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Commercial Building Stock Assessment 4 (2019) Final Report

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Acronym List

Acronym	Definition
API	Application program interface
CBECS	Commercial Building Energy Consumption Survey
CBSA	Commercial Building Stock Assessment
CSV	Comma separated values
DHW	Domestic water heating
EIA	Energy information administration
EUI	Energy use intensity
HDD	Heating degree days
HID	High-intensity discharge
IECC	International Energy Conservation Code
LPD	Lighting power density
MOS	Measure of size
NEEA	Northwest energy Efficiency Alliance
QC	Quality control
SQL	Structured query language
TMY3	Typical meteorological Year 3
W/ft^2	Watts per square foot

Executive Summary

The Commercial Building Stock Assessment (CBSA) study, previously completed in 2003, 2009, and 2014, is a unique regional data collection effort to characterize the physical and energy-use characteristics of commercial facilities throughout the Pacific Northwest. The study's resulting database serves as a valuable resource for regional energy planners, energy efficiency program designers, and researchers. In total, the database for the 2019 study included 932 commercial buildings at 749 individual sites.

Objectives

The Northwest Energy Efficiency Alliance (NEEA) designed the 2019 CBSA with the core objective of enabling regional power planners and energy efficiency program designers to make inferences about the energy characteristics region's commercial building stock. The Cadmus team accomplished this through the following tasks:

- Cataloguing all commercial buildings in the region
- Recruiting a regionally representative sample of commercial buildings to participate in the study
- Collecting information on building characteristics and equipment that affect energy consumption
- Developing case weights that enable analysts to make regionally accurate inferences about commercial buildings

Key Differences from Previous Study

The 2019 CBSA features several substantial differences from the CBSA completed in 2014. These differences impact the sample frame, the resulting sample, data collected, case weights, and the subsequent analysis. Following is a list of the most meaningful differences between the two studies:

- The contractors for the 2014 CBSA developed the sample design, determined the data collection fields, collected on-site data through assessments, and then analyzed the data. For the 2019 CBSA, NEEA contracted with SBW Consulting for Phase 1 of the study to develop the sample design and data collection protocols. NEEA then contracted with Cadmus to implement the sample design and data collection, as well as conduct analysis and reporting.
- The 2014 study relied on tax assessor data for the sample frame. The 2019 CBSA sample frame relied on an innovative virtual catalog to integrate geocoded business data from the Internet with detailed information from conventional tax assessor data.
- For the virtual catalog, we established 1,000 square feet as the minimum floor area for a site. The 2014 study did not establish a minimum floor area for sites included in the study.
- The 2019 CBSA used a two-stage sample design, in which the first stage relied on census blocks as the basic unit of sampling. The second stage used a site as the key unit of measurement. The Phase 1 planning effort defined a site as "a collection of buildings on a census block that share the same taxpayer." The 2014 study sampled based solely on buildings.

- The 2014 CBSA sampled relatively new construction (2004 to 2013) in much higher proportions than other vintages. We did not use building vintage as a criteria for sampling in the 2019 CBSA.
- The Phase 1 study developed a new methodology for within-site sampling procedures on buildings, businesses, and rooms. The new approach changed the manner in which we applied the within-site weights.
- The Phase 1 study consolidated and updated the space types defined within buildings toward functional uses. For example, the 2014 CBSA included space types for Storage – Low Bay and Warehouse – High Bay. The Phase 1 study for the 2019 CBSA combined those into Storage.
- The 2019 CBSA added a "mixed commercial" building type. These represented facilities with multiple business or property use types, such as malls. We classified site and buildings as mixed commercial if the commercial floor space comprised multiple property types in which no use type was predominant (i.e., no single property use type made up over 75% of the parcel). If they had multiple use types but was comprised of one building type that did make up over 75% of the parcel, we categorized the site or building into the predominant type.
- NEEA chose to remove the University building type. A university is a campus made up of different building types (e.g., school, office, laboratory, assembly, lodging, and retail). It has proven difficult for stock assessment studies to accurately characterize a university based on assessing a small number of buildings, which may not be representative of the diversity of buildings on campus. NEEA will continue to explore methods to more accurately characterize universities.
- We removed the small residential care stratum from the study. We determined this stratum is predominantly home-based businesses, and therefore not applicable to the CBSA.
- The 2019 CBSA did not include parking lots or parking garages exterior to the building's envelope. Those types of facilities will be characterized through Bonneville Power Administration's Outdoor Lighting Stock Assessment. The Cadmus team did characterize any parking garages within the building's envelope, such as sub-surface parking.
- The 2014 CBSA relied on a paper-based data collection instrument requiring manual data entry into the study's database. For 2019, Cadmus updated its tablet-based data collection tool to match the CBSA data elements. The tablet-based tool automatically populated the study database with data entries.
- The Phase 1 study for 2019 recommended numerous changes to the data elements for on-site collection. The recommendations trimmed the overall number of elements from approximately 600 in the 2014 CBSA to approximately 500. The primary changes came from eliminating separate surveys for hospitals, universities, and residential areas, as well as streamlining questions and combining pick lists. Cadmus further refined the data elements and their relation to one another as part of integrating them into a tablet-based system. With NEEA's input, we streamlined some sections, such as Major Renovations, while adding content to the HVAC sections. The final data collection tool represented 560 individual fields.

- The previous study's data dictionary asked relatively few questions about pumps (i.e., total pump horsepower in building). To support NEEA's Extended Motors Program initiative, the Cadmus team worked with NEEA to add questions for more granular pump data.
- Based on the two-stage sample design, the Cadmus team developed regional case weights that accounted for the inclusion probabilities associated with each stage. The team also calibrated weights based on the regional floor areas calculated through the virtual catalog.

Sampling and On-Site Assessments

The Cadmus team developed the 2019 CBSA sampling plan to provide an effective design that supports diverse objectives, including these:

- Ensure as accurate as possible saturation estimates for energy-related equipment and operating characteristics, for each major building type
- Ensure the collected sample represents diverse geographies

Stage 1 of the sampling plan selected 5,000 census blocks for the virtual catalog. We stratified those based on scaled floor area, state, utility type, urban/rural classification, and relative density (floor area of commercial buildings in census block divided by the total census block area). Cadmus conducted a manual review of sites resulting from the Stage 1 analysis to develop the sample frame for the Stage 2 sample of sites by building type. We used the recommended Phase 1 Study sampling allocations (shown in Table 1) for a total of 808 sites. We then lowered the residential care target by 42 sites after removing the small residential care stratum. This reduced the total sample target to 766 sites. The Cadmus team successfully completed on-site assessments for 749 sites and 932 buildings.

Table 1. On-Site Assessments by Building Type

Building Type	Planned Site Assessments	Sites Assessed	Buildings Assessed
Assembly	56	60	72
Grocery	68	59	60
Hospital	45	43	53
Lodging	71	66	83
Mixed Commercial	83	99	73
Office	116	108	153
Other	21	13	24
Residential Care	38	40	51
Restaurant	51	46	53
Retail / Service	89	105	133
School	45	44	68
Warehouse	83	66	109
Total	766	749	932

Cadmus also conducted within-site sampling for buildings, businesses, and/or rooms when the site assessor had insufficient time to gather data on all units at the site. All levels of sampling were subject to the practical limitations of the site visit, including safety and security restrictions and participant agreement. We calculated within-site sampling weights based on selection probabilities derived from site-specific within-site sampling plans.

Key Findings

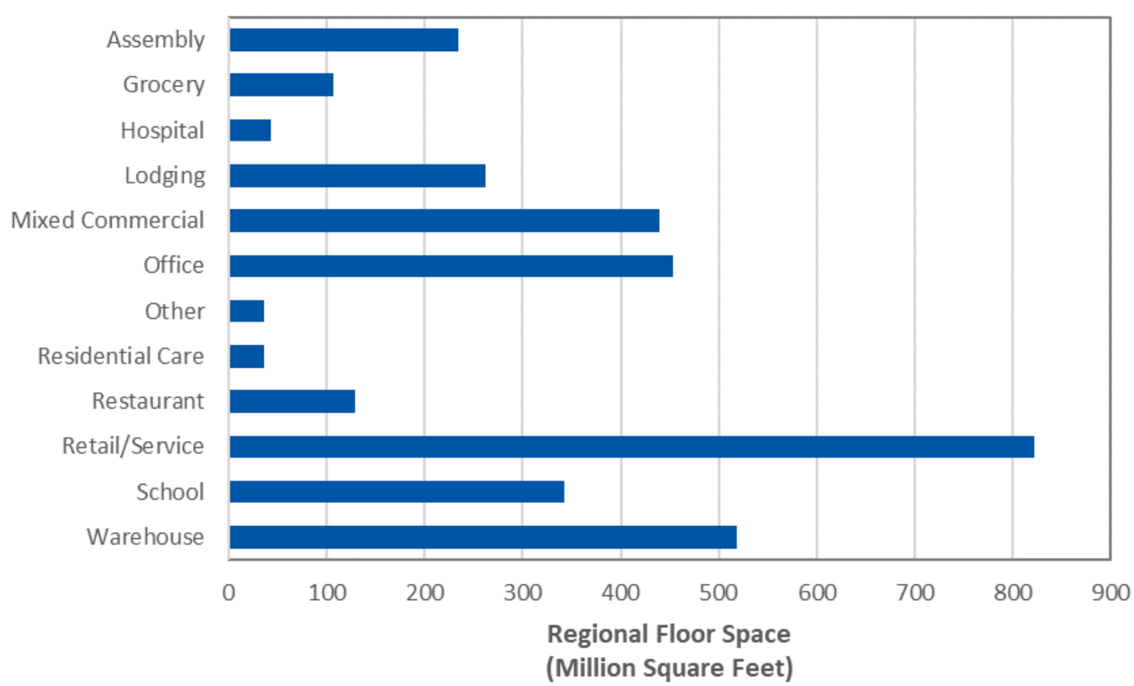
This section summarizes high-level findings from the 2019 CBSA. The Key Findings section in the body of the report provides more detail and comparisons with the 2014 CBSA.

Total Floor Space

Through the 2019 CBSA, the Cadmus team estimated the total commercial floor space of the building types assessed in the Pacific Northwest at 3.4 billion square feet. This represents a 6% increase from 3.2 billion square feet in 2014. This does not include commercial building types excluded from the study.

Figure 1 shows the breakdown of floor area among building types in the 2019 CBSA. The retail/service building type represented the largest portion of floor area, followed by warehouse, office, and mixed commercial buildings.

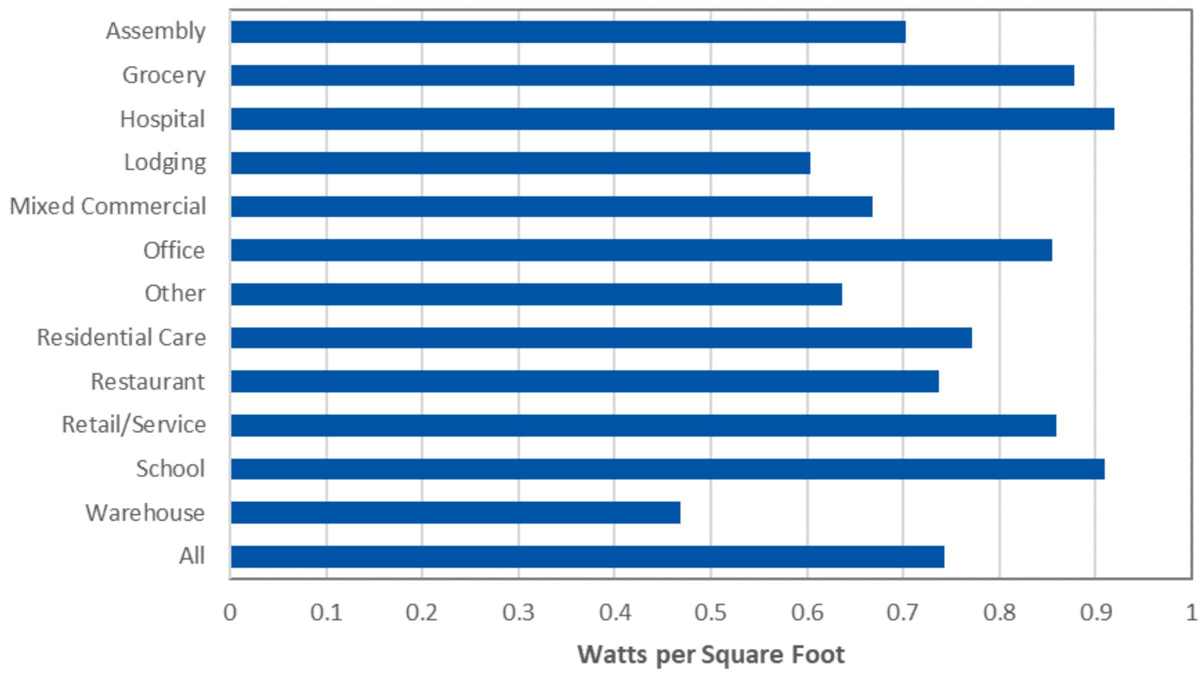
Figure 1. 2019 CBSA Floor Area by Building Type



Lighting Power Density

Average commercial building interior lighting power density (LPD) is 0.74 watts per square foot (W/ft^2) as shown in Figure 2. The LPD is calculated as the ratio of total wattage to total floor space within a category. Since the 2014 study, there has been a 0.25 W/ft^2 decrease in the overall LPD from 0.99 W/ft^2. We believe the decrease is primarily due to the transition from older, less-efficient fixtures to LEDs. Stringent lighting power allowances required by code in Oregon and Washington for new construction buildings also likely represent a factor in reducing LPDs.

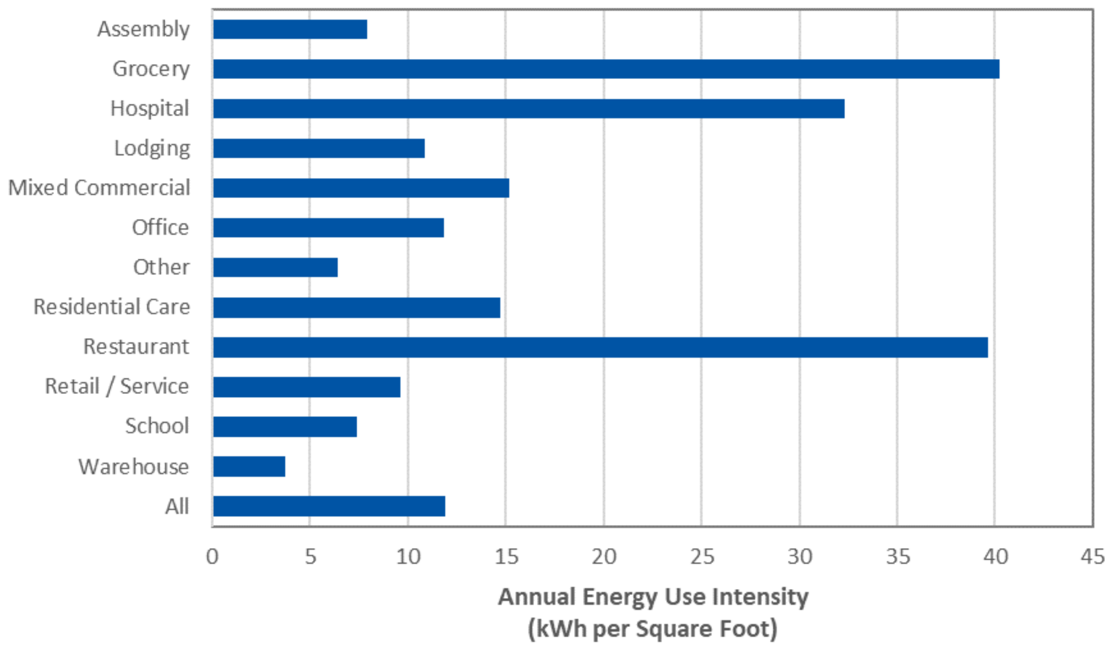
Figure 2. 2019 CBSA Lighting Power Density By Building Type



Energy Use Intensities

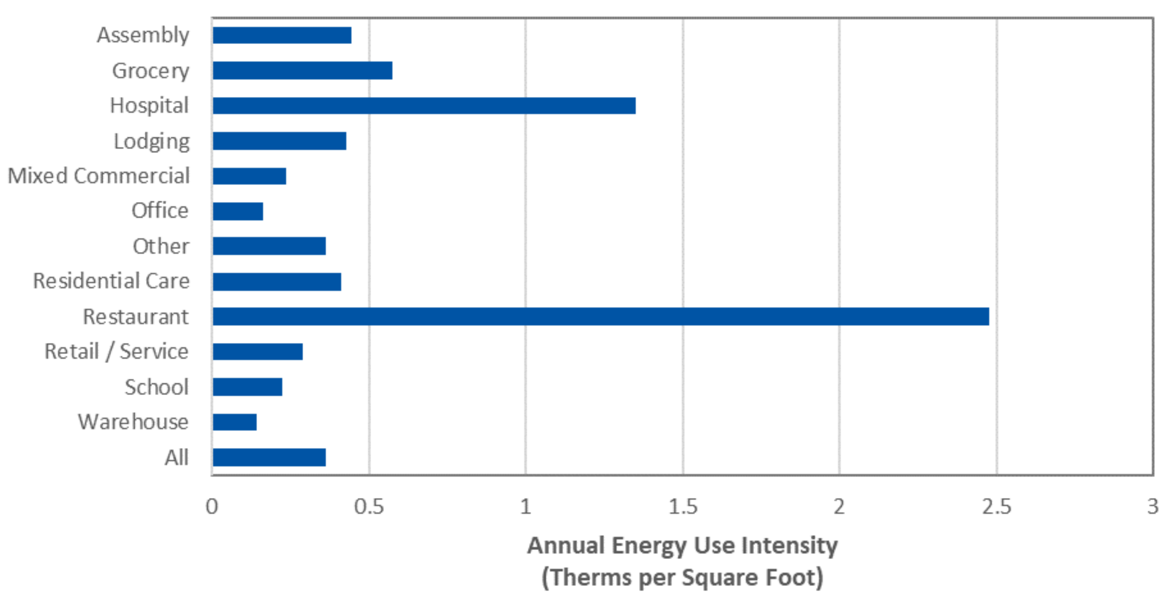
Northwest commercial buildings had an average electric energy use intensity (EUI) of 11.9 kWh per square foot, shown in Figure 3. This value is a decrease from the average 2014 study EUI of 14.2 kWh per square foot. Groceries and restaurants have the highest EUIs in the commercial sector, similar to the 2014 study. The decrease in electric EUI is likely due to decreased lighting power, as well as a lower proportion of electric heating than identified in the 2014 CBSA.

Figure 3. 2019 CBSA Annual Electric EUI by Building Type



Northwest commercial buildings had an average natural gas EUI of 0.36 therms per square foot. This value is a slight increase from the 2014 study EUI of 0.35 therms per square foot. Figure 4 shows the annual natural gas EUIs by building type. The increase from 2014 is largely due to the higher proportion of natural gas heating in the region found in the 2019 CBSA.

Figure 4. 2019 CBSA Annual Natural Gas EUI Building Type



Conclusions

Cadmus developed the following conclusions based on the process of conducting the 2019 CBSA and its subsequent review of the data and major findings. We note there are additional areas that may warrant more analysis and additional conclusions beyond those observed in this report.

Virtual Catalog Provides Option for More Robust Sample Frames

The Cadmus team's experience in developing the virtual catalog as a sample frame indicates the method provides value, but still faces challenges. Using Google Places data provided an effective means of identifying facilities missing from conventional tax assessor data. However, the Google Places data also presents challenges: multiple listings at one address (particularly for doctor's offices at hospitals), flagging home-based businesses as commercial activity, and not capturing all sites missing from the tax assessor dataset. This virtual catalogue creation process has produced valuable lessons that can serve as the basis for similar future efforts; however, the process of combining, cleaning, and clarifying the virtual catalog data is a time and budget-intensive activity that should be weighed against the value provided by the additional data.

New Commercial Buildings Rely More on Electric Heating

The trend toward natural gas heating may be reversing, with the 2019 CBSA sample showing an even split between heating fuels in newly constructed buildings. The 2019 CBSA identified 36 buildings constructed since 2014 with space heating. Those 36 buildings are split exactly in half on space heating fuel, with 18 electric and 18 natural gas. However, the total floor area for electric heated buildings was 686,775 square feet, which was 20% higher than the 571,089 square feet for natural gas heated buildings.

This shift may increase in the future as part of broader national and global trends toward strategic electrification of heating systems to reduce the consumption of fossil fuels. The transition toward electrification is also expected to be driven by legislation such as Washington State's recent Clean Energy Transformation Act of 2019 (SB 5116). The impact of this legislation may be apparent in the next CBSA study.

Increased LED Adoption

The region's commercial buildings have replaced existing equipment with LED lighting at an unprecedented rate. Energy efficiency programs and education in the region appear to have motivated participants to primarily reduce older, less efficient lighting such as incandescent and high-intensity discharge lamps. In 2014, LED lighting power only represented 20 million watts, which was 1% of regional commercial indoor lighting power. By 2019, that value had increased by more than 20 times to 419 million watts, or 17% of the regional total. The rapidly dropping cost of LED lamps and utility energy efficiency programs are primarily responsible for driving this transition. National sales data showed an increasing market penetration for tubular LEDs at the expense of linear fluorescent fixtures starting in 2014.

By comparison, older and less efficient technologies declined in their prevalence at the expense of LEDs. Incandescent lighting decreased from 360 million watts (12% of total lighting power) to 136 million watts (5%). For HIDs, the decline was from 160 million watts (5%) to 38 million watts (1%). LEDs also cut the lighting power provided by CFLs in half, from 270 million watts (9%) to 136 million watts (5%). This transition from the least efficient lighting to most efficient resulted in a substantial decrease in regional lighting power, from 2,944 million watts in 2014 to 2,531 million watts in 2019.

Significant Regional Energy Efficiency Opportunities Remain

Regional energy efficiency programs still have significant opportunities to achieve energy savings through the conversion of older equipment to more energy efficient versions, from lighting to controls to water heating systems. We note three examples of these opportunities below.

Linear Fluorescent Lamps to LEDs

The region's commercial building lighting still relies heavily on linear fluorescent lighting. Linear fluorescent T5, T8, and T12 lamps represented 2,126 watts (72% of total lighting power) in 2014. Despite reductions due to LED replacement, these fixtures still represented 1,737 MW (69% of total lighting power). The regional wattage for the least efficient fluorescent fixtures, T12s, declined by 32 MW to 296 MW, a 10% decrease from 2014 values. It is unclear what portion of the reduction in T12 wattage is due to LED replacements versus retrofits with more efficient linear fluorescent fixtures. The outstanding wattage represented by these linear fluorescent fixtures represents an ongoing opportunity for energy efficiency programs to achieve tremendous savings through early replacement of older, less efficient fixtures.

Lighting Controls

Over two-thirds of lighting power in the region is still controlled by manual on/off switches. Regional energy efficiency programs have the potential to obtain further energy savings through conversions to occupancy sensing, daylighting harvesting, and luminaire-level lighting controls. Currently occupancy sensors control only 13% of total regional wattage, while daylight harvesting controls less than 1%. However, we note there may be challenges with the cost-effectiveness of replacing controls on LEDs compared with older, less efficient lighting types. The LEDs represent a considerable reduction in energy consumption, so the incremental savings from lighting controls may not provide sufficient benefits to offset program costs. This will be a challenge for energy efficiency programs to weigh in the coming years.

Conventional Tank Water Heating Replacement

Approximately two-thirds of natural gas water heating capacity is still in the form of domestic hot water tanks, while that value is 83% for electric water heating. The proportion of efficient tankless water heating has more than tripled from 2014 to 2019, but that still only represents 19% of total regional water heating capacity. On the electric side, heat pump water heaters represent such a small portion of regional electric water heating capacity that they are combined with in the "other" system type, at 5% of the total. There are significant opportunities for utilities to continue to expand the installed capacity of these more efficient technologies in the coming years.

LEDs Reduced Indoor Lighting Power Density

The transition to LEDs has substantially reduced the indoor LPD across all building types throughout the region. The average indoor LPD in 2014 was 0.99 W/ft^2. By 2019 that had declined by 25% to 0.74 W/ft^2. Almost all building types showed an LPD reduction in the range of 19% to 37%. Based on the changes in regional lighting power, it is clear that the reduction was driven almost entirely by LED retrofits.

LEDs Reduced Electric Energy Use Intensity

Regional electric EUIs have also declined as an additional impact of the reduced LPD resulting from increased LED adoption. The regional EUI declined from 14.2 W/ft^2 in 2014 to 11.8 W/ft^2 in 2019, a decrease of 17%. Most building types reduced their EUI by 20 to 40%. Only hospitals increased their EUI from 2014, and it is likely the 2014 estimate was too low based on comparison to the 2012 CBECS value.

We note that a portion of the electric EUI reduction is the difference in proportion of gas heating between the 2014 and 2019 CBSA studies. It is also reasonable to assume that energy efficiency programs throughout the region have reduced electricity consumption through non-lighting measures focused on HVAC, refrigeration, and industrial process equipment, among others. However, the largest driver in electricity reduction is likely the rapid replacement of older, less efficient lighting such as incandescent bulbs, HIDs, and CFLs by LED lamps.

Introduction

Since the early 2000s, in collaboration with its funders, efficiency allies, and other strategic market partners, the Northwest Energy Efficiency Alliance (NEEA) has led a concerted effort to advance the knowledge of residential, commercial, and industrial building characteristics in the Northwest. NEEA has sponsored two comprehensive assessments of residential building stock and three comprehensive assessments of commercial building stock. The results of these studies provide immense value to all regional stakeholders and contribute extensively to planning, forecasting, and program development initiatives by various regional entities, including the Northwest Power and Conservation Council's regional power plan.

In 2017, NEEA contracted with a third-party consulting team to develop a plan for the upcoming Commercial Building Stock Assessment (CBSA). The planning effort was Phase 1 of the study.

Phase 2 of the CBSA encompassed sample frame development, on-site data collection, analysis, and reporting. NEEA contracted with Cadmus in early 2018 to conduct the Phase 2 effort. The Cadmus team included the following subcontractors:

- DNV GL: sampling and case weighting lead
- McKinstry: on-site data collection
- Energy 350: on-site data collection
- Consumer Opinion Services: participant recruitment

Phase 1 Study Design

For the 2019 CBSA, NEEA contracted with SBW Consulting for Phase 1 of the study[1] to develop the sample design and data collection protocols. NEEA contracted with Cadmus to implement the sample design and data collection, as well as conduct analysis and reporting. The Phase 1 consultants assessed the quality of NEEA's existing property list, determined the data collection fields necessary for Phase 2 of the study, and investigated alternative sample designs. They participated in multiple stakeholder working groups to obtain feedback on the planning and study design.

Ultimately, the Phase 1 consultants produced a report documenting findings and recommendations for the Phase 2 study. They determined that the NEEA property list contained a number of deficiencies that limited its effectiveness as a sample frame. After considering various sample designs, they recommended a two-stage design involving census blocks as the first stage and a catalog of commercial properties within each census block as the second stage. The Phase 1 design also included extensive recommendations on the levels of data collection, space types to use, and guidelines for within-site sampling. Finally, they provided a detailed data dictionary with recommended data elements to collect.

[1] SBW Consulting. September 5, 2017. *Plan for Commercial Building Stock Assessment*.

NEEA reviewed and largely adopted the recommendations of the Phase 1 planning study for the Phase 2 data collection effort. This study provided the basis for the sample frame and data inputs, although Cadmus further refined the study design through a series of working groups with stakeholders.

Stakeholders and Working Groups

NEEA established two regional working groups comprising representatives from regional utilities, the Bonneville Power Administration, Energy Trust of Oregon, and the Northwest Power and Conservation Council, to provide guidance to Cadmus on customer contact protocols and study integrity issues such as sampling and weighting. For each working group session, Cadmus developed materials for review, presented updates to the study design, and incorporated feedback from stakeholders. NEEA formed two additional *ad hoc* groups to provide detailed input on sample design and weighting during the project. The activities of these working groups are described below.

Customer Contact

NEEA established the Customer Contact working group and planned for three sessions to agree upon the most reasonable process for conducting customer outreach and participant recruitment. Cadmus and NEEA recognized the importance of maintaining a positive relationship between utilities and their customers, as well as the potential for the CBSA to generate customer questions and complaints. Over the course of three sessions, Cadmus presented its plan for customer outreach, the relevant outreach materials, and options for escalating feedback to utilities in the case of customer concerns. The utility representatives provided feedback relating to their specific experience and areas of concern that allowed Cadmus to refine the final recruitment plan.

Study Integrity

NEEA established the Study Integrity working group and planned for two sessions to discuss any proposed changes to the study design (from what the Phase I plan specified) and present interim study results. The working group included expert users of the CBSA data, including regional planners, utility staff, energy efficiency and program planning experts, and statisticians. The group met three times to review Cadmus' progress, provide feedback, and resolve details on issues related to study integrity, including development of a virtual catalog for building the sample frame, as well as details of data collection requirements and methods. For example, Cadmus conducted a pre-test of the data collection protocols and identified limitations with the Phase 1 study's approach to within-site sampling on sites with many buildings, businesses, and utility meters.

Sample Design

NEEA organized an *ad hoc* group of statisticians and expert CBSA data users to participate in the Sample Design working group. The group met in person twice between July and September 2018 and conducted much of the discussions by email and through memos. The working group provided direction on implementing the sample design, determining appropriate parameters to vet, and identifying the most effective ways for conducting quality control (QC) reviews on the data.

Case Weighting

The two-stage sampling approach required a relatively complex case weighting system for the sample and population. We developed a case weighting approach early in the project during the sampling phase. Following the on-site data collection period, NEEA convened a group of statisticians who, over 10 meetings, provided feedback on the Cadmus team's proposed case weighting analysis methods, interim results, and final weights.

Objectives

The Northwest Energy Efficiency Alliance (NEEA) designed the 2019 CBSA with the core objective of enabling regional power planners and energy efficiency program designers to make inferences about the energy characteristics region's commercial building stock. The Cadmus team accomplished this through the following tasks:

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- Recruiting a regionally representative sample of commercial buildings to participate in the study
- Collecting information on building characteristics and equipment that affect energy consumption
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Previous CBSA Studies

2003 CBSA

Quantec (later acquired by Cadmus) led the 2003 study, which was a unique effort to characterize the physical and energy-use characteristics of commercial facilities in the Pacific Northwest by integrating and updating information from several previous regional data collection efforts. The 2003 CBSA sample was compiled from surveys conducted between 1986 and 1999. Quantec supplemented these surveys using current floor space from the Dodge database compiled by McGraw Hill. In total, the database included 1,157 commercial facilities, divided into three chronological vintages: pre-1987, 1988–1994, and 1995–2001. Quantec compiled extensive technical data for at least two-thirds of the facilities in the three cohorts, providing reasonably detailed information on key structural characteristics, energy systems, and components existing at the time of the study.

2009 CBSA

In 2009, Cadmus led an effort to enhance and update the 2003 CBSA study. It included these activities:

- Expanded the original database using a variety of commercial buildings surveys completed in the region since the year 2000, including the 2007 NEEA New Construction Study and the 2007 Snohomish County Public Utility District Study
- Filled in data gaps for approximately 500 existing sites in the 2003 CBSA database through telephone surveys and drive-by visits
- Visited and performed on-site surveys for an additional 95 commercial facilities

2014 CBSA

Navigant led the 2014 study and sought to improve upon the first two studies by drawing a new random sample of regional commercial buildings and conducting highly detailed audits to develop an updated picture of energy consumption across the region. The sample included 859 sites,[2] stratified by 12 commercial building types, three size categories, two vintage classifications, and an urban/rural stratification. It is unclear how many buildings the contractor assessed at each site, and whether the summary data reflects all buildings at the site. The 859 sites represent 2,342 buildings in total.

Key Differences from Previous Study

The 2019 CBSA features several substantial differences from the CBSA completed in 2014. These differences impact the sample frame, the resulting sample, data collected, case weights, and the subsequent analysis. Following is a list of the most meaningful differences between the two studies:

- The contractors for the 2014 CBSA developed the sample design, determined the data collection fields, collected on-site data through assessments, and then analyzed the data. For the 2019 CBSA, NEEA contracted with one firm for Phase 1 of the study to develop the sample design and data collection protocols. NEEA contracted with Cadmus to implement the sample design and data collection, as well as conduct analysis and reporting.
- While the 2014 study relied on tax assessor data for the sample frame, the 2019 CBSA sample frame relied on an innovative virtual catalog that integrated geocoded business data from the Internet with detailed information from conventional tax assessor data.
- For the virtual catalog, we established 1,000 square feet as the minimum floor area for a site. The 2014 study did not establish a minimum floor area for sites included in the study.
- The 2019 CBSA used a two-stage sample design, in which the first stage relied on census blocks as the basic unit of sampling. The second stage used a site as the key unit of measurement. The Phase 1 planning effort defined a site as “a collection of buildings on a census block that share the same taxpayer.” The 2014 study sampled based solely on buildings.
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- The Phase 1 study developed a new methodology for within-site sampling procedures on buildings, businesses, and rooms. The new approach changed the manner in which we applied the within-site weights.
- The Phase 1 study consolidated and updated the space types defined within buildings toward functional uses. For example, the 2014 CBSA included space types for Storage – Low Bay and Warehouse – High Bay as shown in Table 2. The Phase 1 study for the 2019 CBSA combined those space types into Storage.

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2 The 2014 CBSA report does not explicitly define a site, so there may not be a direct comparison with sites as defined in the 2019 CBSA.

Table 2. Comparison of 2014 and 2019 CBSA Space Types

<table>
<tr><th>2014 Space Types</th><th>2019 Space Types</th></tr>
<tr><td>Classroom</td><td rowspan="2">Office / Classroom</td></tr>
<tr><td>Office</td></tr>
<tr><td>Common Area</td><td>Common Areas</td></tr>
<tr><td>Guest Room</td><td>Living Quarters</td></tr>
<tr><td>Kitchen</td><td rowspan="2">Process</td></tr>
<tr><td>Laundry/Housekeeping</td></tr>
<tr><td>Assembly / Recreation</td><td rowspan="3">Public Access</td></tr>
<tr><td>Dining</td></tr>
<tr><td>Sales</td></tr>
<tr><td>Storage - Low Bay</td><td rowspan="2">Storage</td></tr>
<tr><td>Warehouse - High Bay</td></tr>
<tr><td>Vacant</td><td>Not Used</td></tr>
<tr><td rowspan="5">Other</td><td>Building Support</td></tr>
<tr><td>Exterior</td></tr>
<tr><td>Parking</td></tr>
<tr><td>Refrigerated Storage</td></tr>
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</table>

- The 2019 CBSA used many of the same building types as in the 2014 CBSA. The sole addition was a mixed commercial building type. These represented facilities with multiple business or property use types, such as malls. We classified site and buildings as mixed commercial if the commercial floor space comprised multiple property types in which no use type was predominant (i.e., no single property use type made up over 75% of the parcel). If they had multiple use types but was comprised of one building type that did make up over 75% of the parcel, we categorized the site or building into the predominant type.
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- Based on the two-stage sample design, the Cadmus team developed regional case weights that accounted for the inclusion probabilities associated with each stage. The team also calibrated weights based on the regional floor areas calculated through the virtual catalog.

Study Methodology

The Phase 1 team designed the study to provide 90% confidence with ±15% precision for each building type over the four-state region as a whole. The study also expected the sample design to achieve 90% confidence with ±10% for the entire population of commercial buildings at the regional level, but not at the state level. The Phase 1 study recommended sample sizes to meet these confidence and precision targets, and the Cadmus team applied those sample sizes to the Phase 2 data collection effort. We developed the 2019 CBSA sampling plan to provide an effective design that supports diverse objectives, including these:

- Ensure as accurate as possible saturation estimates for energy-related equipment and operating characteristics, for each major building type
- Ensure the collected sample represents diverse geographies

The Phase 1 team recommended building types based on the 2009 CBSA. NEEA and Cadmus agreed it would be more appropriate to update the building types to those used in the 2014 CBSA to ensure easier comparability. Table 3 shows the mapping between the Phase 1 study's recommended building types and those used in the 2019 CBSA. The key differences involved the addition of assembly buildings, the creation of a mixed commercial building type, and the removal of universities. More detail for each building type can be found in the Key Definitions section.

Table 3. Comparison Between Recommended and Applied 2019 CBSA Building Types

Phase 1 Building Type	2019 CBSA Building Type
Dry Goods Retail	Retail/Service
Grocery	Grocery
Hospital	Hospital
Hotel/Motel	Lodging
Office	Office
Other	Other
	Mixed Commercial
Other Health	Residential Care
Restaurant	Food Service
School	School
Warehouse	Warehouse
University	REMOVED
NOT INCLUDED	Assembly

The Phase 1 study for the 2019 CBSA recommended a two-stage approach to sampling that would ensure unambiguous sampling units, traceable and reliable sample weights, and uniform treatment of all sites. The first stage relied on census blocks as the basic unit of sampling. The second stage used the site as the key unit of measurement. Phase 1 planning defined a site as "a collection of buildings on a census block that share the same taxpayer."

After selecting the Stage 2 sample of sites, the Cadmus team engaged in outreach and recruitment to meet the sample targets recommended from the Phase 1 study. For each recruited site, we collected data on building and operational characteristics through a tablet-based data collection tool.

Following data entry and quality control reviews, the Cadmus team analyzed the data to collect standard metrics such as lighting power density (LPD) and energy use intensity (EUI) for both electric and natural gas. These data allowed comparisons to the results identified in the 2014 study, as outlined in the *Key Findings* section.

Finally, the Cadmus team developed various platforms to store and present the data. We developed a full relational Structured query language (SQL) database to store the final site assessment data and additional information including statistical weights, weather data, and energy usage data. Cadmus also developed database views for all required summary tables, public flat files, and inputs to the reporting tables published as a separate Excel workbook on NEEA's website.

Key Definitions

We have defined a number of potentially ambiguous terms included in the CBSA that will clarify numerous project details:

- **Building:** A structure totally enclosed by wall extending from the foundation to the roof, containing over 1,000 square feet of floor space intended for human occupancy. The definition of a building excludes structures not totally enclosed by walls and a roof (such as oil refineries, steel mills, or water towers), street lights, standalone pumps, billboards, bridges, swimming pools, oil storage tanks, construction sites and mobile homes and trailers, even if they house commercial activity. Building boundaries end at the start of enclosed walkways, corridors, tunnels, parking areas, or other connecting spaces.
- **Commercial:** A commercial building is one in which at least 50% of the floor area is devoted to commercial activities. These include diverse activities such as retail, providing services, education, product storage, and food service.
- **Site:** This is the basic sampling unit for CBSA. While this could be analogous to a building, a site allows for cases in which a set of buildings are operated as a unit or multi-building facility. For example, a site can be one or more buildings within a census block that are situated on one or more contiguous parcels of land that have the same property taxpayer. Sites do not cross named roadways, except in cases where such roadways are contained within a census block.
- NEEA building type categories used in the 2019 CBSA:
  - **Assembly:** facilities where people congregate, including religious facilities and gyms.
  - **Grocery:** facilities where the primary property use type is selling groceries, including convenience stores and gas stations with convenience stores.

- **Hospitals:** facilities with in-patient treatment options (e.g., hospital beds) and diagnostic equipment. Outpatient-only clinics were classified as offices.
- **Lodging:** facilities including hotels, motels, inns, and bed and breakfasts.
- **Mixed Commercial:** facilities with multiple business or property use types, such as malls. Parcels were classified as mixed commercial if the commercial floor space comprised multiple property types in which no use type was predominant (i.e., no single property use type made up over 75% of the parcel). If parcels had multiple use types but was comprised of one building type that did make up over 75% of the parcel, it was categorized into the predominant type.
- **Office:** any office building, including doctor and dentist offices.
- **Residential Care:** facilities with assisted living, memory care, hospice care, and those requiring skilled nursing assistance. All facilities that included independent living only were removed. Later in the study, we determined that most residential care facilities in the small size stratum (1,000 to 10,000 ft^2) were home-based businesses more suited to characterization in the Residential Building Stock Assessment. As a result, we removed that stratum from the study.
- **Restaurant:** all food service facilities, including bars and cafes.
- **Retail/Service:** facilities primarily intended for retail sales of goods or providing services. This building type includes gas stations without convenience stores.
- **School:** facilities including public and private schools, as well as day care/child care facilities.
- **Warehouse:** all storage facilities, including automotive storage, cold storage, and general warehouse storage.
- **Other:** any facility included in the study that did not fit into the previous 11 building types, including parking garages, fire departments, and police stations.

As noted previously, NEEA determined that the university building type did not represent a good candidate for assessment through the methods employed by the CBSA. Universities typically involve large campuses with many different building types. The 2019 CBSA within-site sampling methodology would have required Cadmus to select three buildings to represent the entire university, despite the usage types and how well they represent the rest of the campus. As a result, NEEA chose to remove the university building type from the study.

The 2019 CBSA used a broad definition of commercial buildings during the Stage 1 sample development to ensure a large cross-section of building types. However, we excluded the following types of sites from the Stage 2 sample frame based on the Phase 1 study recommendations:

- Sites with floor area less than 1,000 ft^2
- Home-based businesses
- Sites under construction
- Vacant sites

- Sites containing businesses that are classified as agricultural, extractive, and manufacturing
- Parking lots
- Exterior parking garages
- Specific business types that likely provide little value to regional planners, including:
  - Military bases
  - Ports (train, air, and water transportation)
  - Standalone data centers
  - Courthouses
  - Rail/bus stations
  - Stadiums
  - Detention facilities (e.g., jails, prisons)
  - Power generation, water supply, and waste and water treatment

While the 2019 CBSA largely excluded residential activity, we did include mixed-use buildings with commercial activity on the ground floor and residential units above. In these cases, we only characterized the details of the commercial units and excluded any building characteristics or equipment associated only with the residential portion of the site.

Sample Frame Development and Sampling

This section describes the methods Cadmus used to collect data that comprise the virtual catalog, develop the Stage 1 sample frame and subsequent sampling, clean the Stage 2 sample frame and subsequent sampling, and case weight development based on sampling for the CBSA.

Virtual Catalog Development

Overview

One of NEEA's key objectives for the 2019 CBSA involved improving data quality. One approach achieving this goal was for Cadmus to create an innovative virtual catalog of Northwest commercial buildings that leveraged multiple data sources and the most current technology. This virtual catalog combined standard tax assessor data with geospatial commercial building data to form a more robust sample frame than was available in prior CBSA efforts, that accounted more accurately for building types occasionally under-represented in tax assessor data (e.g., hospitals, government agencies). NEEA recognized that the investment in this approach would likely result in variance from prior regional stock assessment results due to the differences in sample frame development and composition. However, NEEA determined the more robust sample frame was worth any potential variance from past studies.

Building on the framework established in the Phase 1 sampling plan, compiling the virtual catalog was the first step in developing the CBSA sample frame that listed commercial sites. To create the virtual catalog, Cadmus used multiple datasets to ensure completeness and allow cross-validation. The chosen methodology automated gathering, filtering, and matching datasets for efficient, reliable, and consistent preparation of the virtual catalog. The methodology used automated steps to identify erroneous or duplicate records, followed by manual procedures apply QA checks.

Analytical Tools

Cadmus used the following software and analytical tools in developing the virtual catalog:

- ArcGIS Desktop software for the preparation of geospatial datasets
- Google API (that is, application program interface) for obtaining Google Places data and geocoding parcel data
- SQL server database to store merged, manually reviewed, and final virtual catalog data
- ArcGIS Online web-based interactive maps to facilitate visualization and manual review of block-level commercial building data
- Google Maps to access satellite data and calculate floor area estimates as part of the manual review

Data Sources

Tax Assessor Parcel Data

Because Phase 1 planning defined a site as "one or more buildings within a census block that are situated on one or more contiguous parcels of land that have the same property taxpayer," parcel-level tax assessor data were a key component of the virtual database, including property type and floor area, as well as valuation. The parcel dataset selected was a proprietary product from SMR Research that provides an extensive set of commercial property and tenant data at the parcel level, where parcels are identifications of geographic areas of properties defined and used for taxation purposes. The parcel records and tax assessor property records were collected from thousands of local, county, and township governments, including commercial parcels in the four Northwest states.

The data included attributes including building floor area, property use, location, and property types for each parcel. A key attribute for the SMR data was the use of modeled floor areas. A substantial number of tax assessor records fail to report the floor area of commercial buildings, so SMR used a statistical model to estimate floor area in the absence of a reported value. We used the actual and modeled values to populate the virtual catalog. A detailed analysis of the accuracy of the modeled floor area values was outside the scope of our review.

Cadmus used the most detailed property use description in the SMR data to create a building-type crosswalk from the SMR property description to the most appropriate NEEA CBSA building type category. We flagged parcels not relevant to the CBSA, such as residential and government. In some cases, though, when the property use types were too broad to apply such filters, (e.g., some parcel data were labeled as "general commercial buildings"), parcels were not filtered at this step. Instead, we flagged these with an indicator to use the category from Google Places (described below) if the record was present in both data sources. Otherwise, we defined the sites as "other." Although we flagged records not applicable to the CBSA, Cadmus did not remove them from the virtual catalog, but retained them to track out of scope building type categories in the population and sample of commercial buildings. We filtered the flagged records out to develop the Stage 1 sample frame, described below.

Cadmus geocoded all parcel addresses using the Google Maps API and joined the parcels spatially with U.S. Census Bureau census blocks, the sampling unit in the Stage 1 sample.

Google Places Data

The virtual catalog also makes use of the extensive and continuously updated business and establishment information available in Google Maps. Cadmus accessed data through the Google Places API, which uses the same dataset underlying Google Maps but provides a scripted interface to automate the data retrieval. In addition to establishment names and addresses, Google Places data included establishment types that Cadmus mapped to NEEA property type categories (outlined above) and used to flag parcels not in the data frame (i.e., government buildings or farms). Where the Google Places data provided more detailed commercial use descriptions, Cadmus assigned these to the parcel when the description in the SMR data was too general. Google Places data did not include floor area for commercial properties, so when sites were present in the Google Places data but not present in the SMR data, Cadmus flagged them to indicate manual review was necessary to capture floor area.

Cadmus purchased an API license to query Google Places API data. We performed a query on every census block in each of the four states (Washington, Oregon, Idaho, and Montana), excluding blocks from eastern Montana (out of scope of the NEEA CBSA). The Google Places API data query resulted in extensive information about facilities in each census block group, including address, company name, latitude and longitude coordinates, and building property type. Using this information, Cadmus flagged establishment types labelled as locality, campgrounds, RV parks, and ATMs and filtered them out of the Stage 1 sample frame.

Other Datasets

Cadmus used the official U.S. Census Bureau geospatial and tabular datasets derived from the TIGER products. This data included geospatial polygons identifying the boundary and total geographic area of each block. Cadmus also used the U.S. Census Rural-Urban Commuting Areas codes for assigning urban and rural designations to each block.

To designate each block as part of either a private or public utility, Cadmus used geospatial data on utility territory areas provided by NEEA. Multiple shapefiles and file geodatabases for different utilities or areas were projected into a common coordinate system and merged. Service territory polygons were then categorized into public and private utilities. Cadmus calculated the centroid of each block and then spatially joined them to service territories to assign each into either the public or private utility category.

Merging Datasets

In the data preparation steps for each individual dataset, Cadmus geocoded all addresses in the tax assessor parcel data using the Google Maps API to ensure address strings and latitude and longitude coordinates were identically formatted to match and merge data. Cadmus used floor area, address, and establishment type to identify and combine duplicate (or more) parcels and merged the parcel data with Google Places data that had the same latitude and longitude.

After these data were merged, cleaned, and organized, Cadmus created a Stage 1 building type category for each record. The Stage 1 NEEA CBSA building category definition was defined based on whether the SMR tax assessor and Google Places building categories matched. Cadmus assumed the SMR building category was the most accurate categorization due to the detailed property type description and used it in place of Google Places building types when they did not align. Cadmus used building types from Google Places when the parcel category was too broad and when the building was only observed in Google Places. Appendix B provides more information on the steps taken to refine the site's building category if the categories did not match between datasets. To prepare the virtual catalog data for Stage 1 sampling, Cadmus imputed missing commercial floor area for records with missing floor area. We calculated the average square footage within state and Stage 1 NEEA CBSA building category (Google Places did not include floor area, so floor area was missing and imputed for all records found only in the Google Places data). Since the imputation applied a uniform scaling across all records with missing commercial floor area, it did not affect the distribution of selected census blocks, but it did provide a more accurate representation of the total commercial floor area in the region in the virtual catalog and Stage 1 sampling frame. The imputation was critical to developing the regional floor area estimate, as well as developing regional case weights. Table 4 shows the resulting quantity of sites and total commercial floor area based on the initial virtual catalog, along with the portion of sites that required floor area imputation.

Table 4. Quantity of Sites and Total Floor Area by Building Type

NEEA Category	Total Sites	% Total Sites	Total Commercial Floor Area	% Total Floor Area	Portion of Sites with Imputed Floor Area
Assembly	20,131	8%	230,154,528	6%	19%
Food Service	19,016	7%	138,381,220	4%	26%
Grocery	10,976	4%	129,211,630	4%	17%
Hospital	913	0%	56,845,003	2%	22%
Lodging	5,699	2%	129,936,763	4%	19%
Mixed Commercial	20,060	8%	240,982,640	7%	6%
Office	57,619	23%	752,056,244	21%	14%
Other	23,844	9%	312,902,175	9%	16%
Residential Care	5,793	2%	261,631,941	7%	43%
Retail/Service	56,686	22%	605,583,462	17%	23%
School	8,439	3%	264,100,082	7%	26%
Warehouse	25,036	10%	525,243,184	14%	18%
Total	**254,212**	**100%**	**3,647,028,871**	**100%**	**19%**

Stage 1 Sample Frame

Cadmus filtered out records from the virtual catalog that had been flagged as not applicable to the CBSA. We aggregated the remaining data to sum floor areas within each building type and block and used the summed floor areas to calculate a measure of size (MOS) variable that was used for Stage 1 sampling. Cadmus calculated the MOS for each census block as a function of commercial floor area estimates in the frame and a scaling factor and applied it based on the commercial building types represented in each census block. We then merged additional block level information, used to define sampling strata, onto it, resulting in block level data that comprised the Stage 1 sample frame.[3]

Stage 1 Sampling

Cadmus implemented a two-stage sample for the CBSA, following guidance provided in NEEA's Phase 1 study documentation to achieve a representative sample of building types. Cadmus developed the Stage 1 sample frame, stratified by region (Oregon, Washington, and Idaho/Montana), utility type (public/private), geographic grouping (urban/rural), commercial floor area density, and the MOS (based on total commercial floor area) for each building type in each census block.

The Phase 1 study recommended a stratified sample of 15,902 census blocks for the Stage 1 sample, followed by manual review to determine the accuracy of the virtual catalog data. NEEA and Cadmus determined that manual review on that number of census blocks would not be the most efficient use of the study budget and timeline, so we developed an alternate plan with a smaller sample of 5,000 census blocks, using a certainty sample to ensure a larger pool of sites in the final Stage 2 sample frame.

Cadmus sampled the 5,000 census blocks, including the largest 1,500 census blocks with certainty and sampling the remaining non-certainty census blocks from three size bins defined by MOS with probability proportional to MOS. The sampling routine provided Stage 1 selection probabilities for each census block, which Cadmus provided to DNV GL for the purpose of case weight development.

DNV GL confirmed the following:

- Average selection probabilities within each stratum were close to the targeted sampling rate within the stratum.
- Sum of Stage 1 sampling weights (inverse of selection probabilities) divided by the Stage 1 sample was approximately equal to the total number of census blocks in the Stage 1 sample frame.
- Weighted sum of floor area within the Stage 1 sample was approximately equal to the total floor area in the Stage 1 sample frame.

Stage 1 Sample Manual Review

After selecting the Stage 1 sample, Cadmus conducted manual review of records for the 5,000 census blocks using satellite imagery and Google Maps to verify, combine, or remove records. Cadmus applied the following review and updates to the sampled census blocks:

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[3] The scale factor was used to impose differential sampling rates by building type. For example, if the target number of completes within one building type corresponded to one site selected for every 10 million square feet of office space, but another required a sampling rate of one per two million square feet, the scale factor for the latter was five times as large as that for the former in the measure of size.

- Verified and updated building type categories and commercial floor areas
- Flagged ineligible sites, including the following:
  - Commercial sites smaller than 1,000 square feet
  - Home-based businesses
  - Addresses corresponding to nonexistent commercial buildings
  - Sites incorrectly identified as commercial
  - Duplicate commercial sites observed in both the SMR parcel and Google Places data not previously identified as being the same site

Cadmus gave additional scrutiny to sites with building types in the mixed commercial category. We initially categorized buildings as mixed commercial if the SMR property use description specified mixed use or if the building type categories between the SMR and Google Places data were different. During the manual review of Stage 1 census blocks, we assigned additional sites to the mixed commercial category if the review did not indicate a single predominant (i.e., one use type that exceeded 75% of the site total floor area).

In some cases, manual reviewers found commercial sites that were not listed in the virtual catalog. They did not add sites back into the sample frame if they were missing from the virtual catalog or previously inaccurately marked as ineligible. This reduced the overall quantity of sites and total regional floor area in the virtual catalog.

This manual review resulted in site-level data that comprised the Stage 2 sample frame. The Stage 2 sample frame data were more accurate than the Stage 1 sample frame, with updated building types and floor areas for each site in the Stage 1 census block sample. The Cadmus team accounted for the improved accuracy in the final case weight calculations by comparing the floor area from each stage of sampling, calculated site eligibility rates based on the manual review, and used these in determining CBSA inclusion probabilities and final case weights. However, sites missing from the virtual catalog skewed the weighting downward, since the addition of sites did not balance out the sites removed as ineligible during recruitment.

Stage 2 Sampling and Recruitment

Cadmus stratified sites in the Stage 2 sample frame based on building type, Stage 2 floor area, and whether each site belonged to certainty or non-certainty census blocks in Stage 1. Cadmus determined the total number of completes expected to fall into each stratum by allocating the target number of completes (808 sites) and expected response rates according to stratum population sizes, listed below:

- Small: 1,000 to 10,000 square feet
- Medium: 10,000 to 100,000 square feet
- Large: greater than 100,000 square feet

Table 5 shows the resulting sample distribution. The only hard targets for completed site assessments were defined by building type category. The size strata sample by building type were soft targets that we hoped to achieve to maintain the proportionality of the original sample, but did not consider critical.

Table 5. Sample Distribution by Building Type and Size

Building Type	Large	Medium	Small	Total
Assembly	2	21	33	**56**
Grocery	1	23	44	**68**
Hospital	27	18	0	**45**
Lodging	11	32	28	**71**
Mixed Commercial	13	32	38	**83**
Office	15	33	68	**116**
Other	1	7	13	**21**
Residential Care	16	22	42	**80**
Restaurant	0	3	48	**51**
Retail/Service	13	24	52	**89**
School	12	24	9	**45**
Warehouse	14	32	37	**83**
Total	**125**	**271**	**412**	**808**

As noted previously, during recruitment we found that the small residential care stratum represented predominantly home-based businesses. NEEA agreed that these sites were not applicable to the CBSA, and we removed the 42 sites in the small residential care stratum from the sample design. This reduced the overall sample target to 766 sites.

For recruitment, we assigned each site to a sampling wave, which was activated when prior waves were depleted. The waves were assigned randomly, using either random ordering or random sampling.

Cadmus determined that all sites in Stage 1 certainty census blocks would need to be recruited and thus established successive sampling waves using randomized ordering of these census blocks (i.e., no actual sampling). Sites in Stage 1 non-certainty census blocks were assigned to recruitment waves using a mix of random ordering and random sampling, as follows:

- All sites in non-certainty census blocks containing four or fewer sites were included in recruitment waves.
- Sites in non-certainty census blocks with more than four sites were sampled with probability proportional to floor area (scaled according to building type, as in Stage 1, using an updated MOS calculated based on Stage 2 floor areas and building types).

Stage 2 sampling and random ordering of sites (in combination with Stage 1 census block sampling), response rates (the rates at which sites agreed to site assessments), and subsequent completion rates were also factors in determining inclusion probabilities. The Cadmus team managed the recruitment so that it assessed no more than two site visits in any one census block to minimize clustering in the sample and ensure broader representation of census block strata.

Again, the Stage 1 sample's stratified design was intended to ensure thorough representation across key strata, so Cadmus did not apply set any Stage 2 hard targets except for building type. However, we also developed soft targets for each region to prohibit any single state from representing a disproportionate total of the final sample, as shown in Table 6. We did not develop any targets for building type by state.

Table 6. Soft Target Sample Size vs. Sites Recruited by Region

Region	Sample Target	Sites Recruited
ID/MT	134	114
OR	207	194
WA	425	441
Total	**766**	**749**

The Cadmus team's call center found varying degrees of difficulty with recruitment by region. The Idaho/Montana region required approximately 40 contact attempts for each successful recruitment, compared with approximately 10 contact attempts per recruit in Washington. In various cases, we depleted our sample for various building type and size strata in Idaho and Montana, which further increased the difficulty in recruiting sites from that region. We ultimately limited recruitment in western Washington to avoid too much representation from that climate zone and increased the call center's focus on eastern Washington, which shared a similar climate to Idaho and Montana.

In some cases, Cadmus determined sites were ineligible for the study (e.g., industrial, courthouse) during the recruitment calls. In cases where the target number of site assessments within a stratum already had been completed, no additional recruitment was done, resulting in different recruitment rates between strata. Variance in recruitment rates impacted the final inclusion probabilities. Final site inclusion probabilities reflected the possibility that sites were eligible for the study as well as the possibility they were sampled and successfully recruited, as described below.

In addition to Stage 1 census block sampling and Stage 2 site sampling, Cadmus field technicians completed within-site sampling per NEEA's Phase I study documentation, described below in the *On-Site Assessments* section.

Case Weight Development

Case weights were developed as a function of the inclusion probability of each CBSA site. As indicated by the sampling overview, several factors influenced the site inclusion probabilities and they were not constant across sites, strata, or building types. Rather than attempt to enumerate and calculate sampling probabilities, response rates, and eligibility rates explicitly for each site, DNV GL estimated inclusion probabilities using a regression analysis to capture their combined effects. DNV GL also combined the inclusion probabilities and within-site sampling weights to perform additional trimming and calibration, resulting in the final CBSA case weights.

Inclusion Probability Calculation

DNV GL used a logistic regression to model the binary dependent variable indicating whether each site in the Stage 2 sample frame was sampled and subsequently included in the CBSA study, conditional on its census block being selected in the Stage 1 sample. Independent variables in this model included

Stage 1 census block selection probabilities, Stage 2 site floor area as a fraction of the total floor area in the strata, and eligibility rates determined based on Stage 2 recruitment. The regression model equation follows:

$$\text{logit}(p2_{bj} | \text{census block C selected in Stage 1 sample}) =$$

$$\beta_0 + \beta_1 \times p1_{Cb} + \beta_2 \times \text{eligibility rate}_b + \beta_3 \times \text{floor area}_j/\text{stratum total floor area}$$

Where:

$p2_{bj}$ | census block C in Stage 1 sample	=	Stage 2 site inclusion probability for site j of building type b, conditional on census block C having been selected in the Stage 1 sample; logit represents a function of the inclusion probability (log odds) commonly used to model binary dependent variables for case weight development
β_0	=	Intercept, or average of logit($p2_{bj}$ | census block C selected in Stage 1 sample)
$p1_{Cb}$	=	Stage 1 selection probability for sites of building type b in census block C, where β_1 represents its effect on Stage 2 inclusion probabilities
eligibility rate_b	=	Eligibility rate of sites of building type b, where β_2 represents its effect on Stage 2 inclusion probabilities
floor area_j/stratum total floor area	=	site j proportion of stratum total floor area, where β_3 represents its effect on Stage 2 inclusion probabilities

DNV GL estimated the coefficients (β_0, β_1, β_2, and β_3) in the regression model using maximum likelihood estimation and used these estimates to calculate fitted values based on the independent variables observed for each site. The resulting Stage 2 inclusion probabilities were between zero and one.

DNV GL reviewed the logistic regression outputs and screened for variables to retain in the model based on regression statistics of model fitness. They confirmed that the resulting Stage 2 inclusion probabilities were consistent with the overall observed inclusion rates, reviewed eligibility inclusion criteria with the data collection team, and cross-checked eligibility rates in Excel. DNV GL also confirmed that applying the resulting Stage 2 case weights (inverse of inclusion probabilities) to Stage 2 floor areas resulted in total floor area estimates consistent with the Stage 2 sample frame total floor area. DNV GL trimmed and calibrated the weights after additional review to produce final case weights.

Trimming

DNV GL individually adjusted weights corresponding to sites with weighted floor area that represented a large proportion (greater than 10%) of the total weighted floor area, reducing the contribution of any one site to the total regional floor area estimate. DNV GL performed this screening at the building level and then backed the adjustment out to the site level so that the trimming would apply to the site case weights.

DNV GL applied similar review to within-site building, business, and room weights. No trimming was required for building and business weights. Some weighted room floor areas contributed a large portion of building type total floor areas, but most of those rooms were in sites with trimmed case weights and therefore required no additional trimming because the final case weight (the product of site, building, and room weights) incorporated the site-level trimming. DNV GL did apply additional room-level sample weight trimming in a handful of cases, when the sampled rooms contributed a large portion even after applying the site level trimmed case weight. DNV GL reviewed the resulting weighted floor area to ensure the extremes had been reduced as intended.

Calibration

DNV GL calibrated site case weights so that the resulting weighted floor area was equal to the total floorspace in the Stage 1 sample frame within each building type. During the recruitment phase, Cadmus and NEEA agreed to remove the small Residential Care stratum because these sites consistently represented residential characteristics rather than commercial. Therefore, DNV GL did not calibrate weights for Residential Care sites due to the adjustments required to the virtual catalog to separate out small residential care facilities to allow for calibration.

After calibrating the site weights, there remained discrepancies between the total weighted floor area when site weights were applied to site floor areas and the total weighted floor area when room weights were applied to room floor areas. This resulted from the anomalous weights described in the within-site sampling section above. Although the variation was explainable and acceptable, the discrepancies were large. To mitigate differences in total floor area estimates, DNV GL calibrated room weights in those cases so that the corresponding total weighted floor area in those buildings were equal to the observed building total floor area.

DNV GL reviewed the resulting calibrated case weights to confirm the resulting total floor area estimates were sensible, consistent across buildings within a single site, and did not result in within-site sampling weights of less than one.

Data Collection

Cadmus designed data collection activities to collect as much data on as many sites as the study timeline permitted, with priority to achieving the sample targets by building type. We developed soft targets for the distribution of sites by building type and size, as well as by region.

As part of the data collection effort, NEEA and the Cadmus team updated the definition of a site. The original site definition assumed that multiple buildings owned by the same taxpayer on the same parcel should be treated as a single site. Through the data collection effort, it became apparent that this requirement would reduce the number of sites in the sample (as parcel boundaries could not practically be applied to the entire sample frame prior to recruitment) and create substantial barriers in recruitment (as multiple buildings would need to be recruited simultaneously for a site to be fully included). Through discussion of the options, we decided to use the sites as they currently existed in the sample frame to drive the site definition. This approach enabled a more consistent calculation of selection probability than having a mix of recruited and unrecruited buildings within a site or experiencing systematic exclusion due to recruitment challenges.

Recruitment

The Cadmus team used the second stage sampling frame as the population from which to recruit sites. In coordination with the Customer Contact working group, the team produced outreach materials in the form of the following documents, which can be found in *Appendix C. Customer Contact Outreach Materials*:

- Business Verification Letter
- Customer Acceleration Protocol
- CBSA Frequently Asked Questions
- CBSA Information Form
- FirstView Sample Report

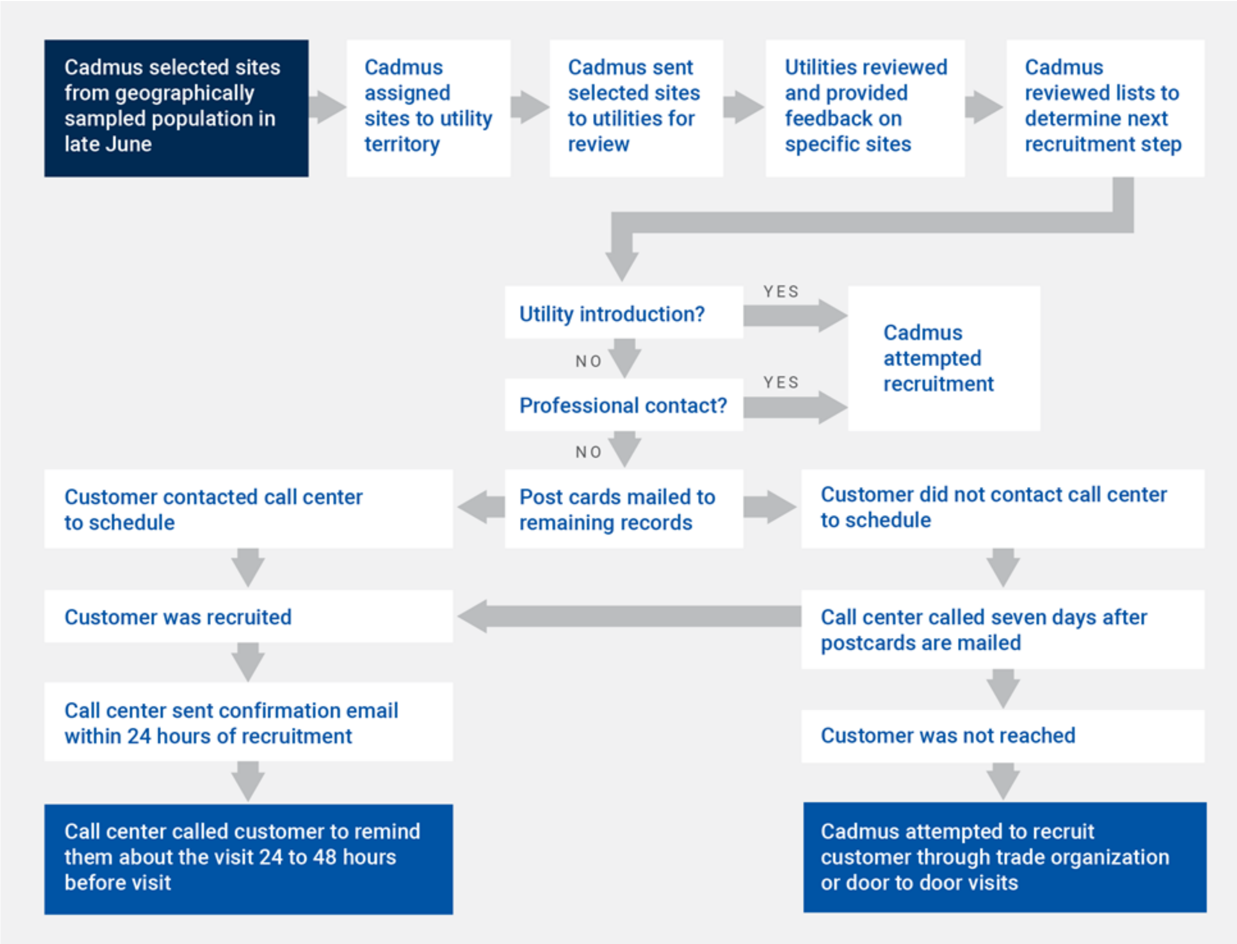
To encourage recruitment, we offered each site the following incentives, based on site size:

- Small: $50 gift card.
- Medium: choice of $100 gift card or site-specific FirstView[4] report for benchmarking.
- Large: choice of $250 gift card or FirstView report.

Our methodology for conducting site outreach and recruitment are shown in Figure 5.

4 New Buildings Institute. 2018. "First View." https://newbuildings.org/resource/firstview/.

Figure 5. CBSA Recruitment Decision Tree



One month prior to recruitment, we notified each utility in the region of our schedule and the sample sites in their territory. Based on utility feedback, we coordinated with them to consider any factors that may impact recruitment, such as other ongoing studies by the utility that may overlap with the site recruitment timeline. Where possible, we attempted to coordinate an introduction to sites by the utility.

Members of the Cadmus team had a prior professional relationship with contacts at various sites in the sample frame. We attempted to recruit participants through those contacts. For most sites, we mailed out a postcard and attempted recruitment through a call center. The call center recruited a majority of the sites. Late in the data collection phase, we identified certain sample strata (e.g., medium hospital, small grocery) for which our recruited sample was relatively low compared with the target. We applied a variety of additional recruiting techniques such as door-to-door visits and outreach through professional organizations (e.g., regional medical associations).

Once we established an agreement for a site visit, we identified the appropriate staff member and provided contact info for the site. The field technician followed up with the site contact prior to the assessment to confirm building characteristics and arrange any further logistical details for the data collection effort.

Data Collection Tool

Cadmus updated its tablet-based data collection tool for the CBSA. Field technicians entered building and equipment characteristics directly into the tablet while on site. Guided questions prompted the technicians for all relevant details, only showing relevant questions based on previous answers. The tool linked assessment photos directly to the related data entries and provided context for QC reviews, as well as additional details after the site visit. Frequent uploads to an online server ensured that field technicians quickly backed up data, which was promptly available for QC review.

Cadmus reviewed the CBSA data dictionary produced by the Phase I study and engaged with the Study Integrity working group to review and refine the questions and response options to achieve a balance between accurate representation of critically important data and efficient use of limited time on site. We converted the data dictionary to our tablet data collection tool format and conducted four pre-test site visits to test the initial draft data collection tool in the field and identify areas for improvement.

On-Site Assessments

Cadmus trained a team of approximately 30 field technicians and engineers from Cadmus, McKinstry, and Energy 350 to conduct site audits. Field technicians were geographically distributed around the Northwest to minimize travel time to sites and conducted assessments at 932 buildings at 749 sites, as shown in Table 7.

Table 7. Sites and Buildings Assessed in 2019 CBSA

Building Type	Original Site Target	Sites Assessed	Buildings Assessed
Assembly	56	60	72
Grocery	68	59	60
Hospital	45	43	53
Lodging	71	66	83
Mixed Commercial	83	99	73
Office	116	108	153
Other	21	13	24
Residential Care	38	40	51
Restaurant	51	46	53
Retail / Service	89	105	133
School	45	44	68
Warehouse	83	66	109
Total	766	749	932

The table shows variance between the number of sites targeted and assessed by building type. Cadmus tracked the sample according to the original building type assigned through the virtual catalog and manual review process. This ensured that case weights would be applied appropriately, despite adjustments resulting from call center or on-site confirmation of the appropriate building type. We ultimately found that 19% of sites had building types that varied from the original description. The two building types with the highest level of variance were mixed commercial and office. We determined that 10 sites originally classified as mixed commercial were primarily offices, while 13 sites originally classified as offices were not any predominant building type, and therefore categorized as mixed commercial. Similar variations occurred throughout the majority of building types. The least impacted building types were schools, hospitals, lodging, and residential care facilities, which the manual reviewers almost always classified correctly.

Within-Site Sampling

In addition to Stage 1 census block sampling and Stage 2 site sampling, Cadmus field technicians completed within-site sampling in the following cases, as prescribed by NEEA's Phase 1 study:

- Building sampling was performed at any site with more than three buildings. This occurred at 27 out of the 749 sites. At these sites, any buildings accounting for over one-third of the total site floor area were selected with certainty, and the remaining buildings were sampled using probability proportional to size.
- Business sampling was performed within any building with more than three businesses and when more businesses were present than were feasible to visit during the site assessment. Businesses accounting for over 50% of the total floor area within a building were selected with certainty, and the remaining businesses were sampled by random sampling within each business type category.
- Room sampling was performed within buildings or businesses with more rooms than were feasible to visit during the site assessment. Rooms accounting for over 50% of the total floor area within a building or business were selected with certainty, and the remaining rooms were sampled by random sampling within each room space type category.

All three types of within-site sampling were subject to refusal by site contacts. Individual tenants in mixed commercial buildings often refused to participate, particularly chain stores and fast-food restaurants where on-duty managers were not authorized to approve a site visit. Site contacts frequently refused access to specific sampled rooms if they were occupied (e.g., in lodging and residential care facilities) or for safety, security, and privacy reasons (e.g., hospital procedure rooms, school classrooms with students, and spaces requiring extensive personal protective equipment). Field technicians worked with site contacts to select alternate spaces to visit, using random sampling wherever possible. However, in some cases, sampling was significantly constrained by limits imposed by site contacts and tenant participation.

The Phase 1 study prescribed the within-site sampling approach described above. Cadmus found this approach difficult to implement at large sites where building drawings were unavailable. Although sampling businesses and rooms proportional to quantity, rather than floor area, was easier to implement (particularly when site drawings were incomplete), it led to challenges discussed below in applying appropriate sampling weights during the analysis.

The specific details of within-site sample and weighting development can be found *Appendix D. Within-Site Sampling and Weighting*. Cadmus calculated within-site sampling weights as the inverse of the within-site selection probabilities. Although within-site sampling did not affect the Stage 2 site inclusion probabilities, they were multiplied with site case weights to estimate regional population characteristics and are critical to the CBSA analysis. DNV GL reviewed the within-site sampling weights by comparing floor area estimates derived from room sampling weights, business sampling weights, and/or building sampling weights to site total floor areas, flagging anomalous values. Cadmus reviewed and corrected these as needed—this was an iterative process with the trimming and calibration that resulted in the final within-site sampling weights included in the CBSA database and analysis.

On-Site Audits of Buildings

Prior to visiting each site, the assigned assessor reviewed all available documentation, including online information, images of the site layout (e.g., from Google Maps), parcel maps (to determine which buildings to include within a site), and any data provided by the site contact, such as building plans, electrical drawings, or equipment inventories to gain an understanding of the site's layout, conduct within-site sampling, estimate initial data on building systems, and plan the on-site effort. When available, staff pre-populated key inputs like building dimensions, placeholders for expected equipment, and space entries for within-site sampling to the data collection tool.

Field technicians worked with site contacts to assess as much equipment as possible while minimizing disruption to occupants and time required from the site contact. Field technicians documented all major central mechanical systems in each assessed building, even if within-building sampling was necessary. This includes central HVAC systems, boilers, chillers, water heaters, and refrigeration systems. Technicians also documented key building envelope and general building characteristics for the entire building. Whenever possible, technicians assessed all HVAC systems, including those distributed throughout the building for smaller spaces, even if they served spaces not sampled. However, we used sampling in some buildings with large numbers of HVAC systems where visiting each individual system was impractical. Field technicians only collected lighting and general equipment in sampled spaces.

At a minimum, technicians collected basic nameplate information, site-specific usage and configuration information, and photographs of all audited equipment on site. Photos were tagged directly to the corresponding data objects when technicians took pictures using the data collection tool. Technicians then used model numbers, photos, and notes to fill in detailed technical specifications and any fields requiring calculations after returning to the office.

Cadmus identified a notable issue regarding small residential care facilities during the data collection phase. Our technicians determined that a large portion of these facilities were conventional single-family homes where both patients and caregivers lived. Cadmus conducted a thorough manual review using aerial map views and confirmed that the overwhelming majority of small residential care facilities matched this description. After raising the issue with NEEA, we agreed that these facilities would be more appropriately assessed as part of the Residential Building Stock Assessment. Therefore, we removed the small residential care facility strata from the 2019 CBSA sample target.

Quality Assurance and Control

Cadmus implemented several layers of quality assurance, beginning with training and the data collection tool and ending with a final data review and cleaning. Prior to conducting assessments, field technicians participated in a two-day intensive training on the specific protocols, data collection tool, within-site sampling procedures, and site visit tracking systems for the CBSA. The training included a variety of classroom presentations, hands-on practice with the tablets and sampling templates, and group site visit assessments of the office buildings where the trainings were held. Senior engineers attended, shadowing site visits with each field technician to guide them through the pacing, prioritization, and data collection methods necessary for a successful CBSA audit. After technicians started conducting solo site visits, senior staff reviewed the data they collected for subsequent visits to ensure it continued to meet quality standards.

The tablet data collection tool software helped field technicians collect accurate data by ensuring that data were entered in a consistent format by all staff. Questions and response options adjusted dynamically to previously entered data to ensure only relevant data were collected. The instant online data uploads from the tablets to the cloud enabled QC staff to review data the same day it was collected and provide prompt feedback to field technicians.

Cadmus developed an automated QC test system that integrates with the data collection tool and identifies common mistakes or unusual data values. Cadmus updated the automated QC checks throughout the course of the study to add new tests whenever manual data review or field technicians' questions revealed a new possible error. Newly added tests were also run against all previously uploaded sites so corrections could be made where needed.

Cadmus analysts thoroughly reviewed and cleaned data after completing site visits. This included filling in missing data by researching model numbers, photos, and notes wherever possible; correlating equipment entries with similar model numbers to obtain missing data unavailable online; searching for and investigating outliers to confirm unusual equipment or make corrections; and adjusting sampling workbooks and weights to reflect any changes from the sampling plan necessitated by site conditions.

Billing Data

Consumption histories, which form the basis of calculating EUI indices, were one of the key data elements in this study. Cadmus coordinated with utilities to determine whether they required a utility-specific billing release, or whether a generic form would be acceptable. We added a page to NEEA’s website through which participants could access their utility’s appropriate billing release form and provide the relevant data. Cadmus reviewed the data for accuracy and reached out to participants for corrections as necessary. However, a portion of these participants declined to provide the necessary data for correcting the billing release. We reached out to each of these participants at least twice to obtain the appropriate data but were unsuccessful for 57 electric and 29 natural gas sites.

Cadmus submitted the billing data requests to utilities in batches. Upon receiving the billing information, we then matched the utility billing data to the CBSA sites. In some cases, one meter from the utility billing data represented the entire site. In other cases, multiple meters were associated with the CBSA site. Cadmus standardized calculating EUI at the overall site level rather than building level due to the potential confusion associated with multiple buildings and meters. However, there were four electric utilities and four gas utilities for which we either could not reach an appropriate contact at the utility, or the utility contact declined to provide the participant billing data. The four gas utilities were not NEEA funders and we were unable to obtain electric billing data for four sites and gas billing data for 37 sites.

Once we linked CBSA sites to utility billing data, we normalized the billing histories to calendar months, and weather-normalized them using Typical Meteorological Year 3 (TMY3) data. At this point, we calculated EUIs for each site using annual energy consumption and verified square footage. Cadmus screened EUI values to check for reasonableness. For buildings with anomalous EUIs, we conducted additional research into the matched meter/meters or square footage. It was possible the billing history for a particular site did not include all meters, or the total square footage of a site did not accurately represent the meter data. Ultimately, we dropped EUIs when we were not confident of the accuracy. Table 8 and Table 9 show the final proportion of buildings in the database that have electric and natural gas consumption histories by building type for the region.

Table 8. Proportion of Electric Billing Data Obtained By Building Type

Building Type	Sites with Electricity Billing Data	Total Sites	Proportion of Total
Assembly	34	63	54%
Grocery	30	60	50%
Hospital	27	43	63%
Lodging	33	66	50%
Mixed Commercial	41	75	55%
Office	65	113	58%
Other	12	15	80%
Residential Care	20	40	50%
Restaurant	26	47	55%
Retail/Service	52	113	46%
School	29	44	66%
Warehouse	31	70	44%
Total	400	749	53%

Table 9. Proportion of Gas Billing Data Obtained By Building Type

Building Type	Sites with Gas Billing Data	Total Sites	Proportion of Total
Assembly	25	50	50%
Grocery	18	34	53%
Hospital	17	27	63%
Lodging	27	57	47%
Mixed Commercial	40	49	82%
Office	40	97	41%
Other	7	12	58%
Residential Care	19	38	50%
Restaurant	32	46	70%
Retail/Service	42	91	46%
School	25	30	83%
Warehouse	22	45	49%
Total	314	576	55%

Data Analysis

Cadmus used the cleaned data to analyze building characteristics throughout the region. We applied case weights to develop summary and analysis tables for parameters such as regional floor area by building and space type, lighting power density, energy use intensity, HVAC, and domestic water characteristics.

Building-Level Analysis

Cadmus sampled the population at the site level, where one site may contain multiple buildings. Some buildings within a single site had significantly different use types and characteristics, so all analysis results were reported at the building level.

We used several different methods to aggregate different types of data. Lighting and general equipment were related explicitly to specific space type areas and were thus aggregated by floor area. We could not reliably determine served floor area for HVAC systems, so we aggregated HVAC by capacity and applied it proportionally to the total building conditioned floor area. Because HVAC systems using boilers or chillers for heating or cooling typically do not have a capacity directly associated with the HVAC equipment, we distributed the capacity of the underlying boiler or chiller to all of the HVAC systems related to each boiler or chiller.

We summarized categorical variables, which group equipment or systems into discrete labeled categories, using the aggregation methods described above and reported as the percentage of the aggregated value falling into each category. We summarized numerical values using the sum or weighted average of each applicable individual value.

Lighting Power Calculations

Many lighting fixture entries were missing wattages because field technicians could not physically access the fixture or the lamp was unlabeled. Field technicians collected lighting wattages from any available alternate source including replacement stock, lighting schedules, or building operator interviews. Technicians recorded 3,152 fixture type entries representing a total of 98,550 installed fixtures. Technicians did not record wattage for 9% of total installed fixtures. Cadmus imputed missing wattages based on the typical wattage of other similar fixtures. We grouped all fixture types with known wattages by the lamp technology, fixture type, detailed lamp type (e.g., screw or pin for CFL; metal halide or high pressure sodium for high-intensity discharge [HID]; and T5, T8, or T12 for linear fluorescent), and whether the fixture length was over or under four feet. Within each of these groups, we calculated the median known wattage, then we updated each fixture type with an unknown wattage to use the corresponding imputed wattage. The final data source is indicated in the database for each fixture type.

After filling in wattages for all fixture types, Cadmus used the room and business sampling weights to calculate the total installed lighting power for each space type in each building. Installed fixture quantities were recorded in lighting groups, where each group contained one or more spaces of the same use type. In most cases the sample weight for each room within a lighting group was the same; if there was any difference, we used the average sample weight of all rooms in the group weighted by the floor area of each room. If business sampling was conducted, each room weight was also multiplied by the sample weight of the business the room was within. Room and business weights were set to 1 if no room or business sampling took place in a building.

Room sampling weights overestimated lighting power and floor area when the sampled rooms were larger than the average room, and underestimated when sampled rooms were smaller than average, because rooms were selected using simple random sampling, not size. We discussed this issue with the Study Integrity working group while reviewing the Phase I within-site sampling procedure, but the working group expected the over- and under-estimation to cancel out on average. Cadmus ultimately found that, overall, these did not cancel but that on average room weights overestimated building floor area when applied to room floor areas, leading to under-estimated LPD.[5] To correct for this known bias, we developed a correction factor for each building and multiplied it to the sampling weight in lighting-related calculations. The correction factor is defined below:

$$\text{Correction Factor } = \frac{A_{\text{bldg}}}{\sum A_{\text{st}} W_{\text{st}}}$$

Where:

A_{bldg} = the total building floor area

A_{st} = the total floor area of rooms in each space type

W_{st} = the combined sample weight for the space type

Cadmus calculated factor-weighted lighting power for each building using this correction factor applied to the sampling weights and lighting power observations. We calculated the LPD for each building by summing the factor-weighted lighting power across space types and dividing by the building total floor area (observed directly).

Energy Use Intensity[6] Calculation

Since billing histories were not available for many sites, Cadmus imputed them for the CBSA analysis. The imputation used regression models to estimate raw annual electric and natural gas EUIs for all sites with missing billing histories. Independent variables in the models included TMY3 heating degree days (HDD) and cooling degree days (base 65) weather variables for the nearest weather station, primary building type of each site, and total floor area. The models included interactions to allow weather variables to have different effects depending on the building type. Cadmus calculated a factor based on ratio between observed raw and weather-normalized EUIs and applied it to the imputed raw annual EUIs to impute weather-normalized annual EUIs.

5 Lighting power density is the ratio of watts divided by floor area, represented as W/ft^2.

6 Energy use intensity is the ratio of energy consumption divided by floor area, represented as kWh/ft^2 and $therms/ft^2$.

Regional-Level Analysis

We estimated regional results by applying the case weights to observed data collected from CBSA sites. The case weights were multiplied to building-level data to estimate regional total floor area estimates corresponding to various building-level characteristics. When building characteristics were observed only within sampled businesses and/or rooms, the building case weights were multiplied by the room and/or business weights to estimate the regional totals.

For values computed as a ratio (e.g., LPD and EUI), Cadmus used the sum-product of the weights with the metrics to estimate the numerator value (e.g., sum of weighted lighting power for all buildings) and the denominator value (e.g., sum of weighted floor area for all buildings) to estimate the regional ratio.

Data Platforms

Cadmus developed a data collection pipeline to go from field data collection to final analysis products. Each step stores data in an optimized format for the associated device and use case.

Data Collection and QC Platform

The data collection tool was a web app and transmitted data to a cloud server over an encrypted internet connection. The cloud server stored the collected data in the same format as the web app. Cadmus ran automated QC tests on the same server.

Relational Database

Cadmus developed a full relational SQL database to store the final site assessment data and additional information including statistical weights, weather data, and energy usage data. After each site passed the automated QC tests and any manual review, the system loaded the data into the SQL database. We reloaded sites from the data collection server to the database as needed when revisions to site data were required. The database contains 96 tables with a total of 1,241 unique columns. The 2019 CBSA contains significantly more detailed information than previous CBSAs about the relationships between various types of equipment (e.g., between pumps and boilers, HVAC systems and chillers, or lighting and spaces). These relationships are defined along with all other database tables and columns in the accompanying data user guide and data dictionary.

Cadmus also developed database views for all required summary tables, public flat files, and inputs to the reporting tables published as a separate Excel workbook on NEEA’s website. The full database was delivered to NEEA as a Microsoft Azure SQL cloud database. The public database was exported as flat comma separated values (CSV) files, described below.

Flat-File Tables

Cadmus developed database views to form the flat file CSV exports published publicly. These tables contain the same values as the underlying database tables, but were modified to consolidate related data into fewer files and to join ID columns with their underlying values. We removed all potentially confidential information and rounded all reported floor area values in the flat files to protect the privacy of CBSA participants.

Key Findings

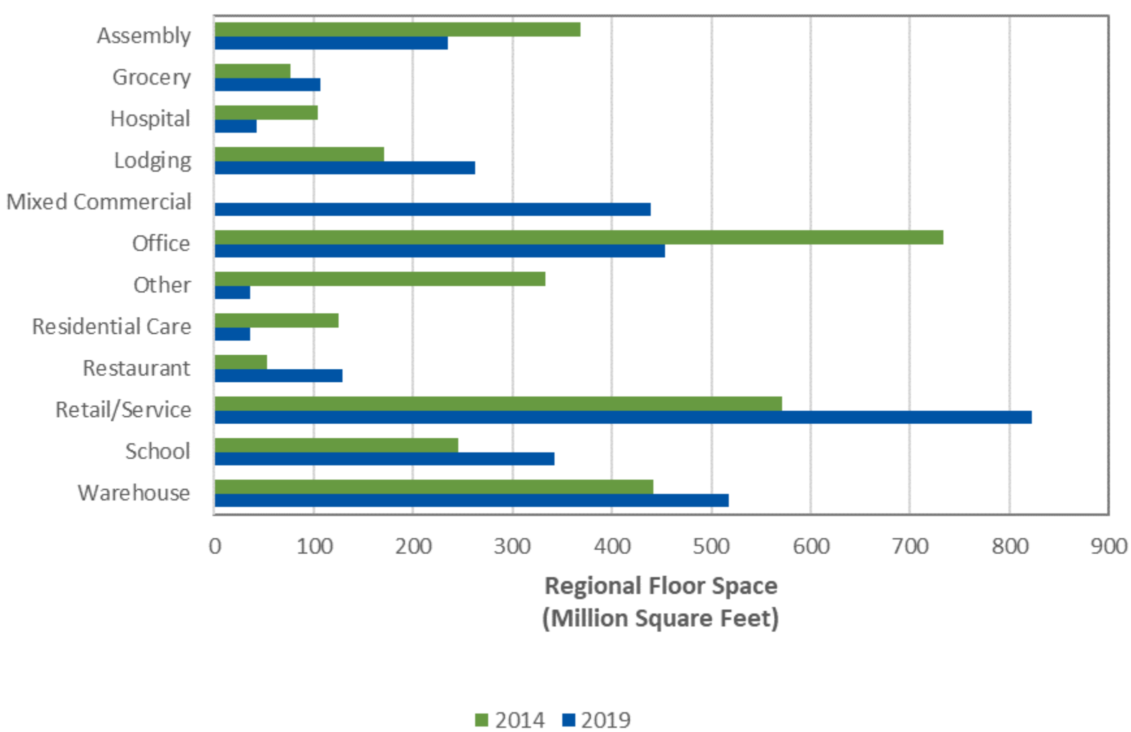
The findings of this study are based on data from the 932 Northwest commercial buildings in the 2019 CBSA database. This section presents a selection of notable findings, including differences from the previous study results. We offer explanations supported by other findings or theories in those cases where we observed meaningful differences. There are several overarching potential sources for variance, including the composition of the 2019 sample compared to 2014, and the more robust 2019 sample frame resulting from the creation of the virtual catalog. We believe the 2019 CBSA findings provide the most accurate representation of the Northwest commercial building stock produced to date given the rigor applied to the virtual catalog creation, two-stage sampling approach, and sample sizes by region and building type.

Building Characteristics

Total Floor Space

Through the 2019 CBSA, the Cadmus team estimated the total Pacific Northwest commercial floor space for the building types assessed at 3.4 billion square feet. This does not include building types excluded from the study. Figure 6 shows the breakdown of floor area among building types in the 2014 and 2019 CBSAs. For all comparison figures, it is important to note variance between building type definitions in the 2014 and 2019 studies.

Figure 6. Comparison of 2014 and 2019 Floor Area



As noted, the two CBSA studies used different data sources, which may have impacted the overall totals. As described in the *Sample Design* section, the commercial floor space is developed from the virtual catalog based on the integration of Google Places and SMR tax assessor data. The development of this dataset combined these data sources to provide a detailed and more accurate population estimate of the Northwest commercial building floor area.

The value of 3.4 billion square feet represents a 6% increase from 3.2 billion square feet in 2014. Some of that increase is due to new construction. The sample included 38 buildings constructed between 2014 and 2019, representing 4% of the total buildings. Their case-weighted floor area represented 3% of the total regional floor area. The Building Vintage section explores floor area by new construction in more detail. The 2019 CBSA estimated that regional commercial floor area has increased by 1.9% on average since 1990. Therefore, the total increase in floor area since the 2014 study would be lower than expected (6.2% rather than 9.5%).

Aside from the difference in source data, there are several reasons for lower floor area in 2019:

- The 2019 CBSA excluded sites smaller than 1,000 square feet from the virtual catalog, and therefore removed the potential for them to be sampled. The 2014 CBSA did not establish a minimum floor area for sites to include in the sample frame. We did not attempt to quantify the floor area for sites with less than 1,000 square feet, but it is reasonable to assume that floor area represents a substantial amount in aggregate.
- We excluded the university building type from the 2019 CBSA. This represented 124 million square feet of commercial floor area in the 2014 study.
- The new study also excluded vacant buildings, along with various building uses that may have previously been classified in the other building type. As Table 7 shows, the other building type showed the most substantial reduction in floor area. This was also in part due to the addition of the mixed commercial building type.
- The residential care floor area declined because the 2019 study removed facilities smaller than 10,000 square feet, as well as independent living facilities. It is unclear from the 2014 study data what portion of the total floor area these areas represented.

The 2019 CBSA also redefined several building types. Again, the updated data sources and sample produced the most substantial adjustments to floor area for various building types. But, the updated building type definitions contributed in the following ways:

- The 2019 CBSA introduced a new building type for mixed commercial for those sites that did not represent 75% or more of one building type. This building type reduced the floor area that might have otherwise been associated with other building types, particularly offices. Field technicians recorded the majority building type in mixed commercial buildings to the extent there was one. The 12 mixed commercial buildings listed as majority office represented 31% of the total floor area for mixed commercial buildings, with retail (18%) a distant second.

- For assembly, we included gyms and similar facilities that were located in strip mall or other mixed commercial sites in the mixed commercial building type category. This resulted in lower floor area in the assembly building type.
- Hospital campuses reflect a wide range of building types and uses. This range of uses resulted in a portion of hospital sites being classified as mixed commercial based on the Phase 1 definition of a site ("all buildings in a census block owned by the same entity"). As an example, one large hospital campus with a university component that we examined during the manual review process included 12 facilities with building types that included assembly, hospital, office, other (laboratories), and schools. No building type represented more than 75% of the campus, so it was classified as mixed commercial. In another case, we found a hospital and residential care facility with the same owner in a census block. We classified this site as mixed commercial because neither building represented more than 75% of the total floor area.

Building type floor area also varied based on the difference between the original building type assumed during the manual review process and the final building type confirmed during the site assessment. The original and final classification for building types can be found in Table 10.

Table 10. 2019 CBSA Building Type Final Classification

Original Building Type	Confirmed Building Type											
	Assembly	Grocery	Hospital	Lodging	Mixed Commercial	Office	Other	Residential Care	Restaurant	Retail / Service	School	Warehouse
Assembly	47			1	5	3				1	1	
Grocery		56			4				1	8		
Hospital			41			2		1				
Lodging				62	1					1		
Mixed Commercial	6	3	1	2	39	12		1	3	8	1	1
Office	4		1	1	12	82	2	1		9		3
Other	1				7	6	6					
Residential Care	2							37				
Restaurant					6				42	3		
Retail/Service					11	1	1			67		3
School						1	1				42	1
Warehouse					14	1	3			8		58

As an example of the adjustment impact, the results show that we reclassified 33 buildings originally thought to be office as other building types, but only reclassified 26 buildings from other types as office. This reduced the overall office sample and indicated the virtual catalog overestimated office floor area in the region. For retail/service, we found the reverse. We reclassified 15 retail/service buildings as other types, but found 38 buildings originally thought to be other types were actually retail/service. These adjustments in the sample contributed to the differences in the overall building type floor area shown in Figure 6.

The Cadmus team adjusted the case weights and building type populations based on reclassify building types based on the on-site assessment results. These adjustments resulted in a more accurate representation of the regional floor area in 2019.

Building Size

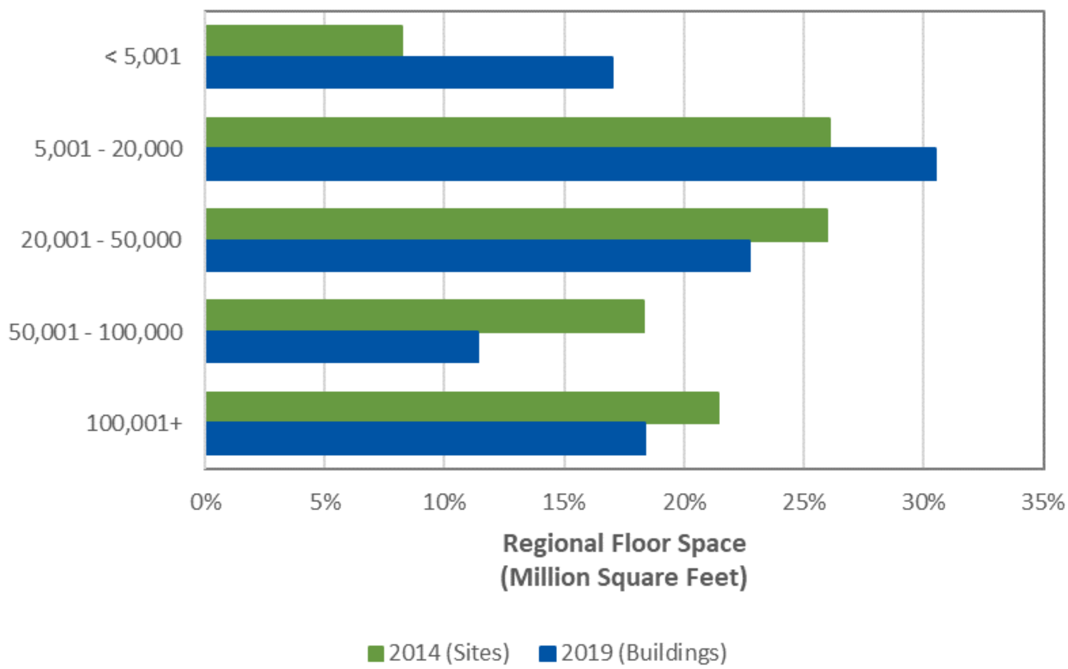
Figure 8 compares square footage by building size bins in the region between 2014 and 2019. The 2014 Building Summary Table does not provide building floor area, so we could not align the data with the three size bins developed for the 2019 CBSA. We adjusted the 2019 CBSA data to match the five 2014 size bins for comparison purposes. As noted previously, the 2019 study applied the following size bins:

- 1,000 to 10,000 square feet[7]
- 10,000 to 100,000 square feet
- Greater than 100,000 square feet

With respect to building size, buildings ranging from 5,001 to 20,000 square feet in floor area represented the plurality of floor area in both the 2014 and 2019 CBSAs (Figure 7). However, the 2019 CBSA shows significantly more floor space for the smallest building category than found in 2014. This could result from the 2014 data representing data as sites rather than buildings. It was unclear whether each site corresponds to one or more buildings, but smaller buildings may have been aggregated into larger sites, skewing the distribution. There is a corresponding decrease in the proportion of 2019 floor area represented by the largest two building categories when comparing the studies, likely due to the same difference in units for comparison.

[7] Note that we assessed buildings smaller than 1,000 square feet when they were part of a larger site or had been inaccurately classified as greater than 1,000 square feet during the manual review.

Figure 7. Distribution of Regional Floor Space by Building/Site Size

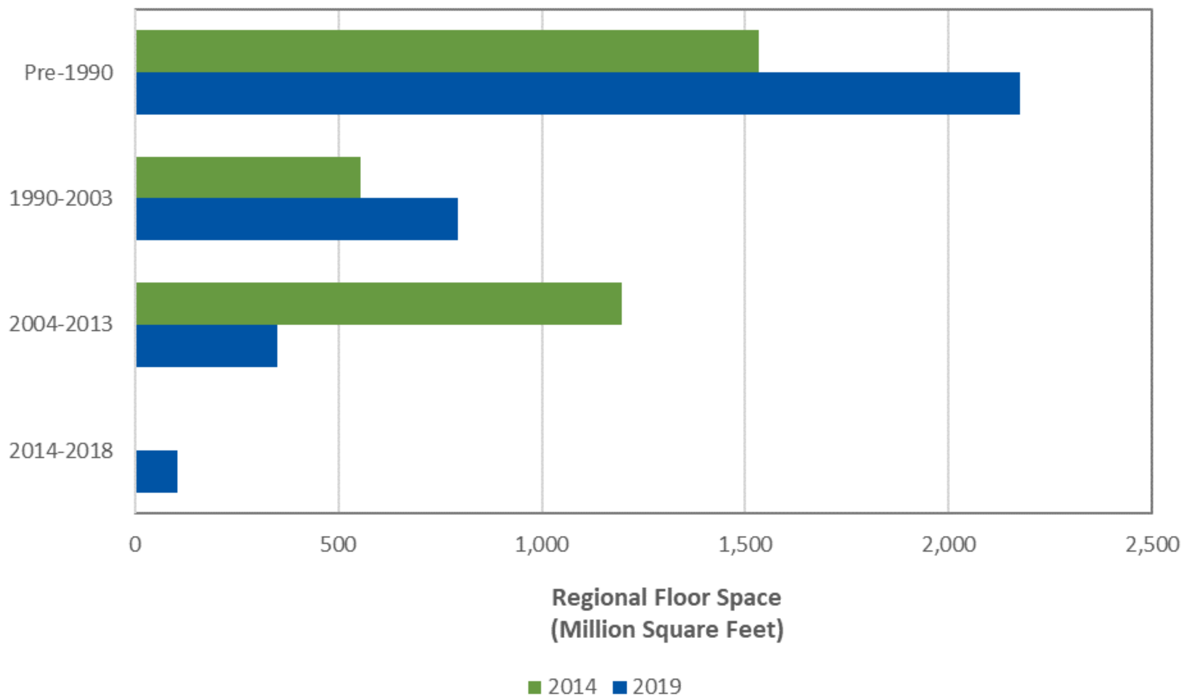


Based on the virtual catalog data and site definition from 2014, we believe the proportions from the 2019 study provide an accurate representation of regional floor area for buildings by size bin.

Building Vintage

Figure 8 displays regional floor space by cohort. The 2019 study found that a majority (64%) of the regional commercial floor area was built before 1990.

Figure 8. Distribution of 2014 and 2019 Floor Space by Cohort



The 2014 study appears to have oversampled relatively new construction. That study indicated that 36% of commercial floor area had been constructed within the previous decade (2004-2013). The 2014 study included 289 buildings constructed from 2004 to 2013 out of the sample of 864, representing 33% of the total. For 2019, that vintage cohort represented 129 buildings, or 14% of the sample buildings.

To provide further clarity on the more reasonable value for Northwest commercial new construction, we referenced the 2012 Commercial Building Energy Consumption Survey (CBECS)[8] conducted by the U.S. Energy Information Administration (EIA). This study provided data on national new commercial construction trends from 1979 to 2012, as shown in Figure 9. This shows an average increase in new construction floor area of approximately 1% per year. The 2019 CBSA data show an average increase in regional commercial floor area of approximately 1.9% per year since 1990. The Northwest has undergone tremendous growth and development over the past 30 years, with the population in the four states increasing from 9.57 million to 14.7 million people. That represents an average growth rate of 1.8%, in line with the average commercial floor area growth estimate from the 2019 CBSA.

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8 EIA. 2015."Commercial Building Energy Consumption Survey (CBECS)." The updated 2018 CBECS should be released by the EIA in 2020. https://www.eia.gov/consumption/commercial/reports/2012/buildstock/

Figure 9. Growth in Commercial Floor Area, 1979 – 2012

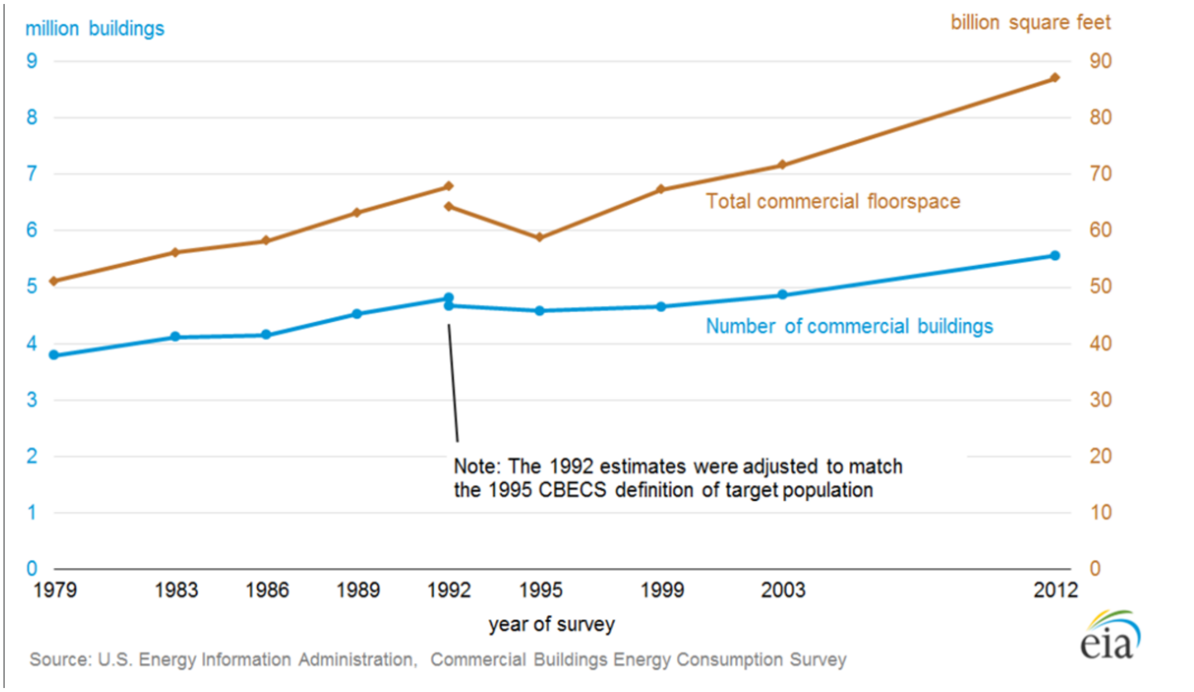


Table 11 provides more context on the comparison between studies. CBECS shows anomalous results from 1992 to 1995 based on a change in the study methodology. This calls into question the 1990 floor area of 65 billion square feet, and likely results in understated growth in commercial floor area over the period from 1990 to 2003. The growth in national floor area from 2003 to 2012 is a better estimate.

Table 11. Comparison of Commercial Floor Area Over Time and Growth Rate Between Studies

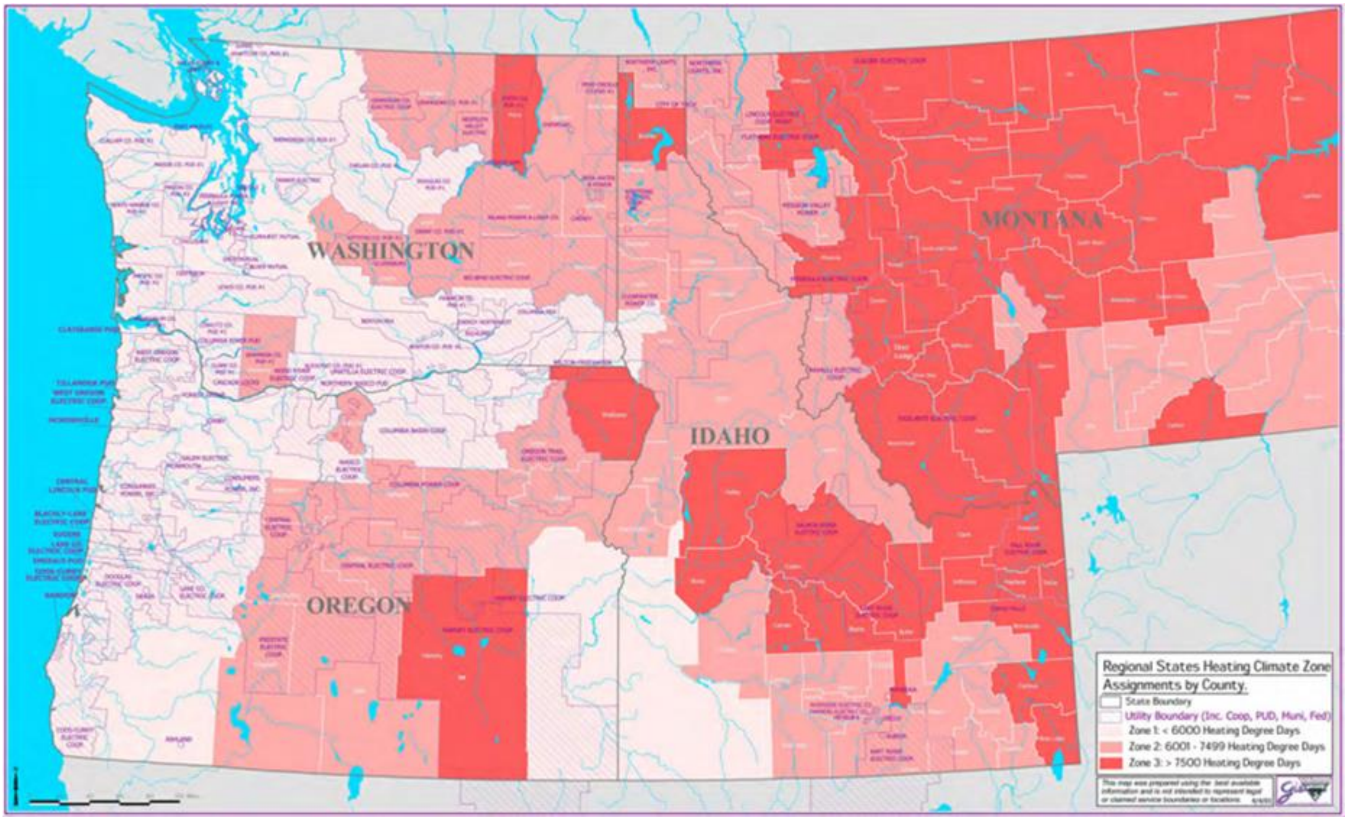
Construction Date Range	2014 CBSA Floor Area (million ft^2)	Cumulative 2014 CBSA Growth Rate	2019 CBSA Floor Area (million ft^2)	Cumulative 2019 CBSA Growth Rate	2012 CBECS Floor Area (million ft^2)	Cumulative 2012 CBECS Growth Rate
Pre-1990	1,534	-	2,174	-	65,000	-
1990-2003	554	36%	793	36%	6,000	9%
2004-2013	1,198	57%	350	12%	14,000	23%

The 2019 CBSA found 350 million square feet in the Northwest commercial building floor area constructed from 2004 to 2013, a 12% increase over the pre-1990 total. This was a period that began with significant construction throughout the Northwest. However, the growth rate declined significantly after the 2008 recession, which had a major impact on the Northwest. That could explain why the construction growth rate in the Northwest was lower than nationally in CBECS. However, it does not align with the 2014 CBSA values that show a 57% increase in commercial building floor area over the pre-2003 values. Based on the commercial new construction trends shown in the 2012 CBECS, we believe the 2019 CBSA provides a better representation of building vintages throughout the region.

Climate Zone

The climate zone affects heating and cooling loads, and thus the potential for energy savings from heating and cooling efficiency measures. Buildings in the CBSA database are classified into the three Northwest climate zones, as defined by Bonneville Power Administration. A map of the heating climate zones is shown in Figure 10.

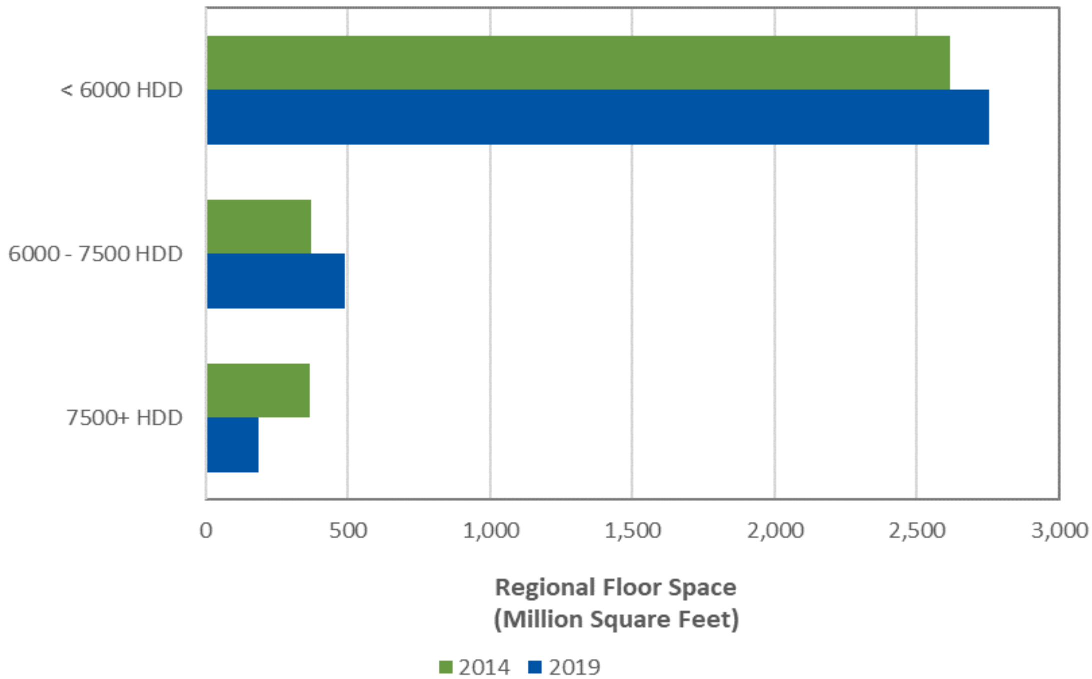
Figure 10. Northwest Climate Zone Assignments by County



Source: Bonneville Power Administration

Figure 11 shows that Northwest regional commercial floor space (80%) is predominately located in Climate Zone 1 (less than 6,000 HDD). Only a small portion of commercial floor area (5%) is located in the colder, higher elevation areas (shown in the darker red on the map) that experience more than 7,500 HDD per year. The values generally align well between the 2014 and 2019 CBSA studies, although the 2019 study found approximately half as much floor area from locations in the greater than 7,500 HDD range than the 2014 study found.

Figure 11. Floor Space by Climate Zone



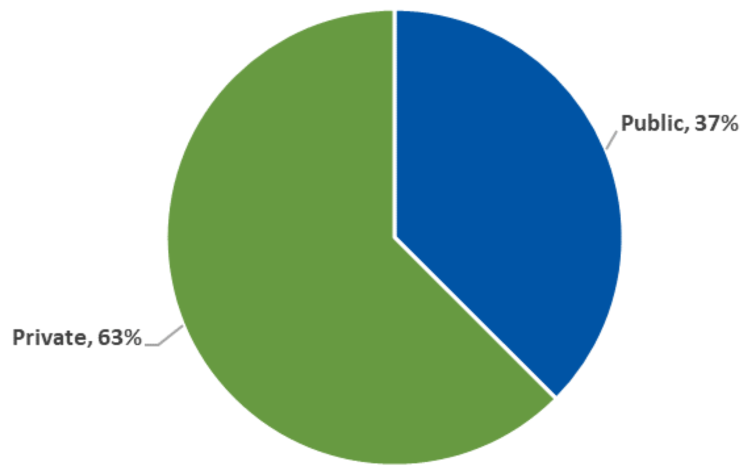
Electric Utility Ownership

The Northwest is served by a variety of electric utility types, but these can generally be divided into two main categories:

- Private, which represents investor-owned utilities
- Public, which represents a mix of cooperatives, municipal, and public utility districts served by Bonneville Power Administration

As shown in Figure 12, nearly two-thirds (63%) of Northwest regional commercial floor area is predominantly served by private, investor-owned utilities in many of the large urban centers such as Puget Sound (outside of Seattle and Tacoma), Portland Metro, Boise, Spokane, and Montana cities served by Northwestern Utilities. The other 37% of commercial floor area is served by the variety of publicly owned utilities.

Figure 12. Public vs. Private Utility Ownership by Building Type



Space Type

Cadmus assigned each space assessed within a building to a space type, based on the list of types developed in the Phase 1 study design. The proportion of total floor area represented by each space type is shown in Figure 13. In general, the proportion of regional floor area represented by key space types did not vary much from 2014 to 2019. However, the Phase 1 space types do not map exactly to the 2014 CBSA space types (shown in Figure 14), so a direct comparison across all space types is not possible. However, we can make some comparisons to note similarities and differences.

The 2019 space type with the largest floor area was Public Access, with 27% of the total, which includes auditoriums, dining, gyms, sales, and galleries. The nearest equivalents from the 2014 CBSA are the assembly/recreation, dining, and sales space types. These represented a combined 26% of total floor area, which aligns well with the 2019 findings.

Common areas represented 12% and 9% of total floor area in 2014 and 2019, respectively. The 2019 space type of living quarters maps most closely to the 2014 space type for guest rooms, and both studies found 6% of total floor area for those space types. The storage space type represented 19% of the total floor area in 2014 and 16% in 2019. These values are relatively close, although there is no documentation available to explain the difference between them.

We found one substantial difference between space types in the two stock assessments. The Phase 1 study specified a combine space type of office/classroom, which accounted for 22% of the total regional floor area in the 2019 study. In the 2014 CBSA, offices had the greatest regional floor area, with 22%, and classrooms made up 5%, for a combined 27% of total regional floor area. The 2019 data therefore shows a reduction in floor area represented by this space type. As shown in Figure 6, Cadmus found the proportion of regional floor area devoted to offices was less than the amount listed in 2014, which likely accounts for the difference.

Figure 13. 2019 Proportion of Floor Area by Space Type

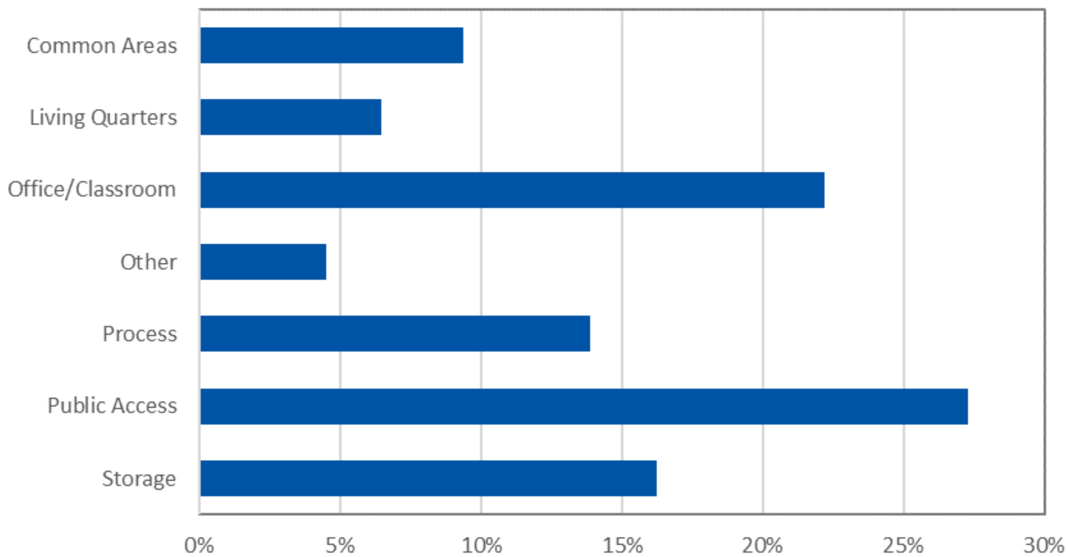
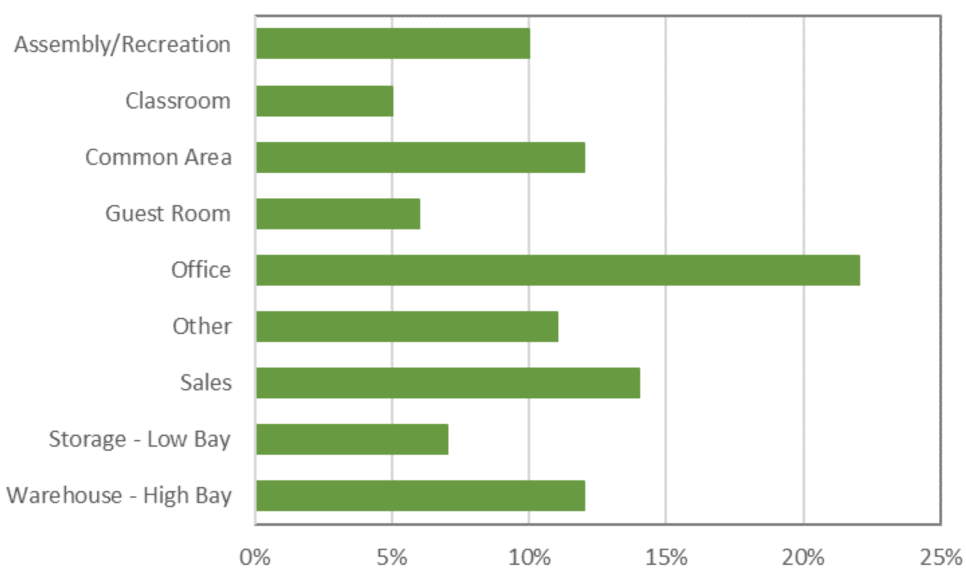


Figure 14. 2014 Proportion of Floor Area by Space Type

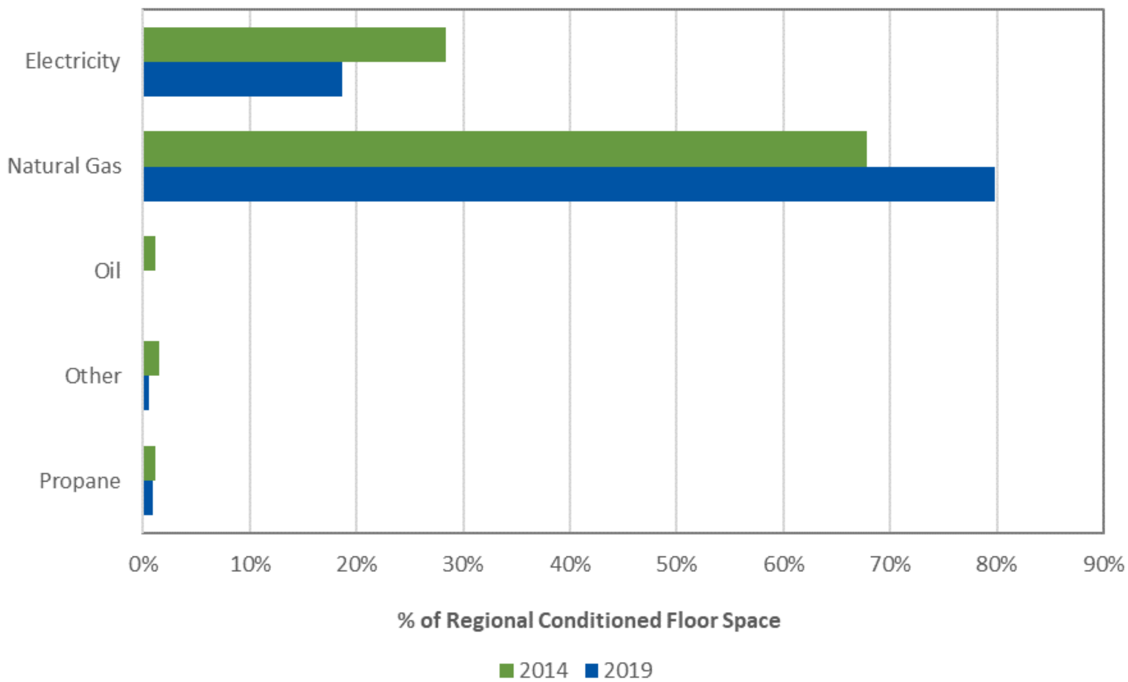


Heating and Cooling

Heating Fuel

Natural gas is the predominant heating fuel for 80% of the regional heated commercial floor space, while electricity only serves about 19% of the heated commercial floor space (see Figure 15). The predominant heating fuel is defined as that used to power the heating equipment with the largest heating capacity in the building.

Figure 15. Heated Floor Space by Predominant Heating Fuel

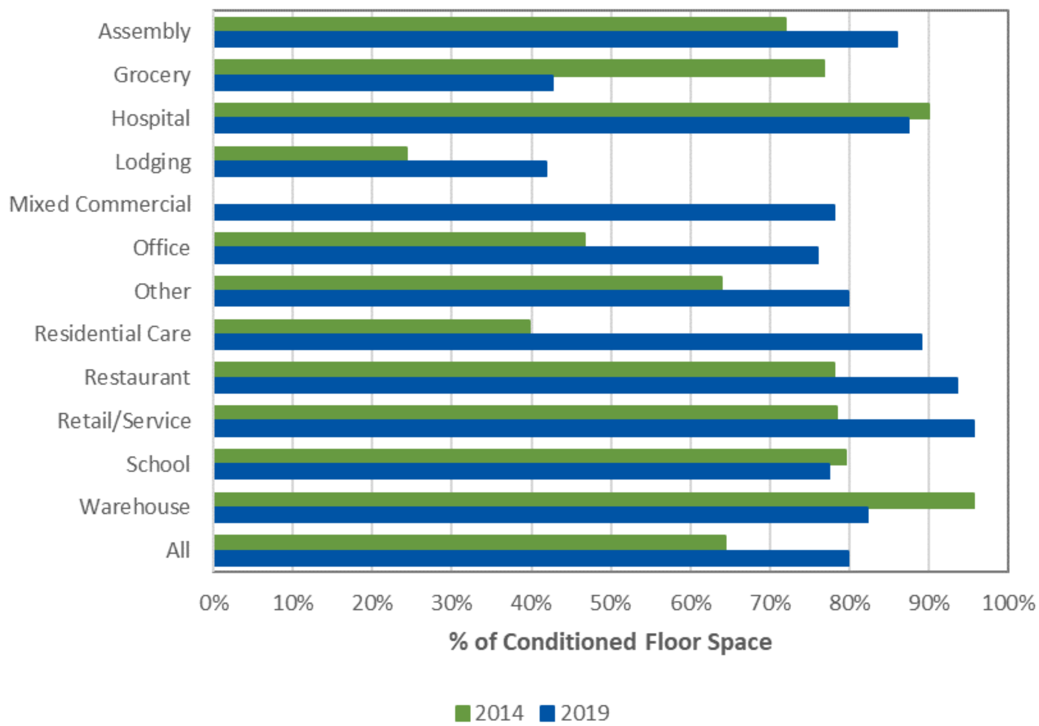


The comparison shows a shift in favor of natural gas heating between 2014 and 2019. That is partially related to the shift in building type floor area shown in Figure 6. The 2019 data showed considerably more floor area for the retail/service building type than 2014. Cadmus found that participants heated retail/service floor area almost entirely with natural gas (96% of total floor area), as shown in Figure 16. The 2014 study found 79% of retail floor area heated with gas, so these changes contributed significantly to the higher proportion of natural gas heating in 2019. The new sample frame and resulting sample sites may have also contributed to the shift in both building floor areas and predominant heating fuel.

As noted in Figure 6, offices represented the largest building type in the 2014 CBSA. That study found that office floor area was split almost in half between heating with electric (48%) and natural gas (47%). Figure 16 shows that Cadmus found the proportion of office floor area heated by natural gas was 76%. Even though the 2019 CBSA found less office floor area than 2014, the higher proportion of natural gas heating for this building type contributed to the overall increase in natural gas heating. Altogether, the comparison data shows the 2019 CBSA found a larger proportion of natural gas heating for most building types, except warehouse and grocery.

Despite the larger proportion of natural gas heating in 2019, Cadmus found an increasing prevalence of electric heating in newly constructed buildings. The 2019 CBSA identified 36 buildings constructed since 2014 with space heating. Those 36 buildings are split exactly in half on space heating fuel, with 18 electric and 18 natural gas. However, the total floor area for electric heated buildings was 686,775 square feet, which was 20% higher than the 571,089 square feet for natural gas heated buildings.

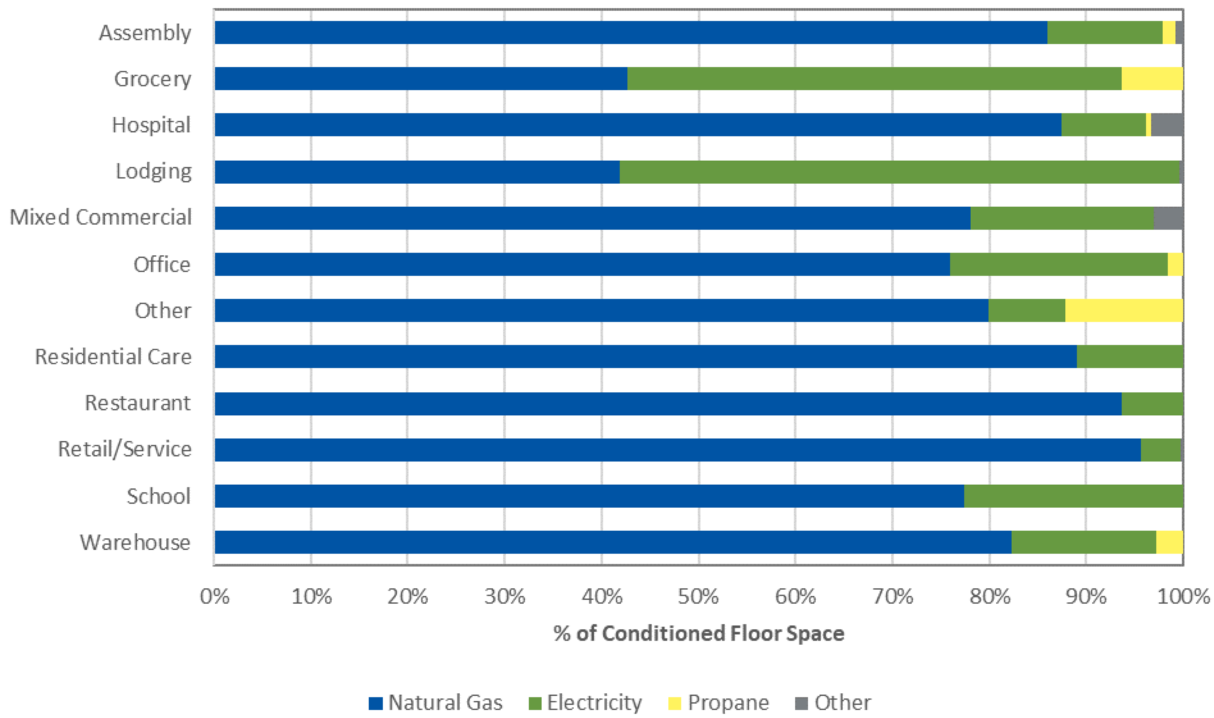
Figure 16. Comparison of Natural Gas Heated Floor Area by Building Type[a]



[a]Note that the variance in heated floor area also represents revised building definitions between the 2014 and 2019 CBSA.

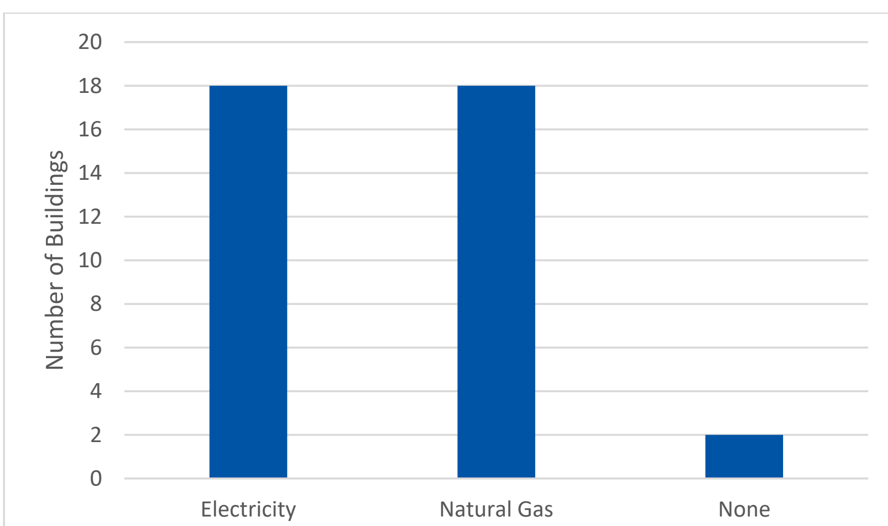
Figure 17 breaks out the predominant heating fuel by building type. Lodging and grocery are the only building types to use electricity as the predominant heating fuel for the largest capacity systems.

Figure 17. Heated Floor Space by Building Type and Fuel



Although natural gas was the predominant heat fuel identified in the 2019 CBSA, the data for buildings constructed since the last study indicated a more even split between fuel types, as shown in Figure 18. The 2019 CBSA identified 38 buildings constructed since 2014. The 36 buildings with space heating are split exactly in half on space heating fuel, with 18 electric and 18 natural gas. However, the total floor area for electric heated buildings was 686,775 square feet, which was 20% higher than the 571,089 square feet for natural gas heated buildings.

Figure 18. Distribution of Primary Heating Fuel for New Construction

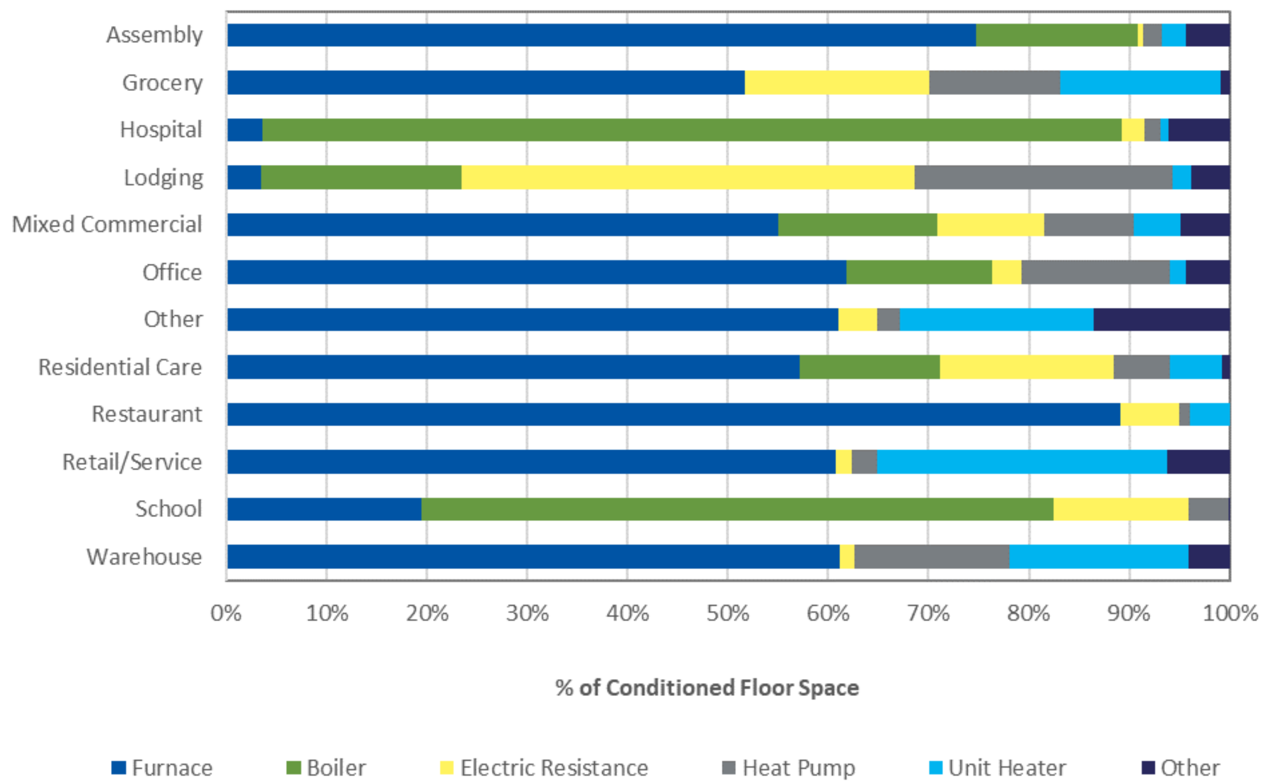


Primary HVAC System

The primary HVAC system is designated as the system representing the largest fraction of total reported HVAC capacity. Boilers, chillers, and water source heat pumps are considered primary systems over packaged systems if both types of systems exist in the building.

The primary heating systems are shown in Figure 19. Furnaces are the predominant heating systems, serving slightly more than one-half of the commercial conditioned floor space. However, schools and hospitals rely more on central heating rather than distributed heating, making boilers their predominant heating system.

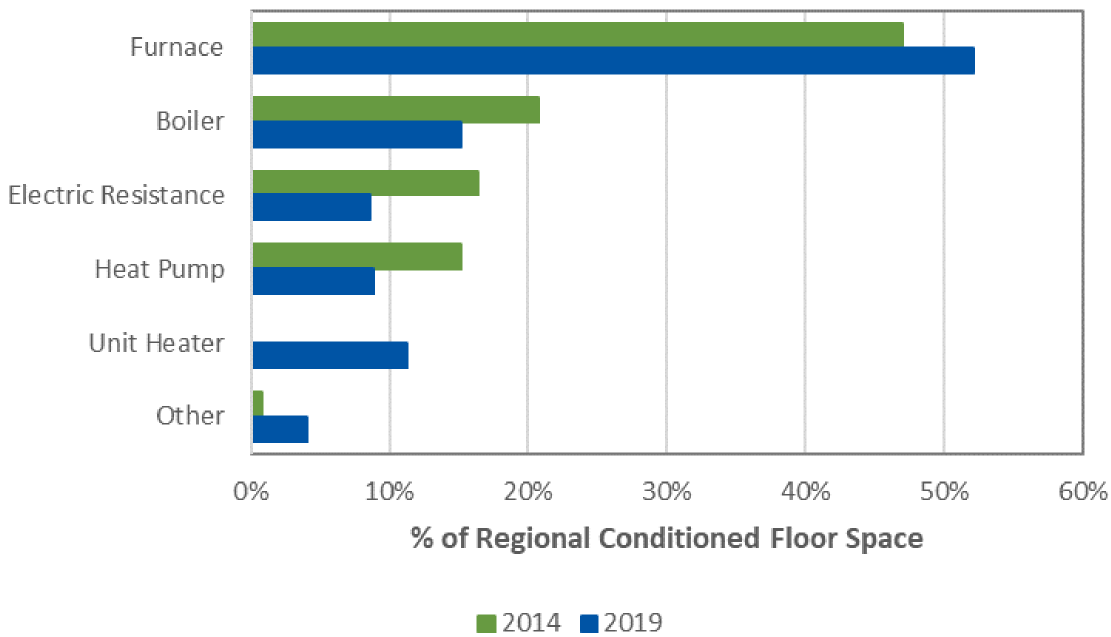
Figure 19. Primary Heating System by Building Type



The comparison with previous data shows a larger proportion of floor area heated by furnaces and unit heaters in 2019 at the expense of other types of systems (Figure 20). This aligns with the 2019 CBSA finding that the region relies more on natural gas heating than noted in 2014. Of particular note is the lower proportion of floor area heated through electric resistance (9% compared with 16%) in the 2019 CBSA. Cadmus notes that some regional utilities provide incentives for commercial participants to replace electric resistance heating equipment with natural gas furnaces, which could partially explain the shift in these heating system types.

We note the figure shows a decline in the proportion of floor area heated by boilers (21% to 15%) from 2014 to 2019. We consider it unlikely that the many building owners are replacing boilers with other heating system types due to the unique design of boiler systems. We believe the updated sample could represent one reason for the difference. Another contributing factor is the differences in primary heating system equipment employed in new construction since 2014. Of the 38 buildings in the sample constructed since the last CBSA, only two employed boilers as their primary heating system. Boilers tend to be an older technology, and the 2019 CBSA data showed 1976 as the average year of construction for sample buildings that used boilers for primary heating.

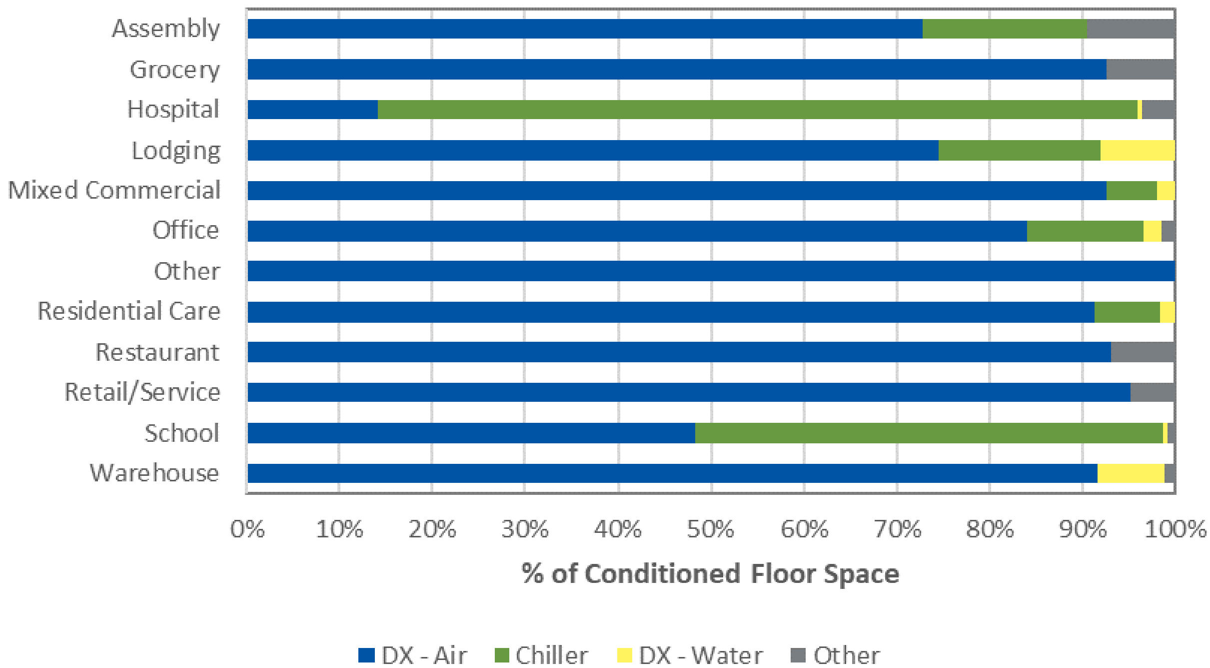
Figure 20. Comparison of Proportion of Total Floor Area Heated by System Type[a]



[a]The unit heater was not a separate option in the 2014 CBSA and was likely included in the "other" category.

The primary cooling systems are shown in Figure 21. Air-cooled direct exchange units are the predominant cooling systems, serving 84% of all commercial buildings. As with the heating systems, centralized chillers are the predominant cooling systems in hospitals and, to a lesser degree, in schools.

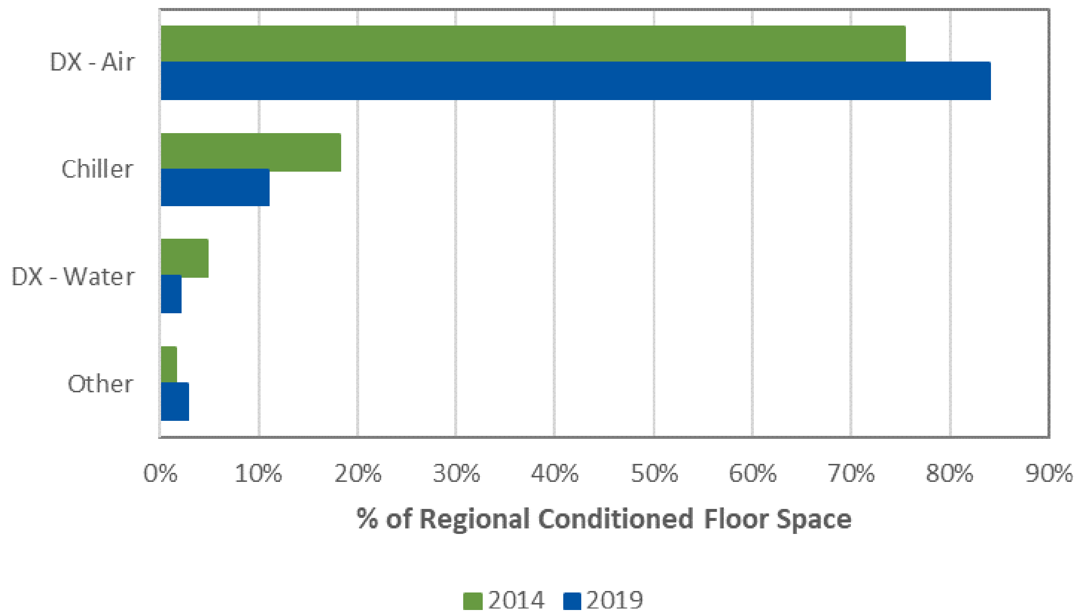
Figure 21. Primary Cooling System by Building Type



The regional floor area with cooling was 2,289 million square feet in 2014, and the 2019 CBSA estimated 2,705 million square feet. A portion of that additional cooled floor area (95 million square feet) came from new construction. All but two of the 38 buildings constructed since 2013 had cooling. The remainder of the shift originated from the updated assessment of regional cooling through the 2019 CBSA sample.

Figure 22 shows a relatively consistent comparison between 2014 and 2019 of the proportion of total floor area cooled by system type, although with a lower prevalence of chilled water cooling. This is likely due to the much larger proportion of floor area represented by service/retail, which is not heated at all by chillers, in the 2019 CBSA. The predominant building types using centralized HVAC systems, hospitals and schools, represent only a small proportion of regional floor area.

Figure 22. Comparison of Proportion of Total Floor Area Cooled by System Type

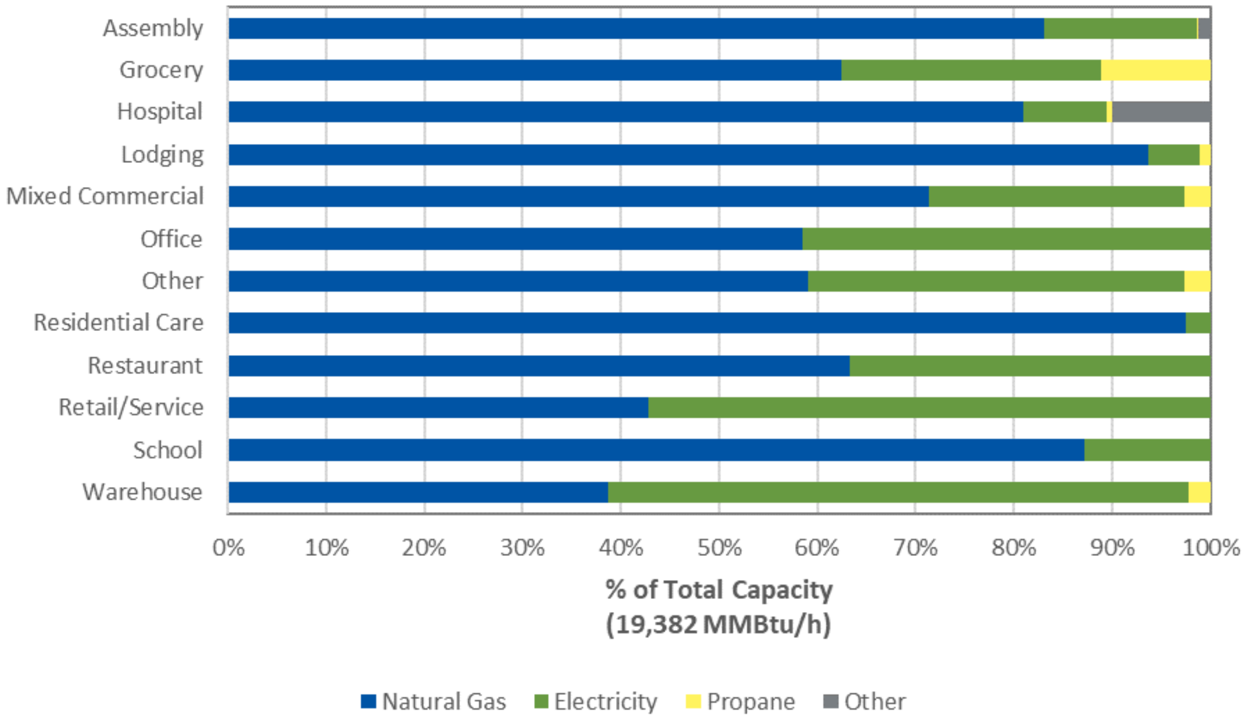


Service Water Heating

Service Water Heating Fuel by Building Type

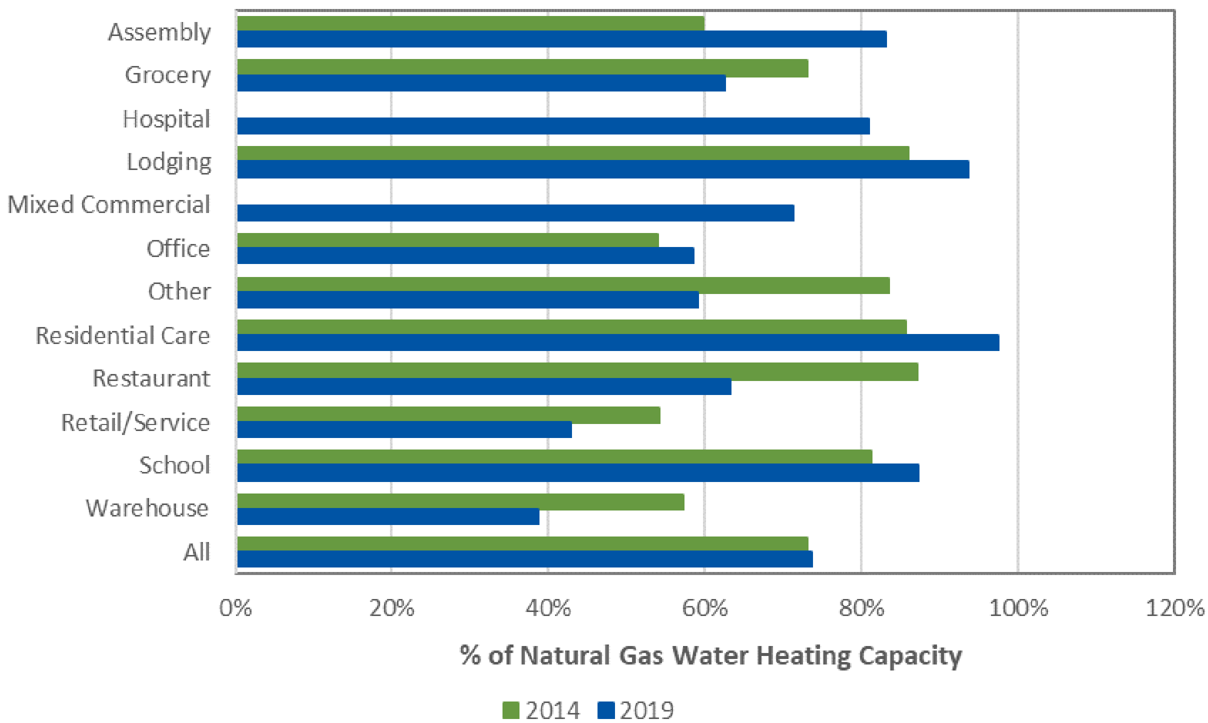
Natural gas is the predominant service water heating fuel for all building types with exception of retail/service and warehouses, which use a majority electric fuel. Figure 23 provides more information on the total capacity by system type in different building types.

Figure 23. Service Water Heating Fuel by Building Type



The overall proportion of natural gas water heating is similar between 2014 (73%) and 2019 (74%). Figure 24 provides a comparison of natural gas water heating between 2014 and 2019 by building type. For most building types, the proportion of natural gas water heating is relatively close between study years. We do not believe there is any significant trend with regard to the water heating fuels. Any difference is likely based on the updated sample for 2019.

Figure 24. Comparison of Natural Gas Water Heating Capacity by Building Type[9]



Gas Service Water Heating System Type by Building Type

Domestic water heating (DHW) tanks represent two-thirds (66%) of natural gas water heating capacity as shown in Figure 25. Hospitals use boilers for the majority of both space and water heating. Schools rely on boilers for space heating, but more often use DHW tanks for water heating. The data also show that a variety of building types are shifting more to tankless water heating systems.

9 These data were not available for hospitals from the published 2014 CBSA data.

Figure 25. Gas Service Water Heating System by Building Type

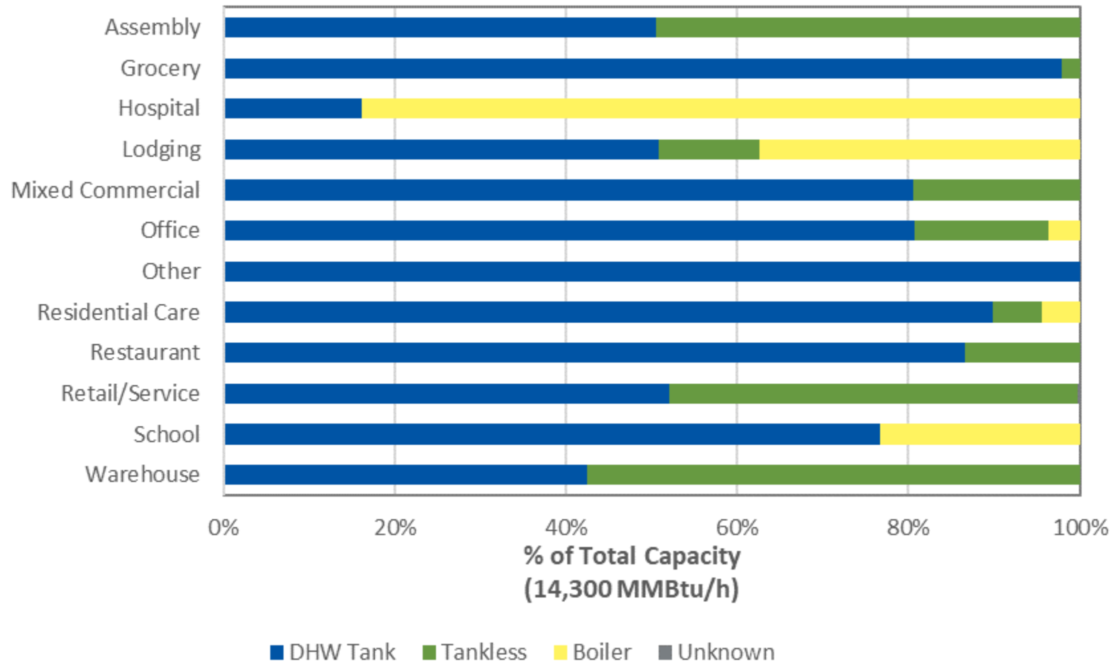
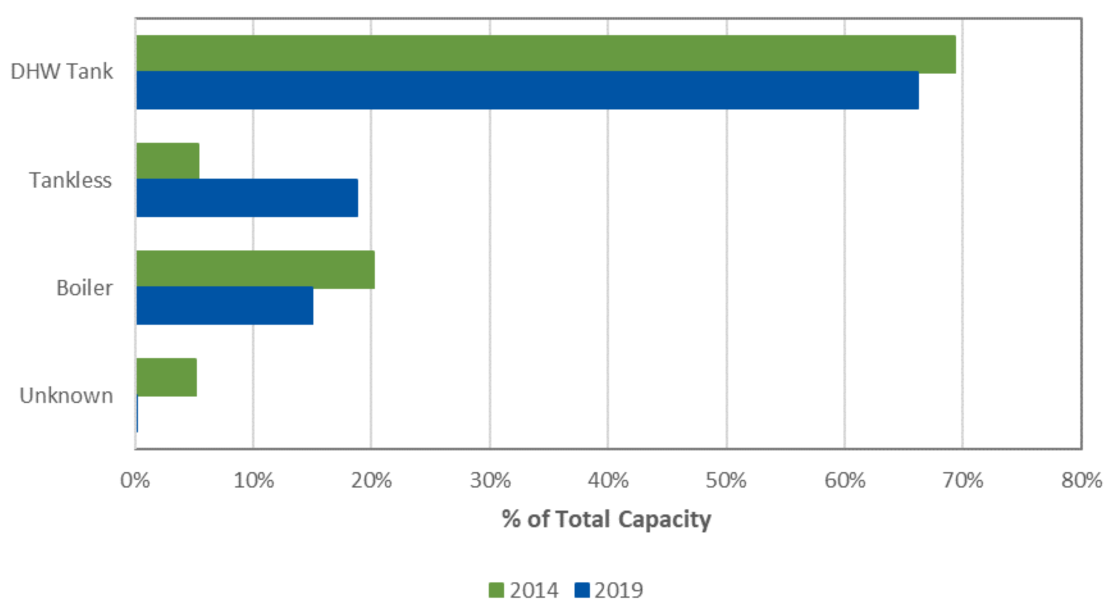


Figure 26 shows the comparison between 2014 and 2019 of total proportion of natural gas heating by system type. As with 2014, natural gas water heating by commercial business is still mostly through DHW tanks. However, the proportion of the natural gas water heating by tankless system increased significantly from 2014, from 5% to 19% of total capacity.

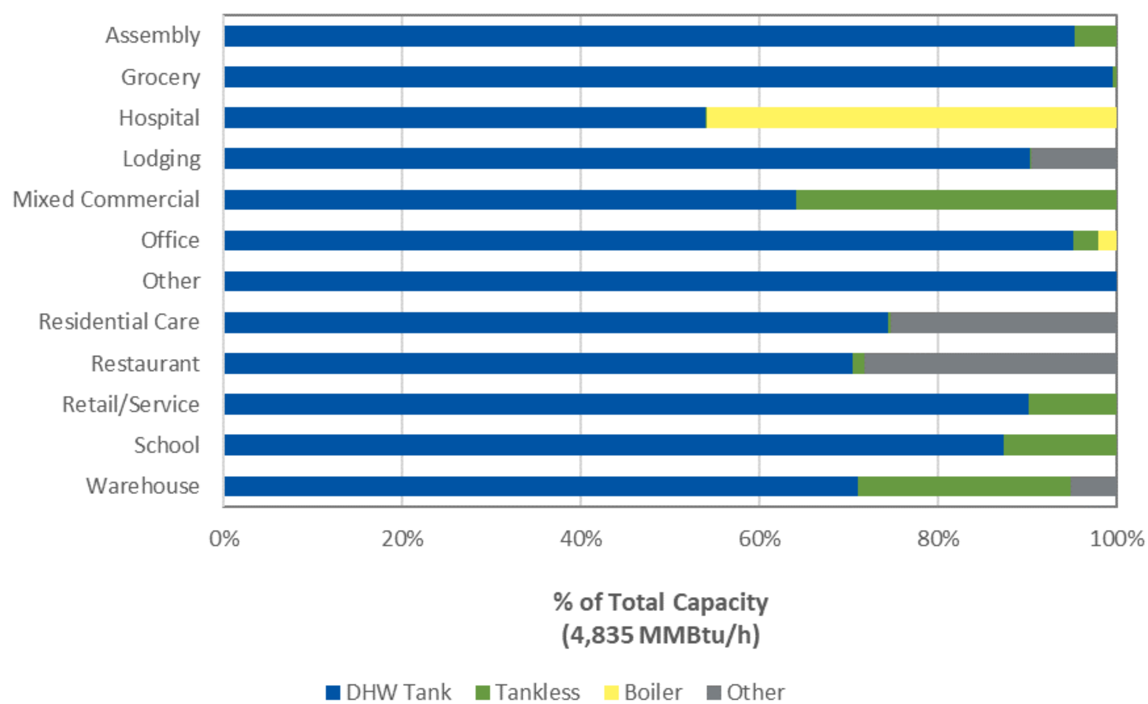
Figure 26. Comparison of Natural Gas Water Heating System Type



Electric Service Water Heating System Type by Building Type

Figure 27 shows the proportion of total electric water heating capacity provided by various systems in each building type. The regional electric water heating capacity was 4,835 MMBtu per hour, which is only 25% of the total. A comparison of 2014 and 2019 data showed almost identical distributions by heating system type, with domestic hot water tanks representing 83% of the electric water heating capacity in both studies.

Figure 27. Electric Service Water Heating System by Building Type



Lighting

Indoor Lamp Types

As shown in Figure 28, the major change over time involved a significant transition to LED lighting power, which only represented 20 MW in 2014 (1% of regional commercial indoor lighting power). By 2019, that value had increased by more than 20 times to 419 MW, or 16% of the regional total. This transition was driven primarily by the rapidly dropping cost of LED lamps and utility energy efficiency programs. As an example, Figure 29 shows the LED retail price for 60-watt equivalent lamp dropping by half or more from 2015 to 2018. Data from NEEA (Figure 30) shows the rapid increase in distribution for four-foot tubular LEDs from 2015 to 2016, followed by relatively high distribution from that point forward. The data show that the volume of tubular LED lamp distribution often exceeded that of T8 lamps.. Anecdotal evidence from NEEA staff indicates energy efficiency programs have been successful at retrofitting large portions of older lighting stock with LEDs.

Figure 28. Indoor Lighting Wattage by Lamp Type

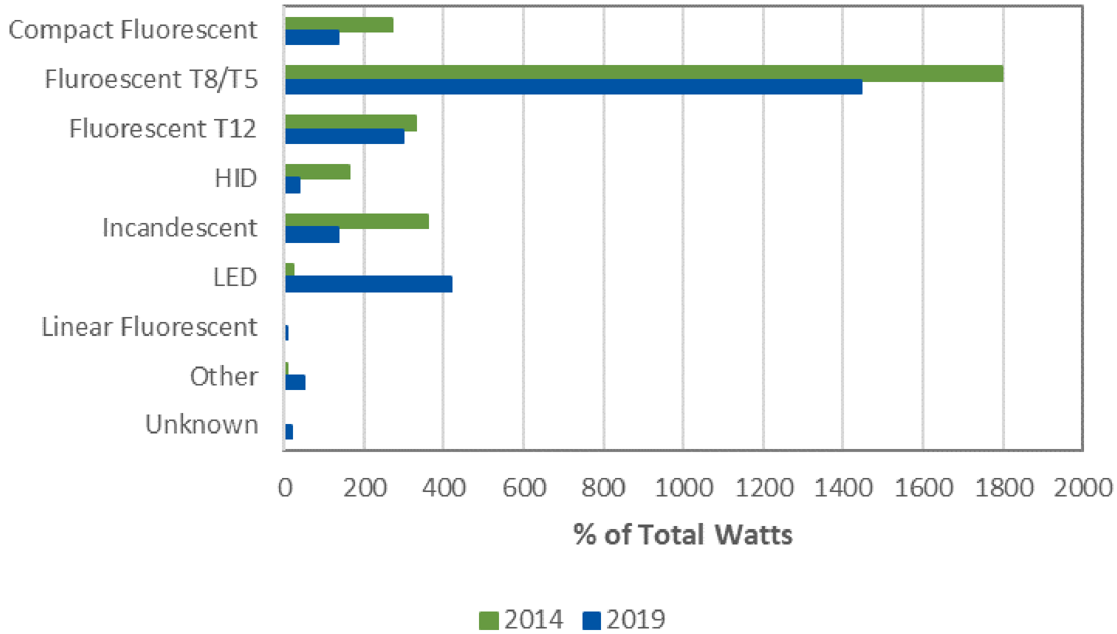
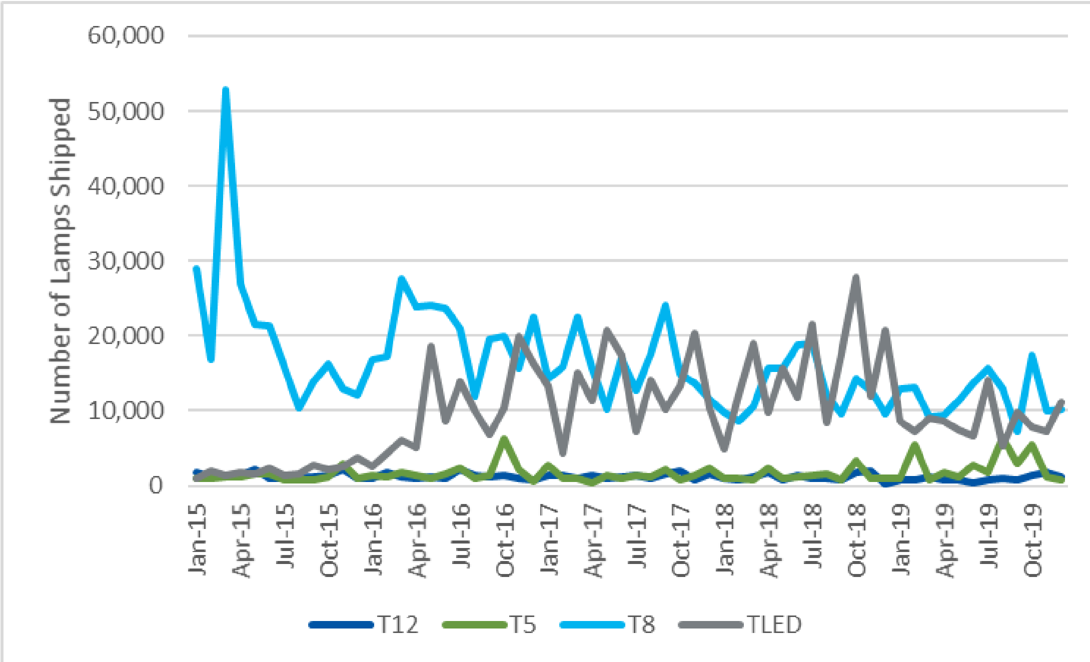


Figure 29. 60W Equivalent Lamp Retail Price (2015-2018)

Source: LEDinside, https://www.ledinside.com/news/2018/8/global_led_lighting_products_price_trend

Figure 30. Distribution Volume by Four-Foot Lamp Type (2015-2019)



Source: NEEA Lighting Shipment Data

By comparison, older and less efficient technologies declined in prevalence at the expense of LEDs. Incandescent lighting decreased from 360 MW (12% of total lighting power) to 136 MW (5%). For HIDs, the decline was from 160 MW (5%) to 38 MW (1%). LEDs also cut the lighting power provided by CFLs in half, from 270 MW (9%) to 134 MW (5%). This transition from the least efficient lighting to most efficient resulted in a substantial decrease in regional lighting power, from 2,944 MW in 2014 to 2,545 MW in 2019.

A majority of commercial indoor lighting wattage (approximately 69%) is from linear fluorescent lamps and fixtures. This value is down slightly from 72% in 2014, however, the 2019 wattage reduction is significantly greater (14%) due to the greater efficiency of LED replacements. T12 fixtures are a relatively old and inefficient lighting type that typically represents “low hanging fruit” for energy efficiency programs. As such, it seemed unusual that T12 fixture wattage only declined by 10% from 328 MW to 295 MW, particularly in comparison to the 20% reduction in lighting power from T5 and T8 fixtures. Energy efficiency programs currently focus on replacing all linear fluorescent lamp types with LEDs, regardless of the lamp type. As shown in Table 12, much of the T12 lighting in the region is installed in small and medium-sized businesses. Small businesses often have limited interaction with energy efficiency programs, which could explain why more T12 fixtures have not been replaced with more efficient T5 or T8 fixtures before this time. This could represent an opportunity for energy efficiency portfolios with small business direct install programs to achieve additional energy savings.

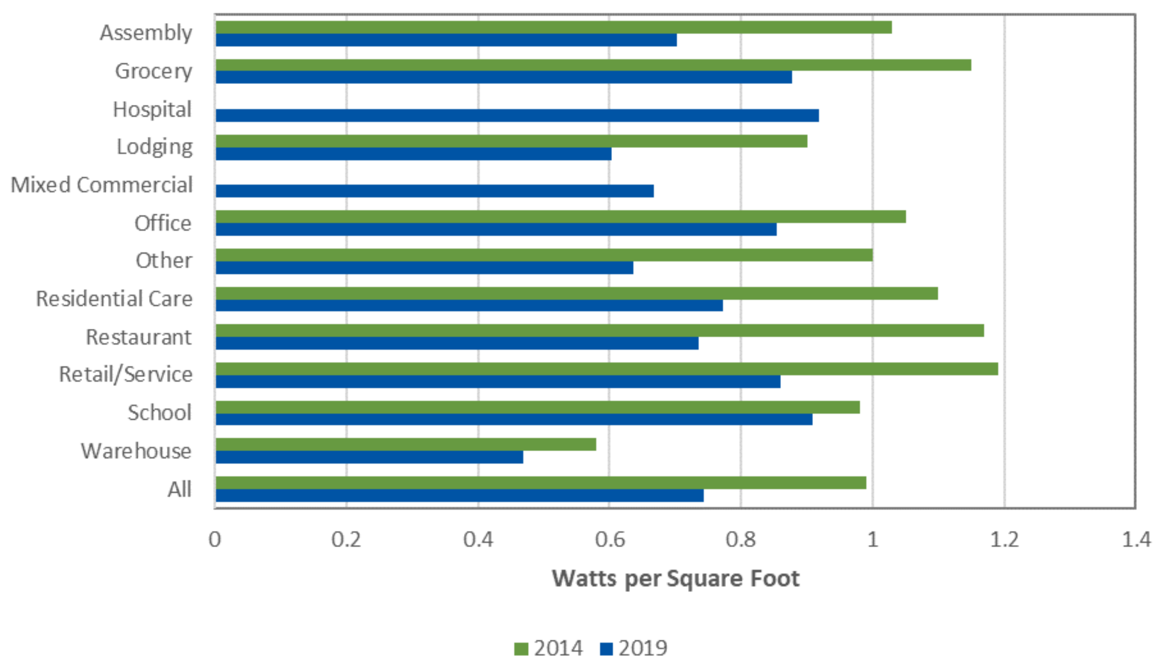
Table 12. T12 Lamps by Business Size

Building Size Category	Assessed Buildings with T12 Lamps	Quantity of T12 Lamps Assessed	Estimated Quantity of T12 Lamps in Region
Small	127	3,699	3,475,343
Medium	68	6,531	2,042,977
Large	7	73	3,782

Indoor Lighting Power Density

The average commercial building interior LPD is 0.74 watts per square foot (W/ft^2). The LPD is calculated as the ratio of total wattage to total floor space within a category. Figure 31 compares average LPDs by building type in 2014 and 2019. Note that the 2014 data did not include a LPD value for hospitals. Since the 2014 study, there has been a 0.25 W/ft^2 decrease in the overall LPD from 0.99 W/ft^2. The amount of LPD reduction varies by building type, but all building types showed a decrease. We believe the decrease is primarily due to the transition from older, less-efficient fixtures to LEDs. Stringent lighting power allowances required by code in Oregon and Washington for new construction buildings also likely represent a factor in reducing LPDs.

Figure 31. Lighting Power Density Reduction Between 2014 and 2019[a]



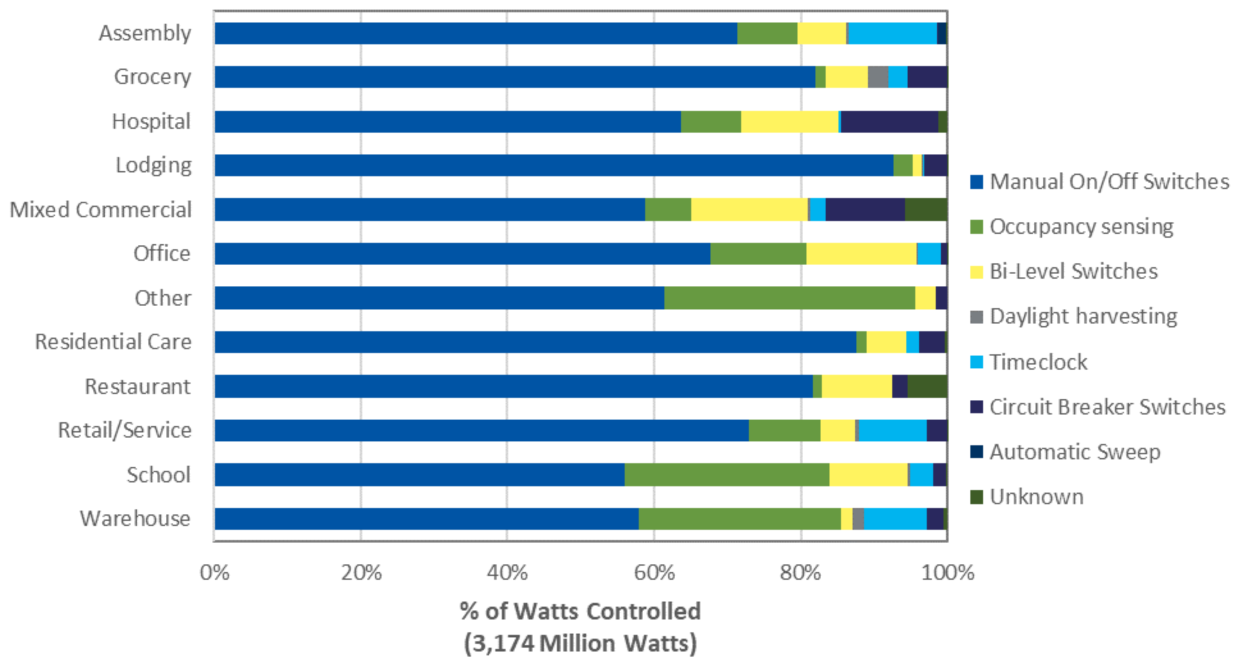
[a]These data were not available for hospitals from the published 2014 CBSA data.

We provide a comparison between state energy code requirements for lighting power density with the values calculated through the 2019 CBSA in *Appendix E. Comparison of LPD to State Energy Codes*. This analysis showed that the average LPD across many building types is already less than the values set by state energy code requirements. There are opportunities to pursue energy efficiency through lighting retrofits in building types where average LPD exceeds the maximum set by state energy codes (e.g., offices in Idaho and Montana, schools in Oregon).

Lighting Controls

Figure 32 shows that manual lighting controls (on/off switches) continue to be the most common lighting control type. The Phase 1 study for 2019 specified more granular types of lighting control systems than collected in the 2014 CBSA, so it is not possible to directly compare the two studies. Two areas of direct comparison indicate the manual controls have continued to be replaced with occupancy sensors, with the proportion of lighting controlled by manual on/off switches declining from 73% to 68%, while occupancy controls increased from 8% to 13%. Lighting controlled by daylight harvesting systems still represents less than 1% of overall lighting power.

Figure 32. Indoor Lighting Control Type



Energy Use Intensities

EUI is the ratio of total energy use to total floor space for a given building. Cadmus contacted as many utilities as possible to collect monthly billing histories for buildings included in the CBSA database. These billing histories generally covered 2018 annual consumption, but some utility billing histories included data from 2017 or 2019. Billing histories for each account were matched to buildings in the database. In the case of sites with multiple meters, Cadmus made every effort to aggregate meters to the appropriate building. It is important to note certain limitations to the collection and analysis of EUIs:

- Mapping meters to the appropriate buildings and square footage served is not straightforward as there can be overlap or multiple meters, which serve the same area(s) in the facility.
- The billing address may not always match the meter location, depending on who pays the bill.

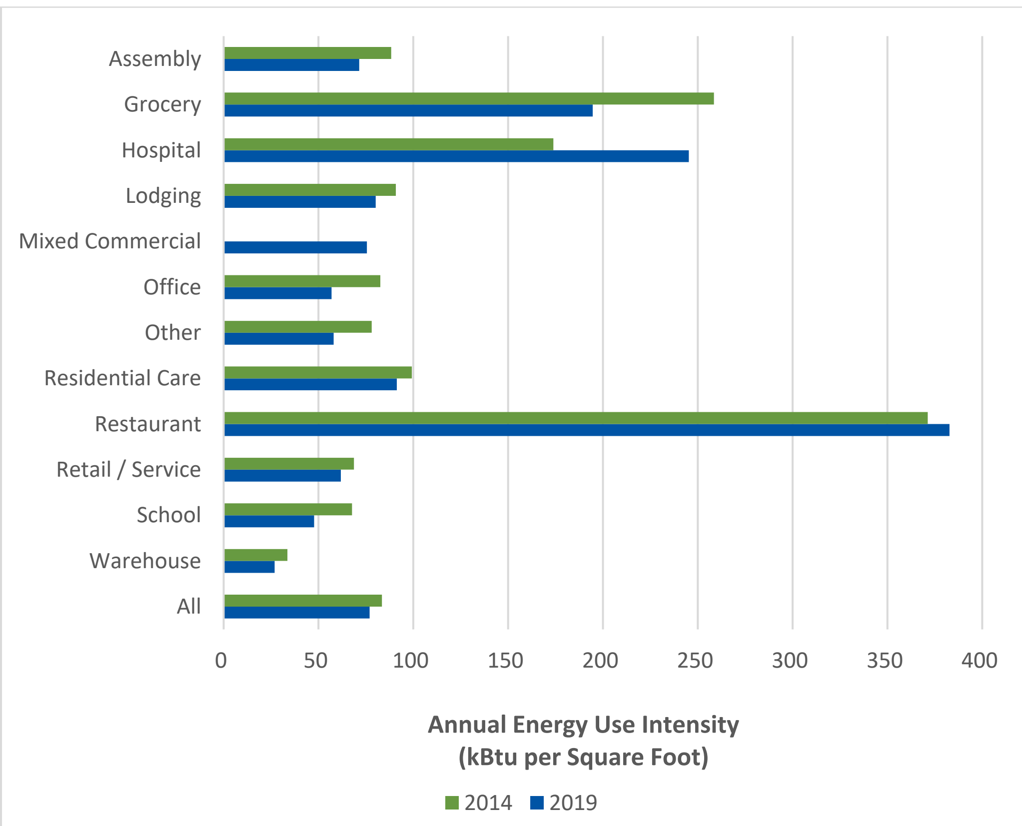
- While mean values are calculated and discussed, it is important to note significant variation occurs in the amount of energy, and how that energy is used, within a building type/category.

Cadmus calculated electric EUIs for 48% of sites and natural gas EUIs for 55% of sites using natural gas as a fuel source. We adjusted consumption histories for long-term (30-year) weather conditions to calculate weather-normalized EUIs. This analysis, however, revealed actual values were very similar to the weather-normalized ones. The availability of consumption data varied by building size, age, and type. Only weather-normalized EUIs, calculated from actual utility bills, are presented in the following sections.

Combined Energy Use Intensity

As noted previously, the 2019 CBSA data showed a substantial shift from electric heating to natural gas heating. This may be due to the new sample rather than regional facility owners replacing electric heating systems with natural gas. Cadmus determined it would be helpful to provide the EUI on a combined fuel basis (in kBtu per square foot) to better understand overall changes in energy use from 2014 to 2019. That comparison can be found in Figure 33.

Figure 33. Annual Combined Energy EUI by Building Type



Average energy consumption generally declined among almost all building types. The potential reasons for these reductions are explored in the following sections on electric and gas EUIs.

The hospital EUI showed the largest increase from the 2014 to 2019, up to 245 kBtu per square foot. Cadmus referenced national benchmarking data from the Environmental Protection Agency's Portfolio Manager[10] to determine which value seems more reasonable. The Portfolio Manager data lists a site EUI of 234 kBtu per square foot for hospitals with a primary function of general medical and surgical. This primary function, among those listed for hospitals in Portfolio Manager, best aligns with the sample of hospitals that Cadmus recruited for the 2019 CBSA. The resulting benchmarking value for the hospital EUI is similar to the value estimated by the 2019 CBSA, compared with 174 kBtu per square foot in 2014. We do not have detailed information on the hospital sample used in the 2014 CBSA for comparison purposes. We consider the EUI value from the 2019 CBSA to be the more reasonable of the two estimates for hospital EUI.

Restaurants showed a larger EUI in 2019 than in 2014, which could result from the new sample. The weighted average EUI from the Portfolio Manager benchmarking for the detailed restaurant types in the 2019 CBSA sample was 315 kBtu per square foot. The 2014 value of 371 kBtu per square foot and 2019 value of 383 kBtu per square foot are both well above that benchmarking estimate. But, the available billing data from 2019 restaurants showed relatively high EUIs for all types of restaurants, including bar/pub/lounge, fast food restaurant, and sit down restaurant.

Grocery stores showed substantially lower EUI in 2019 at 195 kBtu per square foot compared with the 2014 value of 258 kBtu per square foot. The Portfolio Manager benchmarking data lists EUIs of 196 kBtu per square foot for supermarkets and 231 kBtu per square foot for convenience stores. Both of those values suggest the 2014 EUI for groceries may have been overestimated. The 2019 value of 195 kBtu per square foot is a more reasonable estimate of grocery EUI.

Electricity Use Intensities

Northwest commercial buildings had an average EUI of 11.9 kWh per square foot, shown in Figure 34. This value is a decrease from the average 2014 study EUI of 14.2 kWh per square foot.

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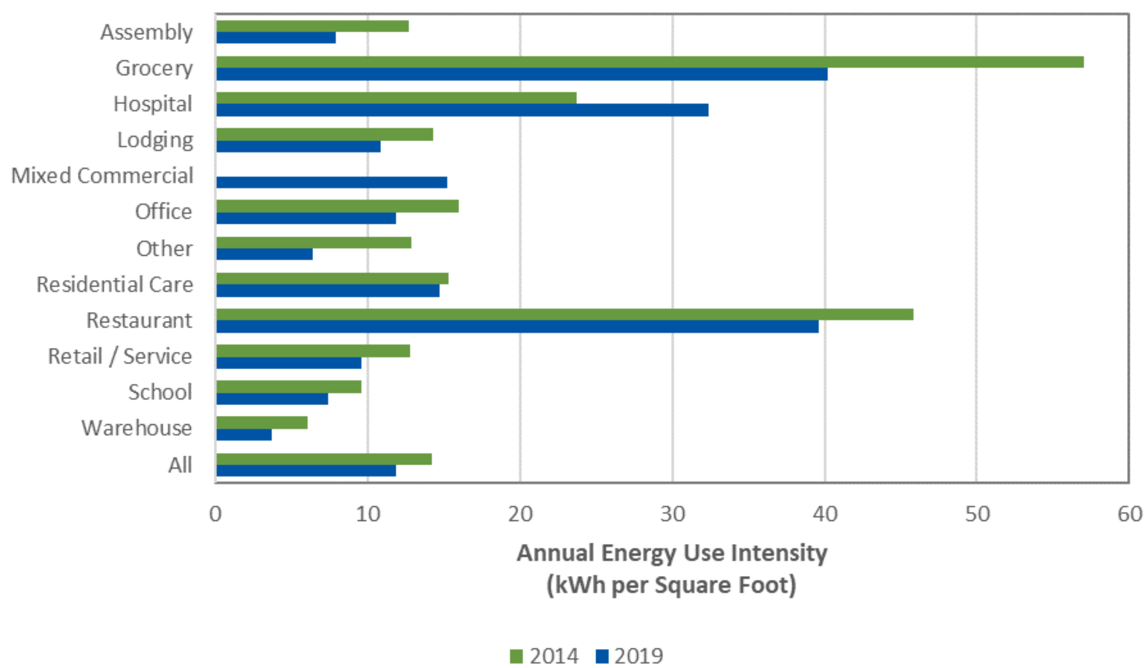
[10] Environmental Protection Agency. "ENERGY STAR Portfolio Manager." https://portfoliomanager.energystar.gov/pdf/reference/US%20National%20Median%20Table.pdf

Figure 34. Annual Electric EUI by Building Type



The major finding from the comparison of electric EUIs between studies is the consistent reduction in values from 2014. There are several potential explanations for the decrease in electric EUI across buildings. As noted previously, the 2019 CBSA found a higher proportion of natural gas-heated buildings than in 2014. As such, the update to the heating fuel resulted in a reduction in electricity consumption, by comparison to 2014, across building types. However, Figure 33 showed a consistent reduction in EUI across most building types that is reflected in the electric EUIs. We also note that lighting power density declined across all building types, largely due to the shift from older, less efficient lighting to LEDs. As such, we believe the decrease in lighting power provided a key source of EUI reduction.

We observed that grocery showed a substantial reduction in electric EUI. As noted in the previous section, we believe the 2014 study overestimated the grocery EUI, so the 2019 value provides a more reasonable estimate of the current EUI for grocery stores in the region.

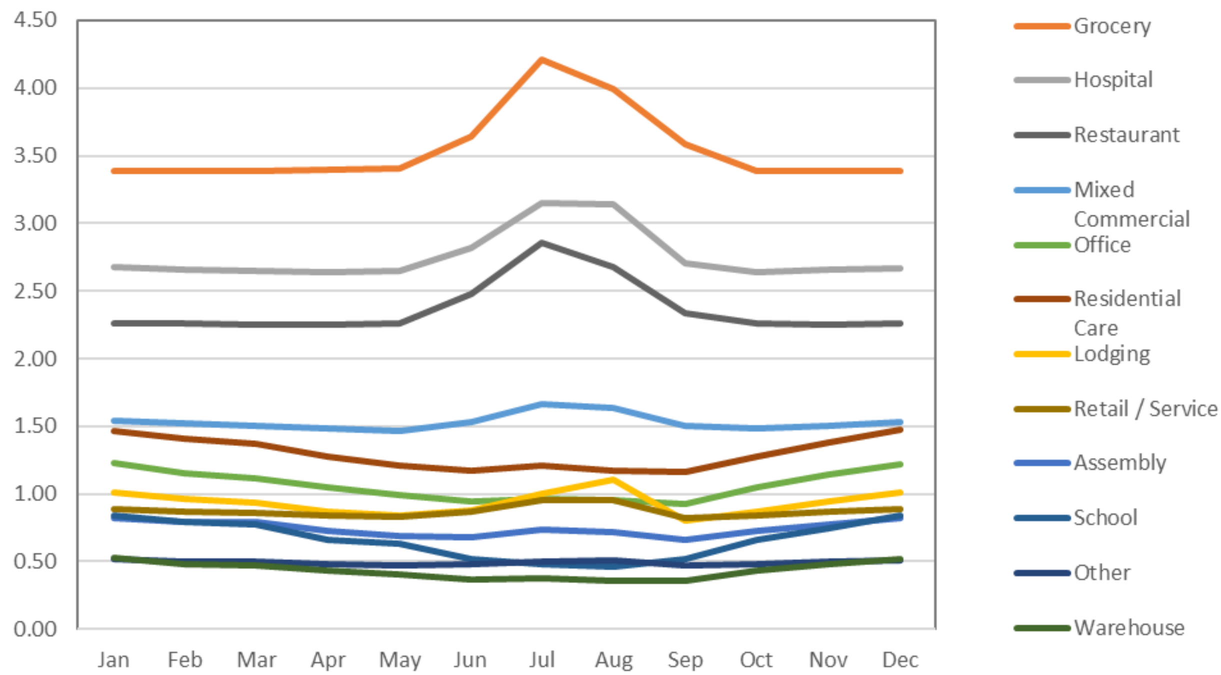
The assembly building type also indicated substantially less electricity consumption in 2019 than in 2014. In reviewing the sample data, we noted that more than half of sites (57%) which provided electricity billing data had a detailed economic use of religious assembly. As indicated in the Portfolio Manager benchmarking data, these sites tend to have a lower average EUI than other assembly buildings. We do not have data on the detailed economic use types for the 2014 sample for comparison.

Monthly Electricity Energy Use Intensities

A majority of commercial building types have a similar monthly electric EUI profile and range, shown in Figure 35. The overall EUI profile follows a similar pattern to offices and lodging, and it is comparatively even throughout the year, with slight peaks in summer. Restaurant, grocery, and hospital buildings—

which have higher EUIs—have more variable monthly EUI profiles, with a noticeable peak during the summer months. As expected, school EUI decreases during the summer.

Figure 35. Monthly Electric EUI by Building Type

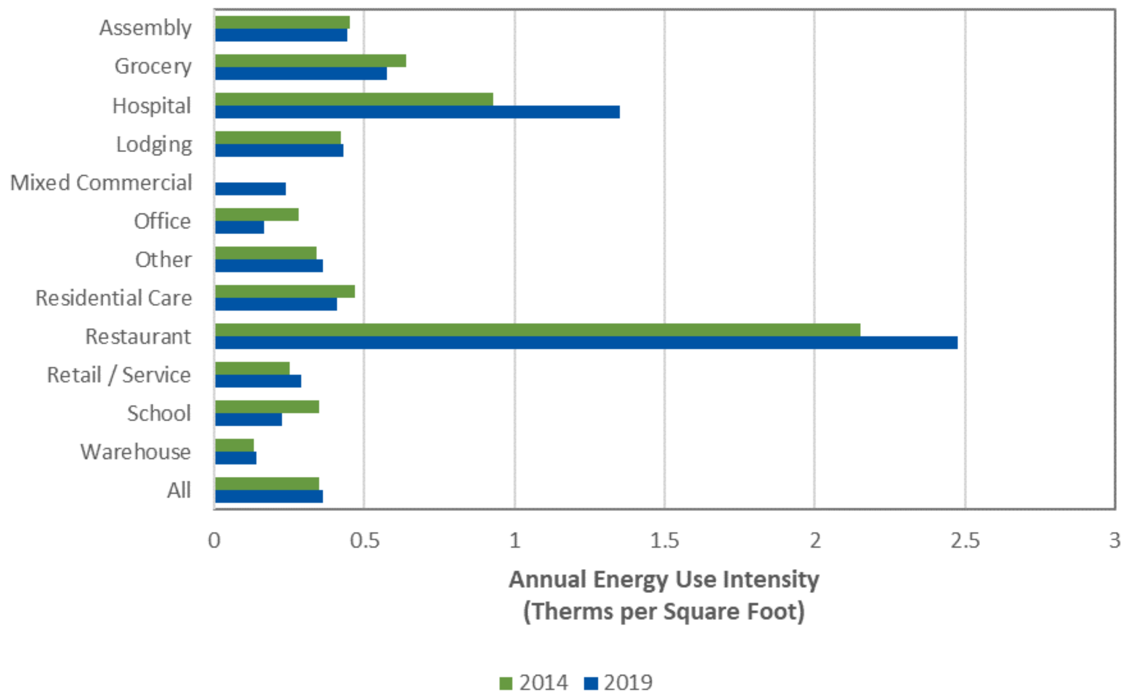


Natural Gas Energy Use Intensities

Northwest commercial buildings had an average natural gas EUI of 0.36 therms per square foot. This value is a slight increase from the 2014 study EUI of 0.35 therms per square foot. Figure 36 shows the annual natural gas EUIs by building type. The overall average increase from 2014 is largely due to substantially higher natural gas EUIs for hospitals and restaurants. The reasons for the high EUIs is outlined in the Combined Energy Use Intensity section.

Most other building types show nearly the same natural gas EUI between 2014 and 2019, or a slightly lower EUI in the case of office buildings and schools. As noted previously, the 2019 CBSA found a higher proportion of gas heating in office buildings relative to 2014, which likely accounts for the difference. The portion of school floor area using natural gas as the primary heating fuel was almost identical in 2014 (78%) and 2019 (80%). The lower natural gas EUI is due to lower billing data consumption for 2019 school buildings, which may reflect more energy efficient school buildings.

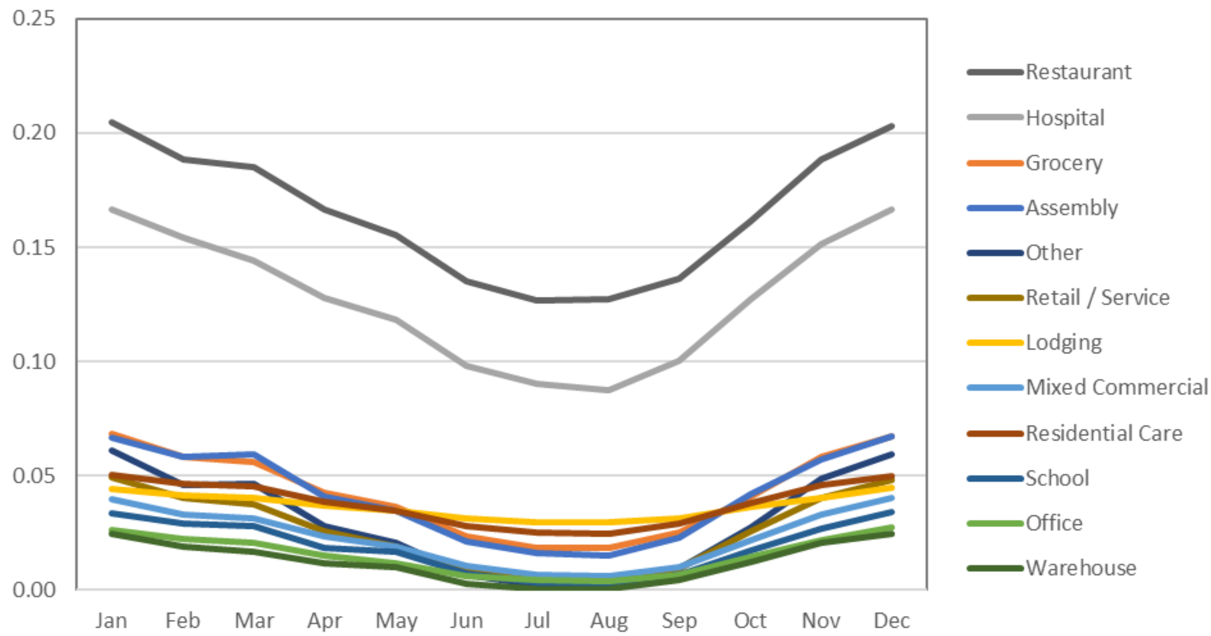
Figure 36. Annual Natural Gas EUI Building Type



Monthly Natural Gas Energy Use Intensities

The monthly natural gas EUI pattern, shown in Figure 37, is generally inverse to the monthly electric EUI with winter peaks for all building types. For all building types, the winter consumption nearly doubled from summer gas consumption. However, restaurants and hospitals in particular have a pronounced gas consumption pattern, due to the more predominant use of gas in that sector.

Figure 37. Monthly Natural Gas EUI by Building Type



Conclusions

Cadmus developed the following conclusions based on the process of conducting the 2019 CBSA and its subsequent review of the data and major findings. We note there are additional areas that may warrant more analysis and additional conclusions beyond those observed in this report.

Virtual Catalog Provides Option for More Robust Sample Frames

The Cadmus team's experience in developing the virtual catalog as a sample frame indicates the method provides value, but still faces challenges. Using Google Places data provided an effective means of identifying facilities missing from conventional tax assessor data. However, the Google Places data also presents challenges: multiple listings at one address (particularly for doctor's offices at hospitals), flagging home-based businesses as commercial activity, and not capturing all sites missing from the tax assessor dataset. This virtual catalogue creation process has produced valuable lessons that can serve as the basis for similar future efforts; however, the process of combining, cleaning, and clarifying the virtual catalog data is a time and budget-intensive activity that should be weighed against the value provided by the additional data.

New Commercial Buildings Rely More on Electric Heating

The trend toward natural gas heating may be reversing, with the 2019 CBSA sample showing an even split between heating fuels in newly constructed buildings. The 2019 CBSA identified 36 buildings constructed since 2014 with space heating. Those 36 buildings are split exactly in half on space heating fuel, with 18 electric and 18 natural gas. However, the total floor area for electric heated buildings was 686,775 square feet, which was 20% higher than the 571,089 square feet for natural gas heated buildings.

This shift may increase in the future as part of broader national and global trends toward strategic electrification of heating systems to reduce the consumption of fossil fuels. The transition toward electrification is also expected to be driven by legislation such as Washington State's recent Clean Energy Transformation Act of 2019 (SB 5116). The impact of this legislation may be apparent in the next CBSA study.

Increased LED Adoption

The region's commercial buildings have replaced existing equipment with LED lighting at an unprecedented rate. Energy efficiency programs and education in the region appear to have motivated participants to primarily reduce older, less efficient lighting such as incandescent and high-intensity discharge lamps. In 2014, LED lighting power only represented 20 million watts, which was 1% of regional commercial indoor lighting power. By 2019, that value had increased by more than 20 times to 419 million watts, or 17% of the regional total. The rapidly dropping cost of LED lamps and utility energy efficiency programs are primarily responsible for driving this transition. National sales data showed an increasing market penetration for tubular LEDs at the expense of linear fluorescent fixtures starting in 2014.

By comparison, older and less efficient technologies declined in their prevalence at the expense of LEDs. Incandescent lighting decreased from 360 million watts (12% of total lighting power) to 136 million watts (5%). For HIDs, the decline was from 160 million watts (5%) to 38 million watts (1%). LEDs also cut the lighting power provided by CFLs in half, from 270 million watts (9%) to 136 million watts (5%). This transition from the least efficient lighting to most efficient resulted in a substantial decrease in regional lighting power, from 2,944 million watts in 2014 to 2,531 million watts in 2019.

Significant Regional Energy Efficiency Opportunities Remain

Regional energy efficiency programs still have significant opportunities to achieve energy savings through the conversion of older equipment to more energy efficient versions, from lighting to controls to water heating systems. We note three examples of these opportunities below.

Linear Fluorescent Lamps to LEDs

The region's commercial building lighting still relies heavily on linear fluorescent lighting. Linear fluorescent T5, T8, and T12 lamps represented 2,126 watts (72% of total lighting power) in 2014. Despite reductions due to LED replacement, these fixtures still represented 1,737 MW (69% of total lighting power). The regional wattage for the least efficient fluorescent fixtures, T12s, declined by 32 MW to 296 MW, a 10% decrease from 2014 values. It is unclear what portion of the reduction in T12 wattage is due to LED replacements versus retrofits with more efficient linear fluorescent fixtures. The outstanding wattage represented by these linear fluorescent fixtures represents an ongoing opportunity for energy efficiency programs to achieve tremendous savings through early replacement of older, less efficient fixtures.

Lighting Controls

Over two-thirds of lighting power in the region is still controlled by manual on/off switches. Regional energy efficiency programs have the potential to obtain further energy savings through conversions to occupancy sensing, daylighting harvesting, and luminaire-level lighting controls. Currently occupancy sensors control only 13% of total regional wattage, while daylight harvesting controls less than 1%. However, we note there may be challenges with the cost-effectiveness of replacing controls on LEDs compared with older, less efficient lighting types. The LEDs represent a considerable reduction in energy consumption, so the incremental savings from lighting controls may not provide sufficient benefits to offset program costs. This will be a challenge for energy efficiency programs to weigh in the coming years.

Conventional Tank Water Heating Replacement

Approximately two-thirds of natural gas water heating capacity is still in the form of domestic hot water tanks, while that value is 83% for electric water heating. The proportion of efficient tankless water heating has more than tripled from 2014 to 2019, but that still only represents 19% of total regional water heating capacity. On the electric side, heat pump water heaters represent such a small portion of regional electric water heating capacity that they are combined with in the "other" system type, at 5% of the total. There are significant opportunities for utilities to continue to expand the installed capacity of these more efficient technologies in the coming years.

LEDs Reduced Indoor Lighting Power Density

The transition to LEDs has substantially reduced the indoor LPD across all building types throughout the region. The average indoor LPD in 2014 was 0.99 W/ft^2. By 2019 that had declined by 25% to 0.74 W/ft^2. Almost all building types showed an LPD reduction in the range of 19% to 37%. Based on the changes in regional lighting power, it is clear that the reduction was driven almost entirely by LED retrofits.

LEDs Reduced Electric Energy Use Intensity

Regional electric EUIs have also declined as an additional impact of the reduced LPD resulting from increased LED adoption. The regional EUI declined from 14.2 W/ft^2 in 2014 to 11.8 W/ft^2 in 2019, a decrease of 17%. Most building types reduced their EUI by 20 to 40%. Only hospitals increased their EUI from 2014, and it is likely the 2014 estimate was too low based on the 2012 CBECS value.

We note that a portion of the electric EUI reduction is the difference in proportion of gas heating between the 2014 and 2019 CBSA studies. It is also reasonable to assume that energy efficiency programs throughout the region have reduced electricity consumption through non-lighting measures focused on HVAC, refrigeration, and industrial process equipment, among others. However, the largest driver in electricity reduction is likely the rapid replacement of older, less efficient lighting such as incandescent bulbs, HIDs, and CFLs by LED lamps.

Appendix A. Appendix NEEA Building Types

NEEA Building Type Descriptions

As part of the Phase 1 study, NEEA identified the 12 property types listed below as the key focus for the 2019 CBSA. These building types are identical to those used in the 2014 CBSA, with minor refinements noted.

- **Assembly:** facilities where people congregate, including religious facilities and gyms.
- **Grocery:** facilities where the primary property use type is selling groceries. This includes convenience stores and gas stations.
- **Hospitals:** facilities with in-patient treatment options (e.g., hospital beds) and diagnostic equipment. Outpatient-only clinics were classified as offices.
- **Lodging:** facilities including hotels, motels, inns, and bed and breakfasts.
- **Office:** any office building, including doctors and dentist offices.
- **Residential Care:** facilities with assisted living, memory care, hospice care, and those requiring skilled nursing assistance. We removed all facilities that were just independent living. However, it was difficult to determine the floor area due to the mix of independent living and assisted living at most facilities. We confirmed the floor area through information we acquired from site contacts during recruitment.
- **Restaurant:** all food service facilities, including bars and cafes. In the 2014 study, this building type was labeled “Food Service.”
- **Retail/Service:** facilities primarily intended for retail sales of goods or providing services. In the 2014 study, this building type was labeled “Retail.”
- **School:** facilities including public and private schools, as well as day care/child care facilities.
- **University:** post-secondary education facilities
- **Warehouse:** all storage facilities, including automotive storage, cold storage, and general warehouse storage.
- **Other:** any facility that did not fit into the previous 11 building types, including parking garages, fire departments, and police stations.

During the course of the Study Integrity Workgroup meetings, NEEA and stakeholders agreed that it would be prudent to add a building type that would capture those buildings and sites with a combination of uses. Labeled as “mixed commercial,” these were facilities with multiple business or property use types, such as malls. We classified sites as mixed commercial if the commercial floor space of a site comprises multiple property use types in which none was predominant. If a facility had multiple uses but predominantly (> 75%) was used as a single building type, Cadmus categorized the entire site as the predominant type. We believe the addition of this building type helped in reducing the size of the Other category from 2014 to 2019.

In addition, NEEA determined that the University building type did not represent a good candidate for assessment through the methods employed by the CBSA. Universities typically involve large campuses with many different building types. The 2019 CBSA within-site sampling methodology would have required Cadmus to select three buildings to represent the entire university, despite the usage types and how well they represent the rest of the campus. As a result, NEEA chose to remove the University building type from the study and investigate the possibility of a small, follow-on study for this building type in the future.

Appendix B. Virtual Catalog Development and Review

The Cadmus team identified a number of challenges in the course of developing and reviewing the virtual catalog. These challenges impacted the resulting data that populated the virtual catalog, as well as the final Stage 1 sample frame. In this appendix, we review specific challenges related to accessing the Google Places data, as well as the results of the manual review process.

Google Places API Limitations

Cadmus had intended the Google Places data as supplemental data to the SMR due to the lack of floor area data in Google Places. We used topologically integrated geographic encoding and referencing (TIGER) block group geospatial data and calculated the centroid and minimum enclosing circle radius around block groups for the query from the Google Places API. We performed these queries at the block-group level because the volume of blocks exceeded the number of API credits. The API allowed up to 60 observations (referred to as "calls") per request within a block group, indicating it was possible that some commercial buildings from Google Places were not included in the virtual catalog because the request maxed out. Cadmus could not quantify the impact of this issue. However, it primarily impacted census blocks containing certain types of sites with many individual entries at one geographic location, such as hospitals (numerous individual doctor's offices) and large retail establishments (numerous individual stores). This impact was an unavoidable aspect of using the Google Places API.

The following provides more clarification on the limitations associated with the Google API requests. The API request could not do the following:

- We **could not** ask the API request to **not** call specific building types
  - For example, we knew we were not interested in ATMs, but we could not specify for the request to not bring in ATMs. So, that business would represent one of the 60 available calls if an ATM existed in the block.
- We **could not** ask the API request to **not** call duplicate buildings.
  - For example, we could not specify that multiple doctors at one hospital should be treated as one call. The API request always treated them as separate calls. So, if a hospital had 100 doctors, the request would always reach the 60 call maximum, regardless of the number of buildings in the block group.
- We **could not** ask the API request to provide the buildings in a block in a different order if we performed a new API request:
  - For example, if we performed a request on BLOCK XX and know that it reached the maximum number of observations, we couldn't specify for the request to re-run in the opposite order to get the sites that were missed due to reaching the maximum:
    - Theoretically, suppose that we knew there were 79 calls in a block group (although we couldn't know that). We would receive data in the following order:
      - Site 1
      - Site 2
      - …

        - Site 78
        - Site 79
    - Theoretically, we know that it reached the maximum of 60, but to get sites 61 through 79, we **could not** ask for the sites in the reverse order:
        - Site 79
        - Site 78
        - ...
        - Site 2
        - Site 1
  - If we performed an API request on the same block group, we received the same observations in the same order; however, we could not specify the order.
- We **could not** know what sites were missing:
  - For example, we could have two separate, theoretical buildings. One has 70 observations in the block group from Google, and one has a single observation. We could not determine if the request would provide us with 60 calls of the duplicate building, or 59 of the duplicate building and the one unique building. We may have known after looking at the block that there were two buildings. But, we couldn't determine which of the following happened if the API request did not pick up both buildings:
    - Google Places data doesn't have both buildings, or
    - The API request maxed out before observing the second building

We only performed one request on each block in the Stage 1 sample. A portion of those reached the maximum number of observations, but we did not quantify this number. We did not have a method to determine how many buildings, businesses, or sites were missing due to this limitation. We attempted to gather as much supplemental data as possible through this process, but understood the final results would have limitations.

Manual Review Results

Manual review of all records in the clean virtual catalog was outside of the scope of the CBSA, so Cadmus reviewed a sample. We sampled 5,000 census blocks in Stage 1 of the CBSA sample and manually reviewed all records in the sampled blocks.

Stage 1 Building Type Categories

After the SMR parcel data and Google Places data were merged, cleaned, and organized, Cadmus created a Stage 1 building type category for each record. The Stage 1 NEEA CBSA building category definition was defined based on the following criteria:

- If a SMR parcel data and places record matched:
  - The SMR tax assessor Stage 1 NEEA CBSA building category was assumed to be the most accurate categorization due to the detailed property type description.
    - If the NEEA CBSA building category matched in the SMR parcel data and Google Places data, it was assigned as the Stage 1 building type category.

  - If the categories differed between the data sources, but were both defined in at least one of the NEEA categories, the SMR definition was assigned as the Stage 1 building type category.
  - If the categories differed between the data sources, the SMR definition was Use Google Places, and the Google Places definition was a valid NEEA category, the Google Places definition was assigned as the Stage 1 building type category.
  - If the categories differed between data sources but the Google Places definition was Defer to SMR and the SMR definition was a valid category, the SMR definition was assigned as the Stage 1 building type category.
  - If the categories differed but both were Unknown or too general, then Other was assigned as the Stage 1 building type category.
- For records found only in the SMR parcel data (no match to a Google Places record)
  - All valid NEEA CBSA building type categories were assigned as the Stage 1 building type category.
  - Records that stated to only keep if matched to a Google Places were dropped from the sample frame (e.g., multifamily residences).
  - Records that stated to Use Google Places building definition but did not match to a Google Places result were assigned as Unknown in the Stage 1 building type category.
- For records found only in the Google Places data (no match to a SMR record):
  - All valid NEEA CBSA building type categories were assigned as the Stage 1 building type category.
  - Records that stated to Defer to SMR building definition but did not match to a SMR parcel record were defined as Other in the Stage 1 building type category.

Stage 1 Sample of Census Blocks

Starting with the clean virtual catalog, Cadmus filtered data to include census blocks with aggregate floor area greater than zero, records with 1,000 square feet or more, building categories that were in scope for the CBSA, and records with valid addresses. The result of this step was the Stage 1 record level data.

Using the Stage 1 record level data, we aggregated floor area within each census block and building type, applied building type scale factors to the building type floor area in each block, and calculated an MOS. Then, we calculated the total floor area and total MOS within each block to produce the Stage 1 sample frame with block level data.

Next, Cadmus sampled census blocks from the Stage 1 sample frame. First, we selected the 1,500 largest blocks based on MOS, assigning them to a certainty stratum. Then we stratified the remaining blocks into three MOS size bins, defined such that each size bin included equal proportions of the total remaining MOS (after assigning the largest blocks to the certainty stratum). Table 13 shows the population and sample sizes.

Table 13. Stage 1 Sample Design

Sampling Type	Population of Blocks	Sampled Blocks	% Total MOS1 Observed[1]
Certainty	1,500	1,500	38.2%
Size 1 (MOS1 > 144.43)	2,692	1,176	20.6%
Size 2 (50.21 > MOS1 ≤ 144.43)	6,785	1,158	20.6%
Size 3 (MOS1 ≤ 50.21)	63,118	1,166	20.6%
Total	**74,095**	**5,000**	**100.0%**

Within each MOS size bin, Cadmus stratified blocks by region, utility type, urban or rural designation, and block density. We sampled blocks with probability proportional to MOS within each stratum and the resulting set of blocks constituted the Stage 1 sample of 5,000 blocks.

Manual Review of Sampled Records

Cadmus did an extensive manual review of the records corresponding to the Stage 1 sampled blocks to develop the Stage 2 sample frame of sites for the CBSA. Our focus in this section is on how the results from the manual review provided insight into the accuracy of the virtual catalog more generally.

The manual review process started by collecting the raw and cleaned record level data corresponding to records in the sampled blocks from the clean virtual catalog. As each record was reviewed, it was either retained (with or without edits) or discarded. When multiple records were determined to correspond to a single site for CBSA purposes, one record was retained and edited to contain the most complete and accurate data and the other(s) were removed. The resulting data set included one record for each site in the Stage 2 sample frame.

Attrition

Cadmus did not track the attrition reasons during the manual review. For the purpose of this analysis, we inferred the attrition reason for each record to the degree possible by developing rules that represented the steps taken during the manual review and that could be applied to records consistently and systematically using statistical software. This process resulted in attrition identification for many records with high certainty. There were some records for which we could not determine the attrition reason and so those remained unknown. The following attrition categories were assigned for this analysis with greater certainty:

- Duplicate records per building or site
- Multiple buildings per site
- Multiple observations with common owner
- Out of scope building type categories (e.g., airports, jails, data centers, etc.)

The following attrition categories were assigned with less certainty:

- Home-based business or residential site

- Industrial site[11]
- Vacant or wrong block[12]
- Unknown

The results are summarized in Table 14 which indicates the primary reason each record was excluded.[13] Cadmus summarized attrition in terms of the number of records and floor area excluded from the subsequent Stage 2 sample frame. In this summary, we included the edited floor area from the clean virtual catalog (both with and without imputed values). Comparing attrition between floor area with and without imputation provides information on potential bias in the clean floor area that could have resulted from imputation.

The attrition reasons are listed in Table 14, with detailed definitions provided in *Appendix A. Appendix NEEA Building Types*. Although many of the attrition reasons and associated reductions in floor area likely reflect inaccuracies in the virtual catalog overall, not all do. Real attrition includes cases where floor area in the virtual catalog overestimates the actual regional floor area. Artificial attrition includes cases where there are duplicate records but the total floor area between them is an accurate estimate—these appear as attrition in Table 14 simply due to the data processing method we used.

Further, the nature of attrition in the excluded building type categories is confounded with other reasons such as duplicate records, multiple buildings per site, and common owners. Although it was out of scope for the current CBSA to do additional analyses to determine to the extent to which duplicates were also present in records with excluded building types, we did produce a data set with fields to indicate which attrition reasons applied to each manually reviewed record.

Finally, the manual review process did not include a step for adding back in sites that did not previously show up in the virtual catalog. This likely results in an underestimation of regional commercial floor area for the building types assessed.

Findings

As shown in Table 14, the following three reasons accounted for the highest percentages of floor area (no imputation) attrition:

- **Duplicate records per building or site (real attrition):** these records had duplicated addresses and duplicated raw floor area data (including cases where a single SMR record was merged to

[11] We assigned the industrial site attrition category to records with industrial building type data, including those initially identified as warehouses.

[12] The attrition table likely understates the number of vacant buildings as these were difficult to identify systematically.

[13] One record could have several reasons for attrition. For example, we labeled exclusions due to out of scope building types as such, even if there were also duplicate records in the virtual catalog. Because there could be competing reasons for attrition, Cadmus created a data set that included all possible attrition reasons for excluded records.

multiple Google Places records) that were consolidated to a single record by keeping the floor area from one record and removing the others.

- **Multiple buildings per site (artificial attrition):** these records had duplicated addresses but distinct raw floor area data (e.g., businesses that are located in the same shopping mall or supermarket) that were consolidated into a single record by summing the floor area from all records in the kept record and removing floor area from other records.
- **Multiple observations with common owner (artificial attrition):** these were records within the same block with duplicated owner data that were consolidated to a single site by summing floor area from all records and removing floor area from other records.

Table 14. Manual Review Findings (Attrition)

Attrition Reason	Records	Clean SQFT (Imputed Values)	% Starting SQFT	Clean SQFT (No Imputation)[b]	% Starting SQFT[b]
Starting total in reviewed blocks	**59,109**	**1,576,337,989**	**100%**	**1,196,809,255**	**100%**
Duplicate records per building/site	9,113	163,008,316	10%	82,735,363	7%
Multiple buildings per site[a]	6,155	153,684,364	10%	105,842,784	9%
Multiple buildings with common owner[a]	2,575	66,336,831	4%	61,037,220	5%
Incorrect floor area for Dayton, WA	19	55,239,732	4%	55,198,451	5%
Excluded Courthouse	32	1,234,058	0%	592,533	0%
Commercial building less than 1000 SQFT	2,425	6,180,440	0%	615,601	0%
Home-based business or residential site	2,364	63,754,207	4%	18,529,542	2%
Multifamily without commercial SQFT	2,309	67,201,531	4%	61,534,704	5%
No structures / non-buildings	2,225	96,396,733	6%	25,367,454	2%
Vacant/Wrong Block	2	31,493	0%	31,493	0%
Unknown	1,017	20,932,503	1%	15,557,564	1%
Industrial site	996	39,014,912	2%	37,457,801	3%
Airport	575	15,178,365	1%	12,969,561	1%
Excluded Transportation NEC / Bus stops	189	9,386,706	1%	9,059,849	1%
Excluded University	140	15,169,207	1%	10,691,675	1%
Excluded Cold Storage	36	3,466,835	0%	3,419,798	0%
Excluded Stadiums	28	1,764,915	0%	1,235,455	0%
Excluded Jails, Prisons, Asylums	21	9,439,918	1%	9,314,874	1%
Excluded Data Center	19	6,899,324	0%	6,794,966	1%
Total attrition	**30,240**	**794,320,388**	**50%**	**517,986,687**	**43%**

[a] Artificial attrition where total floor area in the virtual catalog for affected records is accurate.
[b] Totals appear different than sum of total in table due to rounding.

Based on these findings, Cadmus drew the following conclusions about the accuracy of regional floor area estimates based on data in the virtual catalog:

- Combined, multiple buildings per site and multiple buildings per owner represent the largest source of inaccuracy. However, these inaccuracies only affect the estimated number of sites (overestimated based on the count of records). Total edited floor area in the clean virtual catalog from those records is accurate.

- Duplicated records per building/site represent the next largest source of inaccuracy. Based on the findings above, we expect the virtual catalog is overestimating floor area in the region by 10% based on the edited floor area with imputation (and 7% without imputation).
- Imputation in the edited floor area increased floor area that was subsequently excluded in some attrition categories. However, the imputation only increased attrition due to duplicate records by 3%.

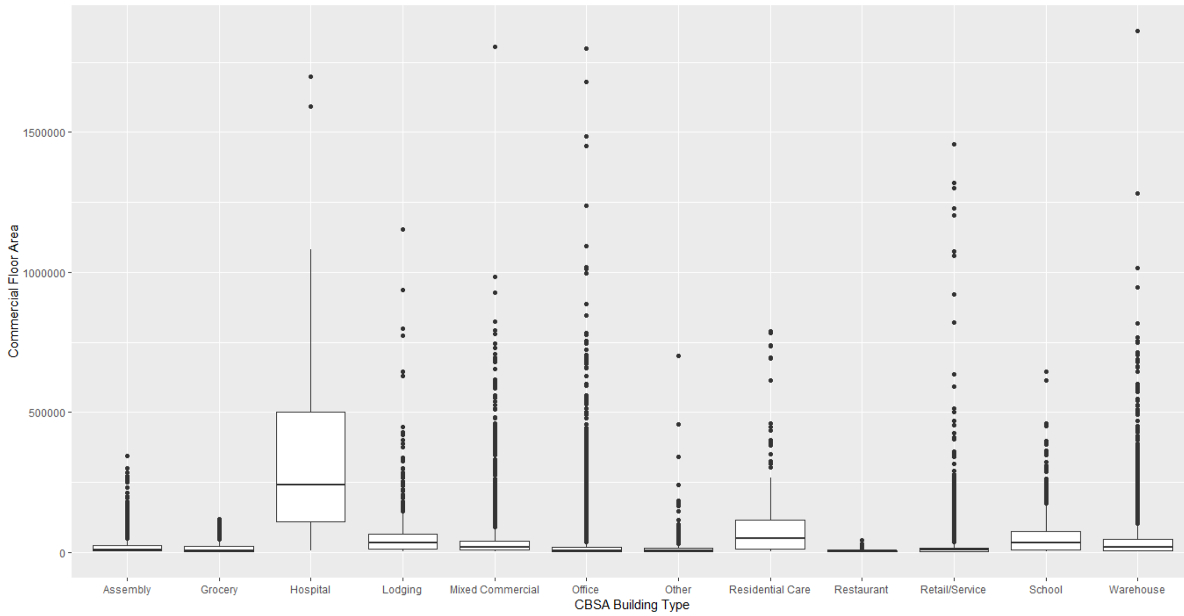
Table 15 shows the change in number of sites as a result of the manual review process.

Table 15. Sites Dropped, Added, and Moved, by Category, Based on the Manual Review

CBSA Category	Total Sites from Raw Data	Sites Dropped	Percent Dropped	Sites Added	Moved From	Moved To	Total Sites Post Review
Assembly	2,734	1,082	40%	10	381	554	1,835
Grocery	2,924	1,308	45%	9	589	242	1,278
Hospital	424	285	67%	4	72	32	103
Lodging	1577	588	37%	4	134	136	995
Mixed Commercial	531	295	56%	25	100	3,674	3,835
Office	12,110	5,850	48%	65	1,563	1,782	6,544
Other	5,324	2,650	50%	3	2,060	275	892
Residential Care	1,610	935	58%	2	280	110	507
Restaurant	4,958	2,118	43%	25	713	594	2,746
Retail/Service	12,308	5,757	47%	40	2,064	1,781	6,308
School	1,498	652	44%	8	139	101	816
Warehouse	5,345	2,235	42%	60	947	1,152	3,375
Multi-Family	774	436	56%	0	338	N/A[a]	-
Defer to SMR	4,154	3,131	75%	0	1,023	N/A[a]	-
University	141	111	79%	0	30	N/A[a]	-
Total	**56,412**	**27,433**	**49%**	**255**	**10,433**	**10,433**	**29,234**

[a] Indicates this category was not part of the final 12 buildings types, so sites would not have been added.

Figure 38. Virtual Catalog Commercial Floor Area Distribution by Building Type



Appendix C. Customer Contact Outreach Materials

This appendix will have the following documents appended as part of the final PDF:

- Business Verification Letter
- Customer Acceleration Protocol
- CBSA Frequently Asked Questions
- FirstView Sample Report
- CBSA Information Form

CADMUS

MEMORANDUM

To:	NEEA and Utility Representatives
From:	Jeff Cropp, Karen Horkitz, and Kristie Rupper
Subject:	CBSA Customer Contact Protocols
Date:	August 20, 2018

The following documents represent the 2018 – 2019 CBSA Customer Contact Protocols, and are provided for your review:

- **Recruitment Process Diagram and Timeline**
- **Proposed Utility Billing Data Protocol**
- **Utility Billing Data Request Form**
- **Recruiter notes, background information, and recruitment script,** for telephone and in-person recruiters.
- **Email and telephone messaging** for various customer touchpoints throughout the lifecycle of the study.
- **Verification Letter.** This letter can be provided to customers via email throughout the recruiting and scheduling process and on-site if requested by customer.
- **Frequently Asked Questions.** List of possible customer questions and answers.
- **Site visit assessment information sheet** outlining the agenda for the site assessment.
- **Proposed customer acceleration protocol** for resolving issues raised by utility customers.
- **Example of site-specific report.**

CBSA Recruitment process and Timeline

For utility reference prior to recruitment

The recruitment process and timeline are shown on the following pages.

neea

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Attachment B: CBSA Recruitment Process

Cadmus selects sites from geographically sampled population in late June

Cadmus assigns sites to utility territory
(based on known information and augmented by NEEA shape files)

Cadmus sends selected sites to utilities for review in early November

Utilities review sites
(30 days to complete review and respond to Cadmus)

1. Confirm sites are customers
2. Identify sites utility wants to notify about the study
3. Identify sites utility wants to attend site visit
4. Identify sites with timing concerns

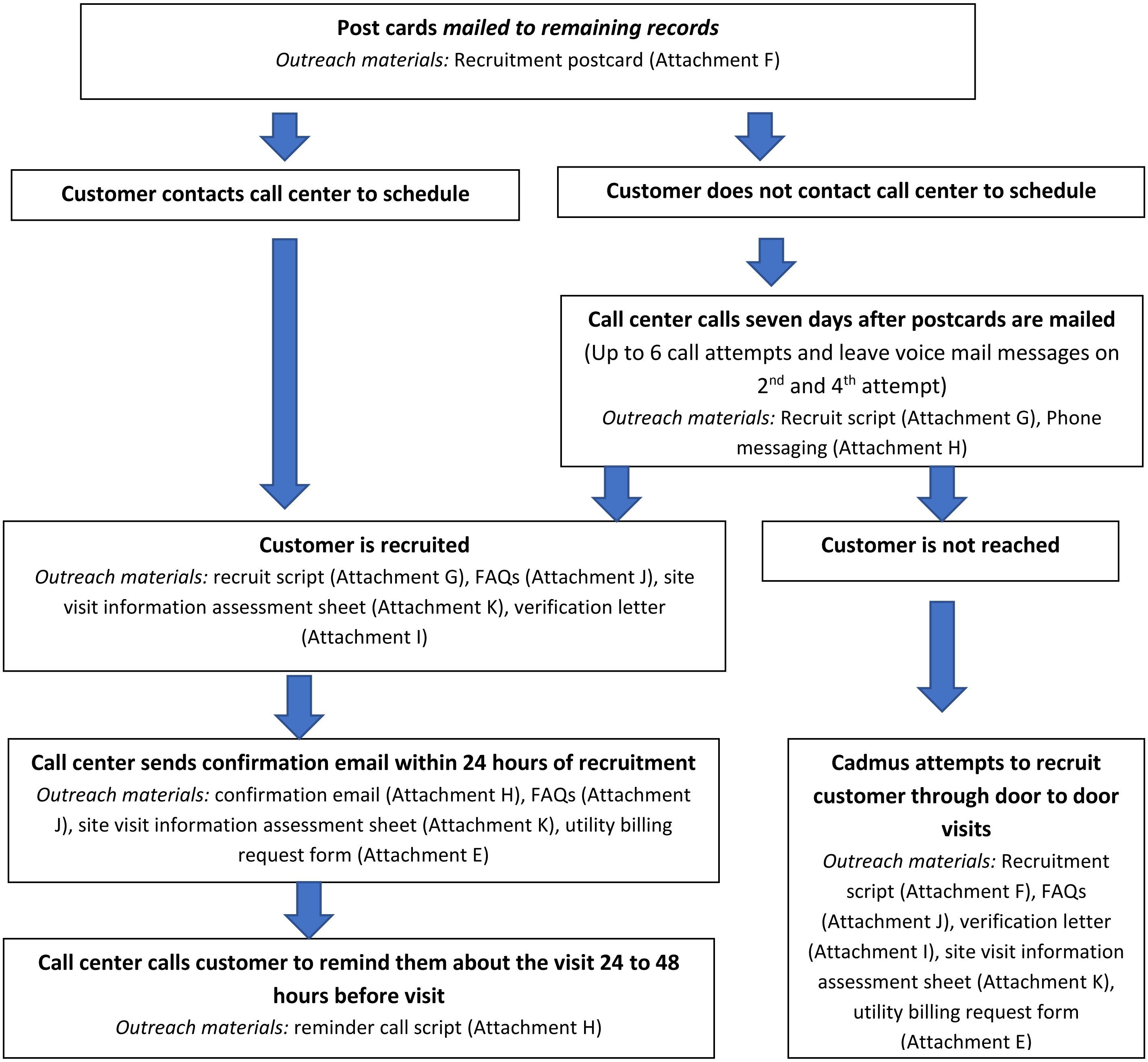
Cadmus integrates annotated customers from utilities into recruitment process

Cadmus review lists to determine next recruitment step

Utility introduction?	Yes → Cadmus to attempt recruitment
No ↓	
Professional contact?	Yes → Cadmus to attempt recruitment
No ↓	
Trade organization?	Yes → Cadmus to attempt recruitment
No ↓	

Cadmus to attempt recruitment

Outreach materials: Email (Attachment H), verification letter (Attachment I), FAQs (Attachment J), site visit information assessment sheet (Attachment K)



Who do I contact if I have questions?

Cadmus works on NEEA's behalf to implement this phase of the research study. You can contact Jeff Cropp by calling 503.467.7120 or emailing Jeff.Cropp@cadmusgroup.com.

To speak with someone at NEEA, contact Dulane Moran by calling 503.688.3908 or by sending an e-mail to dmoran@neea.org

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CBSA Recruitment Timeline

Task	Month / Week	January	February	March	April	May	June	July	August	September	October	November	December
Mail Postcards													
Call Center Recruitment										9/13			
Conduct On-Site Assessments										9/27			
Outreach to Trade Organizations					4/26								
Door to Door Recruitment								7/8		9/13			
Data Analysis												11/29	
Deliver Interim Data													
Deliver Final Database													By 12/31

CADMUS

Utility Billing Data Protocol

For utility reference during recruitment and assessment process

Billing data is an essential component of our data collection effort and a critical element in the database to calculate whole building energy-use intensity. We will need to acquire at least one full year of billing data for the electric and gas accounts tied to the specific building(s) assessed for each site.

The first step in this process will involve identifying the appropriate point of contact at each utility who can facilitate the process of submitting and obtaining the billing data. Cadmus recently completed this task as part of the Residential Building Stock Assessment (RBSA). We have provided the list of utility points of contact from that study to NEEA. NEEA should determine whether those individuals will remain the point of contact or if they can recommend a new contact.

During the RBSA, Cadmus signed nondisclosure agreements for billing data access with some utilities which should still be in force. If necessary, we will negotiate a nondisclosure agreement directly with any utility that requests it for obtaining the data through a secure file transfer protocol site (SFTP).

Many utilities have their own utility billing request forms that Cadmus will provide to participating customers to sign. If a utility does not have their own preferred utility billing request form, we have developed a generic utility billing request form (Appendix J) and submitted it to the Customer Contact Workgroup for approval. NEEA and Cadmus will work together to determine appropriate format and type of authorization form that each utility prefers. We will provide the form that each utility prefers to participants in advance of the site assessment and attempt to obtain the completed form before going on site. If that is not successful, we will request the site contact to either have a printed and signed form waiting for us or to arrange for us to meet with the appropriate authority to sign the billing data release.

We will work with the utilities to establish an ongoing batch submittal process throughout the CBSA project period. We are aware that each utility will have a different process and timeline for producing data, and we will factor that into our analysis timeline.

CADMUS

Utility Billing Request Form

Site ID Number: ____________________ **Bill Release ID:** ____________________

Serves Space(s) (circle): all 1 2 3 4 5

I hereby give permission to the servicing utility or utilities listed below, or their agents, to provide NEEA and its contractors with energy use information related to this business. This information is being collected as part of a research project sponsored by NEEA to gain a better understanding of energy use characteristics of commercial facilities throughout the Northwest.

I authorize the utilities supplying my fuel and/or electricity to provide monthly usage histories and interval meter data, where available, for the past twelve months. I understand that this information will remain confidential, and will be used for purposes of statistical analysis only. I further understand that the information related to my business will not be published, and neither NEEA nor its contractors will contact me for advertising or promotional purposes.

A photocopy of this authorization may be accepted with the same authority as the original. Data will be provided for multiple meters at a single premise provided they are on the noted utilities account(s).

Authorized by (please print): ____________________

Title: ____________________

Phone number: ____________________

Service Address: Business Name: ____________________

Street: ____________________

City, State and ZIP: ____________________

Servicing Utilities (Print full name of each utility company):

Electric Utility Name: ____________________

Account Number ____________________
Meter Number (1) ____________________
Meter Number (2) ____________________
Meter Number (3) ____________________

Gas Utility Name: ____________________

Account Number ____________________
Meter Number (1) ____________________
Meter Number (2) ____________________
Meter Number (3) ____________________

Please fill out the information and email or fax this signed waver back to: **Kristie Rupper** at kristie.rupper@cadmusgroup.com **or fax 301.652.8804.**

Recruiter Notes, Background Information, and Recruitment Script

For customer during recruitment process

Call Notes

- Please make sure to use a professional tone and language.
- Confirm that contact person is familiar with facility operations; if not, request to speak with the appropriate person. This must be a decision-maker at the property who is familiar with facility operations.
- When speaking to the contact person, please follow the language in the script below.
- Follow-up with an email to confirm visit schedule and contact information. Attach the participant FAQ, onsite assessment information sheet, and utility billing request form in the confirmation email.
- Leave a voice mail message on second and fourth call.

Study Background

- NEEA, supported by the region's electric and natural gas utilities, is conducting this comprehensive research study of in Northwest commercial buildings, officially called the Commercial Building Stock Assessment (CBSA).
- The end result of these assessments will be a summary report to NEEA describing the energy consumption profile of commercial buildings throughout the Northwest. The reported data and information will not be identifiable by individual facility sites.
- Field technicians are all trained in assessing energy use in commercial facilities, and are aware of industrial safety and site requirements.
- [SITE VISIT LENGTH] The time required to complete a site visit varies depending on the size and complexity of the facility's energy systems.
  - Small – between 2 and 3 hours
  - Medium – between 4 and 5 hours
  - Large – about 8 hours
- During the walk-through, it would be most helpful if the facility escort is familiar with all facility energy uses and associated equipment, as well as recent energy projects/improvements.
- For some sites, there may be a requirement for safety training and other proprietary concerns to be addressed prior to the walk-through. Should the training requirement exceed two hours, the site may be rejected.
- [INCENTIVE] Participating businesses will receive either a gift card or a site-specific report that highlights energy efficiency opportunities. The gift card can be used for a party for the staff or some other company initiative. It can also be donated to charity.
  - Small companies = $50 gift card or a site-specific report (IF NEEDED: valued at $1,700)
  - Medium companies - $100 gift card or a site-specific report (IF NEEDED: valued at $3,000)
  - Large companies = $250 gift card or a site-specific report (IF NEEDED: valued at $3,750)

Additional Email and Telephone Messaging

For customer during recruitment process

Before the Visit is Scheduled

Email to Accompany Verification Letter

If a customer requests written verification of the study to verify legitimacy, this email will accompany the letter.

Email Text

Subject: Learn more about the Commercial Building Stock Assessment!

Dear [CONTACT NAME],

Thank you for speaking with me today and for considering this important study. Attached is a letter providing additional information about the study and its sponsors. Additional information about the study and answers to frequently asked questions can be found at www.NEEA.org/CBSA. We hope you decide to participate!

To schedule the site assessment, please call (866) 338-6640 or simply reply to this email. If you have additional questions, please contact us.

Thank you,

[NAME OF SCHEDULER]
[PHONE]

[ATTACHMENT: Business_Verification_Letter_Large or Business_Verification_Letter_Medium or Business_Verification_Letter_Small]

Voice Mail Messages

These messages will be left by the recruiting/scheduling team on the 2nd and 4th calls to a company.

Voice Mail Script #1:

Hello, my name is [NAME] from [COMPANY] calling on behalf of the Northwest Energy Efficiency Alliance or NEEA and the region's utilities. NEEA conducts this important study every five years and the information obtained from on-site assessments improves energy efficiency program designs and is important for system planning. **We are not selling anything.** We would like to speak with you about this research and for your participation in the study you will receive a [$XX] gift card or a site-specific energy report. Please return my call at [NUMBER]. I look forward to hearing from you. Thank you.

Voice Mail Script #2:

Hello, my name is [NAME] from [COMPANY] calling on behalf of the Northwest Energy Efficiency Alliance and the region's utilities. As I mentioned in my last message, NEEA is conducting an important regional study to assess energy consumption among commercial businesses in the Northwest by conducting on-site assessments to collect information on energy-using equipment and building characteristics that affect energy consumption. Your site has been selected to participate in this research and it is critical that we speak with you about this. **We are not selling anything** and for your participation in the study you will receive a [$XX] gift card or a site-specific energy report. Please return my call at [NUMBER]. I look forward to hearing from you. Thank you.

Inbound Answering Machine Script:

Thank you for your call. You have reached the voice mailbox for the Northwest Energy Efficiency Alliance Commercial Building Stock Assessment Research Study. Your call is very important to us. Please leave your name, phone number, company name, and a time you can be reached and we will return your call as soon as possible. Please visit www.NEEA.org/CBSA for additional details about the study.

After the Assessment has been Scheduled

Site Assessment Confirmation Email

This email will be sent to confirm the site visit. Included with this message are the **onsite assessment information sheet** (Attachment K), the **FAQs** (Attachment J), and the **utility billing request form** (Attachment E).

Email Script

Subject: NEEA CBSA Site Assessment

Dear [NAME],

Thank you for agreeing to participate in the Commercial Building Site Assessment (CBSA). CBSA will provide the region with information to help businesses (better understand the typical energy consumption), utilities plan more effective programs for commercial customers, and researchers plan more effectively for programs and investments to ensure adequate infrastructure.

Your visit is scheduled for:

[DATE]
[TIME]

We have attached an information sheet describing the agenda for the visit, an FAQ document with answers to common questions about the study, and a utility billing request form. Please review these items and contact us if you have questions.

As part of this study, Cadmus needs to obtain billing history data for the specific buildings that receive site visits. Billing data is critical to estimating whole building energy-use intensity for the selected sites. Please complete the authorization form at [INSERT LINK] within the next couple of days and we will request the data from your utility.

One to two days before your appointment, you will receive a reminder call. If you find it necessary to reschedule your appointment, please contact us as soon as possible.

The address we are planning to visit is [ADDRESS]. If we do not have the correct location, please reply to this email with the correct address.

[IF THEY DO HAVE PROTOCOLS] You indicated the following requirements for the on-site visit: [LIST PROTOCOLS]. If there are additional protocols or these are not correct, please reply to this email as soon as possible so we can alert the field technician.

[IF NO PROTOCOLS] We do not have any instructions about parking, security, or other protocols upon arrival. Please reply to this email if there are specific requirements our field technician should prepare for upon arrival.

If you would like to read more about this research study, please visit www.neea.org/CBSA.

If you have further questions, you can contact Kristie Rupper by calling (204) 240-6217 or by emailing Kristie.Rupper@cadmusgroup.com.

We appreciate your participation in this valuable, regional, energy research study.

Sincerely,

The CBSA Team

Reminder Phone Calls

Participants will be called 24 to 48 hours before the site assessment.

Script

[ASK FOR CONTACT]

Hello, my name is [NAME] from [COMPANY] calling on behalf of NEEA. I am calling to remind you about the site assessment scheduled for [DATE] at [TIME]. The address we are planning to visit is [ADDRESS]. Is this correct?

[IF THEY DO HAVE PROTOCOLS] You indicated the following requirements for the on-site visit: [LIST PROTOCOLS]. Are these correct?

[IF NO PROTOCOLS] We do not have any instructions about parking, security, or other protocols upon arrival. Are there any requirements our field technician should be aware of upon arrival at the site?

Do you have any questions about the assessment? [ANSWER QUESTIONS ABOUT STUDY]

Our field technicians will see you on [DATE] at [TIME].

Thank you for your willingness to participate. Have a nice day!

VERIFICATION LETTER

For customer during recruitment process

The verification letters for each company size (small, medium, large) are shown on the following pages.

Dear [CONTACT NAME]:

We invite you to participate in an exciting, paid research study about energy use in commercial buildings in the Northwest. Upon completion of the onsite visit, each participating business will receive **a gift card or a site-specific report that highlights energy efficiency opportunities!**

Officially called the Commercial Building Stock Assessment (CBSA), it is a comprehensive research study of energy efficiency in Northwest commercial buildings. The CBSA will provide the region with useful information for businesses (to compare their energy use with the average energy use of similar Northwest facilities), utilities (for use in program planning), researchers (for use in energy use characterization), and be a key input into regional power planning.

This important study is sponsored by your utility and the Northwest Energy Efficiency Alliance (NEEA). NEEA has hired an energy consulting and research firm (Cadmus) and its subcontractors (McKinstry, Energy 350, and DNV GL) to conduct this research study.

We would like to conduct an onsite visit of your property. A few weeks before the visit, we will work with your staff to collect any preparatory data that might be available. During the onsite visit, our field technician will tour your facility and collect data on your equipment. Our visit will last about 2 to 3 hours.

The onsite visit is strictly for research purposes; we will not attempt to sell you anything. All participant responses will remain confidential. When published, we will group data by building-types and remove all personal or identifying information.

For more information about this research study, please visit www.neea.org/CBSA.

To schedule the appointment, please call (866) 338-6640 or email NEEA-CBSA@consumeropinionservices.com.

Thank you in advance for your help!

Dulane Moran
Principal Evaluation Lead
Northwest Energy Efficiency Alliance

Northwest Energy Efficiency Alliance
421 SW Sixth Avenue, Suite 600, Portland, OR 97204

Dear [CONTACT NAME]:

We invite you to participate in an exciting, paid research study about energy use in commercial buildings in the Northwest. Upon completion of the onsite visit, each participating business will receive **a gift card or a site-specific report that highlights energy efficiency opportunities!**

Officially called the Commercial Building Stock Assessment (CBSA), it is a comprehensive research study of energy efficiency in Northwest commercial buildings. The CBSA will provide the region with useful information for businesses (to compare their energy use with the average energy use of similar Northwest facilities), utilities (for use in program planning), researchers (for use in energy use characterization), and be a key input into regional power planning.

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We would like to conduct an on-site visit of your property. A few weeks before the visit, we will work with your staff to collect any preparatory data that might be available. During the onsite visit, our field technician will tour your facility and collect data on your equipment. Our visit will last about 4 to 5 hours.

The onsite visit is strictly for research purposes; we will not attempt to sell you anything. All participant responses will remain confidential. When published, we will group data by building-types and remove all personal or identifying information.

For more information about this research study, please visit www.neea.org/CBSA.

To schedule the appointment, please call (866) 338-6640 or email NEEA-CBSA@consumeropinionservices.com.

Thank you in advance for your help!

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Northwest Energy Efficiency Alliance

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This important study is sponsored by your utility and the Northwest Energy Efficiency Alliance (NEEA). NEEA has hired an energy consulting and research firm (Cadmus) and its subcontractors (McKinstry, Energy 350, and DNV GL) to conduct this research study.

We would like to conduct an on-site visit of your property. A few weeks before the visit, we will work with your staff to collect any preparatory data that might be available. During the onsite visit, our field technician will tour your facility and collect data on your equipment. Our visit will last about eight hours.

The onsite visit is strictly for research purposes; we will not attempt to sell you anything. All participant responses will remain confidential. When published, we will group data by building-types and remove all personal or identifying information.

For more information about this research study, please visit www.neea.org/CBSA.

To schedule the appointment, please call (866) 338-6640 or email NEEA-CBSA@consumeropinionservices.com.

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CADMUS

Frequently Asked Questions

For customer during recruitment process

The Frequently Asked Questions for each company size (small, medium, large) and one generic version are shown on the following pages.

COMMERCIAL BUILDING STOCK ASSESSMENT
FREQUENTLY ASKED QUESTIONS

neea CADMUS

What is the Commercial Building Stock Assessment (CBSA)?

The CBSA is a comprehensive research study of energy efficiency in Northwest commercial buildings. The CBSA will provide the region with useful information for businesses (to compare their energy use with the average energy use of similar Northwest facilities), utilities (for use in program planning), researchers (for use in energy use characterization), and be a key input into regional power planning.

Who conducts this study?

The Northwest Energy Efficiency Alliance (NEEA) conducts the CBSA on behalf of the region's energy efficiency organizations and is funded by the region's utilities.

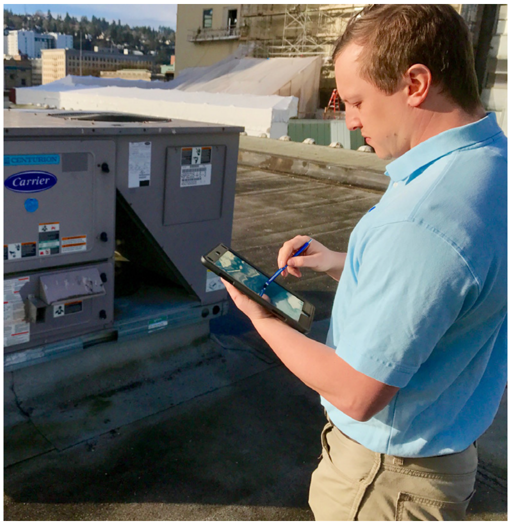
What is NEEA?

NEEA is a collaboration of 140 utilities and efficiency organizations working together to advance energy efficiency in the Northwest on behalf of more than 13 million consumers.

What is Cadmus?

Cadmus is a consulting company contracted by NEEA to perform the CBSA. NEEA chose Cadmus to conduct this work through a competitive process, which included input from regional utilities. Cadmus is working with three other firms throughout the region to gather this important data; they are McKinstry, Energy 350, and DNV GL.

Each participating business will receive a gift card or site-specific report for taking part in the study.



What does this study involve and why are you contacting us?

This study involves gathering information from on-site assessments at participating businesses. Cadmus and our partner firms will collect information on energy-using equipment and building characteristics that affect energy consumption. Site technicians will also report on various energy efficiency opportunities throughout each participating building. Your facility was randomly selected from a list of hundreds of similar facilities in the Northwest to participate in this important study.

Will we receive anything for our participation?

We will work with participating businesses to provide either a gift card or site-specific report with the results of the CBSA assessment. The monetary value and scope of the report will vary based on the size and complexity of the participating business.

COMMERCIAL BUILDING STOCK ASSESSMENT
FREQUENTLY ASKED QUESTIONS

neea CADMUS

What kind of information will you gather during the site assessment?

Using an iPad-based data collection tool, field technicians will gather information needed to characterize energy use by each of the following:

- *HVAC equipment (space heating and cooling)*
- *Lighting*
- *Building envelope (windows, doors, insulation, etc.)*
- *Water heating*
- *Refrigeration and cooking*
- *Computers and miscellaneous equipment*
- *Cooling Towers*

How long will this assessment take?

Field technicians will remain on-site for approximately 2-3 hours, depending on the facility's complexity. The field technicians will initially work with the site contact by phone or email to identify the specific information they hope to obtain on-site. At the site, the field technicians will focus first on the systems expected to use the most energy, such as HVAC equipment, and then work their way down to smaller energy uses.

How will this information be used?

The results of this study will provide immense value to the region by identifying opportunities to save energy and lower utility bills while growing the economy of the Northwest. The information will also allow the region to more effectively characterize current energy loads to meet future demand.

Who will be able to access my information?

Site-specific information gathered through the CBSA can only be accessed by those working on NEEA's behalf to complete the research study. All participant responses will remain confidential. When published, data will be grouped by building-types and all personal or identifying information will be removed.

Who do I call if I have questions?

Cadmus works on NEEA's behalf to implement this phase of the research study. You can contact Kristie Rupper by calling 240.204.6217 or emailing Kristie.Rupper@cadmusgroup.com.

To speak with someone at NEEA, contact Dulane Moran by calling 503.688.5400 or by sending an e-mail to dmoran@neea.org

COMMERCIAL BUILDING STOCK ASSESSMENT

FREQUENTLY ASKED QUESTIONS

neea CADMUS

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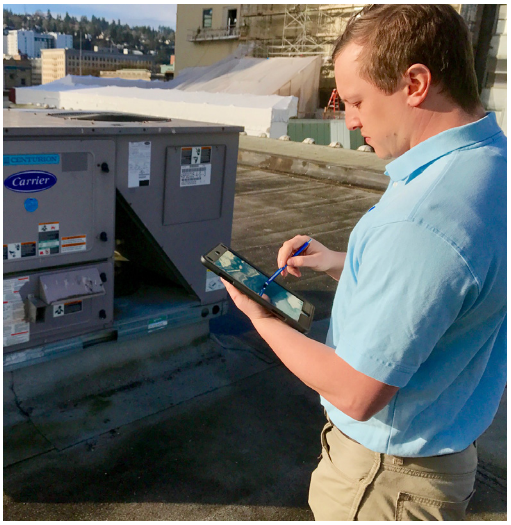
Each participating business will receive a gift card or site-specific report for taking part in the study.



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What does this study involve and why are you contacting us?

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Will we receive anything for our participation?

We will work with participating businesses to provide either a gift card or site-specific report with the results of the CBSA assessment. The monetary value and scope of the report will vary based on the size and complexity of the participating business.

COMMERCIAL BUILDING STOCK ASSESSMENT

FREQUENTLY ASKED QUESTIONS

neea CADMUS

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- *Water heating*
- *Refrigeration and cooking*
- *Computers and miscellaneous equipment*
- *Cooling towers*

How long will this assessment take?

Field technicians will remain on-site for approximately 4-5 hours, depending on the facility's complexity. The field technicians will initially work with the site contact by phone or email to identify the specific information they hope to obtain on-site. At the site, the field technicians will focus first on the systems expected to use the most energy, such as HVAC equipment, and then work their way down to smaller energy uses.

How will this information be used?

The results of this study will provide immense value to the region by identifying opportunities to save energy and lower utility bills while growing the economy of the Northwest. The information will also allow the region to more effectively characterize current energy loads to meet future demand.

Who will be able to access my information?

Site-specific information gathered through the CBSA can only be accessed by those working on NEEA's behalf to complete the research study. All participant responses will remain confidential. When published, data will be grouped by building-types and all personal or identifying information will be removed.

Who do I call if I have questions?

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COMMERCIAL BUILDING STOCK ASSESSMENT
FREQUENTLY ASKED QUESTIONS

neea CADMUS

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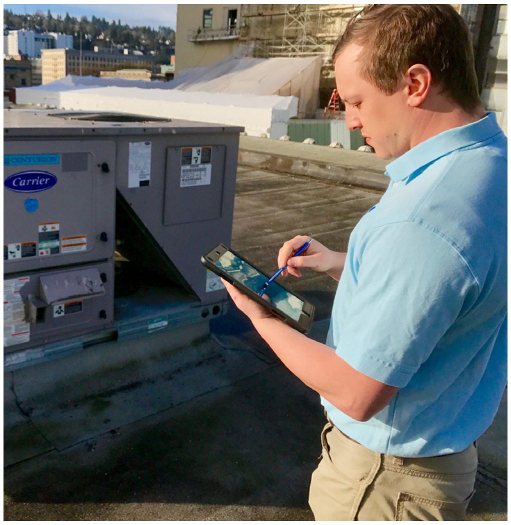
Each participating business will receive a gift card or site-specific report for taking part in the study.



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What does this study involve and why are you contacting us?

This study involves gathering information from on-site assessments at participating businesses. Cadmus and our partner firms will collect information on energy-using equipment and building characteristics that affect energy consumption. Site technicians will also report on various energy efficiency opportunities throughout each participating building. Your facility was randomly selected from a list of hundreds of similar facilities in the Northwest to participate in this important study.

Will we receive anything for our participation?

We will work with participating businesses to provide either a gift card or site-specific report with the results of the CBSA assessment. The monetary value and scope of the report will vary based on the size and complexity of the participating business.

COMMERCIAL BUILDING STOCK ASSESSMENT

FREQUENTLY ASKED QUESTIONS

neea CADMUS

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- *Lighting*
- *Building envelope (windows, doors, insulation, etc.)*
- *Water heating*
- *Refrigeration and cooking*
- *Computers and miscellaneous equipment*
- *Cooling Towers*

How long will this assessment take?

Field technicians will remain on-site for approximately 8 hours, depending on the facility's complexity. The field technicians will initially work with the site contact by phone or email to identify the specific information they hope to obtain on-site. At the site, the field technicians will focus first on the systems expected to use the most energy, such as HVAC equipment, and then work their way down to smaller energy uses.

How will this information be used?

The results of this study will provide immense value to the region by identifying opportunities to save energy and lower utility bills while growing the economy of the Northwest. The information will also allow the region to more effectively characterize current energy loads to meet future demand.

Who will be able to access my information?

Site-specific information gathered through the CBSA can only be accessed by those working on NEEA's behalf to complete the research study. All participant responses will remain confidential. When published, data will be grouped by building-types and all personal or identifying information will be removed.

Who do I call if I have questions?

Cadmus works on NEEA's behalf to implement this phase of the research study. You can contact Kristie Rupper by calling 240.204.6217 or emailing Kristie.Rupper@cadmusgroup.com.

To speak with someone at NEEA, contact Dulane Moran by calling 503.688.5400 or by sending an e-mail to dmoran@neea.org

COMMERCIAL BUILDING STOCK ASSESSMENT
FREQUENTLY ASKED QUESTIONS

neea CADMUS

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What does this study involve and why are you contacting our customers?

This study involves gathering information from on-site assessments at participating businesses. Cadmus and our partner firms will collect information on energy-using equipment and building characteristics that affect energy consumption. Site technicians will also report on various energy efficiency opportunities throughout each participating building. Your facility was randomly selected from a list of hundreds of similar facilities in the Northwest to participate in this important study.

What do participating business receive?

We will work with participating businesses to provide either a gift card or site specific report with the results of the CBSA assessment. The monetary value and scope of the report will vary based on the size and complexity of the participating business.

COMMERCIAL BUILDING STOCK ASSESSMENT

FREQUENTLY ASKED QUESTIONS

neea CADMUS

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- *Lighting*
- *Building envelope (windows, doors, insulation, etc.)*
- *Water heating*
- *Refrigeration and cooking*
- *Computers and miscellaneous equipment*
- *Cooling towers*

How long will this assessment take?

Field technicians will remain on-site for approximately 2-8 hours, depending on the facility's complexity. The field technicians will initially work with the site contact by phone or email to identify the specific information they hope to obtain on-site. At the site, the field technicians will focus first on the systems expected to use the most energy, such as HVAC equipment, and then work their way down to smaller energy uses.

How will this information be used?

The results of this study will provide immense value to the region by identifying opportunities to save energy and lower utility bills while growing the economy of the Northwest. The information will also allow the region to more effectively characterize current energy loads to meet future demand.

Who will be able to access my information?

Site-specific information gathered through the CBSA can only be accessed by those working on NEEA's behalf to complete the research study. All participant responses will remain confidential. When published, data will be grouped by building-types and all personal or identifying information will be removed.

Who do I call if I have questions?

Cadmus works on NEEA's behalf to implement this phase of the research study. You can contact Kristie Rupper by calling 240.204.6217 or emailing Kristie.Rupper@cadmusgroup.com.

To speak with someone at NEEA, contact Dulane Moran by calling 503.688.5400 or by sending an e-mail to dmoran@neea.org

Site Visit Assessment Information Sheet

For customer during recruitment process

Site assessment information sheets for each company size (small, medium, large) are shown on the following pages.

COMMERCIAL BUILDING ON-SITE ASSESSMENT

INFORMATION FORM

neea CADMUS

After obtaining basic facility background information, a field technician will perform a two to three-hour site assessment, depending on the size of your building, to gather information on your building's construction and energy-using equipment.

Pre-Assessment Data Collection Pre-Visit Interview (5 to 10 min)

We would like to coordinate a time and date for the on-site assessment, as well as briefly review your building's construction details and major energy consuming equipment. This will help us be more efficient during the on-site data collection. We would also like to address any of your questions related to the on-site work and how the resulting data will be used and reported.

In preparation for the site visit, it would be helpful if you would gather your utility billing information such as utility name and account numbers(s). Additionally, if you have had equipment efficiency upgrades in the past five years, supporting documentation for these upgrades would be helpful for informational review purposes.

On-Site Assessment Activities

For the on-site assessment, a field technician will spend several hours touring your facility and collecting data on the building and energy-using equipment. Our visit will include the following activities:

- ***Introductions (5 to 10 min)***
  We would like a few minutes to meet the staff who will guide our field technicians around the facility to explain our goals and answer any questions.
- ***Data Collection (1 to 3 hours)***
  The field technician will use an iPad to gather data on building systems: primarily heating, cooling, water heating, lighting, and refrigeration equipment as applicable. The field technician will need access to mechanical room and to any HVAC equipment on the roof. We will not install any monitoring equipment or disturb operating equipment.
- ***Wrap-up Meeting (10 to 20 min)***
  Before we leave we would like to meet with key members of your staff to discuss the data we've collected and clarify any issues or discrepancies with the operating parameters we've obtained. We will also ask about the feasibility of certain potential energy saving measures that were identified during the visit. We would like confirmation that we've collected sufficient data.

Who do I call if I have questions?

Cadmus works on NEEA's behalf to implement this phase of research study. Contact Kristie Rupper by calling 240.204.6217 or emailing Kristie.Rupper@cadmusgroup.com.

To speak with someone at NEEA, contact Dulane Moran by calling 503.688.5400 or by sending an e-mail to dmoran@neea.org

COMMERCIAL BUILDING ON-SITE ASSESSMENT
INFORMATION FORM

neea CADMUS

After obtaining basic facility background information, a field technician will perform a four to five-hour site assessment, depending on the size of your building, to gather information on your building's construction and energy-using equipment.

Pre-Assessment Data Collection Pre-Visit Interview (5 to 10 min)

We would like to coordinate a time and date for the on-site assessment, as well as briefly review your building's construction details and major energy consuming equipment. This will help us be more efficient during the on-site data collection. We would also like to address any of your questions related to the on-site work and how the resulting data will be used and reported.

In preparation for the site visit, it would be helpful if you would gather your utility billing information such as utility name and account numbers(s). Additionally, if you have had equipment efficiency upgrades in the past five years, supporting documentation for these upgrades would be helpful for informational review purposes.

On-Site Assessment Activities

For the on-site assessment, a field technician will spend several hours touring your facility and collecting data on the building and energy-using equipment. Our visit will include the following activities:

- ***Introductions (5 to 10 min)***
  We would like a few minutes to meet the staff who will guide our field technicians around the facility to explain our goals and answer any questions.
- ***Data Collection (3 to 4 hours)***
  The field technician will use an iPad to gather data on building systems: primarily heating, cooling, water heating, lighting, and refrigeration equipment as applicable. The field technician will need access to mechanical room and to any HVAC equipment on the roof. We will not install any monitoring equipment or disturb operating equipment.
- ***Wrap-up Meeting (10 to 20 min)***
  Before we leave we would like to meet with key members of your staff to discuss the data we've collected and clarify any issues or discrepancies with the operating parameters we've obtained. We will also ask about the feasibility of certain potential energy saving measures that were identified during the visit. We would like confirmation that we've collected sufficient data.

Who do I call if I have questions?

Cadmus works on NEEA's behalf to implement this phase of research study. Contact Kristie Rupper by calling 240.204.6217 or emailing Kristie.Rupper@cadmusgroup.com.

To speak with someone at NEEA, contact Dulane Moran by calling 503.688.5400 or by sending an e-mail to dmoran@neea.org

COMMERCIAL BUILDING ON-SITE ASSESSMENT

INFORMATION FORM

neea CADMUS

After obtaining basic facility background information, a field technician will perform a six to eight-hour site assessment, depending on the size of your building, to gather information on your building's construction and energy-using equipment.

Pre-Assessment Data Collection Pre-Visit Interview (15 to 30 min)

We would like to coordinate a time and date for the on-site assessment, as well as briefly review your building's construction details and major energy consuming equipment. This will help us be more efficient during the on-site data collection. We would also like to address any of your questions related to the on-site work and how the resulting data will be used and reported.

In preparation for the site visit, it would be helpful if you would gather your utility billing information such as utility name and account numbers(s). Additionally, if you have had equipment efficiency upgrades in the past five years, supporting documentation for these upgrades would be helpful for informational review purposes.

On-Site Assessment Activities

For the on-site assessment, a field technician will spend several hours touring your facility and collecting data on the building and energy-using equipment. Our visit will include the following activities:

- ***Introductions (15 to 30 min)***
  We would like a few minutes to meet the staff who will guide our field technicians around the facility to explain our goals and answer any questions.
- ***Data Collection (5 to 7 hours)***
  The field technician will use an iPad to gather data on building systems: primarily heating, cooling, water heating, lighting, and refrigeration equipment as applicable. The field technician will need access to mechanical room(s) and to any HVAC equipment on the roof. We will not install any monitoring equipment or disturb operating equipment.
- ***Wrap-up Meeting (15 to 30 min)***
  Before we leave we would like to meet with key members of your staff to discuss the data we've collected and clarify any issues or discrepancies with the operating parameters we've obtained. We will also ask about the feasibility of certain potential energy saving measures that were identified during the visit. We would like confirmation that we've collected sufficient data.
- ***Post Assessment (3 to 6 Weeks)***
  After the field technician(s) have finished the work on site, they will work with the facility contact remotely to obtain any remaining pieces of data in the following weeks. Approximately three to six weeks after the assessment, your facility management will receive the assessment report with all the assessing field technician's findings and recommendations as well as a digital inventory of all observed equipment.

Who do I call if I have questions?

Cadmus works on NEEA's behalf to implement this phase of research study. Contact Kristie Rupper by calling 240.204.6217 or emailing Kristie.Rupper@cadmusgroup.com.

To speak with someone at NEEA, contact Dulane Moran by calling 503.688.5400 or by sending an e-mail to dmoran@neea.org

CADMUS

Customer Acceleration Protocol

For utility reference and Cadmus team use during recruitment and assessment process

The customer acceleration protocol is shown on the following pages.

Customer Acceleration Protocol

As this research is associated with local utilities, customers may use this opportunity to provide information that should be communicated to the utility. This protocol provides information about when customer comments will be gathered, types of comments that should be gathered, and how and when comments should be communicated to the utility.

Cadmus recognizes that customers may provide information that should be relayed to their utility at any customer touchpoint during the CBSA scheduling and site visit process, including the following:

- During or after contact from a utility or trade organization
- After receiving a recruitment postcard
- Messages on the inbound toll-free line
- During or after the scheduling call
- During or after the site assessment

Cadmus will track all customer acceleration content, including those occurring while a field technician is on site. For communication that occurs while the field technician is on site, the field technician will record the relevant customer information and will adhere to the acceleration protocol that follows.

When: Cadmus will gather customer comments if the customer meets the following conditions:

- Has questions or concerns about their energy bills
- Has questions about utility programs, such as energy efficiency programs or other utility-sponsored programs
- Has complaints about the utility
- Requests that their comments be passed on to the utility
- Provides other comments affecting the customer's satisfaction with their utility

What: Call center / Cadmus field technician will gather the following information for each customer comment:

- Customer name (verify spelling)
- Business name (verify spelling)
- Customer utility (both gas and electric, but indicate which utility the customer directs the comment to)
- Customer mailing address
- Customer phone number (the number at which the customer wishes to be contacted)
- Customer e-mail address (if possible)
- Customer comments
- Indication of whether the customer requests follow-up from the utility
- Date of contact

How:

The procedure for electric and gas utilities is the same. Cadmus will e-mail the information directly to the utility the customer wants their comment to be directed within 24 hours of the comment, and will copy Dulane Moran (dmoran@neea.org) at NEEA and Jeff Cropp (Jeff.Cropp@cadmusgroup.com) and Kristie Rupper (Kristie.Rupper@cadmusgroup.com) at Cadmus. Cadmus will compile the information from all individual e-mail messages into a tracking spreadsheet.

Interviewer Statement: This statement will be read to respondent following the conclusion of the comment. "Thank you for your comments. We will pass along your comment to your utility within 24 hours."

CADMUS

Example of Site-Specific Report

For customer during recruitment process

An example of a site-specific report is shown on the following pages.

FirstView® Software Report

new buildings institute

Building Summary

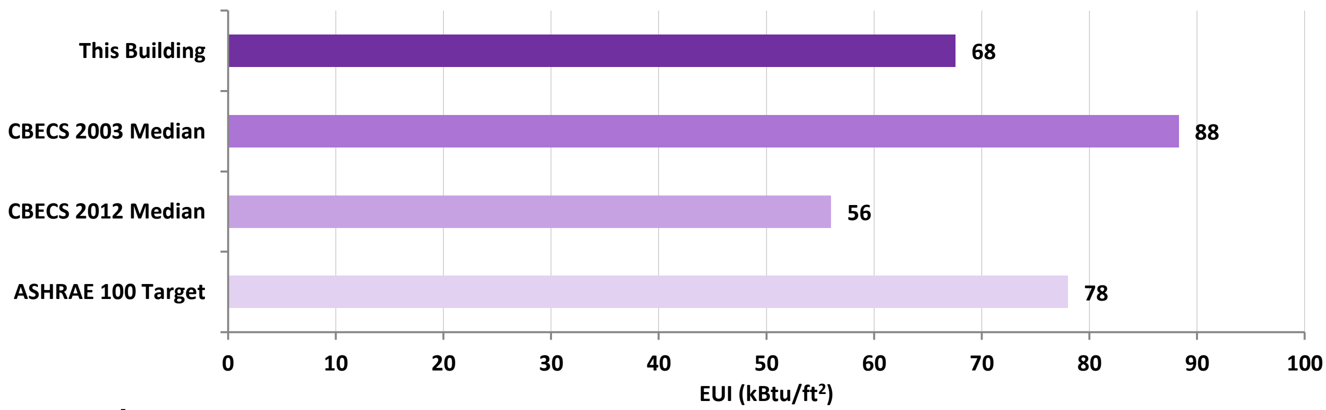
Building	Sample Building
Location	Portland, Oregon
Size	72,000 ft^2
Type	Public Safety

Reference Year Data

	From	To
Electric	Jan 2016	Jan 2017
Gas	Jan 2016	Jan 2017

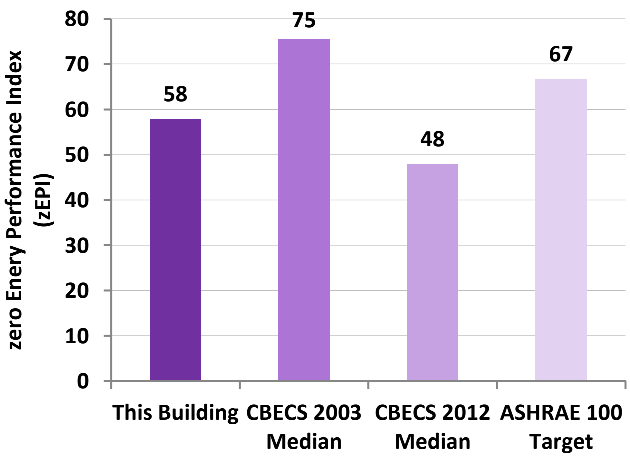
Annual EUI Comparison

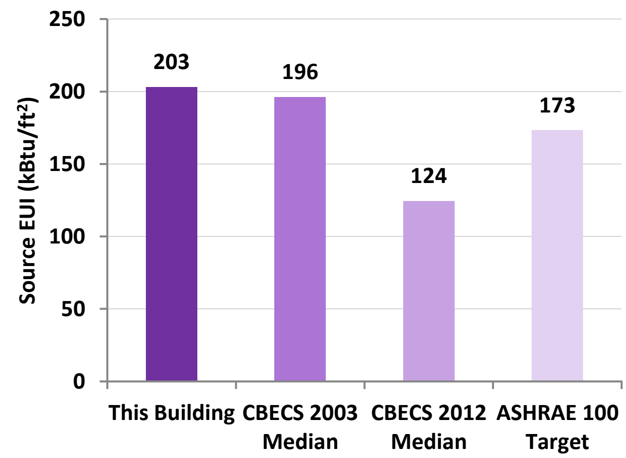
The Annual Energy Use Index (EUI) comparison shows the total energy use of the building during the reference year compared to the median nationwide and climate zone specific target energy use for police station buildings as reported by CBECS* and ASHRAE Std 100,** respectively.



zEPI / Source

The zEPI score*** normalizes the building by type and climate zone. A lower score is better, with 0 representing net zero energy performance. Source EUI takes into account the total raw energy needed to power the building, including generation and transmission losses.





* The Commercial Building Energy Consumption Survey (CBECS), published in 2003 and 2012, is commonly used to represent the energy use of typical existing building stock in the United States.

** ASHRAE Standard 100 details energy use targets for specific building types and climate zones which are derived from CBECS data.

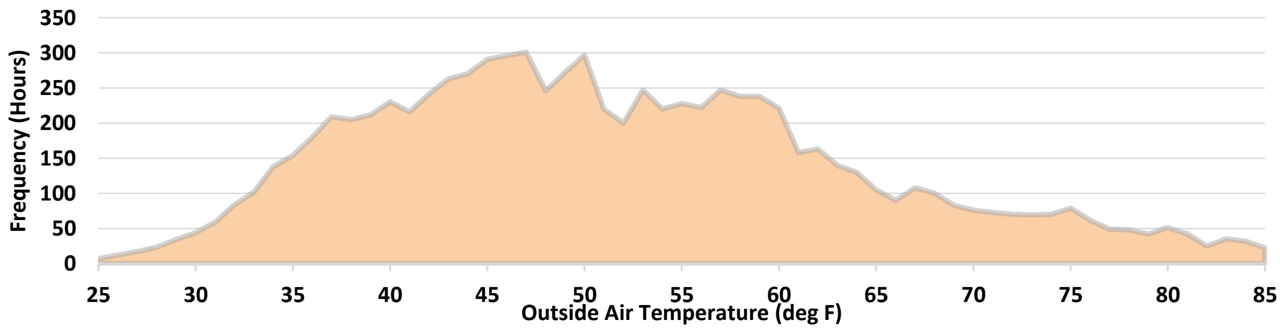
*** zEPI provides a performance score for a building normalized by building type and climate zone. It is based on fixed benchmarks. A score of 100 represents a turn-of-the-century building, while a score of 0 represents net zero energy.

FirstView® Software Report

nbi new buildings institute

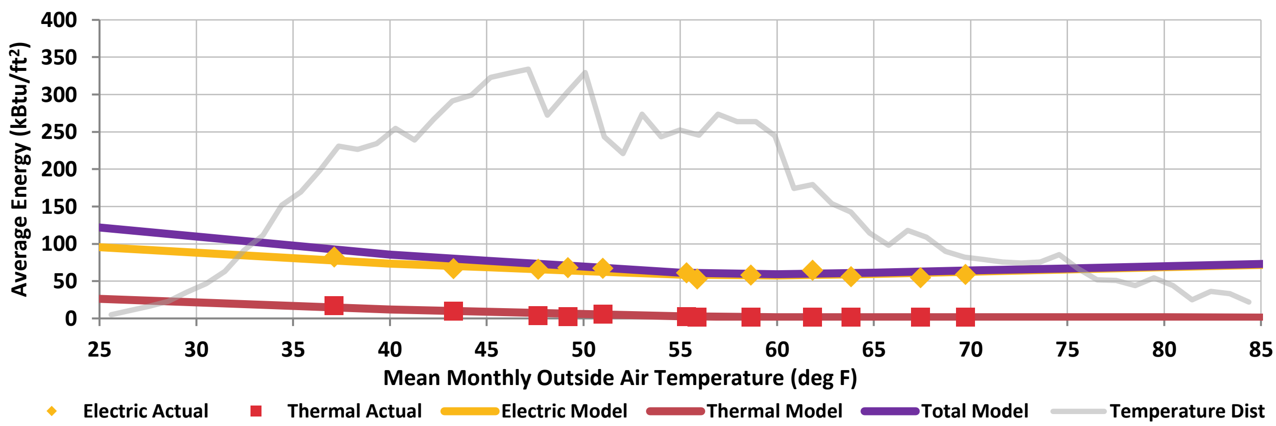
Typical Temperature Distribution

This figure shows the typical temperature distribution seen in Portland, Oregon. Compare this distribution with the energy signatures to see where your building is operating most often.



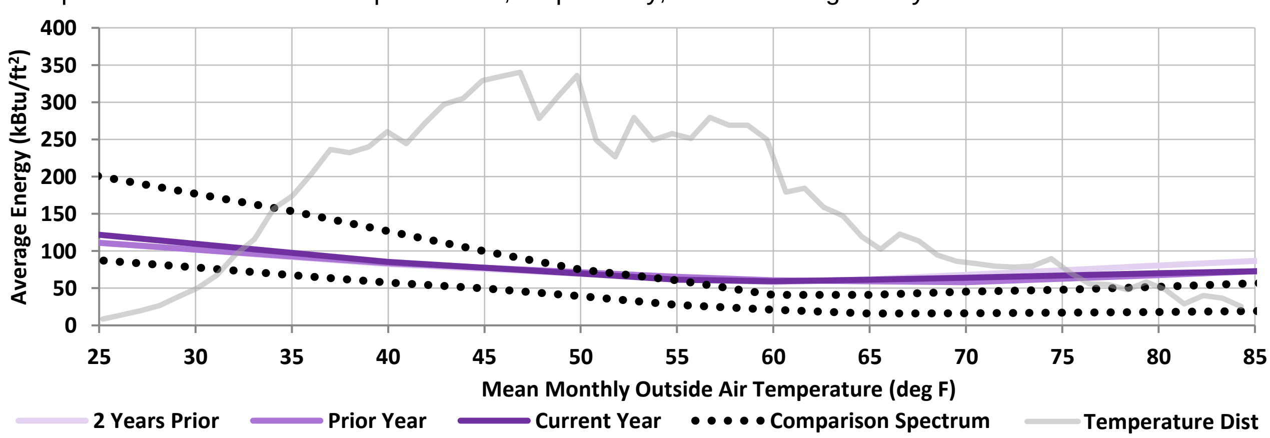
Energy Signature by Fuel

The Energy Signature by Fuel plot shows actual energy usage along with the FirstView modeled energy use, calibrated to the actual usage. Energy Signatures characterize average energy use at various temperatures. The plotted points in this chart represent the building's electric and gas usage, while the solid lines represent the FirstView models of the energy uses. The orange line represents total energy use, or the sum of the modeled lines.



Trending Analysis and Energy Signature Comparison

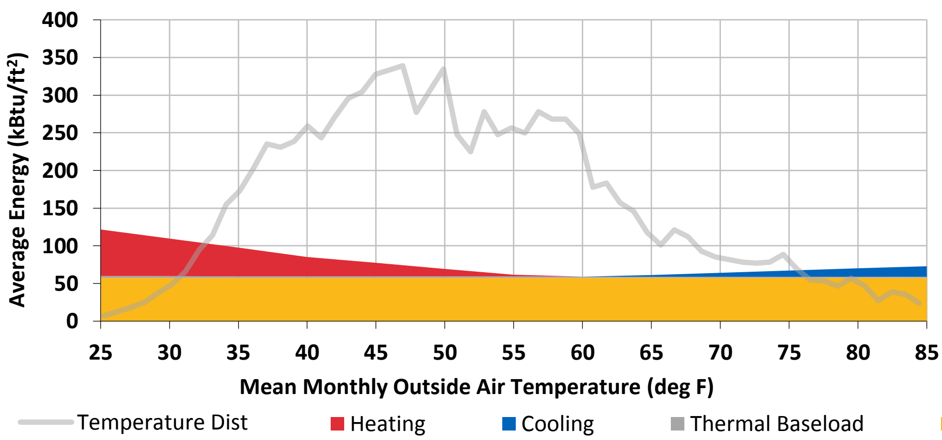
In this graph, the building's energy signature history is compared to a spectrum of other buildings analyzed in this study. This provides the opportunity for a comparison with building peers. The upper and lower dotted lines represent the 75th and 25th percentiles, respectively, of the buildings analyzed.

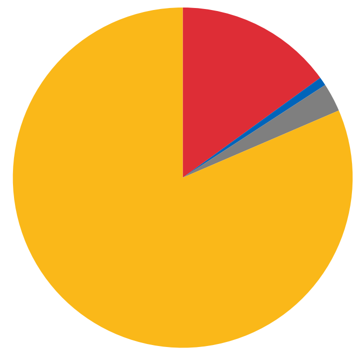


FirstView® Software Report

Consumption by End Use Energy Signature

The Consumption By End Use Energy Signature shows the total energy use split into four end use categories: heating (electric, gas, and/or steam), cooling, electric baseload (e.g. plugs, lights, and equipment), and thermal baseload (e.g. gas or steam used for water heating). This plot shows cumulative energy use at a range of outside temperatures and can offer insights into building consumption patterns. Click here to learn more.





Diagnostics

Category	Status
Heating and Ventilation Efficiency	Poor
Cooling Efficiency	Good
Controls	No apparent problems
HVAC Reheat	No apparent problems
Thermal Baseload	Typical
Light and Plug Loads	High
External/Process Load	No apparent problems
Data Consistency	Orderly

Automated diagnostics are generated by analyzing the shape of the Energy Signature and comparing it to aggregate data collected from similar buildings in the FirstView database. Click here to learn more.

Additional Notes

This building may be a good candidate for potential heating system improvements. Excess outside air rates, high outside air infiltration, poor control settings, and 24-hour fan schedules may be present.

The building has an elevated electrical baseload. Barring process electrical loads, savings may be available via lighting upgrades and/or plug load management.

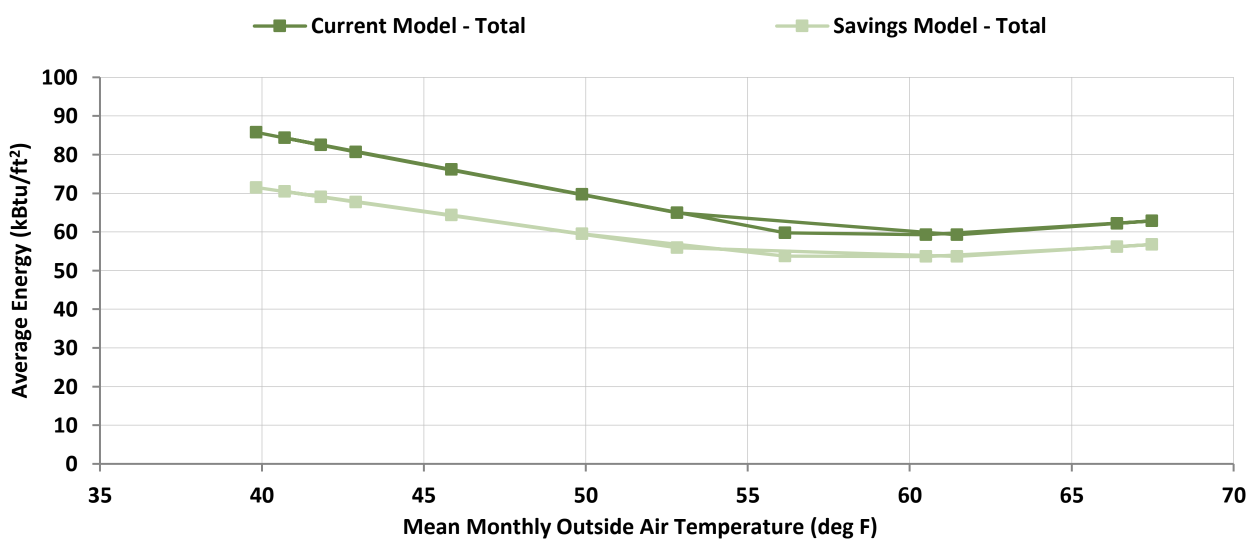
FirstView® Software Report

Environmental Impacts

Annual Energy Consumption	1,684,000 kWh
Annual Carbon Impact	1,224,000 lbs CO_2
Annual Water-Energy Impact	664,000 Gallons

Savings Potential

This plot shows the weather normalized building performance for a typical meteorological year (TMY) as currently modeled compared to the potential performance of the building with improvements as outlined in the table below



Model Variable	Current	Target	% Improvement
Shell and Ventilation Efficiency (Btu/°F-hr-ft^2)	0.73	0.87	20%
Cooling Efficiency (COP)	20.0	22.0	10%
Lights and Plug Loads (W/ft^2)	1.04	0.94	10%
Summer Gas Use (Gallons of hot water/day-ft^2)	0.033	0.03	10%

Annual Costs and Savings Potential Estimates		Current	Target	% Improvement
Energy	kWh	1,684,288	1,417,010	16%
Energy Cost	dollars	$ 32,862	$ 27,923	15%
CO_2	lbs	1,223,697	1,037,731	15%
Watershed	gallons	663,575	651,257	2%

Appendix D. Within-Site Sampling and Weighting

This section provides an overview of the within-site sampling and weighting approach used for the CBSA. The overview includes a review of how Cadmus developed the samples and weights, and how they are applied to the data. This provides more detail for the information found separately in the 2019 CBSA Database Users Manual.

Within-Site Sampling Weights

We calculated within-site sampling weights based on selection probabilities derived from within-site sampling plans. The database reports the within-site sampling weights for each building, business, and room, and users may combine them with site case weights to calculate regional metrics. Additionally, the database includes the combined weights, which users may apply to calculate regional metrics directly.

All levels of sampling were subject to the practical limitations of the site visit, including safety and security restrictions and participant agreement. In some cases, the team could not assess businesses or rooms selected by the sampling plan. Technicians attempted to sample replacement spaces whenever possible while on site. We adjusted the sample weights reported in the CBSA database to reflect the actual spaces visited during each site assessment.

Building Sampling

At any site with more than three buildings, we considered within-site building sampling when there was insufficient time to collect data from all buildings. Our sampling criteria involved the following:

- We selected any building that accounted for more than one-third of the site total floor area with certainty. We set these within-site selection probabilities to 1.
- We selected other buildings with probability proportional to size. For these selections, we set the within-site selection probabilities to the number of non-certainty selections times the ratio of the floor area of the selected building divided by the total floor area of the site (excluding the floorspace of any building selected with certainty).

The Cadmus team calculated building sampling weights as the inverse of each building's selection probability. Users can apply the building sampling weights to building metrics within a site to estimate site totals and site weights to site totals to estimate regional totals. The regional expansion weight is the within-site building weight (inverse of within-site selection probability) multiplied by the site case weight and is provided in the building summary and facility tables in the database.

Business Sampling

At any site or building with more than three businesses or more businesses than were feasible to visit during the site visit, we considered business sampling when there was insufficient time to collect data from all businesses:

- If one business accounted for more than 50% of the floor area, we selected it with certainty and set its selection probability to 1.

- We selected additional businesses at random from within each business type present:
  - Within each business type category, we selected a simple random sample of businesses.
  - We set selection probabilities equal to the number of businesses sampled divided by the number of businesses in each type.

We calculated business sampling weights as the inverse of each business' selection probability and applied the business weight to metrics measured at the business level (within a building) to estimate total building metrics. We then applied the building weight to estimate site metrics and applied site weights to estimate regional metrics. The business table in the database lists the business sampling weights.

Business weights apply to the following tables: onsite_generation, building_controls, water_heaters, pool_and_hot_tub, laundry_equipment, lab_equipment, lodging_information, medical_facility_information, air_compressor, reach_ins_display_cases, refrigerated_walk_ins_storage_boxes, refrigeration_compressors, and refrigeration_condensers. Business weights also apply in any table which uses room sampling, but that we incorporated into the room weights as described below.

Room Sampling

At any site or building with more rooms than were feasible to visit during the site visit, we considered room sampling:

- If one room accounted for over 50% of the floor area in the business or building, we selected it with certainty and set its selection probability to 1.
- We selected other rooms at random from within each of 11 space type categories:
  - Within each space type category, we selected a simple random sample of rooms.
  - We set selection probabilities equal to the number of rooms sampled divided by the number of rooms in each space type.

We calculated room sampling weights as the inverse of each room's selection probability. When a room was sampled within a business, we applied the corresponding business weight to the room weight. We then applied to the room weights to room metrics within a building to estimate building total metrics and applied the corresponding building weight to estimate site metrics. Finally, we applied site weights to estimate regional metrics.

We primarily used room sampling to collect lighting data. We also used it to collect some HVAC, general office, and food service equipment data. The rooms table in the database lists the room sampling weights. However, due to the complex database relationships between rooms and other tables, users should utilize the aggregated weights listed in the various equipment tables. The lighting and HVAC weights are listed in their respective summary tables and are detailed below. The general_equipment and food_service_equipment tables list aggregated sampling weights.

HVAC Case Weights

HVAC sampling was not necessary in over 90% of buildings because our technicians could assess all of the HVAC equipment. HVAC case weights were equal to 1 in these cases. Cadmus developed case weights in the following situations, when technicians could not assess all of the HVAC equipment at a building:

- We conducted within-site business sampling and assessed all HVAC systems within sampled businesses (but not all HVAC systems at the site or in a building). HVAC case weights were equal to business weights in these cases.
- We conducted within-site room sampling and HVAC served individual rooms. HVAC case weights were equal to the room weights in these cases.
- An HVAC system served multiple rooms or businesses, and we determined a more complex sampling approach was necessary due to the distribution of HVAC in a building. We calculated HVAC case weights manually, on a case-by-case basis, based on a review of the quantity of systems, spaces served, and within-site sampling weights of spaces served by the HVAC equipment.

We reported the case weight for each HVAC system in the hvac_system table and the hvac_summary table. Refer to the data dictionary for information on specific column names and definitions.

Lighting Case Weights

Lighting sampling was necessary in many buildings because our technicians could not assess all of the lighting equipment. In buildings where technicians assessed all lighting, case weights were equal to 1. Otherwise, we developed case weights. We based lighting case weights on spaces associated with lighting groups. We sampled each lighting group with one of the following approaches:

- All in building: We collected data on all lighting in the building. Each lighting group contains one or more “miscellaneous space” entries. All lighting case weights are 1.
- All in business: We collected data on all lighting in a sampled business. Each lighting group contains one or more “miscellaneous space” entries within the business. Lighting case weights are equal to the case weight of the business.
- Room sampling: We sampled lighting by rooms. Each lighting group contains one or more “room” entries. Lighting case weights are aggregated from the room weights and the business weights if the rooms are within a business.

When we used either business or room sampling, we calculated the initial within-building lighting group case weights as a weighted average of the room and business sampling weights, weighted by the floor area of the spaces represented in lighting group ‘*j*’ in building ‘*i*’, as follows:

$$\text{initial lighting group weight}_{ij} = \frac{\sum_{k=1}^{K}\left((\text{space floor area}_{ijk})(\text{room sampling weight}_{ijk})(\text{business sampling weight}_{ijk})\right)}{\sum_{k=1}^{K}(\text{space floor area}_{ijk})}$$

Where 'k' indexes the rooms in the lighting group from $k = 1, \dots, K$. These are labeled as initial weights because there were discrepancies between the weighted sum of sampled floor area (in the denominator of the previous equation) and the actual total floor area in some buildings. These discrepancies were due to the Phase 1 prescribed sampling approach that did not account for room or business floor areas during within-building sampling, as well as instances when our technicians could not observe rooms of some space types due to restrictions during the site assessments. The resulting inaccuracies led to over- or under-estimates of the building total floor area, when compared to the observed total.

To address this, we applied a correction factor to the initial lighting group weights corresponding to each building. We calculated the correction factor as the ratio of the observed building floor area divided by the weighted total floor area estimate (calculated based on the weighted floor areas of the sampled spaces), as follows, where 'k' indexes all rooms in the building from $k = 1, \dots, K$.

$$\text{building weight correction factor}_{i} = \frac{\text{total building floor area}_{i}}{\sum_{k=1}^{K}\left((\text{space floor area}_{ik})(\text{room sampling weight}_{ik})(\text{business sampling weight}_{ik})\right)}$$

We then calculated the final lighting group case weights as follows:

$$\text{corrected lighting group weight}_{ij} = (\text{initial lighting group weight}_{ij})\,(\text{correction factor}_{i})$$

We applied these lighting group weights to the wattage observed for each lighting group to estimate building total wattages. Then, we applied building and site weights to building total wattages to estimate regional total wattage.

The lighting_summary table lists the lighting group weight for each lighting group as sample_weight_lighting; users have two options:

- Users can multiply the lighting group weight (sample_weight_lighting) with the building case weight (sample_weight_facility) and the site case weight (sample_weight_site). The resulting product represents the case weight, which users can then multiply to the metric of interest to determine the regional value represented by each lighting group (e.g., wattage).
- The lighting_summary table includes pre-calculated regional metrics of particular importance including wattage (regional_wattage_represented) and lamp counts (regional_lamps_represented); users can directly apply these metrics (i.e., the multiplication described in the previous bullet has already been completed).

The floor area included in one lighting group may overlap with floor areas included in other lighting groups because we created separate lighting groups to aggregate fixtures with different control strategies, installed fixture height, schedules, or other characteristics. Therefore, it is important not to directly sum floor areas from the lighting summary table. The column weighted_sqft_in_space_type in the lighting summary table contains the total floor area for all spaces with the same space type as the predominant space type in each lighting group. This value is the same for each row with the same space_type and facility_id columns. Summing weighted_sqft_in_space_type once for each unique space_type value in a building will yield the total floor area of the building. Refer to the data dictionary for additional details.

General Equipment and Food Service Equipment Case Weights

We calculated case weights for the general_equipment and food_service_equipment tables by taking a weighted average of the room weight times the business weight (or 1, if we did not conduct business sampling) based on room square footage. We provided the resulting weights in the general_equipment and food_service_equipment tables. Users can apply these weights by multiplying them by the metric of interest to acquire the building-level metric. Users can then weight the building-level metric up to the region by multiplying it with the building case weight and the site case weight.

Data Center Sampling

Data center spaces represent the one variance from the within-site sampling approach described above. For these spaces, field technicians compiled the total floor area for all data center spaces (e.g., server rooms, server closets, localized data centers). The data collection protocols required the field assessor to select the largest data center space at the facility for auditing purposes. The assessor did not gather any additional data on other data center spaces except their floor area.

Appendix E. Comparison of LPD to State Energy Codes

Cadmus developed a comparison for assessed lighting power densities against the requirements of state energy codes to better understand the regional progress toward meeting code requirements. The current state energy codes at the date of publication of this report follow:

- Idaho: 2015 International Energy Conservation Code (IECC)
- Montana: 2012 IECC
- Oregon: ASHRAE 90.1-2016
- Washington: 2015 Washington State Energy Code[14]

The LPD for the assembly building type is a straight average of the seven building area types that represent assembly subtypes. Grocery does not have its own building area type LPD under any of the codes, so we used the value for retail. There are no direct comparisons for building area type LPDs available for mixed commercial, other, or residential care, so we excluded those from the comparison. We separated the analysis between buildings constructed before the 2014 CBSA and new construction since that study. The pre-2014 sample contained sufficient sites to look at all nine building types for each region.

Table 16 shows the comparison for the Idaho / Montana region. We highlighted in blue the instances in which the average 2019 CBSA LPD was less than the state energy code requirement. Cells in orange indicate average LPDs greater than state energy code requirements. As the table indicates, the average LPD in older buildings in this region falls below state code requirements, except for offices. Therefore, office buildings in this region may represent an opportunity to target for lighting energy efficiency.

Table 16. Idaho/Montana Building Codes vs. 2019 CBSA LPD (pre-2014 Buildings)

Building Type	Idaho Code	Montana Code	2019 CBSA (pre-2014)	Buildings in Sample
Assembly	0.97	1.2	0.86	4
Grocery	1.26	1.4	1.02	6
Hospital	1.05	1.2	0.97	13
Lodging	0.87	1	0.77	19
Office	0.82	0.9	1.07	37
Restaurant	0.95	1.6	0.66	3
Retail/Service	1.26	1.4	1.01	22
School	0.87	1.2	0.60	2
Warehouse	0.66	0.6	0.53	5

14 The Washington State Energy Code will update later in 2020.

For buildings in Oregon, the results are similar. Table 17 shows that the average LPD in older buildings falls below state code requirements, except for schools. The average LPD for offices matched the state code requirement. We consider it notable that Oregon recently updated its energy code, but nearly all building types already meet or fall below the LPD code requirements. However, there may be opportunities for energy efficiency programs to target offices and schools for lighting upgrades.

Table 17. Oregon Building Codes vs. 2019 CBSA LPD (pre-2014 Buildings)

Building Type	Oregon Code	2019 CBSA (pre-2014)	Buildings in Sample
Assembly	0.81	0.73	12
Grocery	1.06	0.95	21
Hospital	1.05	0.96	15
Lodging	0.75	0.64	19
Office	0.79	0.79	41
Restaurant	0.78	0.46	22
Retail/Service	1.06	0.73	37
School	0.81	0.83	20
Warehouse	0.48	0.43	26

However, in Washington we found a large portion of older buildings had an average LPD that exceeded the code requirement, as shown in Table 18. Washington has the most stringent code among the four states, so it is less surprising that only a small portion of building types had average LPDs below the state energy code. The new Washington energy code will take effect later in 2020, with presumably even more stringent lighting power requirements. These results indicate significant opportunities to achieve additional commercial lighting savings relative to code across many building types in Washington state.

Table 18. Washington Building Codes vs. 2019 CBSA LPD (pre-2014 Buildings)

Building Type	Washington Code	2019 CBSA (pre-2014)	Buildings in Sample
Assembly	0.77	0.64	53
Grocery	1.01	0.73	32
Hospital	0.84	0.89	24
Lodging	0.7	0.49	43
Office	0.66	0.84	73
Restaurant	0.71	1.02	24
Retail/Service	1.01	0.85	69
School	0.7	1.03	39
Warehouse	0.4	0.53	71

The post-2013 sample was not large enough by both building type and region for a reasonable comparison, so we aggregated all new construction buildings across the region. Table 19 shows the average LPD in newly constructed buildings across most building types fell below most, if not all state energy codes. This is likely due, in large part, to the fact that 19 of 32 buildings were constructed in Washington state, with the most stringent energy codes. Only the hospital and office buildings generally exceeded energy code requirements. However, we note that these values represent only a small sample (e.g., one hospital, two offices). This sample size is not sufficiently robust to draw any meaningful conclusions on the relative values of installed LPD versus state energy code in new construction.

Table 19. Regional Building Codes vs. 2019 CBSA LPD (post-2013 Buildings)

Building Type	Idaho Code	Montana Code	Oregon Code	Washington Code	2019 CBSA (post-2013)	Buildings in Sample
Assembly	0.97	1.2	0.81	0.77	0.29	3
Grocery	1.26	1.4	1.06	1.01	0.53	1
Hospital	1.05	1.2	1.05	0.84	1.13	1
Lodging	0.87	1	0.75	0.7	0.34	2
Office	0.82	0.9	0.79	0.66	1.07	2
Restaurant	0.95	1.6	0.78	0.71	0.93	4
Retail/Service	1.26	1.4	1.06	1.01	0.72	5
School	0.87	1.2	0.81	0.7	0.54	7
Warehouse	0.66	0.6	0.48	0.4	0.32	7

Finally, we note It is likely the lower LPDs relative to code requirements reflect the increasing transition to LED lighting at the expense of older, less-efficient lighting sources. We expect this trend to continue, particularly due to the large opportunity still remaining to replace linear fluorescent fixtures in commercial buildings.