Benchmarking Multifamily Buildings in California: How It's Working and What We Can Learn from the Data

Submitted to the California Energy Commission

March 25, 2020

Prepared by:

Ben Cooper
StopWaste
1537 Webster St.
Oakland, CA 94612
bcooper@stopwaste.org

Tabitha Harrison
Nick Dirr
AEA
5900 Hollis St., R2
Emeryville, CA 94608

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Executive Summary

As part of a suite of projects carried out under a Local Government Challenge Grant from the California Energy Commission, StopWaste and its subcontractor AEA provided technical assistance to multifamily building owners to help them comply with the state's Building Energy Benchmarking Program.

During the technical assistance process, AEA encountered challenges to ensuring that complete and accurate data was obtained from the utilities and submitted to the Energy Commission. The chief obstacles include:

- Difficulty ensuring that all meters are included in aggregated data requests
- Building owner disengagement from the benchmarking process
- Benchmarking portals preventing multiple data requests for the same property
- Challenges verifying data quality and maintaining data over time

We were also able to leverage our benchmarking data set to analyze the relationship between energy use intensity (EUI) and various building characteristics and to compare energy model predictions with actual performance.

Our research scope was sufficient to uncover potential improvements to California's data request and disclosure processes, to begin posing questions about actual energy savings compared to predicted values, and to conclude that heating system type is a stronger predictor of EUI than climate zone or building vintage for this data set. However, the sample size was not large enough to confidently claim that the EUI and heating system type relationship will hold up for a broader data set or to answer questions about the relative effectiveness of various energy efficiency measures.

We recommend that the Energy Commission sponsor further research to build on these findings, including:

- A more in-depth study of the relative effect of various building attributes on energy efficiency;
- A more thorough review of energy conservation measure types, building types, and calculation methodologies as predictors of actual energy savings relative to predicted savings; and
- More extensive feedback on the aggregated data request and disclosure processes.

Introduction

StopWaste was awarded a Local Government Challenge Grant in 2017 from the California Energy Commission to develop tools and perform policy research to accelerate comprehensive energy efficiency upgrades in the existing multifamily building sector. As part of this grant, StopWaste and subcontractor AEA were tasked with providing benchmarking technical assistance to multifamily building owners in preparation for California's Building Energy Benchmarking Program.

Between January 2018 and May 2019, we provided benchmarking assistance to 89 properties in eight California climate zones. We fully benchmarked 70 of those properties, meaning we collected energy data for common area meters as well as all dwelling unit meters. As part of this process, we were able to discuss benchmarking and data disclosure challenges directly with property owners as well as gain direct experience with the aggregated data request system.

In addition to providing benchmarking technical assistance, outcomes of this study included an analysis of energy use intensity (EUI) based on building age, location, and HVAC equipment type.

Because many of the properties in our data set had participated in energy upgrade programs, we were also able to compare predicted post-upgrade energy use to actual energy use for 44 properties.

This report provides suggestions for improvement to the benchmarking and disclosure process, as well as the findings of our EUI analysis. Although this study focused on multifamily housing, the observations and suggestions related to data request and disclosure processes may also be applicable to commercial buildings that have to comply with the Building Energy Benchmarking Program.

The study's findings are presented in three sections:

1. Improving Benchmarking Data Quality
2. Reassessing Predictors of Energy Use Intensity
3. Using Benchmarking Data to Understand Actual Energy Performance of Building Upgrades

Improving Benchmarking Data Quality

During the benchmarking technical assistance process, we encountered significant challenges to ensuring that the data obtained from the utilities and submitted to the Energy Commission were complete and accurate. Table 1 shows a high-level summary of the chief obstacles we encountered and our recommended solutions; a detailed discussion follows this table.

Table 1: Summary of Benchmarking Challenges and Potential Solutions

Challenge	Recommendation
1. **Difficult for owners or their consultants to ensure that all meters are included in aggregated data request**	Provide best practices guide that outlines suggested steps and emphasizes the importance of including all meters. Require that utilities provide data for all meters that were active during the reporting period, even if they were removed prior to the data request.
2. **Benchmarking portals denying multiple data requests from the same property**	Allow multiple data requests per meter.
3. **Difficult for owners or their consultants to vet and maintain data**	Encourage more consistency between utilities: • Calendar vs. billing month • Properties with solar systems Increase collaboration with Portfolio Manager to prevent recurring gaps in data.
4. Difficult for Energy Commission to verify data quality after submission	Develop checks to confirm that square footage, EUI, and meter count are within reasonable range. Require the following information to support quality assurance checks of meter count: • From owner: metering structure (direct vs. master metered) and number of meters included in initial data request • From utility: number of meters reporting data each month during the disclosure period
5. Building owner disengagement from the benchmarking process	Provide case studies and other resources to highlight successful energy management efforts made possible by benchmarking.

1. Difficult to Ensure That All Meters Are Included in Aggregated Data Request

Issue

The most common challenge our team encountered was difficulty ensuring that aggregated data requests are complete and accurate. Properties have varied meter counts and layouts that are often difficult to predict. Many properties also have multiple service addresses, which further complicates the process of ensuring that all relevant meters are included in the data request.

We uncovered a related challenge at properties where meters have been removed or replaced. Even if meters were active during the reporting period, data may not be available via the standard request process because benchmarking portals no longer recognize the meters as active. Properties with recent electrification projects are most likely to face this issue.

Recommendation

Utility providers and the Energy Commission should emphasize to owners and their benchmarking consultants the importance of including all relevant meters to ensure that data requests are complete and accurate. The Commission should consider publishing a best practices guide to help ensure accuracy. We also recommend that the Commission further clarify that utilities must provide historic data throughout the reporting period for any currently inactive meters.

Discussion

Because the aggregated data request process is linked to meter numbers, not account numbers, it is essential to start the process with an accurate meter count. Using meter numbers for aggregated data requests is preferable to account numbers, because account numbers can change quite often due to unit turnover or updated rates. However, meter number changes are still possible, and failing to include data from every meter that was active during the reporting period can have a significant effect on data quality. Likely causes of meter changes include removing a fuel source (e.g., electrification), replacement of faulty meters, or updates during major renovation.

Barring the ability to visit a site and physically count meters, it is possible for owners or their consultants to create a credible meter count by considering the following:

- The number of dwelling units at the property
- Whether each dwelling unit is separately metered for gas or electricity
- The number of electricity and gas meters shown on owner-paid bills for common areas or central systems

Most utilities use service address as a starting point for data requests. If the expected number of meters is not found under a property's primary service address, it signals the need to check if there are more service addresses associated with that property.

Unexpected challenges related to service addresses was perhaps the most surprising observation in our study. It was very difficult to predict how many service addresses may be linked to a given multifamily property—even if the property is a single building. A property may have one service address for the leasing or property management office and another for dwelling units in the same building. Garden-style properties present their own set of challenges.

In our study, we observed each of the following possible scenarios for garden-style multifamily properties: one service address for the entire property, one service address per building, and separate service addresses for each apartment.

Ensuring that the data request includes all relevant meters is critical to data quality control.

Figure 1 shows an example of a single multifamily building with meters linked to three different service addresses.

Figure 1: Multiple Service Addresses Complicate Data Requests

If meters have been removed and are no longer active, data cannot be requested through the benchmarking portal. Figure 2 shows an example property where gas meters were removed as part of a large electrification project. The benchmarking portal accurately shows current conditions because there are zero active gas meters. However, in this case the gas meters were removed less than a year prior to requesting data. The regulations are not being met in this case because complete, accurate aggregated data for the last calendar year is not available.

Figure 2: Example of Inactive Meters Redacted

Premise Address	Gas Services	
	No.	Auth Status
APT 101 SACRAMENTO CA	0	N/A
APT 102 SACRAMENTO CA	0	N/A
APT 103 SACRAMENTO CA	0	N/A
APT 104 SACRAMENTO CA	0	N/A
APT 105 SACRAMENTO CA	0	N/A
APT 106 SACRAMENTO CA	0	N/A
APT 107 SACRAMENTO CA	0	N/A
APT 107 SACRAMENTO CA	0	N/A
APT 108 SACRAMENTO CA	0	N/A
APT 109 SACRAMENTO CA	0	N/A
APT 110 SACRAMENTO CA	0	N/A
APT 111 SACRAMENTO CA	0	N/A
APT 112 SACRAMENTO CA	0	N/A
APT 113 SACRAMENTO CA	0	N/A
APT 114 SACRAMENTO CA	0	N/A

Key: No. = Number of Meters; Auth = Authorization; Light text = Inactive premise; N/A = Not applicable

2. Benchmarking Portals Denying Multiple Data Requests

Issue

Some utilities only allow one active data request for a given set of meters. Blocked access to data results in a great deal of frustration and delays. It also jeopardizes data quality and makes it more challenging for building owners to comply with California's Building Energy Benchmarking Program. Denying access to multiple requestors may be a misinterpretation of the final California Benchmarking Regulations, as outlined in the Discussion section below.

Recommendation

Recommend or require that utilities allow multiple active data requests for each meter, to reduce delays and acknowledge the potential need to request data for multiple purposes.

Discussion

Another data request issue our team encountered multiple times was "locked meters." At least one of the utility benchmarking portals only allows one active data request for a given meter. It is not uncommon for an owner or benchmarking consultant to complete a few steps of the data request process only to find that the utility has blocked access to the property's meters because of a previous data request.

Once discovering that data has already been requested by another party, there's no simple way to determine who currently manages the data. An owner or their consultant must either:

- Ask multiple parties connected to the property, hoping that one of them remembers who already requested the data, or
- Contact the utility and request that they release the meters for remapping, which could result in accidentally stripping data access from another party who needs it.

Either of these options can add weeks to the data request process, and in our experience may not succeed at all despite many hours of extra effort.

Here's a simplified example of a situation we came across several times: A property management company is working on an energy efficiency project and obtains meter data from the utility aggregated in a specific way to meet their needs. Separately, a consultant hired by the company to manage benchmarking compliance submits a data request for the same property. Because the utility already provided meter data to another party, their benchmarking portal denies the consultant's request. Even if the two or more parties who require access to data are able to easily connect with one another, if the aggregated data request can't be arranged in a way that meets everyone's needs, at least one party will be left manually manipulating aggregated data to achieve their goals. For example, if aggregated data was requested per building at a garden-style apartment complex for energy management purposes, but another individual needed whole-property data for either benchmarking compliance or another purpose, they would have to gain access to the originally requested data and then manually add data for each building. This opens the door for significant errors.

The final California Benchmarking Regulations released in March 2018 acknowledge the potential need for an owner or owner's agent to request data for multiple purposes.[1] The regulations outline two potential paths for requesting the same data: "…a request for energy use data that is *not* [emphasis added] for compliance with the Benchmarking and Public Disclosure requirements" and "…a request for energy use data for compliance with the Benchmarking and Public Disclosure requirements."

The regulations also do not stipulate that a utility may deny requests from multiple parties for the same data. Rather, they outline the requirement that data be provided to an owner or owner's agent within a specified length of time (28 days for complete, accurate requests). In the regulations, "Owner's Agent" is defined as "A person with authorization from the building owner to act on behalf of the building owner."[2] The regulations do not specify that there can be only one authorized owner's agent for a given property.

The regulations seem purposefully open-ended and flexible in this area, acknowledging the potential need to request data for multiple purposes. However, the aggregated data request system for at least one major utility is not currently set up to recognize that for any given property, there may be valid reasons to request data that is aggregated in different ways and/or by different stakeholders. This limitation has resulted in countless hours of delays for owners, consultants, and the utility's customer service representatives who must spend time trying to determine both who originally requested data, and who has the strongest "right" to request and maintain data moving forward.

[1] 20 CCR § 1682 Data Access, subsections (b)(4)(A) and (b)(4)(B)

[2] 20 CCR § 1681 Definitions, subsection (i)

3. Difficult to Vet and Maintain Data Prior to Submission or Between Reporting Periods

Issue
Our team encountered numerous maintenance and quality concerns once aggregated data was received from utilities. These are particularly difficult to manage and troubleshoot due to the wide variance between utilities:

1. Some utilities provide aggregated data per month on an ongoing basis, while others only provide a one-time export of aggregated data upon request.[3]
2. Some utilities divide and realign data across calendar months to make records appear more consistent, while others allow data to fall into whichever month is closest based on billing date. This results in data that can look erratic or incomplete.
3. Missing months or zero entries have been noted from at least two utilities, for different reasons.
4. Some utilities provide aggregated electricity use before solar allocations for multifamily properties with virtual net energy metering (VNEM), while others provide aggregated electricity use after solar allocations have been subtracted from each benefiting account.

Recommendation
Recommend or require that utilities follow a consistent set of guidelines in terms of data format across calendar versus billing months, to avoid confusion and potentially erroneous data.

Recommend collaboration between utilities and Portfolio Manager to troubleshoot the cause of recurring gaps in data.

Recommend or require consistent handling of aggregated data for properties with VNEM systems across utilities.

Discussion
Thus far, this report has addressed issues that can affect data quality during the aggregated data request process, such as difficulty confirming that all applicable meters are included. Conversely, this section addresses challenges that arise after the data has been requested and received by an owner or owner's agent.

Some utilities divide and realign data across calendar months to make records appear more consistent, while others allow data to fall into whichever month is closest based on billing date. This results in data that can look erratic or incomplete. For example, Figure 3 shows a property with usage in November that is so low, it appears to be an error. However, the utility confirmed that billing periods did not align well with calendar months and as a result, much of the usage for November was split between October and December.

[3] Though this is specifically allowed within the final California Benchmarking Regulations, it can still result in confusion or increased work if owners wish to use data for ongoing energy management efforts.

Figure 3: Billing Period Does Not Align with Calendar Months

☐	9/1/2019	9/30/2019	28,108	4,722.13	☐	☐			11/21/2019 Sacrament Municipal U District SMU
☐	10/1/2019	10/31/2019	22,525	3,269.78	☐	☐			11/21/2019 Sacrament Municipal U District SMU
☐	11/1/2019	11/30/2019	3,240	504.91	☐	☐			11/21/2019 Sacrament Municipal U District SMU
☐	12/1/2019	12/31/2019	32,387	3,827.52	☐	☐			2/3/2020 Sacrament Municipal U District SMU
☐	1/1/2020	1/31/2020	38,409	4,588.49	☐	☐			2/3/2020 Sacrament Municipal U District SMU

Error! Not a valid bookmark self-reference. shows a property where billing periods typically span two months. Rather than realigning data evenly, the utility input zero values for every other month.

Figure 4: Billing Period Spans Two Months

☐	6/1/2015	6/30/2015	0		☐	☐			9/13/2019 Los Angeles Department Water and F LADWP
☐	7/1/2015	7/31/2015	52,370		☐	☐			9/13/2019 Los Angeles Department Water and F LADWP
☐	8/1/2015	8/31/2015	0		☐	☐			9/13/2019 Los Angeles Department Water and F LADWP
☐	9/1/2015	9/30/2015	47,643		☐	☐			9/13/2019 Los Angeles Department Water and F LADWP

Our team found that, contrary to our initial assumptions, the data request process cannot be set up once and then left to automatically update. Even when utilities provide automatic monthly updates, routine maintenance is required due to recurring missing months or data that looks incomplete (Figure 5). Troubleshooting these issues requires contacting the utility to confirm accuracy and/or “re-requesting” data from the utility. This process fills gaps, but also results in duplicated values for other months that must be manually deleted. It was unclear to our team whether missing months in the data are caused by technical issues on Portfolio Manager’s side or with the utility.

Figure 5: Gaps in Data

☐	2/1/2019	2/28/2019	20,130.16	3,977.19	☐	☐			4/16/2019 Pacific Gas Electric Wh Building
⚠ Aggregated Tenant Electric (83 Meters) has a gap of 31 days between the dates of 02/28/2019 and 04/01/2019. Please confirm this is correct or remove the gap by adjusting the dates per your meter entries and saving your changes. For more help, see this FAQ.									
☐	4/1/2019	4/30/2019	17,375.52	3,338.6	☐	☐			6/17/2019 Pacific Gas Electric Wh Building
☐	5/1/2019	5/31/2019	18,228.84	3,679.74	☐	☐			7/16/2019 Pacific Gas Electric Wh Building
☐	6/1/2019	6/30/2019	16,247.97	3,290.33	☐	☐			8/17/2019 Pacific Gas Electric Wh Building
☐	7/1/2019	7/31/2019	16,359.95	3,321.06	☐	☐			9/16/2019 Pacific Gas Electric Wh Building
⚠ Aggregated Tenant Electric (83 Meters) has a gap of 31 days between the dates of 07/31/2019 and 09/01/2019. Please confirm this is correct or remove the gap by adjusting the dates per your meter entries and saving your changes. For more help, see this FAQ.									
☐	9/1/2019	9/30/2019	16,985.13	3,428.12	☐	☐			11/16/2019 Pacific Gas Electric Wh Building

Because the data maintenance process requires a good deal of extra attention and time, it's unlikely that all practitioners will follow the same standards, which could result in inaccurate data submissions to the Energy Commission. Because our project team was tasked with thoroughly researching the data request process and vetting all data, the level of vigilance and attention to detail is very atypical compared to the population at large.

Multifamily properties with solar arrays and virtual net energy metering (VNEM)[4] face another unique set of challenges when vetting aggregated data. Properties with VNEM have a generation meter that tracks total solar production, which is later divided between a set of "benefiting" accounts by the utility as an accounting exercise. The amount of solar production that is assigned to each benefiting meter is typically called a solar allocation. This unique metering structure results in an important question for benchmarking practitioners: does aggregated data include solar allocations or not?

Our team found that some utilities aggregate raw consumption data for each meter, resulting in aggregated electricity use that does not include solar allocations for benefiting accounts. However, other utilities aggregate billing data for each meter, resulting in aggregated electricity use that does include solar allocations because those allocations are taken into account during the billing process.

The lack of clarity and inconsistency around aggregated data for multifamily properties with VNEM solar systems increases the risk that the solar benefit will be either under- or over-valued when reviewing a large set of aggregated data from multiple properties. It also increases the

[4] Virtual Net Energy Metering (VNEM) is a tariff arrangement that enables a multi-meter property owner to allocate the property's solar system's energy credits to tenants. More information: https://www.cpuc.ca.gov/General.aspx?id=5408

difficulty of energy management efforts by owners who wish to confirm that residents are receiving solar benefits.

4. Challenges in Verifying Data Quality After Submission

Issue
It is difficult to confirm the quality of benchmarking disclosure data after it has been submitted to the Energy Commission. Based on the challenges and issues uncovered by our team, if data is not vetted for accuracy, the final result of public disclosure may be of limited usefulness.

Recommendation
Develop automatic checks to confirm that square footage, EUI (adjusted for California), and meter count are within a reasonable range. If data falls outside of the expected range, temporarily exclude the property from public disclosure data and follow up with the owner or owner's agent to request corrections or explanations.

Discussion
Because of the inherent lack of transparency in aggregated energy data, it is difficult to check the accuracy of submitted data. To improve data quality, the Energy Commission should consider instituting a process to quickly assess the quality of submitted disclosures.

Develop a process for quickly assessing the quality of submitted disclosures, based on square footage, an expected range of EUI values, and meter count. These three checks could be part of an initial quality control process:

1. **Check the reported square footage per unit.** The most widely used benchmarking metric, energy use intensity (EUI), is calculated by dividing annual energy use in kBTU by gross square footage. Consequently, inaccurate square footage can have a huge effect on the reliability of benchmarking data. We recommend comparing self-reported gross square footage to the number of units and bedrooms at each multifamily property and flagging reports that fall outside of an expected range.

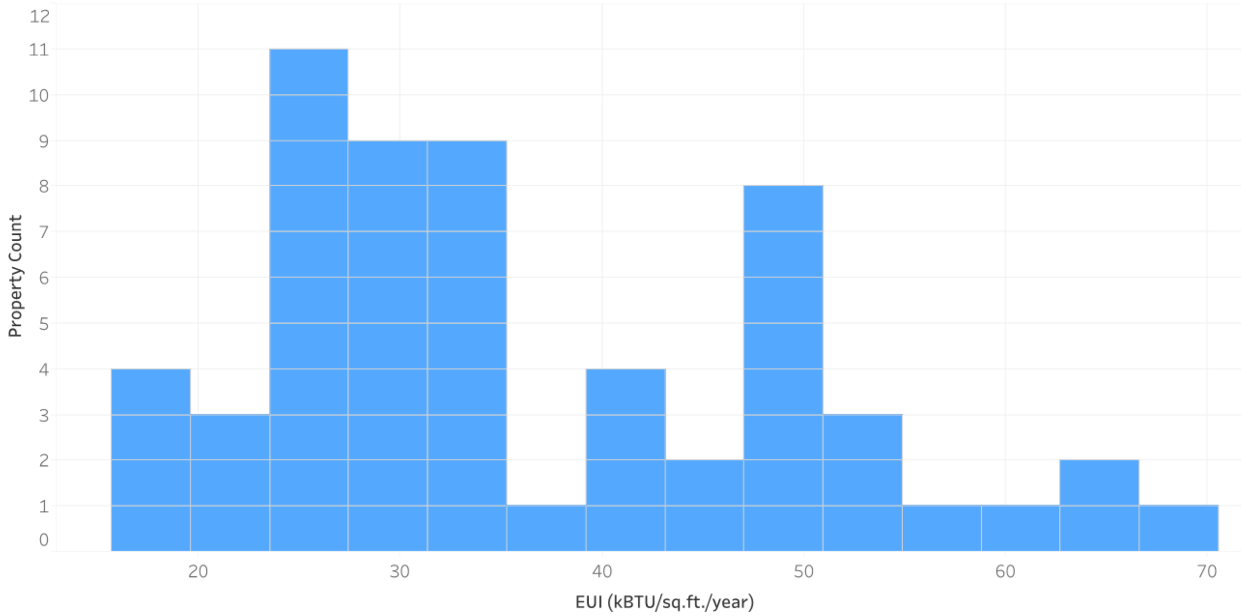
2. **Use a California-specific EUI range.** We recommend creating a custom EUI range that is an accurate reflection of California's multifamily building stock to make this quality control measure more useful.

   Figure 6 illustrates the frequency of EUIs within specific ranges for our data set, with the most common range for site EUI falling between 25 to 35 kBTU/ft^2/yr. In contrast, the national median reference value for site EUI among multifamily properties is 59.6 kBTU/ft^2/yr.[5]

   This finding supports the observation of artificially inflated Energy Star scores for multifamily properties in California, where a combination of factors contribute to low EUIs, including relatively mild climates in densely populated areas, stringent building and appliance energy standards, high energy costs, and efficient building systems.

[5] https://portfoliomanager.energystar.gov/pdf/reference/US%20National%20Median%20Table.pdf

Figure 6: Distribution of EUI



3. **Meter count.** Ideally the following information would be available to the Energy Commission, to help confirm data quality:
   - From owner: number, type (electric, gas), and layout (master, individual) of meters included in the initial aggregated data request; and
   - From utility: report summarizing the number of meters reporting data each month during the disclosure period.

5. Building Owner Disengagement from the Benchmarking Process

Issue

As highlighted by this report, the process of gathering accurate aggregated energy use for multifamily properties can be quite complex and time-consuming. Some building owners lack the time, motivation, or knowledge necessary to accurately collect and report benchmarking data. This is worsened by the wide variety of data request processes between utilities.

Recommendation

Creating a single aggregated data request system for the entire state would likely reduce the confusion and disengagement that we've seen, but the more feasible option may be pushing for a paradigm shift among owners. The Commission could publish case studies highlighting successful energy management efforts that were made possible by benchmarking. It would be important to include a range of projects (large, small, urban, suburban, high rise, low rise) so the information is widely relevant. The Commission could also offer webinars that include a peer knowledge-share segment so owners can learn about the business benefits of benchmarking from other owners.

We also recommend that the Energy Commission either create new resources or highlight existing free or low-cost resources for basic data analysis and energy management. These resources could be offered in a stand-alone section of the Building Energy Benchmarking Program website and could also be linked within relevant case studies.

Discussion

Some property owners told us they are frustrated by the benchmarking requirement and view it as an unnecessary regulatory burden.

Owners of smaller portfolios typically don't have the money to hire consultants and are left navigating the benchmarking process alone. We heard from some owners of large portfolios who do not have internal energy management teams that they don't have the time to benchmark properties themselves. Many choose to hire third parties to complete benchmarking work and have little interest in reviewing their own data for accuracy.

Frustration, confusion, and lack of engagement among owners jeopardizes data quality.

These frustrations are compounded for owners who have properties in multiple utility service areas. Benchmarking disclosure rules and guidelines are laid out in the final California Benchmarking Regulations, but the exact procedures vary widely among utilities. Most utilities have their own instruction manuals for the data request process. Owners with properties in multiple service territories may have to navigate hundreds of pages of instructions. (See Appendix C for more discussion of varying processes among utilities.)

Creating a single streamlined data request system might address some of these problems, but it is a long-term proposition. This might allow more oversight of the implementation of regulations and could help ensure consistency so users only need to familiarize themselves with one process. However, implementing this would be a huge undertaking, and it may be impossible due to the variations in the data management infrastructure at each utility.

In the short term, we recommend focusing on improving owners' understanding of the business benefits of benchmarking data. This may help owners shift from viewing Assembly Bill 802 as a regulatory burden to seeing energy benchmarking as a tool that can benefit their bottom line. To support this shift, we recommend that the Energy Commission strongly emphasize the power of benchmarking data in future education efforts.

Reassessing Predictors of Energy Use Intensity

The benchmarking technical assistance we provided to 89 multifamily properties in eight climate zones allowed our team to explore common assumptions about predictors of building efficiency. The linear regression models[6] of our data set show that:

1. Heating system type is a stronger predictor of EUI than cooling system type.
2. Heating system type is a stronger predictor of EUI than climate zone or building vintage.
3. The relative effects of both building vintage and climate zone on EUI were reduced significantly after accounting for heating system type.

This finding contradicts the common assumptions that building age and climate zone are the principal drivers of energy use. Although our data set is neither deep enough nor broad enough to confirm that this finding is true statewide, it raises interesting questions that merit further research into the relationship between HVAC system type and EUI.

This section provides an overview of our EUI analysis; more information about our linear regression models is provided in Appendix B.

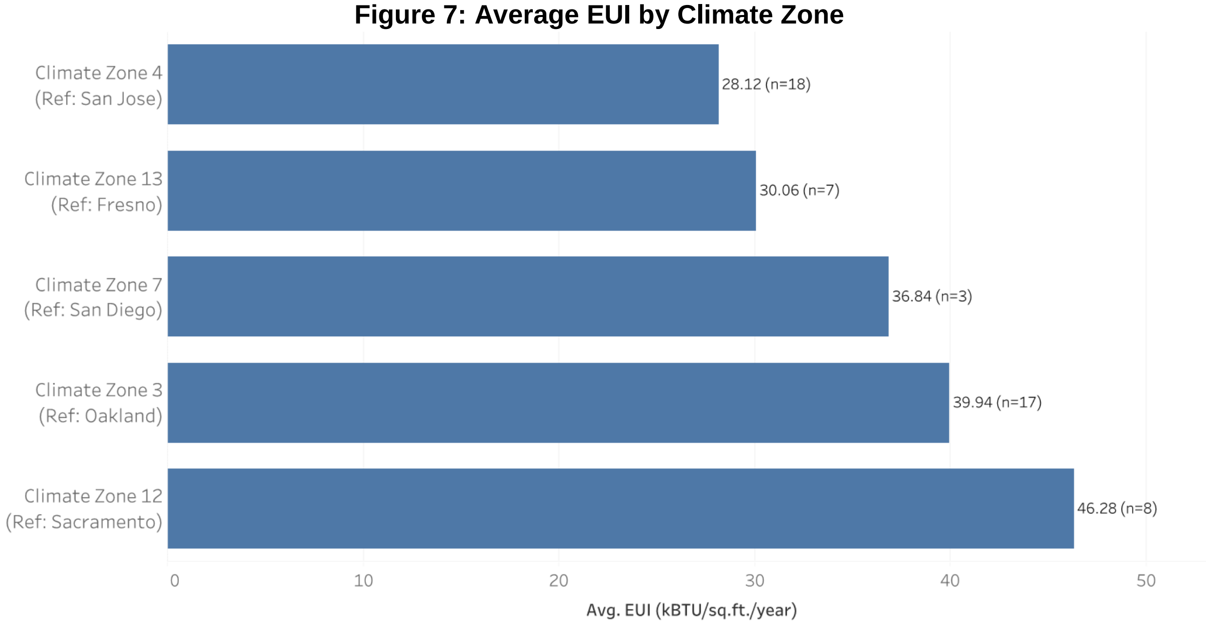
[6] See Appendix B for additional details.

Climate Zone Is a Limited Predictor of EUI

Figure 7 shows average EUI per climate zone for our data set in climate zones 3, 4, 7, 12 and 13.[7] At first glance, the data appear to show that climate zone plays a large role in average EUI.

However, further analysis showed that climate zone's ability to predict EUI was reduced significantly after accounting for other predictive variables such as heating system type. For this data set, it's likely that the main reason climate zone is a fairly good predictor of EUI is due to covariance with building systems: modern, more efficient heating systems are more common in certain climate zones.

Figure 7: Average EUI by Climate Zone



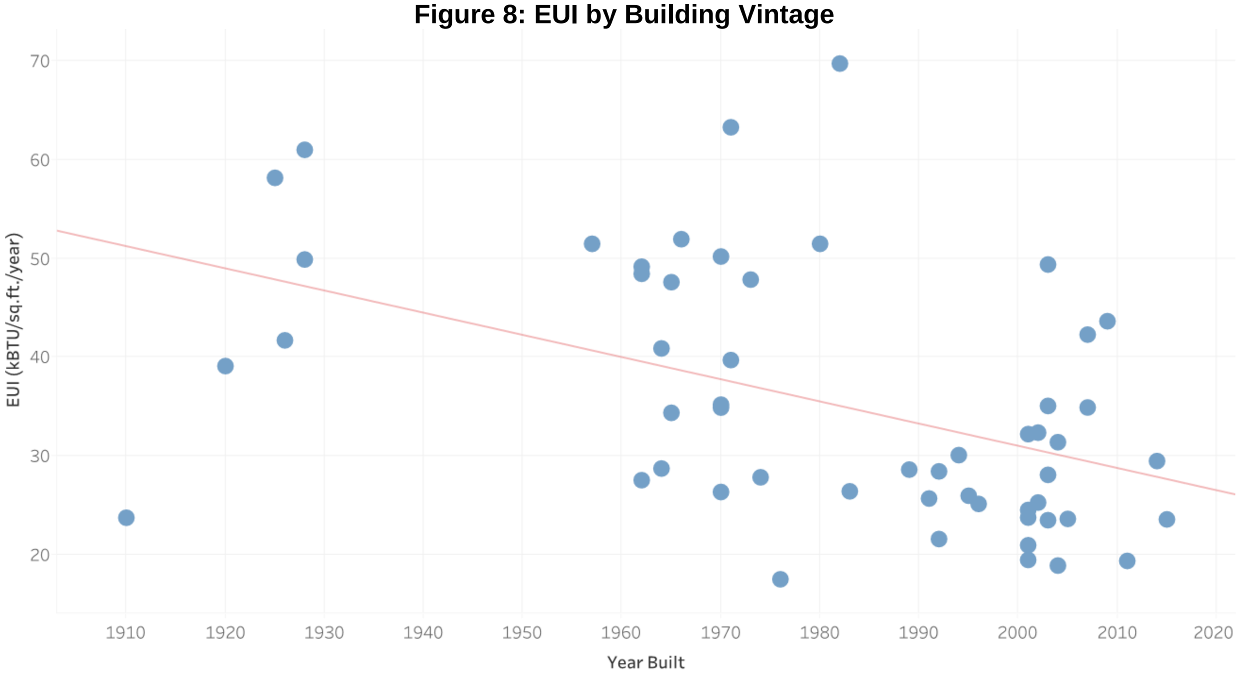
[7] Although we also benchmarked properties in climate zones 2, 9 and 10, average EUI is not reported here due to small sample sizes.

Building Age Is a Limited Predictor of EUI

Most of the properties in our data set had already undergone efficiency upgrades ranging from moderate to significant, making the relationship between building age and EUI shown in the scatter plot in Figure 8 particularly interesting.

Our analysis shows that approximately 21% of the variation in EUI for our data set is explained by building vintage, with EUI decreasing by 0.22 per year on average. However, we found through further analysis that building age was a poor predictor for EUI after accounting for other predictive variables. In addition to covariance between building age and system type (i.e., newer properties tend to have more modern heating systems), we also found that several properties built in the 1960s and 1970s with recent upgrades to heat pumps had comparable EUIs to buildings constructed decades later with the same heating types.[8]

Figure 8: EUI by Building Vintage



R-Squared: 0.214

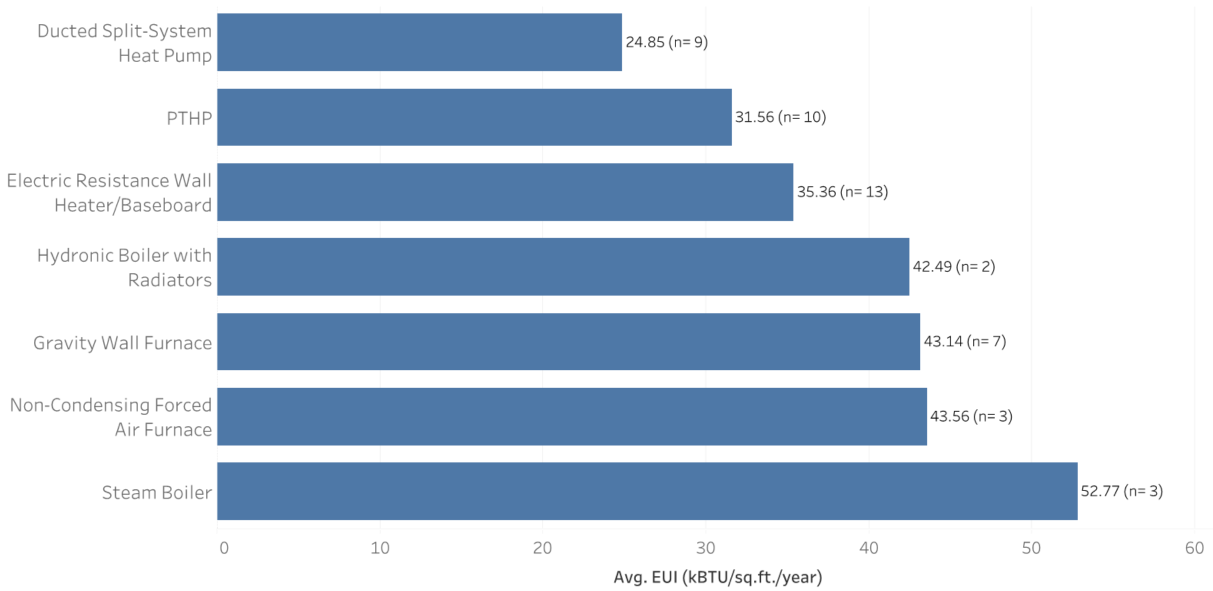
[8] See Figure B-3 in Appendix B.

Properties with Heat Pumps Have Lower EUIs

As Figure 9 shows, properties in our data set that use heat pumps for space heating and cooling have lower EUIs on average than those that have less efficient HVAC systems. This holds true even for properties in our data set that have no cooling systems. This suggests that heating system type may have a larger effect on building EUI than climate zone.

As described above, we used regression models[9] to test this hypothesis. Although a larger data set is needed to confirm this finding, our models show that heating system type is the single strongest predictor of EUI in our data set.

Figure 9: Average EUI per HVAC System Type



[9] See Appendix B for additional details.

Using Benchmarking Data to Understand Actual Energy Performance of Building Upgrades

Having more reliable access to whole-property energy use data via the benchmarking process can provide significant benefits to building owners, energy efficiency practitioners, and the Energy Commission. In addition to providing valuable information about the existing building stock and potential predictors of energy efficiency, this data can be used to understand the actual energy performance impacts of building upgrades. With a large enough data set, valuable conclusions could be drawn about the effectiveness of specific energy conservation measures in the short term and long term.

Many of the properties we benchmarked in this study recently completed energy efficiency upgrades,[10] which gave us the opportunity to perform high-level measurement and verification (M&V) analyses. We analyzed utility data pre-upgrade versus post-upgrade for 44 properties, with the goal of comparing modeled predictions against actual performance.

When properties did not perform as expected, we gathered qualitative data that could potentially inform updates to energy savings calculation methods or program design, including details on which measures were installed and whether any unrelated operational or maintenance changes occurred post-installation. Trends in our data set also helped confirm a recently discovered limitation in energy modeling software's ability to accurately model electrification measures, especially central heat pump water heaters (HPWHs). This limitation has been addressed in more recent versions of the modeling software, and the update was supported by data gathered during this study.

Modeled vs. Actual Electricity Savings

Figure 10 shows the average modeled and actual electricity savings for energy conservation measures affecting common areas or central systems only. The figure is organized from left to right as follows: electrification (9 projects), savings in expected range (13 projects), savings significantly higher than modeled predictions (6 projects), and savings significantly lower than modeled predictions (16 projects).

The average actual electricity savings for electrification projects is significantly lower for our sample set than the average modeled savings. This is driven by two primary forces. First, modeling algorithms have sometimes struggled to accurately predict savings for electrification, which is an issue that has been examined and is being addressed since these projects were originally evaluated. Additionally, seeing a slight increase in electricity use is not surprising given the nature of these projects. Because electrification involves removing existing gas equipment and replacing it with high-efficiency electric equipment such as heat pumps, achieving a net electricity savings would require reducing electricity use in other areas of the building enough to offset the addition of an entire new load. As seen in Figure 10, the huge

[10] See Appendix A.

therm savings from these projects more than counteracts the small average kWh increase. In addition to the nine (9) electrification projects, sixteen (16) other projects showed electricity savings that were lower than expected. Qualitative information was gathered in the form of interviews with project teams to help uncover potential causes, as outlined below.

Figure 10: Modeled vs. Actual Electricity Savings for Common Areas

Based on the initial qualitative data that we collected, common causes of underperformance among these properties may include but are likely not limited to:

- Potential need for updates to modeling algorithms,
- Difficulty accurately assessing runtimes for bi-level lighting, and
- Post-upgrade changes to recirculation pump settings.

Gathering data for more properties would help further support the hypothesis that it may be wise to use more conservative savings calculation methods for some measures, or support revisions to the performance standards for materials and equipment.

Modeled vs. Actual Gas Savings

Figure 11 shows the average actual and modeled gas savings for energy conservation measures affecting common areas or central systems. The figure is organized from left to right as follows: electrification (9 projects), savings in expected range (5 projects), savings significantly higher than modeled predictions (10 projects), and savings significantly lower than modeled predictions (19 projects).

Figure 11: Actual vs. Modeled Gas Savings for Common Area

Based on the initial qualitative data that we collected, common causes of underperformance among these properties may include but are likely not limited to:

- Potential need for updates to modeling algorithms,
- Post-upgrade changes to recirculation pump settings,
- Low persistence for aerators and showerheads,
- Unrelated operations issues such as hot water leaks and crossover, and
- New use of previously non-operational equipment.

Gathering data for more properties would help further support the hypothesis that it may be wise to use more conservative savings calculation methods for DHW recirculation and low-flow fixtures, or support revisions to the performance standards for materials and equipment.

Additional Research for Improving Modeling

In addition to shedding light on the previous limitations around accurately modeling some electrification measures, this data is a starting point for reviewing the short- and long-term performance of other measures. It may also be helpful for understanding the frequency of related (or unrelated) operations and maintenance issues that may affect energy performance after retrofits are completed.

We recommend that the Energy Commission support further research that leverages actual energy use data for properties that have recently completed efficiency upgrades and analyzes trends for various measure types and building types. Also, future research could involve gathering at least three years of actual energy use data for properties that have gone through efficiency upgrade programs to support a more thorough analysis of measure persistence.

Conclusion

The primary objective of this study was to provide benchmarking technical assistance to multifamily property owners to assess potential problems with data quality and recommend solutions. Our sample size was sufficient to uncover potential improvements to California's benchmarking data request and disclosure processes and to show interesting trends in energy efficiency and measure effectiveness. However, the sample size was not large enough to confidently draw conclusions about the relative effectiveness of various energy efficiency measures or the strongest predictor of EUI for multifamily properties in California.

There are several compelling reasons for the Energy Commission to continue building on this data set:

- Continue obtaining feedback on the aggregated data request and disclosure processes, with the goal of making it easier for owners and their benchmarking consultants to provide more complete and accurate data;
- Carry out a more comprehensive review of the relative effects of various building attributes on energy use intensity; and
- Conduct a more thorough review of measure types, building types, and calculation methodologies as predictors of actual energy savings relative to modeled savings.

This study provides a strong foundation for future research that will contribute to increasing the energy efficiency of multifamily buildings in California.

Appendix A: Selection of Properties for Benchmarking

This project provided benchmarking assistance to 89 properties, 80 of which had previously completed energy efficiency upgrades through the Bay Area Multifamily Building Upgrade program (BAMBE) or the Low Income Weatherization Program (LIWP-Multifamily).

Focusing on BAMBE and LIWP projects streamlined the benchmarking process because we already had access to most of the building characteristics needed for benchmarking, including construction year, gross square footage, and unit count. Having this head start allowed us to serve more properties, which in turn led to more experience with the overall data request and disclosure processes.

To support more useful outcomes, we sought to include multifamily properties that would give us a diversity of climate zones, system types, building vintages, numbers of stories, and property size.[11] Figure A - 1 and Table A - 1 shows the distribution of benchmarked properties by city and climate zone.

Choosing properties that had participated in these efficiency programs also gave our team the ability to review predicted versus actual savings, which added significant value to this study.

Of the 89 properties we attempted to benchmark, our team was only able to fully benchmark 70 properties. We were able to partially benchmark an additional eight properties, as outlined below in Table A – 1. The most common reasons why we were not able to fully benchmark properties are listed below.

- Data access issues: in several cases data was inaccessible because someone else had already requested it and we weren't able to determine who had made the original data request.
- Data appeared incomplete or inaccurate, but we were not able to successfully determine the root cause.
- Properties were less than a year old and didn't have accurate annual energy use.
- Properties located in utility service areas where the data request process is particularly challenging to navigate.
- Meters scattered under many different service addresses without good records.

[11] We did primarily focus on properties 50,000+ ft^2 due to the structure of the Building Energy Benchmarking Program.

Figure A - 1: Building Distribution by Climate Zone

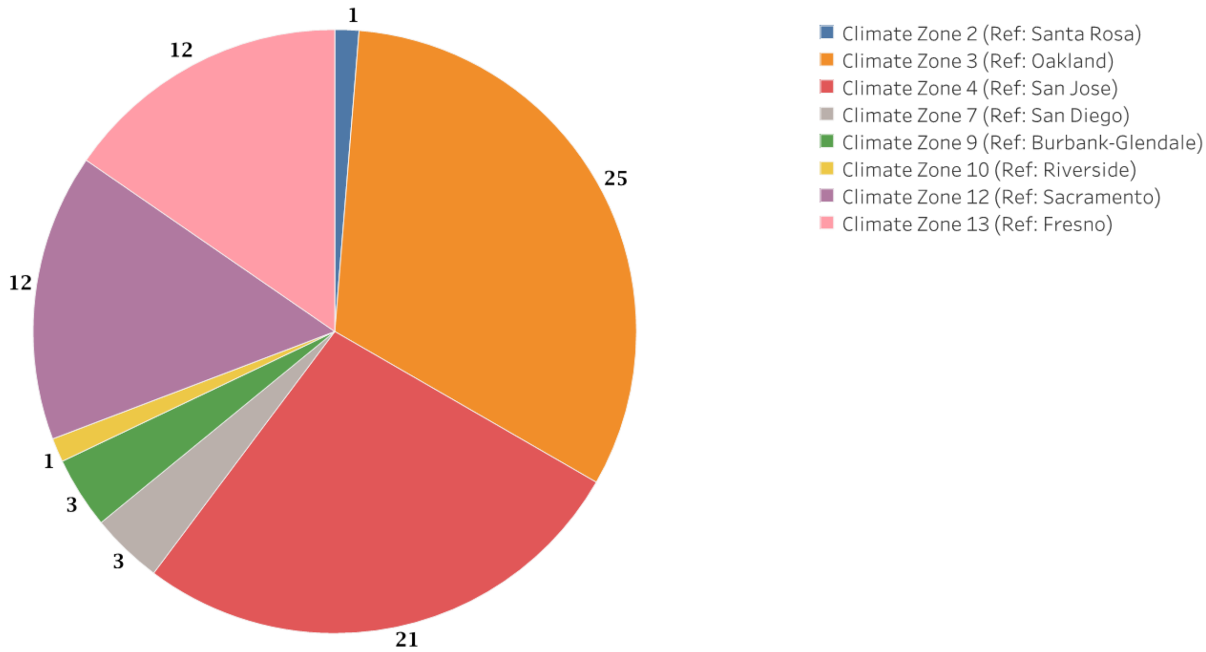


Table A - 1: Number of Benchmarked Properties by City and Climate Zone

Benchmarking Status	CA Climate Zone	City	Property Count
Common Areas Only	3	San Francisco	1
	4	Mountain View	1
		San Jose	2
	9	Los Angeles	1
	12	Sacramento	2
	13	Visalia	1
Whole-Property Data	2	Napa	1
	3	Berkeley	2
		Daly City	1
		Foster City	2
		Oakland	6
		Richmond	1
		San Francisco	10
		San Mateo	1
		Solano	1
	4	Mountain View	1
		Redwood City	1
		San Jose	15
		Sunnyvale	1
	7	San Diego	3
	9	Panorama City	1
		West Covina	1
	10	Riverside	1
	12	Antioch	1
		Concord	3
		Livermore	1
		Modesto	1
		Planada	1
		San Pablo	1
		Walnut Creek	2
	13	Bakersfield	1
		Fresno	3
		La Vina	1
		Madera	1
		McFarland	1
		Richgrove	1
		Wasco	3
Grand Total			78

Appendix B: Regression Models and EUI Analysis

Many of the metrics that may help predict energy efficiency are collinear, which makes understanding their exact contributions to variation in EUI very challenging. However, when using single term linear regressions, it was clear that, of the four predictor variables considered (year built, climate zone, heating system and cooling system), heating systems explained the most variation in EUI. Cooling system was the second ranked variable, followed by climate zone and year built.

We also included all predictor variables in a multiple regression and used a variance partitioning approach to understand each predictor's contribution to EUI. We found that neither year built nor cooling system provided significant explanatory power after considering the effects of the other three variables. Heating system explained the most variation in EUI after accounting for other variables, followed by climate zone. This further supports the hypothesis that, for this particular data set, heating system is the strongest predictor of EUI.

Our models did not explore domestic hot water (DHW) system type as a potential predictor of efficiency due to limited data. Nearly 75% of the properties that we assessed had central gas DHW systems. We recommend exploring this further as the data set grows.

The plots below provide more detail on the relationship between EUI, heating system, and climate zone in our data set. For the two box plots, points represent individual EUI measurements. Boxes cover the interquartile range, with horizontal lines at the medians. Whiskers extend to cover the 10th to 90th percentiles.

Figure B - 1 shows that properties with electric wall heaters had the broadest range of EUIs in our data set, while properties with heat pumps consistently had the lowest EUIs, with the exception of two high EUI properties in the packaged terminal heat pump (PTHP) data set. Interestingly, the highest EUIs in both the electric wall heater category and the PTHP category were master metered properties.

Figure B - 1: Heating System Box Plot

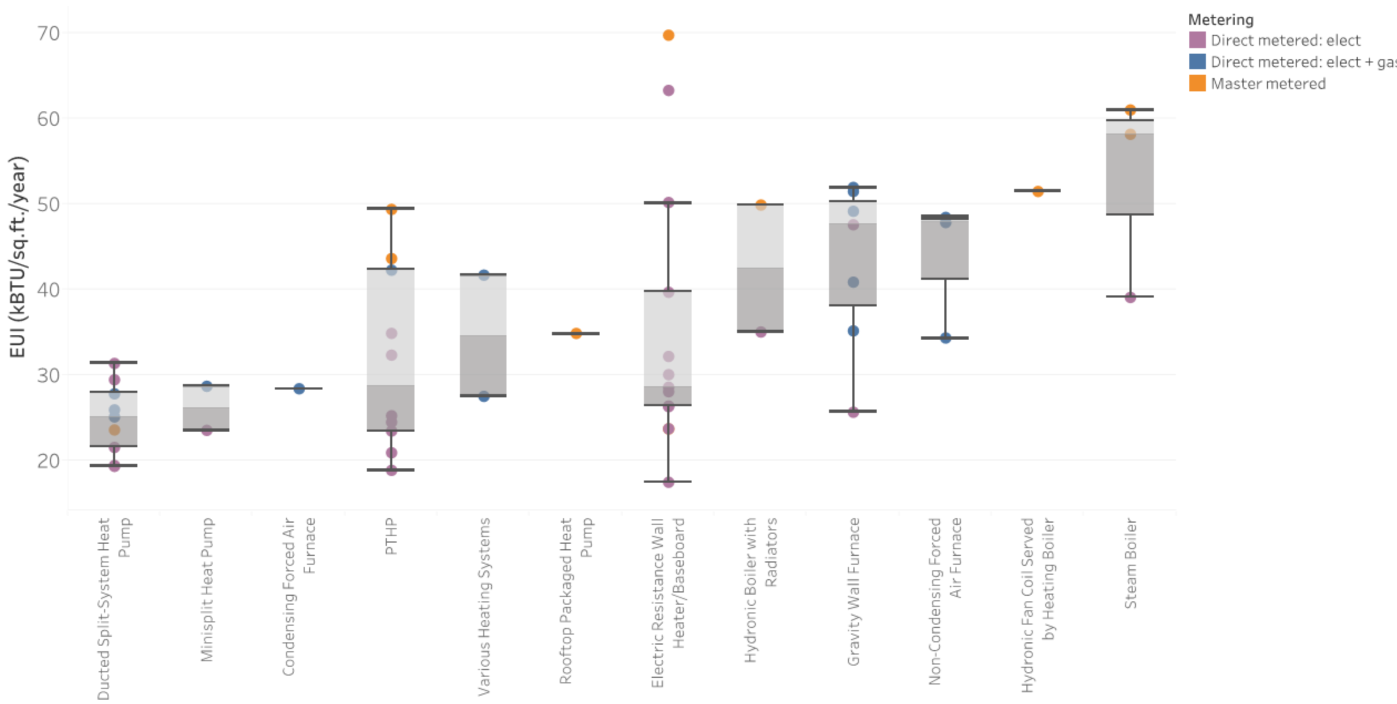


Figure B - 2 shows fairly broad variation of EUI within each climate zone. Although the climate zone variable does provide some predictive value, its predictive value is less significant than heating system type.

Figure B - 2: Climate Zone Box Plot

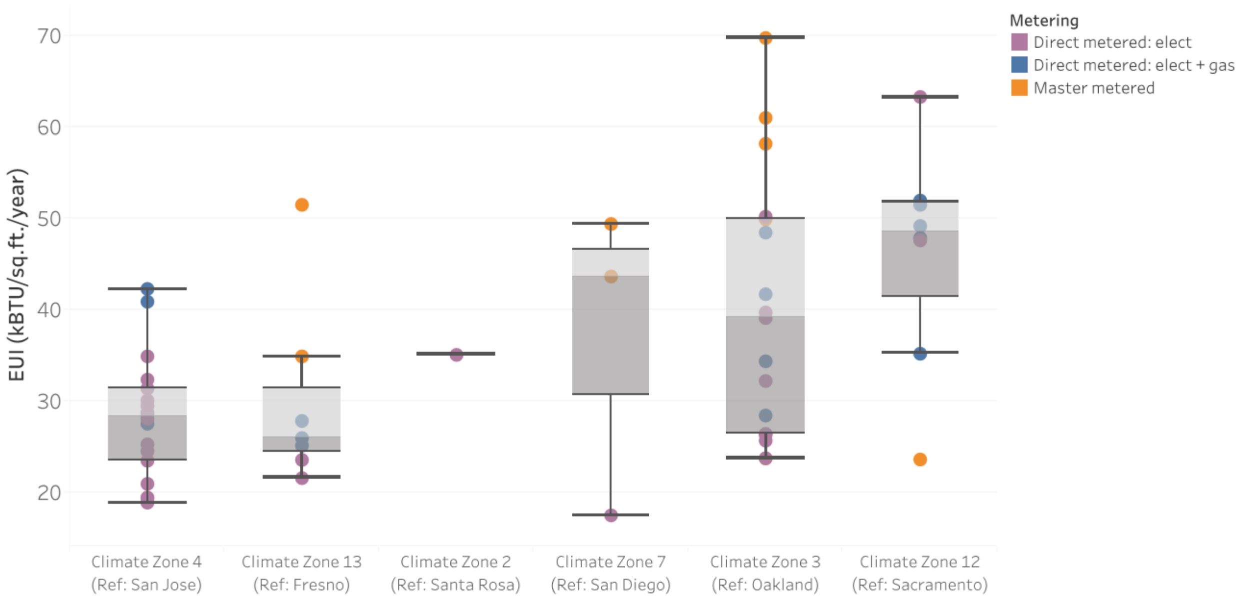
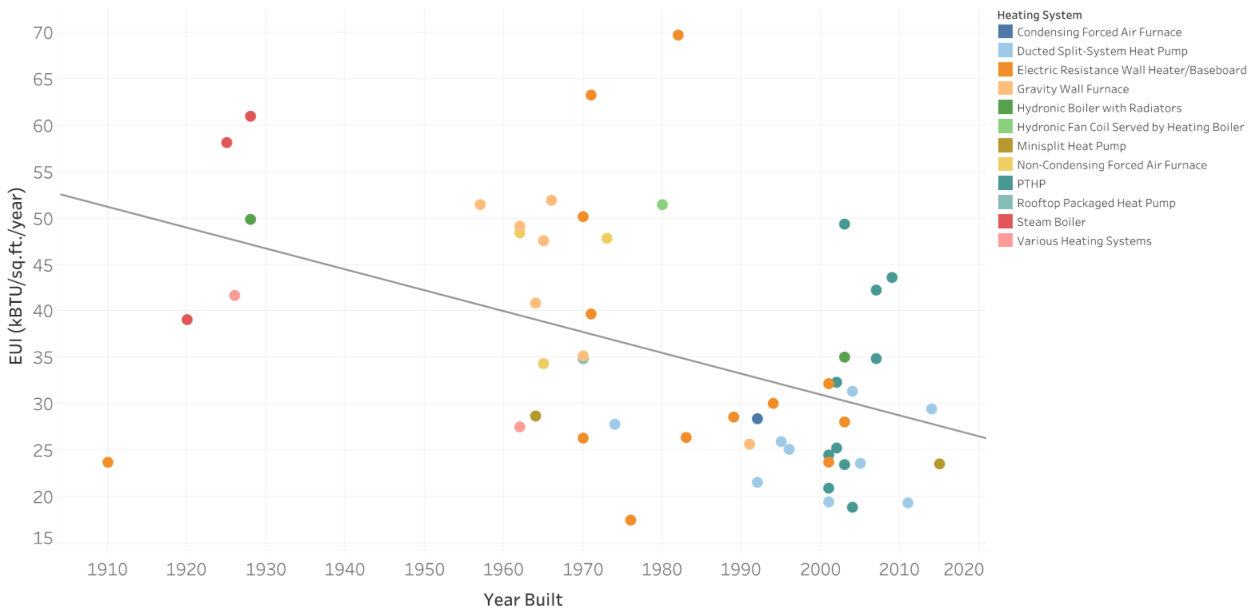


Figure B - 3 shows that when EUI is plotted against both building age and heating system type, heating system type creates a more compelling grouping of data points. Electric wall heaters have greater variation in EUI as compared to other space heating types, which was also shown in Figure B - 1. Although EUI does generally decrease for newer buildings, Figure B - 3 shows that more efficient system types have similar EUIs regardless of construction year. This trend is particularly clear for properties with heat pumps.

Figure B - 3: Building Vintage and Space Heating Scatter Plot



Appendix C: Overview of Utilities' Data Request Processes

Most of the 70 projects we fully benchmarked were in PG&E's service territory, so we had extensive experience using their benchmarking portal. Our team also has experience requesting aggregated data from five other utilities, as outlined in Table C – 1. Our hands-on experience enabled us to compare and contrast the different procedures and informed our findings and recommendations.

Each utility provider has its own process for requesting benchmarking data. Navigating the different systems can be a significant challenge for owners and consultants with properties in more than one service territory.

Figure C - 1 and Figure C - 2 show examples of two significantly different data request systems.

PG&E uses a proprietary online portal that allows the user to search for meters under service addresses and then aggregate meters as desired. Once meters are grouped as desired, users can link data to Portfolio Manager using a sharing key.

Conversely, SoCalGas uses an online data request form that is only functional after users first create and share properties in Portfolio Manager. Meter lists are shared via email for confirmation after users complete the online request form.

Table C – 1 further describes the basic process for requesting data from selected California utility providers.

Figure C - 1: PG&E Portal

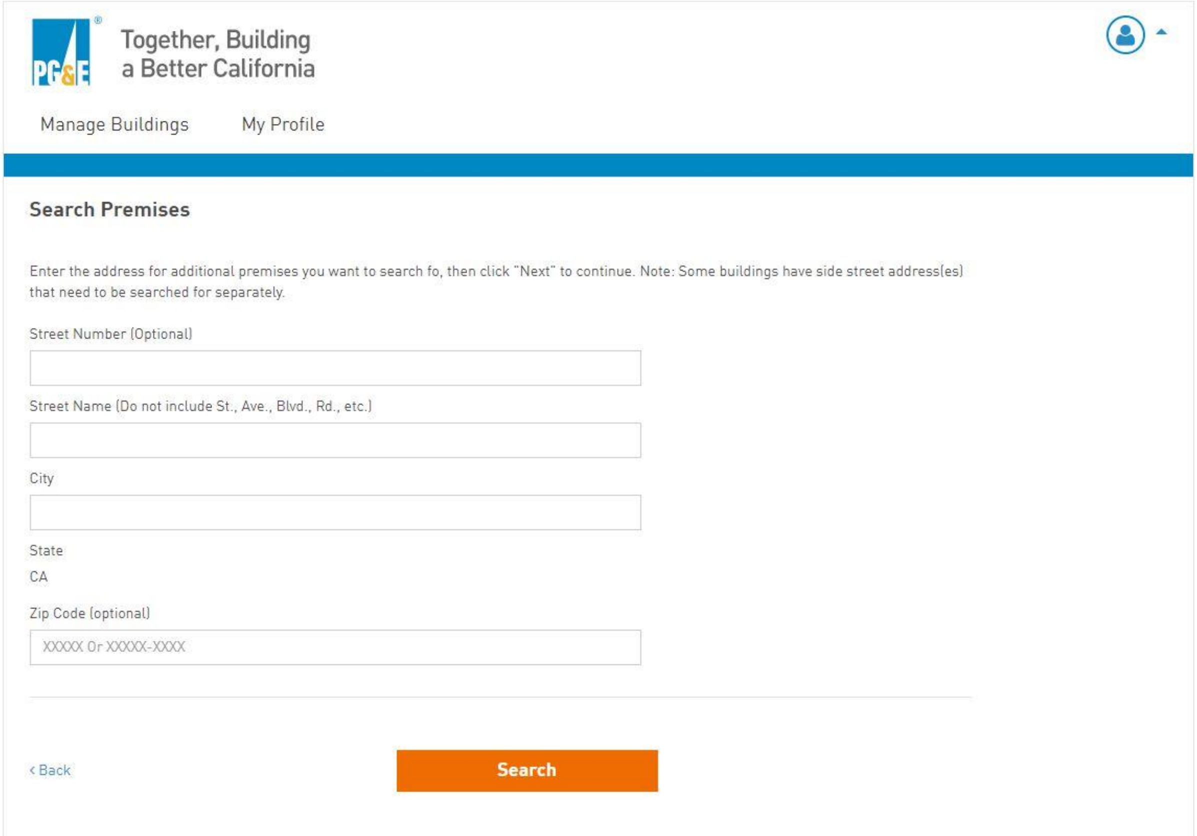
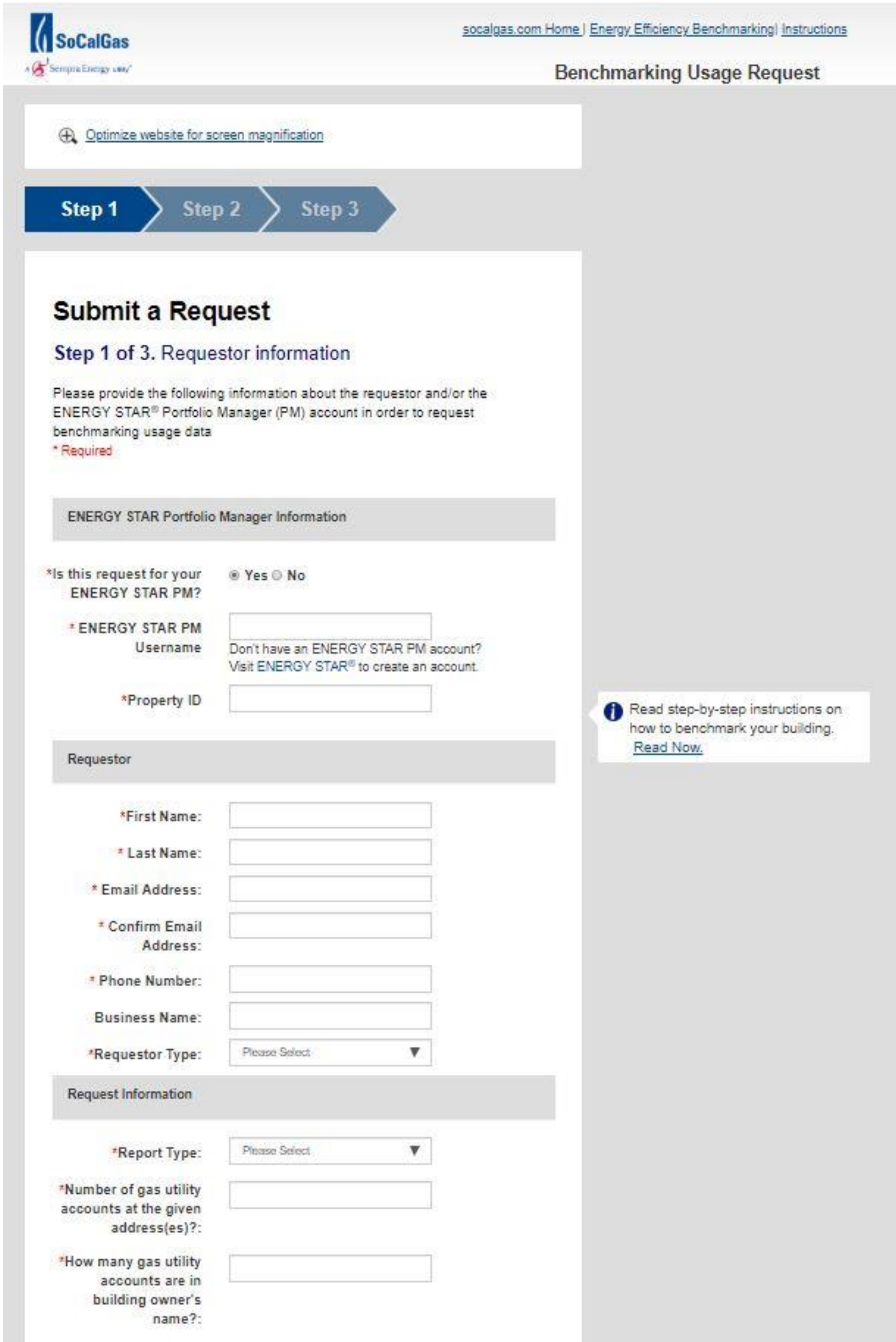


Figure C - 2: SoCalGas Data Request Form



SoCalGas
A Sempra Energy utility

socalgas.com Home | Energy Efficiency Benchmarking | Instructions

Benchmarking Usage Request

Optimize website for screen magnification

Step 1 Step 2 Step 3

Submit a Request

Step 1 of 3. Requestor information

Please provide the following information about the requestor and/or the ENERGY STAR® Portfolio Manager (PM) account in order to request benchmarking usage data

* Required

ENERGY STAR Portfolio Manager Information

*Is this request for your ENERGY STAR PM? ◉ Yes ○ No

* ENERGY STAR PM Username

Don't have an ENERGY STAR PM account? Visit ENERGY STAR® to create an account.

*Property ID

Read step-by-step instructions on how to benchmark your building. Read Now.

Requestor

*First Name:

* Last Name:

* Email Address:

* Confirm Email Address:

* Phone Number:

Business Name:

*Requestor Type: Please Select

Request Information

*Report Type: Please Select

*Number of gas utility accounts at the given address(es)?:

*How many gas utility accounts are in building owner's name?:

Table C – 1: Summary of Utility Providers' Data Request Processes

Utility Provider	Structure	Summarized Process
SoCalGas	Online form, follow-up email	1. Create property benchmarking profile in Portfolio Manager and share with SCG 2. Complete data request form on SCG's benchmarking website (requires pre-shared Portfolio Manager account to validate) 3. Must provide total number of meters at property and number that are in property owner's name 4. SCG responds via email with list of meter numbers for review 5. Once meter list is approved by requester, SCG uploads aggregated data
SMUD	Request aggregated data from within Portfolio Manager	1. Create a property in Portfolio Manager, request aggregated data for each relevant service address by entering a single location number or meter number associated with that address 2. If meter numbers are unknown, email SMUD and ask for a meter number associated with a given service address 3. SMUD will aggregate data for all meters associated with a given service address and deliver to Portfolio Manager
PG&E	Proprietary online portal that can be linked to Portfolio Manager	1. Request access to data on PG&E portal first by uploading proof of authorization 2. Create custom meter aggregation, which can span multiple service addresses 3. Link data to Portfolio Manager using sharing key created from within the PG&E portal
SDG&E	Online form, follow-up email	1. Create property benchmarking profile in Portfolio Manager and share with SDG&E 2. Complete data request form on SDG&E's benchmarking website (requires pre-shared Portfolio Manager account to validate) 3. Select/deselect meters from automatically generated list 4. SDG&E sends email alert when data is uploaded to Portfolio Manager
SCE	Proprietary online portal that can be linked to Portfolio Manager	1. Add property to SCE's benchmarking portal 2. List each applicable service address under property profile 3. Assign meters to buildings after submitting final list of addresses 4. Link to Portfolio Manager using data sharing key
Small munis, irrigation districts	Most appear to be using email for data requests and delivery	1. Email utility directly to request data 2. Receive a spreadsheet of data back via email