Memorandum

To: Bonnie Watson, Bonneville Power Administration

From: Kate Bushman and the Commercial HVAC Team, Cadeo Group

Date: October 23, 2020

Subject: TO32.0001C Commercial HVAC Momentum Savings Methodology

Introduction

This memo outlines the Cadeo team's (the research team or the team) methodology for the Bonneville Power Administration (BPA) to estimate commercial HVAC electricity consumption and Momentum Savings for the Northwest Power and Conservation Council's (the Council) Seventh Power Plan (Seventh Plan) Action Plan Period (2016–2021).

This memo primarily describes the team's methodology for the Seventh Power Plan Action Plan Period (2016-2021). BPA anticipates extending the Commercial HVAC Market Model into the 2021 Power Plan Action Plan Period (2022-2027), in which case, the team will update the methodology to reflect 2021 Plan updates.[1]

BPA is interested in the commercial HVAC market because of its large energy consumption, potential for new technology adoption, and significant potential for market energy savings. BPA's goals for measuring this market are:

1. Understand how commercial HVAC trends are changing over the Seventh Plan and/or 2021 Plan Period.
2. Estimate electric Momentum Savings (kWh or aMW[2]) for the Seventh Plan and/or 2021 Plan Period.
3. Gather valuable data insights about the commercial HVAC market by reviewing and cataloging data from building permit drawings.

This memo precedes model input development and offers a high-level summary of the initial methodology the team plans to use to build the model. This document also identifies key issues the team will address during future model development phases. The research team will continue to refine and revise this methodology during future phases of work.

[1] At the time of this memo, the Council had not finalized the 2021 Plan, so the memo primarily describes the team's methodology for the Seventh Plan Period; however, the team will update the methodology for the 2021 Plan Period after the Council finalizes the Plan and when BPA decides to pursue a 2021 Plan market model.

[2] Average Megawatts (aMW) represent the cumulative impact of energy savings on generation. They are calculated based on the MWh reduction in a given year divided by 8,760 hours to determine the average instantaneous power reduction associated with the given energy savings.

The following sections describe the team's proposed methodology using BPA's Four Question Framework, the standard analytical framework for estimating Momentum Savings.[3] Each section describes the key data sources the team plans to use, recommended analytical decisions, and the assumptions underpinning this methodology.

Methodology

Momentum Savings Analysis Framework

This methodology follows the Four Question Framework, BPA's standard analytical framework for estimating Momentum Savings. The Four Questions, described in greater detail in the following sections, are:

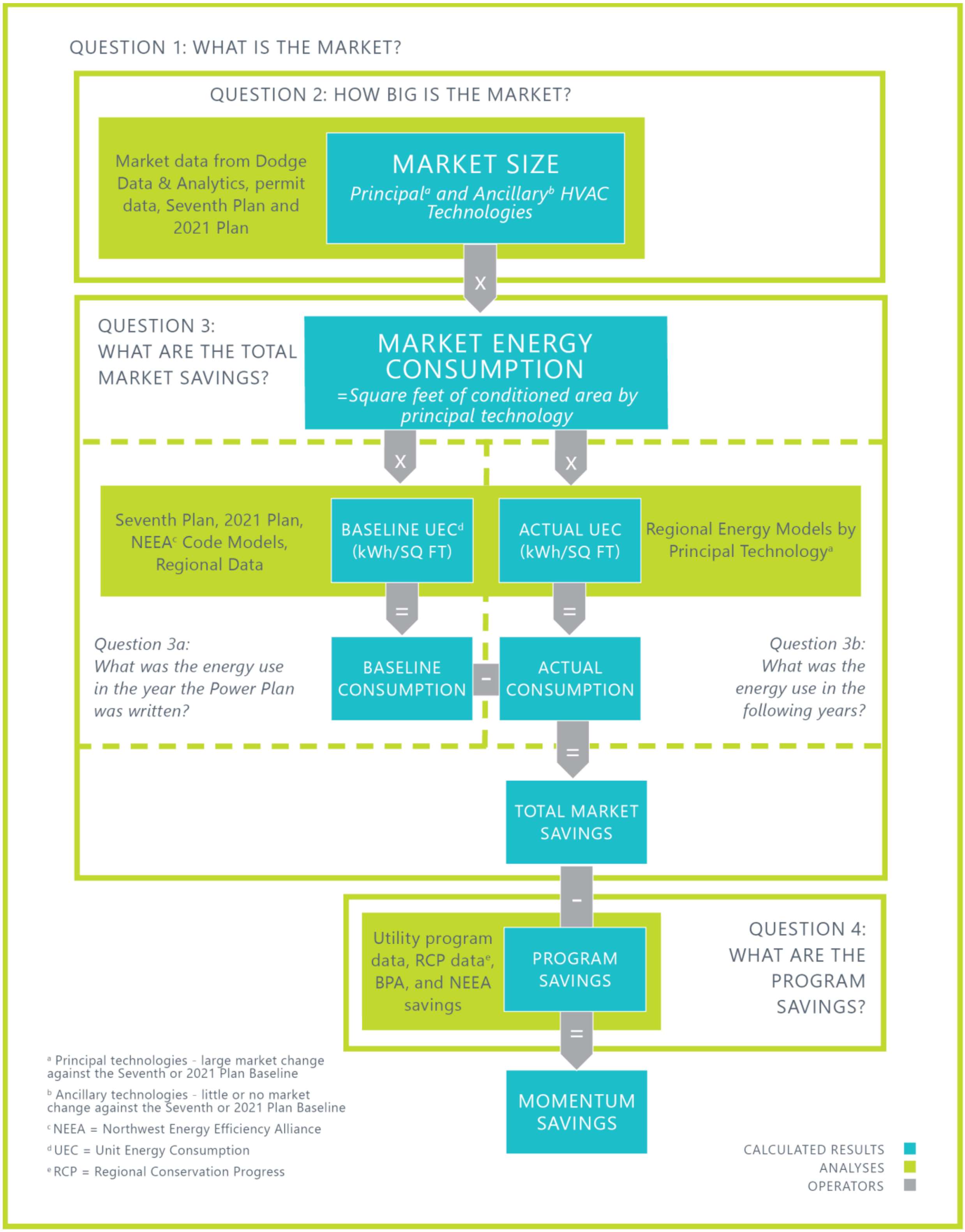
1. What is the market?
2. How big is the market?
3. What are the total market savings?
    a. What was the energy use in the year the Plan was written?
    b. What was the actual energy use in the following years?
4. What are the program savings?

Answers to these questions provide the information necessary to estimate Momentum Savings, which are energy savings above the Council's Seventh Plan or 2021 Plan baseline not reported by programs and not included in the Northwest Energy Efficiency Alliance's (NEEA) net market effects. This memo outlines the team's proposed approach to answering these questions in relation to the commercial HVAC market.

Figure 1 on the following page summarizes how the Four Questions fit together, including details specific to the commercial HVAC market and relevant data sources.

[3] Available at www.bpa.gov/EE/Utility/research-archive/Documents/Momentum-Savings-Resources/Methods_for_calculating_Momentum_Savings.pdf

Figure 1: Overview of the Momentum Savings Analysis Framework for Commercial HVAC



Preliminary Scoping Study

The team conducted a pilot study in 2019 on behalf of BPA to confirm the presence of commercial HVAC market change and to test building permits as a data source for quantifying that change. The team reviewed public building permit records in search of data to inform a potential commercial HVAC Momentum Savings model. Through this exploratory pilot study, the team collected, analyzed, and cataloged detailed mechanical permit data for 50 target buildings.

During the pilot study, the team discovered three key points concerning permits:

1. They are publicly available across the region.
2. They contain detailed commercial HVAC information that can be collected and cataloged.
3. There is substantial evidence of commercial HVAC savings above code.

In a separate 2020 study, the team also explored the reliability of permit data in accurately representing installed systems. The results of these two studies indicate permits are an accurate representation of the installed HVAC systems. The team documented the findings and methodology from the two studies in two BPA memos, which provide greater detail.[4,5]

The team developed the commercial HVAC methodology based on lessons learned during the preliminary scoping study and subsequent commercial HVAC investigation.

Question 1: What is the market?

Question 1 defines the scope of the analysis. The research team defines the commercial HVAC market by technology, sector, building type, fuel type, and geography. Table 1 on the following page provides an overview of the team's market definition as it relates to the model scope. The sections following the table describe additional detail on each element.

[4] Cadeo Group, "Lessons Learned from Commercial HVAC Permit Review, TO26 Deliverable 0003," BPA, January 2020
[5] Cadeo Group, "Permit vs As-Installed Investigation Findings, TO32 Deliverable 0001B", BPA, July 2020

Table 1: Market Definition

Element	Description	Notes
Geographic scope	Oregon, Washington, Idaho, and Western Montana	Includes the four-state region, consistent with the Council's Seventh Plan and 2021 Plan.
Sector and building type scope	All commercial building types with mechanical permits required to meet energy code completed during the analysis period	Includes commercial new construction, additions, and alterations. Includes multifamily buildings, limited to four or more floors with central HVAC systems and common areas. Excludes in-unit HVAC systems and industrial process applications.
Analysis period	2016-2021	Permitted commercial HVAC systems completed between January 1, 2016 and December 31, 2021.
Technology scope	All commercial HVAC systems entering the stock through a permitting process	The model will separate HVAC types into principal and ancillary technologies.[6] The team will collect saturations of all HVAC types to characterize the full market; however, the model will only calculate baseline and actual energy consumption of principal technologies.
Fuel type scope	Electric and gas HVAC equipment	The team will collect saturations of all HVAC types, including non-electric technologies, to characterize the full market; however, the model will only calculate baseline and actual energy consumption of principal technologies. Non-electric technologies will be treated as ancillary technologies.[6]
Unit of account	Square feet of conditioned space	This measurement is appropriate for commercial buildings because HVAC energy consumption per square foot is easier to obtain and can be characterized more consistently than energy consumption per building.

Geographic Scope

The commercial HVAC market includes the technologies summarized above installed in Oregon, Washington, Idaho, and Western Montana, consistent with the Plan's geographic scope, as defined by the Council.[7] The research team excludes building stock in Eastern Montana, also consistent with the Plan's geographic scope.

[6] Principal technologies represent technologies the team identified in the pilot study as the source of the most market change in the region against the model baseline (Seventh Plan or 2021 Plan baseline and/or state energy codes) or technologies with high regional interest. Ancillary technologies represent the technologies with little or no change against the Seventh Plan or 2021 Plan baseline. The distinction between principal and ancillary technologies is that the team will estimate baseline and actual energy consumption of buildings conditioned by principal technologies but not the ancillary technologies. The Technology Scope describes these concepts in more detail.
[7] Northwest Power Act, Northwest Power and Conservation Council, https://www.nwcouncil.org/reports/poweract/3_definitions

Building Type and Sector Scope

The model scope includes commercial building types which the Plan defines as offices, retail, schools, universities, warehouses, supermarkets, minimarts, restaurants, lodging, hospitals, residential care, assembly, and "other."

Because the Northwest's state energy codes include multifamily residential (four stories or greater) as a commercial building type, the team will include multifamily residential buildings when the HVAC equipment serves a central system or common area. The team will exclude in-unit heating and cooling systems since BPA's Residential HVAC Market Model included these systems. Appendix A summarizes how Northwest organizations characterize multifamily to ensure the model accounts for multifamily central HVAC systems consistent with the region.

The team will also exclude industrial process applications of commercial HVAC equipment (i.e., process heating or cooling), but will include HVAC applications in traditional commercial buildings associated with an industrial facility (i.e., conditioning an office building or storage warehouse),consistent with other regional categorizations of commercial buildings associated with industrial facilities.

Permitted Project Types

Within the geographic scope and during the analysis period, the model scope will include all commercial building types with mechanical permits that are required to meet energy code requirements at the time of permitting. The team will refer to these projects as "permitted projects" and the model scope as "new construction" throughout the remainder of this document, which includes major remodel projects (alterations) and other event types described as in-scope in this section and in Table 2 below.[8]

The team recognizes the term "new construction and major remodel" can mean different things in different contexts. In this project's context, the team defines "new construction and major remodel" as any building project that must go through the permit process and includes mechanical equipment that must comply with the relevant energy code. The team chose this definition because it aligns with permit data and can be mapped to the proposed population frame provided by Dodge Data & Analytics (Dodge data).[9] Minor modifications or anything defined by the local Authorities Having Jurisdiction as a "maintenance replacement" would not be included, as these would not be subject to current relevant energy code requirements.

Table 2 describes several types of common commercial construction events and maps these events to Washington State Energy Code (WSEC), Dodge data, permit data, the Seventh Plan, and finally the proposed model scope. As Table 2 illustrates, only commercial HVAC equipment entering the stock as part of a minor like-for-like replacement would not be captured in the model's scope, as previously mentioned.

[8] The team will consider setting a lower limit to project size to filter out smaller replacement projects, a good practice to ensure the sample includes viable projects. The team initially plans on limiting projects to $200,000 or greater but will refine the cost parameters during the development of the sampling plan.
[9] https://www.construction.com/, described in more detail in Question 2.

Table 2: Permitted Project Types Included in Model Scope

Event Description	WSEC Definition	Does the Event Trigger Energy Code?	Included in Dodge Data?	Included in Permit Data?	Included in the Plan's Definition of NC?	Treatment in BPA Model Scope
New building on site that had no existing building before	New Construction	Yes	Yes	Yes	Yes	In Scope
New building after an existing structure torn down	New Construction	Yes	Yes	Yes	Yes	In Scope
Building torn down to studs	New Construction	Yes	Yes	Yes	Yes	In Scope
Expansion or addition to make an existing building bigger	Addition	Yes, for additional area	Yes, but investigate with full data set	Yes	Yes	In Scope
Change to the building substantial enough to include a mechanical system change	Alteration	Yes, for altered area	Potentially, investigate with full data set	Potentially	No	In Scope
Like for like replacement of existing HVAC system	Replacement	No	Not Likely	Not Likely	No	Out of Scope

The team chose to focus on new construction for three main reasons:

1. Building permit data is the best publicly available and up to date source of information on HVAC system characteristics. Permit data contains a high level of detail unavailable in most other data sets. Building permits correspond with the new construction and major remodel market segments, so it follows that the sample scope will focus on these segments as well.
2. In past market research, manufacturers anecdotally reported that permitted projects make up between 50% and 70% of all commercial HVAC installations.[10]

[10] Cadeo Group presentation to BPA, "2019 AHR Expo Findings & Commercial HVAC Research," BPA, March 2019

3. The majority of energy efficiency activity and market change appears in permits since major HVAC remodels require building permits.

It is worth noting that, as proposed, the model will not include a commercial HVAC stock characterization; the model will only characterize commercial HVAC product flows and how these are changing over time. As changing product flows are the *mechanism* for stock change, the model will capture the anticipated magnitude of change, but will not map these changes onto the stock or produce market penetration or energy consumption estimates for the entire commercial HVAC installed base.

Analysis Period

The model's analysis period coincides with the Seventh Plan Period, January 1, 2016 through December 31, 2021. The team will draw a representative sample of permitted commercial HVAC systems with completion dates between January 1, 2016 and December 31, 2019. The team will use the permit's Certificate of Occupancy date as the completion date, consistent with utility new construction programs. The team will exclude permitted projects still under construction from the model scope.[11]

The team limited the sample frame to permitted projects completed through 2019 since projects completed in 2020 may not appear in Dodge's data set. The team will need to extrapolate results to 2020 and 2021, acknowledging the possible drastic shift in construction trends in 2020 resulting from the global COVID-19 pandemic. The team will purchase current data sets from Dodge at the end of the analysis period to inform the extrapolation.

BPA also plans on extending this model into the 2021 Plan Period and will update the model using permitted data during this analysis period (2022-2027).

Technology Scope

The model will include all commercial HVAC systems entering the commercial building stock through a mechanical permitting process, as described in the Building Type and Sector Scope. The team will document the saturation of primary HVAC systems[12] entering the building stock for both principal and ancillary technologies in order to characterize the new construction HVAC market and yield a complete new construction technology mix, broken out by square footage of conditioned space. *Question 2: How big is the market?* discusses this approach in more detail. The team will also more comprehensively model principal technologies compared to ancillary technologies, based on their market change against the Plan baseline and/or state or local energy codes, as well as the regional interest learning about a given technology. The following section describes principal and ancillary technologies in more detail.

Principal versus Ancillary Technology Distinctions

The essential distinction between principal and ancillary technologies is that the team will estimate baseline and actual HVAC energy consumption for buildings conditioned by principal technologies but not ancillary technologies. Limiting the consumption model to principal technologies will allow the team

[11] Permitted projects can span multiple years as they move through the permitting and construction process. The team will only collect data on fully completed permitted projects with Certificates of Occupancy issued and therefore will not include permitted projects only partially through the permitting process.

[12] A primary HVAC system indicates the system serves to condition and/or ventilate the majority of a building's conditioned floor area. The team will also catalog supplementary HVAC equipment in the permits and factor supplementary HVAC equipment's energy consumption into the building's total HVAC energy consumption, but the team will not characterize the total commercial square footage conditioned by supplementary HVAC equipment.

to focus on technologies that reflect the most change against baseline systems. Additionally, categorizing technologies as principal or ancillary maximizes the model's value, focusing on systems that show significant market change while moderating the time and resources associated with cataloging detailed permit information. For reference, once permit drawings are obtained it takes approximately one hour to identify a permitted project's system type, building type, and square footage in order to characterize the market saturation of a given technology. In contrast, it takes up to eight hours to fully characterize HVAC system attributes in order to accurately model the actual and baseline energy consumption for each permit.

The team defines market change against the baseline as an increase in the saturation of technologies more efficient than the minimum efficiency included in the Plan and/or required by state energy codes. For example, the Seventh Plan defines the new construction baseline for Variable Refrigerant Flow (VRF) as a Variable-Air-Volume (VAV) system with electric resistance heat. If the permit data reflects a high saturation of VRF systems, the team will include VRF as a principal technology. Conversely, because the Seventh Plan defines VAV systems as a code-minimum system, the team will define VAV systems as an ancillary technology, regardless of its saturation in permit data. The team would still document the saturation of VAV systems as they contribute to the total conditioned new construction square footage in the Northwest but would not fully characterize the energy consumption of buildings with VAV systems in the new construction market. *Question 3: What are the total market savings?* describes in more detail the approach of defining baselines by technology.

Table 3 below presents the team's current technology assessment based on the observed market change above the code baseline in the pilot study results and regional interest. The team will continue to consider the disposition of technologies in consultation with the Council throughout model development.

Table 3. Summary of Technology Categorization

Technology Category	Technology Type	Model Approach
Principal	VRF, Ductless Heat Pumps (DHP), Heat and Energy Recovery Ventilators, Electric Ducted Systems (Air Source Heat Pumps and Unitary AC)	Fully characterize square footage, HVAC energy consumption, and energy savings for each technology.
Ancillary	Hydronic Systems, Water Source Heat Pump (WSHP), Chillers, Electric Baseboard, Electric VAV Systems, Packaged Systems (PTHP, PTAC), Gas-only Equipment	Characterize the square footage served by each system only. Do not model HVAC energy consumption or savings.

Fuel Type Scope

This scope of work focuses on Northwest electricity consumption changes in the commercial HVAC market due to efficient equipment installation in permitted projects. The team will treat all non-electric technologies as ancillary technologies, documenting their installation rate in permitted projects, but not fully characterizing their HVAC energy consumption.

There are two main reasons for treating all non-electric technologies as ancillary technologies: (1) there is likely little to no change in the electric components of non-electric equipment installed beyond what is required by code, based on the previous pilot study results, and (2) any difference in electric operating power of gas fired equipment from what is required by code is likely to be from fans, which is extremely difficult to assess based on permit information (e.g., permits typically only report rated motor horsepower, not operating energy or brake-horsepower).

Unit of Account

The unit of account describes the metric by which the research team quantifies the market and basis for the model. To provide a consistent basis for modeling and analysis of the principal and ancillary technologies included in the scope, the team will use square feet of conditioned space as the primary unit of account.

Because a building's HVAC energy consumption varies widely, square feet of conditioned space provides a consistent unit of account used widely in the commercial sector. This approach will be consistent with the Seventh and 2021 Plans, NEEA's commercial HVAC initiatives, and other commercial energy consumption metering studies and energy models. It will also provide a consistent approach to validating model energy consumption results. The team will designate a technology's saturation by percentage of total new construction square footage in the region, which will vary based on climate zone, building type, and other factors.

Final model results will be reported, at a minimum, as total HVAC energy consumption of the region's commercial permitted buildings conditioned by principal technologies, in aMW/year, and the total commercial new construction square feet of conditioned space. The model will report consumption and savings by principal technology. The Model Reporting section describes the team's anticipated model outputs and reporting structure. The team will engage with BPA and its stakeholders to identify the more granular model output needs during model development.

Question 2: How big is the market?

The second step in estimating the commercial HVAC market's energy consumption (as defined in Question 1) is defining the market size in each year of the analysis period. The market size, in this case, consists of the total conditioned commercial square footage of the in-scope buildings in Oregon, Washington, Idaho, and Western Montana in a given year.

As Equation 1 illustrates, the total conditioned commercial square footage is the sum of all commercial conditioned square footage being conditioned by new commercial HVAC systems entering the stock through the permit process in any given year of the analysis period. The research team will segment this equation by building type, principal and ancillary technologies, and other attributes to understand growth in certain segments compared to others.

Equation 1: Market Size

$$MarketSize_{N,s}(\text{sq ft}) = \sum CommSqFt_{N,s}$$

Where:

MarketSize = total conditioned square footage of buildings, conditioned by principal and ancillary technologies, entering the commercial stock through the permitting process

CommSqFt = conditioned square footage of a commercial building conditioned by principal and ancillary technologies

N = analysis year

s = segment of the installed stock (e.g., building type, climate zone, principal and ancillary technologies, applicable code, etc.)[13]

For each year of analysis, the research team will develop an estimate of:

1. The total conditioned commercial square footage conditioned by new commercial HVAC systems entering the stock through the permit process.
2. The saturation of both principal and ancillary technologies.

Equation 1 describes the total conditioned square footage of commercial new construction buildings, regardless of whether principal or ancillary technologies condition the building. However, the team will only estimate HVAC energy consumption for buildings conditioned by principal technologies. Equation 2 describes the equation calculating the market size of buildings conditioned by principal technologies, which the team will use to answer Question 3: What are the total market savings?

Equation 2: Market Size of Buildings Conditioned by Principal Technologies

$$\text{PrincipalMarketSize}_{N,s}(\text{sq ft}) = \sum \text{PrincipalCommSqFt}_{N,s}$$

Where:

PrincipalMarketSize = total conditioned square footage of buildings conditioned by principal technologies, entering the commercial stock through the permitting process

PrincipalCommSqFt = conditioned square footage of a commercial building conditioned by principal technologies

N = analysis year

s = segment of the installed stock (e.g., building type, climate zone, principal technologies, applicable code, etc.)

Estimating the Commercial HVAC Market Size

To estimate market size, the team will rely on a representative sample of building permit data. The team will (a) develop a sampling plan, (b) gather permit data for a sample of buildings with new HVAC equipment, (c) use those data to characterize the buildings in the sample, and (d) extrapolate to the total region. This sample will consider different stratification options depending on variations in HVAC energy consumption and equipment saturations within each stratum. Among other potential stratification variables, the team will consider building type, building size, building location, and applicable energy code as initial targets for investigation. The team will develop the sampling plan in the next phase of research prior to permit data collection.

[13] Question 3 describes the model's segments in more detail.

To generate a sample frame, the team plans to rely on Dodge data. Dodge data is a for-purchase dataset which contains information on new construction projects in the U.S. Dodge estimates their data represents between 92-96%[14] of annual U.S. new construction and major remodel square footage.[15] Dodge data is consistent with the Seventh Plan's source data, is the sole source data for the U.S. census on new construction, and represents the most complete set of new construction and major remodel data available.[16]

At a high level, the team will identify the sample using the Dodge data in three steps:

1. Export a list of all the applicable permitted projects within the scope of this model (timeframe, building type, geographic location, etc.).
2. Identify a subset of those permitted projects to serve as a representative sample for the region.
3. Request permit documents from permitting jurisdictions for the sample of permitted projects.

Once the team defines the sample, the team will catalog principal and ancillary technology HVAC data and calculate HVAC energy consumption and savings for each building, as discussed in more detail in *Question 3: What are the total market savings?*

Finally, the team will calculate sample weights for each building based on the sample frame and extrapolate the principal and ancillary technology HVAC findings to the total region.

Question 3: What are the total market savings?

Total market savings represent the difference between baseline energy consumption and actual energy consumption of buildings conditioned by principal technologies, in aMW. As discussed in Questions 1 and 2, the team will only model the HVAC energy consumption of buildings conditioned by principal technologies and will not include ancillary technologies in this analysis. This will allow the team to characterize the majority of the market change in the new construction commercial HVAC market (defined in Question 1) without using extensive resources.

To assess market savings for principal technologies, the team will answer the following questions:

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

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

The team will answer each of these questions by developing Unit Energy Consumption (UEC) values, representing a commercial building's total HVAC energy consumption in kWh per square foot of conditioned space by various commercial building factors like climate zone and building type. The team will only develop UEC values for buildings conditioned by principal technologies.

The UECs will account for all the factors that impact total HVAC energy consumption, including supplementary HVAC equipment, typical control practices, and interactive loads. The team will develop two sets of UECs for each building conditioned by a principal technology: (1) an actual UEC that describes how much HVAC energy the building actually consumed based on the installed principal technology and associated supplementary HVAC equipment, and (2) a baseline UEC that describes the HVAC energy the

[14] Data sourced from the research team's correspondence with Dodge representatives. Phone calls with Mary Hall, Nov 2019.

[15] Minor gaps come from smaller private commercial jobs in rural areas, per email with Dodge 10/15/19.

[16] Dodge has provided construction starts data to U.S. Census Bureau for 40 years. Construction starts are monitored by "reporters" located in 80 major metropolitan areas, with information collected directly from contractors. Data is regularly backchecked by Census Bureau.

building would have consumed if the building had not installed the principal technology. The team will hold most building characteristics constant between the baseline and actual UEC to isolate the savings from just the HVAC system improvements.

The team will develop unique UECs for the range of specific applications, or segments, to account for differences in a building's HVAC energy consumption between various building types, climate zones, and other variables. The team will use building energy models to develop accurate and robust HVAC energy consumption estimates, supplemented by validation against metered data.

The following sections describe the UEC methodology, UEC building characteristics, model segmentation, baseline and actual UEC development, and building energy modeling options in more detail, concluding with the total market savings calculation.

UEC Methodology

As described previously, the team will develop UEC values for buildings conditioned by principal technologies to characterize typical total HVAC energy consumption of a commercial building, in kWh per square foot of conditioned space. Many factors impact how much energy a given building will consume, including but not limited to, geographic location (climate zone and/or state), building type, building shell characteristics, primary HVAC system, the secondary and supplementary HVAC equipment associated with the primary system, building controls, and building operations, summarized in Table 4 below.

The UECs will attempt to capture the key factors while also creating UECs that are representative of typical Northwest commercial HVAC energy consumption. The team acknowledges that any given commercial building's HVAC energy consumption may vary from the UEC values, but the team will aim for accurate UEC values, on average, for each segment of the model, validating the UECs with metered data where available.

The team will develop representative baseline and actual UECs for prototype buildings conditioned by the principal technologies. The UECs will hold all building characteristics (square footage, lighting, envelope, etc.) constant between the baseline and actual UEC, except for the HVAC system. These building characteristics will represent current practice or minimum code requirements, whichever is more efficient, to reflect a typical Northwest new commercial building. The UECs will represent the same prototype building in both the actual and baseline case, with only the HVAC system changing to isolate market savings from just the installation of principal HVAC systems.

Table 4 summarizes the factors that impact a building's HVAC energy consumption, whether the model will vary the factor or hold it constant between the baseline and actual UECs, if the team will segment the factor into multiple dimensions (discussed in the Model Segments section), and the proposed UEC data sources (discussed in the UEC Building Characteristics section).

Table 4: Factors Impacting HVAC Energy Consumption and Their UEC Methodology

UEC Factor	Held Constant or Varies Between the Baseline and Actual UEC	Single or Multiple Dimensions	UEC Data Source
Primary HVAC System Type	Varies	Multiple, by Principal Technology	Baseline UEC: Code Compliant HVAC System[17] Actual UEC: Permits
Primary HVAC System Efficiency	Varies	Multiple, by efficiency levels	
Primary HVAC System Capacity	Varies	Multiple, by capacity ranges	
Supplementary HVAC Equipment (including fans and pumps)	Varies by Primary HVAC System	Single, specific to each Principal Technology[18]	Seventh Plan, 2021 Plan and Regional Building Energy Models
Building Type	Held Constant	Multiple, by Council Building Types	Seventh Plan and 2021 Plan
Climate Zone	Held Constant	Multiple, by Heating and Cooling Zones	Northwest Climate Zones[19]
State Energy Code Cycle	Held Constant	Multiple, by state and year	Energy Codes by State and Jurisdiction
Window Area and U-value	Held Constant	Single, specific to each building and/or system type[20]	Code Compliant Building or Current Standard Practice, whichever is higher efficiency[21]
Building UA Value (insulation and air sealing)	Held Constant		
Lighting Power Density, Fixture Types, and Controls	Held Constant		
HVAC Controls Capabilities	Held Constant		
Building Scheduling, Setpoints, and Occupancy	Held Constant		
Plug and Equipment Loads	Held Constant		
Service Water Heating	Held Constant		

[17] The UEC Building Characteristics section defines this in more detail.
[18] The UECs will hold all building HVAC equipment constant between the baseline and actual conditions, except for the primary HVAC system and the associated supplementary HVAC equipment. For example, the 2021 Plan defines the baseline for a VRF system as a rooftop unit heat pump, which would include associated fans, distribution system, and other equipment. The VRF system may include a different distribution system to meet the same heating load. The baseline UEC would account for all HVAC equipment associated with the baseline HVAC system and the actual UEC would account for all HVAC equipment associated with the principal technology's HVAC system.
[19] https://rtf.nwcouncil.org/work-products/supporting-documents/climate-zones
[20] Where baseline and actual HVAC system types differ, the team will model baseline HVAC controls per code requirements for the applicable standard reference or baseline system.
[21] The Baseline UEC Development section discusses UEC data sources in more detail.

UEC Building Characteristics

As described previously, the UECs will hold all building characteristics constant in the baseline and actual UEC, with only the HVAC equipment varying. The team will define the building characteristics that are held constant, presented in Table 4, by the minimum efficiency level required by the state energy code, or new construction current standard practice, whichever is higher efficiency. Code-compliant building characteristics provide a more accurate representation of a new building's HVAC energy consumption than existing building stock characteristics since the scope of this market model is new construction buildings.[22] In general, buildings constructed during the analysis period will fall under the energy codes in Table 5.

Table 5: Code Cycles by State Aligned with Model Analysis Period

State	Code Cycles
Washington	2012 & 2015 WSEC 2012 & 2015 Seattle Energy Code
Oregon	2010 & 2014 Oregon Energy Efficiency Specialty Code 2016 City of Eugene Reach Code
Idaho	2009 & 2015 IECC
Montana	2009 & 2012 IECC

The team will rely primarily on two data sources for defining new construction building characteristics:

1. **NEEA's Energy Plus Prototype Building Models** which reflect a minimally code compliant building, or the current practice in new construction buildings, whichever reflects higher efficiency in each code cycle year. NEEA's energy code models align most closely with the buildings constructed during the Seventh Plan period. The UEC Modeling Options section describes these models in more detail.

2. **The 2019 Commercial Building Stock Assessment** (CBSA) which includes building characteristics of the existing building stock by building vintage. While the sample size of 2014-2018 vintage buildings in the 2019 CBSA is small, the data will provide a useful representation of the new construction current practice baseline for the model's analysis period.

If regional organizations publish newer code compliance studies, such as NEEA's anticipated Washington code compliance study, the team will consider these additional sources of current practice baselines if they reflect buildings constructed during the analysis period.

[22] The team considered segmenting new construction and remodel UECs to account for differences in building characteristics in existing buildings, but found 80% of the projects in the pilot study were new construction or remodels where all building components meet energy code (e.g., additions or the building was torn down to studs). The team did not document non-HVAC building components like insulation or windows in the pilot, so the team does not know if the remaining 20% of projects with less extensive remodels upgraded non-HVAC building components. The team assumes a portion of those remodels did upgrade the building to current energy code, but a portion kept existing the insulation, windows, or other non-HVAC building characteristics.
The team will assume all building characteristics are brought up to current energy code to simplify building energy modeling. If the team finds during data collection that less extensive remodels are more prevalent than the pilot study, the team will consider segmenting the UECs by new construction and remodel, with remodeled buildings using existing building stock characteristics as UEC inputs.

For non-HVAC building characteristics that the team will hold constant, such as building U-value, window percentage, and lighting, the team will evaluate current practice in new buildings to determine if current practice exceeds minimum code requirements. The team will use building characteristics from new buildings in the 2019 CBSA (defined as 2014 – 2018 vintage buildings) to determine the current practice, limiting the data to buildings with vintages in the analysis period. The team will compare findings with NEEA's prototype models, which incorporates current practices using the 2014 CBSA when current practice exceeds code, such as lighting power density and window performance. When the energy code exceeds current practice, the team will use inputs consistent with a minimally code compliant building. The prototype model summary in Appendix B includes the current practice assumptions NEEA used in their building models.

Question 1 defined the fuel type scope as electric since the principal technologies in this scope are electric technologies. However, a typical building may include supplementary gas HVAC equipment associated with the primary systems or gas domestic hot water. The team will review new construction current practice at the time of model development and develop the UECs to encompass all electric consumption in a building, including, in cases of gas equipment, the electric consumption associated with that gas equipment, such as fans and pumps. Most importantly, the team will hold any gas equipment constant between the baseline and actual UEC to prevent changes in electric consumption due to fuel switching.

Model Segments

Table 4 describes factors that have multiple dimensions in the UECs and the market model. The team will define each of the unique combinations of factors that impact a building's HVAC energy consumption as "segments" of the commercial building stock.

Each segment of the installed stock will have a unique UEC value to account for HVAC energy consumption variations between segments. The team expects each segment's key variables will include building type, climate zone, state energy code cycle, technology, and primary HVAC system capacity and efficiency level. The team may identify additional variables during analysis of the permit dataset.

Due to the high resource cost and complexity required to model numerous segment iterations, the team will consider opportunities to combine segments when consumption data suggests simplification would still produce accurate and reliable results. The team will develop building energy models, described later, for each UEC segment. If a building energy model's results suggest iterations for specific segments produce comparable HVAC energy consumption results, the team will consider combining those segments.

Table 6 summarizes the team's current model segments and the variables and dimensions of each segment.

Table 6: Model Segments Summary

Variables	Dimensions	Opportunities to Simplify
Building type	Council Building Types: Offices (small, medium, large), retail (small, medium, large, extra-large), schools, universities, warehouses, supermarkets, minimarts, restaurants, lodging, hospitals, residential care, assembly, multifamily residential central systems, and "other"	Group building types with similar system types, following Seventh Plan measure groupings, 2019 CBSA categories, or the RTF's Energy Plus Prototype Model building type groupings
Climate Zone	Heating Zones 1, 2, and 3 Cooling Zones 1, 2, and 3	N/A
Code Cycle	WA: 2012 & 2015 WSEC, 2012 & 2015 Seattle Energy Code OR: 2010 & 2014 OEESC, City of Eugene 2016 Reach Code ID: 2009 & 2015 IECC MT: 2009 & 2012 IECC	Model only one energy code per state using the most recent energy cycle. The most recent energy cycle will be the most stringent, which could reduce potential energy savings, but would simplify the number of segments needed
Technology	Principal technologies defined by the technology scope	N/A
Primary HVAC System Capacity	To be determined based on gathered permit data	Minimize number of capacity bins for each technology
Primary HVAC System Efficiency Level	To be determined based on gathered permit data	Minimize number of efficiency levels for each technology

Baseline UEC Development

The team will develop baseline and actual UECs for buildings conditioned by the principal technologies that account for all factors that impact a building's HVAC energy consumption. The UECs will hold all building characteristics (square footage, lighting, envelope, etc.) constant between the baseline and actual UEC except for the HVAC system.

Equation 3 summarizes the energy consumption calculation in the baseline case.

Equation 3: Calculation of Annual Energy Consumption in the Baseline Case

$$BaselineAnnualEnergyConsumption_N \text{ (kWh/yr)} = \sum \left(PrincipalCommSqFt_{N,t,s} \times BaselineUEC_{t,s} \text{(kWh/sq. ft.)} \right)$$

Where:

PrincipalCommSqFt = conditioned square footage of commercial buildings conditioned by principal technologies

N = analysis year

t = principal HVAC technology type

s = segment of the installed stock (e.g., building type, climate zone, etc.)

BaselineUEC = Baseline Unit Energy Consumption value, in kWh/sq. ft.

The Baseline UECs will describe the baseline energy consumption of a building conditioned by each specific principal technology. The baseline efficiency scenario represents business-as-usual efficiency practices as characterized by the Power Plan, current energy code, or current practice, whichever is most efficient. For commercial HVAC new construction measures, the Plan typically characterizes the baseline as a minimally code compliant system in the year the Plan was written. The definition of a minimally code compliant system varies by technology. For unitary equipment, the Plan typically outlines a baseline efficiency level for that specific equipment. For larger HVAC systems, the Plan identifies a baseline *system* that represents the minimally efficient system that would meet code. For example, the 2021 Plan defines the baseline system for a DHP project as a rooftop unit heat pump.

Both the defined baseline HVAC system and the actual HVAC system UECs will account for the primary HVAC system and the associated supplementary HVAC equipment necessary to meet the same building load. For example, the 2021 Plan defines the baseline for a VRF system as a rooftop unit heat pump, which would include associated fans, distribution system, and other equipment. The VRF system may include a different distribution system to meet the same heating load. The baseline UEC would account for all HVAC equipment associated with the baseline HVAC system and the actual UEC would then account for all HVAC equipment associated with the principal technology's HVAC system.

Since this model focuses on HVAC equipment entering the market through permitted new construction or major remodel projects that are subject to code requirements, the team may update the Plan's baseline using each state's energy code requirements if the relevant code requires higher efficiency levels. This approach is consistent with the Council's treatment of new construction measures which use codes or standards as the baseline rather than existing conditions. The team will rely on more current data, such as more current energy code requirements, than the Council had available when they wrote the Plan. The team will engage with the Council staff early in model development to review the team's approach to updating each principal technology's baseline.

To define the baseline code-minimum system for each relevant energy code cycle, the team will use the modeled baseline system specified in the "Total Building Performance Path" section of the applicable energy code. Designers use the Total Building Performance Path to code compliance to demonstrate that a building meets a required efficiency level at or above the level of a building composed of baseline systems. By modeling total building performance, designers show that even if one aspect of a building is below energy code, the whole building performs at or above code energy efficiency levels. This is counter to a Prescriptive Compliance Path, in which a design must comply with each individual code requirement.

The code-defined baseline system demonstrates a code-minimum level of HVAC performance.[23] Specific efficiency requirements may vary from state to state and between code cycles, so the team will update the baseline systems themselves specific to each energy code version. This approach is consistent with the Plan's treatment of new construction measures which use codes or standards as the baseline rather than existing conditions. The assumptions in the Seventh Plan, 2021 Plan, and code-required baselines

[23] Some energy codes include a minimum level of efficiency above the baseline system, which the team will consider in baseline UEC development.

vary by technology and segment, so the team will create unique Baseline UEC building energy models for each principal technology by segment.

If BPA pursues a 2021 Plan market model, the team will update principal technologies based on the 2021 Plan's final conservation supply curves, with input from the Council during model development. At the time of this memo, the Council had not finalized measures for inclusion in the 2021 Plan conservation targets, so the measures reflect the baselines as currently written in the Seventh and 2021 Plan baselines.

The following sections describe the baseline approach specific to the principal technologies.

VRF

The Seventh Plan defines the baseline for commercial new construction VRF systems as a modeled baseline electric VAV system meeting the 2012 WSEC. Since many of the HVAC systems in this scope have been permitted in different states or under later code cycles, the team will use the specific state and code-year the projects were permitted under as the baseline. This baseline may still reflect a VAV system but might also have additional fan efficiency or other requirements that would result in a more efficient Baseline UEC. The team acknowledges that a VAV system and VRF system will have different controls, fans, and additional associated equipment. The intent of the baseline UEC will be to capture a code-minimum system, including controls, fans, and supplementary equipment.

The 2021 Plan defines the VRF baseline as a rooftop unit heat pump system, which the team will use if BPA pursues a 2021 Plan market model. The team will consult with Council staff to review proposed baselines to ensure they are consistent with the intent of the Plan at the time of model development.

DHP

The Seventh Plan defines the baseline for commercial new construction DHP systems using the retrofit DHP baseline, which is an electric zonal system. Since the team will have access to the state and code cycle each DHP was permitted under, the team will update the baseline to reflect a code-minimum system, likely a packaged rooftop heat pump. A heat pump baseline is consistent with the 2021 Plan's new construction DHP measure. The team will review this update with the Council to ensure it is consistent with how the Seventh Plan would have treated DHP in new construction given additional code-specific data. The team will not develop a DHP UEC specific to multifamily in-unit systems since this scope excludes in-unit heating and cooling and BPA's Residential HVAC Market Model included this application.

Heat and Energy Recovery Ventilators

The Seventh Plan and 2021 Plan excluded Heat and Energy Recovery Ventilators (HRV/ERVs) as a commercial HVAC measure due to a lack of cost-effectiveness; therefore, does not have an existing Seventh Plan baseline. The team would only include heat recovery as an add-on measure to other principal technologies.[24] The team will develop a baseline consistent with the Seventh Plan's treatment of similar measures, with input from the Council. Based on the permit data reviewed, the team would use the minimum recovery efficiency for systems where code requires heat recovery, based on the permitting

[24] The team may choose to include heat recovery as an add-on measure to any technology, principal or ancillary, depending on the prevalence of heat recovery in the initial data collection. If the team pursues this option, the team will develop additional UECs for ancillary technologies where heat recovery occurs. In these cases, the UECs would hold all building and HVAC characteristics constant, with no or baseline heat recovery in the baseline case and heat recovery in the actual case.

requirements. Where the code does not require heat recovery, the baseline would reflect an HVAC system with no heat recovery.

The team will request the cost-effectiveness analysis from the Council to identify if cost-effectiveness failed specific to new construction or retrofit. The team will review the reason for HRV/ERV exclusion with the Council and identify the most appropriate approach to reporting HRV/ERV savings. The team may choose to model and report the resulting market savings but choose not to report as Momentum Savings.

Ducted Systems

The Seventh Plan does not include ducted systems. However, at the time of this memo, the 2021 Plan included conservation supply curves for Air Source Heat Pumps (ASHP) and Unitary Air Conditioners (unitary AC). The team will use the 2021 Plan's baseline definition for ducted systems, a federal standard heat pump or unitary AC. The team will review the baseline approach to with the Council and identify the most appropriate approach to reporting ducted system savings. The team may choose to model and report the resulting market savings but choose not to report as Momentum Savings.

Actual UEC Development

The Actual UECs will represent the HVAC energy consumption of buildings conditioned by principal technologies that entered the commercial stock through new construction. As described in the Baseline UEC Development section, only the HVAC system will vary between the baseline and actual UEC. The Actual UEC will be based on the primary HVAC systems identified in the permits and the associated supplementary HVAC equipment. Equation 4 summarizes the energy consumption calculation for the actual case.

Equation 4: Calculation of Annual Energy Consumption in the Actual Case

$$ActualAnnualEnergyConsumption_{N}(kWh/yr) = \sum \left(PrincipalCommSqFt_{N,t,s} \times ActualUEC_{t,s}(kWh/sq.\ ft.)\right)$$

Where:

PrincipalCommSqFt = conditioned square footage of commercial buildings conditioned by principal technologies

N = analysis year

t = principal HVAC technology type

s = segment of the installed stock (e.g., building type, climate zone, etc.)

ActualUEC = Actual Unit Energy Consumption value, in kWh/sq. ft.

The team will develop the Actual UECs by updating the Baseline UEC inputs with the principal technology and associated supplementary HVAC equipment from the permit data, holding all other building characteristics constant. The team will use other data sources, described in Table 4 and the UEC Building Characteristics section, to account for building and HVAC system characteristics not obtained from permit data. These building characteristics will represent current practice or minimum code requirements, whichever is more efficient, to reflect a typical Northwest new commercial building as close to an actual building as possible. The

Sources of Uncertainty and Model Validation section at the end of this memo presents data sources available to compare and validate both the UEC values.

Building Energy Modeling

The team proposes to develop the UECs using building modeling software, supplemented by validation against metered data. The team considered alternatives to building modeling, such as using existing metered studies or existing building models, but identified several limitations in these approaches:

- Metered data comes from many different buildings where numerous factors and building characteristics vary, not just the HVAC system, preventing specific HVAC energy consumption comparisons. It is important for the model to hold all non-HVAC variables constant between the baseline and actual case to accurately isolate HVAC energy savings.
- Existing data does not allow for iterations to account for energy code cycle updates, baseline updates, and updates to HVAC efficiency.
- No single source of data exists to characterize each of the market model's principal technologies. Piecing together multiple studies would introduce uncertainty due to differences and small sample sizes in the available studies. Providing a consistent modeling framework that is comparable between the baseline and actual case is crucial to estimating accurate savings.

While metered building data offers the closest representation of an actual building's energy consumption, commercial building characteristics and energy consumption varies widely, and limited data exists to accurately characterize a typical building based solely on metered data. Engineers, researchers, and other organizations commonly use building modeling software to characterize and compare commercial building energy consumption due to commercial building complexity. Code officials, utility programs, and design engineers regularly use and accept commercial building models as representative estimates of energy consumption. Building models also provide the easiest way to iterate numerous segments, holding all other building characteristics constant while allowing updates related to building energy code cycles and HVAC efficiency.

The team acknowledges that commercial building models have limitations and do not always accurately represent building consumption; however, the industry has calibration tools and modeling best practices the team will use to build robust models. The team will also validate the models' outputs with the available actual metered building data to ensure the results represent realistic building and HVAC consumption. The

Sources of Uncertainty and Model Validation section at the end of this memo describes the data sources available to validate the UEC values.

UEC Modeling Options

Developing an accurate building energy model takes time and expertise. Each building model requires detailed inputs on the building's construction, including square footage, location, HVAC system details, wall U-values, roofing and flooring materials, window U-values, lighting, plug loads, building occupancy, and operations. Developing models for each UEC will require identifying typical building characteristics in the region.

The region has developed several building model prototypes in recent years to estimate building and HVAC energy consumption, energy conservation measure savings, or energy code savings specific to Northwest states. These models use regional data sources like NEEA's 2014 CBSA[25] and state and local energy codes for inputs and assumptions to create buildings representative of the region.

The team plans to use these building energy models as a starting place for developing the UECs, updating the models as needed to represent BPA's scope and analysis period. The following sections describe each of the regional building models available for the team's use. Appendix B includes a more detailed summary of each prototype model and its capabilities, inputs, and data sources as they relate to developing the UECs.

BPA Existing Building Simulations

In 2016, BPA contracted Navigant Consulting to develop a set of Northwest-specific commercial building models, built on Energy Plus modeling software, as reference buildings to assist the region in estimating lighting interaction factors and characterizing energy conservation measures.[26] Navigant built the models starting with the Department of Energy's (DOE) Commercial Reference Building models and updated them using national and regional data sources. The models heavily rely on the 2014 CBSA as a key data source for model inputs. Navigant calibrated the building models to metered building data from the 2014 CBSA metering study.

The Council's Regional Technical Forum (RTF) made the Energy Plus reference models public, along with BPA's model documentation, on the RTF website.[27] While the models include robust documentation and calibration, the newest-vintage buildings in the CBSA represent buildings constructed between 2004 and 2013, which are older and less efficient than BPA's building scope. If the team chooses to use these reference models as a starting place for UEC development, the team will update the inputs to represent building characteristics current with BPA's scope and analysis period.

NEEA State Energy Code Models

In 2018, NEEA contracted with Mike Kennedy, Inc. to develop building energy models to estimate energy savings from WSEC efficiency improvements between the 2012 and 2015 energy code cycles.[28] The Energy Plus models start with BPA's 2016 reference models and update the inputs to reflect a minimally code compliant building or the current practice in new construction buildings, whichever reflects higher

[25] Navigant Consulting, "2014 Commercial Building Stock Assessment," Northwest Energy Efficiency Alliance, December 2014

[26] Navigant Consulting, "Existing Building Simulation Project: Model Documentation," Bonneville Power Administration, 2016

[27] Commercial Building Simulation Models, Regional Technical Forum, https://nwcouncil.app.box.com/v/SimModelsHVACInteractionZIP

[28] Mike D. Kennedy, Inc., "Washington 2015 Non-Residential Energy Code Energy Savings," Northwest Energy Efficiency Alliance, September 2018

efficiency in each code cycle year. Of the four models available for the team to use, NEEA's energy code models align most closely with the buildings constructed during the Seventh Plan period.

NEEA shared the draft report with model documentation with the team, but at the time of this memo NEEA had not made the models themselves or the final modeling report publicly available. The team would need to request the models and final documentation from NEEA to use them for UEC development. If the team uses NEEA's energy code models as starting places for UEC development, the team will need to update the models to reflect Oregon, Idaho, and Montana's energy code requirements and current practice.

RTF Regional Prototype Models

In 2019, the RTF contracted with Big Ladder Software to create commercial building energy models for the region to improve energy conservation measure calculations and offer reference models for regional use. Big Ladder built the Energy Plus models using a combination of the 2016 BPA models, NEEA's energy code models, and Big Ladder's own prototype building models. In general, the model inputs rely on the 2014 CBSA building characteristics, but detailed information about the inputs, assumptions, and data sources were not available at the time of this memo. Big Ladder calibrated the updated models to the 2014 CBSA metered studies, similar to the 2016 BPA models.

The RTF intends the tool to allow for easy iterations to update building characteristics, HVAC systems, and other attributes. The RTF will make the models, and presumably the model documentation and calibration methodology, publicly available on the RTF website later in 2020. The RTF indicated they may update the models to reflect the 2019 CBSA building characteristics, but they do not anticipate this work occurring until 2022.

It is also worth noting that these updated RTF models are still developed and calibrated to an older set of existing buildings, as they are meant to represent the installed commercial building stock, as opposed to specific new or majorly updated buildings.[29]

Pacific Northwest National Lab's Modeling Tools

In 2020, the Pacific Northwest National Lab (PNNL), supported by NEEA, developed a simplified energy modeling tool, the Building Asset Score online modeling tool, for designers and construction managers to use for compliance with the WSEC's 2018 energy code. The 2018 WSEC's performance-based compliance path features a new performance metric, the Total System Performance Ratio (TSPR). PNNL adapted their online modeling tool allows users to enter building characteristics and performance data to calculate the building's TSPR.

The TSPR-specific analysis tool allows users to input building characteristics but will not allow users to input values that do not meet the 2018 WSEC. PNNL's Building Asset Score allows users more flexibility in the input values but is not specific to the WSEC.

Both the Building Asset Score and TSPR modeling tools have several advantages over the other Energy Plus prototype models:

[29] If the team chooses to segment the UECs into new construction and major remodel, where the major remodel segment uses existing building characteristics instead of code-compliant characteristics, the RTF prototype models may represent a good data source for these characteristics.

1. Requires minimal modeling expertise, while Energy Plus requires extensive modeling expertise to accurately characterize a building's HVAC energy consumption
2. Simplifies many aspects of building modeling, which, for BPA's purposes, will include the key HVAC capabilities necessary for UEC development
3. Allows for easy iterations to model the same building with different building characteristics and HVAC systems, which the team will need for the model's numerous segments

PNNL's modeling tools have some system and input modeling limitations. For example, the tool uses industry-accepted data sources, like DOE's reference models and ASHRAE 90.1 guidelines, to account for default values like loads and energy consumption not defined by users. The team will reevaluate the modeling tool at the time of model development to ensure it includes all the relevant system types and user-defined inputs needed to develop UEC estimates for BPA's market model.

With the RTF's 2020 prototype models not finalized and NEEA's ongoing work on additional state energy code models in progress, the team will decide which model will represent the best tool for UEC development during model development. The team will update the building energy models to reflect the building characteristics consistent with the analysis period, regardless of the prototype model chosen.

The

Sources of Uncertainty and Model Validation section at the end of this memo presents data sources available to compare and validate the building energy model outputs. The team will calibrate the building energy models following industry protocols to ensure the models represent realistic building and HVAC energy consumption.

Calculating Total Market Savings

The difference between the baseline energy consumption and the actual energy consumption determines total market savings in each year of the analysis period. Equation 5 describes how the team will calculate the total market savings in each year of the analysis period.

Equation 5: Cumulative Savings

$$TotalMarketSavings = (BaselineEnergyConsumption - ActualEnergyConsumption) \times BusbarFactor$$

The Busbar Factor in Equation 5 converts energy savings at the customer's meter to the generation source. The research team will use an average Busbar Factor consistent with past BPA market models and will work with BPA to determine the correct value to apply in this model.

Question 4: What are the program savings?

The final step in the Momentum Savings Analysis Framework is answering Question 4: What are the program savings? The total market savings estimated in Question 3 will include savings associated with utility programs or NEEA's net market effects. This would result in double-counting if the Momentum Savings methodology did not adjust for these program savings. Therefore, team will subtract all reported commercial HVAC program savings from the total market savings calculated in Question 3 to prevent double counting Momentum Savings and program savings. After subtracting these program savings, any remaining savings are regional Momentum Savings.

Calculating commercial HVAC regional program savings is complex because utility programs often fund commercial HVAC projects through a variety of program avenues (e.g., prescriptive measures, custom programs, midstream incentives) and calculation methods. Programs may use different baselines to calculate their savings. Programs also typically track projects in terms of average kWh *savings* per unit, while BPA's market models calculate HVAC energy *consumption*. The team will use the best available data, but not all programs use the same data sources. Therefore, the research team will use the approach outlined in the following sections to account for permitted projects funded through programs.

Building-by-Building Matching

The team reviewed existing HVAC program offerings to inform this methodology; assessed reported savings from the Council, NEEA, BPA, and utility program data; and interviewed Seattle City Light (SCL) to understand how SCL reports new construction and major remodel HVAC project savings. In past BPA market models, the team used the Council's Regional Conservation Progress (RCP) report as the primary source for program savings data and extrapolated program details, such as measure mix, based on detailed BPA program data. The team found in reviewing BPA and SCL program data that the prevalence of custom programs to incentivize commercial new construction HVAC projects introduces too much uncertainty to use the same approach for this market model. Instead, the team will match the specific permitted projects identified in the permit data with projects funded by utilities in the corresponding service territory.

The team will request program data from the utilities serving the permitted projects in the sample frame that include principal technologies. The team will aim to minimize the burden on utilities to provide custom project data, so the team will limit the request to commercial HVAC or whole building projects funded or initiated during the analysis period. The team will request the project address, measure name, end use, technology, and date completed (if complete).[30] The team anticipates requesting program data from 20-25 Northwest utilities[31] and will determine the specific utilities based on the service territories of the sample of buildings identified in permit data collection.[32] The team will then match the permit data with the program data and remove projects associated with programs as program savings.

This approach assumes that for program-funded projects with a matching address and measure description, the utility incentivized the principal technology. One risk in this approach is that there may be instances where the project addresses match, but the project description lacks detail to definitively identify if the project included a principal technology. The team's review of BPA and SCL program data noted the prevalence of project names including only the building name or general descriptors like "New Construction" paired with general reporting categories like "Interactive HVAC Effects." If the team accounts for these projects as program savings associated with the model's principal technologies, but the project does not actually include the principal technology (e.g., the utility only funded envelope and lighting), BPA will overestimate program savings and therefore underestimate Momentum Savings.

Based on the team's review of BPA and SCL project files, the prevalence of this occurring is very low,[33] but the team will further evaluate this risk by first requesting custom project files from BPA's program data to match permitted projects in BPA's service territory. The team will determine the prevalence of a project matching addresses but *not* incentivizing the principal technology. If the BPA custom project files indicate BPA would overestimate program savings using this approach, the team will consider requesting additional detail from a subset of non-BPA projects to further clarify the scope of the incentivized project as needed.

This approach produces the most confidence in ensuring the model does not report savings programs have already reported. It also eliminates the uncertainty in normalizing program calculation methods and extrapolating from non-detailed RCP reports.

The team will use the projects identified by the building-by-building matching approach to extrapolate the results to the region as a whole. The team will calculate the percent of the permitted projects from the sample that were associated with programs, by each principal technology. The team will extrapolate that percentage to the region, assuming the same percentage of the total region's permitted projects were associated with programs. The team will further refine this methodology during sampling plan development.

[30] Program data often lags behind the completion dates of a new construction project. Requesting program data on in-progress projects will ensure the team accounts for recently completed construction projects where utilities have not finalized the incentive process.

[31] The team anticipates the majority of projects will occur in densely populated areas. The team estimates 26 utility organizations represent most of these regions based on the RTF's utility and population analysis. https://rtf.nwcouncil.org/work-products/supporting-documents/climate-zones

[32] Smaller jurisdictions may require an alternative approach to requesting program data. If a utility only has a few permitted projects in their jurisdiction, the team may choose to inquire if the utility funded the specific project rather than requesting a list of projects.

[33] The team matched six of the 50 pilot project sites to incentivized projects, all with clear program categories and descriptions. The team did not request program data from Energy Trust of Oregon to match project sites from Task 1's permit investigation.

Program Data Sources

The team reviewed the RCP report, SCL's program data, and BPA's custom project data to understand the relative magnitude of program savings for the principal technologies, VRF and DHP, HRV/ERV and ASHP. The team found relatively low VRF and HRV/ERV activity through custom and prescriptive programs while prescriptive commercial DHP and ASHP measures have higher uptake in the region.

Table 7 summarizes the data sources the team reviewed to inform the level of program activity related to the principal technologies. The team will review these sources with Council staff and regional subject matter experts during model development to identify other possible sources of data.

Table 7: Key Program Data Sources

Organization	Data Source	Known Sources of Model Overlap
The Council	• Seventh Power Plan and Action Plan, load forecasts, and VRF and DHP conservation supply curves • 2021 Plan conservation supply curves • 2018 RCP report	The RCP report summarizes regional program activity for a high-level magnitude of program savings
NEEA	• Washington 2015 Non-Residential Energy Code Energy Savings, NEEA, September 30, 2019, Mike Kennedy • NEEA Residential New Construction Programs • NEEA NW DHP Initiative, https://goingductless.com/ • NEEA High Performance HVAC Initiatives • Email correspondence to review commercial HVAC programs	The residential new construction program overlaps with multifamily central HVAC systems in the model
BPA	• BPA IS2.0 Program Data • BPA Custom Project Data • BPA Implementation Manual, 2017-2019 • 2016 BPA Market Intelligence Report • BPA UES Measure List, Version 7-3	Representative of prescriptive and custom utility programs and where the model will most overlap with programs
Puget Sound Energy	• https://www.pse.com/rebates/business-incentives/commercial-hvac-upgrade-incentives/variable-refrigerant-flow • https://www.pse.com/rebates/business-incentives/commercial-hvac-upgrade-incentives/commercial-ductless-heat-pump-rebate	Representative of prescriptive and custom utility programs and where the model will most overlap with programs
Snohomish Public Utility District (PUD)	• https://www.snopud.com/Site/Content/Documents/ci/CI_Rebates_519.pdf	
Energy Trust of Oregon	• https://www.energytrust.org/wp-content/uploads/2016/10/nbe_pg_techguidelines.pdf	
SCL	• Phone and email conversations • SCL Commercial HVAC Program Data	

Regional Conservation Progress Report and BPA Reported Savings

The Council's RCP report presents annual energy savings from all regional program sources[34] including a broad snapshot of regional program activity, which assesses progress toward the Seventh Plan and 2021 Plan goals. The RCP report represents savings from all energy efficiency activities across the region, including all utility and NEEA programs, broken out by specific Technology, Application, or Practice (TAP) categories. The team reviewed the most recent available iteration of the RCP report, which included program savings through 2018.

The team reviewed the RCP report savings to understand the relative magnitude of VRF, DHP, HRV/ERV, and ASHP program savings and where program activity occurs in the region, summarized in Table 8.

Table 8: RCP Reported Commercial HVAC Savings (kWh/year, busbar)

Year	Technology	BPA-Funded	Self-Funded	IOU Funded	Mid-C Funded	NEEA	Total (kWh)	Total (aMW)
2016	VRF	-	-	546,991	-	-	546,991	0.06
2017	VRF	92,800	-	771,231	-	-	864,031	0.10
2018	VRF	104,000	-	312,236	-	-	416,236	0.05
2016	DHP	351,789	104,994	2,668,586	22,881	-	3,148,250	0.36
2017	DHP	515,458	176,847	2,273,649	29,466	-	2,995,421	0.34
2018	DHP	1,007,345	199,548	2,244,273	28,209	-	3,479,375	0.40
2016	HRV/ERV	-	427,822	-	-	-	427,822	0.05
2017	HRV/ERV	-	-	40,328	-	-	40,328	0.00
2018	HRV/ERV	-	-	18,044	-	-	18,044	0.00
2016	ASHP	221,822	1,545,592	3,125,367	14,773	-	4,907,554	0.56
2017	ASHP	55,749	365,870	187,070	-	-	565,876	0.07
2018	ASHP	519,544	35,172	399,587	210,122	-	1,090,743	0.13
Total		**2,868,507**	**2,855,845**	**12,587,362**	**305,451**	**-**	**18,500,671**	**2.12**

The RCP report shows that DHP savings represent more than four times VRF savings, indicating a low level of VRF program activity and a relatively high level of DHP activity.

The team considered an extrapolation method similar to past market models, as previously discussed, that subtracts program savings reported through the RCP based on extrapolated detail in BPA's measure detail. This approach has several limitations:

[34] Regional Technical Forum, "Regional Conservation Progress Survey," Northwest Power and Conservation Council, https://rtf.nwcouncil.org/about-rtf/conservation-achievements/2018

- Extrapolation in past BPA models relied on BPA program measure detail, as reported in BPA's IS2.0 program data. Based on the RCP reporting, BPA utilities only represent an average of 24% of reported regional savings for the principal technologies, so BPA measure detail may not represent non-BPA program activity.
- Utilities commonly fund commercial HVAC projects through custom programs, which they report in broader TAPs that include other commercial HVAC activity. Extrapolating RCP report data to account for custom projects would require assumptions that introduce a high level of uncertainty to the model.
- The RCP report lacks detail about where measures are installed, specifically whether measures are new construction or retrofit. The team would need to further research program activity and make assumptions to estimate which savings correlate to the scope of this model.

The team will pursue the previously described building-by-building approach to avoid the uncertainty associated with using past model methodology in this market model. Once the team establishes regional program savings, the final step is to subtract all permitted projects reported through regional programs from the total market savings calculated in Question 3. After subtracting these program savings, any remaining savings are Momentum Savings.[35]

NEEA Initiatives

The team reviewed four separate areas of NEEA's work relating to commercial HVAC to identify possible sources of overlap with this model: code savings, residential new construction programs, residential HVAC initiatives, and NEEA's commercial high-performance HVAC initiative. The team's review included soliciting feedback from NEEA to ensure the team characterizes the programs accurately to avoid potential overlap with the market model.

NEEA Energy Code Savings

NEEA currently measures and reports energy savings from state energy code improvements for each code update cycle. The team reviewed the most recent available NEEA reports[36] and the savings methodology to identify any overlap in BPA's new construction commercial HVAC Momentum Savings.

The team found that NEEA's reported energy code savings will not overlap with BPA's Momentum Savings methodology, since NEEA reports efficiency improvement savings from each code cycle's update rather than savings beyond code. NEEA's energy code savings analyses do incorporate current practices baselines where current practice exceeds code baselines. BPA's market model would leverage these code and current practice baselines as the model's baseline to avoid attributing savings already accounted for in NEEA's savings.

NEEA Residential New Construction Programs

NEEA collects data on the region's Built Green Home and ENERGY STAR® Homes certification programs for new construction homes. The programs cover both single family and multifamily buildings, and include requirements for water heating, thermal performance, air sealing, heating distribution design, controls, heat recovery, HVAC systems, lighting, and appliances. NEEA reported to the RCP a total savings

[35] The team's Commercial HVAC Program Savings Memo, TO26 Deliverable 0005, provides additional detail and analysis on the team's review of commercial HVAC program savings data sources.
[36] Washington 2015 Non-Residential Energy Code Energy Savings, NEEA, September 30, 2019, Mike Kennedy

of 6 aMW between 2016 and 2018 attributed to these programs. The team confirmed with NEEA that a small percentage of the projects could include multifamily residential with central HVAC systems. NEEA also confirmed the team should be able to identify the projects that include multifamily central HVAC systems, so the team will request this information at the time of model development and ensure the building-by-building matching uses NEEA's program data. The team will also ensure the extrapolation method accounts for projects reported through NEEA's program if the team does not identify matching buildings from the sample of permitted projects.

NEEA Residential HVAC Initiative

NEEA manages a DHP initiative limited to the residential sector and reports residential DHP savings associated with DHP regional sales. The team reviewed DHP savings reported by NEEA to identify potential overlap between BPA's Momentum Savings and NEEA's program savings. The DHP initiative's scope includes in-unit multifamily DHP installations, which BPA included in the Residential HVAC Model. The Residential HVAC Model accounts for the savings overlap between NEEA's program savings and Momentum Savings associated with DHP installation in multifamily buildings. Therefore, the team will limit the scope of its commercial HVAC Momentum Savings model to exclude residential (multifamily) DHP. The team confirmed NEEA's DHP initiative does not report commercial DHP savings, so its initiative will not overlap with BPA's commercial HVAC Momentum Savings.

NEEA's residential HVAC initiative currently only includes their DHP initiative; however, at the time of this memo, NEEA was at the earliest phase of their Initiative Life Cycle process, Concept Opportunity Assessment, focusing on Variable Capacity Heat Pumps that target replacement of residential electric central forced air systems. The initiative could include small commercial installations, so the team will revisit the status of this initiative at the time of model development.

Commercial High-Performance HVAC

NEEA is in the early stages of a commercial HVAC initiative, Very High Efficiency Dedicated Outside Air Systems, that includes high efficiency heating/cooling systems (e.g., VRF, heat pumps, etc.) and high efficiency HRV/ERVs, along with key design principles. However, at the time of this memo, the initiative was not yet in NEEA's market development phase.[37] If NEEA's work does move to a fully launched program, the team will work with NEEA to ensure BPA's market model does not include their reported savings associated with either heating/cooling systems or HRV/ERVs.

NEEA is also preliminarily investigating the electric savings opportunity for gas RTUs, including those that integrate direct expansion. NEEA is still defining the future of this initiative, so the team will reengage with NEEA during model development to identify any potential overlap with the market model.

[37] More information about NEEA's programs is available at https://neea.org/our-work/programs and https://betterbricks.com/solutions/hvac/dedicated-outside-air-system-doas.

Sources of Uncertainty and Model Validation

The model's accuracy and validity depend on primary data, to the extent possible. Dodge data and permits represent the most robust and current sources of information available, so the team has high confidence in the proposed methodology, but the team will use additional data sources to validate the model's results and inform areas of uncertainty.

Key Sources of Uncertainty

The team will document areas of uncertainty throughout data collection and model development and will propose opportunities to reduce uncertainty through additional research or verification activities. The team will follow past market model methodology by quantifying the greatest sources of uncertainty using standard statistical methods and sensitivity analyses.

Sources of uncertainty will evolve over the course of the data collection and modeling efforts, but Table 9 summarizes the team's anticipated areas of uncertainty and the team's proposed mitigation strategies.

Table 9: Potential Sources of Uncertainty and Mitigation Strategies

Area of Uncertainty	Proposed Approach to Reduce Uncertainty
Saturation of HVAC technologies	Validate model results against alternative data sources (summarized in Table 10)
Permits matching installed HVAC system characteristics	Review NEEA's 2020-2021 Washington commercial code evaluation study which will compare installed HVAC systems with permit data Additional spot verification after data collection completion
Accuracy of building energy models to reflect typical building consumption	Calibrate building energy models to existing building data, follow energy modeling calibration best practices, and validate results against metered data
Representativeness of program savings	Compare program savings model outputs against existing program data sources, namely, the RCP and BPA reporting
Baseline HVAC system mix	Investigate fuel trends to better inform systems that would have been gas in the baseline, but installed electric systems in the actual case

Since this market model's approach relies on the accuracy of permit data to reflect installed conditions, BPA has focused on increasing confidence in permit data as a reliable system data source for characterizing the commercial HVAC market. The team completed an investigation in 2020 to evaluate reliability of permit data to represent installed HVAC systems. The results of the investigation indicate permits are an accurate representation of the installed HVAC systems, but the team will confirm this finding in two ways:

1. The team will review the results of NEEA's 2020-2021 Washington commercial code evaluation study, which will compare installed HVAC systems with permit data.

2. The team will conduct additional verification after collecting permit data in 2021 to verify a sample of the project sites by contacting the mechanical firms and/or building owners and confirming the installed HVAC systems.

Model Validation

Due to the specific scope of the market model, the model's total consumption and savings outputs may have limited comparable data available in the region to validate the results as a whole, in terms of total HVAC energy consumption of just commercial buildings entering the stock through permitted projects. However, other opportunities exist to maintain confidence in the model's methodology and reduce uncertainty in the results by verifying all of the components of the market model, such as total building energy consumption, HVAC-specific energy consumption, commercial new construction growth, and HVAC technology trends. The team will follow the best practice of identifying more than one data source for any model input, considering similarities, differences, and impacts to model results. For example, the team will use permits to estimate the saturation of HVAC technologies entering the building stock through new construction but will compare saturation findings with additional data sources like NEEA's 2019 CBSA and NEEA's commercial code evaluation studies for comparison. The team will conduct a thorough review of the model's inputs and outputs and compare to alternative sources.

Table 10 summarizes the available sources of data to validate model inputs and results.

Table 10: Model Validation Data Sources

Model Input	Primary Data Source	Sources of Validation
Saturation of HVAC technologies (market flow)	Dodge data and permits extrapolated to region	2019 CBSA, Commercial Code Evaluation studies, Seventh Plan and 2021 Plan, regional shipments or sales data as available, other new construction and commercial HVAC market assessments
Installed HVAC system	Permits	NEEA's Commercial Code Evaluation Pilot Study to verify installed HVAC systems match permit data
UEC inputs	Seventh Plan and 2021 Plan, NEEA, BPA, & RTF Prototype Models, PNNL's Building Energy Score modeling tool, 2019 CBSA, NEEA code compliance studies	Cross-referenced primary data source inputs (i.e., as a whole, the UEC inputs will come from a variety of primary data sources, all of which can be used for validation; a single UEC input may rely on a single primary source like the 2021 Plan, but can rely on comparative sources like the 2019 CBSA for validation)
UEC consumption outputs	UEC models by segment	CBSA billing or metered data, regional prototype models, regional models submitted through Total Performance Path through permits, WSEC's 2018 TSPR building modeling tool, Seattle and Portland public benchmarking data
UEC savings outputs	UEC model outputs	Seventh Plan and 2021 Plan measure savings, RTF prototype models, RTF measures, BPA program measures, BPA custom project calculations, other utility program calculations
Program savings	Building-by-building matching of utility program data	RCP report, BPA IS2.0 program data, and custom project files from BPA and regional utilities
Market size (sq. ft. entering the stock through new construction)	Dodge data	Seventh Plan and 2021 Plan, 2019 CBSA, other new construction and commercial HVAC market assessments

In addition to reviewing other data sources for input and output comparison, the team will validate the final model results by conducting savings calculations external to the model for comparison. The goal of this calculation will be to try to replicate the model's results through an alternative approach. The team will use comparable data sources provided in Table 10 to conduct Equation 6's validation calculation. The team will compare the validation calculation's results with the model's results.

Equation 6: Model Results Validation Calculation

$$RegionalMarketSavings\ (kWh)_N = \sum \left(PrincipalCommSqFt_{N,s} \times UES_s (kWh/sq.\ ft.) \right)$$

Where:

RegionalMarketSavings = total market savings of the principal technologies entering the commercial building stock through the permitting process in each year of the analysis period

N = analysis year

PrincipalCommSqFt = conditioned square footage of commercial buildings conditioned by principal technologies

s = segment of the installed stock (e.g., building type, climate zone, principal technologies, applicable code, etc.)[38]

UES = Unit Energy Savings of each model segment (including principal technology segments) from the Seventh Plan and 2021 Plan measure savings estimates, RTF measures, BPA program measures, BPA custom project calculations, other utility program calculations

The team will continue to develop and refine mitigation strategies as additional sources of uncertainty become apparent.

Model Reporting

The outputs of the Commercial HVAC Market Model will differ from BPA's past market models due to the complexity of this market and the unique scope. This section summarizes the model's reporting capabilities, the key outputs related to the unit of account, and limitations anticipated from the model results.

Reporting Capabilities

The Commercial HVAC Market Model will report on four key metrics in the region:

1. The saturation of primary HVAC systems (principal and ancillary) in permitted projects, as a percent of total conditioned square footage (Question 2 of the Four Question Framework)
2. The total HVAC consumption of all permitted projects in the region conditioned by principal technologies as the primary HVAC system, by technology, building type, and climate zone (Question 3b of the Four Question Framework)
3. The total HVAC energy savings (market savings and Momentum Savings) of all permitted projects in the region conditioned by principal technologies as the primary HVAC system, by technology, building type, and climate zone, against the Seventh Plan baseline (Question 3 of the Four Question Framework)

[38] Question 3 describes the model's segments in more detail.

4. Regional program savings as a percentage of square feet associated with regional utility programs (Question 4 of the Four Question Framework)

The model will also report on additional aspects of the commercial HVAC market using averages and scalars. These additional reporting metrics will be estimates, as opposed to direct model outputs:

- Average square feet per HVAC unit and heating and cooling capacity per unit for each model segment, by technology, building type, and climate zone
- Total square footage of commercial permit activity, by building type, climate zone, and energy code cycle

Model Outputs and the Unit of Account

The Unit of Account section describes the metric by which the research team quantifies the market and basis for the model. Using square feet of conditioned space as the unit of account provides a consistent basis for modeling and analysis of commercial HVAC systems. Any given commercial HVAC system can vary widely, both in capacity and in energy consumption, so many utilities and organizations, including the Seventh and 2021 Plans and the RTF, commonly use square feet of conditioned space to normalize energy consumption.

The model will result in UEC values in kWh/square foot for each UEC segment. The model will multiply those UEC values by the square footage of conditioned space in the region associated with each UEC segment, resulting in a total kWh (or aMW) per year consumption of permitted projects, by principal technology.

The team will also estimate savings *per HVAC unit*; however, the model will not report these results with as much accuracy as the savings per square feet for two reasons. First, capacity or size varies widely between units, which means consumption and savings will also vary widely. A kWh/unit estimate, not weighted by size, will always be a less accurate average. Second, a kWh/unit estimate would need to be multiplied by the number of units in the region to accurately calculate regional consumption and savings. However, extrapolating number of HVAC units from the permit sample would prove less accurate than extrapolating total regional square footage, due to variations in unit capacity and square footage of conditioned space per unit.

The team will estimate the savings per HVAC unit by technology and the number of units per technology in the region by estimating the average square footage per unit and scaling the number of units in the region; however, the team will note these model outputs as less reliable for regional use. The team will not report these by each model segment due to the limitations of the sample to accurately report number of units by segment.

Model Limitations

The Commercial HVAC Market Model will have some inherent reporting limitations due to the unique model scope. The team anticipates the market model will *not* report on the following areas:

- Total regional commercial HVAC energy consumption and associated savings of all *existing* commercial buildings in the region since the model will only report activity from permitted projects.

- Total regional commercial HVAC energy consumption and associated savings of all permitted projects in the region since the model will not estimate energy consumption of ancillary technologies. The model will limit consumption estimates to principal technologies.
- Regional commercial HVAC activity happening outside of permits, which the team assumes primarily to include the replacement market.
- Regional trends regarding what systems get replaced by efficient equipment in existing buildings since the model will not capture data on HVAC systems in existing buildings.
- Fuel switching trends since the model will not capture HVAC systems being replaced, only new systems entering buildings through permitted projects.
- Regional trends on lighting, envelope, windows, and other non-HVAC building characteristics.
- Control or fan savings as an independent savings category (e.g., the Residential HVAC Market Model reported thermostat savings, but this model does not include controls as a principal technology).
- Total regional commercial HVAC program savings. The model scope is limited to commercial HVAC activity associated with principal technologies in permitted activity, so the program reporting will match this scope.

Next Steps

The team will continue to work with BPA to refine model methodology as permit data collection begins. The team will seek feedback from stakeholders and subject matter experts to provide review and input throughout the modeling process and will update the methodology as needed. This team of experts will provide external input on the methodology and development of the model and periodically meet with the research team to solicit feedback.

The team will also review the 2021 Plan documents following plan finalization and update the methodology in the future when BPA pursues 2021 Plan model development.

Appendix A: Regional Characterization of Multifamily Buildings

BPA's Commercial HVAC Market Model will include multifamily residential buildings with central HVAC systems. The team reviewed how Northwest organizations characterize multifamily buildings to ensure the model defines multifamily buildings consistent with the region. While organizations characterize multifamily buildings with in-unit heating and cooling as a commercial building, the team will continue to model units with in-unit heating and cooling in the Residential HVAC Market Model.

Table 11 summarizes how each regional organization defines multifamily residential buildings and how the definition relates to BPA's market models.

Table 11: Definition of Multifamily Buildings by Organization

Organization	Multifamily Definition	Residential and Commercial Distinctions	Relation to BPA Models
The Council's Seventh and 2021 Plans	Five or more units Low-rise: 1-3 stories Medium/High-rise: 4 or more stories[39]	Residential sector: Only assesses in-unit conservation potential and excludes common-area or building-area HVAC systems Commercial sector: Does not include multifamily common-area or building-area HVAC systems	Consistent with current characterizations
NEEA	Five or more units Low-rise: 1-3 stories Medium-rise: 4-7 stories High-rise: More than 7 stories[40]	Energy Code Initiative: Multifamily defined as commercial, consistent with state energy codes	Consistent with current characterizations
		Residential New Construction Programs: Build Green Homes and ENERGY STAR Homes includes multifamily buildings	Consistent with current characterizations
		DHP Initiative: Limited to in-unit heating	Consistent with current characterizations
		Commercial High-Performance HVAC: Multifamily currently not part of the initiative's scope	Reconfirm during model development

[39] https://www.nwcouncil.org/reports/seventh-power-plan
[40] https://neea.org/data/residential-building-stock-assessment

Organization	Multifamily Definition	Residential and Commercial Distinctions	Relation to BPA Models
BPA programs	Five or more units Low-rise: 1-3 stories Medium/high-rise: 4 or more stories[41]	Qualified commercial sector measures: Includes central heating in multifamily buildings	Consistent with current characterizations
		Energy Efficient & Zero Ready New Multifamily Construction Measures: Includes multifamily buildings	Consistent with current characterizations
State energy codes	One and two-family dwellings	IECC 2012 and later: "Residential" includes one and two-family dwellings, townhouses, and Group R-2 and R-3 buildings[42] three stories or less. "Commercial" includes all buildings not covered by "residential"[43]	Consistent with current characterizations
		All four Northwest states follow the IECC definition[44]	

[41] https://www.bpa.gov/EE/Policy/IManual/Documents/2020-2021_IM_Updated_3-20.pdf
[42] Group R-2 includes one and two-family apartments, dorms, hotels, motels. Group R-3 includes residential care, transient boarding houses. https://up.codes/s/residential-group-r
[43] https://sbcc.wa.gov/state-codes-regulations-guidelines/state-building-code/energy-code
[44] https://www.energycodes.gov/adoption/states/

Appendix B: Regional Building Model Prototypes

Table 12 summarizes the available regional prototype models for BPA's use and their modeling capabilities, inputs, and data sources as they relate to developing the UECs. This table does not comprehensively include all model inputs and capabilities but represents the most important aspects to BPA in developing accurate UECs. NEEA's energy code models describe the current practice baseline assumptions when the current practice exceeds the energy code's minimum requirements. At the time of this memo, the RTF had not publicly posted the 2020 RTF prototype models or documentation, so the team will review these models in more detail when the materials become available.

Table 12: Summary of Regional Building Model Prototypes

Data	Sub-discipline	NEEA Washington 2012 & 2015 Energy Code Models[45]	2016 BPA/RTF Prototype Models[46]	2020 RTF/Big Ladder Prototype Models[47]	PNNL TSPR & Building Asset Score Models[48]
Architectural					
% Window Area	Glazing	30-34% Window to Wall Ratio by building type	10-53% Window to Wall ratio, varies by building type, CBSA 2014 (post-2004)	CBSA 2014 regional building characteristics	User-defined[49]
Window Performance	Glazing	Varies by building type: SHGC is 5% more efficient than code, both in 2012 and 2015	Oregon 2014 code, WSEC 2004 code, & IECC 2004 Code (ID & MT)	CBSA 2014 regional building characteristics	User-defined
Building UA Value	Envelope	Varies by building type: UA/ft^2 is 5% more efficient than code, both in 2012 and 2015	Oregon 2014 code, WSEC 2004 code, & IECC 2004 Code (ID & MT)	CBSA 2014 regional building characteristics	User-defined

[45] Mike D. Kennedy, Inc., "Washington 2015 Non-Residential Energy Code Energy Savings," Northwest Energy Efficiency Alliance, September 2018
[46] Commercial Building Simulation Models, Regional Technical Forum, https://nwcouncil.app.box.com/v/SimModelsHVACInteractionZIP
[47] Big Ladder Software Training Workshop, "Modelkit/EnergyPlus Models for the Pacific Northwest," January 2020
[48] Building Energy Asset Score, U.S. Department of Energy and Pacific Northwest National Laboratory, https://buildingenergyscore.energy.gov/
[49] The TSPR tool restricts users from inputting values less efficient than the 2018 WSEC while the Building Asset Score provides users more flexibility in inputs.

Data	Sub-discipline	NEEA Washington 2012 & 2015 Energy Code Models[45]	2016 BPA/RTF Prototype Models[46]	2020 RTF/Big Ladder Prototype Models[47]	PNNL TSPR & Building Asset Score Models[48]
Electrical					
Lighting Power Density	Lighting	Current Standard Practice modeled as 15% more efficient than code maximum LPD, varies by space type, ranging from 0.69 w/sf to 1 w/sf	2014 CBSA LPD, ranges from 0.87-1.28 by building type	CBSA 2014 regional building characteristics	0.66 W/ft2 (Fixed)
Exterior Lighting Power Density	Lighting	Uses CBSA 2014 average, reduced by 25% to align with WSEC	2014 CBSA LPD, ranges from 0.11 to 0.66 by building type, assumes dusk to dawn operation	CBSA 2014 regional building characteristics	Not modeled
Lighting Controls: Daylighting	Controls	Modeled explicitly by building type as required by code	PNNL Lighting Schedule values (includes some lighting controls)	Unspecified	User-defined
Lighting Controls: Occupancy Sensors	Controls	Modeled as operational reductions by building type and space as required by code	PNNL Lighting Schedule values (includes some lighting controls)	CBSA hours per week	Not modeled
Mechanical					
Economizer Inclusion	HVAC	Included where required by code	Modeled for most building types	Unspecified	User-defined
Mech. Equipment Efficiencies (supplementary systems)	HVAC	Varies by equipment type, generally code-minimum	90.1-2001 compliant systems	CBSA 2014 regional HVAC system characteristics	User-defined

Data	Sub-discipline	NEEA Washington 2012 & 2015 Energy Code Models[45]	2016 BPA/RTF Prototype Models[46]	2020 RTF/Big Ladder Prototype Models[47]	PNNL TSPR & Building Asset Score Models[48]
Controls - DCV	Controls	Assumes DCV in spaces required by code	Modeled for retail, not other building types	Unspecified	User-defined
Controls - Building Warmup	Controls	Not modeled explicitly or not documented	Unspecified	Unspecified	Not modeled
Fan Control	Controls	Variable speed or 2-speed flow where required by code; fan power varies by building type.	CBSA fan efficiencies and control	Unspecified	User-defined, limited modeling
Pump Control	Controls	Not modeled explicitly or not documented in report	Unspecified	Unspecified	User-defined
Building Control System	Controls	Not modeled explicitly or not documented in report. Follows PNNL's prototype operations and scheduling.	PNNL prototype HVAC control settings	Schedules derived from CBSA 2014 buildings (hours per week)	Not modeled explicitly
Control Setpoints	Controls	Follows PNNL's prototype setpoints	PNNL prototype setpoints	Unspecified	Follows PNNL's prototype operations and scheduling
Hydronic Controls	Controls	Not modeled explicitly or not documented in report	Unspecified	Unspecified	User-defined
Hydronic Valve Types	Equipment	Not modeled explicitly or not documented in report	Unspecified	Unspecified	Not modeled
Hydronic Valve Placement	Installation	Not modeled explicitly or not documented in report	Unspecified	Unspecified	Not modeled

Data	Sub-discipline	NEEA Washington 2012 & 2015 Energy Code Models[45]	2016 BPA/RTF Prototype Models[46]	2020 RTF/Big Ladder Prototype Models[47]	PNNL TSPR & Building Asset Score Models[48]
Controls - Occ Sensor	Controls	Not modeled explicitly or not documented	Not modeled explicitly or not documented in report	Unspecified	Not modeled
DOAS (with or without heat recovery)	HVAC	Modeled either as DOAS single zone systems or as high performance VAV by building type	Not modeled explicitly or not documented in report	Unspecified	User-defined
Heat or energy recovery	HVAC	Excluded but noted as an area for future model changes	Not modeled	Unspecified	User-defined
Operations & Scheduling	HVAC	Follows PNNL's prototype operations and scheduling	CBSA annual reported hours	Schedules derived from CBSA 2014 buildings (hours per week)	Setpoints, ventilation rates, and all schedules of operations based on ASHRAE 90.1 Normative Appendix C, as specified in the WSEC
Mechanical & Plumbing					
Service Water Heating: Efficiency & Type	Equipment	Not modeled	PNNL inputs	Unspecified	User-defined
Service Water Heating	Recirculation Controls	Not modeled	PNNL inputs	Unspecified	User-defined
Building Loads					
Equipment Loads	Plug Loads	Follows 2016 BPA/RTF prototype models with modifications for plug load controls	Includes an equipment power density based on PNNL modeled office equipment	Unspecified	Plug and process loads based on ASHRAE 90.1 Normative Appendix C, as specified in the WSEC

Appendix C: Permit Compliance Paths

As part of the permit data collection process, the team will collect applicable code and energy code compliance paths for all permitted projects containing principal technologies. Permitted projects can pursue energy code compliance by prescriptively complying with all code requirements, or by providing an energy model that demonstrates the whole building performs better than a code baseline building. Determining whether a permitted project used prescriptive or Total Building Performance compliance pathways is not always clear. Figure 2 describes the process the team will use to make this determination during the permit review process.

Figure 2: Process to Determine Energy Code Compliance Path