SEATTLE ENERGY BENCHMARKING
Analysis Report

2016 DATA

SEPTEMBER 2018

Seattle
Office of Sustainability
& Environment

Acknowledgments

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Executive Summary

BENCHMARKING HIGHLIGHTS FOR 2016

With three consecutive years of high compliance rates and a focus on improving data quality, the 2016 dataset provides the most extensive building performance data to date. Energy benchmarking is foundational to reducing energy use and greenhouse gas emissions as part of Seattle's Climate Action Plan—raising the awareness of energy consumption among building owners and managers enables opportunities to reduce energy use and save money.

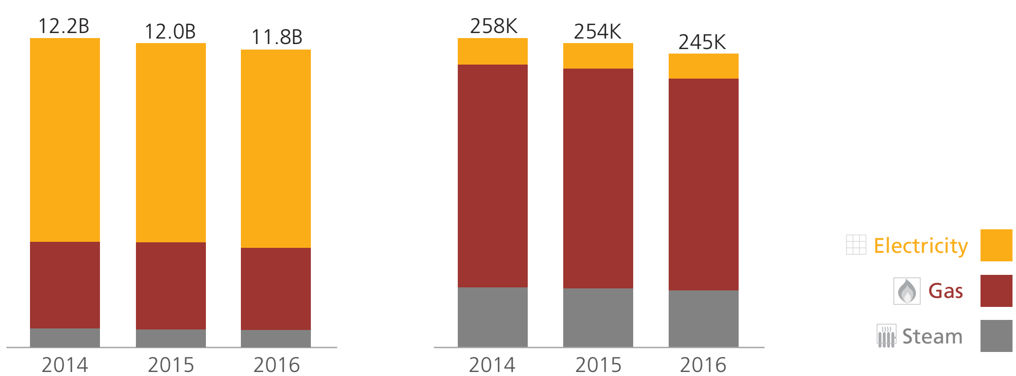
1 GROWING CITY, IMPROVING ENERGY STAR SCORES

From 2013 to 2016, the benchmarking program added 136 buildings and nearly 43 million square feet of space as Seattle's construction boom has continued. The median ENERGY STAR score for all buildings has increased by seven points (or 10%) in that time while the program has maintained over 99% compliance each year.

2016				
	3,352 buildings	323 million square feet	75 Median ENERGYSTAR score	99% Compliance Rate

2 EXISTING BUILDINGS IMPROVING PERFORMANCE

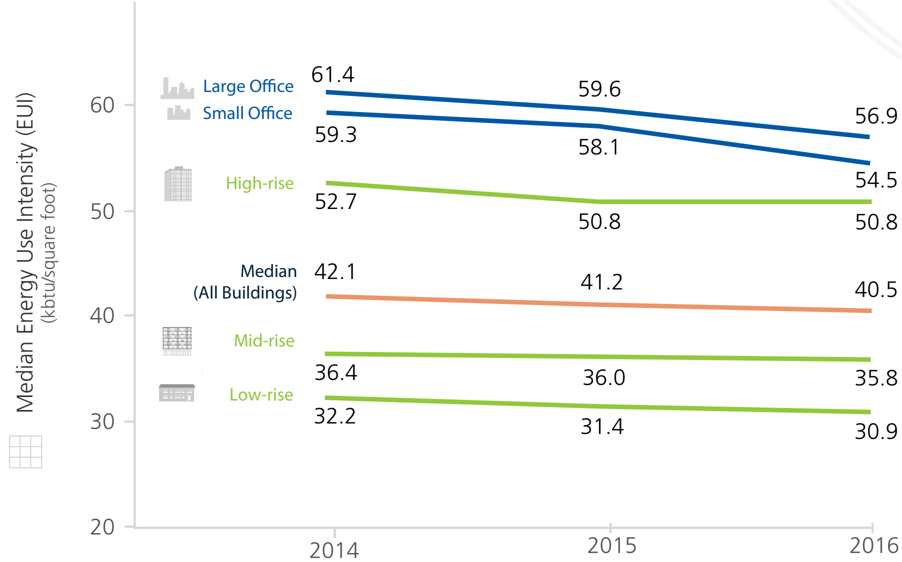
Buildings reporting three or more consecutive years of data have reduced overall energy consumption and associated greenhouse emissions. From 2014 to 2016, total energy use for these buildings declined 3.7% and total emissions declined 4.8%.



Energy Use (kBtu) ↓ 3.7%

Emissions (MT) ↓ 4.8%

During this time period, most major building categories have seen decreases in median energy use intensity after accounting for weather variation. Office buildings have seen some of the biggest improvements–the median EUI for large office buildings declined 7% from 2014 to 2016. The median EUI for all buildings decreased from 42.1 to 40.5 or 3.8%.

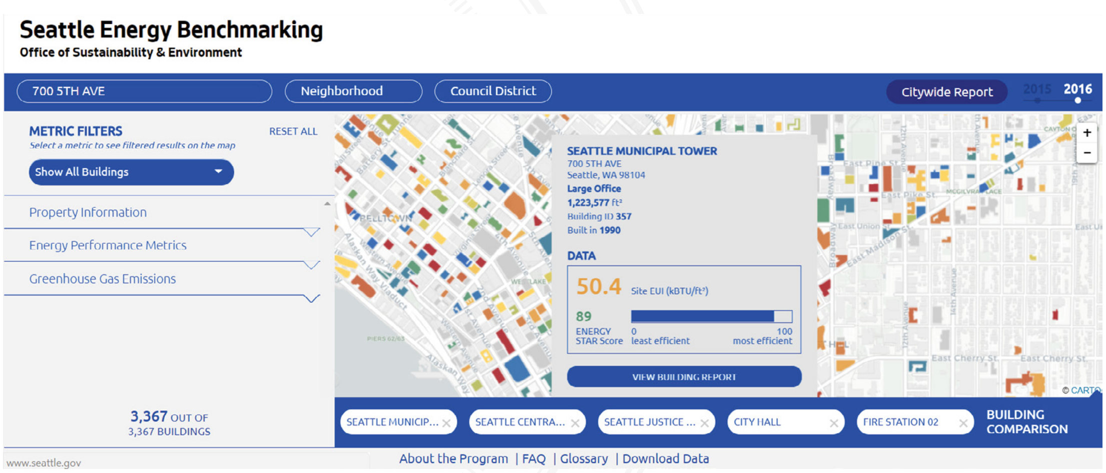


3 EMISSIONS REDUCTION OPPORTUNITIES

Although energy reductions since 2014 have led to reduced emissions, many buildings still have room for significant emissions reductions. Building types with significant gas end uses like hotels, hospitals, high-rise multifamily buildings, labs, and restaurants have the highest emissions per square foot and offer the largest savings opportunities.

4 INCREASING DATA ACCESSIBILITY THROUGH ONLINE PROFILES

Seattle moved to online building performance profiles to allow for easier public sharing, customized reports for all building types, and to streamline creation. Online building reports for 2015 and 2016 are now available for all buildings. The site allows the public to compare buildings on key metrics and filter by building type, size, or year built.



www.seattle.gov/energybenchmarkingmap

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1. Introduction

This report summarizes Seattle's 2016 building benchmarking data analysis efforts, including updates to key building characteristic and energy performance metrics last reported using 2013 benchmarking data.[1] Data on building characteristics, energy use, and greenhouse gas emissions from multifamily and non-residential buildings 20,000 square feet and larger are presented along with a summary of recent program accomplishments, data cleaning and analysis methods, and recommendations for future analyses methodology improvements.

Building benchmarking is a first step toward understanding and managing energy use. Benchmarking helps owners identify opportunities to increase profitability by lowering energy and operating costs.

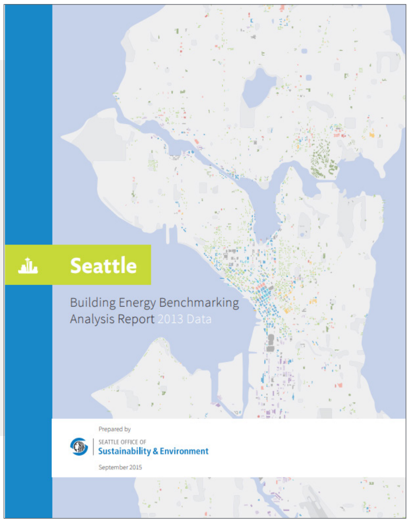
Seattle Energy Benchmarking Program

Adopted in 2010, Seattle's Energy Benchmarking Program (SMC 22.920) requires owners of non-residential and multifamily buildings 20,000 square feet or larger to track energy use and report benchmarking scores annually to the City. Owners are required to use the U.S. Environmental Protection Agency's free online benchmarking tool, ENERGY STAR Portfolio Manager®, which is the national standard for tracking energy use. As of the 2016 data reporting deadline (April 2017), over 3,000 buildings have been required to report for three or more years with newly constructed buildings added to the data every year. With high compliance rates each year since 2013 and improving data quality a focus of the program, the 2016 dataset provides the most complete performance data to date.

Seattle updated the benchmarking ordinance in 2016 to make reported data publicly available so that key information about building performance is now easily accessible for building owners,

MORE INFORMATION ON SEATTLE'S BENCHMARKING POLICY

- OSE Director's Rule 2017-01 provides detailed ordinance requirements and clarifications and was updated after the ordinance was amended in 2016.
- Annual benchmarking data for 2015 and after can be downloaded at data.seattle.gov or explored in detail at seattle.gov/energybenchmarkingmap.
- Past reports and additional background are available on the benchmarking website.



1 The 2013 data report was published in September 2015 and provides additional information on the history of Seattle's building energy benchmarking efforts. The report is available online at www.seattle.gov/energybenchmarking.

managers, tenants, and other interested market actors. It is estimated that Seattle's benchmarked buildings represent about two-thirds of citywide non-residential square footage. Benchmarking and transparency are foundational to reducing energy use and greenhouse gas emissions – raising the awareness of energy consumption among building owners and managers enables opportunities to reduce energy use and save money. The data also helps the City track overall building energy use and emissions while informing energy efficiency policy and program development.

Recent Program Accomplishments

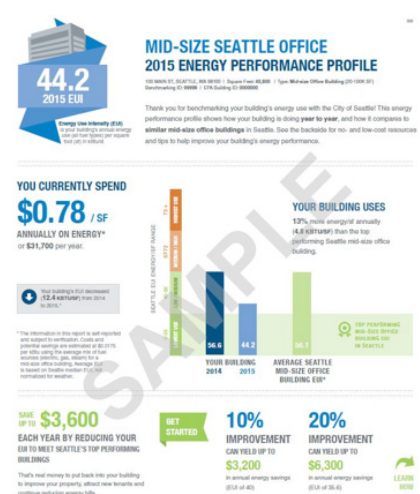
Seattle's Energy Benchmarking Program has focused on improving access to benchmarking data for building owners' and the public, maintaining the highest compliance rate in the nation, and improving data accuracy via the City's ability to automate data accuracy and compliance checks. This section includes a sample of recent program accomplishments in those areas as we work to drive increased awareness of building energy use and emissions as part of Seattle's Climate Action Plan.[2]

Figure 1: **Benchmarking Highlights 2013-2016**

2013	**3,216** buildings	**281** million square feet	**68** Median ENERGY STAR score	**99%** Compliance Rate
2016	**3,352** buildings	**323** million square feet	**75** Median ENERGY STAR score	**99%** Compliance Rate

Making Building Energy Usage More Accessible: Data Transparency and Building Profiles

After updating the benchmarking ordinance to make data publicly available, Seattle published 2015 and 2016 building performance data for more than 3,300 buildings through the City's Open Data portal (data.seattle.gov). Users can download, sort, or filter the data. The portal displays a wide range of building information—such as address, floor area, age, and building uses—as well as energy performance metrics like energy use per square foot (EUI), ENERGY STAR score, and greenhouse gas emissions.[3]



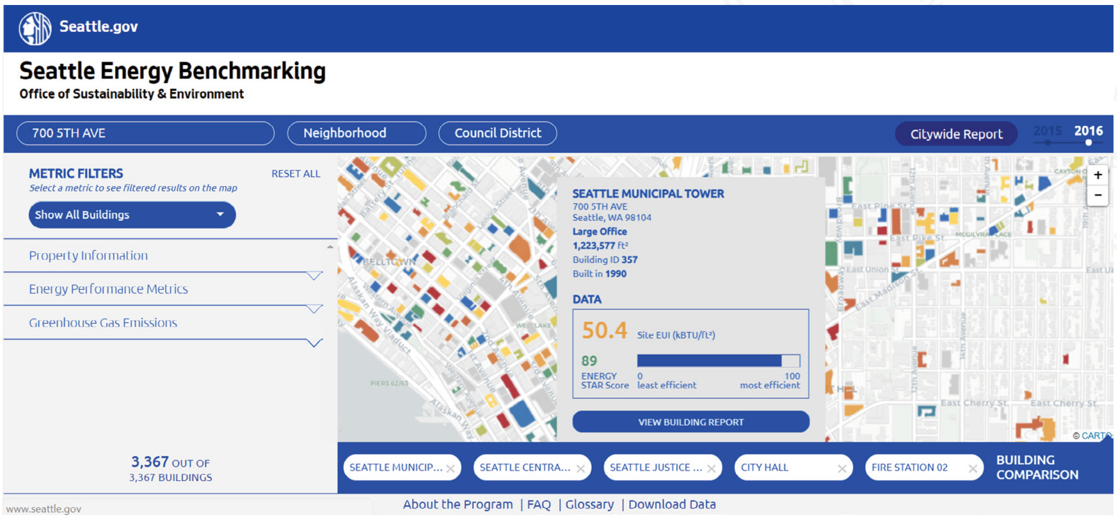
After a successful pilot program, Seattle developed customized benchmarking performance profiles for both 2014 and 2015 energy data. The 2014 and 2015 scorecards were sent to building managers

2 Visit *www.seattle.gov/environment/climate-change/climate-action-plan* to download the plan.

3 *Building performance data can be found by searching on data.seattle.gov or on OSE's website at www.seattle.gov/enegybenchmarking.*

and owners, reporting their building's performance data, ENERGY STAR score, and information on rebates provided by Seattle City Light. For 2014 building data, the performance profiles were tailored to five building types: large (>100K sq. ft.) and mid-size (20-100K sq. ft.) offices and three multifamily sectors (low-rise, mid-rise, and high-rise). For 2015 data, custom templates were added for retail and hotel buildings–and all building types had a version to recognize high performers.

Figure 2: **Benchmarking Data Visualization Tool**



www.seattle.gov/energybenchmarkingmap

In 2017, Seattle moved to online building profiles to allow for easier public sharing, customized profiles for all building types, and to streamline the creation of the annual profiles (see Figure 2). Online building profiles for 2015 and 2016 are now available for all buildings. Metrics include energy use per square foot (EUI), ENERGY STAR scores, greenhouse gas emissions, and fuel consumption breakdown. The tool allows for easy comparison within a building type as well as a summary of the overall dataset in a citywide report.

Continued High Compliance Rates

The Energy Benchmarking Program works continuously throughout the year to prioritize compliance, resulting in low violation rates. A Benchmarking Help Desk is available to assist building owners meet the annual benchmarking and reporting requirement twelve months a year, providing free technical assistance. Additionally, a formal warning letter and a grace period of three months after the April 1st deadline give owners an additional opportunity to become compliant before violations are issued. Program staff and the help desk continue working with owners to bring buildings into compliance even after violations are issued. This continuous outreach and support well beyond the reporting deadlines has resulted in four years of compliance rates above 99%.

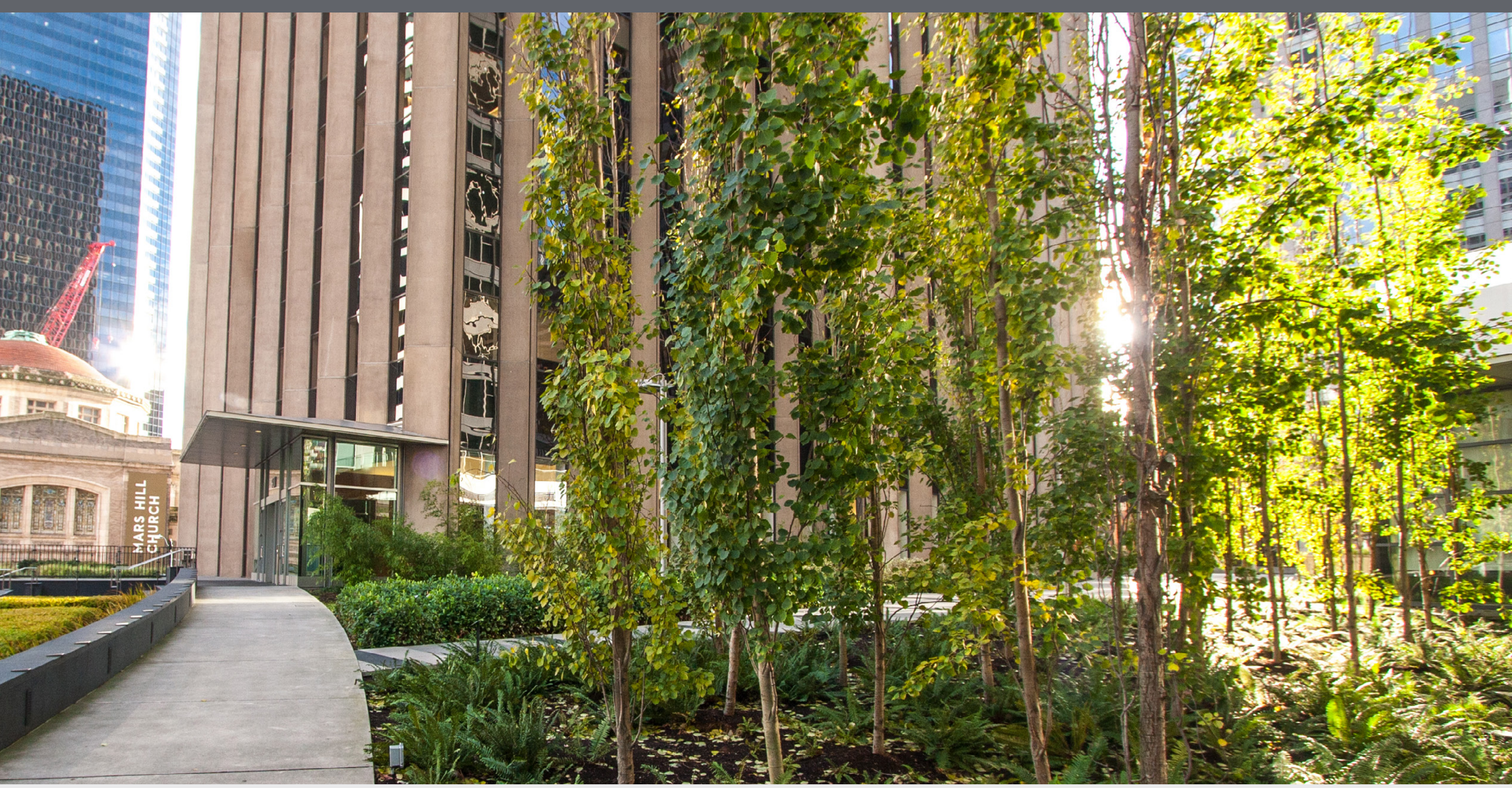
Improvements in Data Accuracy and Automation

To more efficiently identify possible data accuracy issues and optimize staff time, the City has built automated data quality checks into the benchmarking database over the past three years. When the City downloads data from Portfolio Manager, building data is automatically checked for default values in space details, for incomplete energy reports (missing electricity data or not generating an

EUI), and for energy use outside a reasonable range for its building type. This automation allows staff and the help desk to easily identify non-compliant buildings or likely errors when working with customers or to conduct proactive outreach in advance of the reporting deadline to help owners comply.

ENERGY STAR Award for Excellence in Data Innovation

Many of these program accomplishments led to an ENERGY STAR Award for Excellence in Data Innovation in 2017 from the U.S. Environmental Protection Agency's (EPA) ENERGY STAR program. EPA recognized the Office of Sustainability's "strategic approach to data innovation" and highlighted the City's efforts to increase the accessibility of building performance information and motivate city-wide energy efficiency improvements. EPA gives this award annually to recognize partners who increase the use of Portfolio Manager and use these metrics and data to drive energy performance improvements.



2. Data Cleaning and Analysis Approach

Data quality is essential to providing accurate analyses and insights about Seattle's existing buildings, therefore the City has continued to develop and refine a systematic approach to cleaning the reported data as part of its work. Reviewing and assessing Seattle's benchmarking data for quality and accuracy are primary objectives of the City's annual data analysis efforts. A related but equally important consideration is knowing which buildings to look at when conducting analyses over time. As the population of buildings reporting in each year changes slightly (as new buildings report and existing buildings change uses or are demolished), it is a best practice to include only buildings reporting in all years when summarizing changes over time, such as energy use or emissions changes.

Data Cleaning

The City compiled data for the analyses presented in this report from multiple sources, including Seattle's benchmarking data, King County Assessor data, and information from other City departments. These data contained fields with information on building characteristics, energy consumption, and greenhouse gas emissions. To ensure that the analyses drew upon accurate data, any identified inaccuracies in the data were removed to develop a "cleaned set." Buildings exhibiting data errors were identified and removed using several checks. These included:

Buildings missing electric or gas consumption values. Buildings with missing values lacked an energy use type where it was expected; for instance, they may have had gas consumption one year but not the next or they might be missing electric consumption data.

Buildings missing the data needed to calculate energy use intensity (EUI). This calculation is based on both energy consumption and floor area, so buildings that lacked either of those values were excluded.

Buildings with a year-over-year change in EUI greater than +/-50%. Buildings with such a large swing in EUI from one year to the next are typically errors or due to major occupancy changes.

Buildings identified as outliers by EUI. Buildings in the lowest or highest one percent by EUI among major building types were excluded as outliers.[1]

After these steps, the cleaned set contained 3,111 buildings for analysis. This is the set of buildings used for most analyses that are specific to 2016.

1 This check could only be applied to categories with at least 100 buildings.

In addition to identifying and excluding the likely errors above, the City ran another analysis to identify possible square footage errors in benchmarking data. We compared Assessor building and parking square footage data with Portfolio Manager square footage data to identify instances where building owners may have benchmarked building and/or parking square footage incorrectly. Each building was then assigned a code to allow for future follow up – No GFA Error, Possible Discrepancy, Likely Error. Most buildings flagged as "Likely Error" benchmarked parking square footage incorrectly by adding it to building square footage and either not including parking square footage or double counting it. Buildings with possible discrepancies or likely errors were flagged for follow up by the help desk to address any errors for the next reporting year.

Data Cleaning Recommendations for Future Analyses

In the process of cleaning the data, the City developed several recommendations to help guide future benchmarking analyses.

Moving to a standard deviation outlier approach will facilitate better detection of EUI outliers by building use.[2] While the current percentile approach works well for building categories with more than 100 buildings, using a standard deviation approach would allow for an outlier threshold to be set for all use categories.

Randomly selecting a sample of buildings to verify specific values may be helpful in ensuring overall data quality. Such a sample could focus on buildings identified as problematic by other data cleaning checks and multifamily buildings, which change management and ownership often. The City might also include buildings with ENERGY STAR scores greater than 98 or less than 2 as these buildings are more likely than others to have errors.

Analysis Approach

Analyses in this report were performed on one of three distinct subsets of the benchmarking data, depending on the objective:

Independent or 'Full' Set (3,352 Buildings)

Single-year analyses were conducted using an 'independent set' of buildings for a given year. When looking at Seattle as a whole at a single point in time, we began with the full benchmarked building population of 3,352 buildings for 2016. This is the primary lens for viewing non-energy characteristics of Seattle's benchmarked buildings, such as building vintage and location.

Cleaned Set (3,111 Buildings)

In addition, some analyses excluded buildings with outliers and questionable or missing data. The resulting "cleaned set," which contains 3,111 buildings, is the primary lens when looking at 2016 energy consumption metrics.

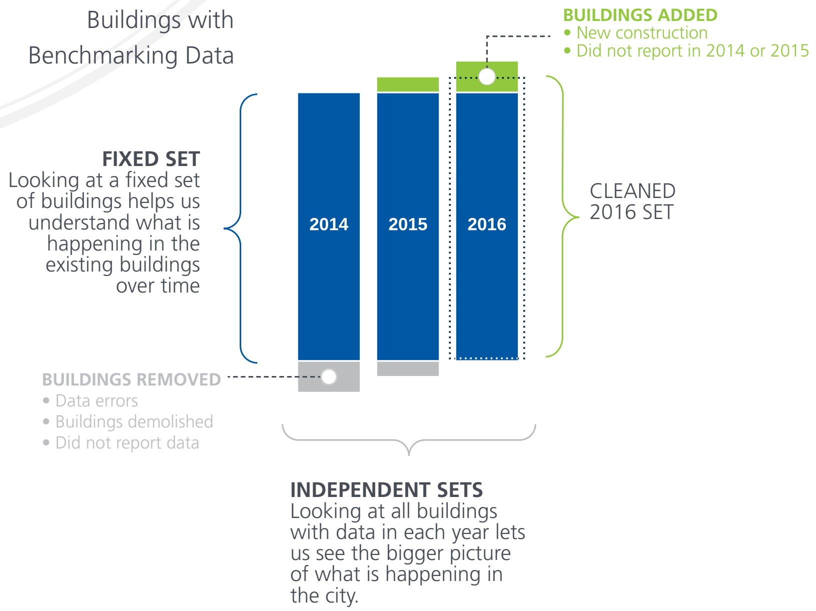
2 More specifically, EUI values should be log-transformed prior to application of a standard deviation cutoff. Additionally, applying a log transformation to the EUI data will help address some of the right skew inherent in the data. Based on a preliminary analysis of this benchmarking data, we note that 2.5 standard deviations appears to be an appropriate cutoff for future outlier identification.

Fixed Set (2,463 Buildings)

When looking at year-to-year trends in energy consumption or emissions, we filtered the "cleaned" set further to view only buildings that reported in every year between 2014 and 2016. This is the primary approach for understanding how a fixed group of benchmarked buildings has changed over time. This dataset contains 2,463 buildings.

The independent set contains more buildings than the fixed set and is thus the more appropriate set to use when looking at building energy characteristics in a single year (i.e., 2016). Alternatively, using the fixed set is more appropriate to understand the possible impacts from participation in the benchmarking program over time. Figure 3 shows this framework in a graphical format.

Figure 3: **Analysis Set Framework**



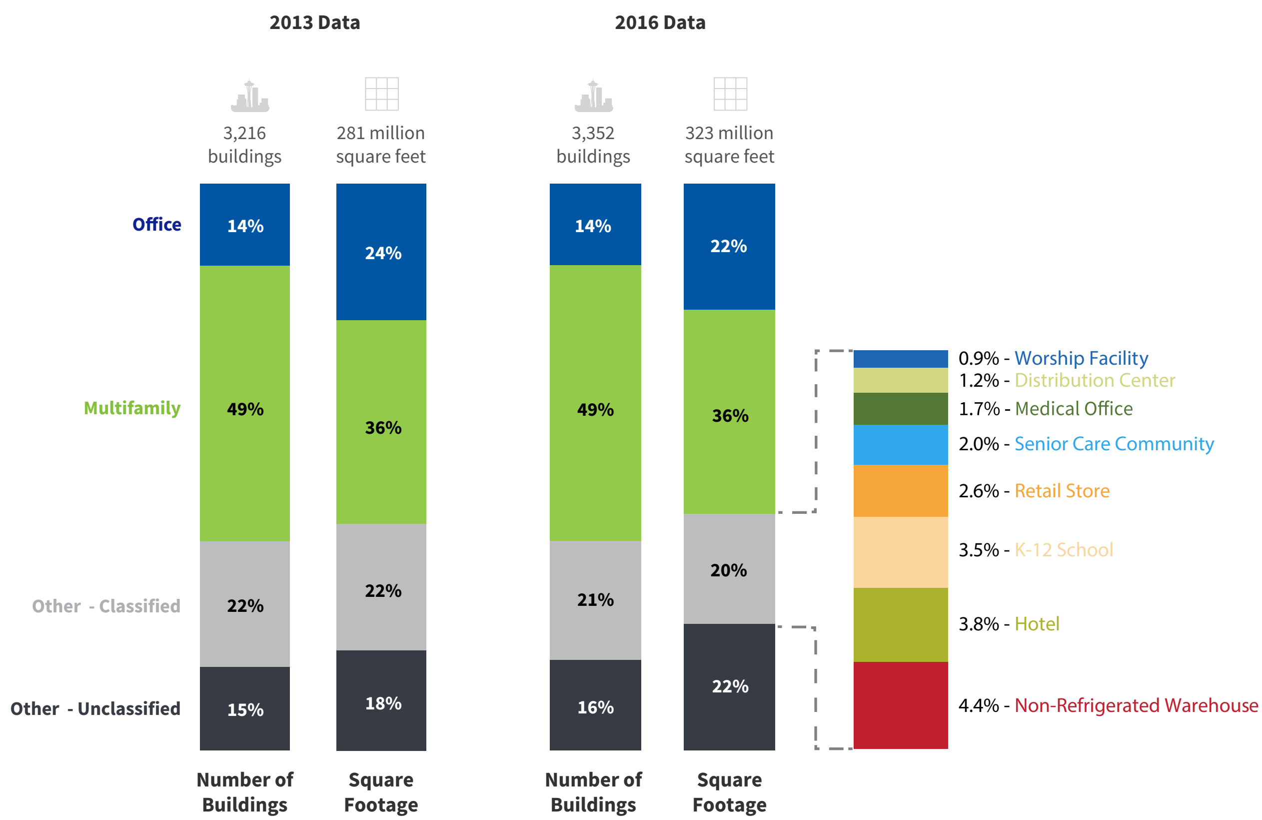
3. Building Characteristics

Seattle's Building Energy Benchmarking program provides the City with a detailed understanding of the composition of the non-residential and multifamily buildings in Seattle that are 20,000 square feet and larger. From this data, the City can glean more information than previously available about building type, square footage, age, and location. This chapter presents an analysis of the non-energy characteristics of the buildings in the 2016 dataset.

Non-Energy Characteristics of Benchmarked Buildings in 2016

The full or independent set of benchmarked buildings is most useful in examining the key characteristics of Seattle buildings citywide, for example in understanding how the composition of building types changes over time. Two major building types—office and multifamily—make up over half the city's benchmarked building population in both number of buildings and square footage.[1] This holds true for both 2013 data and 2016 data.[2] Non-refrigerated warehouses and hotels also make up large percentages of the City's gross floor area. Figure 4 shows this comparison.[3]

Figure 4: **Comparison of the Percentage of Buildings and Percentage of Gross Floor Area by Major Building Types in 2013 (left) and 2016 (right)**



1 Building types are defined by Portfolio Manager as the building's majority space use in square footage.

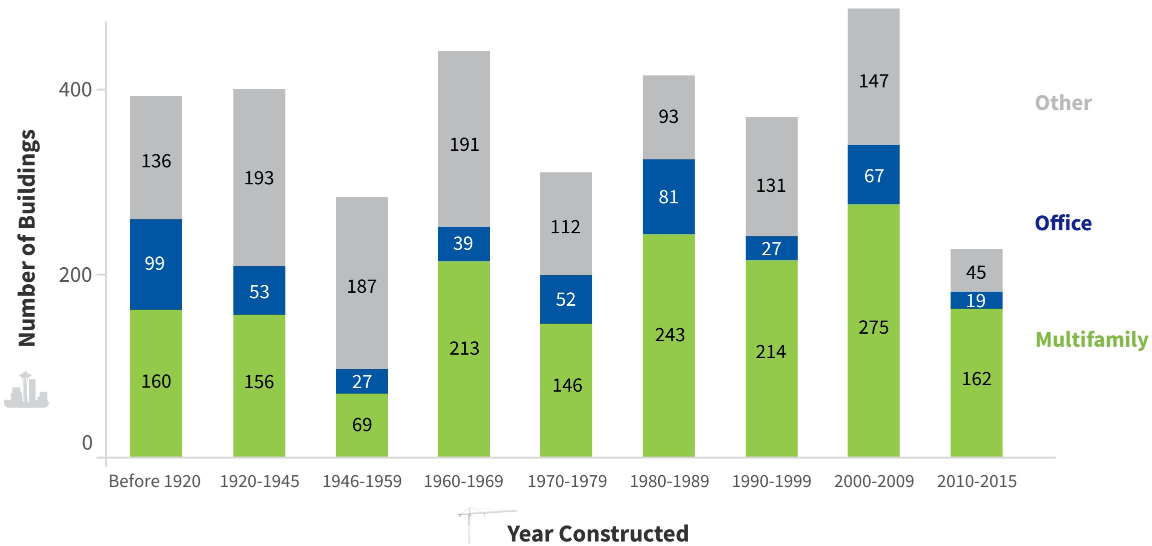
2 Analysis of the 2013 data was reported by the City in the previous building energy benchmarking report published in 2015. See www.seattle.gov/energybenchmarking.

3 The 2013 report did not include most of the University of Washington campus and therefore under represents the actual square footage reported in Figure 4. The campus began reporting in 2015.

Building Vintage

Building vintage (i.e., the date it was constructed) is important in understanding growth trends in Seattle (Figure 5). Seattle's buildings are young, with approximately 54% of buildings constructed since 1970. The most recent full decade, 2000-2009, saw more buildings constructed than in any other decade, especially multifamily buildings. The 2010-2015 category may be incomplete, as buildings are required to be occupied for a full calendar year before reporting.

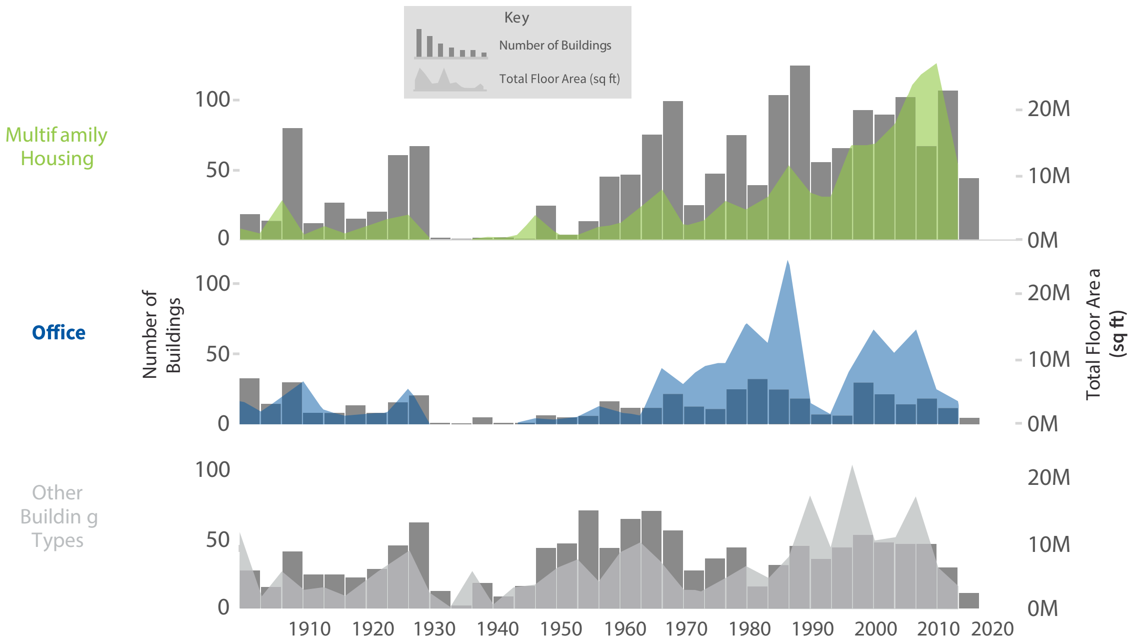
Figure 5: **Number of Buildings Built by Building Type by Decade [2016] (n=3,352)**



Compared to previous decades, buildings constructed from 2000-2009 also showed substantial growth in gross floor area (Figure 6). In this decade, over 50 million square feet of building area was added. This growth trend has continued—while there is not yet complete data available, over 30 million square feet of gross floor area have already been added since 2010. This trend is not surprising, given that Seattle's population grew 18.7% (about 114,000 people) since 2010 according to the US Census. Figure 6 shows the gross floor area added by year constructed (area in color), with the number of buildings constructed each year shown as bars.[4]

4 See "*114,000 more people: Seattle now decade's fastest-growing big city in all of U.S.*" at www.seattletimes.com

Figure 6: **Gross Floor Area (sq ft) by Year Built [2016] (Full Set; n=3,352)**



Seattle's growth has not been uniformly distributed throughout the city (Figure 6a/b). The Lake Union, East, and Northeast neighborhoods have seen the most growth in number of buildings constructed. In Lake Union alone, 36 buildings have been built since 2010.[5] The Lake Union and Downtown neighborhoods have added the most square footage.[6]

Figure 7a: **Map of Gross Floor Area Added in South Lake Union and Downtown since 2010**

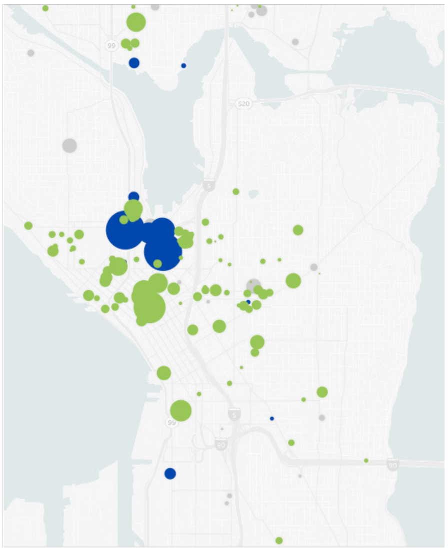
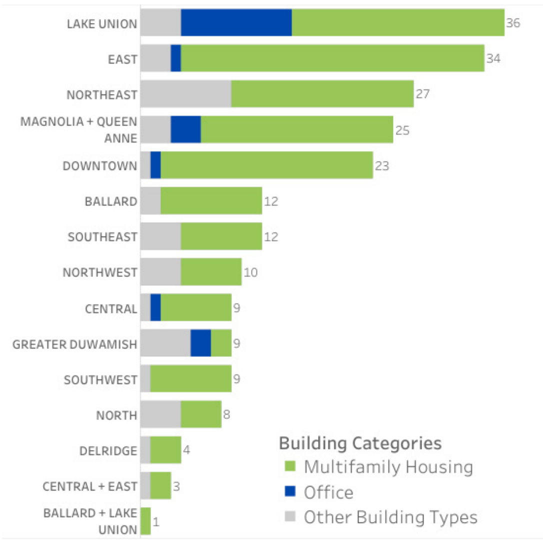


Figure 7b: **Number of New Buildings (2010 and Later) Constructed by Neighborhood**



5 Data only includes buildings 20,000 sf and above that are required to participate in the benchmarking program and were fully occupied for a full calendar year before January 1, 2016.

6 Appendix B has more information on neighborhood definitions and geographic spread of new buildings and square footage.

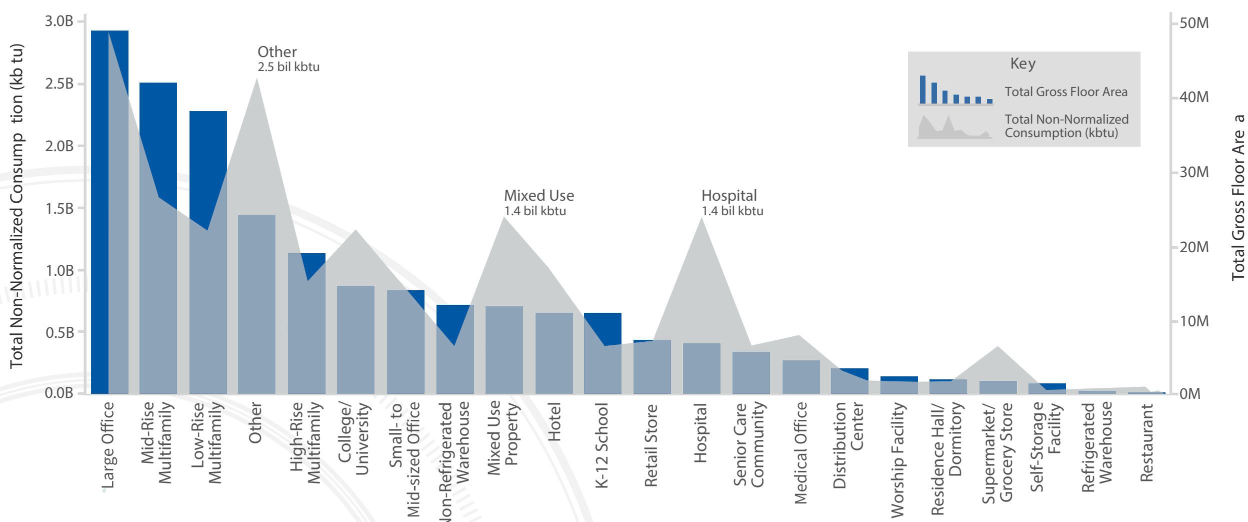
4. Energy Consumption Trends

One of the major objectives of the Energy Benchmarking program is to understand how Seattle's buildings contribute to Seattle's greenhouse gas emissions through energy consumption. This is explored in Chapters 4 and 5. In these chapters, it is important to remember that non-residential and multifamily buildings 20,000 square feet and greater are a subset of the entire population of Seattle's buildings. Energy use from all buildings contributes to 37% of Seattle's core greenhouse gas emissions.

Overall Approach

To understand the magnitude and composition of Seattle's benchmarked building energy consumption and emissions, the City first looked at the characteristics for all buildings in the full (independent) benchmarked dataset. To understand trends in energy consumption over time, the City relied primarily on the fixed set, which is limited to benchmarked buildings with valid data over the period 2014-2016. Additionally, for analyses looking at trends over time, the City used weather-normalized metrics to account for differences in weather between years. For consumption and greenhouse gas emission data, we use both non-normalized and weather-normalized versions of the key variables. Weather-normalized variables adjust annual values based on modeling that accounts for average and actual weather conditions. For instance, if a year had a higher than average number of very cold days, buildings in that year would be expected to consume more gas than in an average year. That year would also be expected to have a lower weather-normalized consumption quantity compared with its non-normalized consumption quantity. In this report, weather-normalized values are used when making comparisons between data from multiple years, while non-normalized (actual) values are used when looking at 2016 data in isolation.

Figure 8: **Snapshot of 2016 Building Energy Consumption (kBtu) by Building Type and Number of Buildings [2016] (Full Set; n=3,352)**



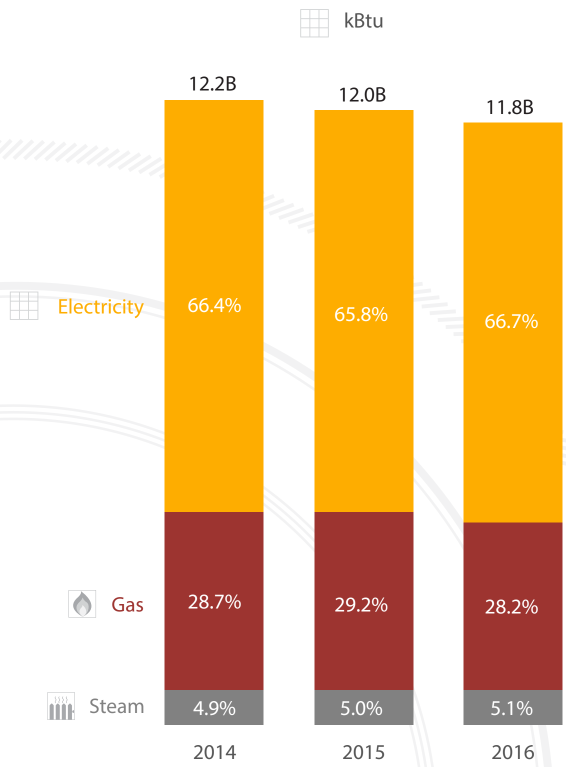
Energy Consumption by Building Type

Considering the full "independent set" of buildings that reported data in 2016 provides a snapshot of Seattle's energy consumption. Figure 8 provides a high-level view of Seattle's 2016 benchmarked buildings. This view displays the total non-normalized consumption (gray shaded area) and total gross floor area (blue bars) associated with each building type. Building types such as colleges, hospitals, and supermarkets have relatively high consumption for their size. Low-rise multifamily, mid-rise multifamily, and non-refrigerated warehouses have high square footage values compared with their energy consumption.

Benchmarking Consumption Trends: Year-Over-Year Analysis

The set of benchmarked buildings with valid data for 2014, 2015 and 2016 highlights how the benchmarked buildings have changed over time. The following analyses use this "fixed set" of 2,463 buildings.

Figure 9: **Change in Total Weather-Normalized Consumption (kBtu) [2014-2016] (Fixed Set; n=2,463)**



The total weather-normalized consumption associated with buildings benchmarked for three consecutive years declined 3.7% between 2014 and 2016, from 12.2 billion kBtu in 2014 to 11.8 billion kBtu in 2016 (Figure 9). While there are many possible factors affecting this trend, overall it suggests that benchmarked buildings are becoming more energy efficient in their operation. This downward trend is particularly notable, as this time period also saw a concurrent decreasing trend in office building vacancy rates (from 10.7% in 2014 to 9.2% in 2016)[1] and a decreasing trend in apartment vacancy rates (from 3.7% in 2014 to 3.4% in 2016).[2]

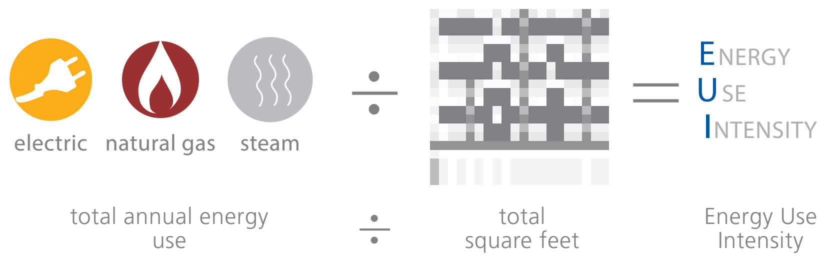
1 Based on JLL's analysis of the Seattle-Bellevue area. Available at www.us.jll.com/united-states/en-us/Research/US-Seattle-Bellevue-Office-Insight-Q3-2017-JLL.pdf

2 Based on Kidder Matthews' analysis of the Seattle multifamily market. Available at www.kiddermathews.com/downloads/research/multifamily-market-research-seattle-2017-3q.pdf

Energy Use Intensity

What is an EUI?

Energy Use Intensity (EUI) is a building's total annual energy use (electricity, natural gas, and steam) divided by its gross floor area. It is measured in kBtu/sf (one thousand British thermal units per square foot). Since EUI normalizes for size, the energy use of similar building types can be compared. Higher EUIs show greater energy use, whereas lower EUIs indicate more energy efficient buildings.



Decreasing Median EUI for Benchmarked Buildings

Energy use intensity (EUI) normalizes the impact of building size on energy consumption, and thus provides a good standard for assessing building energy usage. Just as with overall consumption, weather-normalized median EUI has fallen over the 2014 to 2016 time period, from an overall median of 42.1 in 2014 to 40.5 in 2016. This suggests that per-area consumption is decreasing in the benchmarked building set. The Benchmarking Program is designed to facilitate this type of continuous efficiency gains, as it encourages buildings to adopt more efficient technologies, improve building operations, and motivate building managers to more closely monitor their energy usage and pursue energy efficiency measures through utility programs.

The pattern of decreasing median EUI generally holds for office and multifamily buildings. Figure 9 shows the changes in median EUI for these major building categories over the three-year period. Office buildings have decreased their energy use intensity most sharply, which is promising as office buildings consume the most energy of any building category.

Higher EUIs mean **more energy.**

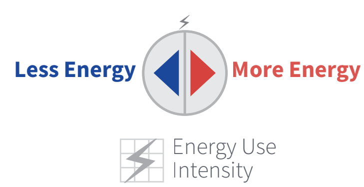
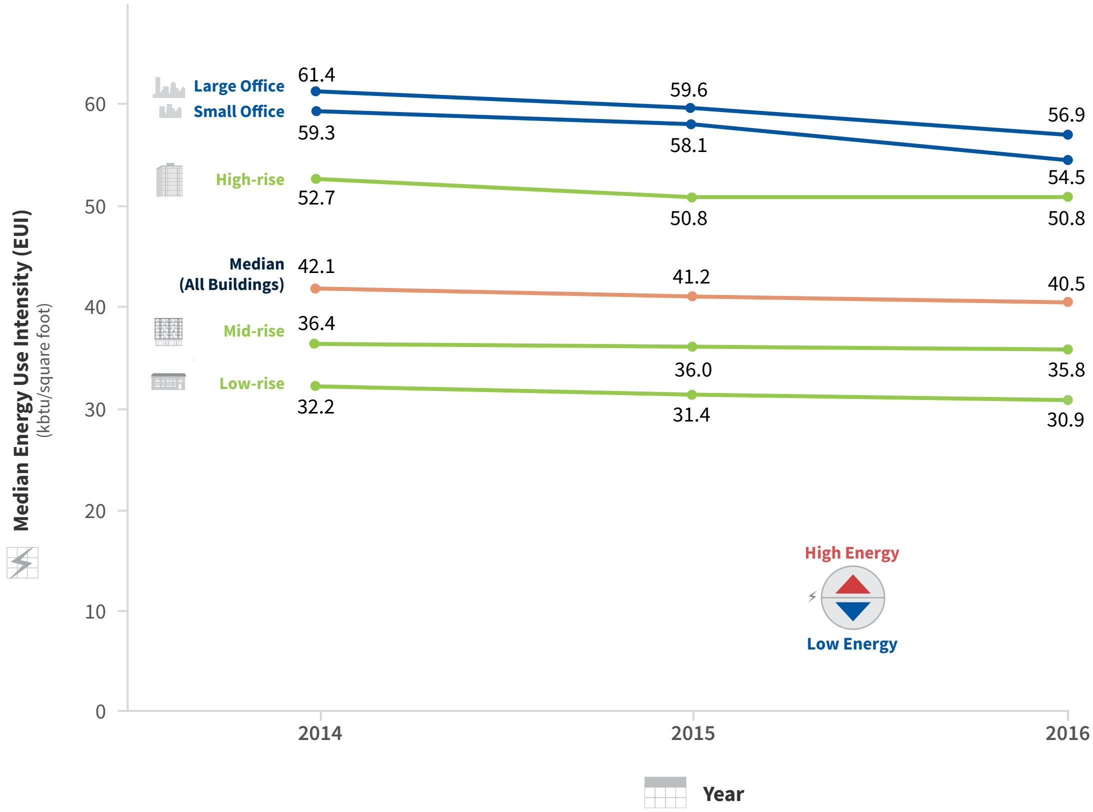


Figure 10: Change in Median Weather-Normalized EUI (kBtu/sq ft) for Major Building Types [2014-2016] (Fixed Set; n=2,463)



Multifamily EUIs have declined less steeply and have flattened for the past two years for high-rise. This suggests a need for innovation and investment into multifamily energy efficiency, especially given the growth in mid- and high-rise properties.

Building Type	2016 Annual Energy Use Intensity (Site EUI in kBtu/sf)								EPA ENERGY STAR Score
	Median EUI	Lowest Use (1st Quartile)	Medium-Low (2nd Quartile)	Medium-High (3rd Quartile)	Highest Use (4th Quartile)	Number of Buildings	Year Built (median)	Size (median sf)	(median)[1]
Low-rise Multifamily[2]	29.8	≤25	26-30	31-38	≥39	980	1978	31,500	73
Mid-rise Multifamily[2]	33.9	≤28	29-34	35-44	≥45	564	1999	60,736	84
High-rise Multifamily[2]	46.6	≤38	39-47	48-58	≥59	105	1982	169,565	53
Small- to Mid-size Office[3]	51.5	≤38	39-52	53-68	≥69	310	1964	40,988	73
Large Office[3]	55.3	≤46	47-55	56-72	≥73	155	1985	275,734	88
Warehouse	26.8	≤13	14-27	28-46	≥47	187	1964	40,028	60
Distribution Center	30.4	≤18	19-30	31-44	≥45	53	1967	49,950	56
Self-storage Facility	15.7	≤10	11-16	17-25	≥26	28	1958	43,266	NA
Refrigerated Warehouse	49.8	≤34	35-50	51-108	≥109	12	1955	25,548	75
K-12 School[4]	37.3	≤30	31-37	38-46	≥47	140	1963	52,700	85
Retail Store	53.4	≤34	35-53	54-81	≥82	92	1966	44,552	75
Hotel/Motel	80	≤58	59-80	81-96	≥97	77	1979	104,352	63
Worship Facility	31.8	≤22	23-32	33-40	≥41	71	1952	26,033	73
Medical Office	78.9	≤70	71-79	80-102	≥103	39	1986	94,500	51
Senior Care Community	64.9	≤45	46-65	66-98	≥99	45	1992	93,397	71
Hospital	210.9	≤183	184-211	212-235	≥236	10	1960	395,049	44[5]
Supermarket	250.6	≤190	191-251	252-296	≥297	38	1996	44,955	40
Restaurant	152.9	≤115	116-153	154-211	≥212	12	1923	29,910	NA
Residence Hall	54.8	≤32	33-55	56-73	≥74	23	1970	44,086	72
University	68.6	≤46	47-69	70-91	≥92	25	1967	76,700	NA
Mixed Use Property	56.5	≤39	40-57	58-97	≥98	128	1966	48,420	75
Other	79.2	≤43	44-79	80-126	≥127	258	1969	44,375	67

EUI PERFORMANCE BY BUILDING TYPE ONLINE

Additional information on EUI performance by building type are published annually on both seattle.gov/energybenchmarking and data.seattle.gov. Typical annual data published by building type includes median site energy use intensity (not normalized for weather), quartile ranges, and summary metrics on size, ENERGY STAR score, and year built.

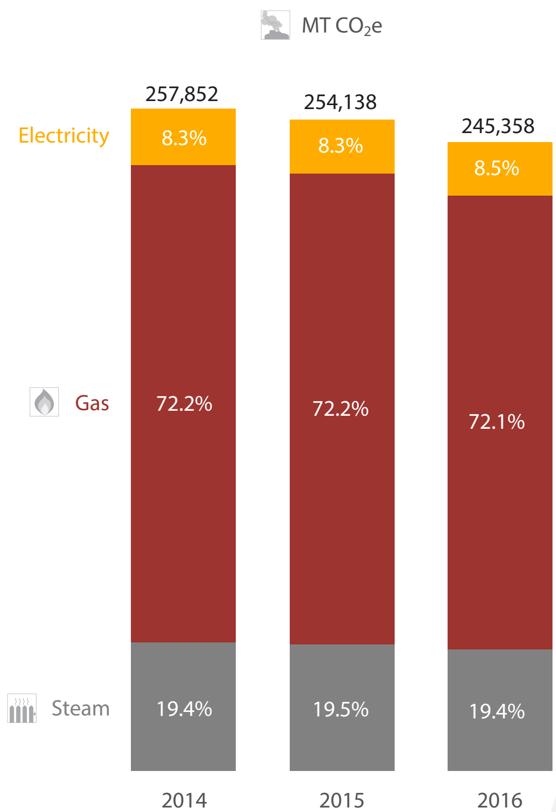
5. Greenhouse Gas Emissions Trends

Fuel mix is an important metric associated with greenhouse gas (GHG) emissions. Figure 11 shows that among buildings that have data for 2016, the fuel mix composition includes mostly electricity, but also includes natural gas and steam. This is important to monitor, as fuel sources contribute differently to greenhouse gas emissions.

Figure 11: Fuel Source Consumption (% kBtu) Contributions in 2016 (Cleaned Set; n=3,111)

During the 2014-2016 period, there is a promising trend in weather-normalized greenhouse gas emissions, with an overall 4.8% decline during this time (Figure 12). As this represents a fixed number of buildings, it does not capture emissions from new buildings—but it does show that existing buildings as a whole are decreasing their overall emissions. As with energy consumption, in

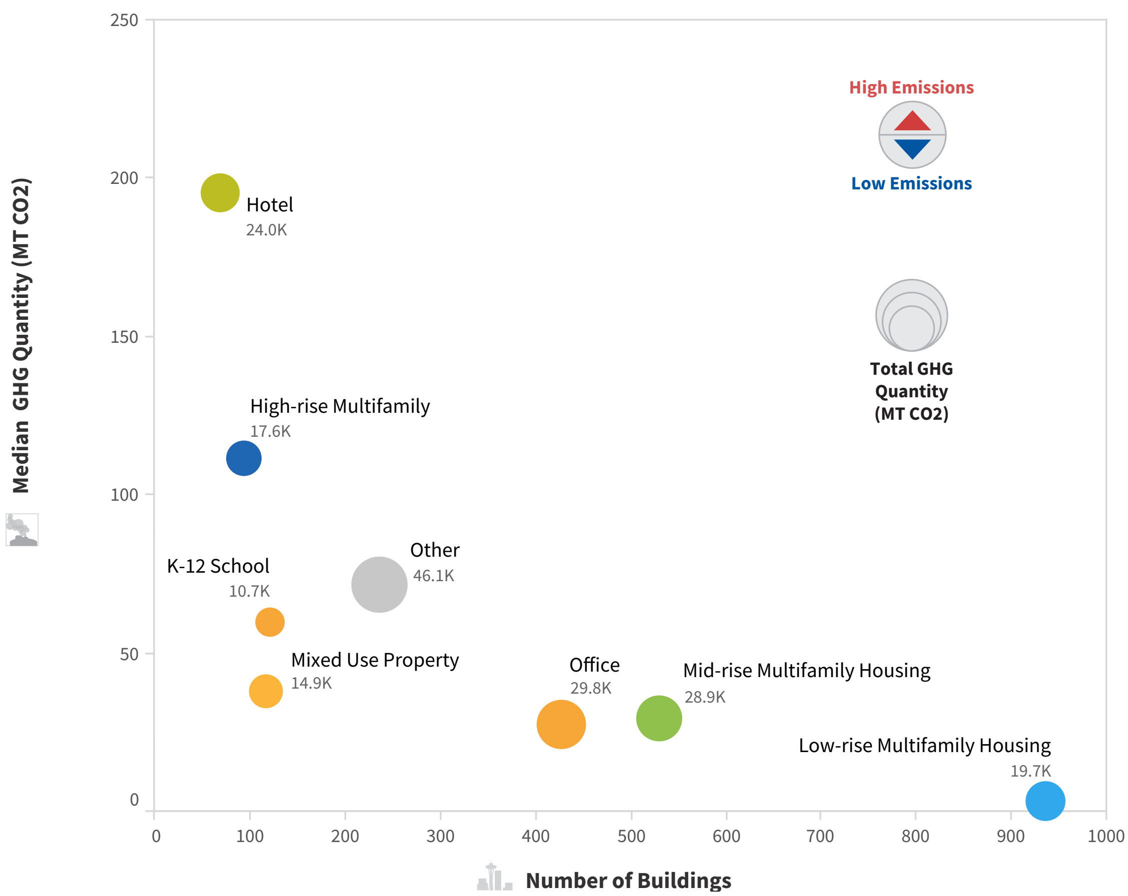
Figure 12: Weather-Normalized Greenhouse Gas Emissions (metric tons [MT] CO_2) [2014-2016 (Fixed Set; n=2,463)



this chapter the City uses weather-normalized values to accurately compare between years. These variables adjust for year-to-year changes in weather.[1]

Figure 12 also shows that Seattle's carbon-neutral electric utility, Seattle City Light, has a minor contribution to GHG emissions, whereas natural gas and steam have larger impacts. This is somewhat different from most other U.S. cities which tend to have a "dirtier" electricty supply. Although emissions are overall declining, the largest GHG emissions source–natural gas–has remained nearly constant at almost three-quarters of Seattle building energy emissions.

Figure 13: Non-Normalized GHG Emissions (MT CO_2) by Building Type [2016] (Cleaned Set; n=3,111)

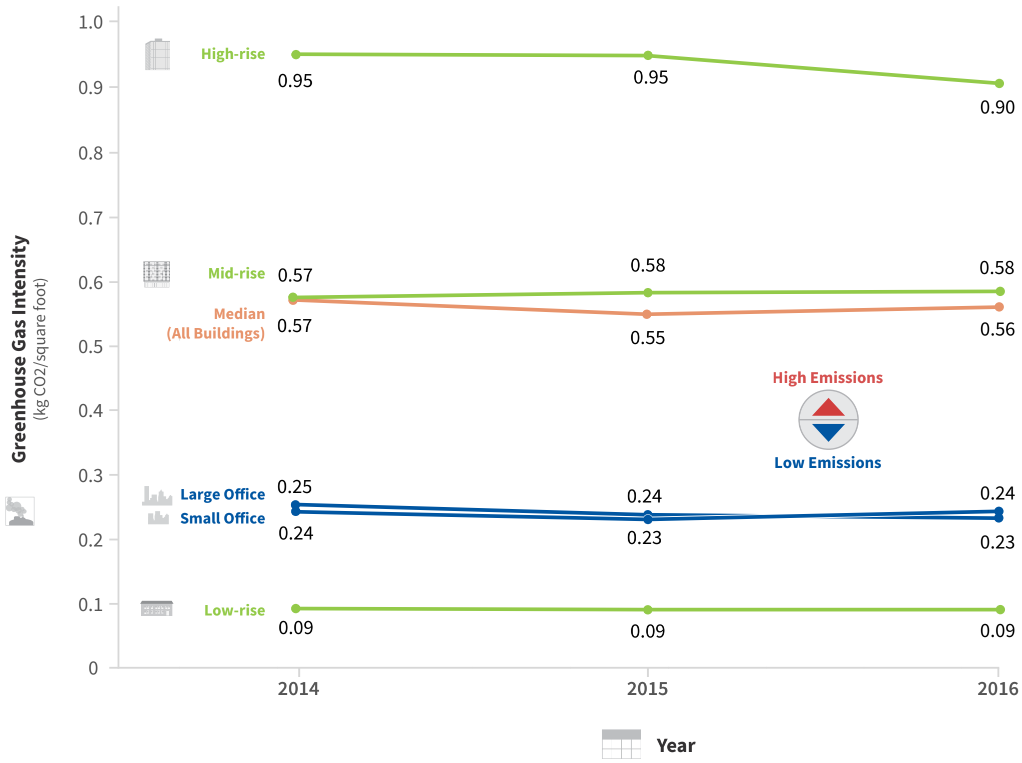


To understand which types of buildings contribute most to Seattle's greenhouse gas emissions—and where the opportunities for lowering emissions are—the City compared the contributions from each of the major building types for the 2016 data (Figure 13). This analysis relies on non-normalized greenhouse gas emissions since there is no longitudinal comparison required. Figure 13

1 Details on this methodology are located in Appendix C. The emissions values reported here use custom emissions factors provided by Seattle City Light and Enwave for electricity and steam, respectively. Natural gas calculations use a standard emissions factor from Portfolio Manager. Seattle City Light (SCL) secures carbon offsets equal to the greenhouse gas emissions resulting from all aspects of SCL's operations, including those created by the generation of electricity the utility buys, employees' travel, and the trucks and other equipment used in its operations. For more technical details on conversion from consumption to greenhouse gas emissions, please see Appendix D.

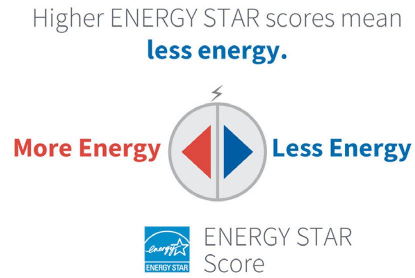
shows the categories that contribute most to greenhouse gas emissions. In this visual, the largest circles represent the categories that contribute most. Besides buildings classified as "Other" (which include large, energy-intensive buildings like correctional facilities and labs), the most significant contributors to these emissions include hospitals, hotels, offices, and high-rise multifamily buildings. As these categories continue to add buildings, it is important to monitor their relative contributions to greenhouse gas emissions in the city.

Figure 14: Weather-Normalized GHG Emissions Intensity (kg CO_2/sq ft) by Building Type [2016] (Fixed Set; n=2,463)



To better understand the drivers of GHG emissions, it is useful to look at GHG emissions intensity—that is, the relative emissions contribution per square foot. This metric (measured in kg $C0_2$/sq ft) provides more information than EUI because it accounts for the carbon intensity of energy consumed. Like EUI, GHG emissions intensity allows for comparisons across buildings. Figure 14 breaks out emissions intensity by building type for the period 2014-2016. During this three-year period, the weather-normalized GHG emissions intensity declines or stays relatively stagnant for the major building types.

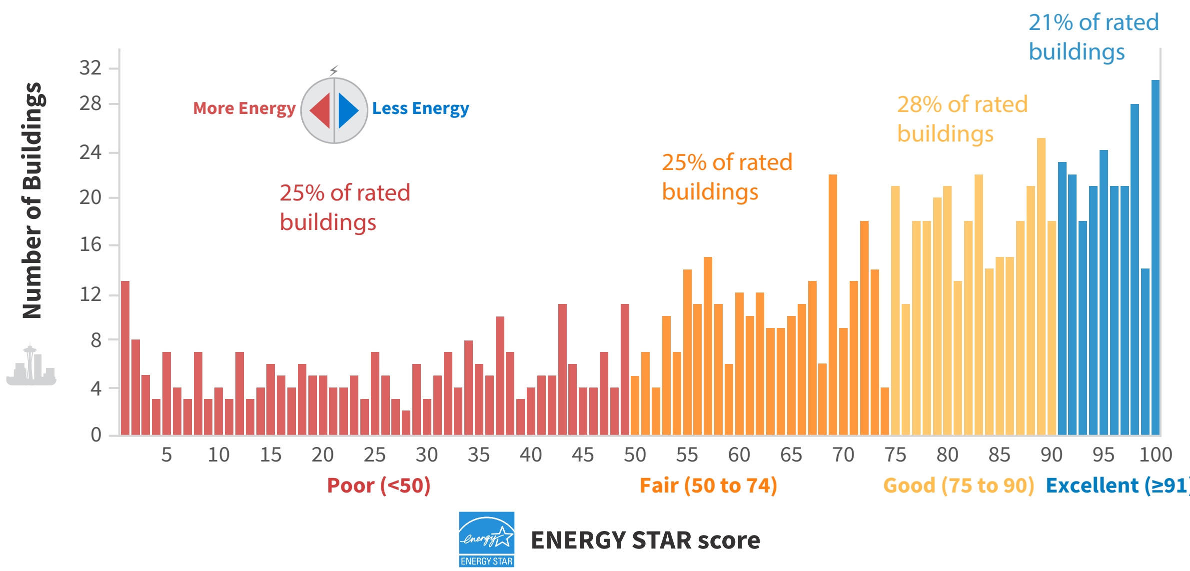
6. Energy Star Performance



The ENERGY STAR score is a nationally used metric that compares a building's energy use to other U.S. buildings on a scale from 1 to 100, where 1 is least efficient and 100 is most efficient. In 2016, 2,511 buildings reported ENERGY STAR scores.

The City categorizes buildings by ENERGY STAR scores to help understand the relative performance of buildings, using four categories from poor to excellent. As in previous analyses, many of Seattle's buildings have high scores in the 'excellent' category (91 or greater, as shown in Figure 15). Three quarters of buildings received scores that represent at least fair performance. Despite these strong results, many buildings received the lowest score (1) or highest score possible (100), which likely indicates a reporting error or inaccuracy – often an error in a building space use, missing energy meters, or other errors. This represents a possible data issue for improvement in future analyses. Other improvements to address very low or very high scores could include outreach to building owners or a threshold on ENERGY STAR scores to require verification.

Figure 15: **Number of Buildings by 2016 ENERGY STAR Score (Cleaned Set; n=3,111)**

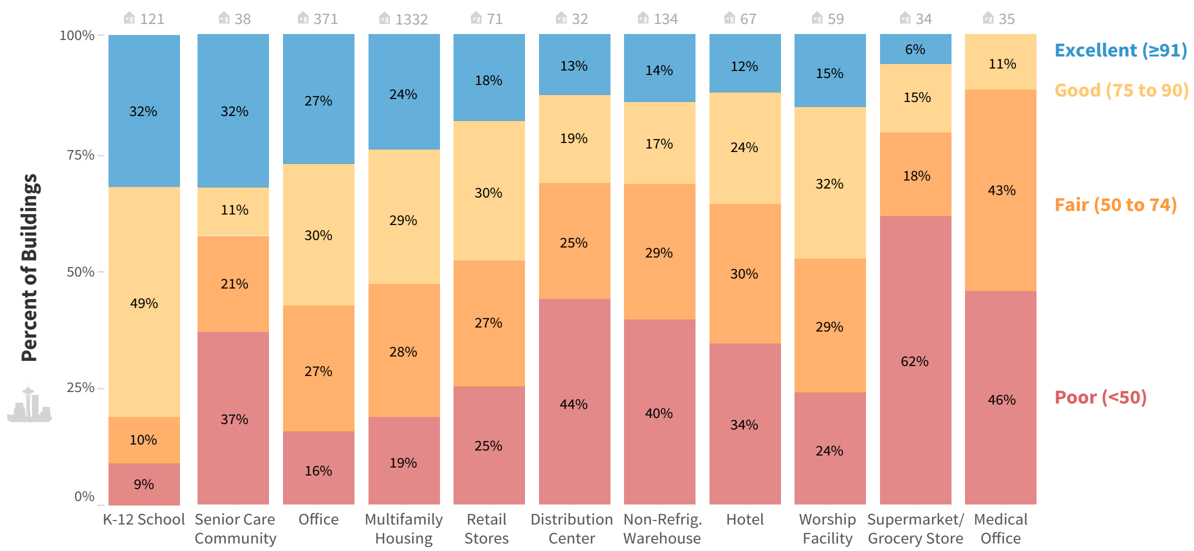


Overall, ENERGY STAR scores are high for 2016.[1] Multifamily housing and office buildings each have over half of their buildings in the good or excellent performance categories. As these two categories make up over half the benchmarked building population by number of buildings and total floor area, these categories are especially important.

1 *Updates to ENERGY STAR scores were made in August 2018 to update many of the models used to calculate scores. This will result in lower scores for most buildings. The City of Seattle will publish the updated scores as part of the 2018 data. For more information on the score changes visit www.energystar.gov/scoreupdates.*

Figure 16 shows the breakdown of buildings in performance categories by building type. While most building categories have similar performance to 2013 data, overall the percentage of 'excellent' performers increased from 17% of buildings in 2013 to 21% of buildings in 2016. Within each building type, however, there remains a subset of buildings classified as 'poor' performers.

Figure 16: ENERGY STAR Performance Categories by Building Type [2016] (Cleaned Set; n=3,111)



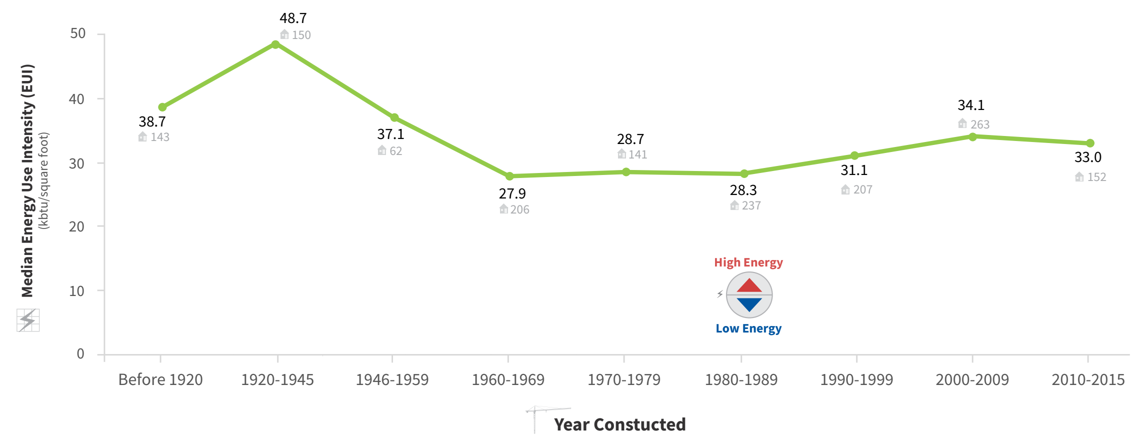
7. Multifamily Building Trends

This chapter details energy performance trends for the multifamily buildings reported in the benchmarking data, which comprise nearly half of the reported buildings. Overall, the analysis shows that although multifamily buildings constructed over the past couple decades are getting taller and larger, ENERGY STAR scores are increasing. The median EUI for more recently constructed multifamily buildings is not improving in proportion, which indicates the buildings have more units per square foot and more amenities.

Building Vintage and EUI

As discussed in previous benchmarking reports, older multifamily buildings (constructed before 1945) had the highest median EUIs in the 2016 data (Figure 17). Multifamily buildings built in recent decades have lower median EUIs, but median EUI has increased among buildings built in recent decades.

Figure 17: Multifamily Building Median Non-Normalized Site EUI (kBtu/sq ft) by Date Constructed [2016] (Cleaned Set; n=3,111)



Many factors besides age affect the energy usage of multifamily buildings, such as size, density, whether an apartment or condominium, and presence of secondary spaces with other uses, such as retail, restaurant, and office. To better understand changes in multifamily building energy efficiency, the City first looked at ENERGY STAR scores. Multifamily ENERGY STAR scores account for a building's number of units, bedrooms per unit, and height, thus providing a measure of relative

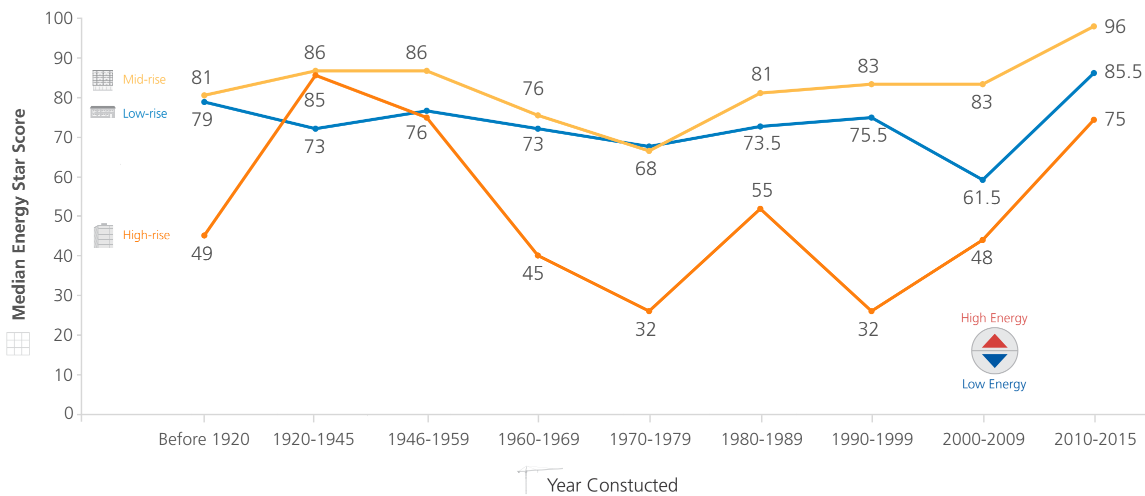
Number of floors

Portfolio Manager defines low-rise multifamily properties as 1-4 floors, mid-rise as 5-9 floors and high-rise as 10 or more floors.

High-rise	10+ Floors
Mid-rise	5-9 Floors
Low-rise	1-4 Floors

energy performance that is more comparable across buildings. As shown in Figure 18, mid-rise buildings have the best median ENERGY STAR scores, but scores have improved for low-, mid-, and high-rise multifamily buildings built since 2010.

Figure 18: Low-, Mid-, and High-Rise Multifamily Building Median 2016 ENERGY STAR Score by Date Constructed (Cleaned Set; n=3,111)



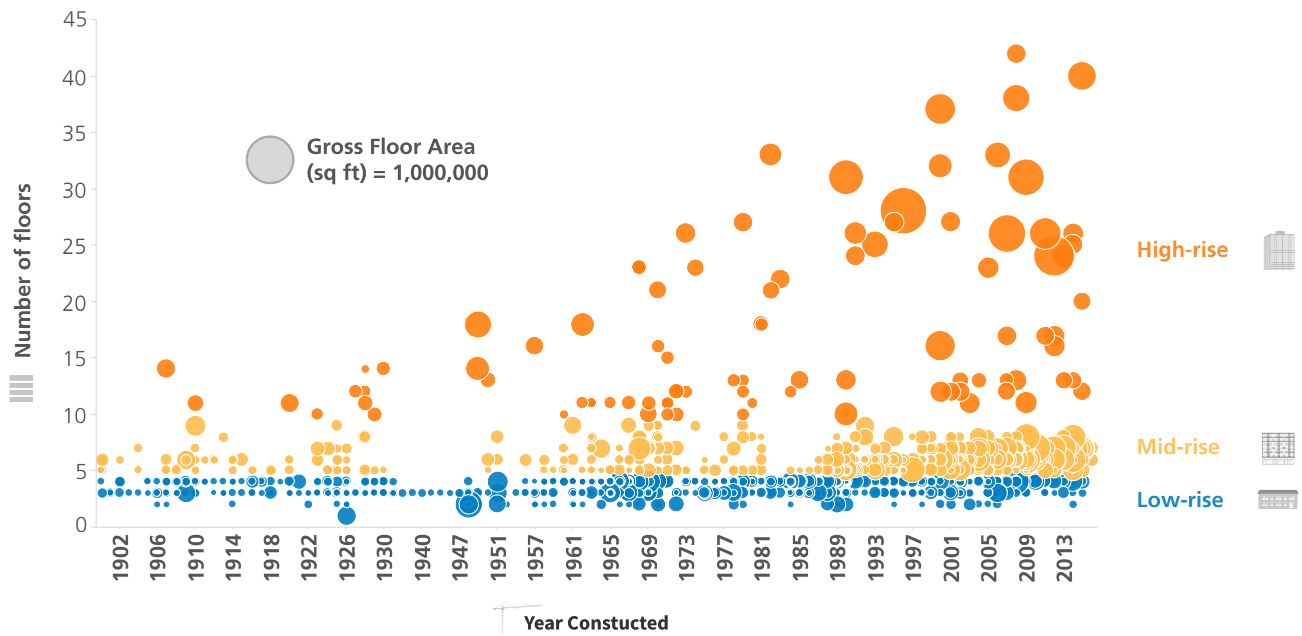
The City conducted a series of statistical analyses to differentiate between the various factors that drive energy consumption in multifamily buildings. Based on these analyses, the most important factors identified for all types of multifamily buildings were building vintage, unit density, and height.[1] Presence of secondary spaces is also important, but more so for smaller buildings. These factors are presented in more detail below.

Building Size and Density

Seattle has seen extensive growth in the multifamily sector in recent years, both in number of buildings and square footage. Figure 19 shows each multifamily building by year built and number of floors, with the size of the dot representing the building's square footage. Newer high-rise buildings are considerably taller and have larger floor areas than older high-rise buildings. The number and relative size of mid-rise buildings has also increased.

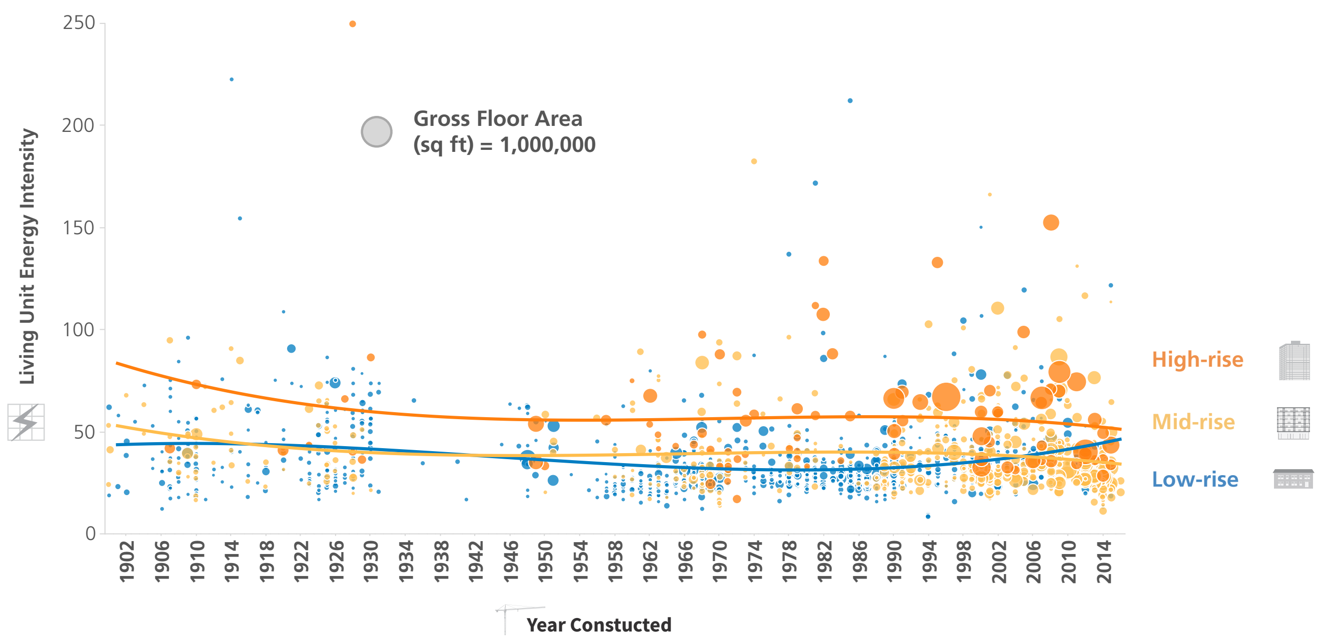
1 The City developed a number of regression models that modeled EUI as a function of number of floors, building vintage, living unit density, presence of a secondary space, and whether a building was condo, including models that included various interactions between these terms and separate models for low-, mid-, and high-rise buildings. Based on these regressions, the most important factors correlated with EUI are building age and living unit density, followed by height and secondary spaces (for low- and mid-rise buildings only).

Figure 19: **Number of Floors and Square Footage of Multifamily Buildings by Year Built**



Apartment and condo unit sizes in Seattle vary greatly and thus the impact on the number of units in buildings on their energy use is another important variable to assess. To this end, the City looked at living unit energy intensity, defined as annual energy use per housing unit. While living unit energy intensity is higher for high-rise buildings, it appears to be decreasing in newer mid-rise and high-rise buildings (which together represent the majority of new multifamily housing). In other words, newer buildings are slightly more efficient than older buildings on a per living unit basis, as shown in Figure 20.

Figure 20: **Living Unit Energy Intensity of Multifamily Buildings by Year Built**

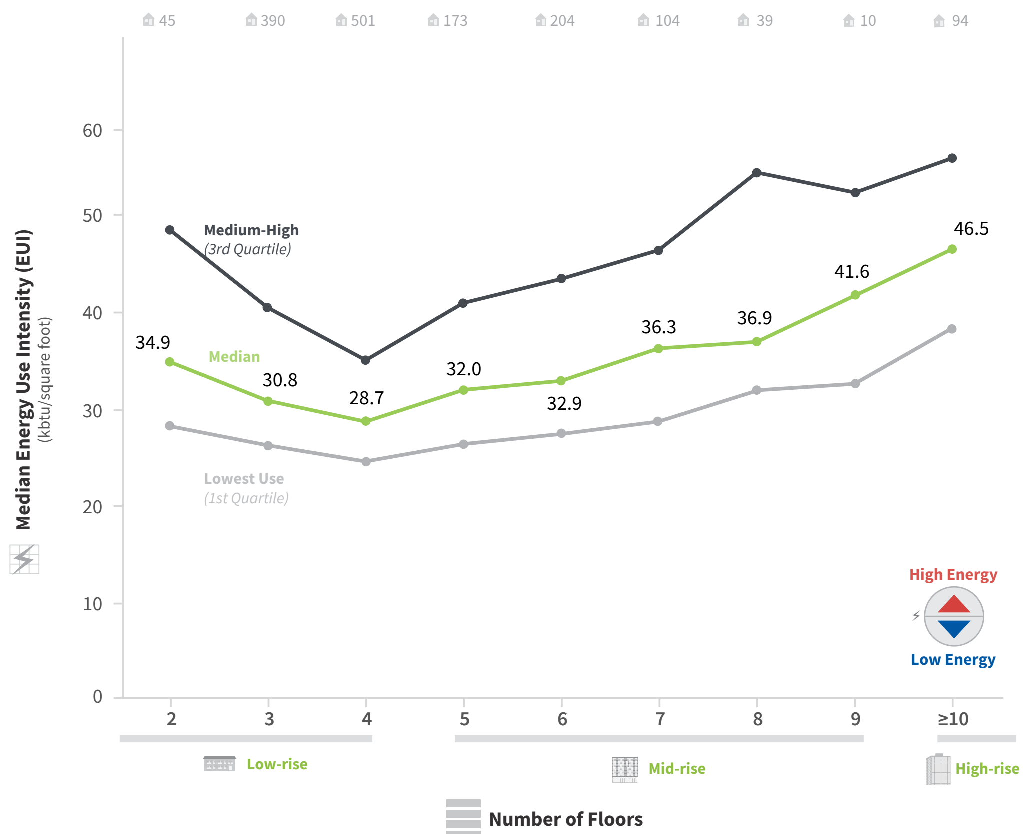


Building Height and EUI

As in previous analyses, multifamily building height had the strongest impact on median EUI in 2016. Even after controlling for building density and secondary uses such as a retail store, restaurant, or supermarket, taller buildings used more energy per square foot. Figure 21 shows that median non-normalized EUI increases as number of floors increases, although this trend is reversed in buildings with four or fewer floors.

High-rise multifamily buildings present both an opportunity and challenge for energy efficiency. While high-rise multifamily developments have the benefit of concentrating residents on a per square mile basis and provide access to public transportation and walkable neighborhoods, they use more energy per square foot and per living unit than low and mid-rise housing. This is because high-rise buildings tend to require more complex heating, cooling, and ventilation systems and have more windows. On the plus side, they may have thermodynamic advantages such as low surface-area-to-volume ratio. Only a few high-rise multifamily buildings in Seattle have achieved energy efficiency levels like smaller buildings. Overall, Seattle's largest apartments and condominiums contribute to the city's overall energy use and thus should be prioritized to lead the way on multifamily energy efficiency.

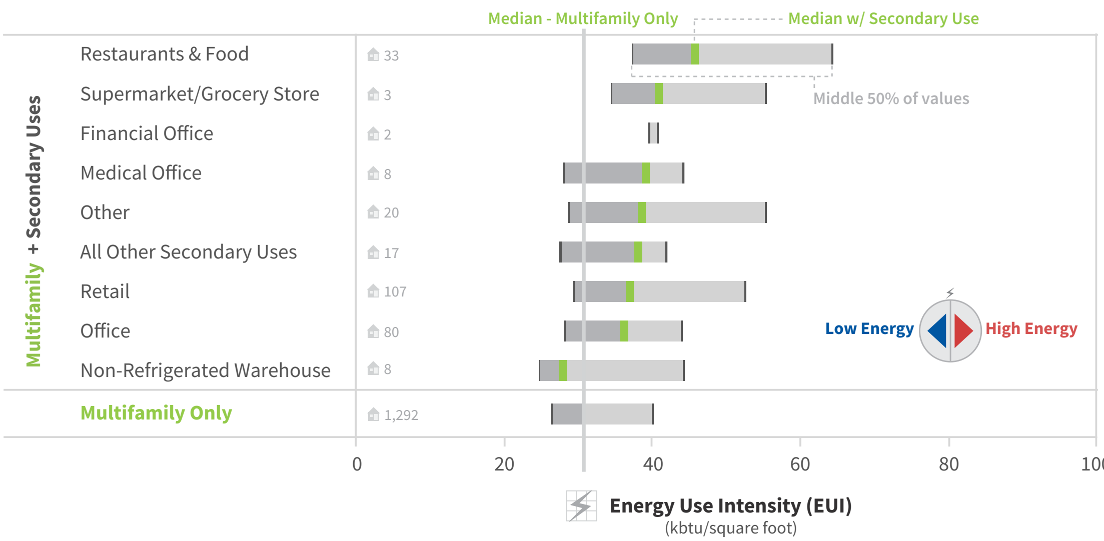
Figure 21: **Multifamily Building Median Non-Normalized EUI (kBtu/sq ft) by Number of Floors [2016] (Cleaned Set; n=3,111)**



Secondary Uses

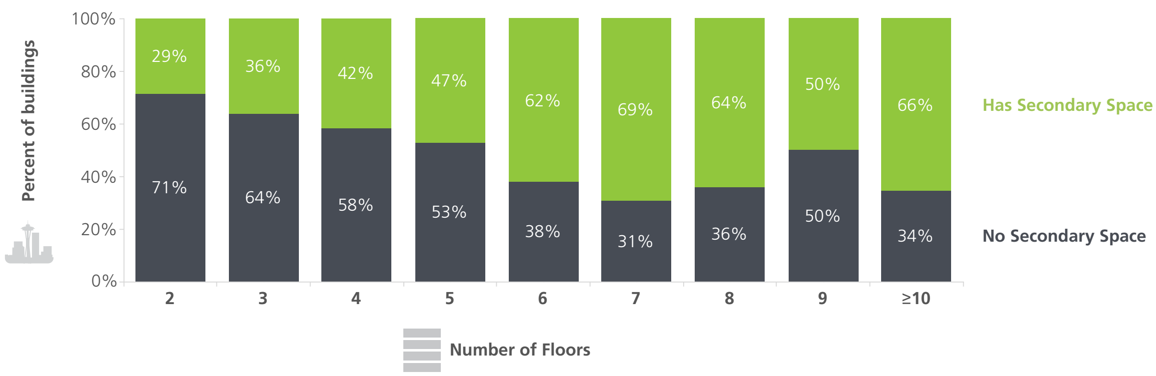
Many multifamily buildings also have other "secondary" uses such as a retail store, restaurant, or supermarket. Secondary spaces are often more energy intensive than multifamily spaces. As shown in Figure 22, these secondary spaces often increase the EUI of a multifamily building. Some space types are stronger drivers of high EUIs than others. In particular, supermarkets and restaurants impact site EUIs substantially. Retail and office spaces also drive multifamily building EUI up and are some of the most common secondary space types.

Figure 22: **Multifamily Building Median Non-Normalized EUI (kBtu/sq ft) by Secondary Space Type [2016] (Cleaned Set; n=3,111)**



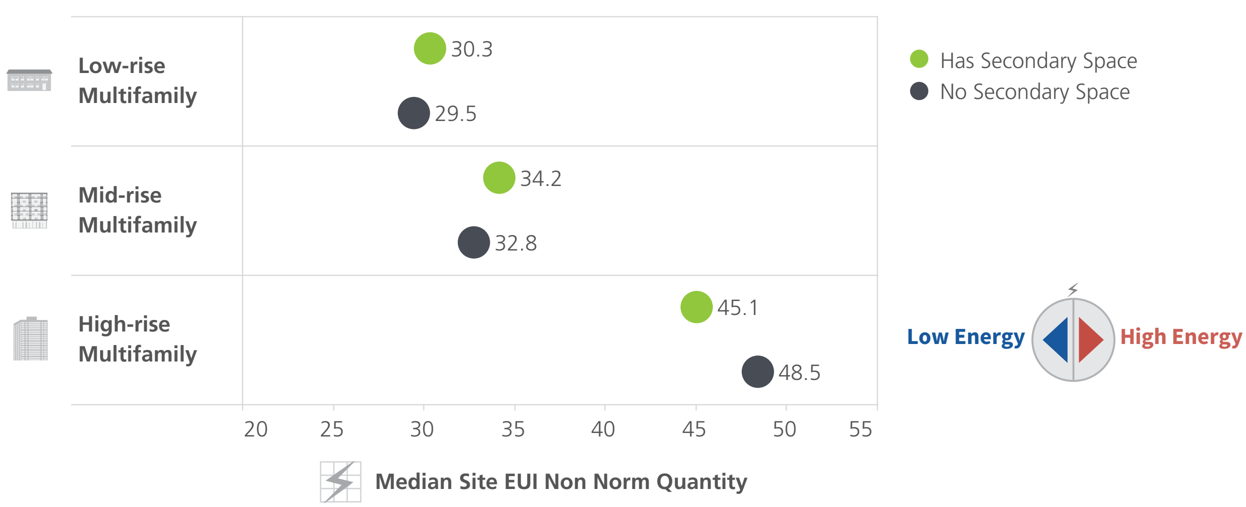
Secondary spaces are found in all size buildings but are more common in taller buildings, as shown in Figure 23. Based on our statistical analyses, secondary space appears to be a more important driver of overall building energy usage for low- and mid-rise buildings. While our analysis found that having a secondary space increased energy intensity by approximately 9 kBtu/square foot across all buildings, the impact was less in taller buildings. This is seen in Figure 24, which compares median EUI for buildings with and without secondary spaces within building size category. While median EUI is higher with secondary spaces for low- and mid-rise buildings, the opposite is true for high-rise buildings. This may be because the secondary space is a smaller portion of overall energy consumption in taller buildings.

Figure 23: **Presence of Secondary Space by Number of Floors**



On the whole, new multifamily buildings are bigger, taller, and have more units per square foot than older multifamily buildings. While newer buildings are becoming more dense, energy usage is not increasing proportionally (even though living unit density is one of the most important drivers of energy consumption). In sum, Seattle's newest multifamily buildings are more efficient than older multifamily buildings as energy usage per living unit is decreasing while ENERGY STAR scores are rising. However, overall energy use per square foot is not decreasing for newer buildings, which suggests there are still opportunities to increase efficiency.

Figure 24: **Energy Usage Intensity by Presence of Secondary Spaces**



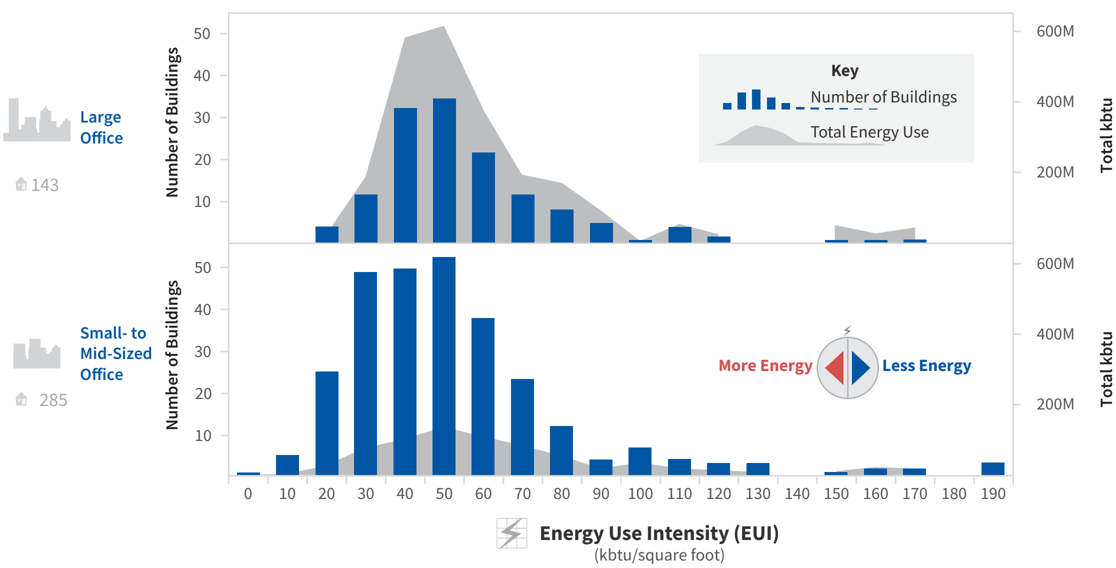
8. Office Building Trends

After multifamily housing, office buildings are the most common building type in Seattle's population of benchmarked buildings and the largest energy use category. In this chapter, the City discusses energy performance trends of this important building category.

Energy Performance

Within the office building category, small- to mid-sized office buildings (less than 100,000 square feet) are almost twice as common as large office buildings. However, large office buildings as a group use much more energy overall due to their size. This has important implications for Seattle as large office buildings continue to be constructed in the city. Figure 25 shows the number of buildings (blue bars) in each EUI category, with the total energy consumption in kBtu shown in gray behind.

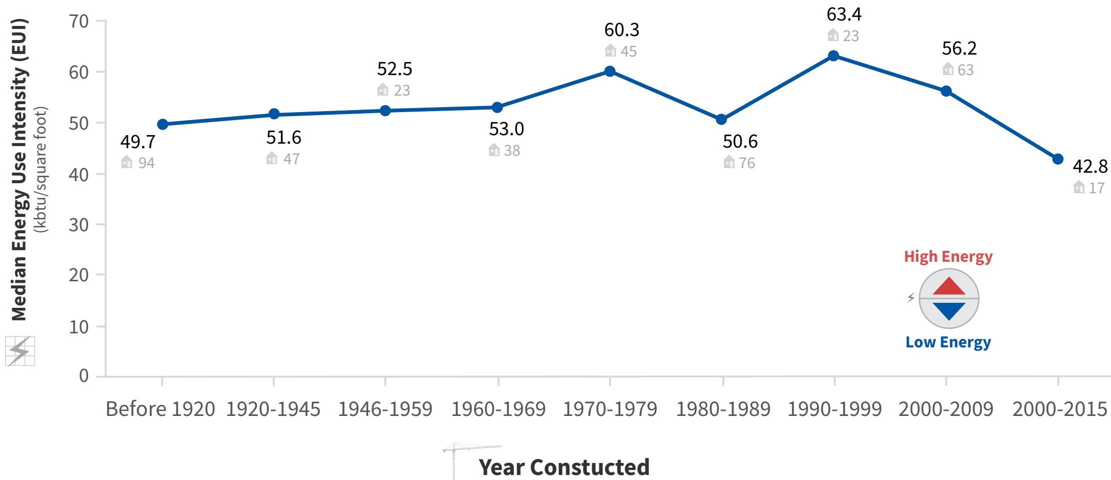
Figure 25: **Office Energy Consumption (kBtu) and Number of Buildings by Median Non-Normalized EUI (kBtu/sq ft) Bin [2016] (Cleaned Set; n=3,111)**



Building Vintage and EUI

The median EUI for office buildings is relatively stable across decades in which buildings were constructed, though there is a downward trend in EUI beginning with buildings constructed in the 1990s. Figure 26 shows these trends in median non-normalized EUI by date constructed for office buildings. This trend highlights that the City's efforts to improve energy performance of new construction through energy codes and incentive programs has likely had a positive effect. Furthermore, certifications such as ENERGY STAR have rewarded the market for high performance buildings.

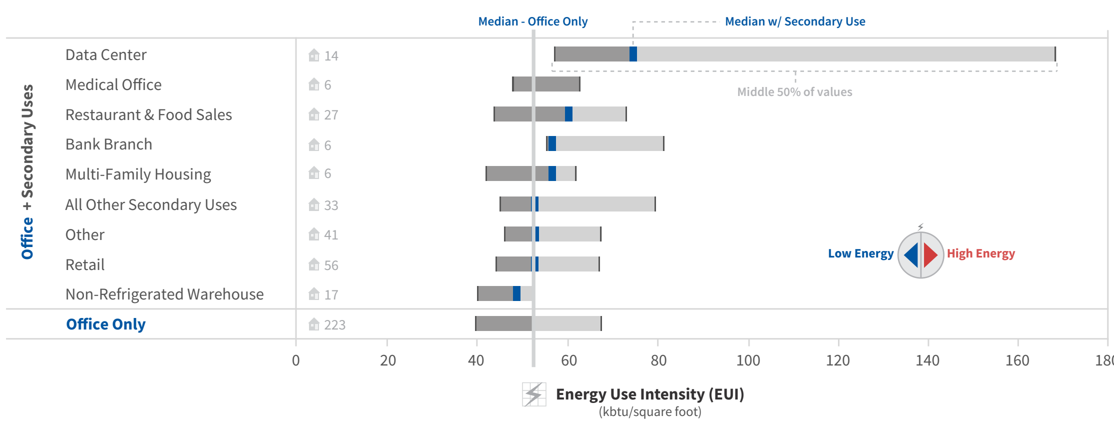
Figure 26: **Office Building Median Non-Normalized Site EUI (kBtu/sq ft) by Vintage [2016] (Cleaned Set; n=3,111)**



Secondary Uses

As with multifamily buildings, most secondary space types drive up the energy intensity of office buildings (Figure 27). For office buildings, data centers and medical offices have the strongest impact on increased office EUIs. Retail and restaurant secondary space types are the most common secondary spaces in office buildings, and each of these space types also has a substantial impact on EUI.

Figure 27: **Office Building Median Non-Normalized EUI (kBtu/sq ft) by By Secondary Space Type [2016] (Cleaned Set; n=3,111)**



9. Next Steps and Recommendations

Based on the analysis of the 2016 benchmarked building set, the City offers the following recommendations for future applications and analyses of the benchmarking data.

Continue supporting a compliance help desk, improving data quality and analyzing benchmarking data to understand trends in citywide consumption over time, and to track progress toward carbon reduction goals.

The City has laid out an ambitious building emissions reduction goal of 39% by 2030 (over a 2008 baseline). Building energy benchmarking data provides a year-by-year progress indicator toward this goal, and sheds critical light on the relative contributions of existing buildings and new construction.

Align building benchmarking data with utility consumption and incentive program participation data by integrating data systems and using a common identifier for buildings.

Utilities have good data on some aspects of buildings in their territory, but lack data on other important building aspects. Integrating building benchmarking data with utility-held data on program participation would support two opportunities: (1) the utility could better understand the high-level effects of past program participation, and (2) the utility could better target new programs to those buildings that have the greatest potential for energy savings. Utilities could then draw upon this information for targeted marketing to building owners and managers.

Use building benchmarking data to better understand the efficacy and impacts of building codes and standards and evaluate new performance or outcome-based codes.

The degree to which buildings meet prescriptive codes or standards is not generally known. Additionally, other studies suggest that prescriptive codes do not ensure that buildings are performing post occupancy at the level expected by that code. Performance or outcome-based codes, on the other hand, require that buildings provide evidence of having met efficiency targets as measured by building energy consumption over time. Integrating building benchmarking data into the development and enforcement of codes and standards could facilitate a move away from prescriptive-based code and toward more effective performance or outcome-based codes.

10. Appendices

Appendix A: Data Accuracy

Data quality is an important consideration in the analysis of building energy benchmarking data. The City performed a comprehensive data cleaning process prior to conducting any analyses. The initial dataset obtained through Portfolio Manager included 3,352 buildings. All buildings in this set were included in the analyses of benchmarked building characteristics.

To analyze energy trends, buildings with identified errors were removed in addition to outlier EUI reports for the three largest building types. These exclusions included the following:

- Buildings likely missing some or all natural gas consumption;
- Buildings that reported steam consumption in incorrect units; and
- The top and bottom 1% of office, multifamily, and non-refrigerated warehouse buildings.

These data cleaning steps removed 241 buildings from the total benchmarking dataset, leaving 3,111 buildings for performance trends analysis.

Table A1: **Summary of Data Cleaning for 2016 Data**

Stage	Number of Buildings
Original Dataset (2016)	3,352
Error Identified in 2016 (including outliers)	(241)
2016 Analysis Set	3,111

To create the "fixed" data set used for year-over-year analyses (2014-2016), buildings were first excluded based on errors found in any one of the years 2014, 2015, or 2016. Buildings without complete and consistent data for the entire three-year period were further excluded. These included buildings that were either missing data, or had a year-to-year change in EUI of 50% or more. A total of 2,024 buildings were excluded for one or more of these reasons, resulting in a dataset of 2,463 for longitudinal analyses.

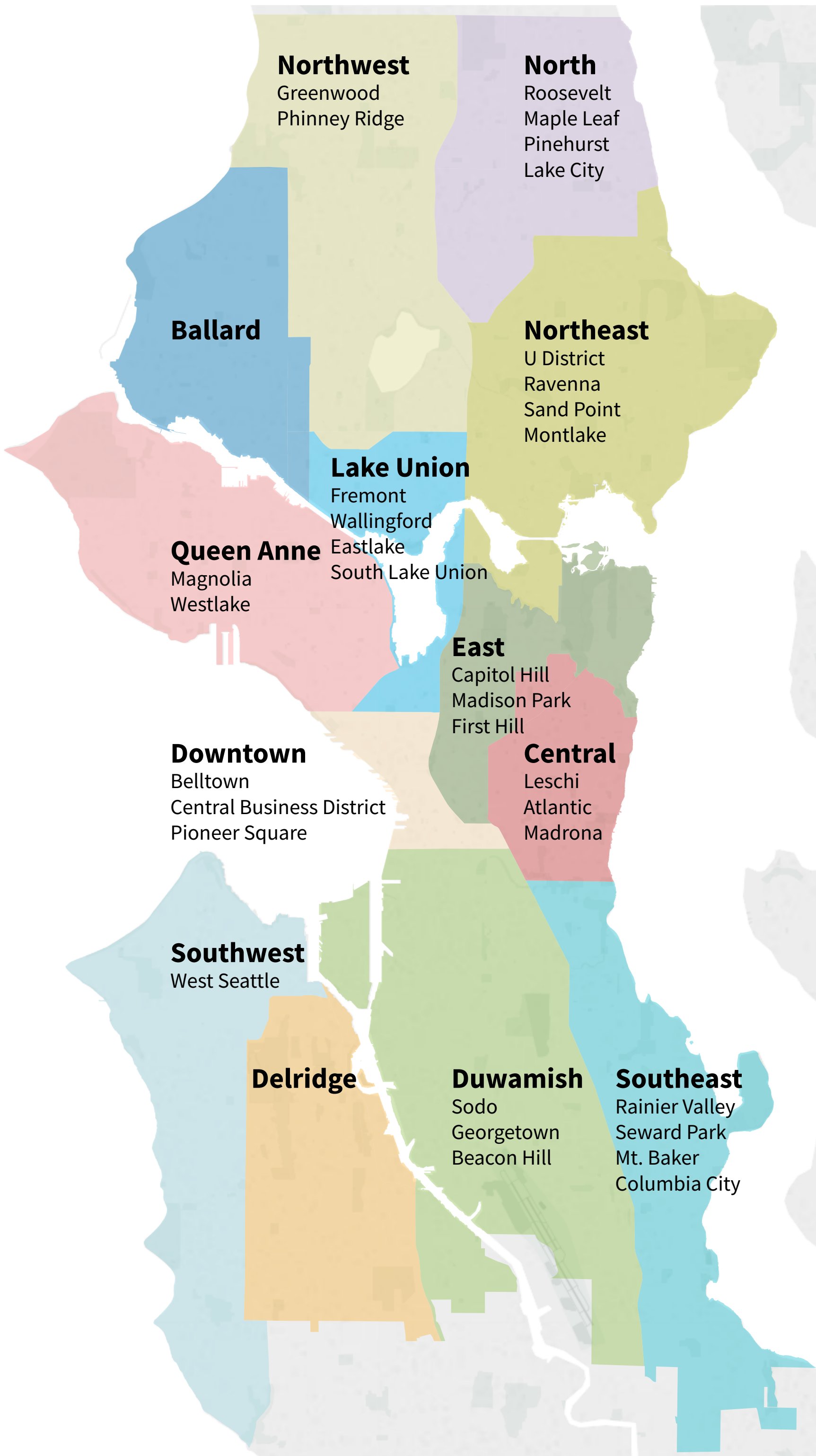
Table A2: **Summary of Data Cleaning for 2014-2016 "Fixed" Dataset**

Stage	Number of Buildings
Original Compliance Dataset (2014, 2015, 2016)	4,487
Error identified in 2014, 2015, or 2016	(490)
Buildings with Incomplete Data for Entire Period	(1,534)
2014-2016 Fixed (Longitudinal) Set	2,463

Appendix B: Geographic Information by Neighborhood

The neighborhoods within the City used in the energy benchmarking analyses are shown in Figure B1 below.

Figure B1: City of Seattle Neighborhoods



The distribution of new buildings (i.e., those built in 2010 or later) required to submit benchmarking data is shown below in Table B1, broken out by neighborhood. Across all building types, these data show that Lake Union has added the greatest number of buildings as well as the most square footage during this time period. However, the bulk of multifamily housing square footage has been added in the Downtown area.

Table B1: **Geographic Distribution of Benchmarked Buildings Built 2010 or Later**

Neighborhood	Multifamily Housing			Office			Other Building Types			Total		
	Num. bldgs	Sq Ft	% Sq Ft	Num. bldgs	Sq Ft	% Sq Ft	Num. bldgs	Sq Ft	% Sq Ft	Num. bdgs	Sq Ft	% Sq Ft
LAKE UNION	21	2.3M	12%	11	3.1M	65%	4	0.7M	13%	36	6.1M	21%
DOWNTOWN	21	4.5M	24%	1	<0.1M	1%	1	0.2M	3%	23	4.7M	16%
MAGNOLIA + QUEEN ANNE	19	2.0M	11%	3	1.2M	25%	3	0.2M	4%	25	3.5M	12%
NORTHEAST	18	1.4M	7%				9	1.7M	33%	27	3.1M	11%
EAST	30	2.4M	13%	1	<0.1M	1%	3	0.4M	8%	34	2.9M	10%
BALLARD	10	1.6M	8%				2	0.1M	2%	12	1.7M	6%
SOUTHEAST	8	1.0M	5%				4	0.2M	4%	12	1.3M	4%
NORTHWEST	6	0.9M	5%				4	0.3M	6%	10	1.3M	4%
NORTH	4	0.6M	3%				4	0.4M	9%	8	1.1M	4%
CENTRAL + EAST	2	0.2M	1%				1	<0.1M	2%	3	1.0M	1%
SOUTHWEST	8	0.8M	4%				1	<0.1M	1%	9	0.9M	3%
DELRIDGE	3	0.6M	3%				1	0.4M	7%	4	0.9M	3%
GREATER DUWAMISH	2	<0.1M	<1%	2	0.3M	7%	5	0.3M	7%	9	0.8M	3%
CENTRAL	7	0.4M	2%	1	<0.1M	1%	1	<0.1M	1%	9	0.5M	2%

Appendix C: Weather Normalization Details

For consumption and greenhouse gas emission data, we use both non-normalized and weather-normalized versions of the key variables. Weather-normalized variables adjust annual values based on that accounts for average and actual weather conditions. For instance, if a year had a higher than average number of very cold days, buildings in that year would be expected to consume more gas than in an average year. That year would also be expected to have a lower weather-normalized consumption quantity compared with its non-normalized consumption quantity. In this report, weather-normalized values are used when making comparisons between data from multiple years, while non-normalized (actual) values are used when looking at 2016 data in isolation.[1]

1 Weather normalization is done using data collected by weather monitoring stations and published by the National Climatic Data Center (NCDC), which is part of the National Oceanic and Atmospheric Administration (NOAA).

In Portfolio Manager, there are two key metrics that account for these effects:

- **Weather Normalized Energy.** Weather normalized energy is the energy a building would have used under average conditions (also referred to as "climate normals"). The weather in a given year may be much hotter or colder than that building location's normal climate; weather normalized energy accounts for this difference. Note that the adjustment is for weather only, but not climate. That is, the metric evaluates a building over time, but does not account for differences between that building and other locations that have different average (normal) climates. Weather normalized energy is not available for new building design projects because they have not yet experienced years with different weather.
- **ENERGY STAR Score.** The 1-100 ENERGY STAR score is a percentile ranking, which compares a building to its peers. The ENERGY STAR score accounts for both climate and weather. To provide a score, a regression equation is used to predict the energy a building is expected to use given its climate, weather, and business activity. Buildings that use less energy than this prediction score better and vice versa. The regression equation used to predict usage is based on a national analysis that includes buildings in all locations with different climates. Because of this national representation, regression coefficients on terms like Cooling Degree Days (CDD) and Heating Degree Days (HDD) incorporate the differences among these climates. To predict energy for a building in any given year, we will incorporate that building's actual experienced weather data for that year. Buildings are predicted to use more energy in a very hot year, for example. In the case of a new building design, the ENERGY STAR score will use the average normal climate conditions to compute the energy prediction, as no actual weather has been experienced.

Appendix D: Greenhouse Gas Emissions Details

To estimate greenhouse gas (GHG) emissions quantities, it is first necessary to convert from energy consumption (e.g., kBtu) to emissions (measured in metric tons of CO_2 equivalent, i.e., MT CO_2). Seattle-specific emissions factors were used to perform these conversions for electricity and steam. As shown below, these conversion factors are dependent on the fuel type:

- Emissions factor for electricity from Seattle City Light (2014): 20.08 lbs. CO_2/MWh
- Emissions factor for steam from Enwave (2014): 170.17 lbs. CO_2/MBtu
- Emissions factor for gas (from Portfolio Manager): 53.11 kg CO_2/MBtu

In all cases, to convert from energy to emissions, additional unit conversion factors were applied (e.g., there are 2,204.62 lbs. in a metric ton).

For this report, GHG emissions were estimated using weather-normalized energy consumption data to allow for year-over-year comparisons. For electricity and gas, these calculations are simple to perform using benchmarking data and can be computed directly by taking the total amount of energy in kBtu and converting to MT CO_2. The conversion process for steam cannot be performed directly, as Portfolio Manager does not provide a weather-normalized steam quantity. Instead, weather-normalized steam consumption was computed by subtracting the sum of electricity and gas use from the total energy consumption for a given building. By "backing out" this quantity, we could then convert to MT CO_2 using the conversion factors shown above.

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