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Pacific Northwest
NATIONAL LABORATORY

Using Metered Data for Energy and Water Evaluations

September 2018

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

Federal agencies are required by law to install energy meters and conduct energy and water evaluations at their facilities. Per Section 103 of the Energy Policy Act of 2005, agencies are required to collect at least hourly energy data, incorporate metered energy data into data management systems, and provide the data to energy managers. Comprehensive energy and water evaluations of federal facilities are required by Section 432 of the Energy Independence and Security Act of 2007, which states that “covered facilities” which constitute at least 75 percent of facility energy use at each agency must be evaluated every 4 years for cost-effective energy and water savings opportunities. Energy and water metered data can help energy managers make informed operations and investment decisions throughout the energy and water evaluation process. Metered data can be used to identify the facilities with the highest energy use, benchmark facility performance, track facility energy and water use, set energy and water use goals, and prioritize facility investments.

This reference document explains the legislative basis for comprehensive energy and water evaluations, describes the steps of the typical evaluation process, and connects evaluation steps to metered data analysis techniques and common evaluation questions. The intended audience for this reference document is energy managers and others who are new to using metered data to support evaluations and have limited experience with metered data analysis.

Acronyms and Abbreviations

BCS	Building control system
CBECS	Commercial Building Energy Consumption Survey
CDD	Cooling degree-day
EWCMs	Energy and water conservation measures
EISA	Energy Independence and Security Act of 2007
EPAct	Energy Policy Act of 2005
ESPC	Energy savings performance contract
EUI	Energy use intensity
HDD	Heating degree-day
HVAC	Heating, ventilation, and air conditioning
LED	Light-emitting diode
M&V	Measurement and verification
OAT	Outdoor air temperature
UTC	Coordinated universal time
WUI	Water use intensity

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1.0 Introduction

Federal agencies are required by law to install energy meters and conduct energy and water evaluations at their facilities. Metered data can provide useful insight into a facility's energy and water performance when conducting an evaluation. This reference document describes techniques for analyzing metered data to support energy and water evaluations.

Energy Metering

"…ALL FEDERAL BUILDINGS SHALL, FOR THE PURPOSES OF EFFICIENT USE OF ENERGY AND REDUCTION IN THE COST OF ELECTRICITY USED IN SUCH BUILDINGS, BE METERED…"

Sec. 103 of the Energy Policy Act 2005

Metered data records the amount of a utility, such as electricity, gas, or water, that is consumed by a facility. The purpose of installing meters on facilities is to collect, analyze, and act on the performance data. Agencies are required to collect at least hourly energy data, incorporate metered energy data into data management systems, and provide the data to energy managers.[1] Metered data can be used to improve operations, reduce use and cost, and identify when equipment needs to be replaced.

Energy and water evaluations are used to identify energy and water efficiency and conservation measures (referred to as EWCMs) and are required every 4 years for all applicable facilities. [2] A comprehensive energy and water evaluation is required to include a recommissioning/retro-commissioning assessment along with an energy and water audit.[3] It is expected that life cycle cost-effective EWCMs will be implemented within 2 years of the evaluation.

Energy and Water Evaluations

"… ENERGY MANAGERS SHALL COMPLETE, FOR EACH CALENDAR YEAR, A COMPREHENSIVE ENERGY AND WATER EVALUATION FOR APPROXIMATELY 25 PERCENT OF THE [COVERED] FACILITIES OF EACH AGENCY..."

Sec. 432 of the Energy Independence and Security Act 2007

Energy and water metered data can help energy managers make informed operations and investment decisions throughout the energy and water evaluation process. Metered data can be used to identify the facilities with the highest energy use, benchmark facility performance, track facility energy and water use, set energy and water use goals, and prioritize facility investments.

This reference document offers examples of how metered data can be used in support of energy and water evaluations. The basic energy and water evaluation process is outlined and then metered data analysis techniques are explained, connecting common evaluation questions to analysis techniques. The intended audience for this reference document is energy managers and others who are new to using metered data to support evaluations and have limited experience with metered data analysis.

[1] Energy Policy Act of 2005, 42 U.S.C. 8253.

[2] Energy Independence and Security Act of 2007, 42 U.S.C. 8253.

[3] See FEMP guidance, *Facility Management Guidelines and Criteria for Energy and Water Evaluations in Covered Facilities:* https://www.energy.gov/sites/prod/files/2013/10/f3/eisa_s432_guidelines.pdf

2.0 Comprehensive Energy and Water Evaluations

Comprehensive energy and water evaluations of federal facilities are required by Section 432 of the Energy Independence and Security Act of 2007 (EISA), which states that "covered facilities" which constitute at least 75 percent of facility energy use at each agency must be evaluated every 4 years for cost-effective energy and water savings opportunities. To comply with this mandate, each year every federal agency must identify a set of covered facilities (approximately 25%) to prioritize for evaluation.

Covered Facility

"… FEDERAL FACILITIES, INCLUDING CENTRAL UTILITY PLANTS AND DISTRIBUTION SYSTEMS AND OTHER ENERGY INTENSIVE OPERATIONS, THAT CONSTITUTE AT LEAST 75 PERCENT OF FACILITY ENERGY USE AT EACH AGENCY."

Sec. 432 of the Energy Independence and Security Act 2007

Most energy and water evaluations can benefit from the use of metered data. With access to metered data, evaluators can establish a baseline of energy and water use for a facility. Utility bills are considered to be the authoritative source for energy and water use data, but because they are typically reported at monthly intervals and may combine multiple facilities on a single meter, they are unable to provide a sufficient level of granularity to understand how a facility is operating from day to day; this is where facility-level interval data from advanced meters can be leveraged for more detailed analysis. These two data sources, together with supporting sources such as property and weather data, can be combined and analyzed to support decisions at every step of the evaluation process.

The key steps of an energy and water evaluation in which metered data can be used to support decisions include:

- Data review and preparation
- Facility selection
- Evaluation type selection
- Evaluation scoping
- Site visit
- Modeling and measure identification
- Measurement and verification.

The sections that follow will briefly discuss each key evaluation step and show how metered data could be used to support decisions at that step of the process. The structure of this section generally follows the traditional on-site evaluation process. Not all of these steps will apply to every agency's or facility's particular situation. For example, virtual energy and water evaluations do not require a site visit, and performing measurement and verification (M&V) would only be necessary if an EWCM had been implemented at a facility. Additionally, not all of these steps will apply to every reader, depending on the reader's role in the evaluation process.

2.1 Data Review and Preparation

The first step in the evaluation process is to determine what data are available for the facilities under consideration for evaluation and how reliable those data are. Utility bill data, property data, equipment inventories, utility payments, and capital project records may all be needed for a facility evaluation, but these data are sometimes incomplete or inaccurate. When initially reviewing the available data, care must be taken to ensure that the data used to support key decisions are reliable. Especially in cases where data are manually transcribed from one source to another, such as when utility bills are hand-typed into an enterprise utility reporting system, there is a chance that errors will occur; common problems include data transposition and “fat finger” errors.

Advanced meters, despite collecting and reporting data automatically, can also suffer from data quality and availability problems. Before metered data are used to supplement an energy and water evaluation, the data should be inspected. Common data quality problems affecting metered data include periodic unavailability, reporting unit miscalibration, and timestamp offsets. Figure 1 illustrates a timestamp offset for an electricity meter; note that the peak load occurs during the middle of the night.

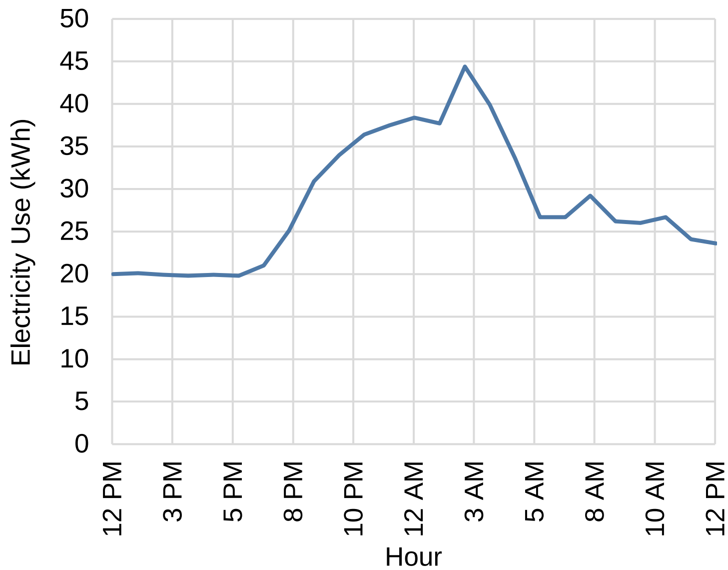

Figure 1. Example of a Timestamp Offset in Time Series Data.

The most common causes of data quality problems include loss of power or service, broken equipment, software malfunctions, and system replacement or reset/restart. For a detailed approach to preparing energy data, refer to the Simplified Processing Method for Meter Data Analysis technical report.[4] That report offers specific strategies for addressing common metered data problems.

[4]See Fowler, K.M., et al. *Simplified Processing Method for Meter Data Analysis*: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-24331.pdf

2.2 Facility Selection

When an agency begins the process of prioritizing facilities for evaluation, there are a number of factors to consider, including facility age, size, use type, and mission criticality; whether the facility has been evaluated previously; how soon the facility must be evaluated to comply with the 4-year requirement; physical proximity to other high-priority facilities; and a variety of other factors.

Of particular importance when considering whether to select a facility for an evaluation is the facility's energy and water use relative to similar comparison facilities. High-use facilities may represent opportunities for significant savings through EWCMs. Utility bills often serve as the primary source for high-level comparisons of energy and water use, but advanced meters can supplement utility bills when a facility does not have a utility meter or more detailed comparative analyses are required.

Figure 2 illustrates how energy and water use can be compared across multiple facilities. The metrics graphed in this example are energy use intensity (EUI) and water use intensity (WUI), which take annual energy and water use, respectively, and divide by the total floor area of the facility. This per-square-foot calculation allows for comparison of use across facilities of varying sizes. In this example, Facilities A and B both appear to be higher priority for evaluation than Facility C, which has both the lowest EUI and lowest WUI of any of the three facilities.

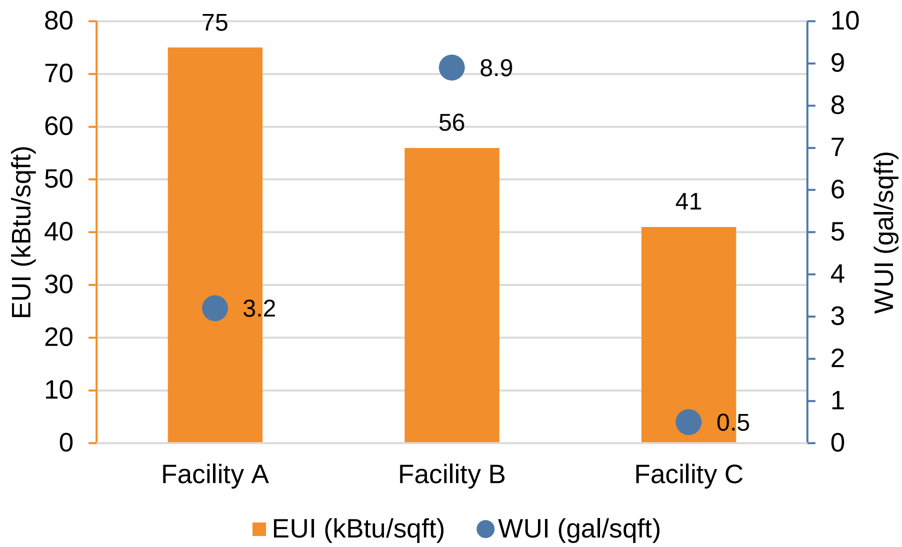

Figure 2. Comparison of EUI and WUI across Three Facilities.

Note that calculations of EUI and WUI require both metered data and property data inputs. See Section 3.2 for additional discussion about how to graph and analyze these metrics, and see Section 3.6 for additional discussion on dual-axis graphs.

2.3 Evaluation Type Selection

Once a facility has been identified for a comprehensive energy and water evaluation, the appropriate evaluation type must be selected. Not every facility requires a traditional in-person evaluation; depending on certain factors, a more limited evaluation may be appropriate. For example, if sufficient supporting data are available for a facility, and the facility has had major upgrades recently or there have been no major changes to facility equipment or operations since the previous evaluation, it may be appropriate to forego another traditional on-site evaluation and instead conduct a remote evaluation. These two broad categories encompass a spectrum of evaluation options, as illustrated in Figure 3.

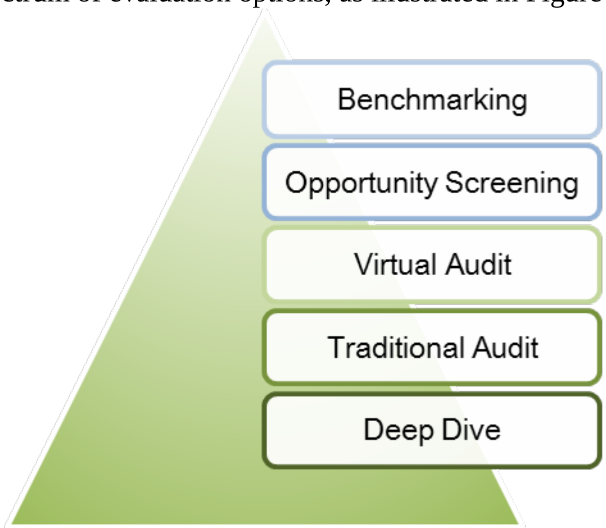

Figure 3. Types of Facility Evaluations.

The first three evaluation types represented in the graph are typically conducted remotely, and consequently they are less detailed and less costly than on-site evaluations. Benchmarking is the practice of accounting for and comparing a metered building's current energy performance with its energy baseline or historical performance, or comparing a metered building's energy performance with the energy performance of similar types of buildings. Energy use intensity and water use intensity are common metrics. Opportunity screening goes a step further than the standard benchmarking process by including more detailed information about the facility, identifying high-level energy and water conservation measures (EWCMs) and/or tracking EWCM implementation. Another term for this type of activity is "preliminary assessment" or "desktop audit". Virtual audits are usually performed without visiting the site. These could be performed using a specialized software tool or through subject matter expert screening of facility data.

The last two evaluation types involve a site visit by evaluators. Traditional audits are detailed evaluations that include data collection in-person at the facility, followed by detailed analysis at the conclusion of the on-site portion of the analysis. A traditional audit identifies no-cost and low-cost opportunities, and also provide EWCM recommendations in line with financial plans and potential capital-intensive energy savings opportunities. A traditional audit includes an in-depth analysis of energy costs, energy use, and building characteristics and a more refined survey of how energy is used in the building. A deep dive evaluation would go beyond the depth of a traditional audit. The evaluation could be an effort focused on either very specific areas or connecting several areas.

In the event that a remote evaluation is selected, energy and water metered data are crucial to understanding a facility's operations. Ideally, whole-facility metered data will be further supported by time series data from the building control system (BCS) allowing the evaluator to compare energy and water use against the operation of individual heating, ventilation, and air-condition (HVAC) system components, such as valve and damper positions, fluid temperatures and pressures, and reset values. Discussion of BCS data analysis is outside the scope of this reference document, but Section 3.7 will describe inferences that may be made about some controls from comparing metered energy use data against outdoor air temperature (OAT) data.

2.4 Evaluation Scoping

If an on-site evaluation type is selected for a facility, evaluators will travel to the facility and physically inspect its energy and water systems. During a typical on-site evaluation, all systems are reviewed, including building envelope, controls, domestic hot water, HVAC systems, lighting, renewable energy systems, water, and miscellaneous loads. Depending on the number, size, and complexity of the facilities to be evaluated and the time available, however, the evaluators may be constrained to reviewing a subset of systems in some or all facilities. This is common for evaluations at large sites such as military installations that may house hundreds or thousands of facilities; in such cases, evaluators must typically sample a subset of facilities and equipment and then extrapolate to the facilities that they are unable to visit.

Metered data can be used to support prioritization during pre-visit scoping if a complete evaluation of all energy and water systems is not possible. For example, if a facility's metered water use data shows consistent nighttime use and that facility is known to have only plumbing as a water end-use, a leak in the domestic water system could be causing the nighttime use. Evaluators might specifically target the facility's plumbing system for inspection during the pre-visit evaluation scoping process. Figure 4 illustrates a case like the one just described; note that in this time series of water use, hourly use never drops below 10 gallons, even in the middle of the night.

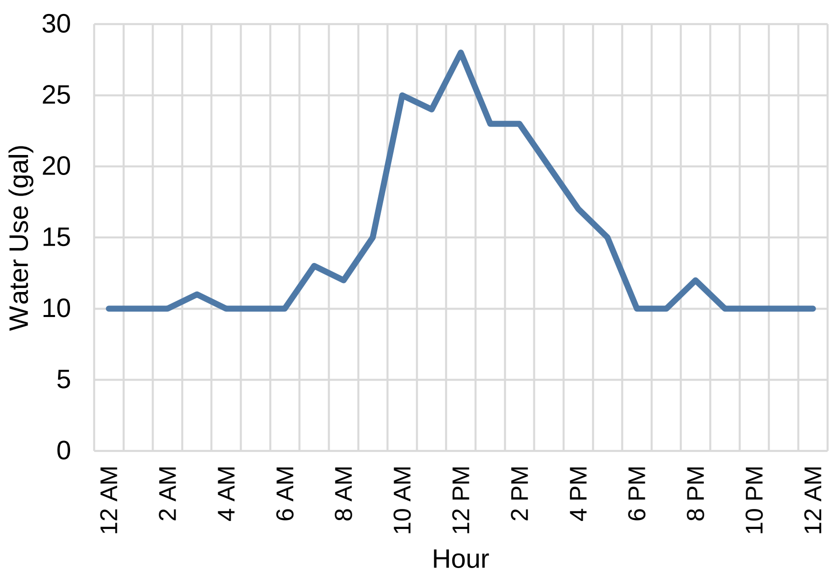

Figure 4. Water Meter Time Series Showing Consistent Nighttime Use.

See Section 3.3 for additional discussion about how to graph and analyze time series data.

2.5 Site Visit

Once evaluators are on site, metrics and insights derived from analyses of metered data can support discussions with facility managers and occupants. They can also inform specific questions about equipment operations and controls for further investigation.

For example, if a facility's daily electricity load profile does not show a significant decrease from peak use until late in the evening, this could suggest that the cooling system is still running at high capacity while the facility is unoccupied at night. While on site, evaluators could ask the facility manager about the facility's typical occupancy schedule and then compare that against the programmed occupancy schedule in the BCS. If the programmed occupied hours exceeded actual occupied hours, the schedule could be reprogrammed while evaluators were on site, resulting in immediate savings.

Figure 5 illustrates an electricity load profile for a facility that appears to have an unusually high load outside of typical occupied hours.

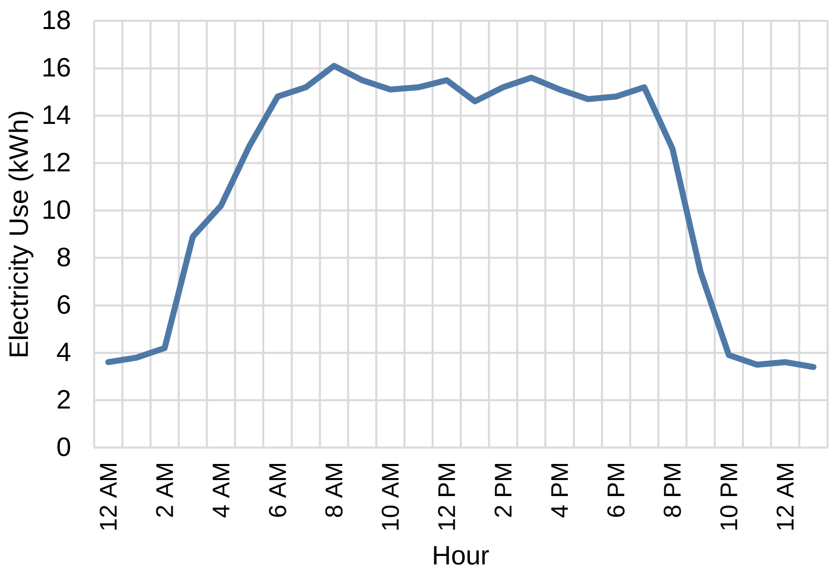

Figure 5. Facility Energy Load Profile Exhibiting Apparent Early Start and Late Shutoff.

The facility appears to start early, with systems ramping up around 2 AM, and shut off late, with electricity use not returning to a nighttime baseline until 9 PM. A load profile like this would prompt an evaluator to review the facility's programmed HVAC schedule and compare it against actual occupancy patterns. The evaluator might determine that the facility is receiving unnecessary cooling outside of occupied hours; however, if the facility is indeed occupied between 2 AM and 9 PM, this pattern could simply reflect normal HVAC, lighting, and other facility loads.

See Section 3.5 for additional discussion about how to graph and analyze load profiles.

2.6 Modeling and Measure Identification

Once an evaluation is complete, the data gathered during the evaluation, along with the pre-visit information, are used to construct models of facility energy and water use. These models are then used to evaluate the cost-effectiveness of a range of energy and water conservation measures based on applicable utility service rate schedules. Before measure evaluation is performed, the model must be calibrated with respect to actual energy and water use.

Metered data can be used to support the model calibration process by allowing the modeler to compare actual use to modeled use and to investigate significant deviations. In addition, if the metered data analysis identified potential operational issues that are confirmed during the evaluation, controls measures addressing the issues can be modeled resulting in additional savings. As an example, Figure 6 illustrates how metered data can be used to calibrate an electricity simulation model.

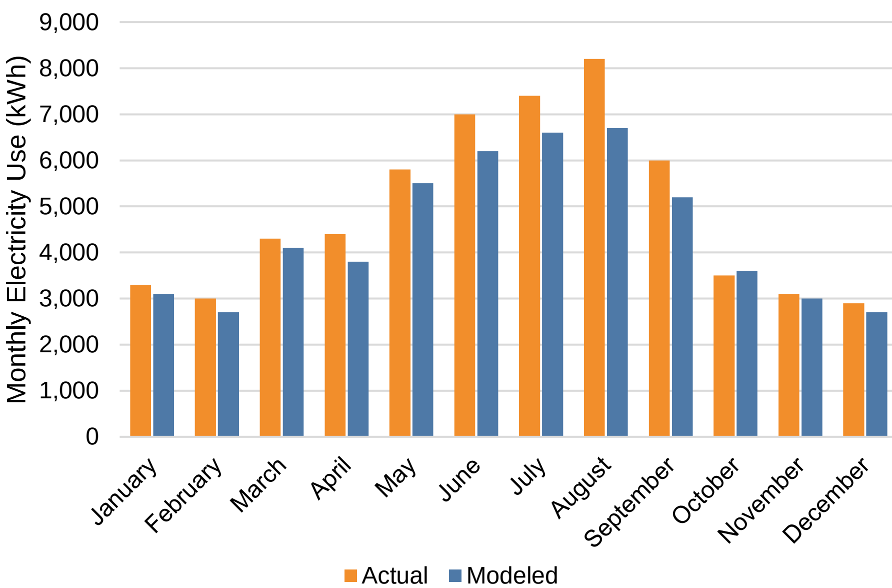

Figure 6. Bar Chart Comparison of Actual Monthly Electricity Use to Modeled Monthly Electricity Use.

Overall, the model's performance is reasonably good, with a difference between the actual metered use and modeled use of just under 10%. Clearly some of the model parameters will have to be adjusted to reduce that difference, but which ones? Graphing the data on a monthly basis helps to illustrate where the model may be falling short. During the heating months, the model captures baseline electricity use fairly accurately; however, it consistently underestimates the facility's electricity use during the summer. One possibility is that the model is underestimating the facility's cooling load, perhaps by assuming too high of a cooling temperature setpoint. After re-running the computations with lower cooling setpoints, the evaluator should review this monthly comparison graph to see whether the model is now capturing more of the summer cooling load.

See Section 3.1 for additional discussion about how to graph and analyze summary graphs.

2.7 Measurement and Verification

If energy and water conservation measures are implemented at a facility, metered data can be used to perform measurement and verification (M&V) of projected savings. Depending on the mechanism used to fund the project and the performance criteria stipulated in the project contract, M&V may or may not be required.

There are a variety of approaches to using whole-facility or sub-metered energy and water data to perform M&V that are beyond the scope of this reference document, but which are detailed in the FEMP M&V Guidelines document.[5]

Approaches that use metered data compare energy or water use before implementation to use after implementation. It is possible to apply this approach to verify project savings. For example, a facility coordinator might indicate that the facility received an LED lighting upgrade about a year ago and that HVAC controls were also optimized to include scheduling and setbacks. Analysis of the facility's metered data might indicate a notable reduction in the daytime peak load, likely attributable to the more efficient lighting, and a reduction in nighttime energy use, resulting from improved HVAC scheduling. In such a case, performing M&V could help to confirm the facility coordinator's findings. The results of these comparisons can be helpful in selecting facilities for evaluation. If the facility has had recent projects implemented and M&V analysis indicates that the facility has achieved energy and water savings, then the facility might be considered a lower priority or a candidate for a less intensive evaluation (i.e., a desk evaluation).

[5]See FEMP guidelines document, *M&V Guidelines: Measurement and Verification for Performance-Based Contracts Version 4.0:* https://www.energy.gov/eere/femp/downloads/mv-guidelines-measurement-and-verification-performance-based-contracts-version

3.0 Metered Data Analysis Techniques for Evaluations

This section presents metered data visualization and analysis techniques that can be used to support an energy and water evaluation. It cross-references the evaluation steps described in Section 2.0, and explains how each analysis technique can help answer some common evaluation questions.

The analysis techniques presented in this section are graphical and qualitative in nature. It is assumed that user of this reference document has had some experience with comprehensive energy and water evaluations and has access to metered data, but has limited experience with using metered data to support an evaluation. Therefore this section focuses on introducing qualitative analytical concepts and connecting those concepts to practical questions that arise throughout the evaluation process. More advanced quantitative techniques for metered data analysis are beyond the scope of this document.

The questions that accompany each analysis technique are provided as examples to help the reader begin investigating metered data; they are not intended as a definitive or comprehensive list. Note that in many cases, questions can be investigated using more than one analysis technique and may apply to more than one evaluation step. Often, insights from analysis results are useful throughout the entire process. Users of this document are encouraged explore additional uses for metered data that are not discussed in this section.

In addition to metered data, many of the questions posed in this section require supporting contextual data. The purpose of using metered data to support an evaluation is to understand both how a facility operates and also how its operations deviate from an evaluator's expectations. An evaluator can observe usage trends over time from metered data, but additional context is needed to establish the implications of those trends. If a facility shows unexpectedly high energy use, what characteristics about the facility could explain it? Important contextual information includes facility size, use type, location, operational characteristics, and occupancy patterns, as well as contextual information for relevant comparison facilities. (See Appendix A for further discussion of supporting data sources.) All of these supporting sources of information are important for establishing expectations about facility performance and enabling the evaluator to identify deviations from expected behavior. Deviations from expected performance represent potential opportunities for energy and water savings.

The metered data analysis techniques discussed in the following sections are:

- Summary graphs
- Energy and water use intensity
- Time series graphs
- Rolling averages
- Load profiles
- Dual-axis graphs
- Scatter plots
- Heat maps.

3.1 Summary graphs

Summary graphs use aggregate calculations to present a simple visual summary of trends in metered data. Common aggregate calculations include sums, averages, maximums, and minimums. Metered data are frequently summed on a monthly or annual basis and displayed with a bar graph. Figure 7 illustrates a typical bar graph, in which metered electricity use data is summed by month.

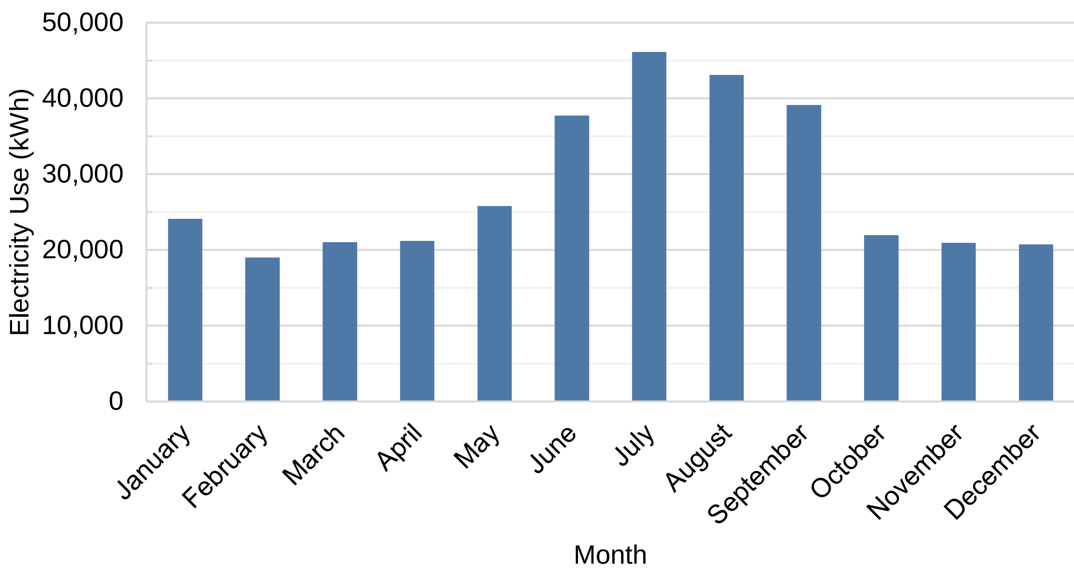

Figure 7. Example Summary Graph.

Summary graphs provide an important point of reference throughout the evaluation process. Aggregate measures like total energy and water use, and derived metrics like energy and water use intensity, are useful in comparing overall performance among facilities during facility selection. They can also help an evaluator to prioritize high-use facilities during a site visit, and they provide the annual baselines used to calibrate energy and water models. Table 1 lists some potential questions to ask during the energy and water evaluation process and how summary graphs can help answer them.

Table 1. Potential Questions to Investigate with Summary Graphs.

Evaluation Step	Question	Data Inputs
Data Review and Preparation	**How closely do the monthly or annual summed interval metered data match the corresponding totals reported on utility bills?** *Driver:* This comparison is an important check on the accuracy and reliability of both data sources. For each utility, the summed totals reported by these two sources should be within a few percent of each other. If there is a large discrepancy, it could indicate a problem with data quality in one or potentially both sources. *Guidance:* Calculate monthly and annual sums for corresponding metered and utility bill data and create a summary bar graph comparing them side-by-side.	Metered data, utility bill data

	If a facility shows unreasonably high or low annual energy or water use, could it be due to a data quality problem? *Driver:* Depending on which data source shows unreasonably high or low monthly or annual energy use, it could be indicative of bad readings in the metered data or data entry errors that occurred during the transcription of utility bills. *Guidance:* For the metered data, review time series for evidence of large positive or negative spikes that could be evidence of bad readings. For the utility bill data, if copies of the original utility bills are available, check the data against those bills.	Metered data, utility bill data
Evaluation Type Selection	**Is there a quantifiable difference in facility energy and/or water performance before and after EWCM project implementation?** *Driver:* Measurement and verification of energy and water savings is required for many large capital improvement projects, especially those financed through third-party mechanisms such as an energy savings performance contract (ESPC). After implementation, ongoing metering can allow evaluators to perform before-and-after calculations to verify savings from new equipment and controls. Savings should be evident in reduced energy and water use over time. If savings are not evident, the facility might warrant a follow-up evaluation to determine whether the project was implemented properly. If savings are evident, the facility may be a candidate for a remote evaluation. *Guidance:* Create a summary graph showing a facility's annual energy or water use. For energy use, if weather data are available, divide annual use by combined annual heating degree days (HDD) and cooling degree days (CDD) to get weather-normalized values; this helps to reduce the variable influence of weather on energy use from year to year and present a clearer picture of facility performance. See Section 3.2 for further discussion of normalization.	Metered data, capital improvement project records, weather data (optional)
Facility Selection	**Which facilities are the highest overall energy and water users?** *Driver:* High-use facilities may represent opportunities for significant savings through energy and water conservation measures. *Guidance:* For each facility in the portfolio, calculate annual sums of energy and water use. Then for each utility, create a summary bar graph with the facilities sorted from highest use to lowest.	Metered data

	How does a facility's monthly energy and water use compare to that of similar facilities? *Driver:* If a facility's energy or water use is high relative to relevant comparison facilities, it may be a good candidate for an evaluation to identify EWCMs. *Guidance:* Comparison facilities are usually grouped by similar characteristics, such as size, use type, age, and geographic location, which are attributes that can be found in property data for the agency's portfolio of facilities. For a given facility, identify several relevant comparison facilities, then create summary graphs comparing their annual and monthly energy and water use.	Metered data, property data
Modeling and Measure ID	**How accurate is the facility energy model relative to actual energy use?** *Driver:* An important part of the modeling and measure identification process is calibration of the facility energy model with respect to actual energy use data. An accurate energy model ensures that the potential energy and cost savings calculated for proposed retrofits are not overstated. *Guidance:* Calculate monthly sums of the model energy use outputs. Create a summary bar graph comparing the modeled monthly totals with actual monthly totals.	Metered data, facility energy simulation outputs

3.2 Energy and water use intensity

Energy use intensity (EUI) and water use intensity (WUI) are metrics that normalize energy and water use by a facility's total floor area. This allows an evaluator to directly compare energy and water use across facilities of different sizes. For energy, the metric is usually calculated as:

$$\frac{Annual\ energy\ use\ (kBtu)}{Total\ building\ area\ (gross\ sqft)}$$

For water, the metric is usually calculated as:

$$\frac{Annual\ water\ use\ (kgal)}{Total\ building\ area\ (gross\ sqft)}$$

As indicated in the formulas, EUI and WUI are most commonly reported on an annual basis, although metrics using monthly energy or water use are sometimes used as well. Figure 8 illustrates a typical EUI bar graph, which compares annual EUIs for two facilities side-by-side over a 3-year period. Note that the EUI for Facility B is increasing each year, while Facility A appears to be holding steady at around 38 kBtu/sqft.

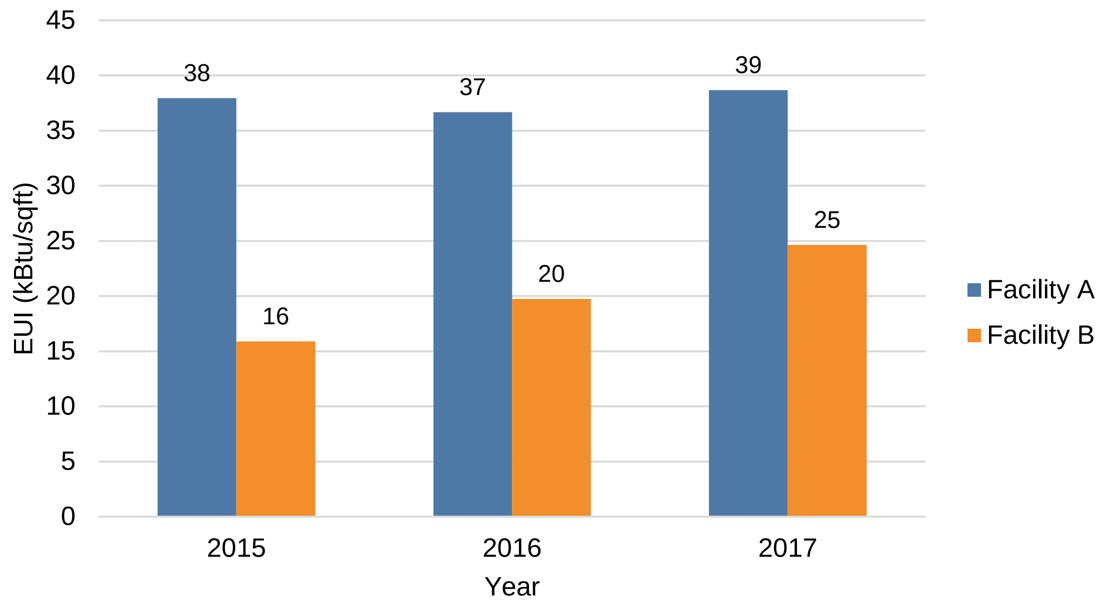

Figure 8. Example EUI Graph.

The EUI and WUI metrics build on the previous analysis technique by taking summarized energy or water use and then normalizing that value. These metrics can be used in conjunction with summary graphs to provide context for unusual observations. For example, energy use at a large facility may appear to be very high relative to a set of comparison facilities, but on a per-square foot basis it may appear much more reasonable. Note that energy and water use can be normalized in other ways too; another common metric is energy use normalized by HDDs or CDDs. Table 2 lists some potential questions to ask during the energy and water evaluation process and how energy and water use intensity graphs could help answer them.

Table 2. Potential Questions to Investigate with EUI/WUI Graphs.

Evaluation Step	Question	Data Inputs
Data Review and Preparation	**Do any facilities report unreasonably high or low energy or water use intensities?** *Driver:* Unreasonably high energy or water use intensity could be an indicator of underlying problems with the quality of the metered data or the property data. For example, a data entry error like a missing digit in the property data could cause the floor area to be underreported, which would dramatically increase the calculated EUI and WUI for that facility. *Guidance:* For the metered data, review time series for evidence of large positive or negative spikes that could be evidence of bad readings. Review the property data to assess the reliability of facility floor area values.	Metered data, property data
Facility Selection	**How does a facility's monthly energy and water use intensity compare to that of similar facilities?**	Metered data, property data

	Driver: High energy or water use intensity relative to comparison facilities could be an indicator of excessive use, meaning that a facility might be a good candidate for an evaluation to identify EWCMs. Normalizing energy and water use allows an evaluator to compare facilities of different sizes, which may reveal facilities that have low total use but high use relative to their size. *Guidance:* For both energy and water, create a summary bar graph that displays total annual use divided by total floor area for a set of comparison facilities.	
	How does a facility's energy and water use intensity compare to a regional or national average of similar facilities? *Driver:* In some cases, comparisons with similar facilities within an agency's portfolio may not reveal evidence of high energy or water use intensity. For example, if all of the comparison facilities are old facilities constructed around the same time, it is possible that they are all running outdated, inefficient equipment and might all be good candidates for a retrofit. In this case, no one facility's energy or water use intensity would stand out as unusually high. External sources of facility energy and water use data can be a useful point of comparison for facility performance. *Guidance:* For a given facility, identify a regional or national benchmark and compare the energy and water use intensity of the facility against that of the benchmark. Create a summary bar graph to view a side-by-side comparison.	Metered data, property data, external sources of facility energy and water use data (e.g., CBECS)[6]
	Have any facilities shown a substantial increase in energy or water use intensity in recent years? *Driver:* If a facility's EUI or WUI is trending higher relative to comparison facilities, it could suggest that operational problems have arisen, such as a manual override of controls; however, it could also suggest that the facility's mission and operational requirements have changed. *Guidance:* If multiple years of metered data are available, calculate EUI and WUI for each year available. It is preferable to have at least 3 years of data. Create a bar or line graph plotting EUI or WUI against years.	Metered data, property data
Site Visit	**Can a high EUI be explained with the information received during the pre-visit assessment?** *Driver:* Sometimes a facility's unexpectedly high EUI is only partially explained by the facility information received	Metered data, on-site evaluation data (including

[6] See EIA resource, *Commercial Buildings Energy Consumption Survey (CBECS)*. Available at: https://www.eia.gov/consumption/commercial/

	during the pre-visit evaluation scoping process. In such cases, once onsite, evaluators should look for additional explanations as to why EUI is so high. *Guidance:* During an on-site evaluation, an evaluator should keep the facility's high EUI in mind and look for explanations such as unaccounted-for equipment, previously unknown operational requirements, or inefficient control strategies.	BCS trend data, if available)

3.3 Time series

Time series graphs are used to plot a quantity such as electricity, gas or water use over a period of time. A time series graph of metered data is a direct visual representation of the meter readings at each timestamp, without any further calculations to summarize or normalize the data. Figure 9 illustrates a typical time series graph, which shows hourly meter readings over a 1-month period.

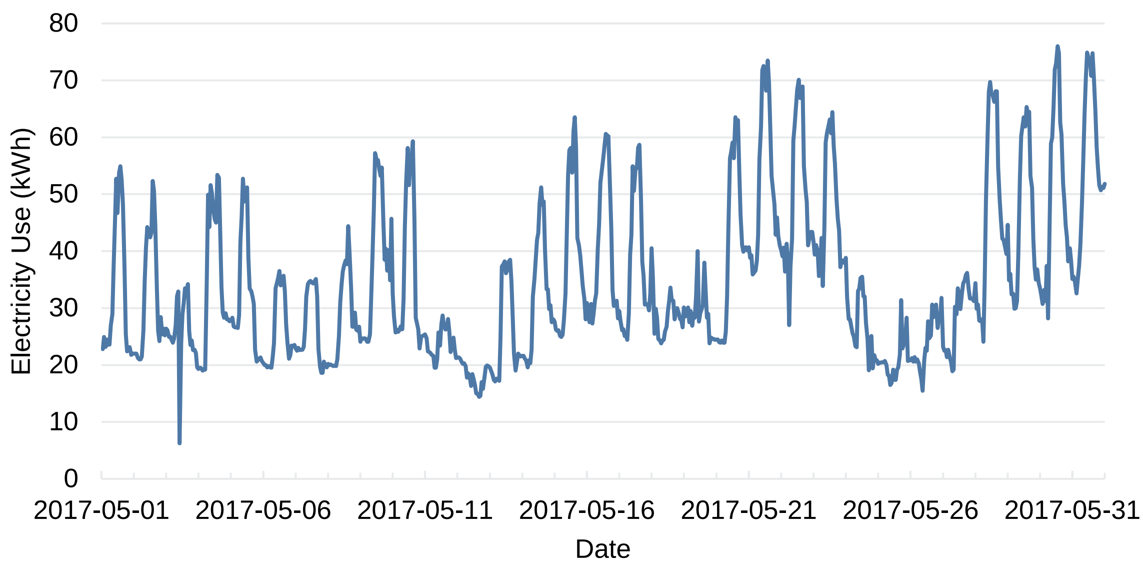

Figure 9. Example Time Series Graph.

Time series graphs are useful for visually inspecting patterns in performance over time. They can range over any period, but for analyzing metered data it is common to look for trends in annual, monthly, weekly, and daily graphs. Annual and monthly graphs can help to identify seasonal patterns in use, while weekly and daily graphs allow an analyst to pinpoint specific instances of unusually high or low energy or water use. Table 3 lists some potential questions to ask during the energy and water evaluation process and how time series graphs could help answer them.

Table 3. Potential Questions to Investigate with Time Series Graphs.

Evaluation Step	Question	Data Inputs
Data Review and Preparation	**Are there any issues with metered data quality or availability that could compromise analysis results?** *Driver:* Problems of data quality and availability can occur with some energy and water meters. Unfortunately, if the data are not reliable, then any conclusions reached through analysis of those data will not be reliable either. Common data quality issues affecting metered data include periodic unavailability, reporting unit miscalibration, and timestamp offsets. *Guidance:* Review the time series for data gaps, large positive or negative spikes, identical repeated values over unusually long spans of time, and recurring peak readings at unexpected times of day.	Metered data
Evaluation Type Selection	**If a remote evaluation is being considered, is there at least 1 year of reliable meter data available for each utility service to the facility?** *Driver:* It is very useful to have at least 1 year of reliable metered data when conducting a remote evaluation because it allows the evaluator to observe facility performance under a full range of weather conditions, including the heating, cooling, and shoulder seasons. Depending on the scope of the remote evaluation and the extent of the other data available for the facility, however, metered data may not always be necessary. *Guidance:* Review the start and end dates of the time series. If there are data quality problems, investigate whether there is a subset of continuous, reliable data covering at least 1 year.	Metered data
Site Visit	**Does the time series show any unexpected nighttime energy or water use?** *Driver:* In general, an evaluator would expect to see a reduction in nighttime energy and water use in the metered data. Water use in particular is typically expected to drop to near zero at night; evidence of higher than expected nighttime use could indicate a leak in the facility's water supply piping system. Exceptions can occur, however; for example, the facility might have 24-hour operations, or the water meter may be measuring nighttime landscape irrigation in addition to facility water use. *Guidance:* If the time series shows consistent, higher than expected nighttime energy or water use, evaluators should look for an explanation during an on-site evaluation. For water, look for specific evidence of leaks, and ask occupants about nighttime occupancy, special processes	Metered data

	requiring water use at night, and irrigation scheduling, if known.	

3.4 Rolling averages

A rolling average smooths out short-term variability in time series data to give an indication of an underlying trend. This can be helpful for noisy data where there appears to be a lot of short-term change masking a stable or slowly increasing or decreasing baseline. A rolling average is a type of aggregate calculation that is re-calculated at each step in the time series. To create a weekly rolling average, at each time step, calculate the average of all of the readings from the preceding week. Figure 10 illustrates a typical time series graph with a rolling average trend applied, showing that despite the daily fluctuations in electricity use, the underlying trend is stable with a modest increase moving into the cooling season.

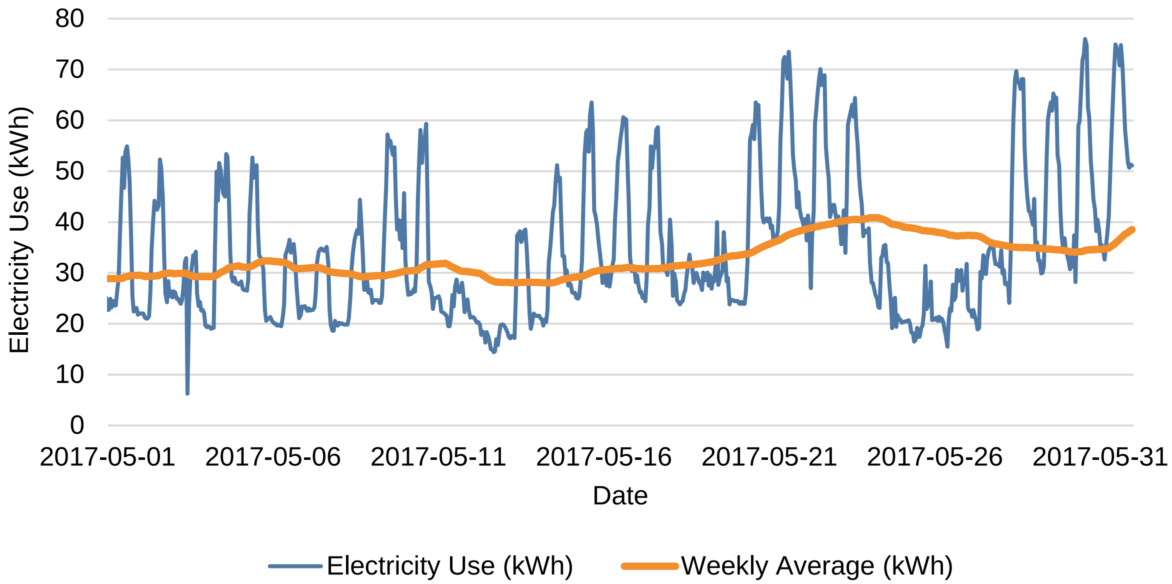

Figure 10. Example Rolling Average Graph.

Table 4 lists some potential questions to ask during the energy and water evaluation process and how rolling average graphs could help answer them.

Table 4. Potential Questions to Investigate with Rolling Average Graphs.

Evaluation Step	Question	Data Inputs
Facility Selection	**Is a facility's energy or water use trending higher over time?** *Driver:* As noted in the EUI/WUI section above, energy or water use trending higher over time could suggest that operational problems have arisen or that the facility's mission and operational requirements have changed. It is	Metered data

	useful to examine trends at a summary level, as with a bar graph plotting annual EUIs; however, it is also useful to examine trends in more detail, to investigate the extent to which unusual, short-duration events like usage spikes could be affecting those summary values. In the aggregate, usage spikes could cause annual performance to appear to be trending in one direction while typical daily performance is actually trending in the opposite direction. Adding a rolling average to the time series can help clarify a facility's long-term performance trend by smoothing out those short-term spikes. *Guidance:* Add a rolling average to the time series and examine the smoothed trend for evidence that use is increasing or decreasing over time. It is preferable to have more than 1 year of time series data because the smoothed trend will show some inevitable seasonal change up and down.	
Evaluation Scoping	**Is there substantial seasonal variability in the facility's electricity use baseline?** *Driver:* A substantially higher summer baseline may suggest weak or nonexistent temperature setbacks. An evaluator would expect to see some seasonal rise in the baseline even in a facility with properly scheduled setbacks because during the hottest months, the facility will still require some nighttime cooling to maintain the unoccupied setpoint temperature; however, a substantial increase (e.g., 100%) in baseline between winter and summer may indicate that the unoccupied setpoint is not set back, with the cooling system running and using electricity unnecessarily at night. *Guidance:* Compare the values of the rolling average trend during the summer months to those during the winter months. If the ratio is large, look for other evidence of weak or nonexistent setbacks in the load profiles.	Metered data

3.5 Load profiles

Load profile graphs are a way to visualize the daily performance of a facility. Most commonly, a load profile is created by taking the values reported by a meter during a given month and then calculating the average value for each hour of the day. This smooths out the fluctuations in usage patterns to produce a graphical representation of average daily performance for that month. Figure 11 illustrates a typical load profile graph, which displays a full year of monthly load profiles.

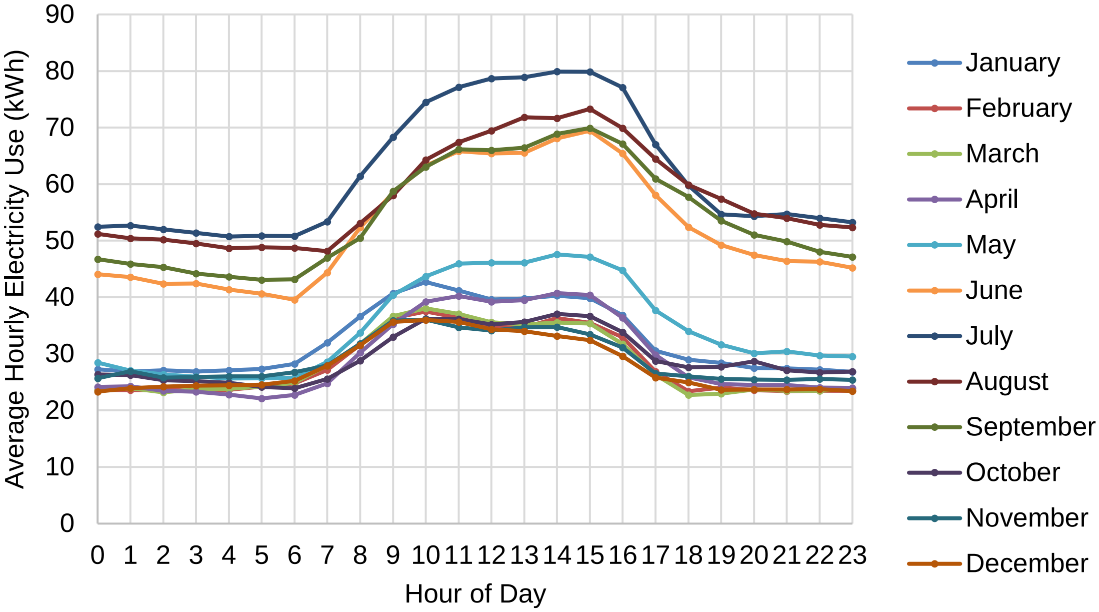

Figure 11. Example Monthly Load Profile Graph.

Load profiles can be used to compare nighttime baseline and daytime peak energy use across multiple seasons. This visualization can inform an analyst of the seasonality of a facility's energy or water use as well as the 24-hour variation, indicating the hours at which a facility's energy or water use ramps up and back down. This insight can support inferences about facility operation such as the presence, timing, and size of HVAC temperature setbacks, the heating/cooling load, occupancy hours, and lighting schedules. Table 5 lists some potential questions to ask during the energy and water evaluation process and how load profile graphs could help answer them.

Table 5. Potential Questions to Investigate with Load Profile Graphs.

Evaluation Step	Question	Data Inputs
Data Review and Preparation	**Does the facility energy load profile exhibit strange behavior, like an inverted baseline or peaking at an unexpected time of day?** *Driver:* Occasionally an energy load profile will show higher use at night than during the day. While there may be a legitimate operational reason for this behavior, it is more likely a consequence of a data quality issue. One possibility is that the meter's reported time of use is offset from the	Metered data

	actual time of use. This could happen if a meter is configured to assign timestamps according to universal coordinated time (UTC) while the database receiving the data is configured to log the data according to the local time zone, or vice versa. Another possibility is that the meter is connected to an external load, such as parking lot lights, in addition to the facility itself. In the case of parking lot lights, the meter would record a large, consistent load that could hide the evidence of nighttime setbacks in the load profile. Either of these conditions would compromise analysis results. *Guidance:* Create monthly load profile graphs of energy use and review them for strange behavior. If they exhibit the problems described above, there may be problems with the metered data that are so serious that no further analysis is possible. Solutions to these issues are beyond the scope of this document.	
Modeling and Measure ID	**Does the facility's energy use pattern suggest a lack of weekend/holiday temperature setbacks?** *Driver:* Typical administrative-type facilities are occupied during the work week but unoccupied during the weekend and on holidays. If a facility's average daytime peak electricity use is not substantially lower on the weekends and holidays than on weekdays, a possible explanation is that weekend and holiday setback schedules are not in place. An evaluator should review actual occupancy data to determine whether it is reasonable for the facility to exhibit typical weekday electricity use patterns on unexpected weekends and holidays. *Guidance:* Within the metered electricity dataset, assign a label of "weekday" or "weekend" to each metered data observation, as appropriate. Create separate monthly load profile graphs for weekday and weekend electricity use and compare the shapes of the corresponding profiles. Look for evidence that the daytime peak is lower is lower in the weekend profile.	Metered data
Site Visit	**Can abnormalities in a facility's energy or water load profile be explained by data gathered during the evaluation?** *Driver:* Sometimes energy or water use patterns that are higher than expected can be justified by observations made during the on-site evaluation. An unexpectedly high cooling load may turn out to be partially explained by a high proportion of glass on the facility façade; high weekend use may be a result of actual weekend occupancy in the facility, rather than a lack of weekend setbacks programmed in the BCS. It is important for evaluators to review their inferences about facility performance after gathering on-site data to ensure that their models are	Metered data, on-site evaluation data (including BCS trend data, if available), facility energy simulation outputs

accurate and any measures they recommend are valid with respect to the actual equipment and operation of the facility.
Guidance: Review the load profiles again after the site visit to determine whether any previously unexpected observations can now be explained in light of the data gathered on site.

3.6 Dual-axis graphs

Dual-axis graphs allow the evaluator to overlay two variables with different units of measurement on a single graph to look for a relationship in the two trends. For metered data analysis, it is common to overlay OAT on a time series graph of energy use. Figure 12 illustrates an electricity use time series with corresponding hourly OAT readings overlaid for year of 2017. Note that electricity use is measured on the left axis in kWh, while OAT is measured on the right axis in °F.

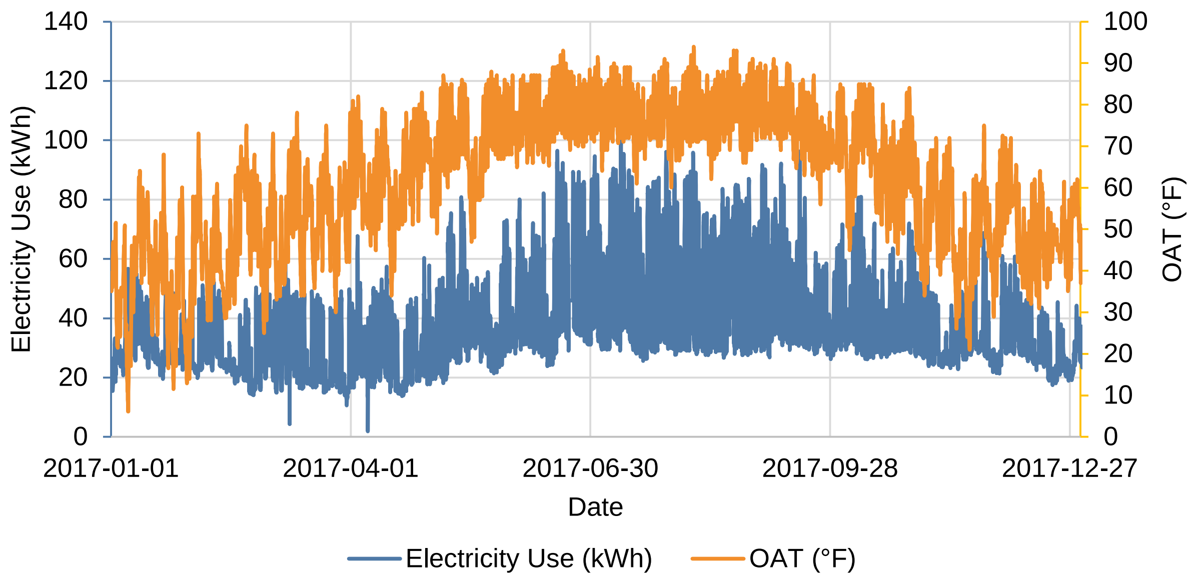

Figure 12. Example Dual-Axis Time Series Graph.

Dual-axis graphs can be investigated for evidence of a temporal relationship between two variables at varying time scales. For example, a graph spanning several months might show energy use that sharply increases as OAT decreases. Zooming in on a single week, the evaluator might further see that energy use consistently shows dramatic shifts that appear to be directly correlated to changes in OAT. In addition to potentially suggesting HVAC control issues, this observation may prompt the evaluator to investigate other possible explanations, such as poor/limited insulation or excess infiltration from poorly sealed windows and doors. Such observations can be further investigated using scatter plots of energy use against OAT, discussed in Section 3.7. Table 6 lists some potential questions to ask during the energy and water evaluation process and how dual-axis graphs could help answer them.

Table 6. Potential Questions to Investigate with Dual-axis Graphs.

Evaluation Step	Question	Data Inputs
Data Review and Preparation	**Are data spikes correlated with OAT?** *Driver:* Individual spikes in the metered data can result from reporting problems at the meter, but in some cases they may be legitimate readings. It may be difficult to determine the cause of the spike by just looking at the time series by itself. Overlaying OAT on the time series graph can sometimes provide some insight in this situation. If the spike coincides in time with an unusually high OAT, it could suggest that it was caused by an unusually high demand for cooling on that day; conversely, unusually low OAT could lead to an unusually high demand for heating. *Guidance:* Create a dual-axis time series with OAT time series data overlaid on facility energy use. Set the bounds of the dual-axis time series to include only a day or two on either side of the spike to get a clearer view of the readings on and around the spike.	Metered data, weather data
Site Visit	**How responsive is energy use to OAT?** *Driver:* If the two variables track very closely—in particular if energy use spikes in direct response to rapid increases or decreases in OAT—it may be evidence that the facility has challenges maintaining an internal temperature setpoint. Possible causes to investigate include HVAC controls, poor insulation, and excessive infiltration of outside air. *Guidance:* Create a dual-axis time series with OAT time series data overlaid on facility energy use. Examine the dual-axis time series at various time scales (monthly, weekly, daily).	Metered data, weather data

3.7 Scatter plots

A scatter plot graphs two continuous variables against each other to investigate whether there is any correlation between them. It is useful both in situations where an analyst would expect to see a causal relationship between two variables such as facility energy use and OAT, as well as in purely exploratory situations where the relationship, if any, is unknown. A scatter plot of energy use versus OAT can indicate the temperatures at which cooling and heating systems begin to use energy to maintain facility setpoint temperatures.

If a facility's occupancy schedule is known, the data points can be separated among two plots according to occupancy status and compared side-by-side for evidence of setbacks. Figure 13 illustrates two scatter plots side-by-side, with the first plot showing the distribution of a facility's electricity use versus OAT during occupied hours, and the second showing the distribution during unoccupied hours. The highest electricity use readings are recorded during occupied hours.

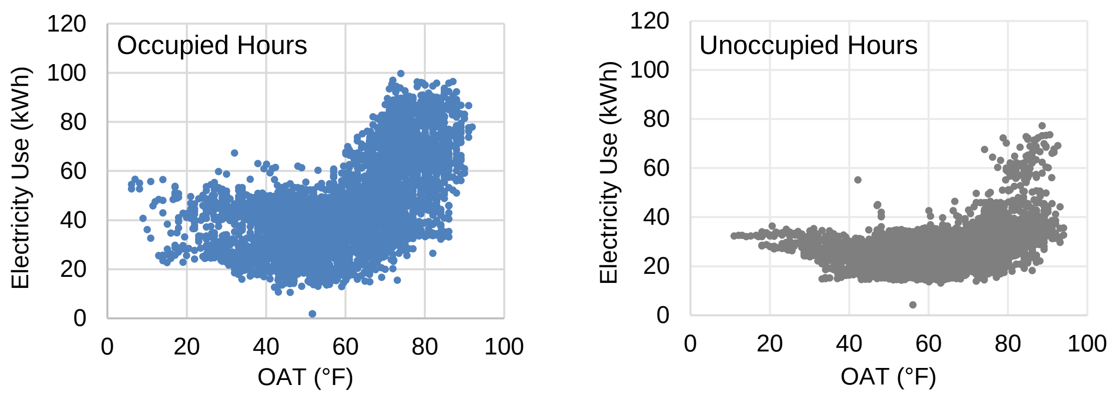

Figure 13. Example Scatter Plots of Electricity Use versus OAT.

Two important concepts to understand when analyzing scatter plots are *base loads* and *change points*. As illustrated in the "Occupied Hours" scatter plot in Figure 13, a typical facility's electricity use distribution follows a familiar pattern: below a certain OAT (roughly 60°F in the plot above), electricity use is generally flat. There is variability within the data, with most readings ranging between 15 and 50 kWh, but there is no overall trend upward or downward. This is known as the base load or weather-independent load, which includes lighting, plug loads, and other miscellaneous loads that are independent of outside weather conditions. Below about 60°F, the facility does not require cooling energy to maintain the setpoint temperature. Above 60°F, however, a clear positive relationship between OAT and electricity use emerges; as OAT increases, so does the electricity used to meet the increasing cooling demand of the facility. Again, there is a range of readings at each temperature, but the overall trend is positive. The temperature at which the electricity use trend pivots from generally flat to generally increasing is known as the change point temperature.

An evaluator would infer that this facility does not have electric heating in addition to electric cooling, because the distributions show only one change point. If the facility did have electric heating, the scatter distribution would likely show a second change point at a lower temperature. Electricity use below that second change point would start to rise again with decreasing OAT, indicating an increasing demand for heating under colder outdoor air conditions. Figure 14 illustrates a scatter distribution of natural gas versus OAT at a facility that uses natural gas for heating. In this case, the change point appears to be slightly above 60°F, and natural gas use increases as temperature falls below that point.

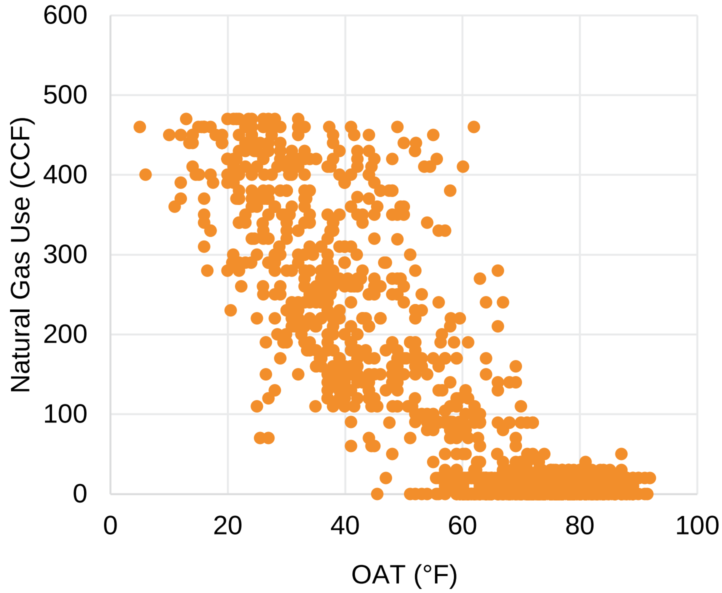

Figure 14. Example Scatter Plot of Natural Gas Use versus OAT.

Comparing the trends and change points in a facility's scatter plot distributions can yield useful insights into energy performance. Table 7 lists some potential questions to ask during the evaluation process and how scatter plots could help answer them.

Table 7. Potential Questions to Investigate with Scatter Plots.

Evaluation Step	Question	Data Inputs
Site Visit	**Do the facility electricity use change points appear to differ between occupied and unoccupied hours?** *Driver:* An evaluator would expect the unoccupied cooling change point to occur at a higher OAT than the occupied cooling change point, suggesting that the setback schedule prevents the cooling system from turning on at lower OATs during the night. The inverse should be true for heating. *Guidance:* Within the metered electricity dataset, assign a label of "occupied" or "unoccupied" to each metered data observation as appropriate based on the facility's occupancy schedule. Create a separate scatter plot of electricity use versus OAT for each set of observations. Examine the plots side-by-side. If each scatter plot distribution shows a relatively clear pattern of flat base load use below a certain OAT and increasing use above it, compare the two change point temperatures to determine if the unoccupied change point is clearly higher than the occupied change point.	Metered data, weather data, occupancy data

	Does base load differ between occupied and unoccupied hours? *Driver:* In general, an evaluator would expect the unoccupied base load (baseline energy use without heating or cooling loads) to be lower than occupied base load, because lighting and miscellaneous loads should be reduced at night. *Guidance:* Create separate “occupied” and “unoccupied” scatter plots of electricity use versus OAT. Examine the plots side-by-side. If each scatter plot distribution shows a relatively clear pattern of flat base load use below a certain OAT, compare the occupied and unoccupied base loads to determine if the unoccupied base load is clearly lower than the occupied base load.	Metered data, weather data, occupancy data
	Do heating and cooling change points occur at reasonable OATs? *Driver:* Without proper controls, heating and cooling may run unnecessarily. For example, if the occupied cooling change point occurs below 55°F, it may indicate that there is no OAT lockout configured on the chiller. Similarly, if the occupied heating change point occurs above 75°F, it may indicated that there is no OAT lockout configured on the boiler. *Guidance:* Create scatter plots of energy use versus OAT, separating data by fuel type, occupancy status, and season. Examine the plots. If the scatter plot distributions show relatively clear change points between base load and cooling/heating energy use, consider whether the OATs at which those change points occur are reasonable.	Metered data, weather data, occupancy data
Modeling and Measure ID	**How closely do the scatter plots of modeled energy use versus OAT match the scatter plots of actual energy use versus OAT?** *Driver:* Comparing model outputs against actual energy performance in a scatter plot format can be another useful way to review the model for accuracy and help calibrate model outputs. *Guidance:* Create scatter plots of energy use versus OAT for both the modeled energy use and actual energy use and compare the distributions.	Metered data, weather data, facility energy model outputs

3.8 Heat maps

A heat map converts a time series into a two-dimensional matrix with a color gradient representing the range of values taken on by the metered data. In a heat map, time is represented on the horizontal and vertical axes, and metered data values are represented by colored cells.

Typically, days are represented as rows of the heat map and hours are represented as columns. Each hourly value is mapped to a color on a gradient that ranges between the minimum and maximum values in the time series. In the example shown in Figure 15, the gradient ranges from green to red, with cooler colors indicating lower values and warmer colors indicating higher values.

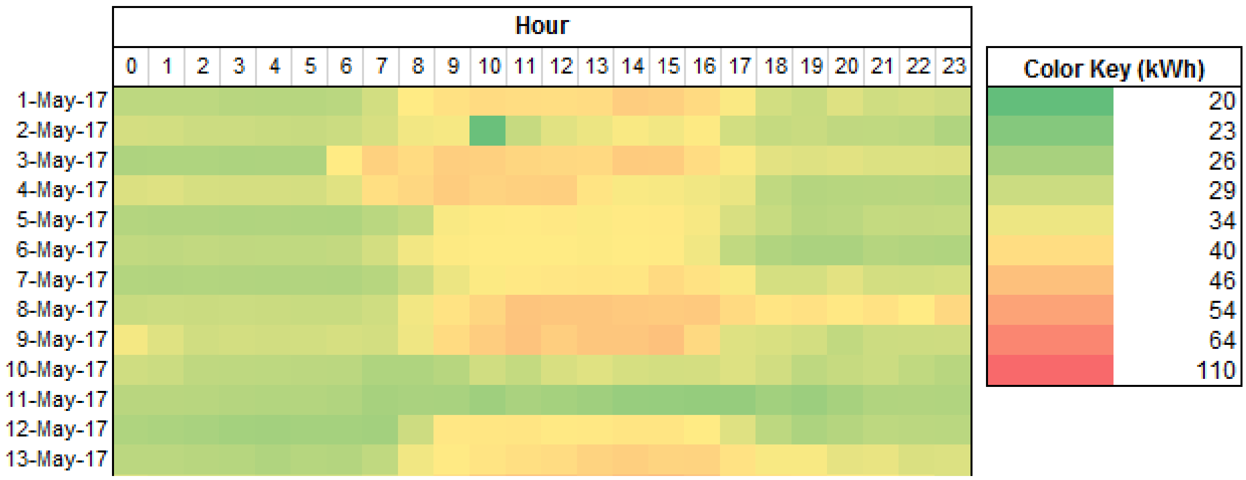

Figure 15. Example Heat Map.

Two-dimensional color maps can help to visualize patterns such as nighttime and weekend HVAC temperature setbacks and lighting use patterns, with cooler regions of lower energy use contrasting visually with warmer regions of higher energy use. A typical facility would show cooler colors near the left and right sides of the map, indicating nighttime setbacks, as well as two regularly recurring bands of cooler colors, indicating weekend setbacks. If an entire year of metered data were plotted, an evaluator would also likely to see an overall seasonal shift in the warmth of the colors displayed on the heat map. Deviations from expected performance are identified as cells showing a warm color where a cool color would be expected, and vice versa.

Heat maps are an effective way to condense the information contained in a time series into a more compact visual representation. The information represented in a heat map is exactly the same as the information represented in a time series graph, however; the only difference lies in the graphical presentation of the data. Therefore, questions posed in Sections 3.3 and 3.4 would also be appropriate to investigate with a heat map. The alternative graphical format may help an evaluator find new insights in the same metered data.

Note that implementing a heat map in Microsoft Excel requires some advanced skill with data transformation and conditional formatting. Many energy management software packages provide heat maps as a built-in feature.

4.0 Conclusion

In the preceding sections, this reference document explained the legislative basis for comprehensive energy and water evaluations, described the steps of the typical evaluation process, and connected evaluation steps to metered data analysis techniques and common evaluation questions. The intended audience for this reference document is energy managers and others who are new to using metered data to support evaluations and have limited experience with metered data analysis.

As this reference document has shown, metered data play a valuable part in the evaluation process. In most cases, an evaluation requires metered data directly from the utility, in the form of monthly utility bills, to establish energy and water baselines for a facility. Baselines are used to compare performance among facilities during facility prioritization and selection, to set evaluator expectations about overall facility energy and water performance, and to calibrate energy and water models during modeling and measure identification.

With facility-level interval metered data, however, an evaluator has the ability to learn much more about the performance of that facility. For example, metered water data may show unusually high nighttime use, which could indicate a leak in the facility's plumbing system. A facility's average monthly electricity load profile may reveal that no HVAC controls are in place to set the facility's temperatures back at night, leading to excessive nighttime electricity use. A scatter plot of natural gas use against OAT might show a change point of 75°F, suggesting that the boiler is providing heating to the facility when outdoor air conditions make it unnecessary. All of these insights can help guide an evaluator throughout the evaluation process, prompting the evaluator to validate those operational concerns and recommend corrective actions or equipment retrofits as necessary.

The analysis techniques described in this reference document are graphical and qualitative in nature. The focus in this reference document is conceptual, introducing qualitative analytical concepts and connecting those concepts to practical questions that arise throughout the evaluation process. There are quantitative techniques for metered data analysis as well, but they are beyond the scope of this document. Once users of this document are familiar with the techniques described in Section 3.0, they are encouraged to explore more advanced statistical modeling and data analysis techniques to extract additional insight from their metered data.

5.0 Additional Resources

Energy Independence and Security Act of 2007 (EISA 2007). 2007. Public Law 110-140.

Energy Policy Act of 2005 (EPAct 2005). 2005. Public Law 109-58.

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U.S. DOE. 2017. FEMP Metering Training Modules:

- *Metering Benefits and Federal Drivers*. Available at: http://www.wbdg.org/continuing-education/femp-courses/femp53
- *Building Metered Data Analysis*. Available at: http://www.wbdg.org/continuing-education/femp-courses/femp54
- *Using Metered Data to Improve Energy and Water Efficiency*. Available at: http://www.wbdg.org/continuing-education/femp-courses/femp55

Appendix A

Supporting Data

A.1 Supporting Data Types

The data used to support energy and water evaluations can be divided into two categories: metered data and supporting data. Metered data is manually or electronically read from the meter and can be available in many different forms. Metered data can include:

- Monthly utility data
- Whole-facility meter interval data
- Sub-meter data
- Building control system data.

Supporting data offers context for metered data. With metered data, an evaluator could summarize a facility's monthly natural gas use, investigate a time series for evidence of nighttime water use, and observe the difference between baseline and peak use in the facility's electric load profile; however, without any supporting context, the evaluator would be unable to draw any conclusions about whether the facility was performing as expected. If the evaluator had access to specific details about that facility, such as size and use type, they could compare the performance shown in the metered data to expected performance based on knowledge of similar facilities. By providing an initial basis for performance expectations, supporting can be used to derive useful insights from metered data.

Table A.1 summarizes some common types of supporting data used in metered data analysis and includes some of the key questions each data type addresses.

Table A.1 Common Supporting Data Types.

Supporting Data Type	Key Questions Addressed
Facility Size A facility's square footage is combined with metered energy and water data to calculate EUI and WUI.	• What is the facility's EUI/WUI?
Facility Use Type What a facility is used for can set general but defined expectations in terms of its performance. For example, a grocery store or hospital might be expected to have a higher EUI/WUI than an office or school. A data center or a hospital might have a large base load with smaller daytime surges, while the load profile for a school or retail store might see dramatic shifts between daytime and nighttime use.	• How does the facility's EUI/WUI compare to similar facilities? • Is the energy base load reasonable/expected? • Are the daytime peaks reasonable/expected?
Facility Location/Climate Where a facility is located drives initial expectations concerning the impact of climate on energy use. For example, a retail store in Minneapolis might be expected to use much more natural gas for heating than a similar sized retail store in El Paso. The retail store in El Paso might be expected to see greater daytime peaks in the summer with the increased cooling loads, whereas in Minneapolis, cooling might be less significant, so there may be minimal seasonal variation in daytime peaks.	• Do monthly summary graphs show expected seasonal variation? • Are electric and heating (e.g., natural gas, propane) EUIs expected? • Do load profiles exhibit expected seasonal variation, considering base load and daytime peaks?
Facility Age A facility's age may have implications for energy and water performance, but it sometimes less clear what the impact will be. An older library might be expected to use older, less efficient equipment than a new one, but also may have less equipment in the first place. But, if a facility's gas use is found to be higher than normal, and the facility is of older vintage, the facility's envelope might be an area for further investigation. Older facilities are also less likely to be controlled by building control systems, so scheduling and setbacks may not be implemented.	• Do monthly summary graphs show expected levels of seasonal variation? • Do load profiles or heat maps indicate significant nighttime loads?

Supporting Data Type	Key Questions Addressed
Weather Closely tied to location, weather offers a more detailed data source. Whereas a facility's climate region can generally inform EUI values and load profiles at a very high level, weather data provides a closer and more direct look at how the facility responds to changes in outdoor conditions. With access to hourly weather data, an evaluator can create dual-axis graphs and scatter plots.	• Does the dual-axis graph show energy use following weather conditions? • From time series data and heat maps, does heating energy increase or decrease at night?
Facility Occupancy A facility's occupancy details can be used at a high level to benchmark a facility's performance, and at a more detailed level to directly identify potential areas for improvement. For example, normalizing energy data by occupancy may indicate the facility uses more energy per occupant than other similar facilities. Upon closer inspection using heat maps, it may be found that the facility's heating energy intensity is highest at night, when the facility is unoccupied.	• What is the facility's annual energy/water use per occupant, and how does this compare to other similar facilities? • Do heat maps, load profiles and time series data indicate energy usage patterns that follow occupancy schedules?
Facility Operations Sometimes a facility may have unique operating characteristics that can inform the metered data analysis. For example, an office facility might contain a large control set of server racks, resulting in a notably higher base load than typical. Or a restaurant may leave its exterior doors open to enhance its ambience, resulting increased space conditioning and a higher EUI than expected.	• Are any observations of metered data explainable by a unique operating characteristic of the facility?

Other Supporting Data Sources
Facility System Inventories When available, details for the equipment that serves a facility, such as plumbing fixtures, lighting technologies, and HVAC equipment schedules, can help an evaluator to develop more precise expectations of facility energy and water performance. As-built floorplans, existing equipment inventories and discussion with facility staff are typical sources for this information.
Utility Bills and Rate Schedules Because utility bills are considered the authoritative source for energy/water consumption, they can be used to verify interval metered data. In addition, interval metered data can be considered through the lens of a particular rate schedule. For example, if the facility is billed for electricity according to on peak and off peak periods, interval metered data can be used to assign the distribution of the facility’s electricity use into each period. And if the site is billed at a particularly high demand rate, interval data can be used to determine when the peak demand is occurring.

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