on top of the maintenance is critical. With washable filters for example, you do not need to produce a custom maintenance program per facility and maybe even per room. In some cases, you might need four or five cleaning intervals in a year, depending on how the space is. And if you do not get those clean, those units will fail. The Achilles heel is partially the solid-state technology. Also, you need to make sure you have good controls contractors, because the supervisory overlay on top of the factory stuff, especially with the VRF, needs to be done right, otherwise it will never work. For my next projects, I al going to look at designing more of a hybrid system. We are starting to see refrigerant between the outdoor unit and the branch selector box. And then going to a hydronic system with the DSP fan coil units. Let's say that I have to replace a fan coil unit. That is a complex process, which is one of the downsides to the systems. In talking with my suppliers at Johnson Barrow, they are starting to see more of those hybrid systems being installed. I am really interested in looking at that in the future.

Pete Kramer added. In response to the second question, I think retail prefers gas because of cost. Package units are still very cheap and are readily available in the marketplace. The secondary piece is maintenance, it is easy to get contractors and parts are readily available. VRF and heat pump product have made a lot of progress today versus where it was 20 years ago. I think the competency within our contractor community is growing a lot. You probably still see some of those numbers there within schools, this is a function of that too where the savings are not coming up as much.

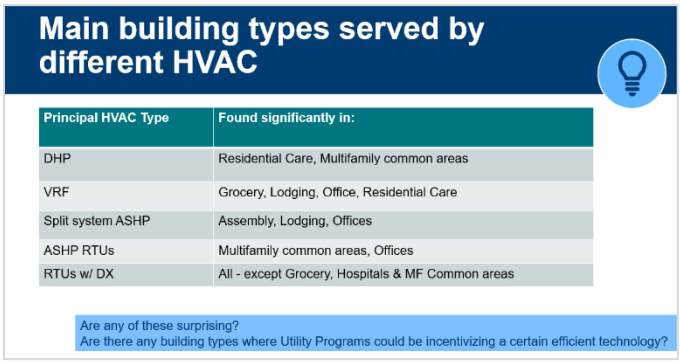
Chris had two comments. First about schools, we are looking at what we call HE DOAS, which is a sort of a hybrid system. But it is still doing the same thing as we do with VHE DOAS where we decouple the boiler in the fan coils and decouple the ventilation. You continue to have the boiler and the DX cooling, but now you are using a DOAS unit with ERV to help supplement. Obviously, the heating savings is still on the gas side because it is a boiler, but you can right size the boiler. So, you are not using as much boiler as it is, but you are also seeing the cooling savings on the DX side, because again, you have decoupled, and you are using the ERV to supplement and reduce the amount mechanical heating needed from either of those two units. It may not 100 percent get rid of the boilers because that is a tough thing for a school to do. Heat pump boilers are not quite able to provide the temperatures needed to do that. But for retail, I think that much of what was just said about why they are put on the RTUs versus VRF is that it is cheap and that is one of the reasons we are looking at ERVs on RTUs. Because

you can see our initial estimates are maybe 26 percent efficiency gain by putting ERV on an RTU either built in or bolt on. It allows for a huge gain in efficiency of that RTU where there are a lot of them out there without having to go to the extreme of decoupling, where a VRF does include some of that.

Rick asked Chris a question. Are you doing case studies or research on that schoolwork?

Chris replied. I have a case study right now that is out on one that we have done. We are in the process of deciding how we are going to proceed with it. But we will definitely have more case studies. Unfortunately, case studies for this type of work take a long time. If I had one that was installed today, I'm not going to have a case study for a year or longer. It will be a while before we have more. But we do have one for sure. Bretnie, if you do not have it, just tell me and I will ship it to you.

Interesting findings



Rick continued. These may not be surprising to anybody, but one of my big questions was where are all these technologies going, especially mini splits? So, we looked at our different principal technologies and then the building types they are commonly found in. They are also found in other building types, but these are the ones that have a significant amount of floorspace. Mini splits were in residential care, multifamily common areas. That made sense. VRF was in grocery, which was a little surprising. We did have a pretty small sample size for grocery buildings, so it would be great to get some feedback on that. But then VRF was also in lodging, office, and residential care. The split system heat pumps were in assemblies, assembly buildings, lodging, and offices. Heat pump rooftop units were in multifamily common areas and some offices also. DX, of course, was pretty much everywhere. We did not see them in grocery, but again, we had a small sample size on that. And we did not see them in hospitals and multifamily common areas.

Christian asked. The only one that stands out — and maybe it is just because it is mostly gas in the baseline — is any kind of RTU either or ASHP or RTU with DX in retail. Can you explain why that one is missing?

Rick replied. It would be in the in the RTU with the gas packs. It was very large, maybe 80 percent. Retail was served by these.

Pete Jacobs asked. I was curious about VRF applications and if you saw any of those going into spaces that were more or less single zone, which did not give you the opportunity to do any heat recovery from one side of the building to the other. Were there any situations you might classify as a misapplication of a VRF system?

Rick replied. I do not think we tracked any that were only single zone.

Bretnie clarified. We did not track whether or not it was single zone or multi.

Rick added. So that was not really one of our questions that we gave our permit data collection folks. So, I do not have any insights there.

Pete Jacobs added. I guess it depends on where in the grocery it goes. You could argue with VRF just serving the sales area, this might fall under that category.

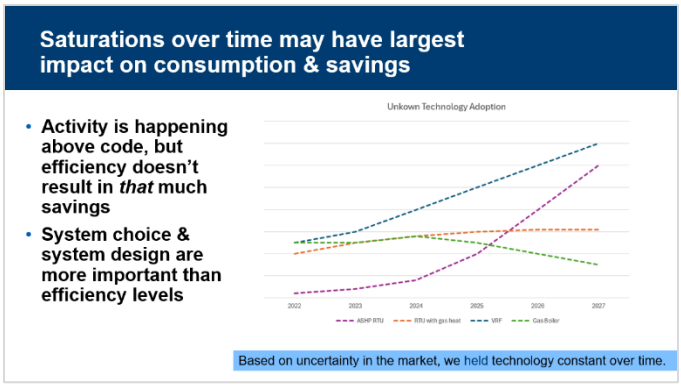
Rick replied. We did have one grocery building that had VRF and I was curious about that one. I looked at that one and it served a lot of the building, a little over 50 percent. But I cannot remember which

areas. I cannot give you insights there either, but that is good to know. Maybe we can maybe look at that later.

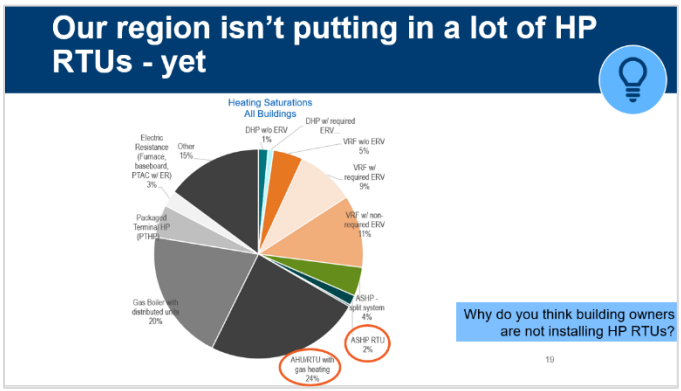
Brandon added. Talking about grocery stores, we are talking about a pretty sophisticated system, but a grocery store is a great opportunity to execute a lot of the cooling and heating loads with the VRF. You have case cooling, a meat and a deli selection, which typically is going to be cooled individually, and you have walk-ins. I am starting to see sit-down mini restaurant spaces and grocery stores that require more of a heating load around the checkout areas. Going back to my Department of Energy (DOE) days, these were conversations we would have. What if we could build out an entire hall that is entirely refrigerant based and you have a quick couple disconnects for your refrigerators, water heater, space heating, and everything. You could do the same with a grocery store. I do not think the technology is there yet. But getting to the question of is there a type of building that might benefit from a specific incentive to drive market transformation. That is an area that sticks out to them.

Rick replied. Are you saying having the cooling spaces, the walk in coolers and that kind of thing also cooled by the same system?

Brandon replied. Ultimately, yes. But we are not there yet. How cool would that be? Otherwise, I would say all buildings need utility incentives. Let's start throwing some more money into these projects. Albert added. Just to support what was said there, we are getting pretty close. Ecotope just got a study funded on a new heat pump product that combines domestic hot water with heating and cooling. Depending on the season and what your needs are in that application, it is big enough. It is CO_2 refrigerant with big domestic hot water storage. Maybe the grocery store does not use enough. But you can put the cooling in the freezers and the heating in the building, as long as the building needs the heating. So, we are getting there.



Rick continued. Just a reminder that this activity is happening above code, but efficiency does not result in that much savings. The efficiency above code of technologies is not a big factor, but the system choice and system design are more important. As we are moving into the next round of this model, these saturations over time may have the largest impact on consumption and savings. If people are putting in ERVs on ducted cooling systems, that is a good thing to note. But how these saturations change over time is going to be critical for us. And a reminder, because there was so much uncertainty on what would happen between now and 2027, we decided to keep them flat at the current level. In our model, all these lines are straight across, but we know that things are going to change over time.



Rick continued. In our permit data, heat pump RTUs were only 2 percent of the floorspace. But when you compare that with gas packs and with air handlers that have gas heating and DX cooling, that is 24 percent of the floorspace. There are a lot of those out there, and retail is a large chunk of them.

Why do you think building owners are not currently installing more heat pump rooftop units? Is it technology based where we are still catching up on the rooftops in heat pumps? Or is

it that it is just weird, and different people are not used to it yet? Or are there cost factors or maintenance factors or something else that that we should know about? Any insights into that?

Chris replied. We have obviously see a lot of this. We have a program specifically around the gas pack with this. I think that one of the biggest things that we see is that the majority of the energy use of that RTU is in the heating section. Twenty percent is cooling, 80 percent is heating. And the energy use in the modeling that we have done on this shows that even in moderate to cold climates, we have seen that it is about 80/20. Eighty percent of the energy use of an RTU is in the heating mode, not the cooling mode. And right now, especially if you get to cold climate areas, those heat pump are not efficient enough to be able to get out of going to your backup heating. So, you have to pay for two heating systems with those because you have to have a backup on it to take it down when it gets below a certain degree temperature. They cost more. There are a couple of different things that go into why they are not meeting it. One of the things that we are looking at is maybe going fuel neutral because the stuff we are looking at has efficiency gains regardless of the fuel. But that is more about the heating side than it is the cooling side. With RTUs, you are usually sized by cooling. The majority of the energy use is on the heating side. Right now, there are not a lot of rooftop heat pumps out there. And I think they cost significantly more than what it does to put in a gas pack.

Albert asked. I wonder if it also has to do with the loads in combination with what was said. I think these are more retail applications, which might have a different heating load. Something that is harder than an office building, which has high ventilation loads and those ventilation loads can match with maybe a VRF system. But as you get into these other applications, maybe the load and the defrost do not add up. I feel like it might have something to do with that because those RTUs need a lot of flow. That is difficult with an ERV because the more flow you give it, you lose some efficiency. Again, this is not my area of expertise and somebody more familiar with those applications might be able to comment on that.

Pete Jacobs added. I think the whole question about air source heat pump RTUs probably gets parsed into a couple different buckets. One would be a dual fuel air source heat pump RTU where you would size for cooling and run in heating mode but would switch over to gas at some reasonable point. My understanding is that those are available that the cold climate air source heat pumps that would allow one to do full displacement. There was important about those at the ASHRAE show a few months ago, but they are still just crawling their way into the market. I am sure distributors are taking orders just yet.

Rick replied. I was talking with Daikin, and they said California cannot get enough of these heat pump RTUs.

Brandon added. That sounds like Daikin. I would say that I have put in maybe about 60 tons of inverter heat pumps in the last couple of years with all with natural gas backup. That is our standard there so that we do not kill the offset. First cost is a hurdle, and these units are heavy. The structural reinforcements you have to do the rooftop framing sometimes might turn some people off. Especially if you are looking at replacing an existing unit, these are generally going to be heavier than your baseline unit. You are going to need a structural engineer and some additional structural members to reinforce the framing to support those loads. That can scare off contractors also.

Rick replied. I have always been surprised that they are heavier. It seems like it is the reversing valve, the heavy part.

Brandon added. They have a lot of pipe and a lot more material inside; the cabinets are bigger too.

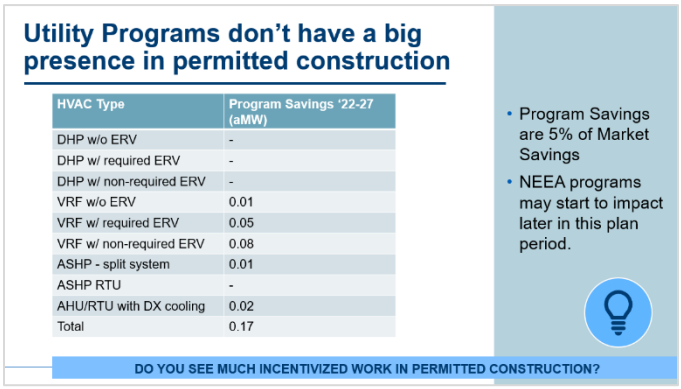
Chris added. I think the other part is that because the heat pump versions are not readily available that what we find a lot of this is the five-minute market, especially on the retrofit side, they need to replace it fairly quickly. What is in stock at the distributor makes a huge difference. If my RTU breaks, I do not have time to wait for them to get 9, 10, 20 weeks to get the heat pump unit replaced. But I can get a gas pack almost anywhere at any time pretty quickly. They probably do not have to wait very long for it

— less than a week — because they are everywhere. I think that makes a difference when it comes to replacement.

The other thing is, from what we have seen, they make these units live for a longer time than they maybe should live. They do not want to replace them because they are such a high first cost. And if it is even a higher first cost to go with the heat pump version of it, then you have additional external costs, it is the same problem with like condensing furnace rooftop units. There are so many added costs that make them unattractive.

Rick asked. What about with Washington and the new codes? Do you think we are going to start seeing more heat pump RTUs there?

Chris replied. Codes only apply to new construction, but they do not apply to retrofits. At least that is my understanding. So, I do not know. I think Washington would like to see the answer be yes, but I do not know if that is 100 percent true. It will depend. Seattle maybe but go to Spokane or tri-cities, I have a feeling you are probably not going to see as much of it.



Rick continued. Remember the 4.3 and average megawatts program savings was .2? That is 5 percent of the market savings for permitted construction. These are not retrofits, but for major remodels and for new construction there is not a lot of market activity currently. NEEA programs may really start to impact that later in this plan. But looking back at what we have seen in in the recent past, there were no program savings for mini splits or ductless heat pumps. Most of the activity was in the VRF area. Do you have any insights for the near future? Do you see much incentivized work in permitted construction? Not in retrofits, but in the potentially major remodels and new construction.

Bretnie asked. Is that surprising to anybody that we are not seeing a lot of program activity in this slice of the market?

Christian said. It is hard to overstate how low that number is. That seems very low. I have not heard of much program activity, so I guess I am not surprised. But it is eye opening.

Brandon added. It does not surprise me. I think it is a symptom of laziness. The architecture and engineering (A&E) community or design community does not look at projects the way energy people do. And the design engineer world is decoupled from the energy engineering world. It is almost incompatible. It is really unfortunate because this is where you can get a lot of traction. If you do an incremental benefit to cost analysis, if you look at the adder cost from code to premium efficiency, you would calculate the energy savings over the economic life where you pick some term. And if you can combine a utility incentive, often times it is very easy to make the case for cost-effective implementation on the better equipment. But that takes extra step and extra analytics. And the architects certainly are not going to do it. They can barely get the dimensions right, let alone be technical. The design engineers are very busy, which might be part of it. But also, they do not have the energy analytics training and are not looking at projects this way. There are very few companies that do, and they are not getting hired for new construction very often.

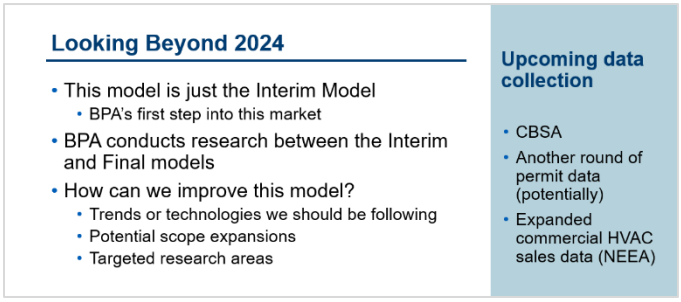
Chris added. The hardest part about new construction is that the baseline is so high, whether it is designed worked or not. Think of it as an RTU; the code set those pretty high. There is obviously better stuff out there, but everybody knows about stuff being cut when you do design. If you have a super high-efficient RTU and you can save $50,000 off of that by going to minimum code. And how much

savings is there between that and code minimum? You do not have a tough time producing that incentive between code minimum and what an efficient product is because there is not much extra savings there. Small incentives are not going to incentivize people go there. So, if we are going to see something, it will be on something that is not required by code, which is going to be the ERV. Other than Washington, where there are portions where that it is required. But that is going to be where you are going to see the ability to possibly have a utility incentive in place. If this is retrofit, that is a different story because they can do what is in place to what they are installing. If there is more ability to have more savings, it is there. But code minimum to whatever this is, that is tough unless you are going to go down that fully decoupled VHE DOAS route where you can show a huge savings number above what code. The problem with that is that tends to not be a deemed savings. That becomes a custom savings. Custom savings are always a bigger pain for everybody, utilities included. You do not really know what that is until you start to actually see the savings that are in place. And if you have one thing wrong, somebody does something, one wrong control thing or something switched, then all that savings goes out the window. Then there is no money the utility gets. It is tough when it comes to the new construction side for getting incentives.

Albert added in the chat window. If anyone wants a local retrofit VRF with ERV case study there is one here: https://betterbricks.com/case-studies/portland-firm-engineers-thermal-comfort-and-hvac-efficiency

Juan Carlos added. We know it is low. It might be a bit artificially low because many programs have just started. And since there was no data for us to forecast off of, we had to put in zeros. So, it might be a little bit low for what the reality will be at the end, and that is something we will look into during this interim. We know there are programs that are really early or are just starting that will affect that program number as we move into the second-half of our research.

Future research questions



Juan Carlos noted. As we move forward, we are going to finish the interim model over the next month, take your input and thoughts, and then finalize these numbers of the model. For the research period between the interim and final models, we are going to look back, brainstorm, and do a deep dive on the market to see what the value was of this model and think of ways we could improve it moving forward for the second model. We also are looking forward to some data collections that are happening. The commercial building stock assessment (CBSA) that NEEA is running is currently in process. They will start surveying next month. I am intimately involved in the planning for that. We should have results by early 2026. We will be able to include some of those results in our next model. There is a chance that we will do another permit study. We did a permit study from 2015-2020 that formed the basis of this study. It is a little dated, and we want to refresh that. We are hoping to do another permit study around the same time that CBSA gets followed up. The CBSA will give us stock data, and the permit study will give us new construction and large retrofit data. We have also been working really hard with NEEA and the industry to get some expanded HVAC sales data over the next couple of seasons. It has been very difficult to get sales data in the commercial space. We have been much more successful in the residential space, but the commercial space has been tough. If we are able to get that, it will inform the next model. Those are some of the things we are focused on in terms of data collection, but we do have these big questions on how we can improve this model. What trends or technologies did we not point out here that we should be following? How do we increase the scope if or do we increase the scope, is there targeted research areas we need to focus on?

Juan Carlos continued. In this period where we are not modeling, we are not focused on building the model and getting that momentum savings number. We are much more focused on the bigger pictures of what the market is doing and how we can improve our research. On the slide, we have a few questions for you. Are we starting to see RTUs getting installed more frequently? Are we seeing those RTUs in retrofits and remodels, new construction? What barriers are we seeing for heat pump installations?

Bretnie added. Do you think this is a trend worth following over the next five years? I think that the kind of question we are asking ourselves is do we think this is an area of growth?

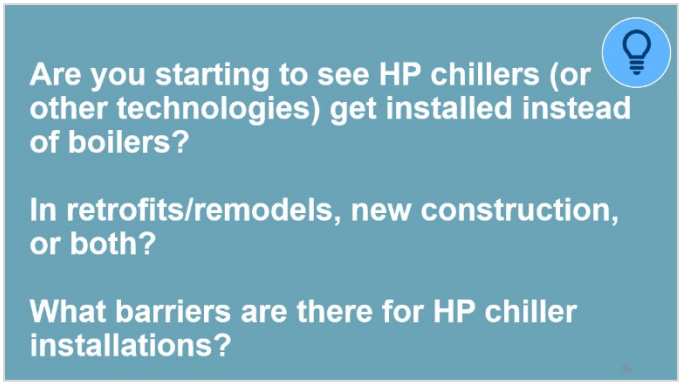
Rick added. It seems like the heat pump RTU technologies are changing and expanding. Do you agree that technology is going to have a big impact?

Chris replied. I think it is definitely worth keep an eye on. I think that there are a few things that are going to dictate some of this. I think local energy codes are going to define some of this. I do not know if I will see it taking over the market in the next 5 years. I think we might see steady growth, but I do not think it is going to be the predominant product in the RTU market. We are going to do a modeling study on all RTUs and how they work efficiency wise, including heat pump and cold climate RTUs that include ERVs and HRVs in multiple regions. It will also include gas, dual fuel, and electric. It will provide better understanding of the energy efficiency gains across the board on these units, especially if we can add ERVs to the RTUs. That study will be mid next year probably. Hopefully, that could be used to help make sure your modelling is defined by the stuff that is going to define this hip hop RTU world. Right now, they are more expensive and harder to get. If that changes, then you might see more of them. If code says you have to put them in, that changes and makes you do it. We have heard about all of those being potential barriers, e.g., they weigh more, especially if they are dual fuel. I think that is probably the more realistic route that this is going to go as a dual fuel unit. I do not think we are going to see an all-electric unit that is going to take over the world on this particular path. But I think we are going to see a switching valve put in on an RTU that will give you a gas pack with a heat pump. How that is programmed and where the changeover points are will define how where the more critical savings are going to be. That will be the more critical pieces. Where does it change over and where do you go from electric heat to gas heat and how efficient everything is? There are a lot of questions.

Pete Jacobs added. In terms of barriers, to the extent to which fully electric full displacement systems would enter the market, I would imagine that there may be some issues e.g., if it is just size for heating, it might bump a cabinet size, which might then mean a bigger curb, which might then mean larger ductwork, etc. Beyond the weight, there may be some dimension barriers that that people would have to solve. I do not know if anybody's seen that or not.

Chris replied. Yes, we have heard it. We have not seen it, but we have heard about all those as potential barriers.

Rick continued. Another potential opportunity is boilers. A lot of this floorspace is served by rooftops and gas packs. The other big chunk is, is gas boilers. In the permit data, we saw about 20 percent of the floorspace was served by gas boilers for permitted construction.



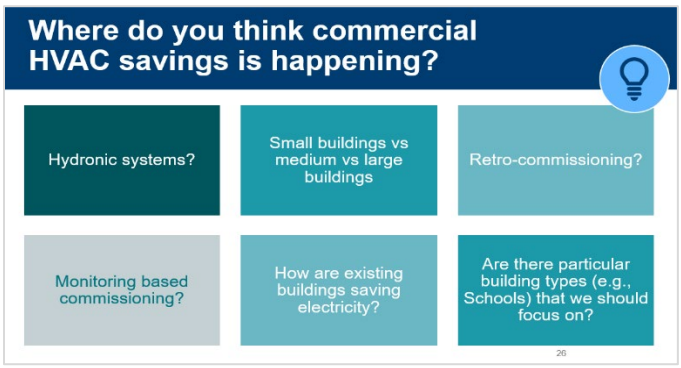
Rick continued. We have a similar question for displacing the boilers. Are you starting to see heat pump chillers, or some other technology, get installed instead of boilers? Is it happening in one type of construction versus another and what barriers do you see?

Peter Kramer replied. Typically, if you are swapping something that is gas, you are almost certainly going to have a high electrical service. So, what costs are there for upsizing that? I would say that could still apply, although less so here with a heat pump chiller, because you have a little more room to move with sizing. Typically, when chillers are sized and with the cooling loads that they are serving, there is quite a bit of heat you are getting off that you could effectively use. I would say it is less of an issue, and we are starting to see more interest in that. They are certainly making decisions not to select a boiler or some kind of gas-heated product and instead will try to extract heat out of the building with heat recovery and or heat pump chillers. They may use air source and try to extract the heat out of the air too. I definitely see it in retrofits when it is applicable.

Chris added. One of the barriers with a heat pump boiler is they are at the very front edge of technology. There is not a lot of room to grow on the heat pump boiler to get them up to temperature for what the systems are working on. But we saw some installed. And one of the things that we see as a barrier is where the boilers are located do not always have enough air for those systems to work properly. Or we have seen where you have had to install two of them and to make up for a boiler. And then you do not have enough air in the boiler room to allow for them to function properly. And then they fail. Or, in a snowstorm, they dump off all the cold air in there. And there are barriers on whether they fit where the old boiler was and whether they get enough airflow for a pump to work.

Pete Jacobs added. You might want to parse that boiler segment into hot water versus steam. And then on the hot water side, condensing versus noncondensing mostly for the ability of an air to water heat pump and some of the supply temperature limitations. The piece of the market that might fill in first would be the places where there are already existing condensing boilers, and the system is designed to run at a lower temperature. That would be compatible with available air to water heat pumps. **Rick** replied. That is a great point; we had not considered that.

Albert asked. I am assuming that this boiler question excludes domestic hot water, right? **Bretnie** added. Right now, the model would not consider that part of the commercial HVAC. Maybe a future model could be domestic hot water. **Albert** added. In domestic hot water, there is a lot going on, but the supply temperatures of air to water heat pumps and space conditioning are definitely still a challenge.



Rick continued. Where do you think commercial HVAC savings is happening that we could compare it to what we currently looked at, but are there other areas that we should be considering? This is what we are trying to get at here. Are there some sort of hydronic systems that we should pay attention to? Is it more important to look at a certain building size? I personally have a lot of hope, but not a lot of faith, in retrocommissioning and monitoring-based commissioning. I think there is some potential there, but I am not sure how or what. Currently, we are just looking at permitted construction.

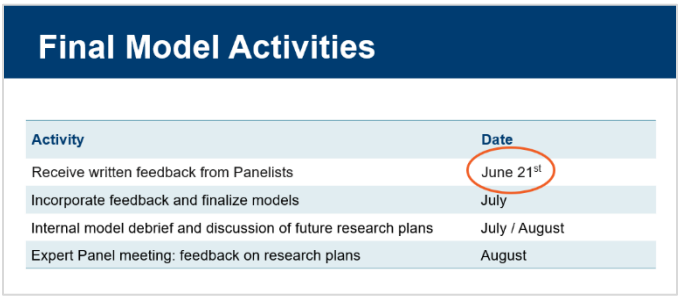
But what about existing buildings? What are they doing to save electricity? We have looked at those office, retail, and schools building types. Is there a particular one that we should be looking at in in the near future or is there anything else that we are missing here? Where do you think commercial HVAC savings is happening and where, where should we look?

Peter Kramer replied. Regarding commissioning, monitoring and retrocommissioning. Without a doubt, I think this should be an enormous driver for the existing building market. As much as you can continue to advocate or look at product and gain whatever percent efficiencies, whether it is off of code or even off of what was existing for product specs or performance. Ultimately, it is all about how stuff operates. How we manage in the buildings. And the “we” makes it really messy, murky, and challenging that “we” is a lot of people. It is every building operator. Education is key and there will be enormous ground to be gained in that world when we can help better manage. You try, as much as possible, to remove some of the human element from that. To some degree, VRF was doing a decent job in some cases. But you tie in that VRF system with overlaid BAS systems overhead and they start not communicating well or not managing the system well. And then you lose whatever gains you might have gotten. I think that is where it is going to exist, especially more of that monitoring-based where I think we are going to have systems that are going to be around for a long time, buildings should be around for a long time and mechanicals. The more we can manage them efficiently at low cost. Service contractors coming in with 6- or 7-figure service agreements to manage it is not going to move the needle.

Brandon added. I agree with Pete. Let's not give up on continuous monitor-based commissioning and retrocommissioning. We are going to lose all the benefit of this technology if we do not keep on top of it. Building operators just do not have the skills and the new building offers that are being hired, even less so. Private commercial is getting more outsourced. Again, it is the lowest common denominator. Something maybe to think about is, is there a place for the utilities and utility stakeholder groups to provide regional funding for circuit rider programs where you have a list of qualified retro commissioning agents, and they get assigned to a utility account? It is paid for by the utility and they go through twice a year and do seasonal tuning and retrocommissioning. It has to be supported. The industry is clearly not doing it on its own, and the building owners are not either. We barely even commissioned new buildings and that is still not in code. I think if there is a place for the utility to support that and make it “no pain all gain” for the building of it. That is when it will get better. **Rick** replied. One of my questions is how much are folks doing retrocommissioning, ESCO monitoring-based commissioning? I know Trane is working with Brain Box, is there any significant work there?

Peter Kramer replied. I think that is still a very new thing. I think that will remain to be seen. I am excited to see what comes from our partnership with Brain Box. Trane has been doing something for a while with their intelligence services, which is loosely monitoring-based commissioning. But I cannot speak to how significant or widespread it is within our region or across the country. But there has been some successes. I would like to think SEM programs are tracking what kind of progress they have made. I think some pretty extensive SEM has been going on for a while in Washington and Oregon. I do not know as much about Idaho and Montana. That overlays with what I think you would be trying to do in a monitoring-based commissioning effort. I really like what Brandon said earlier too as far as a potential go to market with the utilities.

What's next?



Juan Carlos discussed upcoming activities and the deadline for providing feedback for this working session.

Working Session: Research Planning – Aug. 22, 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: Juan Carlos Blacker, Bonnie Watson

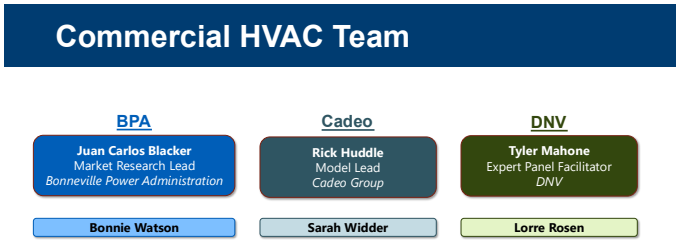
DNV: Tyler Mahone, Lorre Rosen, Alison Cyr

Cadeo: Rick Huddle, Sarah Widder

Invited Panelists	Affiliation	Attended	Did Not Attend
Albert Rooks	**Small Planet Supply**	☐	☒
Brandon Adams	**Vector Energy Solutions**	☒	☐
Cassandra Beck	**Trane**	☐	☒
Peter Kramer	**Trane**	☒	☐
Jesse Dean	**Edo Energy/McKinstry**	☐	☒
Mark Lessans	**Johnson Controls**	☐	☒
Pete Jacobs	**Building Metrics**	☒	☐
Eric Mullendore	**BPA**	☒	☐
Chris Wolgamott	**NEEA**	☐	☒
Kevin Smit	**Council**	☐	☒
Christian Douglass	**Council**	☒	☐

Introductions

Tyler introduced the presenters and panelists.



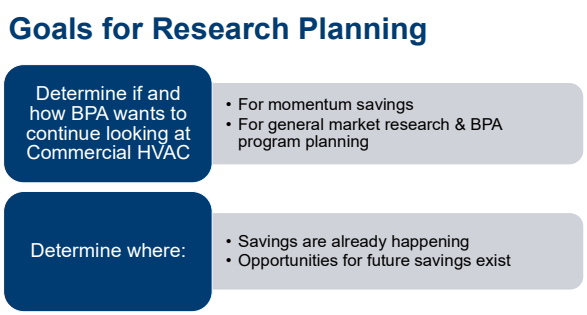
Juan Carlos discussed the purpose of this research planning meeting and discussed the agenda. We are now in what we call the interim results period. This is a period of about 1.5-2 years where we think about the research we have done, how the model was built, and what research we can do moving forward. If we want to keep the model the same in terms of the methodology and the data we are using, or if we want to change that up. It is also a period where we can talk about market research that is not directly related to the model and how and what might be valuable not only to BPA and our savings goals but also to the market as a whole.

Agenda

- Goals of research planning

- What we learned
- Brainstorming
- Next steps

Goals of Research Planning

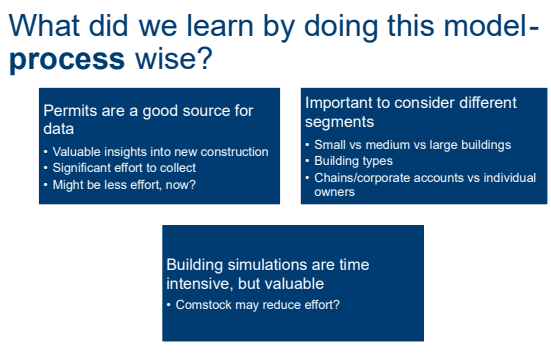


Juan Carlos continued. First, we are trying to determine if doing research in the commercial HVAC sector is still important for the momentum savings. That is how we justify our research. The momentum savings is a resource that we use at BPA. There is some actual monetary value to the momentum savings we gain even if it is not a huge amount. It was 1.7 average megawatts, which is small in the grand scheme of things. So, is it valuable for that? Second, is it valuable for the general market research and BPA program planning? We want to determine if continuing in this market makes sense. Are savings already happening without programs and without our research or are there opportunities there? If there are opportunities, what do they look like, where do they exist, and how do we get the data to claim them? That is our big goal for our planning period and a big goal for our discussion today. Can we answer some of these questions and what direction should we move going forward?

Tyler added. I will remind everybody that we want today to be a discussion. Please brainstorm, ask questions, probe context, etc. We are trying to understand where we want to move forward with commercial HVAC research and modeling.

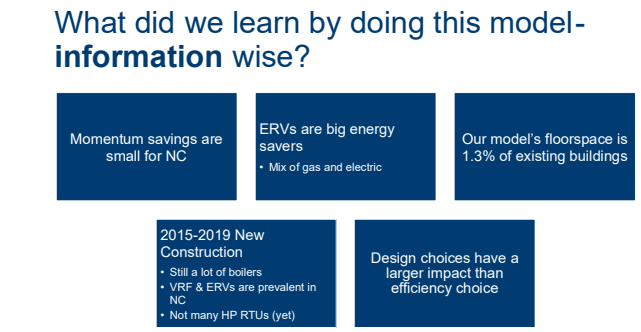
Juan Carlos added. It is also an opportunity for some of you to put in a plug for something you might want specifically for your own work.

What we Learned



Rick began by reminding everyone what we learned while developing this model. This first slide talks about what we learned process-wise. This is mainly important regarding how we did things and how we might do things differently in the future. First, the permits were a great source of data. The big permit data collection was very accurate and representative of the market. That was new construction and major remodels. It took a lot of time and effort to collect all that data. We question if it might be less of an effort now with more jurisdictions going to PDF permits and potentially even using AI to scrape the permits for data. **Juan Carlos** added. That first permit data collection was done during COVID.

Rick continued. Next, we realize that it is important to consider the different segments. Building type, the size of the buildings, and the ownership chain and corporate accounts versus owner-occupied buildings. Although time-intensive, building simulations were valuable and helpful as we compared different technologies in different regions. Those comparisons and all the 1200 different simulations felt like one of our big successes from the project. We might be able to use the Comstock data to reduce that effort.



Rick continued with information reminders. The momentum savings are small in permitted construction, new construction, and major remodels. The ERVs (Energy Recovery Ventilation) are big savings. You might remember that 80 percent of the savings in the model were from ERVs. Those are both gas and electric savings, but we only counted the electric. As we move forward and think about what to do next, remember that the model we created only covered 1.3 percent of the existing buildings. This is a really small portion of the total floor space in the region.

Juan Carlos added. That is because it is all based on the permits, which were new construction and major retrofits. There is quite a bit of the market that we are not covering. That is one of our big question marks/concerns.

Peter K. asked. I wanted to touch on that. You say a big concern is that you are still not evaluating or capturing a large percentage/the vast majority of the build environments, right?

Juan Carlos answered. Correct.

Peter K. added. It would be nice if these manufacturers, like Trane, provided you with information. I apologize, I have pushed in the past and am happy to be an advocate again. It is frustrating that we cannot get better data on what gets sent out. Are we going to talk more about the base of the data collection, ideas and thoughts, and what that could look like going forward?

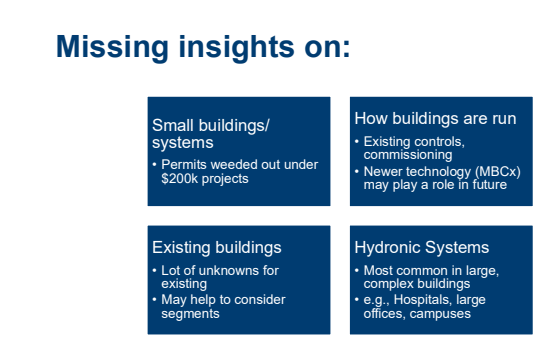
Juan Carlos answered Peter K. We have plenty of time to talk about that. And Peter, if you have insights we would love to hear them.

Rick continued. In the permitted data set that we saw, collected between 2015 and 2019, there were still a lot of boilers, VRF (Variable Refrigerant Flow) and ERVs were prevalent, and there were not many heat pump RTU (Rooftop Units) yet. Another thing to keep in mind is that we saw the design choices people install have a larger impact than efficiency choice upgrades. Changing from a HSPF (Heating Seasonal Performance Factor) of 8.8 to 9.5 is small potatoes when you consider if an ERV was put in. Those design choices are important.

Christian asked. Were the boilers mostly in Oregon? I am trying to think how far back the Washington code changes go. Or are these Washington buildings, right before the codes, that made gas hard to do? I assume these are gas.

Rick answered Christian. Yes, there are still a lot of gas boilers. It was throughout both Washington and Oregon. I think 2019 was before any of the changes or shifts were happening.

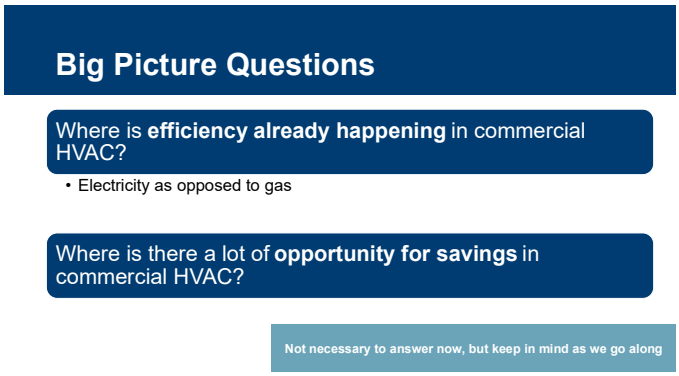
Juan Carlos added. Yes, those permits were prior to the new regulation.



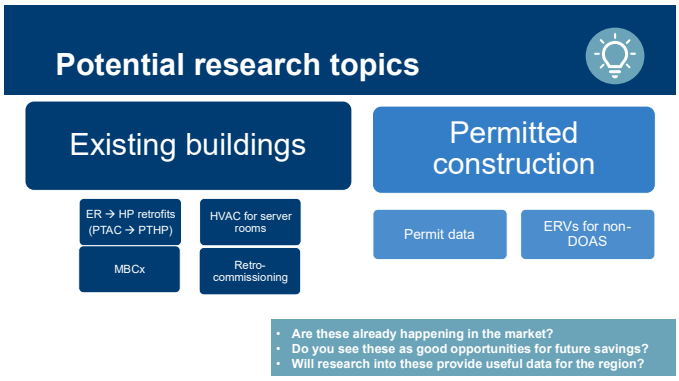
Rick continued. We did not look at small buildings or small systems in this interim model. During our permit data collection, we weeded out any projects that were under $200,000 in construction value in an attempt to focus on projects with HVAC. We probably missed out on some of the smaller tenant improvement projects. We did not get any insights into how buildings are run in the controls or commissioning of systems. We did a research project in early 2024 to see if we could include controls in our model but we had a big gap in data again. Maybe we can put our thinking caps back on as we talk about how buildings are run and if there are sources of data as we move along. Monitoring-based commissioning may play a role in collecting some of that in the future. Again, we did not have insights into existing buildings. We did not look at hydronic systems for a couple of reasons, mainly on the heating side. It was generally gas in the past, so we were not as concerned with that consumption and savings, but we are missing out on those hydronic systems.

Juan Carlos requested panelists share their thoughts on the big questions asked in the next 5 slides.

Brainstorming



Rick continued. We are curious about where efficiency is already happening in commercial HVAC. We are focused on electricity and where there is an opportunity for savings. We can think about those two separate buckets. These are just some thoughts to think about as we move forward.



Rick continued. These are the research topics that we currently have in mind. We are not sure if or how to do any or all of these, but these are the things we have been thinking about so far. Looking at existing versus permitted construction in existing buildings, the first idea we have is ER (Electric Resistance) to heat pump retrofits. In my mind, those are probably PTAC to PTHP. Lodging and residential care have a lot of PTACs. Are those switching over to PTHPs now or do you think they will in the future? Another one for existing buildings is HVAC in server rooms. This is not the big data centers. BPA has a couple of reasons for not looking at data centers. In commercial buildings, this would be a whole floor, or half of a floor, with a server room with a big HVAC load. How common are those? Are they trying to make those more efficient? Or are they making those more efficient? MBCx (Monitoring Base Commissioning), so that continuous commissioning, is that happening or can it be a big part in the future? Similarly with retro-commissioning, how much is happening? Can we get data on that? For permitted construction, we are curious about the permit data.

We would definitely consider another round of that. In our current model, we did not look at any heat or energy recovery on non-DOAS systems, we just did it for the DOAS systems. That might be another thing to consider. Our big picture questions are: Are these already happening in the market? Do you see these as good opportunities for the future savings? Will research into these provide useful data for the region?

Peter K. commented. As far as the monitoring base commissioning you showed here and in the previous slide, I can speak to things happening in Oregon and Energy Trust in particular. ETO had some programs. Some pilots in the past have had a tough time trying to move that along. It does get a little bit messy to manage. They have established SEM programs, as I think BPA does as well. There could be some clear overlap. Tons of opportunity exists for getting that built environment operating better. I have not heard or run into utilities across the country that are knocking it out of the park as far as figuring out how to do it and monitoring, tracking, capturing those savings, and ensuring things persist. Getting persistence is always a challenge. That falls in line with retro-commissioning to an extent.

You asked earlier, where savings are happening today in existing buildings. I think, first and foremost code. We have talked about it several times through the panel discussions. Code has driven a lot over the course of these four years. Code alone has made a healthy impact. I also think just general building controls, whether it is building automation or getting capable thermostat control in spaces like semi-smart thermostats, has helped move the needle. I think in commercial space that is where savings occur more than anything else. Because even if the customer elected to buy whatever percent improved efficiency piece of equipment, if that piece of equipment runs horribly you are not getting much benefit. As far as capturing or understanding the impacts, I do not have good insights yet, but I am sure other people on this call do.

Juan Carlos asked Peter K. Did you see more controls and/or monitoring-based commissioning projects in the sales you do outside of utility, without the utility program's assistance?

Peter K. answered Juan Carlos. I think several manufacturers, including Trane, in more of a service capacity versus a project or install base there is a lot more remote monitoring and monitoring-based commissioning we do for customers. Sometimes we can leverage it to get utility incentives or make it part of a program or pilot, but often we cannot. So yes, that is an offering that will only continue to grow. They are coming out. More and more, the Trane factory is coming out with products that come ready and available to start downloading smarts. I can monitor my chiller and see what is going on. Say there are drift points that are off, we can notify and do some type of corrective intervention in the name of energy. Without a doubt, that has grown over the tenure of my time at Trane and certainly a lot more in the last five years.

Rick asked Peter K. Is that mainly through Brain Box?

Peter K answered Rick. Brain Box AI and Trane are a recent connection. Everything I am speaking to predates Brain Box. This would be interesting as we step forward with that relationship. It will be interesting to see how that will look as we all try to implement AI in our entire lives, or it gets implemented in our entire lives. But what I was speaking to was good engineering concepts that were being implemented that we have currently today in product.

Eric commented. I have a couple of different thoughts here. Regarding the electric resistance to heat pump, we have a lot of downstream incentives targeting we have seen a sort of middling uptake. I am interested in current stock assessment. I know that it is going to be a few years. How much of that electric resistance really still exists in the commercial market? This is a major question for us. How much to dedicate to identifying and replacing that baseline? Assuming that there is some, I think a key approach for utility programs is how to identify those end users and screen for it using billing data. I can tell you there is not enough of it. Trying to do mass market outreach, we can offer enough money to 90

percent of the people who have the upgrade opportunity to make a more efficient choice, but not enough for them to replace their existing heat pump or their existing natural gas unit. For me, that feels like a very targeted program outreach effort.

For monitoring basic commissioning and retro-commissioning, I think of them as tools rather than program designs or measures. I am very interested in seeing both leveraged as part of SEM-type programs that look at whole-building approaches to calculating savings. I am hesitant to dive too deep into developing programs that are specific to those approaches because the tools in the toolbox might not be right for every building or building class. When I think of whole-building regression model approaches to calculating savings, I would rather keep that generic program approach and then see these things implemented as part of the approach to solving those. I will note that our SEM program has an incentive offering for performance tracking systems which could absolutely be leveraged to support a monitoring-based commissioning installation and the fees associated with doing that every year.

On the permit data, I am interested in whether the building performance standards in Washington and eventually in Oregon are pushing a higher rate of remodels that would trigger permit requirements. We have the city of Seattle and the state of Washington coming through and saying your existing buildings no longer get a free ride on this. You need to hit these EY targets, and we have fines associated with not doing that. If that drives a higher rate of remodel, we could see the percentage of the market covered by the permit data increase. This is something I hope to see happen. That alone would be a reason to go back. I know we are not going to pick up much of that activity in this next round, but we will at least have two data points, one pre-COVID and one sort of COVID and recovery time frame to set a baseline around remodel activity in the region.

Lastly, I will note that NEEA has a midstream program, a market transformation program around ERVs right now. They have set the bar fairly high on the efficiency in order to qualify but we might be able to go to the same distributors and get their non-qualifying units as well to get a better picture of ERV activity as a whole in the region.

Peter K. added to chat. For any commercial office space of a medium size, there is still a LOT of electric heat. Most buildings of this type use large VAV RTUs, and heat happens at the VAV box level.

Brandon commented. As somebody else in the field and industry, I want to echo Peter's comments. I think the biggest impact is for both monitored base commissioning and retro-commissioning. I do not think it necessarily needs to be a third party. Most contractors want to make sure the equipment is working right and if you are working with good reputable manufacturers, they also want to make sure their equipment is working right. Starting with commissioning, to make sure stuff is working right out of the gate, and then persistence. As we have seen in the modeling, the savings impact from these efficiency upgrades or increases is incremental. As we know, these buildings become runaway freight trains when they are not monitored and continually tuned. I have almost been in this business for 30 years and when I was still in college, we were talking about getting commissioning requirements in code and we are still not there. I think it is something we need to keep talking about. To point to something that is working, an example of this being supported by utilities on the industrial side, BPA still has an M&V requirement for certain conservation projects and industrial facilities. I think that adds a lot of value to the projects. I am thinking about compressed air projects, for example. There is something else to look at in addition to continuous monitor-based commissioning and retro-commissioning. But also, is there a way we can tie measurement verification into that at some point in the future if there is ever a program?

On permit construction, I agree with Eric. I am cautiously optimistic that the energy benchmarking legislation passed in Washington state will drive more meaningful retrofit, and we get better data from that. We are starting to look at that program ourselves to prepare ourselves for when that legislation makes it down to Oregon. Hopefully, that helps drive some of these retrofits. Outside of commercial

institutional public sector, I do not see a lot of private sector Class A office projects doing these kinds of projects out of the goodness of their heart. I think when you look at Washington state, the enforcement is going to be limited to public agencies. Then you are going to have a swath of private industry doing it because it is part of their corporate goals and responsibilities.

The last thing I will say is, I have a supplier partner I will reach out to. I talked to them about this program, and they expressed some interest in trying to help. I will reach back out to them on their willingness to share some of their sales data to see how much VRF with heat recoveries going out DOAS with heat recovery to help your data set. I will let you know how that conversation goes, Rick.

Rick replied. Thank you, Brandon. I appreciate that.

Pete J. commented. One comment on the monitoring-based commissioning, I agree with Brandon about its role in this ecosystem. I think monitoring-based commissioning is a tool to identify projects and track persistence, but it is not a particularly good tool for savings calculations. Based on experience in other states where MBX programs have been evaluated, especially the pre-data, there is often not enough data, or it is taken at the wrong time of year to come up with a reliable savings estimate. It is great for identifying opportunities and the post data is great to verify the savings that the actions persist, but in terms of energy savings calculations, a separate IPMVP Option C style analysis with adequate pre/post data and good model statistics is the right way to go.

Rick asked Pete J. I am curious, Pete, have you looked at any insights into NYCERDA's MBCx program?

Pete J. answered Rick. No, I have not. My MBCx experience is all in California.

Christian commented. On the whole, I think you have identified 90 percent of what I would identify, and all these look interesting. We have to identify where the electric heating opportunities are, which can be tricky. Remind me, do we consider mid and high-rise multifamily commercial or residential?

Rick answered. The in-unit is residential, but we have been trying to capture anything that is common area in our model.

Christian added. I do not know if there is the ability to change that scope. When you look at the data, you see electric heating anywhere you have living or sleeping spaces. You identified lodging, there is a lot of PTAC to PTHP, especially if we start to see better PTHPs, inverter-driven ones, but also zonal, baseboard, there is still a fair amount of that. If there is the ability to look at mid/high rise multifamily, there is still a ton of electric zonal heating there. I think that it is an untapped market where we are actually looking at an electric baseline. Another big one is in existing buildings. It is difficult because it is a really small commercial. A lot of the 'commercial' out there is almost like residential construction, but they are businesses. A lot of those have residential-style systems. You see a lot of zonal electric resistance heating, residential-style electric furnaces, DHPs, etc. I think there are DHP and zonal opportunities out there in terms of existing buildings. For permitted I am curious what you think about this, looking at buildings with existing VAV with electric reheat. I realize there is a little bit of gas there doing some preheating and tempering, but we hear that the primary heat is electric and there is a ton of it. Going from a system like that to VRF with DOAS, I wonder if that is something we could look at.

Rick added. I am curious what other industry folks think about that. To me, that seems like a huge infrastructure change. You need to have a much bigger driver than just the electrical savings. Maybe a corporate ESG goal is driving that, but it is probably not savings.

Peter K. added. In the commercial office building market, there is a lot of VAV (Variable Air Volume) electric heat today. There is not a drop in replacement solution that is a lot more efficient. You start having to tie back to the main system. To your point Rick, you are then starting to look at like VRF, but you are yarding out the whole thing. Nike headquarters as an example, their campus buildings in Beaverton were built over a 20 year period. Some have been retrofitted now. They have done the brute

force, moving everyone out to do a total gut, which I do not see as practical. They are doing it for various reasons. At that point they are converting, they are going away from electric and doing either a heat pump or VRF style solution. Actually, in some cases, some of the electrical is still staying in place but they are making sure they do not have any gas. To my knowledge, Trane does not have a great solution yet. Hopefully someday in the near future, they can come up with something. But that is a messy one in my opinion.

Eric asked. It is something we would see in the remodel data.

Rick answered Eric. Yes, that is a major remodel for sure.

Tyler asked. You mentioned earlier the cut off used in the previous round of data collection was $200,000 projects and we were able to do a sample there. Why was that threshold picked? You mentioned using AI or something to try to gather data from PDFs. Do you have any sense of how that market would expand from lowering that threshold on permits?

Rick answered. I will start with why we did that; I think that will help explain. I am not sure how scientific the $200,000 was, but when you get under a certain level, there is the opportunity for projects that do not have HVAC at all. If we look at all of those permits, we have to look to see if it had HVAC. So now, we just spent 30 minutes to an hour looking at this permit that did not have any HVAC at all, which was useless to us. So, it was a way of weeding out projects that would not pertain to us. It could be interesting if there is a better way to weed those out or do it quicker. It would be great to include those, we could see some of those smaller retrofits like Christian said.

Tyler added. I was thinking about the MBCx and Retro-commissioning, those programs and buildings are a great driver of savings. I am curious how it would affect momentum savings. How much of that is happening outside of program activity that is affected by prior program activity, where you would see that drift from a baseline to something that is not program-related? While I do think that is an interesting energy savings area, I would want to know more before recommending that for momentum savings.

Eric added to chat. And how to quantify impact.

Sarah asked the industry folks. Manufacturers are certainly developing these tools, offering services, and expanding their smart capable technologies. To the extent people are adopting them, how much is driven by savings versus operational comfort performance, better insight into the building, or other things besides savings? To Tyler's point, that could be something that would drive adoption outside of a program if people are doing these for other non-energy-based reasons. I do not know if anybody has insight into that.

Peter K. replied to Sarah. I cannot speak to the rest of Trane across the US, but here within our office serving Oregon and Washington. I would say the customer said yes to probably 80 percent or more of the intelligence services monitoring we are doing because of operational benefits, not energy savings. A little biased but I would attribute some of it to the people out there selling, advocating, or presenting it to the customer. I do not think they are doing a good job presenting the energy component to it. The customers see value because it is a lower cost of service oftentimes. Example: “Hey, we can help maintain your building at a lower cost per year because we are not rolling trucks as often, etc.” And I think that is consistent from what I have seen for at least some of our counterparts.

Eric added. I would say even in our energy programs, that is often a key selling point for these types of systems. In fact, there is generally resistance to the energy savings component because you are usually pitching them to facilities folks. Because this is their job, they are resistant to the idea that the buildings are not currently well controlled.

Eric commented. I am kind of bullish personally on the building performance standards and their potential to impact energy use. Just like your study here, codes have forever been limited to new

construction and major remodel. I know we are already grouping codes and federal regulations there, but I would really consider building performance standards as a new class of code that greatly expands the potential impact. It is the stick that we have been waiting for on the utility side and we are just holding carrots. I could see that having a significant impact on HVAC. I am also very interested in seeing whether time of use impacts or time of use rates start to drive different choices in equipment selection and increase focus on reducing the peak demand of these systems. I know that is not where the building performance standards are pointed. They are completely annual, but it could have the time of use rates again, money talks and the extra money that people are going to spend meeting those peak demands is likely to drive behavior. Potentially even more than the fines coming for none not meeting the EUI targets on the building performance statements. Lastly, I do not know about artificial intelligence, but I think just advancement in controls and reduce cost and improved reliability of control systems is going to be a major driver over the next two to five years. It already is, but it is a wave that has not crested yet.

Rick asked Eric. On the time of use, I am not familiar if those are happening in our region yet. Do you know? **Eric** replied. It is coming. Some of the larger PUDs have already shifted and I think you will continue to see pressure in that direction.

Brandon commented. To follow up to what we were talking about earlier, the switch from an electric resistance to a reheat to maybe like a hydronic source or something. One of the things that will prevent that kind of project from happening is virtually no utility programs will incentivize a fuel switch, even if you are saving BTUs. One thing I am curious about the VRF technology is that we are still not solving the greenhouse gas issue with the refrigerants. Some of the new refrigerants are actually worse for the environment than the old stuff we have been using. A comment I made a couple of rounds ago is talking with our VRF suppliers. I am curious if Pete is seeing more of this through Trane. They are starting to design and sell these hybrid systems where it is refrigerant on the condenser side and hydronic on the downstream side of the branch locker box. I think there is going to be other potential hurdles or bottlenecks to driving refrigerant based heating and cooling solution because of environmental regulation that is going to try to manage and mitigate the refrigerants. On the AI conversation, it seems like this is not a 2- to 5-year outlook, it is a little longer, but I think there is a lot of momentum starting to build right now. I am looking at more AI-based smart grid applications. I am not talking utility meters that help them with time of use, but I am looking at a pitch deck right now on one of my monitors from Grid Science AI. They are pitching a smart transformer, smart grid technology that is able to monitor load profiles and basically manage the grid based on how much EV charging load there is and how much net metering is going on from solar install. They are able to see when components are failing so part of their pitch is forest fire mitigation. I do think this ties into the owner's side of the meter and the monitoring piece at some point. But curious to see if we take advantage of this time we are in where our transmission and generation infrastructure is not only antiquated, but the generation infrastructure is starting to change as we are taking dams out. And are we going to see this new technology make its way into that rebuild or is it going to be more of the same? I think there is a lot of opportunity there.

Eric asked in chat. Is that switch to hybrid greatly impacting price per sq ft? **Peter K.** replied in chat. Brandon, yes, that hybrid VRF I think is where Trane is focused for VRF. Pulling a lot of refrigerant out of the system and out of the building is important. **Eric** asked in chat. Peter, do you have any thoughts on my question about project cost? **Peter K.** replied in chat. I would be bad at making a guess. My gut is it would be more than a 'traditional' VRF all other things being the same. I am happy to reach out to our VRF experts at Trane to see if they have a handle on this. Let me know. **Eric** replied in chat. That would be great. I'm wondering if it is going to slow overall adoption of VRF. **Peter K** replied in chat. Yeah, it might. I will ask some questions within Trane and get back to you.

Rick continued. A different way of thinking about this is what is changing and what segments are important over the next few years. We can think about building types and ownership types. Are office is going to come back? I listed all of the different building types here, schools, retail, assembly, etc. Does anything pop out that you think will change in the near future? And then the ownership types like we talked about. If chain restaurants, for instance, have the ESG goals that are going to be driving things. We should be paying attention to ownership and building types.

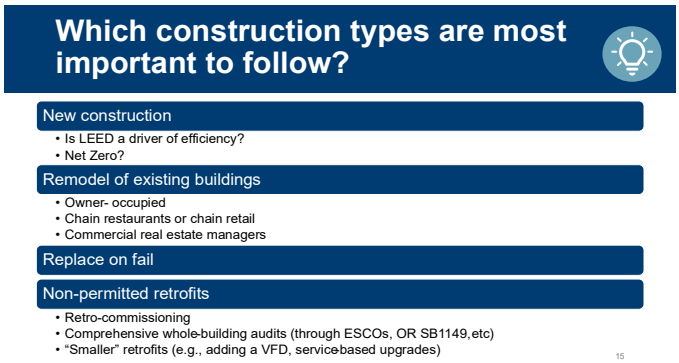
Eric added. On the program side, we have continued to see low levels of activity in the office space. That might be a lagging indicator. I do not know but certainly not expecting occupancy and total square footage of offices in the region to rebound and start growing again like they were pre-pandemic. Schools have seen a lot of investment though really varied. It is very jurisdictional; some are growing and have huge budgets. Washington is sort of a cluster, for lack of a better term, for many school districts because they have this mandate but no funding to meet it with the building performance standards. They are struggling badly. For others, it is a great opportunity, and they are identifying those laggard schools and helping get them in good shape. But definitely some rural areas that are that are struggling. I would say multifamily/mixed-use continues to be one of BPA's biggest hurdles for the way we split that across two different sectors and do not have a great solution on how to engage that portion of the market. I have seen a lot of activity. I do not have any comments on ownership model, but I am interested. Rick, you made a comment about the ESG pressures on some of the corporate chains. I do hear that in interactions with different folks, but they still must make every project pay off so they would happily miss their ESG target if it kept costs down.

Pete J. added. Following up on a previous comment and that earlier slide talked a little bit about codes and standards. I am also curious about the intersection of policy and rate making. It may not be as big a deal in the Northwest, but I know in other parts of the country fuel switching from gas to electric, even with a really efficient heat pump is not a great deal for the customer, just customer energy cost wise. The extent of conversations where the policy people influence rate making such that the differential between electric and gas can be brought to the point where it is a good deal for the customer. I think that it is going to drive a lot of it too.

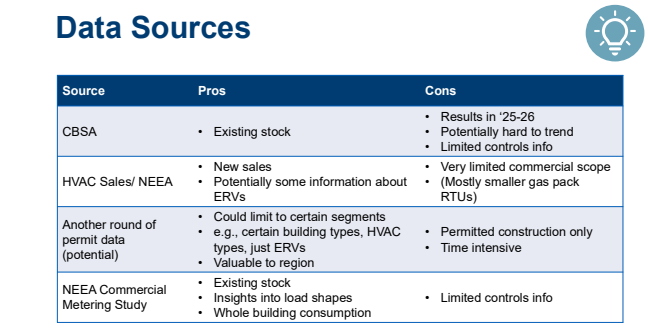
Eric added. On the industrial side, we have been looking at industrial heat pumps and it looks like there needs to be at least a four-to-one spread on the cost of gas to electricity where it needs to hit that or less before it becomes cost effective to fuel switch.

Pete J. added. You need to have a COP of four before it breaks even on the customer energy cost side. And then you need to go beyond that to justify the investment.

Brandon added. Depending on the electric utility you are still maybe worse off in terms. For Pacific Power, you are going to need way better than four COP to offset 11.7 BTS per metric tons per therm.



Juan Carlos added. Let us skip this slide as it is similar and jump to data sources to give everybody an indication of what is possibly available to us for the next modeling period. I want to talk a bit about where else we might be able to augment this.



Juan Carlos continued. NEEA is currently conducting the CBSA, the commercial building stock assessment. The results will be ready by early 2026. We have to finish our model in 2027. I am involved in the planning of that study so we should be able to get a lot of existing stock data which we can compare back to the earlier CBSAs from 2019 to 2014. There may be a lot of data we can add to the model for the next model iteration. Hopefully, the data is thorough enough to get what we need. NEEA is also doing HVAC sales collection. We are currently in the process of analyzing the 2023 data. The problem with the HVAC sales data we get from NEEA is that it is very limited in the commercial scope. It works well for our residential HVAC model, but not so much for our commercial HVAC model. They have promised to try to get more commercial sales data in there. And Pete, this is where you come in, maybe there is some way to help. As we showed at the beginning, the permit data we did went from 2015 to 2019 permits, so it is dated. Does it make sense for our second iteration to follow up with another permit data collection with a similar scope, or maybe even a different scope, than the one we did before? I think it is rather important we do another permit data if we are going to finalize this model, but I wanted to get your thoughts on that. And then finally, there is this Commercial Metering Study which will give us some information on existing socks and insights of the load shapes, but it is limited in control info. So those are the data sources we know are coming and that we could potentially use in the next model or in general market research. We would like your thoughts on these sources or any other data sources you think we might be able to get within the next year/year-and-a-half that could help inform our research, both for the model and for general research purposes.

Brandon added in chat. Actually, NG is 11.7 lbs/therm.

Rick added. You can see in the CBSA and the NEEA Commercial Metering Study the limited controls info. We do not have much information on how buildings are run for any of them so if you have any ideas on what or how to get that information, it would be great.

Christian commented. On the NEEA Commercial Metering Study, even though we might not have audit type data on the controls. From what we have seen from HEMs, you can still pick up on some control stuff empirically, seeing resistance spikes and how those correlate to temperature and other things. You might be able to see similar things on ventilation loads; getting ventilation spikes correlated to outdoor temperature. I am always a fan of those data sets. On the permit data, I personally think that it is fruitful especially if we can throw something automated at it. I do not know how sophisticated it would need to be. If you can throw a bunch of those PDFs in one folder and have a simple Python crawling script crawl through those to look for keywords, that could do a lot of good. I would throw that out there as a possible avenue.

Tyler replied to Christian. We have some automated document readers that could work pretty well for something like that.

Eric added. I am always interested in what is happening on the controls side in general, but I struggle to see that as a momentum savings play because we do not have enough information about the savings impact to develop a top-down model on the net impact in our region. At some point, I would love to see the states start sharing some of their EUI data. That seems like the whole building approach. I know NEEA has pitched this as a market transformation effort. I could see that being a way to scoop up the impact of those controls without trying to build it bottoms-up per unit. I like the idea of getting another round of permit data. It has the potential to see if there are any trends. We did it once in a very particular time frame. See if there is any trending there, particularly around fuel choice and the system design. That is where we said the majority of the savings is from, somebody's choice to go VRF with an energy recovery ventilation, which has a big impact on the total energy use of their building. That seems like it fits within our momentum savings or market transformation, any sort of market model approach to seeing the savings.

Juan Carlos asked Peter K. Peter you mentioned at the beginning that you would love to try to get Trane to provide sales data or some market data, which would be fantastic, but for our purposes, it becomes difficult if we only get one manufacturer. Do you have any thoughts on how we might be able to get all manufacturers to provide data? Or more than one?

Peter K. replied to Juan Carlos. I think you have been on some of those conversations in the past. The commentary back is there is HRI data. You just use HRI data to help explain and it only goes so far, there is not a lot of granularity to that data set. There is a limited list of categories captured with that. The best and foremost is to try to do it industry-wide so you do not need to rely on the manufacturers. I have been working hard within Trane to get them to share willingly. I have said this is very safe and there are NDAs in place so we can ensure the data is safe and secure. I really do not know how you can get Trane, let alone others, to step up willingly. It seems there is always a concern, they are worried that sensitive information would make its way out.

Sarah asked Peter K. I have a follow-up question to that Peter. What level of granularity is shared with HRI that then creates the high-level results?

Peter K. replied to Sarah. I do not know the details of that. I used to get more reporting but now I see less of it. Maybe it still exists. It feels like I am less aware of what is being made available. From a geographical perspective, you can get down somewhat tight to states, or maybe even tighter than that. But it is not project specific. Whether it is done monthly or quarterly, the manufacturers are presenting what went out to the marketplace. Where I speak to limited granularity is certainly on the details of what went out. It is like, “there were commercial 5 to 10 ton package rooftop units and these went out,” but no specifics about performance efficiency or otherwise.

Closing

Tyler and Juan Carlos requested any additional thoughts and feedback within the next week, reminded folks the next panel will likely be in the new year, and thanked everyone for their participation and feedback.