IS THERE GOLD IN THEM THAR' HILLS? MINING PUBLIC RECORDS FOR COMMERCIAL HVAC SYSTEM DETAILS

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ABSTRACT

Energy efficiency program administrators rely heavily on detailed commercial building data to define accurate baselines, understand code compliance, and design effective programs. Data from permitted construction projects are of particular interest because new and remodeled buildings provide an early look at market transformation—where new technologies appear most. Program administrators and researchers' efforts depend on reliable, current data sources. Finding these sources of commercial new construction data, however, has historically challenged these organizations. Existing market data sources like building stock assessments provide quality information but often lack granularity, represent a single point in time, and come at a high cost. As the industry seeks opportunities for energy efficiency in more complex building systems, the need for cost-efficient data collection methods grows.

A regional organization's market research team and its contractor identified a new opportunity to observe regional commercial heating, ventilation, and air conditioning (HVAC) market trends by gathering publicly available permit data for commercial new construction buildings. This paper will present the methodologies and results of a statistically representative commercial HVAC data collection effort completed in 2021 following a pilot effort that was described in a 2020 Summer Study paper.

This paper discusses the sampling approach, project request and replacement processes, results, and lessons learned. Results include new construction trends in efficient HVAC technologies like variable refrigerant flow, heat recovery ventilators, and trends in electrification. The success of this data collection effort points to permit records as an underutilized goldmine of market intelligence.

Introduction

The Bonneville Power Administration's (BPA) market research team contracted with Cadeo Group (Cadeo) to gather permit drawings as a data source to identify heating, ventilation, and air conditioning (HVAC) trends in commercial new construction and renovations. BPA has worked to clearly characterize commercial HVAC markets in the Pacific Northwest (BPA 2015). The commercial HVAC market has proven to be more difficult to characterize than other commercial markets, often relying on anecdotal information from market actors due to a lack of available data (BPA 2019). Utilizing permit data has proven to be an effective approach to market research that offers a new path to data collection that eliminates the end user (or building occupant) from the task of obtaining data about commercial buildings.

Through months of planning, data collection, cataloging, and review, the Cadeo team collected detailed equipment information on nearly 2,000 individual HVAC units across more than 200 building sites. The resulting database of regional building and HVAC information is poised to be a phenomenal resource for energy efficiency advocates and utility program development. BPA and Cadeo used this approach specifically to gather HVAC data in this case, and the team saw multiple opportunities to pursue similar data collection techniques in other energy efficiency sectors. This paper shares the data collection methodology, highlighted trends from the collected data, and many lessons learned to help others embark on similar permit data mining endeavors.

Literature

The traditional data sources energy efficiency professionals use to characterize commercial HVAC energy consumption include resources like regional building stock assessments, utility program data, and code compliance studies. These tools all provide useful data, but they differ from permit drawing data collection both in methodology and in the data obtained.

What is Permit Data?

A typical commercial building project moves from design development to the final installed conditions through a design process involving engineers and architects. Near the end of the design process, the engineers and contractors must submit project drawings and documentation to the local permitting office (often referred to as the "Authority Having Jurisdiction" [AHJ]). The permitting office reviews the drawing set, along with accompanying calculations and documentation, for compliance with various codes. After any deficiencies in the plans have been corrected, the permitting office will approve the drawings for construction.

The approved permit drawings are typically kept by the permitting office and referred to by inspectors to ensure a project complies with the code and the approved plan set. These plan sets and documentation were the basis of this study. Collection of "permits" or "permit drawings" as a data source specifically refers to collecting the approved permit drawings and documentation from the local permitting authority for a given project.

While the research team attempted to collect all permit documentation for the projects included in this study, there were instances where projects were too large to obtain all drawings and supporting documentation. In these cases, the team requested only mechanical drawings, general drawings that included high level project information, and any drawings with energy code information. "Permit data" are the data cataloged through review of the permit drawings.

Existing Data Sources for HVAC Market Characterization

Regional building stock assessments, such as the 2019 Commercial Building Stock Assessment (Cadmus 2020), provide a great overview of building stock at a specific point in time. Since assessments are typically only conducted every four to five years, identifying trends in commercial HVAC systems and equipment can take a decade. In addition, building stock assessments typically rely extensively on on-site investigation and interviews with occupants or

building managers, which can be time consuming, expensive, and sometime inaccessible (as was the case during the COVID-19 pandemic).

Utilities collect data from customers who apply for energy efficiency incentive programs, which provide detailed information about the energy efficiency measures used at a specific site. However, the prevalence of efficient equipment purchases and installations that occur outside of utility incentive programs is impossible to know. Characterization of the commercial HVAC market using only utility program data would consistently exclude the portion of the market that does not pursue utility program incentives.

In the Pacific Northwest, commercial code evaluations have gained traction in the past decade, with studies completed in Oregon and Washington (Larson 2019; Cadmus 2022). These studies aim to collect data on how designers and contractors meet commercial energy efficiency code requirements. Commercial code evaluation studies capture trends in new construction, but they also require interaction with an owner or building operator, are time intensive, and are typically limited to a single state. The code compliance study recently completed in Washington cited COVID-19 limitations as causing the study to run significantly behind schedule and over budget (Cadmus 2022). The US Department of Energy recently completed a national code evaluation study (PNNL 2021). This study did not find permit collection to be faster than field investigation but it was also conducted outside of the Pacific Northwest region, where access to buildings may have been easier.

Permit Data Are Different

Permit drawings, with few exceptions, are public records. Identifying a population of projects or sites for which to request permit drawings takes effort, but most jurisdictions maintain good records and can provide the permits when requested. The research team recently completed data collection of over 300 permitted projects that represented newly constructed or improved conditioned square footage in the Pacific Northwest (Washington, Oregon, Idaho, and Montana) between 2016 and 2020. The data collection required no physical contact with permitting offices; all data requests were completed either online, via email, or over the telephone. Jurisdictions almost exclusively stored and shared records electronically, which further reduced the need to visit local permitting offices.

In addition to being readily accessible, data contained in permit drawings and documentation can provide an early view into developing market trends. Where stock assessments may take several years to identify market changes, recently constructed buildings can indicate the speed of stock turnover and the prevalence of new technologies entering the market. This approach could work similarly for other technologies like water heating and controls.

Validity of Permits for Commercial HVAC Data

Regional energy efficiency stakeholders gave feedback that permit drawings may not accurately represent installed conditions since contractors can propose alternative lower-cost equipment after permitting as part of a value-engineering process. At the request of stakeholders and subject matter experts, the team conducted a brief comparative study of permit drawings to as-built drawings for a sample of 20 new construction projects in Oregon. The team found that

HVAC system type, fuel type, capacity, and efficiency very rarely changed between permitting and construction, which confirmed the validity of data contained in permit drawings as a market evaluation resource for the purposes of BPA's market research.

Permit Data Acquisition Process and Findings

The permit data acquisition process was a multiyear effort that spanned representative sampling, permit requests, drawing curation, document review, data entry, quality control, and data analysis. This section shares the general process of permit data collection and a sampling of findings from the research.

Starting with a Representative Sample

Once the team established that permit drawings were a valid source of commercial HVAC information, the next step was to determine how to representatively sample permitted projects in the region. This step required the team to choose a data source from which to select permitted projects, narrow the data to the sample frame of interest, clean the data to focus on projects that included commercial HVAC work, and determine how to stratify the sample.

Sampling Goals

BPA's primary goal was to estimate the total floor area served by new HVAC systems and the share of that floor area associated with various HVAC system types. The team designed a stratified random sample of projects that represent new HVAC systems installed in Idaho, Oregon, Washington, or western Montana.[1] Other criteria used to achieve the sampling goals were:

- Projects with HVAC systems serving commercial buildings or central systems serving multifamily buildings with five or more units and four or more floors
- Projects with mechanical permit information necessary to meet local energy code requirements at the time of permitting
- Projects completed between January 1, 2016, and December 31, 2020

Data Sources Considered

The research team considered three data sources as a basis for the sample frame: Dodge construction projects,[2] tax assessor parcels, and permit data from permit aggregators.[3] Dodge's sample frame's population contained the most detailed information needed, including building type and type of work (e.g., new construction, addition, alteration, etc.) details for all projects, construction value, address, and square footage data, and these data are identified as reliable by the US Census Bureau in its accounting of commercial building square footage (Census Bureau, n.d.).

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[1] Western Montana counties included only those in BPA service territory.
[2] Dodge Data and Analytics is an aggregator of construction project data, primarily targeting manufacturers, contractors, and project developers in search of bidding opportunities.
[3] Purchased permit data from permit aggregators contains information about permits, such as permit year and permit type.

The team also evaluated matching assessor data to validate Dodge records and identify HVAC systems up front but found the purchased assessor data lacked complete records and not useful for sample characterization.

Projects Included in Frame

The team reduced the initial full population of Dodge records to only projects in BPA's scope of interest. The population was further limited the likelihood of requesting permit drawings from buildings that had no new HVAC work. The team narrowed the population based on the following criteria:

- **Start Year.** The study's scope included permitted HVAC systems that became operational between January 1, 2016, and December 31, 2020. The team included projects with start dates between January 1, 2015, and December 31, 2019, in the frame as a proxy for projects completed between 2016 and 2020, based on judgment that a typical commercial project duration of one year was representative of the market. The team selected these start dates to reduce the risk of selecting projects that were completed before 2016 or would not have been completed by the end of 2020.
- **Building Type.** The team excluded specific building types from the frame that were noncommercial applications, were unlikely to include HVAC scope, or would be very difficult to obtain project drawings for data collection purposes. Excluded building types included all manufacturing facilities, laboratories, warehouses (refrigerated and nonrefrigerated), automotive service facilities, airline terminals, military buildings, and detention facilities.
- **Multifamily Residential Building Size.** Multifamily residential buildings may include central HVAC systems, which are within the scope of the study. The team excluded multifamily residential projects with fewer than five dwelling units because of the regional power plan delineation between commercial and residential spaces (NPCC 2016).
- **Geographic Area.** The team excluded projects outside of BPA's service area.
- **Construction Value.** The team determined that projects with low construction value (e.g., non-building structures) are unlikely to include permitted HVAC systems. The team excluded all projects with construction values less than $200,000, consistent with other regional commercial studies (Baylon, Kennedy, and Borrelli 2001; Baylon, Robison, and Kennedy 2008; Larson et al. 2019). The team also excluded all projects labeled "Alterations, Renovations, and Interior Completions" valued less than $1,000,000 because of their lower likelihood to include HVAC systems.

The research team stratified the final sample by building type, geographic location (east/west of Cascade Range), and construction value. Although the preference would have been to stratify the buildings by square footage, most Dodge records did not include building square footage. The team used construction value as a proxy for square footage for stratification purposes.

Sources of Uncertainty

The team attempted to develop a frame and a sample that is representative of the population of the commercial HVAC market for permitted HVAC projects in Idaho, Oregon, Washington, and western Montana completed between 2016 and 2020. Utilizing Dodge as the primary source of project identification introduced some uncertainty, mainly due to the incompleteness of the Dodge data set. Dodge was the most complete data set the team identified, but the US Census Bureau estimates that approximately 20 percent of new construction projects are not captured by Dodge (Census Bureau, n.d.). In addition, Dodge did not include complete data on project completion dates, square footage, or construction value, which were all considered during sample frame generation.

The study's goal was to draw conclusions about the prevalence of HVAC technology types by building floor area. Floor area was not available consistently from the Dodge data for a significant portion of projects within the frame, so the team used construction value for stratification. Additionally, the floor area listed for a project in Dodge data may not have been the same as the floor area served by an HVAC unit. Therefore, there may have been some unquantified uncertainty in the total floor area of the population. The team used the best available correlated data for choosing a representative sample from which the floor area of the population can be extrapolated (i.e., construction value). The research team calculated the relative precision for each domain using square footage, construction value, and the number of projects in the sample and full population by domain. The team discovered that cataloged square footage as an indicator of construction value is a poor proxy for square footage and contributed to poor relative precision in some domains. Precision was highest in the largest market segments, including office, schools, and multifamily residential building types.

Finally, there was uncertainty as to how accurately the sampled data allow for characterization of individual HVAC technology trends. Perhaps some HVAC technologies were not included at a high enough rate in the sample for a robust characterization of the technology's occurrence in the market. In the case of this research, the team accepted this uncertainty and acknowledged that low prevalence of specific HVAC technologies was still an important finding.

Collecting Commercial HVAC Data from Permit Drawings

Once the research team finalized the representative sample of 300 projects, the team requested permit drawings and documentation and recorded building and mechanical data for those projects. The team used a process to acquire approved/permitted project drawing sets from jurisdictions and to catalog the HVAC data from those plan sets. This section discusses the process followed and lessons learned by the research team for each step.

Data Acquisition Methodology

For each project in the sample, the team requested permit files from permitting jurisdictions through each jurisdiction's public records request process, typically an online request form. Most jurisdictions required additional information and some (roughly 25 percent) required permission from the owner and/or charged fees for providing plan sets. Additional information required included assisting the jurisdiction in identifying the permitted project requested. Many commercial buildings, especially those in campus environments, had many permitted projects associated with the time frame the research team was requesting. Permitting

offices typically used online tools or discussed options on the phone to help the team narrow down a permitted project request to a single drawing set to avoid excess data collection and drawing review.

When jurisdictions were unable to provide plan sets within the research team's time frame, researchers requested files directly from the owner or architect, or used an online project aggregator, ConstructConnect, as secondary resources.[4]

Projects for which permit drawings were not available or were determined to not meet the sample criteria were replaced using the process defined by the sampling plan. The team selected the next available project sample from the sampling plan from the same stratum and region. Where no samples remained in the same stratum, the team selected a replacement from the next size stratum available.

Criteria for Project Replacement

The team had to request 520 projects to achieve the 300-project sample. Reasons for project replacement include:

- The team was sometimes unable to obtain permit drawings because of secret or sensitive information contained in the drawings.
- Some projects did not have complete or valid addresses, which did not allow the jurisdiction to find a corresponding permit drawing or application.
- Some jurisdictions were unable to provide permit documentation, either due to internal policies on not sharing the data or having not retained the permit drawings after construction. In these cases, the team inquired with the architect to obtain plans directly.

Additionally, the team replaced projects based on the following characteristics obtained from permit files if the team determined the project was outside the study scope:

- Multifamily buildings with fewer than five units or fewer than four stories
- Industrial process buildings
- Unconditioned buildings
- Permitted projects that do not include HVAC system installations
- Buildings not yet completed based on the building permit's Certificate of Occupancy date

Data Acquisition Lessons Learned

The research team requested project plan sets through jurisdictions' formal public records request processes, as defined by each jurisdiction, using an approach developed from previous pilot project permit-gathering experiences. Acquiring permit drawings for this full-scale data collection effort resulted in many successes but presented several distinct challenges as well.

First, pandemic restrictions associated with COVID-19 caused delays in acquiring plan documents. Limited staff availability in-person and access restrictions reduced options to review

[4] The team purchased an account to access ConstructConnect's online permit database, https://www.constructconnect.com/. Contractors typically use ConstructConnect as a lead-sourcing website for construction activity; however, ConstructConnect also includes digital records of building permits and approved plan sets for some permitted projects.

and scan physical files and increased pressure on jurisdictions' staff. These challenges resulted in long wait times for some jurisdictions, and other jurisdictions were unable to provide any files. Researchers adjusted to this by making extremely detailed requests and accepting files in a variety of unconventional formats to reduce the burden on jurisdictions.

Unexpected bureaucratic barriers, such as unreasonably high costs for public records requests, months-long time frames to send files, or responses claiming exemption from public records requests, led to higher replacement rates and longer time frames. When this occurred, the research team attempted to contact the architect of the project directly. If that failed, the team searched other online data sources to find the project.

In some cases, the jurisdictional ownership was unclear and data collectors struggled to locate the appropriate contact for a given project. This required consistent communication and tracking to narrow the location of that project's permit drawings.

The size of the jurisdiction also presented some challenges for the research team. Specifically, small jurisdictions often lacked the resources and internal systems to provide the projects in question. Larger jurisdictions struggled in that the research team often had many projects associated with that jurisdiction, requiring significant investment of jurisdiction staff to fulfill the permit documentation request. These situations required distinct flexibility to accommodate the needs of each individual jurisdiction.

Last, late project sample replacements resulted in an extending of the project time line. To address this, the research team requested permit drawings for more projects than required, factoring in a likely replacement rate into the size of the request. This allowed for the team to confidently acquire the number of permitted plan sets needed without having to continuously extend the total timeframe.

Data Cataloging Process

Once the research team acquired a project's plans, researchers cataloged the data associated with each project in two stages. These stages captured the general project and HVAC information needed to support modeling energy use and savings in the region.

Data Entry Tools. The data collection team developed an Excel-based tool to guide the cataloging of HVAC equipment information. The tool separated data collection into two stages and included features like dynamic inputs and notes to help eliminate confusion and questions that arose during past drawing review. This helped to minimize questions and review time because common questions were addressed as the user entered data.

Staged Data Collection. Stage 1 cataloging captured basic project information including project square footage, completion date, and primary heating and cooling systems. These three inputs were used to verify the project was in-scope and to determine which projects should proceed to Stage 2 data collection.

If Stage 1 cataloging identified a project's primary heating or cooling system as a variable refrigerant flow (VRF), ductless heat pump, air source heat pump, or ducted cooling system, the research team cataloged additional HVAC system information in Stage 2.[5]

[5] BPA defined these HVAC systems as key technologies of interest, or "principal technologies" during project planning. "Ducted cooling systems" include unitary air conditioning systems, such as cooling-only heat pumps and packaged rooftop units with electric cooling.

During Stage 2 cataloging, the data collection team captured detailed system variables including HVAC equipment capacity and efficiency, fuel type, heat recovery ventilator (HRV) performance, fan horsepower, and the capacity and efficiency of supplemental HVAC systems. These details are captured from mechanical equipment schedules in the permitted drawings of the project. A sample schedule for is shown in Figure 1 below.

VRF OUTDOOR HEAT PUMP SCHEDULE

SYMBOL	SPECIFIED MANUFACTURER AND SERIES NO.	AREA SERVED	COOLING CAP. *		HEATING CAP.**		OUTDOOR FAN		COMPRESSOR		MAX. WEIGHT LBS	UNIT ELECTRICAL		
			TOTAL MBH	EFF	MBH	EFF	QTY	KW (EA)	QTY	RLA (EA)		MCA	MFS	VOLTS/PH
CU-1	DAIKIN REYQ216PBTJ	FIRST FLOOR EAST	206	17.2 / 16.4 IEER	231	3.5 / 3.3 COP	2		2	12.2 + 16.8	600 + 600	41.3 + 36.1	60 + 50	208/3
CU-2	DAIKIN REYQ192PBTJ	FIRST FLOOR WEST	184	18.7 / 16.9 IEER	206	3.4 / 3.4 COP	2		2	7.8 + 16.8	600 + 600	36.1 + 36.1	50 + 50	208/3
CU-3	DAIKIN REYQ216PBTJ	LOWER FLOOR	206	17.2 / 16.4 IEER	231	3.5 / 3.3 COP	2		2	12.2 + 16.8	600 + 600	41.3 + 36.1	60 + 50	208/3

Figure 1. Sample VRF Outdoor Heat Pump Equipment Schedule from anonymized project in Washington State.

The research team found that collecting the detailed HVAC equipment data was much more time intensive than the Stage 1 data collection, but necessary to provide key inputs for modeling of regional commercial HVAC energy savings. HVAC equipment schedules are not standardized, so equipment may be named or scheduled differently by different mechanical designers. Standardized electronic energy code compliance software can help alleviate this issue, but data from ComCheck (BECP 2022) and a recently launched Washington State online code compliance tool (WSEC 2022) are not currently publicly available.

Data Cataloging Lessons Learned

Experienced advisers trained catalogers on using the data entry tool and provided technical support to reduce the number of judgment calls catalogers needed to make. With the complexities of commercial HVAC equipment, which can include different names for the same equipment, unique applications, and large plan sets, and despite ongoing training, cataloging permit data required considerable time and oversight to ensure entries were accurate and complete. A thorough quality control process ensured accurate data cataloging, though it was resource intensive at times. Programming embedded flags and checks into the catalog tool mitigated some of the time constraint involved in this process.

To maximize accuracy when cataloging it was critical to create strong protocols and ensure staff had sufficient technical knowledge. The research team leveraged junior level staff to input data, but more experienced staff needed to be readily available to answer questions and review inputs. To assist with this, the research team recommends that technical trainings are prioritized early on in the project time line and existing technical resources are accessible to nontechnical team members.

Identifying Trends from Commercial HVAC Permit Data

The research team spent nearly nine months collecting permit drawings and cataloging and reviewing data from the drawings. Although the process was more time consuming than the team had anticipated, the resulting database of regional building and HVAC information provides both high level HVAC system information for the 300-building sample frame and

detailed HVAC equipment information for nearly 2,000 units of HVAC equipment. The research team has begun the early stages of analyzing some of the data and has identified several trends in new construction and efficient HVAC technologies, with a few findings included below.

Electrification Trends

On the electrification front, the team found that most new construction projects installed electric primary heating sources. Although this finding was somewhat expected after several years of pushing heat pumps in regional energy codes, the prevalence over natural gas systems was still surprising since the region has typically been primarily heated by natural gas.

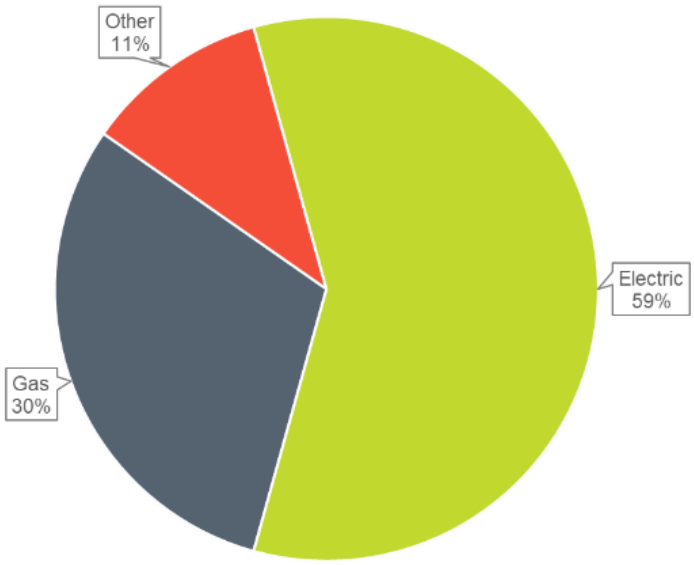

Figure 2. Primary heating fuel type in newly constructed commercial buildings (Pacific Northwest Region, 2016–2020).

Looking closer at these primary heating sources, more than 50 percent of newly constructed buildings installed some form of heat pump as their primary heating system. Figure 3 shows the breakdown of electric heat pump systems, which includes both ducted and ductless systems.

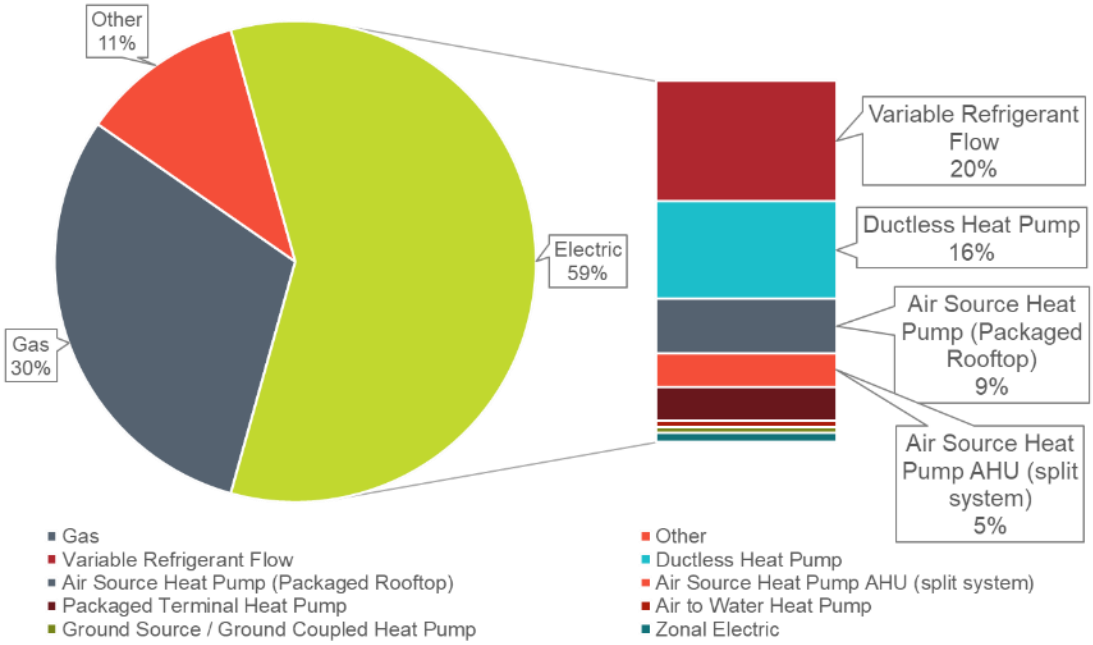

Figure 3. Breakdown of electric primary heating systems in newly constructed commercial buildings (Pacific Northwest Region, 2016–2020).

Regional Average Efficiencies

The research team analyzed regional weighted average efficiencies of VRF equipment. Figures 4 and 5 show efficiencies broken down by system size for comparison with federal minimum efficiency requirements. The team found that efficiencies exceeded code requirements, typically by 10 percent or more, although the largest systems showed the least improvement over minimum efficiency requirements.

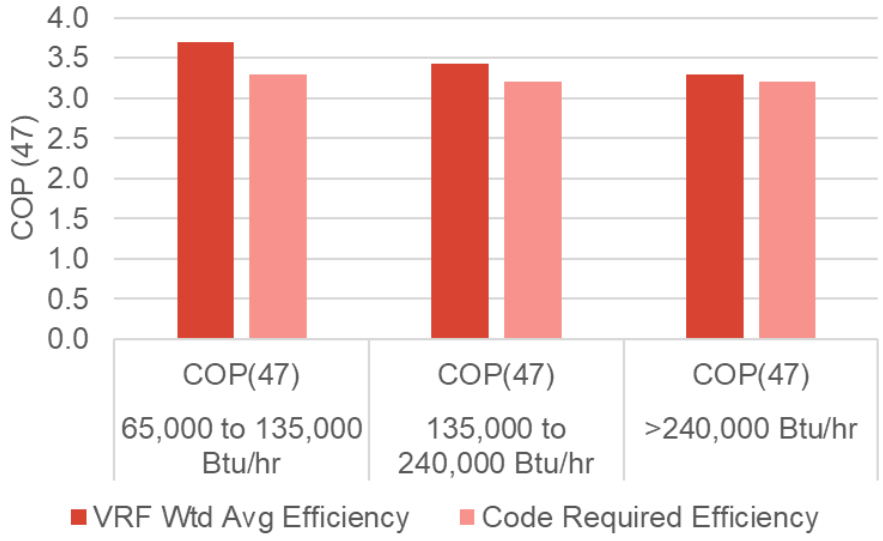

Figure 4: Comparison of regional weighted average VRF heating coefficient of performance (COP) to code minimum efficiency requirements (by equipment size).

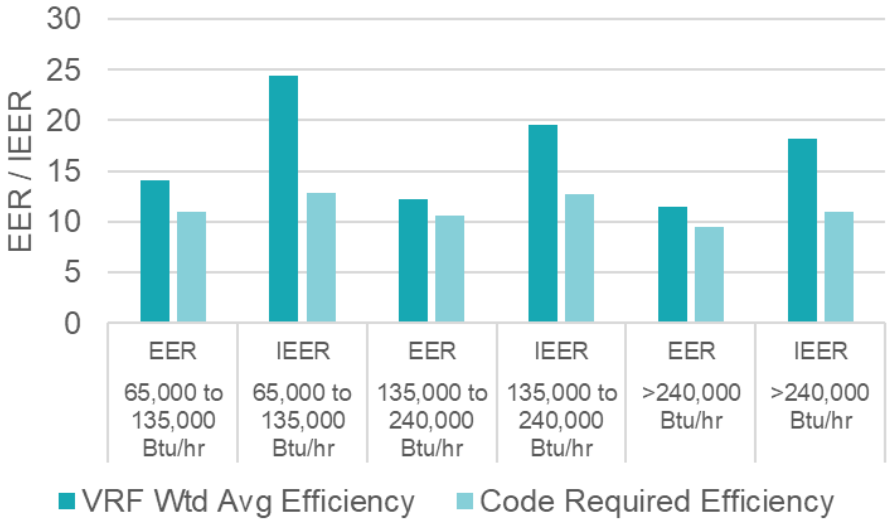

Figure 5: Comparison of regional weighted average VRF cooling energy efficiency ratio (EER) and integrated energy efficiency ratio (IEER) to code minimum efficiency requirements (by equipment size).

HRV/ERV Prevalence and Efficiency

The research team analyzed the prevalence and efficiency of air-to-air energy recovery systems. These systems are of particular interest in the Northwest due to recent emphasis on Dedicated Outdoor Air Systems. The team found that energy recovery systems were included most frequently with ductless heat pumps systems (including VRF), and that energy recovery effectiveness exceeded code with average values over 65 percent total effectiveness. The team also looked at typical fan power compared with cubic feet per minute (CFM) of energy recovery ventilators and found a linear trend, as shown in Figure 6.

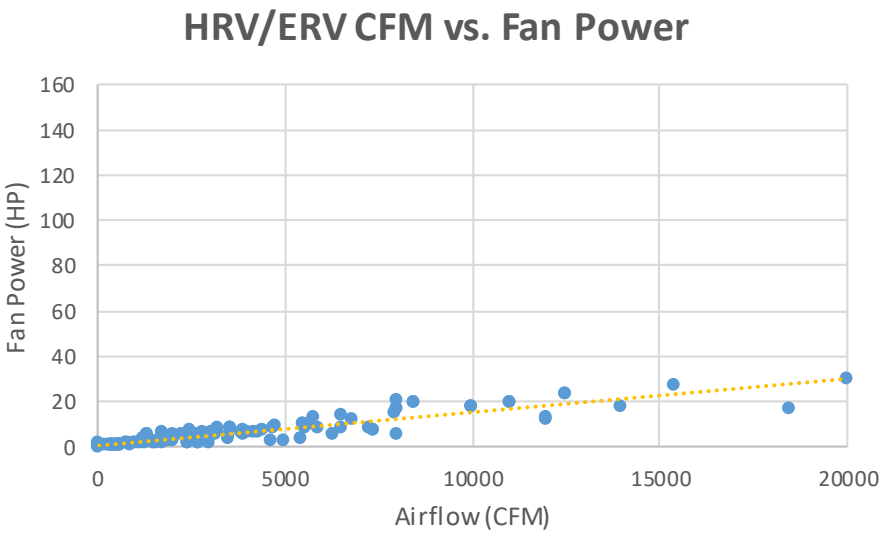

Figure 6: Airflow vs. fan power (horsepower) of air-to-air heat and energy recovery ventilators.

The team's collected permit data can be used to identify additional trends in new construction and other equipment-specific regional average efficiencies for newly installed equipment.

Recommendations and Conclusions

As with any new process, the research team identified several barriers when collecting mechanical permit data. This section outlines the challenges identified by the team, along with recommendations for mitigating those challenges.

Future Data Collection Recommendations

The project saw remarkable success given the novelty of the data collection technique, but certain overarching lessons emerged throughout the process. The following list wraps these lessons into several key recommendations:

1. **Use online secondary data sources to supplement public records requests.** Leveraging online sources that aggregate construction project files such as ConstructConnect will be increasingly useful as digital file storage increases. This recommendation would simplify document acquisition and reduce the burden on jurisdiction staff to physically scan or copy permit files.

   The research team recommends using an online construction project aggregator service at the onset of data collection to find the sample's permit files and then sending public records requests only if the project files are not readily available through the aggregator.

This process could save 10 to 25 percent of data collection time, depending on how much digital file availability increases through construction project aggregator services and what percentage of the sample can be obtained through such systems.

2. **Work with large jurisdictions in advance of future data collection efforts.** The region's largest jurisdictions had a high number of projects in the sample, which required substantial interactions with the jurisdictions' public records staff. In future data collection efforts, the research team recommends contacting jurisdictions (through existing energy efficiency partnerships when possible) in advance of collection to explain the research, confirm the jurisdiction has resources to support the work, and identify an approach that works for both parties (e.g., agreeing on time frames, batched requests, communication preferences, and strategies to minimize the burden on jurisdictions).

3. **Request more projects than the sample requires to minimize replacement delays.** The research team started by requesting project files for the 300 sampled projects, only adding cases when it became apparent a replacement project was required. This approach reduced the time required to request files but created delays when projects dropped out. To keep the project on schedule, the research team requested more projects than needed to complete the sample within the established time frame. The research team requested records of 520 files to complete the sample.

   The research team recommends a two-phased approach for future data collection efforts. For the first phase, researchers recommend requesting only original sample records (looking in secondary data sources first, as described in number one above). After identifying initial replacement for specific strata and domains, the research team recommends a second phase of requests including replacements plus 25 to 50 percent additional backup replacement records. The number of additional requests would depend on the number of projects in each stratum and domain and the number obtained in the first phase. For example, if one domain of the sample includes 10 projects out of a total 100 projects in the population, and the team receives seven of the 10 requests in the first phase, the team may request six replacement projects to fulfill the remaining three projects in the sample, but will use judgment to balance the burden of requests on jurisdictions and the timeframe available to make additional requests. The exception to this recommendation is projects in the largest two strata, which have fewer replacement options and a higher likelihood to need replacing, as jurisdictions had more difficulty providing files for the largest projects in the sample.

   The research team also recommends establishing a firm project replacement timeline. If project files are not received within a specific number of weeks, the project will require replacement.

4. **Take an "account management" approach to working with jurisdictions.** The research team found each jurisdiction had unique processes and constraints, with no single solution or approach that worked for everyone. Researchers recommend

approaching future jurisdiction data collection with flexibility, such as adapting to their staffing and administrative situations, identifying barriers early, building positive relationships with staff, and being open to creative solutions.

Other Potential Use Cases: Lighting Controls

The success of using publicly available permit information for characterizing commercial HVAC equipment will naturally lead to exploring this data source for other commercial equipment.

The data collection team conducted a follow-on pilot study to investigate the prevalence and types of networked lighting controls in commercial buildings. The team found that permit documentation is likely not a viable source of data for characterizing market adoption of lighting controls data due to lacking sufficient detail, clarity, and continuity in drawings. Differences between permit and as-built drawings were also difficult to confirm, since the as-built files often included no extra detail. The research team recommends using other data sources to characterize market adoption of lighting controls in commercial buildings.

Even though permit drawings aren't a reliable data source for lighting, the success of the HVAC data collection means there are opportunities to use permitted projects for deeper investigation into HVAC, water heating, controls and automation, building envelope, or other building characteristics.

Conclusions

The success of this data collection effort and the resulting findings point to permit drawings and documentation as an underutilized goldmine of market intelligence. Permit data collection is a challenging process with many potential hurdles, but also presents an opportunity to collect vast amounts of information without the need to contact building occupants. This research study provided insight into the commercial HVAC market characterization potential of permit data, and further research will continue to uncover additional market applications for this new methodology. Real-time construction trends are important in determining the direction of markets, and availability of more online data and construction project aggregator resources will continue to provide value to energy efficiency professionals and others looking to characterize market trends.

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