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Facility Metering for Improved Operations, Maintenance, and Efficiency

Metering and sub-metering of energy and resource use is a critical component of a comprehensive operations and maintenance (O&M) program. Metering for O&M and energy efficiency refers to the measurement of quantities of a utility delivered (e.g., kilowatt-hours of electricity, cubic feet of natural gas, pounds of steam, gallons of water). Metering may also involve identifying times-of-use for the various energy sources, the instantaneous demand for energy, as well as identify energy use for a collection of buildings, individual buildings, rooms, or specific equipment (e.g., a boiler, chiller, or motor).

Facility metering has a variety of applications for the federal energy/O&M manager. The necessity to control costs, diagnose equipment malfunction, allocate usage, and set resource efficiency goals are all increasingly important reasons for energy and water

metering. Furthermore, with the escalating volatility of energy and water rates, these needs are becoming more important.

Historically, the federal sector has lagged the private sector in metering applications. To this day at federal sites, it is common to find one “master” meter serving loads representing a few buildings to well in excess of 500 buildings. These master-metered accounts make it very difficult to manage energy use and are the primary drivers for proposed legislation requiring at least building-level metering for the majority of federal-sector buildings.

Federal institutions should not wait for proposed legislation or executive directives. Metering of energy use in many federal buildings is smart business and, done properly, will prove to be a good investment.

The Energy Policy Act of 2003, H.R. 6, *Energy Use Measurement and Accountability* (proposed as of this writing) directs:

- The Department of Energy, within 6 months of passage, to draft federal metering policy.
- All federal agencies, within 6 months of federal policy, to submit comprehensive metering plans.
- By October 1, 2010, 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 or sub-metered in accordance with guidelines established by the Secretary [of Energy] under paragraph (2). Each agency shall use, to the maximum extent practicable, *advanced meters* or advanced metering devices that provide data at least daily and that measure at least hourly consumption of electricity in the federal buildings of the agency. Such data shall be incorporated into existing federal energy tracking systems and made available to Federal facility energy managers.



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Importance of Metering

Metering provides the information that when analyzed allows the building operations staff to make informed decisions on how to best operate mechanical/electrical systems and equipment. These decisions will ultimately affect energy costs, equipment costs, and overall building performance. Reasons for metering vary by site; listed below are some rationale to consider for sub-metering at your site:

- monitor existing utility usage
- verify utility bills
- identify the best utility rate tariff
- measure, verify, and optimize equipment performance
- isolate utility/reimbursable use and costs
- measure, not estimate, tenant energy use
- diagnose equipment and systems operations
- manage utility use
- benchmark utility use.



Typical utility socket-type meter.

Metering Applications

The uses for metered data vary from site-to-site and while not all sites have the same uses, some of the more common applications are presented below (Sydlowski 1993).

- **Data Recording.** Advanced meters can duplicate the conventional metering function of recording total utility consumption, plus offer enhanced functions such as time-of-use, peak demand, load survey, and power outage recording. For electric metering, advanced meters may also include recording of other electric characteristics, such as voltage, current, and power factor.
- **Total Consumption.** This is the most basic data recording function, which duplicates the standard kilowatt-hour of electricity (kWh), hundred cubic feet volume (CCF) of gas, or gallons (gal) of water consumed between meter readings.
- **Time-of-Use Metering.** Different rates can be charged for on-peak and off-peak time periods by accumulating the total consumption during operator-defined time windows. The time windows may vary during both time of day and weekday/weekend/holiday.
- **Peak Demand Metering.** Billing of many larger commercial and industrial customers is based on total consumption and the highest 15-, 30-, or 60-minute demand during the billing period. The peak demand may be reported as a single highest value, highest four values, or highest value during each hour (all peak demand values must be accompanied by an associated time stamp).
- **Load Survey (Profile or Time-Series Data).** Energy consumption and conservation impact studies, as well as more complex analysis of system loading, require more detailed demand data. A load survey provides periodic consumption or demand data (in time increments of 1, 5, 15, 30, or 60 minutes).
- **Monitoring and Control.** A two-way communication link between a central station and customer site provides the opportunity for integrating some other utility functions into the metering functions. Meters can be programmed to detect and report by exception (for example, report only when a fault is detected) for power outage, leak detection, and tamper detection. The meter can also dispatch control functions, such as remote service disconnect/reconnect, demand-side management (DSM) load control, and load scheduling.

The importance of metering can be summed up in the energy manager's maxim:

**If you don't collect it...
you can't measure it.**

**If you don't measure it...
you can't manage it.**

- **Load Control.** Load control includes DSM control functions such as air conditioner and water heater load-shedding. The DSM load control could be triggered by a fixed algorithm operating independently or real-time central station control.
- **Load Scheduling.** This includes scheduled start and stop of equipment to minimize or shift load to take maximum advantage of the demand and time-of-use billing rate structures.
- **Leak Detection.** Continuous monitoring of gas or water usage or pressure can be used to detect leaks.
- **Benchmarking.** Metering affords the ability to benchmark energy use for better comparisons, progress tracking, and opportunity identification.

Metering Approaches

The four predominant levels of resource metering (EPRI 1996) are:

- One-Time/Spot Measurements
- Run-Time Measurements
- Short-Term Measurements/Monitoring
- Long-Term Measurements/Monitoring.

Each level has its own unique characteristics—no one monitoring approach is useful for all projects. A short description of each monitoring level is provided below.

One-Time/Spot Measurements

One-time/spot measurements are useful in many “baseline” activities to understand instantaneous energy use, equipment performance, or loading. These measurements become particularly useful in trending equipment performance over time. For example, a spot measurement of a boiler-stack exhaust temperature, trended over time, can be very diagnostic of boiler efficiency.

Related to energy performance, one-time/spot measurements are useful when an energy-efficiency project has resulted in a finite change in system performance. The amperage/wattage of an electric motor or lighting system taken before and after a retrofit can be useful to quantify system savings—assuming similar usage (hours of operation) before and after.

Equipment useful in making one-time/spot measurements include clamp-on amp probes, contact and non-contact temperature devices, non-intrusive flow measurement devices, and a variety of combustion-efficiency devices. Most of these measurements are obtained and recorded in the field by the analyst.

One-Time/Spot Measurements Advantages

- **Lowest cost**
- **Ease of use**
- **Non-intrusive**
- **Fast results**

One-Time/Spot Measurements Disadvantages

- **Low accuracy**
- **Limited application**
- **Measures single operating parameter**
- **Measurement at a single point in time**

Run-Time Measurements

Run-time measurements are made in situations where hours-of-operation are the critical variable. These measurements are prevalent where an energy efficiency project has impacted the use (e.g., hours of operation) of a device. Appropriate applications for run-time measurements include the run times of fans and pumps, or the operational characteristics of heating, cooling, or lighting systems.

Because run-time measurements do not capture the energy-use component of the system, these measurements are typically used in conjunction with one-time/spot measurements. Equipment useful in making run-time measurements include a variety of stand-alone (battery-operated) data loggers providing time-series record on run-time. Most of these devices are non-intrusive (i.e., the process or system is not impacted by their use or set-up) and are either optically triggered or take advantage of the electromagnetic characteristics of electrical devices. Run-time measurements are usually obtained in the field by the device, recorded to memory, and then downloaded into a computer at a later date.

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Run-Time Measurements Advantages

- **Low cost**
- **Relatively easy of use**
- **Non-intrusive**
- **Useful for constant-load devices**

Run-Time Measurements Disadvantages

- **Limited application**
- **Measures single operating parameter**
- **Requires additional calculations/assumptions**
- **Requires recovery and/or manual data download**

Short-Term Measurements/Monitoring

Short-term monitoring combines both elements of the previous two levels into a time-series record of energy or resource use: magnitude and duration. Typically, short-term monitoring is used to verify performance, initiate trending, or validate utility efficiency improvement. In this level, the term of the monitoring is usually less than one year, and in most cases on the order of weeks to months. In the case of utility efficiency improvement validation, also known as measurement and verification, these measurements may be made for two-weeks prior and post installation of an efficiency improvement project. These data are then, using engineering and statistical methods, extrapolated over the year to report the annual impact.

Equipment useful in short-term monitoring includes a host of portable, stand-alone data loggers capable of multivariate time-series data collection and storage.

Short-Term Measurements/Monitoring Advantages

- **Mid-level cost**
- **Can quantify magnitude and duration**
- **Relatively fast results**
- **Data can be recovered remotely over data lines**

Short-Term Measurements/Monitoring Disadvantages

- **Mid-level accuracy**
- **Limited application**
- **Seasonal or occupancy variance deficient**
- **More difficult to install/monitor**

Most of these data loggers accept a host of sensors including temperature, pressure, voltage, current flow, etc., and have standardized on input communications (e.g., 4 to 20 milliamperes or 0 to 5 volts). These loggers are capable of recording at user-selected intervals from fractions of a second to hourly to daily recordings. These systems usually rely on in-field manual downloading or, if available, modem and/or network connections.

Long-Term Measurements/Monitoring

Long-term monitoring also makes use of time-series recording of energy or resource use, but over a longer duration. Different from short-term use, this level focuses on measurements used in long-term trending or performance verification. The term is typically more than a year and quite often the installation is permanent.

Useful applications for this level of monitoring include situations where system use is influenced by variances in weather, occupant behavior, or other operating conditions. Other applications include reimbursable resource allocation, tenant billing activities, or in cases where the persistence of energy or resource savings over time is at issue.

Equipment useful in long-term monitoring included a variety of data loggers, utility-grade meters, or fixed data acquisition systems. In most cases, these systems communicate via a network connection/phone modem to a host computer and/or over the Internet.

Long-Term Measurements/Monitoring Advantages

- **Highest accuracy**
- **Can quantify magnitude and duration**
- **Captures most variance**
- **Data can be recovered remotely over data lines**

Long-Term Measurements/Monitoring Disadvantages

- **High cost**
- **Most difficult to install/monitor**
- **Time duration for result availability**

Metering System Components

There are four necessary components to a viable building-level metering system: the meters, the data collection system, the data storage/retrieval system, and the analysis system/capability (AEC 2003; EPRI 1996). Each component is described below.

Meters

At the most basic level, all meters track and provide some output related to resource use (e.g., energy, water, natural gas). Beyond this basic level, more sophisticated meters take advantage of additional capabilities, including electrical demand tracking, power quality measurements, and multiple-meter communication for leak detection applications.

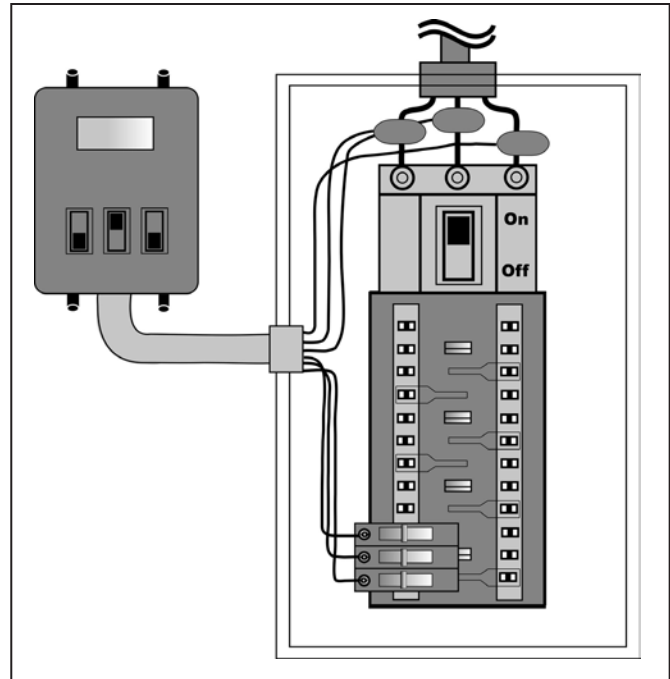
For electrical systems, meters can be installed to track whole-building energy use (e.g., utility meters), sub-panel energy use (e.g., a lighting or process circuit), or a specific end use (e.g., a motor or chiller). These meters usually involve current transformers (CTs), potential transformers (PTs) and some form of logic to calculate demand and power use. An increasingly useful electrical meter type is known generically as the *interval meter*. These meters measure electrical energy use and demand (kilowatts–kW) over a predetermined interval—commonly every 15 minutes to match typical utility billing intervals. Other intervals (e.g., 1 minute, 5 minutes) can be useful for examining equipment performance, trending, and start/stop characteristics.

New electrical metering should utilize digital metering technologies; retrofit applications should consider analog to digital conversion technologies. In either case, the technology should have at least hourly-interval-resolution capability.

For water, natural gas, steam, and other flow-related applications, meters are typically in-line installations using positive displacement, insertion turbine, or pressure-related techniques. Depending on the need, any of these meters will vary in size, type, output configuration, accuracy, and price.

Water, steam, and natural gas metering should also use digital technology where possible and have at least hourly-interval-resolution capability.

To better understand portable meters or data loggers and their vendors, the report *Portable Data Loggers*



Typical electrical sub-meters (box on left) used in long-term monitoring.

Diagnostic Tools for Energy-Efficient Building Operations (PECI 1999) is particularly good. A list of vendors of larger, dedicated, whole-building meters can be found in *Advanced Utility Metering* (AEC 2003).

Data Collection

Modern metering data collection systems take advantage of recent developments in communications technologies. Over the past 15 years, automated meter reading (AMR) systems have increased in sophistication and reliability, and now represent a very economic means of data collection. Available technologies include the use of radio frequency, phone modem (including wireless/cellular), local area networks, and Internet solutions.

Data Storage

The need for, and the duration of, data storage should be carefully considered in the design and implementation of a metering system. A clear understanding of data needs and applications will drive storage decisions. At the most basic level, metered data is easily stored in one of many available database systems. The duration of data storage is a function of data use; long-term end-use studies require longer-duration storage, short-term daily comparisons require less. There are a variety of

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Metering Strategies

There are four predominant metering strategies to consider, each with its own level of data activity and estimated savings (Lewis 2003).

1. Install meters only with software for collecting data

Action:

- Storing energy data from individual buildings

Use of Meters/Data:

- Storing of information

Typical Savings: Installation of meters: 0%

2. Install meters with data collecting and cost allocation software

Action:

- Accountability for meeting conservation goals
- Cost allocation to departments and outside vendors/reimbursable

Use of Meters/Data:

- Monthly reports for all departments
- Monthly bills to outside vendors/reimbursables

Typical Savings: Installation of meters and bill allocation: 2% to 5%

3. Install meters with data collecting and cost allocation software, and conduct operational analysis and building tune-up

Action:

- Accountability for meeting conservation goals
- Cost allocation to departments and outside vendors
- Identification of inefficient operations
- Fine-tuning of building controls

Use of Meters/Data:

- Monthly reports for all departments
- Monthly bills to outside vendors
- Internal review and adjustment of building operations (time schedules, etc.)

Typical Savings: Installation of meters, bill allocation, and tune up: 5% to 15%

4. Install meters with data collecting and cost allocation software, and conduct continual operational analysis and building commissioning

Action:

- Accountability for meeting conservation goals and verifying savings from energy conservation measures (ECMs)
- Cost allocation to departments and outside vendors
- Continual commissioning(tm) of energy-using systems
- Outside review of energy savings goals with staff

Use of Meters/Data:

- Monthly reports for all departments
- Monthly bills to outside vendors
- Action plan and fine-tuning for high energy users
- Review with building staff and outside consultants to verify energy savings of ECMs

Typical Savings: Installation of meters, bill allocation, and persistent commissioning: 15% to 45%

application service providers (ASPs) that can provide data storage and retrieval services on a fee-based structure.

Data Analysis

Large-scale analysis of energy data can be time-consuming and expensive. In many cases, the manufacturers of metering equipment also provide off-the-shelf or custom software applications to assist these functions. In addition to the meter manufacturers, third-party software vendors, including some ASPs, can provide data capture, collection/storage, and analysis services. Analytical services can range from simple use-reporting and tenant billing, to more sophisticated activities of energy use diagnostics, system performance indicators, and leak detection.

Metering Economics

The economic value of metering is directly proportional to the use of the resulting data. The range of potential resource savings related to metering vary with the building, equipment, and the use of the metered data. Economic savings attributed to metering can be as high as 20%; the higher savings percentages requiring a very proactive use of the metered data. (See Metering Strategies on previous page.)

Metering system installed costs will vary with system, existing infrastructure, meter type, communication needs, number purchased, etc. On average, long-term whole-building type meter installed cost runs between \$1,000 to \$10,000 per point or meter. An average per-meter-installed cost may be in the range of \$3,000 to \$5,000.

As federal agencies move toward increased metering, decisions need to be made on the optimal level of metering. In the extreme case, one would have difficulty justifying a meter installation on a small, seldom used, remote storage building. On the other hand, a large, continuously occupied administrative building would make a better case. At issue is where to draw the line. That is, metering should be implemented on a declining marginal utility basis. Below some set of criteria (e.g., cost of energy, building energy use, application of metered data) the economic case for metering becomes marginal.

The methodology below presents one approach to this decision. This calculation provides, given certain assumptions, the annual energy bill necessary to justify a building-level metering installation. Note that the values presented here were chosen for their ease of use and scalability to other more realistic circumstances.

Metering Justification Example

Assumptions:

1. Building-level electrical meter data analysis will save 2 percent of current annual electricity consumption.
2. Metering system installed costs is \$5,000 per meter.
3. Desired simple payback: 10 years or less.
4. Monthly cost per meter of \$25¹ including metering operations, maintenance, and data collection, storage, and analysis.

Formula and sample calculation:

$$\frac{\left[\left(\frac{\text{Installed Cost}}{\text{Desired Simple Payback}} \right) + \text{Annual Cost} \right]}{\% \text{ Annual Savings}} = \text{Minimum Annual Electric Bill}$$
$$= [(\$5,000) \div (10 \text{ years}) + (\$25 \text{ per month}) \times (12 \text{ months per year}) \div (0.02)] = \$40,000$$

Results:

Given the above parameters, it is economic to meter any building that has an annual estimated bill over \$40,000 to achieve a 10-year simple payback. The threshold for annual building electrical costs to justify cost-effective metering applications will vary by site based on metering costs and anticipated energy savings.

Factors Affecting Metering Costs

There are many factors affecting the cost for metering equipment. These factors include functionality, communications method, metering infrastructure, and site conditions. How a meter is purchased may also affect the price. For example, economies of scale may be realized if large purchases are made for a single site or if an agency or sites pool a purchase. Another example would be where meters are installed as a part of a larger project such as to provide measurement and verification as part of an energy savings performance contract.

¹ Monthly operations, maintenance, data collection, storage and analysis costs will vary by installation. For the purposes of this guidance, this monthly fee is estimated to most likely be in the range of \$20 to \$30 per month per meter.

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The annual cost of utilities in unmetered buildings can be estimated using energy-use intensity (EUI) data appropriate for the building type, the Department of Energy's Facility Energy Decision System (FEDS) software (PNNL 2002), or other private-sector computer models.

Steps in Metering Planning

The development of a metering program is highly dependent on a site's needs, existing metering equipment, and available infrastructure. When it comes to metering, one size *does not* fit all. Below are some very general guidelines identifying the steps and actions necessary for a quality metering program. These guidelines summarize information found in AEC (2002), EPRI (1996), and Sydlowski (1993), where more detailed information can be found.

- Formalize objectives and goals of metering program
 - Identify and confirm goals of stakeholders/users
 - Prioritize goals as near-term, mid-term, and long-term
 - Formalize necessary/expected outcomes
- Develop program structure. Identify data needs, equipment needs, analysis methodologies, and responsible staff.
 - Develop data and analysis needs based on necessary outcomes
 - Develop equipment needs based on data needs
 - Take advantage of existing infrastructure
 - Identify responsible staff, preferably a metering “champion”
- Develop criteria for evaluation metering costs, benefits, and impacts to existing systems, infrastructure, and staff.
 - Determine relative economics of proposal
 - Justify with cost/benefit, return on investment, or payback metric

- Develop a prioritized implementation plan targeting manageable successes
 - Screen opportunities based on success potential
 - Start small/manageable—build off success
- Develop a sustainable plan targeting use, updates, calibration, maintenance, and program reinvestment.
 - Maintain your investment
 - Make this success visible
 - Plan for future implementation/reinvestment

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O&M First!—FEMP is pleased to present this series of fact sheets as a way to promote energy efficiency by first applying O&M best practices. It is our hope that the experiences shared will provide federal facility managers with strategies they can apply to their own facilities, as well as introduce the FEMP O&M program to federal site staff.

A copy of the FEMP O&M Best Practices Guide can be downloaded at www.eere.energy.gov/femp/operations_maintenance/om_best_practices_guidebook.cfm. This guide, which covers a full range of facilities O&M topics, provides the rationale for a proactive O&M program; identifies O&M management issues and their importance; explains the various O&M program approaches; introduces maintenance technologies; and explores O&M procedures for the predominant equipment found at most federal sites.



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Energy efficiency and clean, renewable energy will mean a stronger economy, cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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FEMP is committed to providing federal facility staff tools and knowledge to help optimize their O&M programs. Visit the FEMP homepage for information on O&M and other FEMP programs and activities at www.eere.energy.gov/femp.

FEMP also offers the workshop Operations and Maintenance Management. To find out more about this course, visit www.eere.energy.gov/femp/services/training_om.cfm.

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