Laying the Foundation: Assessing Data Quality in Municipal Building Benchmarking Datasets

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ABSTRACT

Datasets collected under building benchmarking policies have tremendous potential for changing the way cities and utilities approach energy efficiency. Comprehensive benchmarking data can be used to understand key trends, target utility programs, and track progress toward policy goals. However, these uses rely on data quality. Benchmarking datasets consist largely of energy data and facility characteristics reported by building owners with little to no training, professional experience, or stake in energy benchmarking. This paper asserts that a process-oriented approach is an important first step to understanding data quality, based on analysis of the City of Seattle's benchmarking data.

A process-oriented approach uses existing datasets and knowledge of data flows to promote deeper understanding of the data and its limitations. The first step in analysis of the City of Seattle's dataset was identifying points where error could be introduced. The research team drew a statistical sample to understand building owner data input practices. The second step was comparing the Seattle benchmarking dataset with municipal and third party building datasets to test for inconsistencies. The third step was testing for trends in factors that could explain variability in the data, such as occupancy levels and mixed-use buildings.

By testing for sources of error and variability, the authors were able to verify the overall quality and utility of the Seattle dataset. The assessment also produced actionable recommendations for improvements in benchmarking programs, such as outreach strategies and instructions to building owners.

Introduction

With the passage and implementation of building benchmarking ordinances, building owners, policymakers, and planners have unprecedented access to building energy performance information. For the first time, cities across the U.S. have a complete picture of how energy is used in large buildings in their jurisdiction. Likewise, many building owners have received their first reports of whole building energy performance and performance relative to buildings of a similar type.

The City of Seattle was among the first cities in the U.S. to implement its benchmarking ordinance, Ordinance 123226. Limited rollout began in 2011, progressing to full implementation in 2012 for commercial and multifamily buildings 20,000 square feet or greater. Ordinance requirements vary by city; the Seattle ordinance is notable for its relatively low ceiling of 20,000 square feet and “transactional” disclosure requirements. Ordinance 123226 includes requirements for disclosure of benchmarking information in real estate transactions (sale, lease, and financing) but does not require public disclosure of the data (City of Seattle 2010). Without a public disclosure requirement, the City cannot access all of the building profile information and energy consumption data; for example, space use attributes such as occupancy are not included in data available to the City (Seattle DPD 2011).

With a full year of data from 2012, the City of Seattle used the dataset to set a baseline for measuring progress toward policy goals, provide building owners with parameters for judging their relative performance, and gain insight into energy consumption trends in the Seattle building stock. As data accuracy was essential to each use, assessing data quality, accuracy, and reliability was a foundational step in analysis and a focus of the City's 2011/2012 analysis report (Seattle OSE 2014).

This paper describes the approach used to assess data quality, which (1) focused on identifying systematic biases that could affect summary statistics, (2) leveraged the domain expertise of benchmarking implementers, and (3) looked at data quality from a process perspective by collecting metadata on data input practices and following up with outlier cases. The research team also assessed drivers of energy use that could explain variability in the data. The approach can be executed with a relatively small resource commitment, making it scalable across jurisdictions in which analytical resources are limited.

Data Quality and Benchmarking Ordinances

Similar to other municipal benchmarking ordinances, Seattle's Ordinance 123226 is targeted at providing energy performance information to real estate markets and facilitating cost-effective energy efficiency improvements by correcting for imperfect information. The transactional disclosure requirement aims to create appropriate valuing of a building's energy performance in real estate transactions.

Disclosure requirements—public or transactional—are an essential piece of all eleven existing state or municipal benchmarking ordinances.[1] If the data are used in market transactions or are publicly available, then data quality and accuracy are an even greater imperative. Public disclosure has already generated media attention to individual buildings, such as the LEED-certified Bank of America Tower in New York (Roudman 2013). Accurate data will keep the conversation focused on building energy performance and not on the ordinance or its implementation. The barrier, of course, is the mandatory and self-reported nature of the benchmarking. Many building owners have no interest or stake in benchmarking and comply only to avoid fines.

For policymakers, utilities, and planners, city benchmarking datasets are a critical tool for tracking progress toward policy goals, assessing trends, measuring energy savings potential, and targeting utility and municipal energy efficiency programs. The City of Seattle has set goals in its Climate Action Plan to reduce energy use by 10% in commercial buildings and by 20% in residential buildings by 2030; the benchmarking data can be used to track progress toward the goals. The datasets have the potential for a wider range of uses when combined with other data, such as research in New York comparing asthma rates to energy use intensity (EUI) (Kerr, Beber, and Hope 2012).

[1] Cities include Austin, Boston, Chicago, Minneapolis, New York, Philadelphia, San Francisco, Seattle, and Washington D.C. States include California and Washington.

Research Approach

Data Quality

There is no single tool or analysis to assess and address data quality issues. As stated by Dasu and Johnson (2003), "solving data quality problems requires highly domain-specific and context-dependent information, involving interaction of domain experts." Data quality problems invariably arise at some point in the data flow from measurement to input to calculation to output. A process-oriented approach to assessing data quality focuses on identifying these points. In the case of benchmarking, the primary outputs of EUI and ENERGY STAR rating rely on at least three, but potentially dozens, of inputs. Domain experts—implementers of benchmarking policies—are knowledgeable about the data process and can identify the data flows and rules that will result in accurate, reliable data.

The mandatory building energy benchmarking datasets are composed of largely self-reported data, so it can be expected that the datasets will be initially "messy" with many outliers. In initial analysis, testing for systematic errors may be an important first step before attempting to reduce variation by identifying and removing outliers. This is because systematic errors lead to biases that can shift entire distributions. The City of Seattle prioritized testing for systematic errors to ensure the 2012 data could be used to set a baseline and could be analyzed for meaningful trends.

Data Flow

Informed by the knowledge of benchmarking implementers, the data quality assessment for the City of Seattle benchmarking dataset focused on building type, inputs to EUI, and the EUI output. The data flow through the benchmarking software, EPA Portfolio Manager, is documented in Figure 1. EUI is the ratio of energy use to square footage and the building type is determined by the majority space use by square footage.[2] The benchmarking implementers played a major role in specifying the research design and interpreting findings.

Before analysis, the research team applied standard cleaning procedures, removing buildings with no energy data, buildings less than 20,000 square feet, buildings exempted from compliance, and the top and bottom 1% of buildings by EUI (54 buildings). This is not shown in the data flow.

To understand data input practices and view all inputs, the research team manually accessed a statistical sample of buildings 50,000 square feet or greater (n=75) through the Portfolio Manager portal, as disaggregated data by fuel use and space use attributes were unavailable in data extracts. This simple random sample was designed to meet 90% confidence and 10% precision targets for the 50,000 square feet and greater buildings, in their second year of reporting and assumed to have passed beyond the initial learning curve. Indicators of data quality included usage rate of automated benchmarking services (ABS), percentage of buildings with electric, gas, and steam accounts, and rate of updates to occupancy information.

[2] If there is no majority space use, then the building is classified as "other."

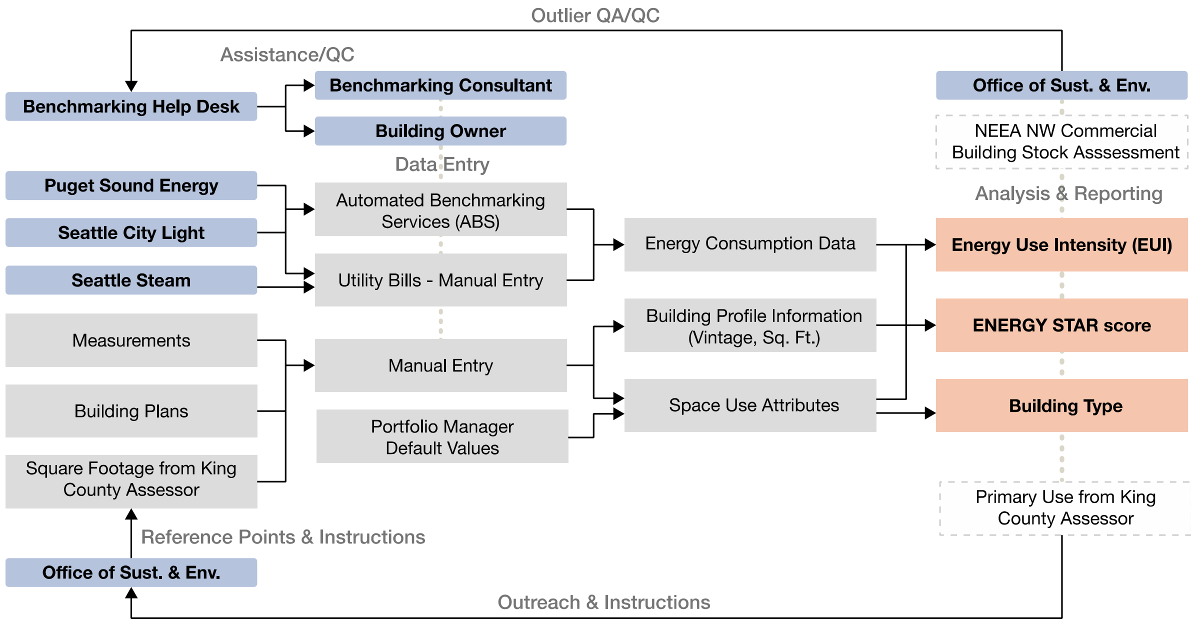

Figure 1. Seattle building benchmarking data flow through portfolio manager.

To assess the accuracy of outputs, the research team made comparisons to external datasets: the Northwest Energy Efficiency Alliance Northwest Commercial Building Stock Assessment and records from the King County Assessor. The former was used for EUI comparisons, and the latter was used for square footage and building type comparisons. These comparisons were used to detect differences or shifts in distributions indicative of systematic errors.

Results

Energy Consumption

In the statistical sample, the research team found a 78% rate of use of automated benchmarking services (ABS) for electric accounts. Use of automated benchmarking services (ABS) eliminates errors in transcription and minimizes the possibility of excluded data. ABS does not, however, guarantee the inclusion of all meters associated with the building and depends on quality control on the part of the utility and reporting individual. Nonetheless, the high rate of use of ABS for electric accounts was considered a positive indicator of data quality.

All buildings in the sample recorded electric fuel usage, 61% recorded gas usage, and 5% recorded steam usage. The percentage of buildings with gas service in Seattle is lower than in many other cities, as all-electric buildings were very common for much of the 20th century, particularly in the multifamily sector. Buildings constructed since 2000 are more likely to incorporate gas as a substantial energy source (Ecotope 2009). The research team considered this gas usage rate to be reasonable.

An assessment of ABS use for gas accounts was not possible due to changes in the Puget Sound Energy (PSE) system that occurred during the benchmarking period.

This was one potential source of error that was not investigated, and will be important to assess in the future, particularly for small multifamily buildings where manual data entry can be a barrier.

Occupancy

With fluctuating economic conditions in Seattle, occupancy rates have also varied substantially in the past decade. From 2011 to 2013, office rates in the Puget Sound Area fell from 18.8% to 15.5% (CBRE 2013). Occupancy density is a key driver of energy usage and intensity (Kontokosta 2012) and thus it is important that occupancy is measured and updated to reflect tenancy changes. In the sample, 15% of buildings with required occupancy information updated occupancy data in the 2011 to 2012 time period. This rate of update does not seem sufficiently high to capture variations in tenants' employment patterns (building owners are also unlikely to be aware of these changes), but it may capture major tenancy changes.

Building Type

For buildings in the sample, the research team compared building types from Portfolio Manager to the primary use documented in the King County Assessor records. Correct building type classification is essential for generating a meaningful ENERGY STAR rating and for enabling peer comparisons by EUI. The comparisons yielded few differences, and in only 3% of cases did the Portfolio Manager building type appear to be erroneous.

Square Footage

As part of its notification process, the City of Seattle provided property owners with the King County Assessor record of their building's gross square footage as a guideline or reference point, but asked owners to use the most accurate value known when benchmarking (see Figure 1). The King County Assessor square footage typically includes the building uses (rentable and non-rentable), basement area, and parking area. (In other cities, assessor square footage values often exclude underground spaces.) Although some errors have been found in the King County square footage data, the benchmarking implementers considered King County to be a good source for obtaining reasonably accurate square footage. Parking area, however, should be excluded for Portfolio Manager benchmarking when separately metered.

The analysis found that about half (50.4%) of the Portfolio Manager reports used a square footage that fell within 1% of King County records. To investigate whether inputting the King County value into Portfolio Manager was a reasonably accurate choice, the two records were compared to look for the error of over-reporting of square footage by inappropriately including parking area. The vast majority of the buildings (87%) with "matching" square footage did not have any parking listed in the King County record, thus using the provided "matching" value appeared to be reasonable.

The other half of reported buildings that had "non-matching" values were also compared to the supplied King County value. Of those buildings, the majority (71.5%) reported a smaller value than the King County value (Figure 2). This percentage appeared to be reasonable as more than half of these buildings had parking listed in the King County record, suggesting that parking square footage was separately metered and correctly omitted when inputting square footage into Portfolio Manager. This finding also suggests there was no systematic inflation of square footage values to manipulate EUIs downward.

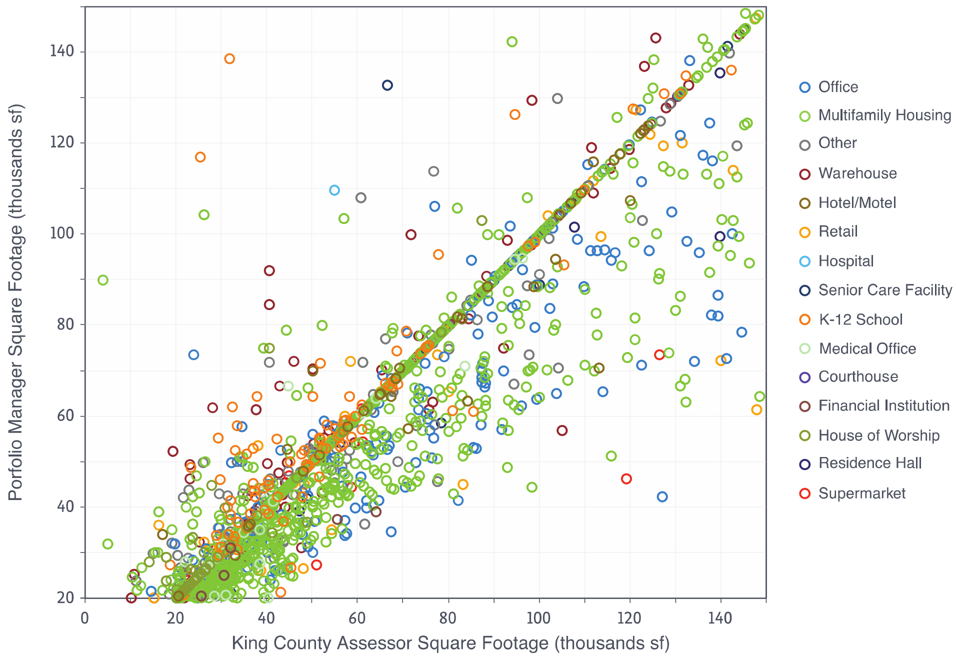

Figure 2. Scatter plot of portfolio manager and king county assessor square footage. *Source:* Seattle OSE 2014.

Energy Use Intensity

The NEEA Northwest Commercial Building Stock Assessment (NCBSA), conducted in 2007 and based on audits, provided a validated dataset comparison for the Seattle benchmarking dataset (NEEA 2009). The NCBSA included a subset of Seattle buildings, but offices were the only building type with enough buildings (n=49) to allow for a meaningful comparison of distributions.

The boxplots in Figure 3 show very similar distributions of EUIs for office buildings in the two datasets. The median EUI differs by only 0.1 kbtu/sf—59.1 kbtu/sf for the Seattle Benchmarking dataset and 59.0 kbtu/sf for the NCBSA. The shape of the distributions is also similar, with the Seattle benchmarking dataset showing a wider distribution due to the larger number of buildings in its office-specific subset (n=350).

This finding suggests that, while the data contain some noise and numerous outliers, the overall summary statistic for offices in the benchmarking dataset is accurate. This finding has positive implications for the accuracy of summary statistics for other commercial buildings. However, resources and knowledge of building owners may differ in other sectors such as multifamily.

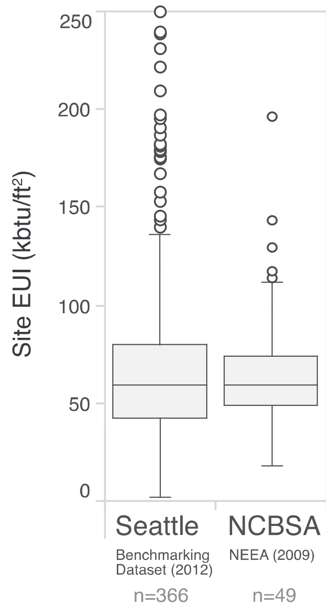

Figure 3. EUI distributions for offices in Seattle benchmarking dataset and NCBSA. *Sources:* Seattle OSE 2014 and NEEA 2009.

Within the Seattle benchmarking dataset, the research team compared buildings benchmarked by a known energy efficiency service provider (or "vendor") to other buildings, presumed to be largely owner-benchmarked. The distributions of EUI in multifamily and office buildings, which together made up 66% of buildings in the dataset, are shown in Figure 4 for vendor and owner-benchmarked buildings. Again, the distributions appeared to be similar between the groups, with the median for multifamily differing by 0.2 kbtu/sf and the median for offices differing by 2.2 kbtu/sf.

While the EUIs generated by energy efficiency service providers may not be accurate, the consistency between the distributions is a positive indicator, as the results do not suggest one group is doing better, or more accurate, benchmarking than the other.

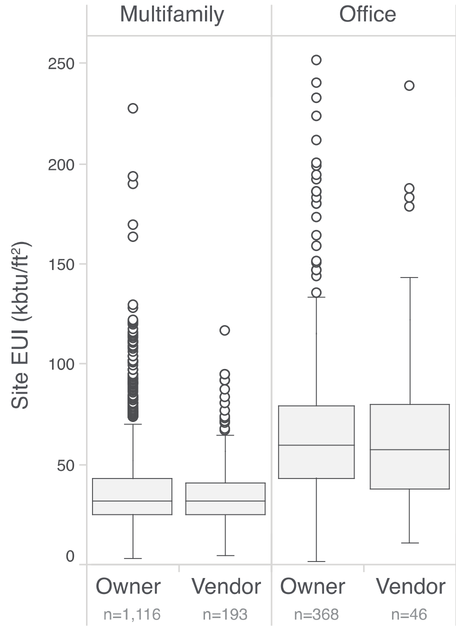

Figure 4. Comparison of distributions between owner and vendor-benchmarked Office and Multifamily buildings. *Source:* Seattle OSE 2014.

Energy Use Drivers

After the data quality assessment, the research team looked for trends in the data that could explain variability in EUI, such as mixed uses, vintage, occupancy, and size. These are described in detail in the annual report (Seattle OSE 2014) and briefly summarized here. Mixed-use development appears to be one major driver of variability in EUIs within office and multifamily buildings. Increasing numbers of use types are associated with higher EUIs, as secondary space uses are generally more energy intensive than office or multifamily uses (Figure 5).[3] EUIs for office and multifamily buildings were found to vary by building vintage, and it is likely that an increasing proportion of mixed-use development in Seattle has driven some of the recent trends.

Although occupancy data was not accessible for the dataset, an analysis of affordable multifamily housing with housing units as a proxy for occupancy suggested that differences in occupant density accounted for the higher EUIs seen in low-income and affordable housing relative to other multifamily buildings. This finding was supported by recent research; Kontokosta (2012) found worker density, operating hours, and affordable housing to be significant factors in regression models for energy intensity.

Building size was found to have a positive relationship with energy intensity for multifamily housing—although the strength of the relationship appeared to vary by building vintage. The underlying factor in the relationship could be building structure—low-rise, mid-rise, or high-rise— which is a specification in the proposed ENERGY STAR rating for multifamily buildings (EPA 2013).

[3] Examples of space types found in mixed-use developments include retail, restaurants, data centers, supermarkets, and medical offices.

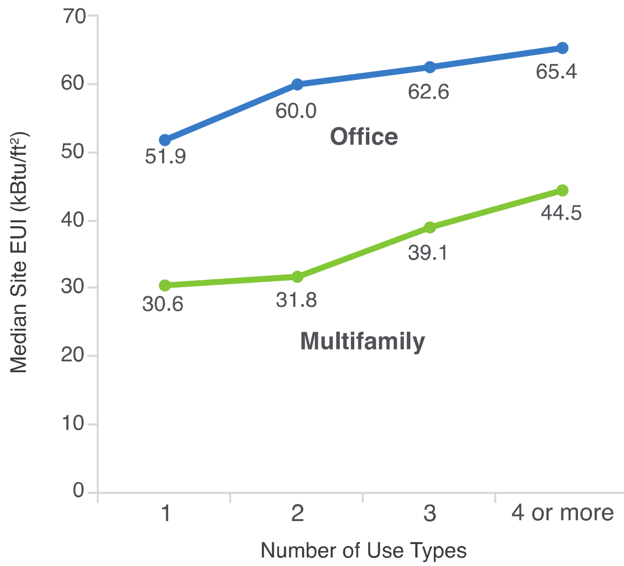

Figure 5. EUI by number of use types in office and multifamily buildings. *Source:* Seattle OSE 2014.

Discussion

Overall, the data quality assessment of the Seattle benchmarking dataset identifies no major issues in the selected tests and indicators. While a number of fields were not investigated and numerous outliers remain in the dataset, the assessment suggests that the 2012 data can be used as a baseline for future comparisons and are useful for analysis of trends.

This paper describes the process-oriented approach to assessing data quality in the Seattle benchmarking dataset. This approach focused on identifying systematic errors. Hsu (2014) classifies data quality theories as falling into the dimensions of user needs, process control, and data. The Seattle approach emphasizes the latter two, particularly the process element. While similar to the approach of New York City (see Lee et al. 2013), the Seattle approach differs in its use of a statistical sample to understand data input practices and its comparison to an external validated dataset. This paper suggests that specific research and analysis of data input practices can produce a set of valuable indicators of data quality and may be an appropriate methodology for jurisdictions with limited analytical resources.

Efforts to make continued improvements to data quality can leverage the knowledge gained from this preliminary assessment. Our research included basic identification of outliers in the data cleaning step and in comparisons between 2011 and 2012 data; these outliers were provided to the help desk for follow-up (see Figure 1). Further outlier identification will be an important next step and will build off the insights gained from trend analysis. Hsu (2014) recommends partitioning benchmarking data in subgroups by building type to identify outliers; this analysis indicates that even deeper subsets (e.g., single-use, low-rise multifamily housing) may be warranted. Or alternatively, in a model-based approach, these factors should be incorporated as inputs.

With additional understanding of the factors driving energy use, benchmarking implementers can provide further outreach and instructions to encourage building owners to correctly input and update key data fields, such as occupancy and square footage. These outreach activities are an additional input to the data flow (Figure 1). Building owners may need support resources to guide them through the process; improving data quality could require additional investments from cities.

Future research options to study data input practices include larger stratified samples for the review of Portfolio Manager inputs or research directly involving building owners such as surveys, interviews, or even software usability tests. As with outreach, fields that are key drivers of energy use should be the focus of this research. The research with building owners could also evaluate actions taken as a result of benchmarking, as done by Vaidya et al. (2012). The Seattle data quality assessment did not look at reliability of data for building vintage, inclusion of space types, space type square footage, or use of ABS for gas accounts, and the statistical sample did not include buildings 20,000 feet and smaller; these present further areas for study. An additional data quality issue not covered in this study is bias toward default values for space type attributes (Kontokosta 2014).

The Seattle benchmarking dataset represents a picture of energy use in the city that has never before been available. It is already useful as a baseline and has yielded a number of insights. With improvements to data quality over time, self-reporting building benchmarking datasets have an enormous potential for influencing real estate markets, for updating national databases (see Hsu 2014), for targeting energy efficiency programs, and for understanding how energy is used across the country.

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