Energy and Performance Monitoring for Owners

Multifamily Building Energy and Performance

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FRANKLIN ENERGY, ASSOCIATION FOR ENERGY AFFORDABILITY, REDWOOD ENERGY, STONE ENERGY ASSOCIATES

This technology brief is intended for multifamily building owners and operators to learn of the various methods by which their building can be monitored to understand performance and identify issues. This paper draws from the findings of the EPIC research project (EPC 15-097) optimizing domestic hot water in four multifamily affordable all-electric new construction projects in California. The research focused on the evaluation of domestic hot water heat pump systems in four multifamily affordable all-electric new construction projects in California. Final Report: Getting to All-Electric Multifamily ZNE Construction Publication Number: CEC-500-202X-XXX.

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Introduction

Energy and performance monitoring is necessary for verifying the success of a building's zero net energy (ZNE) design. A building owner or developer has a variety of accessible options to track energy and performance of their building. System-level monitoring equipment or building management systems (BMS) are not required for the level of energy benchmarking that would give useful insight into building performance.

For research purposes each of the four demonstration sites in this study (CEC EPC 15-097) used several different types of monitoring to evaluate appliance, system and building performance. Based on this experience with research grade monitoring, it was clear that providing guidance on cost-effective building performance monitoring was needed to support building owners and management entities in understanding the performance and energy impact of their building, and to confirm whether their investment in ZNE design is being realized.

Building owners can utilize building utility data from accessible sources to understand performance:

- Aggregated Utility Data
- Utility Smart Meter Data (15-minute interval data)
- Consumer Grade Home Energy Monitoring Systems

Each monitoring methodology is discussed below including application and limitations of analysis, as well as an example of how the data can be visualized for a particular application. This is preceded by a discussion of key components of energy data and their definitions to establish a common set of vocabulary to reference.

Understanding Data

Before discussing what data is available and how it can be used, the foundational vocabulary must be understood. The below list of definitions is not exhaustive but defines common concepts or data streams that will be encountered.

Net Energy: The difference between total gross energy consumed and energy produced by a photovoltaic (PV) renewable energy system.

Gross Energy Consumed – PV Energy Produced = Net Energy Consumed

Net Energy Consumed + PV Energy Produced = Gross Energy Consumed

Gross Energy: Total energy consumed. Gross energy can be measured at the meter-level (for example, per apartment unit), the building level, or whole site level.

Net Energy Metering (NEM): Net Energy Metering is the mechanism by which a single utility meter tracks both electricity drawn from the grid and excess solar energy that is sent back to the grid. For these systems, some renewable energy is consumed on-site or "behind the meter." Because the utility meter only tracks the net of the energy pulled from the grid minus solar energy exported to the grid, either a 3rd party solar PV monitoring system or detailed end use monitoring equipment is required to understand the property's gross energy consumption and total solar PV generation. In both cases, the monitored production or consumption data must be lined up on the same time scale with the net energy consumption interval data; the interval data represents the net consumption of building loads connected to that meter.

Virtual Net Energy Metering (VNEM): Virtual Net Energy Metering is the mechanism by which a PV system is connected to the utility electric grid through a solar production meter, and not to the building's energy consumption meter(s). All energy produced is fed back to the electric grid rather than being consumed onsite. The measured solar production is allocated as credits to benefitting meters based on a set percentage allocation per benefitting meter. This mechanism is most commonly used for multifamily building PV systems in order to provide PV benefits and offset to individual tenant meters, and is not offered by every utility. In this case, the interval data for the electric consumption meter represents the total, or gross, energy consumed by the building loads connected to that meter. The interval data for the separate PV production meter represents the energy produced by the portion of the solar PV system connected to that meter.

PV Production Meter: (technical term: Net Generating Output Meter (NGOM)) The PV production meter is a meter installed by the utility to which a VNEM PV system is tied. This meter measures how much solar PV energy is produced and provides data to the utility so that credits can be allocated to individual account holders' electric bills.

Generating Account: Utility account associated with a NGOM electric meter dedicated to measuring energy produced by a renewable energy system.

Benefiting Account: Utility account associated with an electric meter dedicated to measuring energy consumption that receives solar credits from a VNEM system.

House Meter: Utility meter that measures energy consumption of common area loads and is paid for by the building owner. A house meter can have many different loads connected to it, depending on the building configuration and services.

Tenant Meter: Utility meter that measures energy consumption of apartment loads and is most typically paid for by the tenant living in that apartment.

Aggregated Data: Energy data that is combined or summed for a set of meters over a specific temporal period. The most discussed aggregated data in this Brief is aggregated monthly building data and refers to groups of at least five electric meters (per requirements of Assembly Bill 802 (AB 802)).

Interval Data: Energy data that is measured by and displayed for one individual electric meter on a specific time interval. The most discussed interval data in this Brief is 15-minute time interval energy data derived from a single electric meter. 15-minute intervals are the greatest granularity shown by a utility meter; however, some utilities only report on hourly intervals.

Home Energy Monitoring System (HEMS): Data collection devices that are typically connected to individual circuits in an electrical panel to collect energy consumption data of each individual energy system and appliance to provide energy usage feedback to a resident. HEMSs can have visual displays to represent energy usage in ways other than through numerical datasets and can also have web- or app-connected dashboards to summarize energy usage.

Aggregated Monthly Utility Data

Accessing individual tenant meter data can be incredibly difficult if not impossible; however, because of the passage of California Assembly Bill 802 (AB 802), property owners and authorized third party contacts can access monthly tenant utility (gas and electric) data on an aggregate level. A building owner or operator (or other authorized contact) can request aggregated whole-property data directly from utilities for any multifamily property with at least five meters for each fuel type.

This data can be used to (1) analyze the impact of a building's renewable energy system and overall performance of a building, and whether the building achieved its ZNE design (2) review performance of the building over time to identify performance issues and (3) compare actual performance to expected performance.

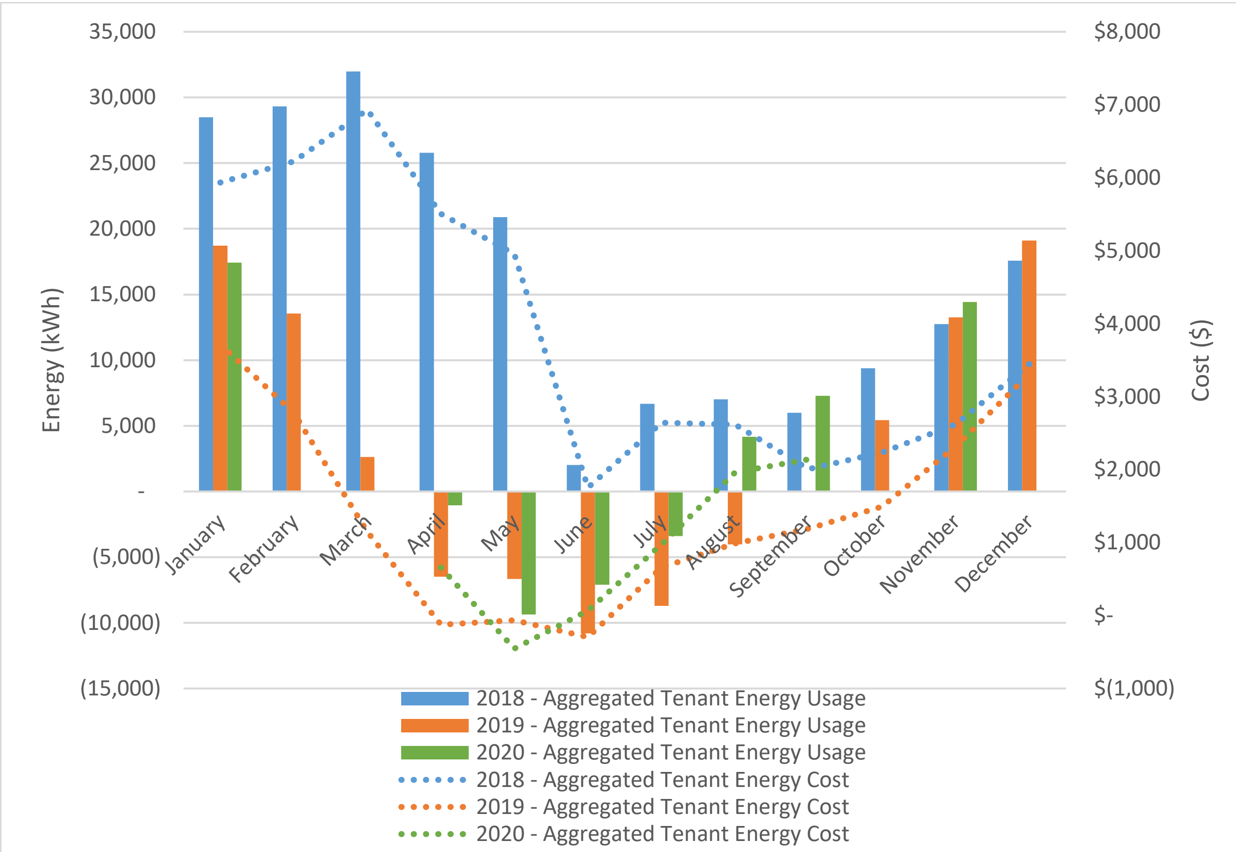
The most useful way to assess ZNE performance is to track gross energy consumption and renewable energy production over time using data from EnergyStar Portfolio Manager. These two data points can be used to derive net energy consumption over specific periods of time such as monthly or annually. It is important to note that different utilities present different energy data via Portfolio Manager (for example, one utility might report monthly kWh usage as net consumption, and another might report kWh usage as total gross consumption). It's important to confirm with the specific utility whether the aggregated data that provided for properties with VNEM solar systems is net or gross energy.

Reviewing monthly data over time will show trends in performance, and variances in performance from system changes or degradation may be visible triggering further investigation into a system (i.e. PV) or piece of equipment.

Buildings are designed with performance targets including energy consumption. A comparison of monthly energy consumption to expected (modeled) energy consumption over the course of several years can provide insight to variations in expected versus actual energy consumption. This comparison can demonstrate whether a building is performing as expected. Yet, because the models are based on typical year, this comparison will require several years-worth of data in the analysis to provide useful insights. Comparing a single or several months-worth of data is useful to identify high-level discrepancies between actual consumption and expected consumption; however, the smaller the sample compared, the greater the variety of attributable reasons there are, including year-to-year variations in weather.

A building owner or operator can use aggregated tenant utility data to track building energy consumption and performance with graphical data visualization. Using common software tools, such as Excel, or using Portfolio Manager itself, an owner can track and store monthly aggregated tenant energy usage and cost data (when it is available) over time. This monthly data can be compared over the years to show any trends in usage or cost and shed light on general performance. The graph in Figure 1 below is an example created from monthly energy and cost data organized in Excel by Month and Year. This graph shows that there was a shift in energy consumption and/or energy production between 2018 and 2019 that resulted in less overall net energy usage and lower energy cost (many utilities do not always or ever provide energy cost data as this provision is not mandated by AB 802). In this case, the solar PV system was connected to the utility grid and turned on in late May 2018, which accounted for the drastic change in net consumption. The cause of other year-to-year variations in monthly comparisons can be speculated; in this case, differences in weather year to year, presence of wildfire smoke, changes in occupancy (COVID shelter-in-place in 2020), changes in equipment performance amongst others can account for those variations, but it is difficult to zero in on which causes are the primary driver(s) using aggregated data alone.

Figure 1. Example of Aggregated Tenant Energy Use and Utility Cost Over Time*



**Note that there is missing data in this graph for September 2019 and February-March, October and December 2020*

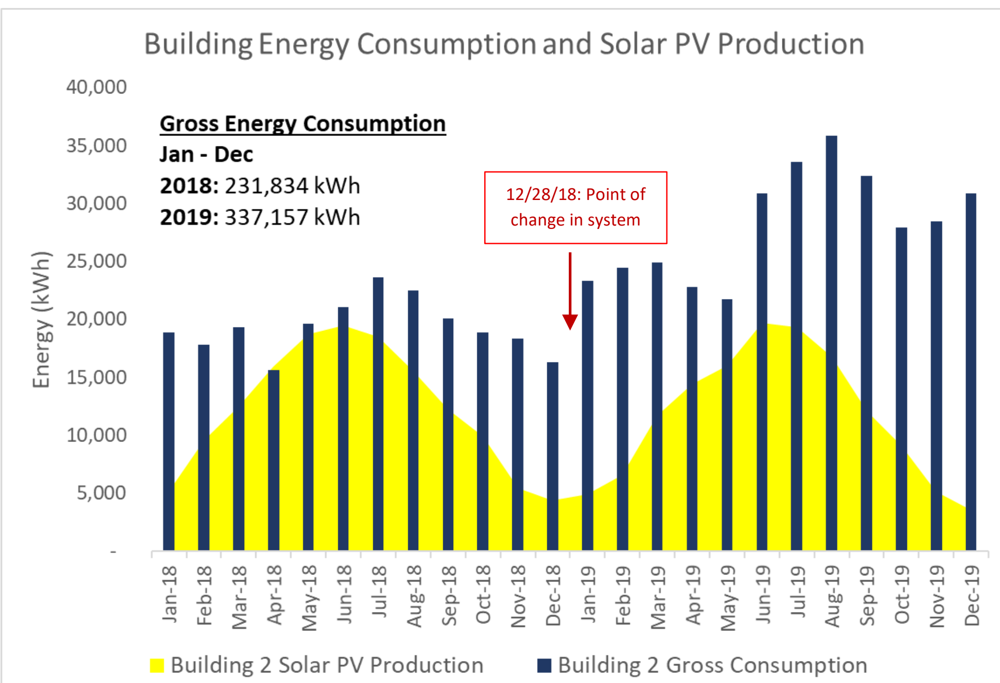
Utility Smart Meter Interval Data

A building owner or operator can also use electric meter-level interval data to understand more detailed building energy consumption and performance than with aggregated monthly utility data. 15-minute or hourly interval data can be (1) summed to monthly data or (2) used to analyze equipment operation or occupant behavior on a more granular level. The electric interval data is the most granular utility data available and is used by the utility to calculate energy consumption for billing. Interval data from a utility meter is accessible typically down to 15-minute summed intervals (though sometimes it is only available in hourly or daily, depending on the utility) with access via utility login or authorization for linked accounts. A building owner or operator can access this through their own house account login, available for any online account connected to a smart meter in any CA investor-owned utility. Typically, historical data can be accessed back to the creation of the utility account with that meter and can be downloaded via Excel file for use. Note that this is for the house meters only and not for tenant account meters; historical tenant utility data is only accessible to a building owner with tenant authorization and formal utility approval via utility authorization process where it exists.

A lot can be done using interval data, but most importantly, a building owner can use it to shed light on the performance of individual systems or a group of systems within a building. The interval data can be used in a similar way to the aggregated data mentioned above, but it yields far greater granularity. The level of granularity and insight on consumption and performance is dependent on the number and type of loads connected to the meter and/or the ability to disaggregate loads. Such granular data can allow for focusing on when a change might have occurred, or an issue developed in a building. Where aggregated monthly data could show a change in monthly consumption year of year, interval data shows both that same change and allows the owner to further identify the source of the change based on which systems are connected to the individual meter and operational changes that occurred around the same time.

Figures 2, 3, & 4 show how a building house meter's interval data can be summed and graphed at a monthly level, showing an increase in energy consumption over the course of a year, and that same interval data can be viewed on a more granular 15-minute basis to help identify when events that affected energy use may have occurred. In this case, the house meter tracked energy use for lighting, a central laundry room, and a central combined space conditioning and domestic hot water system. The central combined plant was shut down on 12/28/18 for 1.5 days during which an operational change was made to the system resulting in a large increase in system energy consumption. After this operational change was made at the tail end of the year, the previous year and next year's annual energy consumptions were compared, and the annual energy consumption measured by that meter had increased by 45% as a result of that change. The same data is presented in different ways: Figure 2 shows performance year to year, Figure 3 shows performance month by month to compare years, and finally Figure 4 shows a week of data during which the change occurred.

Figure 2 & 3. Example of Monthly Building Energy Consumption and Solar PV Production over Two Years and Same-Source 15-Minute Interval Energy Consumption Data over a Week.



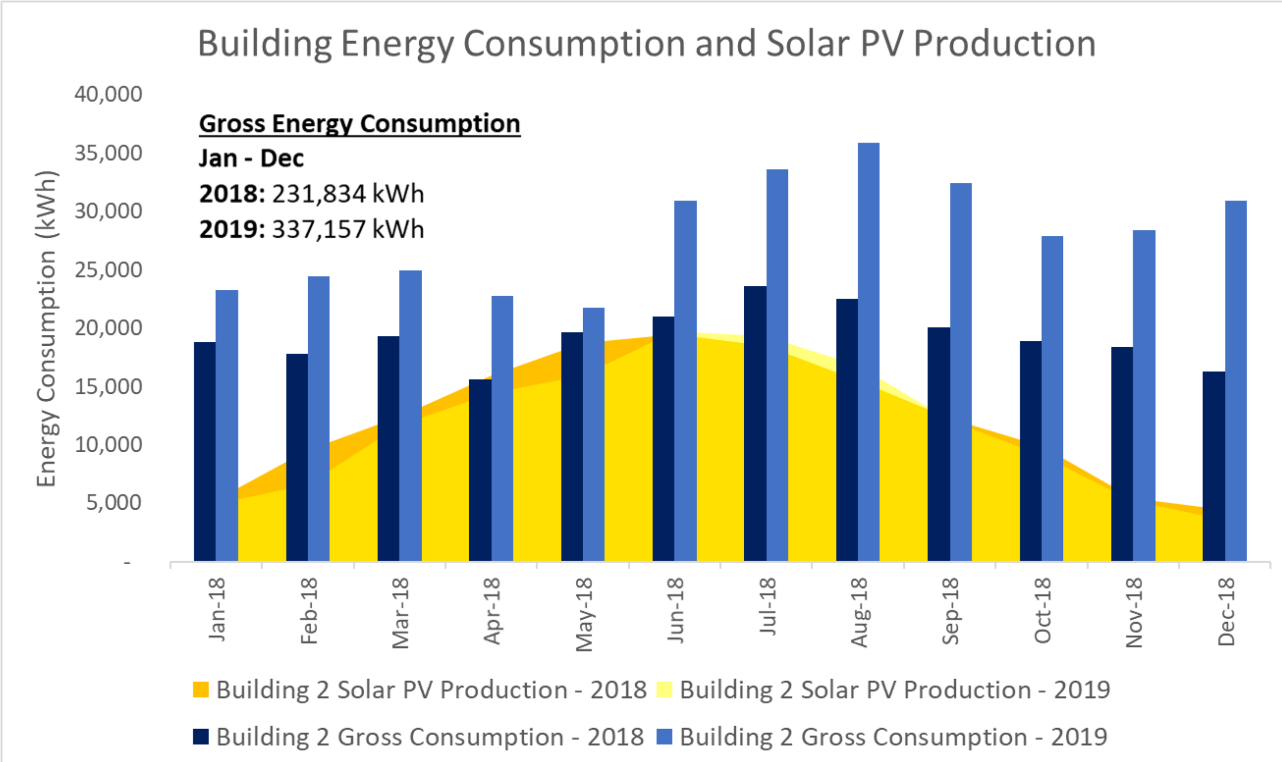
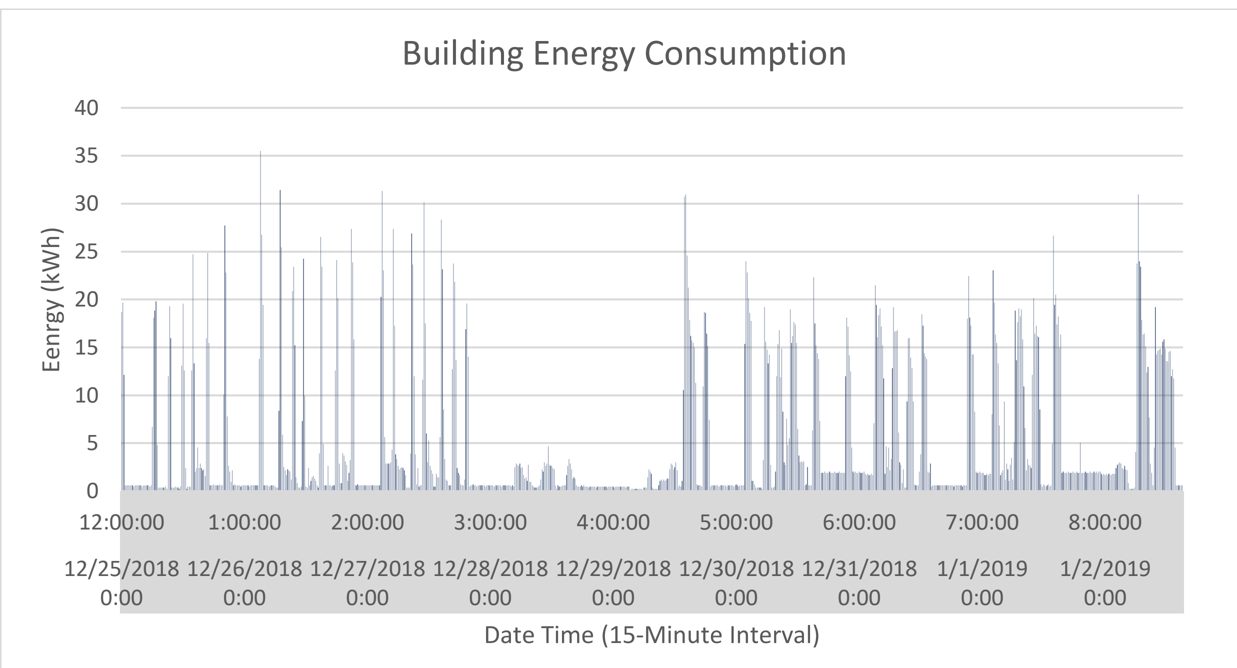


Figure 4. Example of More Granular Data Using 15-Minute Interval Data to Hone in on Point of Change Reflected in the Energy Consumption Increase Shown in Figures 2 & 3 Above.



A building owner or operator could prepare similar graphs using interval data from their utility account(s) to help review energy consumption over time. The data can be visualized in different ways as shown above to illuminate changes or occurrences; different visualization tactics may result in different occurrences being illuminated. An owner reviewing their own utility data could see that an increase in energy usage occurred on a specific meter, and could then learn what systems are connected to that meter, catalogue whether any work had been done on or changes made to any of those systems, and direct maintenance staff or hire a contractor to investigate systems. Even if the owner does not immediately know *what* caused the change in consumption, interval data can empower them to direct further investigation by helping determine *when* and *on what* meter/systems the change occurred.

Utility interval data is the most powerful, free benchmarking tool to which each utility account holder with a smart meter has access. It is highly encouraged that every building owner or operator utilize this free data source for building benchmarking and monitoring.

Home Energy Monitoring System

A customer-grade home energy monitoring systems (HEMSs) can provide even more granular, circuit-level energy data, while also making the information readily accessible to occupants through web-based dashboards, smartphone apps, or in-home lighting displays. HEMS products make detailed whole-house and systems-level data accessible; however, HEMSs are generally not an effective energy monitoring strategy for a building owner to measure performance and energy consumption of a multifamily building as there is not a standardized option to support a building-level dashboard to view and manage multiple units, or view apartment consumption in aggregate.

HEMSs installed in individual units can instead be used as a tenant engagement strategy to educate tenants on how their activities in the home relate to energy consumption and utility costs. This strategy does not result in a clear way for building owners to measure and assess building performance, yet utilizing HEMSs for their tenant engagement benefits is more likely to result in better building energy outcomes. Past studies have shown the benefits of HEMSs, particularly those with visual displays, and this research is ongoing and continuing to be funded.[1]

Figure 5 shows an example of the level of detail available through HEMs monitoring. The building owner will not see this level of information unless tenants share it. If tenants are willing to share this detailed data, it can be referenced alongside any complaints about comfort or functionality in the apartment to help maintenance in any troubleshooting.

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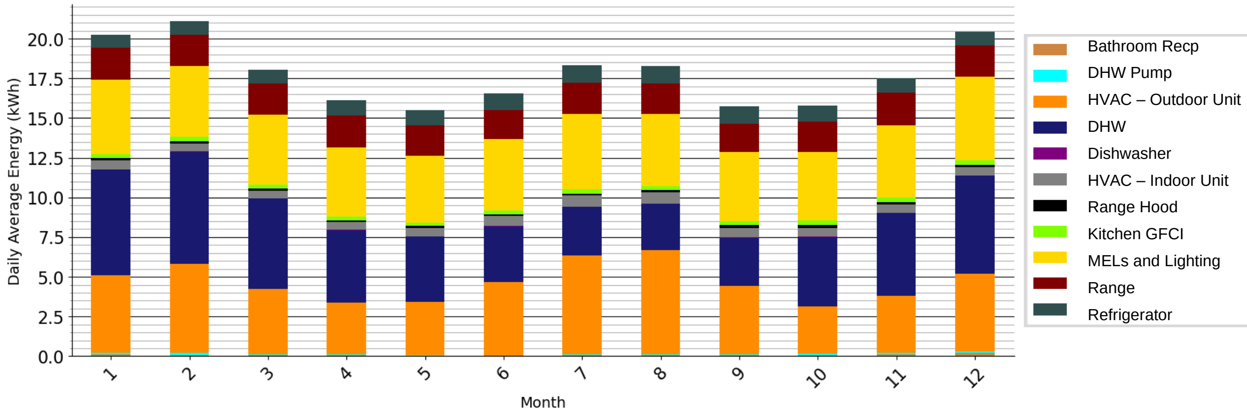
[1] Darby, Dr Sarah (2006), *The Effectiveness of Feedback on Energy Consumption: A Review for DFRA of the Literature on Metering, Billing, and Direct Displays.* Environmental Change Institute of Oxford University, (April, 2006).

Paige, Frederick. Philip Agee and Farrokh Jazizadeh. *flEECe, an energy use and occupant behavior dataset for net-zero energy affordable senior residential buildings*. Scientific Data(2019) 6:291. https://doi.org/10.1038/s41597-019-0275-3

Dryden, Amy, Andy Brooks, Emily Higbee, Greg Pfotenhauer, Meghan Duff, Nehemiah Stone, and Sean Armstrong. 2021. *Getting to All-Electric Multifamily Zero Net Energy Construction*. California Energy Commission. Publication Number: CEC-500-202X-XXX.

__Figure 5. Example of Daily Average End Uses Showing Distribution by Month.__



However, empowering residents by shedding light on the ways in which their behavior drives consumption is a far more effective use case for this technology in multifamily building applications. There are numerous opportunities for owners to engage tenants around their energy use and in-unit monitoring. For example, an owner can host a community meeting to discuss energy use and average or expected usage (i.e., for plug loads) during which tenants could be asked to reflect on how their own usage compared. A discussion could follow about strategies to minimize higher usage including either behavior or specific technology (i.e., using smart power strips). Another opportunity to engage tenants is around proper equipment operation. Typical and atypical or malfunctioning profiles of a specific appliance such as a heat pump water heater can be shared with tenants, so they may be able to identify poorly operating equipment and notify management.

Engagement can begin at the individual level in educating tenants on how to view and understand the energy dashboard available in a HEMS; Figure 6 shows the dashboard display of the Emporia HEMS product, where residents can see the breakdown of consumption in their home and consumption over time. Some HEMS products, like the Emporia, can include an energy budget and track in-home energy consumption against that budget. This feature can be used as a tenant engagement strategy, for example using gamification to incentivize tenants to use energy within their budget and reward when they have done so, using the dashboard as a tracking mechanism. In addition, if the management staff see trends in high baseline usage or peak usage, this could trigger tenant engagement activities around energy usage such as baseline/ plug load reduction strategies or operating your home under TOU rates to assist tenants in achieving lower utility bills.

Figure 6. Example of a User Interface for a HEMS for Emporia Energy Device

Conclusion

There are many ways in which a building can be monitored and its performance both assessed instantaneously and tracked over time. Different monitoring methods demand varying levels of engagement and expertise, but the few data sources described in this document present opportunities for quick and straightforward ways for building owners to benchmark and monitor their buildings' consumption and performance. The lowest level of monitoring, through utilizing aggregated utility data, is encouraged for all building owners and designers to validate the success of the built design. The final report for EPC 15-097 "Getting to All-Electric ZNE MF Construction" and supporting documentation describe the monitoring conducted at each demonstration site and provide insight into the ways in which data can be collected and used to track performance and carry out commissioning. Realizing high performance in buildings, particularly confirming if ZNE design is achieved, demands measurement and monitoring. Utilizing utility data is a low-cost and low-effort pathway for building owners to be able to do that. To take the first step, contact your utility to begin accessing your energy consumption data and empower your organization with insight into your building's performance.

Author(s): Meghan Duff, Association for Energy Affordability (AEA)

Contributors: Amy Dryden, AEA; Andrew Brooks, AEA; Tabitha Harrison, AEA

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