Memorandum

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From:	Kate Bushman and the Commercial HVAC Team, Cadeo Group
Date:	February 19, 2021
Subject:	TO32.0002c Commercial HVAC Data Collection Sampling Plan

Introduction

This memorandum describes the Cadeo and SBW team's (the team) sample design for the Bonneville Power Administration's (BPA) Commercial HVAC Data Collection study (the study).

Sampling Goals

The purpose of the study is to collect data from commercial new construction and major renovation building projects which will eventually be used to estimate commercial HVAC electricity consumption for the Northwest Power and Conservation Council's (the Council) Seventh Power Plan Action Plan Period (2016-2021). The team will (a) develop a sampling plan, (b) develop a frame of projects that best represents the population of projects within the study scope, (c) draw a representative sample of projects from the frame, (d) gather permit data and supporting documentation for selected projects, (e) use those data to characterize the prevalence of HVAC systems and their characteristics of the projects in the sample, and (f) extrapolate the prevalence of HVAC systems and their characteristics to the entire region served by BPA as a regional data resource and for use in the eventual market model.

The team has identified the following goals for the sample to support the objectives of the study.

- Design a random sample of projects that represent new HVAC systems that:
    - Serve commercial buildings or are central systems serving multifamily buildings with 5 or more units and 4 or more floors
    - Have mechanical permits that are required to meet energy code requirements at the time of permitting (Appendix A)
    - Started operation between January 1, 2016 and December 31, 2020
    - Are in Idaho, Oregon, Washington, or Montana counties served by BPA
- Estimate total floor area served by new HVAC systems and the share of that floor area associated with various types of HVAC systems.

Sample Summary

The sample frame consists of 6,792 new, addition, or alteration commercial and multifamily residential projects from Washington, Oregon, Idaho, and western Montana with construction start dates between 2015 and 2019[1]. The team divided the frame into domains by Council building types and climate zones and stratified the frame by construction value. The team allocated 300 random sample projects among domains and strata to target a relative sample precision less than or equal to 10% for a confidence level of 90% for each domain.

Terminology

- *Population* – All projects in the scope of the study.
- *Frame* – Most complete and available listing of the population.
- *Sampling Unit* (project) – Each listing in the frame, which is a Dodge construction project.
- *Sample* – A random selection of projects that represent the frame, and if the frame is complete, also represents the population.
- *Relative Precision* (RP) – How well the sample estimates a characteristic of the frame (e.g., the total construction value associated with the projects in the frame). RP is determined for a confidence level (e.g., the team is 90% confident the sample estimate of total construction value is within +/- 10% of the true total).
- *Domain* – Portions of the population for which the team needs to achieve a certain RP (e.g., by building type or climate zone).
- *Measure of Size* (MOS) – A characteristic of all projects that is correlated with other important characteristics that are only available from the sample. For this population, the MOS is construction value (CV) of construction projects. CV is correlated with floor area, which is a key characteristic that the study needs to associate with different types of HVAC systems.
- *Stratification* – Projects within a domain are partitioned into strata by MOS and sampled by strata. For example, if a domain has two strata, projects with construction values below an optimized cutoff are in the first stratum and projects with construction values above the cutoff are in the second stratum. Separate random samples are drawn from each stratum. When the MOS is skewed (i.e., a large portion of the total construction value is associated with a small number of projects), stratification can achieve a target RP with fewer sampled projects than a simple random sample.
- *N, n* – *N* is the count of projects found in the frame for a domain or stratum. *n* is the count of randomly selected projects (i.e., the sample).
- *Construction Value* (CV): Construction value, in USD, of Dodge construction records estimated at ground breaking.

[1] Project completion dates were not available. Project start dates from 2015-2019 were used as a proxy for projects completed in 2016-2020.

Structure of the Memorandum

This memo includes the following five sections:

1. Methodology for developing the sample frame
2. Sample design and methodology the team used to develop the sample frame and design, including the decisions, assumptions, and risks associated with the sample design process
3. Sample selection process and how the team will deploy the sample frame
4. Sources of uncertainty in the sample
5. Appendix

Development of the Sample Frame

This section describes the data sources the team considered to build the sample frame, the data the team purchased, decisions and assumptions the team made regarding the data, and the composition of the sample frame.

Data Sources Considered

The team considered three data sources as a basis for the sample frame: Dodge construction projects, tax assessor parcels, and permit data.[2] Each data source comes with pros and cons, as described in Table 1, as they contain different information, originating from different sources. Dodge Data and Analytics is an aggregator of construction project data, primarily targeting manufacturers, contractors, and project developers in search of bidding opportunities. Multiple vendors aggregate tax assessor parcel and permit data from counties and smaller jurisdictions, with varying coverage and quality of information.

[2] Purchased permit data from permit aggregators contains information about permits, such as permit year and permit type. Separately, the team will collect supporting documentation for sampled projects for all permits associated with selected projects.

Table 1: Pros and Cons of Sample Frame Data Sources

Data Source	Pros	Cons
Dodge construction reports	• Contains building type and type of work • Longest history and best market coverage of potential vendors • Used by U.S. Census Bureau, the Council, and Northwest Energy Efficiency Alliance (NEEA)	• Construction completion date is not available. Start date is available • Need to resolve records not associated with whole building construction
Tax assessor parcels	• Contains year built, building type, and HVAC characteristics	• Uncertainty in year built • HVAC information is sparse • High cost
Purchased permits	• Contains year and HVAC characteristics	• Does not contain building type • Need to resolve permits not associated with whole building construction • High cost

Purchased Data

The team used Dodge construction projects as the starting point for the frame because it contained building type and type of work (e.g., new construction, addition, alteration, etc.) details for all projects, which are important in determining which projects are in the scope of the study. Additionally, it has the longest history of the vendors considered and has been used by the U.S. Census Bureau, the Council, and NEEA. The team purchased all Dodge construction records for commercial buildings and 3+ unit multifamily residential buildings in Idaho, Montana, Oregon, and Washington with construction start dates from January 1, 2016 to December 31, 2019, that had reached or passed the "start" action signal. The "start" action signal is reached when projects are scheduled to begin construction within 60 days. Dodge does not track projects beyond this point. The team purchased a second set of data from Dodge with start dates from January 1, 2014 to September 30, 2020 to provide additional coverage of projects that may have been completed during the Seventh Power Plan Period, and as a starting point for the 2021 Plan Period. Projects that started construction in 2015-2019 were included in the frame as a proxy for projects completed between 2016 and 2020. Subject matter experts weighed in that construction duration varies with building size and complexity, but typically takes approximately 9 months for smaller buildings, and up to several years for very large buildings. The team concluded that building construction started in 2015 represented a reasonable balance between including as many Plan Period projects as possible, while not missing too many large buildings with earlier starts.

The team also purchased tax assessor parcel and permit data from ATTOM Data Solutions (ATTOM)[3], matched by address to the subset of Dodge projects with 2016-2019 start dates, non-excluded building types, greater than $200,000 in construction value (CV), and complete addresses (not missing street

[3] The team considered several permit and tax assessor aggregators, including ATTOM, BuildFax, and CoreLogic. ATTOM was selected because it was the only aggregator that provided unique project IDs to identify projects with multiple permits, and because it was within budget.

address, city, state, or zip code). This match sought to provide additional information about whether projects were complete, when projects were completed, floor area, heating and/or cooling fuel type, and HVAC permits. Table 2 summarizes the purchased data.

Table 2: Purchased Data

Record Type	Record Details	Number of records
Dodge construction reports	ID-MT-OR-WA 2014-2020 Start Dates Commercial or 3+ unit multifamily buildings	26,473
Purchased permit and parcel records	Permit and parcel matches for 9,865 unique, complete addresses from the 2016-2019 Dodge data. Parcel/permit data included records before 2016	5,374 parcel records 185,013 permit records

The tax assessor parcel data did not match well to the Dodge construction records and data of interest was poorly populated for parcels that were matched successfully (Table 3). The team did not use parcel data to develop the frame and did not attempt a second round of matching for the 2015 data. The team used the purchased permit data in a limited capacity to develop the frame to exclude a subset of projects unlikely to contain new HVAC. During data collection, the team will verify the accuracy of matched parcel and permit data (e.g., heating fuel), where present, to determine the usefulness and reliability of permit and parcel data from data aggregators like ATTOM for use in future studies.

Table 3: Tax Assessor Parcel and Permit Data Match for Projects in the Frame

	% of Total Projects, N	% of Total Construction Value, CV
Matched to parcel(s)	44%	46%
Matched to parcel with heating fuel	3%	2%
Matched to parcel with year built	27%	27%
Matched to permit(s)	23%	27%
Matched to HVAC permit(s)	21%	23%

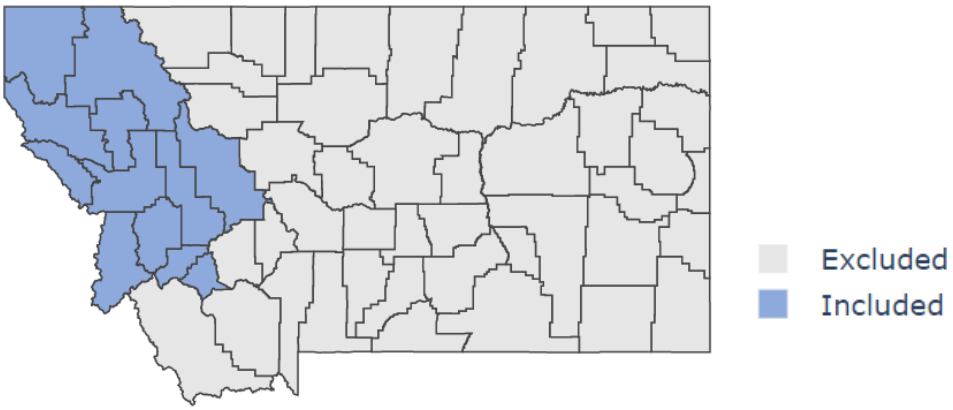
Derived Data Elements

Some information important to the sample frame development was not directly available in Dodge data but was derived from fields that were available.

Dodge defines building types with two fields: a general "Structure Group" and a more detailed "Structure Code." The team mapped these building types to 11 building types used by the Council (Appendix B**Error! No text of specified style in document.**) or excluded building types from the frame if they fell outside BPA's market model scope (Appendix C).

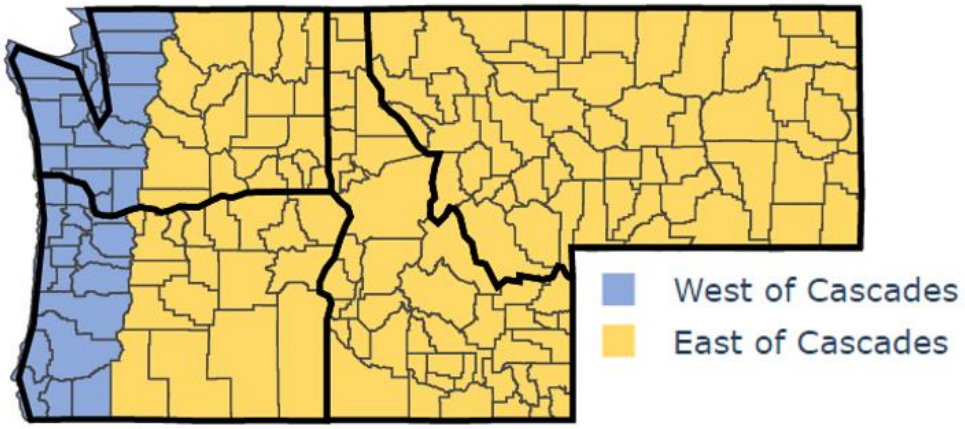
The study's scope includes projects in Idaho, Oregon, Washington, and the counties in western Montana that are part of BPA's service area.[4] Figure 1 shows the counties in Montana that the team included in the frame.

Figure 1: Montana Counties in BPA's Service Area



The team assigned climate zones east and west of the Cascade Mountain Range by county using criteria consistent with BPA's 2018 Residential Heat Pump Field Study[5]. The team assigned climate zones because HVAC energy consumption and building code standards for HVAC systems differ by climate zones. Figure 2 shows assignments of counties by climate zone.

Figure 2: Counties Defining Climate Zones East and West of the Cascades



Projects Included in Frame

The team developed the frame by excluding certain projects from the full list of Dodge projects based on the following criteria.

Start Year. The study's scope includes permitted HVAC systems that became operational between January 1, 2016 and December 31, 2020. Dodge provides start dates for projects, but not completion dates. The time between the start of a project and the beginning of HVAC operation varies between

[4] The study includes all buildings that meet the study's criteria within this geographic area, including those served by non-BPA utilities.
[5] https://www.bpa.gov/EE/Utility/Momentum-Savings/Documents/2019_BPA_Heat_Pump_Field_Study_Final_report.pdf

projects. 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 2016-2020. The team selected these start dates to balance the risk of missing projects completed within the study period against 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 some Dodge building types from the frame because the projects were associated with industrial processes (e.g., manufacturing). The research team originally planned to align included building types with those included in the 2019 Commercial Building Stock Assessment (CBSA). Upon review of building types included in the 2019 CBSA, the team identified some building types excluded from the CBSA that have potential to provide useful information (e.g., military facilities and universities), and some building types included in the CBSA that were unlikely to include commercial HVAC systems (e.g., auto service facilities) or unlikely to include useful information about market change (e.g., warehouses). The team assigned some of these buildings to a special category ("Verify for Exclusion"). The team will examine a small selection of permits and supporting documentation from the "Verify for Exclusion" projects to identify the installed HVAC system to verify assumptions about HVAC System characteristics within these building types, but they will not be included in the sample of 300 projects or calculations of the sample confidence and precision. Appendix C lists "Excluded" and "Verify for Exclusion" building types.

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 5 dwelling units, per the scope of the Seventh Power Plan.[6] The team did not exclude projects with an unknown number of dwelling units. The team also excluded multifamily residential projects with fewer than four stories from the frame because the Washington State Energy Code does not consider these commercial buildings.[7] Number of dwelling units and/or stories was not available for some multifamily residential projects in the Dodge data. The team included projects with an unknown number of stories in the frame unless their project details contained keywords indicating that the project is outside of the study's scope[8].

Construction Value (CV). Since the goal of the study is to identify projects that include a new permitted HVAC system, the team sought to reduce the risk of sampling projects without HVAC systems in the permits. The team determined that projects with low construction value are unlikely to include permitted HVAC systems (e.g., non-building structures). Therefore, the team, excluded all projects with CV ≤ $200,000, consistent with other regional commercial studies.[9] The team determined that "Alterations, Renovations, and Interior Completions" type projects were less likely to include permitted HVAC systems (e.g., alterations that only include aesthetic or non-HVAC upgrades), so for this type of work, the team raised the CV cutoff to values greater than $1,000,000.

Geographic Area. The study includes Idaho, Oregon, Washington, and the counties in western Montana that are part of BPA's service area. The study includes all buildings within this geographic area, including those served by non-BPA utilities. The team excluded projects in Montana counties outside of BPA's service area (Figure 1).

[6] https://www.nwcouncil.org/reports/seventh-power-plan

[7] https://sbcc.wa.gov/state-codes-regulations-guidelines/state-building-code/energy-code

[8] "single family", "singlefamily", "town home", "townh", "rowhouse", "duplex", "triplex", "fourplex", " plex", "-plex"

[9] Baylon et al. 2001; https://neea.org/resources/baseline-characteristics-of-the-non-residential-sector-idaho-montana-oregon-and-washington. Baylon et al. 2008; https://neea.org/resources/baseline-energy-use-index-of-the-2002-2004-nonresidential-sector-idaho-montana-oregon-and-washington. Larson et al 2019; https://neea.org/resources/2019-oregon-new-commercial-construction-code-evaluation-study.

Purchased HVAC Permits. The team had limited success in matching Dodge projects by address to permit data purchased from ATTOM, a permit aggregator. Of projects that were successfully matched to permit records, some were matched only to non-HVAC permits. The team excluded projects with "Alterations, Renovations, and Interior Completions" type of work that were only matched to non-HVAC permits, because they are unlikely to have permitted HVAC systems. The team kept all other projects—projects matched to HVAC permits, projects not matched to any permits, and "New" or "Additions" type projects—because they might involve HVAC systems. Table 4 summarizes the percentage of projects and CV excluded from the frame by each of the criteria above.

Table 4: Summary of Projects Included in and Excluded from the Frame

	Exclusion Step	% N	% CV
All Dodge Projects 26,473 Projects $120 Billion	Start dates outside of 2015-2019	22%	21%
	Excluded Building Types	6%	8%
	Verify for Exclusion Building Types	7%	7%
	Multifamily <5 units, <4 stories, or no central HVAC	7%	5%
	≤ $200,000 CV	15%	0.4%
	≤ $1 Million CV Alterations, Renovations, and Interior Completions	16%	2%
	Eastern Montana Counties	1%	1%
	Alterations/Renovations without HVAC Permits	0.3%	0.3%
	Sample Frame 6,792 Projects $66 Billion	26%	55%

Composition of the Frame

The following Table 5 through Table 11 describe the composition of the frame, which contains 6,792 projects (N) totaling $66 billion in CV. % N quantifies the percentage of projects out of 6,792 and % CV quantifies the percentage of construction value out of $66 billion associated with a given characteristic. Additional tables exploring the composition of the frame are available in Appendix E.

Table 5 shows the percentage of records and CV of those records missing data in fields of interest. No projects were missing fields used to create the frame or to define domains– state, county, building type, start date, or type of work. A large percentage of projects were missing floor area in the Dodge data set, especially projects with lower CV.

Table 5: Frequency of Missing Data in the Frame

Field	% N missing	% CV missing
State	0%	0%
County	0%	0%
Building Type	0%	0%

Field	% N missing	% CV missing
Start Date	0%	0%
Construction Value	0%	0%
Type of Work	0%	0%
Floor Area (sq ft)	44%	18%

Table 6 shows the percentage of projects in each state. Washington accounts for the largest proportion of projects and CV. Montana counties in BPA's service area account for the smallest proportion of projects and CV.

Table 6: Composition of the Frame by State

State	% N	% CV
Idaho	14%	7%
Montana	3%	2%
Oregon	31%	28%
Washington	51%	64%

Table 7 shows the percentage of projects in each climate zone. Western Oregon and western Washington account for the largest proportion of projects and CV.

Table 7: Composition of the Frame by Climate Zone

Climate Zone	% N	% CV
East of Cascades	31%	20%
West of Cascades	69%	80%

Table 8 shows the percentage of projects by type of work. The majority of projects include new (whole building) construction or additions. These types of projects have, on average, higher CV than "Alterations, Renovations, and Interior Completions" even though the latter were subjected to a higher cutoff for CV.

Table 8: Composition of the Frame by Type of Work

Type of Work	% N	% CV
Includes New or Additions	74%	87%
Alterations, Renovations, and Interior Completions	26%	13%

Table 9 shows the percentage of projects by building type. Offices, multifamily residential buildings, and K-12 schools account for the largest share of projects and construction value.

Table 9: Composition of the Frame by Building Type

Building Type	% N	% CV
Assembly	9%	8%
Hospital	2%	4%
Lodging	5%	8%
Multifamily Residential	17%	28%
Office	24%	19%
Other	4%	2%
Residential Care	2%	2%
Restaurant	5%	1%
Retail	11%	3%
School (K-12)	15%	20%
School (University)	5%	7%

Table 10 shows the percentage of projects by start year. Projects are distributed relatively evenly among start years.

Table 10: Composition of the Frame by Start Year

Start Year	% N	% CV
2015	16%	15%
2016	19%	18%
2017	21%	21%
2018	22%	23%
2019	22%	23%

Table 11 shows the percentage of projects by CV. The frame is skewed such that a small portion of large value projects account for a large percentage of the total CV and vice versa.

Table 11: Composition of the Frame by Construction Value

Improved Value	% N	% CV
$200,000 - $1,000,000	22%	1%
$1,000,000 - $5,000,000	43%	11%
$5,000,000 - $10,000,000	12%	9%
$10,000,000 - $100,000,000	21%	56%
>$100,000,000	1%	23%

Sample Design

The team used a single stage stratified random sample design. The team defined the domains by building type and climate zone. The following sections detail the sample design methodology and characteristics of the sample.

Methodology

The team used a single round of sampling. Dodge projects do not contain information about HVAC type, and the team was unsuccessful in supplementing the Dodge projects with HVAC details from permit and parcel records matched by address. Therefore, important but infrequently occurring HVAC types may not be sampled in high enough numbers to model with precision or may be missed altogether.

The team considered a two-stage sample design. The first stage would sample a much larger number of projects and determine the HVAC types for all projects in that large sample. The second stage would sample a smaller number of projects and target HVAC types of interest.

The team concluded a two-stage sample design for this study would be unreasonably costly due to the need to catalog thousands of permits during the first stage. The team could consider an improved single-stage or multi-stage sample design for the Seventh Power Plan 2021 Action Plan Period and other future studies, using the findings from this study to inform ways to improve HVAC sampling. For instance, BPA could explore the possibility to contract with Dodge to collect basic HVAC information about projects.

Sampling Error

Relative precision (RP) quantifies how well the sample estimates a characteristic of the frame, for example, the total CV associated with the projects in the frame. RP is determined for a confidence level, e.g., the team is 90% confident that the total CV of the frame extrapolated from the sampled projects is within +/- 10% of the true total.

A **domain** is a portion of the population for which a study sets a goal for sampling error. For example, a sample could target 90% confidence and 10% relative precision at the building type level.

The team set confidence at 90% for this sample. The targeted and achieved relative precision are limited by the total sample size (300) and the number of domains. Relative precision can be aggregated to a higher level than domains. For example, if a sample uses building type and climate zone to define domains, RP can be estimated at the domain level as well as at the building type level, climate zone level, or region-wide level.

Stratification

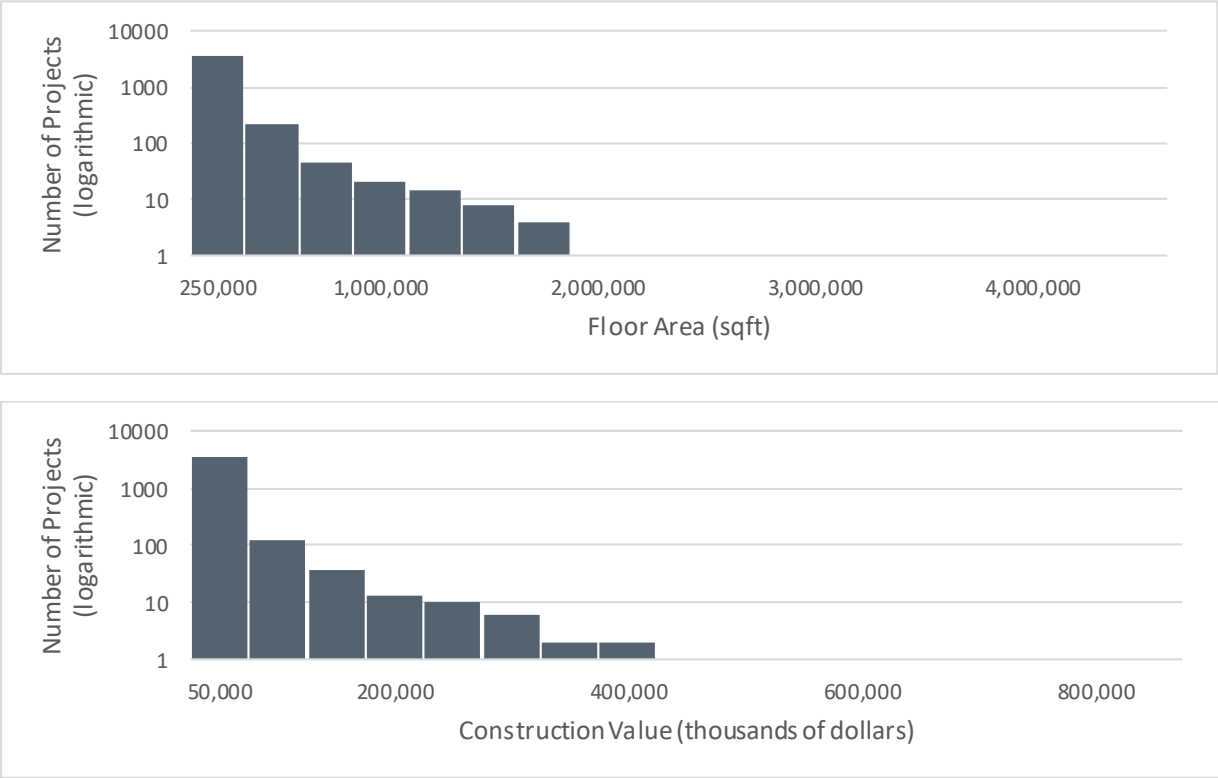
Stratified random sampling is a method of improving **sampling efficiency**—achieving a target precision with fewer samples. Stratified random sampling is particularly beneficial for highly skewed frames, such as the frame in this study.

Strata are portions of a domain's population defined by a range in the measure of size. The **Measure of Size (MOS)** of projects in a frame is used to determine strata bounds and assign projects to strata. The study goals include quantifying the prevalence of HVAC technology types by floor area of projects.

Therefore, the team would prefer to use floor area as the MOS. However, floor area is not available in the Dodge data for a large percentage of projects, so the team will use CV as the MOS because it is correlated with floor area (R^2 = 0.33 for projects with floor area provided in the Dodge data), exhibits similar skewness to floor area (Figure 3), and is available for all projects.

Figure 3 shows the distribution of CV and floor area for the 56% projects in the frame which had floor area. Of these projects, the largest floor area is 4,235,774 sq ft, and the largest CV is $827,000,000. Histogram bins containing a single project are not visible on the plot. Floor area data is too sparse to make meaningful conclusions by type of work. Only 12% of "Alterations, Renovations, and Interior Completions" projects have floor area in the frame compared to 72% of "New" and "Additions" projects.

Figure 3: Distribution of CV and Floor Area among Projects



How does stratification improve sampling efficiency? The variance of a frame or domain determines how many samples are needed to achieve a target RP. Skewed frames have high variance and large projects contribute disproportionately to the variance. In stratified random sampling, projects are allocated to strata based on their MOS such that each stratum has approximately the same variance and, consequently, the same number of sampled projects. For example, consider the domain of hospitals east of the Cascades in this sample design (Appendix D). The domain is divided into five strata, including the certainty stratum. Thirty-four projects are in the smallest stratum and eight projects are in the largest non-certainty stratum, but the same number of projects (three) are sampled from each stratum. The stratified random sample achieves a relative precision of 9% at 90% confidence with 13 samples. A simple random sample would require 58 samples to achieve the same RP.

The team divided each domain into 3-6 strata, depending on the characteristics of the domain: number of projects, skewness, and target RP. The team selected the largest two or three projects in each domain

with certainty. Certainty selections reduce the number of samples needed to achieve a target RP. The team assigned all projects not sampled with certainty to strata based on their CV and ordered them randomly within their domains and strata. The team allocated a quota of *n* sampled projects to each domain and stratum. The team assigned strata boundaries and allocated sampled projects based on Cohran's Sampling Techniques.[10] The team limited the ratio of *n* sampled projects to *N* total projects per stratum to allow for replacements.

Domain Selection

The team prioritized the following domains in the sample design. Domains comprise one or more of the following, but each element used further divides the frame and makes it more difficult or impossible to achieve reasonable RP with a sample of 300 projects. For example, a design with 11 building types, two climate zones, and five years results in 110 domains, allowing for an average of less than three sampled projects per domain if the sample size is restricted to 300 projects.

1. Building type
2. Climate Zone (east/west of the Cascade Mountain Range)
3. State
4. Year

The team defined domains by building type and climate zone. The team prioritized building type as the most important domain element. Additionally, the team prioritized climate zone as the second domain element because HVAC technology types may vary by climate zone due to the characteristics of the climate. Areas west of the Cascades have more moderate year-round temperatures than areas east of the Cascades. This domain definition created 22 domains.

A design with building type and state domain fields would have divided the frame into 44 domains. It was not reasonable to achieve 90% precision at 10% confidence for 44 domains with 300 samples. Furthermore, Montana, particularly the sub-population included in the frame, accounts for a small fraction of projects. Finally, HVAC technologies may vary more by climate zone than by state due to climate and regulation differences in different regions (eastern vs. western Oregon and Washington).

Year was the lowest priority and was not included in the domains because it would have divided the frame too many times, and because construction completion years were not available in the Dodge data. However, since BPA's Commercial HVAC Market Model will need to account for annual trends, the team will estimate annual market size by extrapolating from the overall change from sampled projects completed between 2016 and 2020.

Sample Characteristics

The sample design selects 300 projects from 22 domains defined by Council building types and climate zone. Table 12 provides a summary of the sample aggregated to domain, building type, and BPA region-wide levels. *N* is the total count of projects per level, *n* is the count of sampled projects per level, and RP is the relative precision with 90% confidence. Appendix D provides a full summary with strata-level details.

[10] Cochran, William G., *Sampling Techniques*. New York: John Wiley & Sons, 1977.

Table 12: Sample Design Summary

Building Type	Climate Zone (Side of Cascades)	N	n	RP (%)*
Assembly	East	242	14	10
Assembly	West	401	14	10
Assembly		**643**	**28**	**8**
Hospital	East	65	13	9
Hospital	West	91	13	9
Hospital		**156**	**26**	**7**
Lodging	East	127	13	9
Lodging	West	223	16	10
Lodging		**350**	**29**	**8**
Multifamily Residential	East	161	12	10
Multifamily Residential	West	977	18	9
Multifamily Residential		**1,138**	**30**	**9**
Office	East	539	13	10
Office	West	1,113	21	10
Office		**1,652**	**34**	**8**
Other	East	102	12	10
Other	West	136	11	9
Other		**238**	**23**	**7**
Residential Care	East	41	8	9
Residential Care	West	84	13	10
Residential Care		**125**	**21**	**8**
Restaurant	East	132	12	9
Restaurant	West	185	12	9
Restaurant		**317**	**24**	**7**
Retail	East	242	13	9
Retail	West	540	16	10
Retail		**782**	**29**	**8**
School (K-12)	East	359	13	10
School (K-12)	West	690	14	9
School (K-12)		**1,049**	**27**	**7**
School (University)	East	122	12	9
School (University)	West	220	17	10

Building Type	Climate Zone (Side of Cascades)	N	n	RP (%)*
School (University)		**342**	**29**	**8**
Region-Wide		**6,792**	**300**	**3**

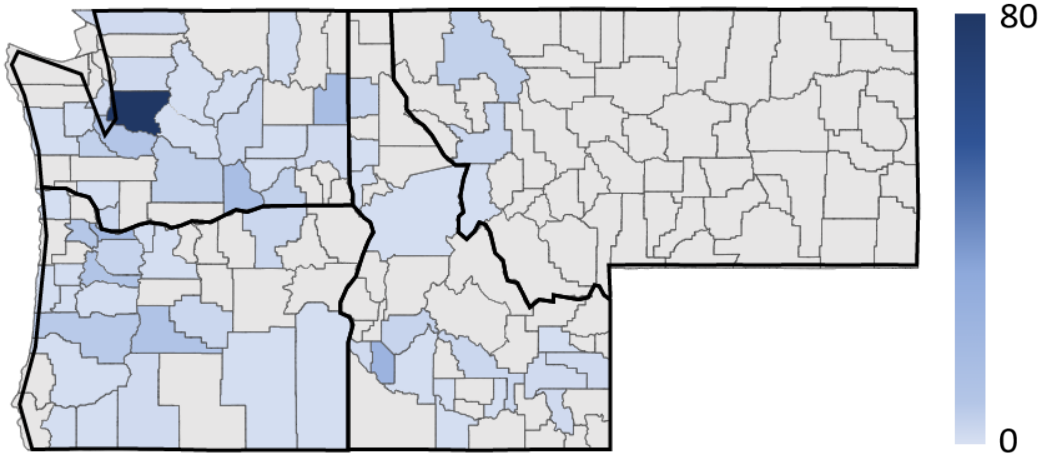
* Relative precision at the 90% confidence level

Table 13 and Figure 4 show the geographic distribution of the first 300 projects randomly assigned to the selection. The distribution may change slightly if projects are replaced, but the general distribution of projects will still skew towards selecting more projects in Washington, Oregon, and urban counties since those are the areas with the greatest numbers of projects in the frame.

Table 13: Sample Projects by State and Climate Zone

State	Climate Zone	% N	% CV	n	% n
ID	East of Cascades	14%	7%	51	17%
ID		**14%**	**7%**	**51**	**17%**
MT	East of Cascades	3%	2%	9	3%
MT		**3%**	**2%**	**9**	**3%**
OR	East of Cascades	5%	5%	23	8%
OR	West of Cascades	27%	23%	57	19%
OR		**31%**	**28%**	**80**	**27%**
WA	East of Cascades	9%	7%	52	17%
WA	West of Cascades	42%	57%	108	36%
WA		**51%**	**64%**	**160**	**53%**

Figure 4: Distribution of Projects in the Sample by County



Sample Selection and Deployment

The team has randomly assigned projects within domain and strata and assigned a completion quota for each stratum. The team generated a separate list and quota for "Verify for Exclusion" building types.

If the team must replace a project, it should be replaced with the next project in random order within the same domain and stratum. If no replacements remain in a stratum, the next random project in the next lowest stratum should be selected. If the team runs out of replacement projects in the lowest stratum in a domain, the sampled project can be reallocated to a different domain at the discretion of the survey manager. The team limited the number of strata and ratio of selected to total projects per stratum to limit the likelihood of running out of projects to sample in a given stratum.

The team developed the frame with the intent that every project will fall within the model scope. However, the team acknowledges that scenarios may arise that require the team to reject and replace projects as the team collects permit files for selected projects. In such instances, the team will track the reason(s) for rejections.

The team may reject projects if their permits cannot be obtained.

- Projects may not have complete or valid addresses. In such cases, the team will make best efforts to match projects in the sample frame to permits based on address, construction start date, project name, customer name, and/or project details, as available.
- The team may encounter jurisdictions that are unable to provide permit files, particularly in smaller jurisdictions. The team anticipates that approximately 10% of jurisdictions will not have permit plan sets readily available for distribution, based on the team's findings in the Commercial HVAC Permit Data Pilot Study. In these cases, the team may work with the authority having jurisdiction (AHJ) in question to schedule an in-person visit or inquire with the architect to obtain plans directly.

Additionally, the team will reject projects based on the following characteristics obtained from permit files if the team determines the project is outside the study scope:

- Multifamily buildings with fewer than 5 units or fewer than 4 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

The team will pause when permit documents for 20%, 40%, and 60% of projects are collected and assess response rates to identify any potential bias non-response introduces. Additionally, the team will record the response status for all projects in the frame (e.g., completed, not contacted, non-response, out-of-scope). The non-response case represents a situation in which the permitting agency is unable or

unwilling to provide permit data. The team will investigate appropriate handling of non-response and out-of-scope cases. There are many different methods of handling these cases.[11]

Sources of Uncertainty

The team has attempted to develop a frame and a sample that is representative of the population of the commercial HVAC market for permitted HVAC projects in western Montana, Idaho, Oregon, and Washington completed between 2016 and 2020. Some uncertainty remains in the following areas:

- The team used Dodge projects as a starting point because it was the most complete available source of new construction. However, it may not contain all projects in the population. The U.S. Census Bureau estimates that 20% of new construction is not captured in the Dodge data.[12]
- The team attempted to capture projects that completed construction within the study period while not capturing projects that completed construction before or after the study period, or projects whose construction was cancelled. The team set the cutoffs for start dates between January 1, 2015 and December 31, 2019 to improve the likelihood of capturing projects that completed construction between January 1, 2016 and December 31, 2020. Additionally, the team only included projects which had reached a "start" action signal as defined by Dodge, the furthest stage to which Dodge tracks projects, to reduce the chances of including projects that were never constructed.
- The frame may include projects without permitted HVAC systems or exclude projects with permitted HVAC systems. The team took steps to minimize the risk of including projects without permitted HVAC systems. The team excluded projects with CV ≤ $200,000 and excluded "Alterations, Renovations, and Interior Completion" projects with CV ≤ $1,000,000 and/or only non-HVAC permits.

Additionally, there is uncertainty in which HVAC technology types will be sampled and how accurately BPA can characterize individual HVAC technology market trends. For instance, if an HVAC technology type is of significant interest to BPA, but accounts for only 1% of the population, the technology may not be represented in the sample at all, or the technology may not be included at a high enough rate in the sample for a robust characterization of the technology's occurrence. The team accepts this uncertainty, acknowledging that if a technology of interest does not appear in the sample at a high rate, that finding is still meaningful to BPA as an indication of the low prevalence of that technology.

Finally, the study's goal is to draw a conclusion about the prevalence of HVAC technology types by building floor area. Floor area was not available for a significant portion of projects within the frame, so the team used CV as the MOS for stratification. Additionally, the floor area listed for a project in Dodge data may not be the same as the floor area served by an HVAC unit. Therefore, there is unquantified uncertainty in the total floor area of the population. The team used the best available correlated data for

[11] One, but not necessarily the best, example of methods for handling non-response cases and estimating non-response bias comes from the Office of Management and Budget.
https://contattafiles.s3.us-west-1.amazonaws.com/tnt45760/8HE76lRMRaNzdyr/USA_standards_stat_surveys.pdf
[12] https://www.census.gov/construction/c30/methodology.html

choosing a representative sample from which the floor area of the population can be extrapolated (i.e., CV). The team will also obtain floor area of sampled projects from the cataloged permits.

The team will determine the best method of extrapolating floor area for the population during the analysis of collected data. One possible method of extrapolating floor area uses the floor area of the sampled projects, extrapolated at the stratum level and summed to the domain or population-total level as shown in Equation 1.

Equation 1: Extrapolated Floor Area

$$Extrapolated\ frame\ floor\ area\ per\ stratum = \left(\frac{N}{n}\right) \times (sampled\ floor\ area\ per\ stratum)$$

Table 14 shows an example of estimating floor area from a theoretical sample of the portion of the frame with floor area available. For this sample, assuming the floor area in the frame is the true floor area of the projects, the sample yields an 11% difference between the extrapolated floor area and the total floor area. The uncertainty in floor area extrapolated from any given sample is unknowable.

Table 14: Example of Estimating Floor Area of the Population from Floor Area of the Sample

			Total Floor Area (sq ft)		
Stratum Boundaries (CV)	N	n	Sampled Projects	Frame (Extrapolated)	Frame Total
$203,000 - $20,500,000	3,145	153	9,026,130	185,537,116	162,435,498
$20,500,000 - $106,925,000	618	99	22,576,616	140,932,815	125,957,759
$107,500,000 - $827,000,000	71	47	34,106,248	51,522,204	50,721,001
Total	3,834	299		377,992,136	339,114,258

Appendix A: Project Types Included in Model Scope

The following table describes construction project types and whether they trigger energy codes and are therefore included in the BPA model scope. Project type terminology aligns with type of work descriptions for Dodge projects, but the team will not know if the Dodge type-of-work descriptions — "New," "Additions," and "Alterations, Renovations, and Interior Completions" — are exclusively limited to projects in the BPA model scope until the team pulls supporting documentation for permits for selected projects.

Table 15: 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	Yes	Yes	In Scope
Change to the building substantial enough to include a mechanical system change	Alteration	Yes, for altered area	Yes	Yes	No	In Scope
Like for like replacement of existing HVAC system	Replacement	No	No	No	No	Out of Scope

Appendix B: Mapping Dodge Building Types to Council Building Types

Table 16: Mapping Dodge Building Types to Council Building Types

Dodge Structure Group	Dodge Structure Code	Council Building Type
Amusement, Social and Recreational Bldgs	Arenas/Coliseums	Assembly
Amusement, Social and Recreational Bldgs	Auditoriums	Assembly
Amusement, Social and Recreational Bldgs	Bowling Alleys	Assembly
Amusement, Social and Recreational Bldgs	Clubs and Lodges	Assembly
Amusement, Social and Recreational Bldgs	Communications Buildings	Assembly
Amusement, Social and Recreational Bldgs	Exhibition Halls	Assembly
Amusement, Social and Recreational Bldgs	Gyms/Field Houses/Indoor Pools	Assembly
Amusement, Social and Recreational Bldgs	Miscellaneous Amusement/Recreational	Assembly
Amusement, Social and Recreational Bldgs	Theaters	Assembly
Apartments	Apartments 3 or 4 Units	Multifamily Residential
Apartments	Apartments 5+ Units, 1-3 Stories	Multifamily Residential
Apartments	Apartments 5+ Units, 4+ Stories	Multifamily Residential
Apartments	Apartments Alterations, Stories Unknown	Multifamily Residential
Dormitories	Dormitories	Lodging
Government Service Buildings	Capitols/Court Houses/City Halls	Other
Government Service Buildings	Police/Fire Stations	Other
Government Service Buildings	Post Offices	Retail

Dodge Structure Group	Dodge Structure Code	Council Building Type
Hospitals and Other Health Treatment	Clinics/Nursing Convalescent Facilities	Assign_In_Code
Hospitals and Other Health Treatment	Hospitals	Hospital
Hotels and Motels	Hotels/Motels (Stories Unknown or Alts)	Lodging
Hotels and Motels	Hotels/Motels 1-3 Stories	Lodging
Hotels and Motels	Hotels/Motels 4+ Stories	Lodging
Office and Bank Buildings	Banks/Financial, 1-3 stories	Office
Office and Bank Buildings	Banks/Financial, 4+ stories	Office
Office and Bank Buildings	Offices, 1-3 stories	Office
Office and Bank Buildings	Offices, 4+ stories	Office
Religious Buildings	Funeral/Internment Facilities	Assembly
Religious Buildings	Houses of Worship, Other Religious Bldgs	Assembly
Schools, Libraries, and Labs (nonmfg)	Colleges/Universities Except Community	School (University)
Schools, Libraries, and Labs (nonmfg)	Community Colleges	School (University)
Schools, Libraries, and Labs (nonmfg)	Junior High Schools	School (K-12)
Schools, Libraries, and Labs (nonmfg)	Laboratories/Testing/R&D	School (University)
Schools, Libraries, and Labs (nonmfg)	Libraries	Assembly
Schools, Libraries, and Labs (nonmfg)	Museums	Assembly
Schools, Libraries, and Labs (nonmfg)	Primary Schools	School (K-12)
Schools, Libraries, and Labs (nonmfg)	Senior High Schools	School (K-12)
Schools, Libraries, and Labs (nonmfg)	Special Schools	School (K-12)
Schools, Libraries, and Labs (nonmfg)	Vocational Schools	School (University)
Stores and Restaurants	Food/Beverage Service	Restaurant
Stores and Restaurants	Shopping Centers	Retail
Stores and Restaurants	Stores	Retail

Appendix C: Excluded Building Types

Table 17: Excluded and Verify for Exclusion Building Types and Rationales for Exclusion

Dodge Structure Group	Dodge Structure Code	Council Building Type	Exclusion Rationale
Government Service Buildings	Armories/Military Buildings	Verify for Exclusion	Excluded from 2019 CBSA. The team would like to further understand HVAC systems used in these buildings.
Government Service Buildings	Detention Facilities	Verify for Exclusion	Excluded from 2019 CBSA. The team would like to further understand HVAC systems used in these buildings.
Miscellaneous Nonresidential Buildings	Airline Terminals	Verify for Exclusion	Excluded from 2019 CBSA. The team would like to further understand HVAC systems used in these buildings.
Miscellaneous Nonresidential Buildings	Bus and Truck Service	Verify for Exclusion	Spaces are typically primarily non-conditioned, but team would like to verify HVAC system types used in these spaces, as well as the breakdown of conditioned vs non-conditioned space.
Miscellaneous Nonresidential Buildings	Bus, Truck and Railroad Terminals	Verify for Exclusion	Excluded from 2019 CBSA. The team would like to further understand HVAC systems used in these buildings.
Parking Garages and Automotive Services	Auto Service	Verify for Exclusion	Spaces are typically primarily non-conditioned, but team would like to verify HVAC system types used in these spaces, as well as the breakdown of conditioned vs non-conditioned space.
Warehouses (excl. manufacturer owned)	Warehouses (Non-Refrigerated)	Verify for Exclusion	Team anticipates that these spaces are primarily unconditioned or heated with non-electric technologies but would like to verify this assumption.
Manufacturing Plants, Warehouses, Labs	Mfg Labs: Chemical Plants (Enclosed)	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Labs: Classification Unknown	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Labs: Electrical Machinery	Excluded	Laboratory - process/non-commercial application

Dodge Structure Group	Dodge Structure Code	Council Building Type	Exclusion Rationale
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Aircraft and Parts	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Chemical	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Chemical (Outdoors)	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Electrical Machinery	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Fabricated Metal Products	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Food and Kindred	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Industry Unknown	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Lumber and Wood ex Furniture	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Machinery except Electrical	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Motor Vehicles and Equip.	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Paper and Allied Products	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Petroleum and Coal Prod.	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Petroleum Refineries	Excluded	Laboratory - process/non-commercial application

Dodge Structure Group	Dodge Structure Code	Council Building Type	Exclusion Rationale
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Plastic Plants	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Precision Goods	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Primary Ferrous Metals	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Printing, Pub and Allied	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Ship and Boat Building	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg Plants: Stone, Clay and Glass	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg War: Chemical Plants	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg War: Classification Unknown	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg War: Fabricated Metal Products	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg War: Food and Kindred Products	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg War: Lumber and Wood ex Furniture	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg War: Machinery, Ex Electrical	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg War: Miscellaneous Manufacturing	Excluded	Laboratory - process/non-commercial application

Dodge Structure Group	Dodge Structure Code	Council Building Type	Exclusion Rationale
Manufacturing Plants, Warehouses, Labs	Mfg War: Paper and Allied Products	Excluded	Laboratory - process/non-commercial application
Manufacturing Plants, Warehouses, Labs	Mfg War: Precision Goods	Excluded	Laboratory - process/non-commercial application
Miscellaneous Nonresidential Buildings	Aircraft Service	Excluded	Excluded from 2019 CBSA
Miscellaneous Nonresidential Buildings	Animal/Fish/Plant Facilities	Excluded	Excluded from 2019 CBSA
Miscellaneous Nonresidential Buildings	Freight Terminals, Truck Rail and Marine	Excluded	Excluded from 2019 CBSA
Miscellaneous Nonresidential Buildings	Railroad/Boat/Other Vehicle Service	Excluded	Excluded from 2019 CBSA
Parking Garages and Automotive Services	Parking Garages	Excluded	Typically, unconditioned space
Warehouses (excl. manufacturer owned)	Refrigerated Warehouses	Excluded	Process loads (non-commercial space)

Appendix D: Sample Design with Strata Detail

Table 18: Sample Design with Strata Detail

Domain	Stratum	N	n	Construction Value ($, thousands)				RP (%)*
				Lower Bound	Upper Bound	Sampled	Total	
East-Assembly	1	131	3	210	1,800	2,219	112,222	
East-Assembly	2	64	3	1,926	5,100	9,803	202,775	
East-Assembly	3	19	2	5,284	11,649	15,100	152,732	
East-Assembly	4	15	2	12,500	21,700	27,000	252,161	
East-Assembly	5	11	2	24,000	40,000	65,000	336,755	
East-Assembly	Certainty (9)	2	2	48,000	62,000	110,000	110,000	
East-Assembly		**242**	**14**	**210**	**62,000**	**229,122**	**1,166,645**	**10**
West-Assembly	1	246	2	205	2,949	2,909	296,200	
West-Assembly	2	101	3	2,994	10,100	17,025	560,092	
West-Assembly	3	33	2	10,163	25,000	25,964	534,126	
West-Assembly	4	14	2	27,000	58,000	102,448	525,575	
West-Assembly	5	5	3	60,000	181,000	364,596	524,596	
West-Assembly	Certainty (9)	2	2	764,420	827,000	1,591,420	1,591,420	
West-Assembly		**401**	**14**	**205**	**827,000**	**2,104,362**	**4,032,009**	**10**
Assembly		**643**	**28**	**205**	**827,000**	**2,333,484**	**5,198,654**	**8**
East-Hospital	1	34	3	350	5,000	9,235	72,063	
East-Hospital	2	14	2	5,000	12,500	17,500	120,557	
East-Hospital	3	7	3	12,859	29,000	66,638	124,022	
East-Hospital	4	8	3	29,000	51,050	102,000	311,050	
East-Hospital	Certainty (9)	2	2	59,660	80,000	139,660	139,660	
East-Hospital		**65**	**13**	**350**	**80,000**	**335,033**	**767,352**	**9**
West-Hospital	1	48	2	222	6,000	4,622	110,823	
West-Hospital	2	23	3	7,000	21,364	56,400	299,954	
West-Hospital	3	11	2	22,200	45,000	87,000	364,150	
West-Hospital	4	6	3	45,000	106,925	175,500	411,925	

Domain	Stratum	N	n	Construction Value ($, thousands)				RP (%)*
				Lower Bound	Upper Bound	Sampled	Total	
West-Hospital	Certainty (9)	3	3	180,000	283,000	668,800	668,800	
West-Hospital		**91**	**13**	**222**	**283,000**	**992,322**	**1,855,652**	**9**
Hospital		**156**	**26**	**222**	**283,000**	**1,327,355**	**2,623,004**	**7**
East-Lodging	1	48	3	275	5,000	7,350	144,800	
East-Lodging	2	47	3	5,000	10,000	19,174	355,287	
East-Lodging	3	20	2	10,125	19,903	25,018	255,594	
East-Lodging	4	10	3	20,358	40,000	88,575	309,365	
East-Lodging	Certainty (9)	2	2	55,000	60,000	115,000	115,000	
East-Lodging		**127**	**13**	**275**	**60,000**	**255,117**	**1,180,046**	**9**
West-Lodging	1	107	3	203	7,500	11,000	372,704	
West-Lodging	2	65	3	7,895	19,610	33,898	818,873	
West-Lodging	3	31	3	19,733	39,261	95,180	890,533	
West-Lodging	4	11	2	39,543	77,875	99,715	621,240	
West-Lodging	5	7	3	78,000	168,620	324,100	806,681	
West-Lodging	Certainty (9)	2	2	193,000	224,000	417,000	417,000	
West-Lodging		**223**	**16**	**203**	**224,000**	**980,893**	**3,927,031**	**10**
Lodging		**350**	**29**	**203**	**224,000**	**1,236,010**	**5,107,077**	**8**
East-Multifamily Residential	1	68	2	485	3,000	4,644	104,697	
East-Multifamily Residential	2	42	2	3,149	7,535	8,626	210,546	
East-Multifamily Residential	3	29	3	7,585	14,710	32,800	304,455	
East-Multifamily Residential	4	20	3	15,000	26,000	58,587	397,682	
East-Multifamily Residential	Certainty (9)	2	2	43,700	53,200	96,900	96,900	
East-Multifamily Residential		**161**	**12**	**485**	**53,200**	**201,557**	**1,114,280**	**10**

Domain	Stratum	N	n	Construction Value ($, thousands)				RP (%)*
				Lower Bound	Upper Bound	Sampled	Total	
West-Multifamily Residential	1	429	3	450	6,500	9,698	1,258,489	
West-Multifamily Residential	2	271	3	6,500	17,200	28,275	3,083,400	
West-Multifamily Residential	3	165	3	17,345	33,000	70,620	3,985,705	
West-Multifamily Residential	4	70	2	33,130	66,000	93,494	3,142,083	
West-Multifamily Residential	5	26	2	68,860	133,000	225,095	2,608,243	
West-Multifamily Residential	6	14	3	138,332	310,400	592,545	2,499,891	
West-Multifamily Residential	Certainty (9)	2	2	397,965	428,843	826,808	826,808	
West-Multifamily Residential		**977**	**18**	**450**	**428,843**	**1,846,535**	**17,404,619**	**9**
Multifamily Residential		**1,138**	**30**	**450**	**428,843**	**2,048,092**	**18,518,899**	**9**
East-Office	1	414	3	202	2,830	3,123	429,733	
East-Office	2	96	2	2,847	10,100	9,158	517,412	
East-Office	3	21	2	12,076	38,197	41,215	433,297	
East-Office	4	6	4	51,070	205,000	435,070	700,070	
East-Office	Certainty (9)	2	2	400,000	750,000	1,150,000	1,150,000	
East-Office		**539**	**13**	**202**	**750,000**	**1,638,566**	**3,230,512**	**10**
West-Office	1	726	4	202	3,129	1,835	942,205	
West-Office	2	244	3	3,132	10,195	16,490	1,385,992	
West-Office	3	79	3	10,505	31,075	47,105	1,509,308	

Domain	Stratum	N	n	Construction Value ($, thousands)				RP (%)*
				Lower Bound	Upper Bound	Sampled	Total	
West-Office	4	36	2	32,008	59,573	96,000	1,525,796	
West-Office	5	16	3	64,000	129,500	277,900	1,462,099	
West-Office	6	10	4	140,000	263,900	590,059	1,957,861	
West-Office	Certainty (9)	2	2	275,000	330,721	605,721	605,721	
West-Office		**1,113**	**21**	**202**	**330,721**	**1,635,110**	**9,388,982**	**10**
Office		**1,652**	**34**	**202**	**750,000**	**3,273,676**	**12,619,494**	**8**
East-Other	1	41	2	237	1,500	1,400	35,633	
East-Other	2	29	3	1,950	3,992	9,600	84,871	
East-Other	3	18	2	4,000	7,148	13,680	96,076	
East-Other	4	12	3	7,595	13,600	29,695	118,634	
East-Other	Certainty (9)	2	2	17,500	29,000	46,500	46,500	
East-Other		**102**	**12**	**237**	**29,000**	**100,875**	**381,714**	**10**
West-Other	1	80	2	205	3,652	2,290	126,104	
West-Other	2	34	2	3,702	10,762	7,859	210,509	
West-Other	3	13	2	10,840	31,700	32,940	199,195	
West-Other	4	7	3	34,496	72,000	175,400	360,196	
West-Other	Certainty (9)	2	2	77,705	210,000	287,705	287,705	
West-Other		**136**	**11**	**205**	**210,000**	**506,194**	**1,183,709**	**9**
Other		**238**	**23**	**205**	**210,000**	**607,069**	**1,565,423**	**7**
East-Residential Care	1	14	2	650	3,159	4,204	30,752	
East-Residential Care	2	12	2	3,200	6,386	11,386	56,808	
East-Residential Care	3	13	2	6,462	9,641	15,500	103,117	
East-Residential Care	Certainty (9)	2	2	25,000	28,000	53,000	53,000	
East-Residential Care		**41**	**8**	**650**	**28,000**	**84,090**	**243,677**	**9**

Domain	Stratum	N	n	Construction Value ($, thousands)				RP (%)*
				Lower Bound	Upper Bound	Sampled	Total	
West-Residential Care	1	37	2	209	4,115	1,740	80,429	
West-Residential Care	2	20	2	4,500	10,555	16,555	151,818	
West-Residential Care	3	17	3	11,000	20,000	38,000	260,179	
West-Residential Care	4	8	4	20,140	43,900	123,900	233,150	
West-Residential Care	Certainty (9)	2	2	57,460	62,300	119,760	119,760	
West-Residential Care		**84**	**13**	**209**	**62,300**	**299,955**	**845,336**	**10**
Residential Care		**125**	**21**	**209**	**62,300**	**384,045**	**1,089,013**	**8**
East-Restaurant	1	73	3	203	550	1,054	27,514	
East-Restaurant	2	32	2	555	1,200	1,155	25,636	
East-Restaurant	3	16	2	1,200	2,230	2,895	26,938	
East-Restaurant	4	9	3	2,320	4,500	9,878	26,480	
East-Restaurant	Certainty (9)	2	2	5,500	9,000	14,500	14,500	
East-Restaurant		**132**	**12**	**203**	**9,000**	**29,482**	**121,068**	**9**
West-Restaurant	1	80	2	210	640	700	30,103	
West-Restaurant	2	58	2	679	1,400	2,150	52,423	
West-Restaurant	3	23	2	1,408	2,500	3,515	44,851	
West-Restaurant	4	13	2	2,580	4,500	5,580	44,090	
West-Restaurant	5	9	2	4,500	7,125	10,806	50,781	
West-Restaurant	Certainty (9)	2	2	7,443	18,565	26,008	26,008	
West-Restaurant		**185**	**12**	**210**	**18,565**	**48,759**	**248,256**	**9**
Restaurant		**317**	**24**	**203**	**18,565**	**78,241**	**369,324**	**7**
East-Retail	1	103	3	271	1,200	1,705	67,867	
East-Retail	2	79	2	1,200	2,200	3,500	129,864	
East-Retail	3	36	2	2,250	4,200	5,200	108,524	

Domain	Stratum	N	n	Construction Value ($, thousands)				RP (%)*
				Lower Bound	Upper Bound	Sampled	Total	
East-Retail	4	14	2	4,400	9,000	11,500	89,268	
East-Retail	5	8	2	9,000	15,000	21,000	95,909	
East-Retail	Certainty (9)	2	2	20,600	25,000	45,600	45,600	
East-Retail		**242**	**13**	**271**	**25,000**	**88,505**	**537,032**	**9**
West-Retail	1	259	3	220	1,360	2,700	198,514	
West-Retail	2	175	3	1,365	3,216	6,885	346,007	
West-Retail	3	63	2	3,350	7,000	10,413	326,875	
West-Retail	4	29	3	7,285	15,000	32,817	312,697	
West-Retail	5	11	2	15,000	30,000	53,000	228,602	
West-Retail	Certainty (9)	3	3	40,000	49,622	131,622	131,622	
West-Retail		**540**	**16**	**220**	**49,622**	**237,437**	**1,544,317**	**10**
Retail		**782**	**29**	**220**	**49,622**	**325,942**	**2,081,349**	**8**
East-School (K-12)	1	153	2	245	3,509	1,942	271,887	
East-School (K-12)	2	87	2	3,800	10,000	11,300	558,331	
East-School (K-12)	3	66	2	10,000	17,200	27,780	885,895	
East-School (K-12)	4	38	2	17,260	30,000	41,000	897,174	
East-School (K-12)	5	12	2	30,415	65,000	89,317	575,601	
East-School (K-12)	Certainty (9)	3	3	66,742	112,687	265,821	265,821	
East-School (K-12)		**359**	**13**	**245**	**112,687**	**437,160**	**3,454,709**	**10**
West-School (K-12)	1	326	2	210	3,781	3,582	589,627	
West-School (K-12)	2	136	2	3,788	13,268	16,350	946,687	
West-School (K-12)	3	98	2	13,640	25,036	39,704	1,916,419	

Domain	Stratum	N	n	Construction Value ($, thousands)				RP (%)*
				Lower Bound	Upper Bound	Sampled	Total	
West-School (K-12)	4	73	2	25,417	40,180	77,420	2,302,159	
West-School (K-12)	5	38	2	40,250	68,320	92,672	1,920,817	
West-School (K-12)	6	17	2	70,000	146,000	141,213	1,538,787	
West-School (K-12)	Certainty (9)	2	2	165,800	186,395	352,195	352,195	
West-School (K-12)		**690**	**14**	**210**	**186,395**	**723,136**	**9,566,691**	**9**
School (K-12)		**1,049**	**27**	**210**	**186,395**	**1,160,296**	**13,021,400**	**7**
East-School (University)	1	55	2	205	3,055	2,946	87,574	
East-School (University)	2	29	2	3,093	8,562	10,593	158,365	
East-School (University)	3	18	2	8,745	15,800	31,400	226,320	
East-School (University)	4	8	2	16,500	32,000	49,276	202,868	
East-School (University)	5	10	2	32,303	52,000	75,450	393,352	
East-School (University)	Certainty (9)	2	2	52,000	61,900	113,900	113,900	
East-School (University)		**122**	**12**	**205**	**61,900**	**283,565**	**1,182,379**	**9**
West-School (University)	1	120	3	250	5,292	5,298	257,497	
West-School (University)	2	53	3	5,900	16,600	36,393	549,387	
West-School (University)	3	29	3	16,750	34,587	82,087	709,480	
West-School (University)	4	11	3	34,670	77,000	109,670	597,370	
West-School (University)	5	5	3	83,700	215,750	482,750	677,160	

Domain	Stratum	N	n	Construction Value ($, thousands)				RP (%)*
				Lower Bound	Upper Bound	Sampled	Total	
West-School (University)	Certainty (9)	2	2	230,000	288,800	518,800	518,800	
West-School (University)		**220**	**17**	**250**	**288,800**	**1,234,998**	**3,309,694**	**10**
School (University)		**342**	**29**	**205**	**288,800**	**1,518,563**	**4,492,073**	**8**
Region-Wide		**6,792**	**300**	**202**	**827,000**	**14,292,773**	**66,685,710**	**3**

* Relative precision at the 90% confidence level

Appendix E: Composition of the Frame

Table 19: Composition of the Frame by State and Start Year

State	Start Year	% N	% CV
ID	2015	2.0%	1.0%
ID	2016	2.6%	1.0%
ID	2017	2.5%	1.3%
ID	2018	3.7%	1.6%
ID	2019	3.5%	1.7%
MT	2015	0.7%	0.3%
MT	2016	0.4%	0.3%
MT	2017	0.7%	0.4%
MT	2018	0.8%	0.4%
MT	2019	0.7%	0.3%
OR	2015	4.8%	3.9%
OR	2016	6.6%	5.0%
OR	2017	6.6%	6.0%
OR	2018	6.0%	5.4%
OR	2019	7.3%	7.7%
WA	2015	8.3%	10.0%
WA	2016	9.8%	11.2%
WA	2017	11.3%	13.7%
WA	2018	11.3%	15.3%
WA	2019	10.5%	13.5%

Table 20: Composition of the Frame by Climate Zone and Start Year

Climate Zone	Start Year	% N	% CV
East of Cascades	2015	5%	3%
East of Cascades	2016	6%	3%
East of Cascades	2017	6%	4%
East of Cascades	2018	8%	4%
East of Cascades	2019	7%	5%
West of Cascades	2015	11%	12%
West of Cascades	2016	14%	14%

Climate Zone	Start Year	% N	% CV
West of Cascades	2017	15%	17%
West of Cascades	2018	14%	18%
West of Cascades	2019	15%	18%

Table 21: Composition of the Frame by Construction Value and Start Year

State	Start Year	% N	% CV
$200,000 - $ 1,000,000	2015	3.4%	0.2%
$200,000 - $ 1,000,000	2016	4.2%	0.2%
$200,000 - $ 1,000,000	2017	4.0%	0.2%
$200,000 - $ 1,000,000	2018	5.4%	0.3%
$200,000 - $ 1,000,000	2019	5.4%	0.3%
$1,000,000 - $ 5,000,000	2015	6.6%	1.7%
$1,000,000 - $ 5,000,000	2016	8.4%	2.1%
$1,000,000 - $ 5,000,000	2017	9.5%	2.3%
$1,000,000 - $ 5,000,000	2018	9.3%	2.2%
$1,000,000 - $ 5,000,000	2019	9.6%	2.4%
$5,000,000 - $ 10,000,000	2015	2.1%	1.5%
$5,000,000 - $ 10,000,000	2016	2.6%	2.0%
$5,000,000 - $ 10,000,000	2017	2.9%	2.1%
$5,000,000 - $ 10,000,000	2018	2.3%	1.7%
$5,000,000 - $ 10,000,000	2019	2.3%	1.7%
$10,000,000 - $ 100,000,000	2015	3.5%	8.6%
$10,000,000 - $ 100,000,000	2016	3.9%	9.9%
$10,000,000 - $ 100,000,000	2017	4.4%	12.1%
$10,000,000 - $ 100,000,000	2018	4.7%	13.0%
$10,000,000 - $ 100,000,000	2019	4.4%	12.4%
> $100,000,000	2015	0.2%	3.3%
> $100,000,000	2016	0.2%	3.2%
> $100,000,000	2017	0.2%	4.6%
> $100,000,000	2018	0.2%	5.3%
> $100,000,000	2019	0.3%	6.5%

Table 22: Composition of the Frame by Building Type and Start Year

State	Start Year	% N	% CV
Assembly	2015	1.8%	1.1%
Assembly	2016	1.6%	0.9%
Assembly	2017	2.0%	1.4%
Assembly	2018	2.1%	2.2%
Assembly	2019	2.0%	2.3%
Hospital	2015	0.5%	0.7%
Hospital	2016	0.4%	0.5%
Hospital	2017	0.6%	1.1%
Hospital	2018	0.5%	1.1%
Hospital	2019	0.4%	0.5%
Lodging	2015	0.9%	1.4%
Lodging	2016	1.1%	1.6%
Lodging	2017	1.0%	1.7%
Lodging	2018	1.0%	1.3%
Lodging	2019	1.0%	1.6%
Multifamily Residential	2015	2.7%	4.1%
Multifamily Residential	2016	3.5%	5.3%
Multifamily Residential	2017	3.5%	5.3%
Multifamily Residential	2018	3.3%	6.4%
Multifamily Residential	2019	3.8%	6.7%
Office	2015	2.9%	2.7%
Office	2016	4.8%	4.1%
Office	2017	4.7%	4.5%
Office	2018	5.6%	2.9%
Office	2019	6.3%	4.7%
Other	2015	0.6%	0.3%
Other	2016	0.6%	0.3%
Other	2017	0.8%	0.8%
Other	2018	0.7%	0.4%
Other	2019	0.8%	0.6%
Residential Care	2015	0.3%	0.2%
Residential Care	2016	0.4%	0.4%
Residential Care	2017	0.5%	0.4%

State	Start Year	% N	% CV
Residential Care	2018	0.4%	0.3%
Residential Care	2019	0.4%	0.3%
Restaurant	2015	0.8%	0.1%
Restaurant	2016	1.1%	0.1%
Restaurant	2017	1.0%	0.2%
Restaurant	2018	0.9%	0.1%
Restaurant	2019	0.9%	0.1%
Retail	2015	2.0%	0.5%
Retail	2016	2.5%	0.9%
Retail	2017	2.8%	0.8%
Retail	2018	2.3%	0.6%
Retail	2019	1.9%	0.4%
School (K-12)	2015	2.3%	2.9%
School (K-12)	2016	2.3%	2.4%
School (K-12)	2017	3.1%	3.6%
School (K-12)	2018	4.0%	5.6%
School (K-12)	2019	3.7%	5.1%
School (University)	2015	1.1%	1.3%
School (University)	2016	1.1%	1.1%
School (University)	2017	0.9%	1.6%
School (University)	2018	1.0%	1.7%
School (University)	2019	0.9%	1.0%