Chapter 8 Metering for Operations and Maintenance

8.1 Introduction

Metering and sub-metering of energy and resource use is a critical component of a comprehensive O&M program. Metering for O&M and energy/resource efficiency refers to the measurement of quantities of energy delivered, for example, kilowatt-hours of electricity, cubic feet of natural gas, pounds of steam, and 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 resource metering has a variety of applications for the Federal facility energy 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.

Energy Policy Act of 2005, Public Law 109-58, Section 103

By October 1, 2012, in accordance with guidelines established by the Secretary under paragraph (2) 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. 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 managers.

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 driver for the legislation below.

Energy Policy Act 2005 (EPAct 2005): Section 103 of EPAct 2005 requires that "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 … to the maximum extent practicable." This requirement of law is the driving force behind the ongoing efforts of Federal agencies to meter their electric use. The primary metering requirements established in Section 103 of EPAct 2005, Energy Use Management and Accountability,[1] are summarized by these key points:

Figure 8.1.1. Typical utility socket-type meter

- By October 1, 2012, all Federal buildings will be metered for electricity if practicable.
- Installed meters will support the efficient use of energy and reduction in cost of electricity used.
- Advanced metering devices that provide interval data on at least a daily basis will be used subject to practicability.

[1] The metering requirements of EPAct 2005 amended Section 543 of the National Energy Conservation Policy Act (42 U.S.C. 8253).

- Metered data will be used made available to Federal facility managers.
- Requires Federal agencies to submit to the Department of Energy (DOE) an implementation plan identifying personnel responsible for achieving metering requirements, and any determination by the agency that advanced meters or metering systems are not practicable in their specific situation.

Energy Independence and Security Act of 2007 (EISA 2007): Among other requirements EISA 2007 further strengthens the metering requirements of EPAct 2005 with the following language:

- Not later than October 1, 2016, each agency shall provide for equivalent metering of natural gas and steam, in accordance with guidelines established by the Secretary under paragraph (2).

In addition to energy, gas, and steam metering of water is encouraged to obtain data to support the water intensity reduction goals outlined in EISA 2007.

8.2 Importance of Metering and the Business Case

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.

Outside of single-building sites, there is limited building or equipment sub-metering within the Federal sector. Single building sites are metered for total use by their servicing utility providers, while multi-building sites usually rely on a master meter provided by the utilities at the utilities' points of entry to the site. Sites are billed by their utility providers based on the cumulative usage readings obtained from these utility, or revenue, meters over the billing period, usually about one month. But now consider the application of meters to individual buildings and even energy-intensive equipment that provides facility managers and operators real-time information on how much energy has been or is being used. This type of information can be used to assist in optimizing building and equipment operations, in utility procurements, in building energy budget planning and tracking, and so on.

It is important to keep in mind that meters are not an energy efficiency/energy conservation technology per se; instead, meters and their supporting systems are devices that provide building owners and operators data that can be used to:

- Reduce energy/utility use
- Reduce energy/utility costs
- Improve overall building operations
- Improve equipment operations.

How the metered data are used is critical to a successful metering program. Depending on the type of data collected, it can enable the following practices and functions:

- Verification of utility bills
- Comparison of utility rates
- Proper allocation of costs or billing of reimbursable tenants

- Demand response or load shedding when purchasing electricity under time-based rates
- Measurement and verification of energy project performance
- Benchmarking building energy use
- Identifying operational efficiency improvement opportunities and retrofit project opportunities
- Usage reporting and tracking in support of establishing and monitoring utility budgets and costs, and in developing annual agency energy reports.

Ultimately, the business case for metering energy/utility use is based on the anticipated benefits to the site. Most of the metered data uses listed above will result in energy cost savings that can be used to justify the cost to purchase, install, and operate the metering system. The degree of cost savings realized depends on the unit cost of the energy/utility being saved and on the effectiveness with which the site analyzes the data and acts upon its findings/recommendations. But other potential benefits should also be considered as part of the metering business case. Examples can include

- Supporting efforts to attain Energy Star and/or LEED-EB (Leadership in Energy and Environmental Design – Existing Buildings) certifications
- Promoting tenant satisfaction by providing information that tenants find useful in managing their operations
- Prolonging equipment life (and reducing capital investment requirements) and improving its reliability by verifying the efficient operation of equipment
- Assessing the impact of utility price fluctuations prior to or as they happen, allowing sites/agencies to address budget shortfalls on a proactive basis.

8.3 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 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, pounds (lb) of steam, 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 (e.g., 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.
- **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.

8.4 Metering Approaches

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

- One-time/spot measurement
- Run-time measurement
- Short-term monitoring
- Long-term monitoring

Each level has its own unique characteristics – no one monitoring approach is useful for all projects. Only long-term monitoring meets requirements set forth in EPAct 2005. A short description of each monitoring level is provided below.

8.4.1 One-Time/Spot Measurements

One-time 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.

One-time/Spot Measurement Advantages

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

One-time/Spot Measurement Disadvantages

- Low accuracy
- Limited application
- Measures single operating parameter

Related to energy performance, one-time measurements are useful when an energy efficiency project has resulted in a finite change in system performance. The amperage 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.

8.4.2 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 (i.e., 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.

Run-Time Measurement Advantages

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

Run-Time Measurement Disadvantages

- Limited application
- Measures single operating parameter
- Requires additional calculations/assumptions

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 by the analyst at a later date.

8.4.3 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 energy 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 energy 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.

Short-Term Measurement Advantages

- Mid-level cost
- Can quantify magnitude and duration
- Relatively fast results

Short-Term Measurement Disadvantages

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

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

8.4.4 Long-Term Measurements/ Monitoring

Long-Term Measurement Advantages

- Highest accuracy
- Can quantify magnitude and duration
- Captures most variance

Long-Term Measurement Disadvantages

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

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.

8.4.5 The Metering Hierarchy

Given the above described metering approaches, there is a logical order, or hierarchy, to consider as you look to maximize your metering value while minimizing your metering cost. Figure 8.4.1 presents this concept as a function of level of effort and diagnostic capability that applies to electric metering. This proposed hierarchy starts at the most aggregate level of data collection and processing – the *whole-building* meter. Assuming access to interval electric data (these are data collected usually at 15-minute intervals), this meter and resulting data can be diagnostic in identifying trends and variance in whole-building performance. In addition, these data can useful in understanding the operation and efficiency of major building systems (e.g., chillers, boilers, air handlers). While the resolution of whole-building data may not be fine enough to identify specific operational or efficiency issues, it can often be used to "frame the question" of what equipment/system is performing inconsistently and in need of further exploration.

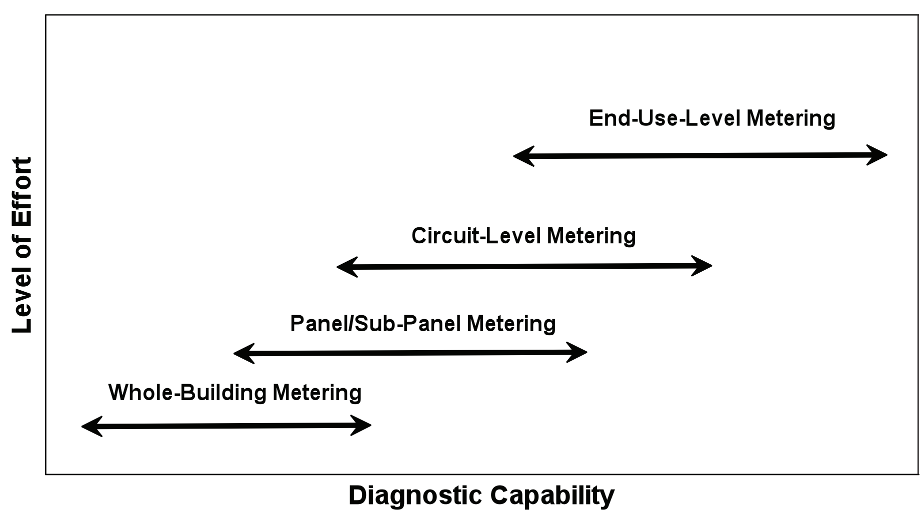


Figure 8.4.1. Electric metering hierarchy

If the whole-building meter represents the most aggregate level, the next finer level is at the *electrical panel/sub-panel*. This second tier in the metering hierarchy focuses on loads connected at a panel (or sub-panel) level as aggregations of specific loads. Examples of panel-level monitoring include lighting panels or motor panels (i.e., motor control centers – MCCs) where hours of operation or efficiency project validation are of interest.

Moving up one more level in the hierarchy, we examine *circuit-level* monitoring. The focus of metering at this level is within the panel or sub-panel and the monitoring of a specific circuit of interest. This circuit may have specific plug loads of interest such as computers or other peripherals, or may be of interest for power quality or harmonics studies.

The final level in the hierarchy, having the finest data resolution, is the end-use level. End-use monitoring serves to isolate a particular system or equipment type for detailed study. In many cases, the objective of end-use monitoring is equipment performance, whether to identify inefficiency or validate savings estimates. Chillers, boilers, cooling towers, pumps and motors are often end-use metered for performance metrics.

While the above hierarchy presents a step-wise approach to metering and efficiency diagnostics, by no means are we suggesting that all hierarchy steps need be followed sequentially when moving from whole-building to end-use metering. In fact, in some cases there should be enough information to move from the whole-building level directly to end-use level when diagnosing or trending efficiency opportunities. In cases where inefficiency by specific equipment is not so apparent, the additional steps may be beneficial to properly identify the poorly operating equipment.

8.5 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.

8.5.1 Meters

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

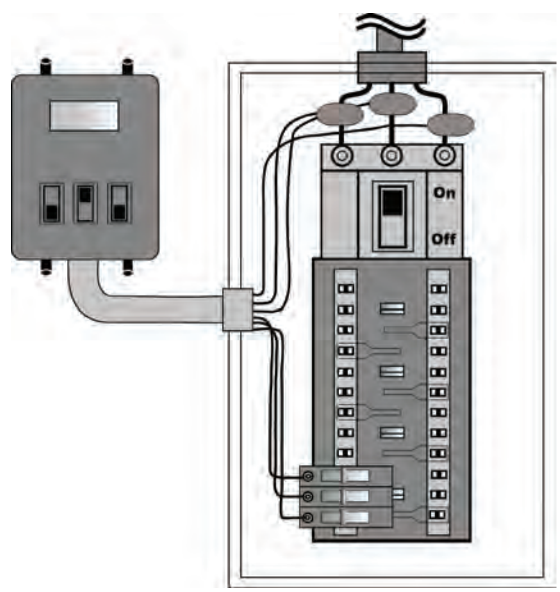


Figure 8.5.1. Typical electrical sub panel (box on left) used in long-term monitoring

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). See Figure 8.5.1 for sub-panel. For water, steam, natural gas, 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. A more complete treatment of utility meters, applications, and evaluation criteria can be found in the FEMP Metering Best Practices Guide (FEMP 2007).

To better understand portable meters or data loggers and their vendors the report titled *Portable Data Loggers 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 the report titled *Advanced Utility Metering* (AEC 2003).

8.5.2 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. When developing the communications portion of your metering program, it is important to consider what existing communications infrastructure you can take advantage of (e.g., building automation system, local area network) to potentially lower the cost of AMR. In addition, if you have a large site with distributed buildings you may find benefit in considering multiple communications technologies (e.g., networks in one area, phone lines in another, and wireless in a third) to gain the necessary communications coverage. Available technologies include:

- *Traditional or cellular phone modem:* Considered a proven technology, generally available and secure. This mode can be expensive and one needs to be connected to access to real-time data
- *Local area networks:* A proven technology with increasing availability and always connected. This mode can have IT security concerns/issues.
- *Building automation systems:* When present provides advantage of accessibility and fast communication. Some systems can have compatibility or data availability issues.
- *Radio frequency/wireless networks:* With no wires to install, this mode has great logistical and cost advantage. Issues do arise with potential for electrical interference and hardware costs.
- *Power line carriers:* Excellent use of existing infrastructure and connect-ability. Overall system cost and data transfer rates need to be researched before implementation.

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

The specific requirements of the data storage/database system should be decided with assistance from site IT staff or others knowledgeable, or those who will be using the system. Below are concepts and specifications based on work done for the California Energy Commission Public Interest Energy Research Program (PIER) and the Building Technologies Program of the U.S. Department of Energy

(CEC 2007). A more complete list of data storage software and hardware considerations can be found in the FEMP Metering Best Practices Guide (FEMP 2007).

- Data shall be stored in a structured query language (SQL)-compliant database format or time series format. Minimum requirements are a SQL server or equivalent.
- The database shall allow other application programs to read and access the data with appropriate password protection while the database is running. The database shall not require shutting down in order to access or have data added.
- Trend data shall be archived in a database from field equipment in time intervals no less than once per day.
- All data shall be stored in database file format for direct use by third-party application programs.
- Sufficient data storage capacity will be able to store at least two years of data for all data points. In addition, storage capacity will also allow for compression of one year of data for historic trends and archiving.
- Time stamps shall be collected on all data. The time stamp, depending on system architecture, will be captured at the field controller or system controller and directed to the database archive.

8.5.4 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 and system performance indicators.

8.6 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.

Metering system installed costs will vary with system, existing infrastructure, and meter type. On average, long-term whole-building type meter installed cost runs between $1,000 to $5,000 per point or meter. This range is so large because some buildings require extensive rewiring and additional activities related to bringing existing systems up to code. Assuming limited requirements and code issues, an average per meter (electric) installed cost is roughly $1,500.

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, below some set of criteria the economic case for metering becomes marginal.

EPAct 2005 requires that Federal buildings be metered for electricity "where practicable." The following formula to cost-justify an electric meter (or other utility meters) was presented in DOE (2006):

$$\frac{\left[\left(\dfrac{\text{Installed Cost}}{\text{Desired Simple Payback}}\right) + \text{Annual Cost}\right]}{\text{\% Annual Savings}} = \text{Minimum Annual Electric Bill}$$

Where:

- *Installed Cost* refers to the total cost to purchase, install, and commission the meter. As previously noted, the cost of a meter application will vary based on a number of factors. Building electric meters are often in the range of $1,000 to $5,000 completely installed. This broad range reflects the uncertainty of system upgrades that may be associated with electrical code compliance issues.
- *Desired Simple Payback* represents the number of years it will take the metering system to produce (lead to) cost savings equal to the installed cost. Most agencies prefer a simple payback period of 10 years or less.
- *Annual Cost* is the total annual cost of the fees and expenses to cover communications, data collection and storage, and data analysis, as well as meter operations and maintenance. The annual cost will vary based on several factors and is typically in the range of $120/year ($10/month) to $600/year ($50/month).
- *% Annual Savings* is the estimated cost savings benefits to be realized from the productive use of the metered data. Federal sites are advised to use a minimum of 2 percent annual savings when considering meters for EPAct 2005 compliance.

Using the above formula also requires that there be a reasonable way to estimate the current annual electricity (utility) costs for the building being considered. Except in cases where the buildings already have standard meters, actual usage data to estimate the annual costs will not be available. In these cases, one of the following accepted methods of estimating building energy use should be applied (FEMP 2007):

- Square footage
- Energy-use intensity
- Calibrated software
- Short-term metering

To demonstrate how the metering cost justification formula is used, the following values will be used:

- Installed cost = $5,000
- Desired simple payback = 10 years
- Annual cost = $25/month = $300/year
- % annual savings = 2 percent

Sample calculation: **(NOTE: The values in this sample are for demonstration purposes only. Sites considering metering applications should use values specific to their site.)**

$$\frac{\left[\left(\frac{\text{Installed Cost}}{\text{Desired Simple Payback}}\right) + \text{Annual Cost}\right]}{\text{\% Annual Savings}} = \text{Minimum Annual Electric Bill}$$

= [($5,000) ÷ (10 years) + $300/year] ÷ (0.02)

= $40,000 minimum annual electric bill

In this *example*, an electric meter application will be cost-justified if the building's annual electricity use is more than $40,000.

As previously mentioned, the results from this equation are sensitive to the input variables.

8.7 Metering Financing Options

There are a number of potential financing alternatives available to Federal sites. Factors affecting the financing alternatives available include estimated system cost, agency policies, and utility company support offerings, to name a few. In some cases, sites will be able to finance their metering systems through a combination of approaches, while in other cases they may be limited to single options.

8.7.1 Metering Financing Hierarchy

As a way for sites to begin their initial considerations of financing alternatives, the metering financing hierarchy has been developed (Figure 8.7.1). This hierarchy is based on life-cycle costs to the site's facility, utility, or energy management program as many consider life-cycle costs to be the most significant factor in selecting their financing approach. Additional hierarchies may be developed based on factors such as speed of implementation or lowest first/up-front cost. Note that a lowest first cost approach may allow for faster implementation or a metering program with expanded capabilities.

The Metering Financing Hierarchy

"No-Cost" Options:

Policy-directed approaches

- Include in construction and renovation projects
- Assess tenant fees
- Reinvest energy savings

Utility provided (for time-based rates customers)

Appropriations Options:

- Line item appropriations
- Locally managed appropriations

Alternative Financing:

- Utility company financing
- Energy savings performance contracts (ESPCs)

Figure 8.7.1. The metering financing hierarchy

The approaches addressed at the top of the hierarchy are the so-called "no cost" options. This is not to imply that the meters are free: instead, the costs to purchase and install the meters are covered in part or in total by programs other than the site facilities, utilities, or energy program.

The appropriations approaches are next in this hierarchy's order. While the costs for the metering system are now being incurred by the site or agency facilities programs, agency appropriations are a familiar approach where the total costs of the meters are paid at the time of purchase and installation.

Alternatively financed approaches appear at the bottom of this hierarchy since the overall life-cycle costs are higher than the appropriations approaches due to added financing charges. This is not to imply that these approaches are any less likely to succeed than the other options. Site metering opportunities at some sites may benefit from alternative financing as a way expand the metering system or add capabilities beyond the EPAct 2005 requirements.

Specific to alternatively financed approaches and as described in the document titled: *Approaches for the Application of Advanced Meters and Metering Systems at Federal Facilities through Alternatively Financed Contracts* (LBNL 2005), there are at least five potential approaches to using alternatively financed projects to achieve the benefits of advanced meters and metering systems. Each of these approaches is briefly described below with more detail provided in the above mentioned report:

1. **Install as part of other energy conservation measures (ECMs) or the M&V effort of the project** – the meters installed as part of other ECMs (such as peak load management) or the M&V plan of an ESPC or the performance assurance plan of a UESC (either as required for M&V or augmented by additional facility funds) can be used to achieve the benefits of advanced metering.

2. **Install using project savings** – a portion of savings from other ECMs can be used to install and use advanced metering. This approach has been used in a relatively large, complex facility with significant potential for additional supply side savings opportunities.

3. **Install as ECM with stipulated savings** – This approach has also been used in a relatively large facility with significant potential for follow-on savings.

4. **Install as an ECM with stipulated initial savings and follow-on share of savings** – This approach is an extension of approach 3 with the application of the Award Fee Plan incentive concept, which allows a sharing of subsequent savings from actions taken on opportunities identified by the metering system.

5. **Install in support of retro-commissioning ECM** – the cost-effective use of retro-commissioning of relatively large and complex buildings has been repeatedly demonstrated by Texas A&M University.

Advanced metering technologies are unique energy conservation measures because their primary benefit is to help identify energy saving opportunities. The problem is resulting energy savings are often difficult to quantify prior to installation and use. Thus, installation through alternative financing for several of the identified approaches does rely on stipulating savings, which is contrary to FEMP M&V guidance.

Critical to the success of advanced metering technologies is the availability of staff that are motivated and trained to use the data. This includes the ability to gather, analyze, direct, and implement changes that work to optimize performance and energy efficiency. *Remember, metering by itself does not save energy; instead, metering should be viewed as a technology that enables optimized performance and energy efficiency*. The strategies summarized all require dedicated staff capable of affecting changes as a result of the analysis of metered data. These staff can be in-house, with an energy services company, or even a Resource Efficiency Manager.[2]

[2] See **http://www.energy.wsu.edu/projects/rem/** for information on Resource Efficiency Managers.

8.8 Steps in Meter Planning

The development of a metering plan is highly dependent on a site's needs, its mission, 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 FEMP (2006), AEC (2002), EPRI (1996), and Sydlowski (1993) where more detailed information can be found.

Whichever approach a site uses in its planning effort, there are key elements that should be addressed for all utility metering programs (FEMP 2006):

- Establish program goals and objectives
- Identify needs to support selected analysis approaches
- Develop and apply evaluation criteria
- Implementation, design, and installation
- Performance validation and persistence

Figure 8.8.1 provides a more detailed overview of the planning process.

8.8.1 Establish Program Goals and Objectives

The critical first step for all metering programs is to establish the site's overall metering objective. While the ultimate goal of the metering program is to reduce utility use and/or costs, how this is done will depend on how the metered data are used. Some of the more typical uses include cost allocation among tenants, bill verification, demand management, and energy use diagnostics. Examples of possible objectives might be:

- To fully enable energy bill allocation throughout an entire facility.
- To effectively manage electric loads to minimize costs under a time-based rate schedule.
- To identify system-specific operational efficiency opportunities.

8.8.2 Identify Needs to Support Selected Analysis Approaches

The information obtained in this step is used to ensure that the necessary data are obtained and its analysis is supported. Inclusive is the survey of any existing metering components that are operational and in use as they may support the new program's goals and objectives.

- *Data needs serves as the starting point for this portion of the plan's development*. What specific types of data are needed to support the program's goals and objectives. For example, allocation electricity costs based on actual use will require (at a minimum) kWh and kW data at the building level or for portions of the buildings occupied by different tenants.
- *Analysis methodologies are a critical component of a site's metering program*. Data by itself is not of much use without some analysis to determine what it means.

- *Equipment needs are based on the data requirements and the analysis methodologies identified*, and should identify what types of metering/monitoring equipment and hardware/software tools would be most appropriate to provide that data and its communication and storage.
- *Survey existing metering systems*. Many multiple building sites have some level of building metering or sub-metering in place.
- *Staffing resources* needed to operate the metering system when in place are also critical to a successful metering program.

Some Questions to Consider in Developing Your Objectives

- What are the annual utility costs for your facility?
- Who are the primary energy users and why?
- What operations actions can help reduce utility costs?
- Where is the poorly designed or operating equipment?
- What equipment should be replaced and when?
- Do like buildings use similar amounts of energy?
- Do buildings have similar operating schedules?
- Do buildings have unique operating requirements?
- By building, how much energy do you use daily? Weekly? Monthly?
- Are your energy savings strategies/projects producing results?
- What utility rate opportunities can you take advantages of?
- Are there regional or national/agency initiatives to address specific utility usage issues (e.g., water management)
- Has utility price volatility been, or could it be, an issue at your site?

- *Security requirements vary widely across the Federal sector*. In general, information technology (IT) staff should be asked to participate in the development of the metering program planning efforts at the very beginning of the process.

8.8.3 Develop and Apply Evaluation Criteria

Meters should be applied where they will lead to a cost-effective reduction in utility use and/or costs. Determining which buildings can be metered cost-effectively requires that criteria be established and applied that take into account the life-cycle costs to meter and the benefits to be realized. The primary variables that impact the cost-effectiveness of meters are:

- The annual utility cost of the building being metered
- The cost to purchase and install the meter and associated hardware
- Expected savings resulting from the productive use of data, typically in the range of 2 percent to 10 percent, but sometimes higher depending on how the metered data are used
- Site economic criteria – usually payback period.

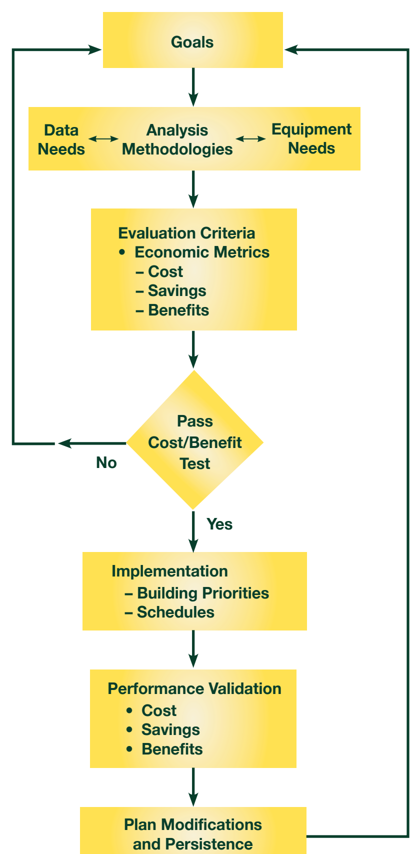


Figure 8.8.1. Development process for meter system planning

8.8.4 Implementation, Design, and Installation

The planning process up to this point has been largely analytical. Based on the goals, objectives, analysis needs, and application of evaluation criteria, there is now enough information to design the actual metering system. Elements of the implementation, design, and installation steps include the following sub-elements discussed below:

- System financing, or how much funds are available and how will these funds be obtained, needs to be addressed early in the design process and revisited once cost estimates based on actual designs are completed.
- Prioritization of buildings and/or utilities to be metered. There may be a need or a greater benefit to metering some buildings and/or some utilities before others.
- The design of the metering system hardware application needs to:
  - Satisfy functional requirements
  - Define a system architecture
  - Develop equipment specifications
  - Review and refine the cost estimate to purchase and install the metering system.

8.8.5 Performance Validation and Persistence

Once the metering system is up and running, the overall program focus shifts to making sure:

- Accurate data are obtained and put to timely productive use
- The metering system continues to operate effectively and reliably.

8.9 Case Study – General Services Administration's Kastenmeier Federal Courthouse

In 2005, the operations staff at the Kastenmeier Federal Courthouse in Madison, Wisconsin, agreed to serve as a pilot site for the demonstration of the newly developed web-enabled Whole-Building Energy Diagnostician (WBE). The WBE was originally developed by the Pacific Northwest National Laboratory (PNNL) with funding from the Department of Energy's Building Technologies Program. In an effort to make the tool more affordable and more widely available to the Federal sector, DOE's Federal Energy Management Program (FEMP) funded the development of a web-enabled version of the WBE. The WBE module installed at the Kastenmeier Federal Courthouse was a commercialized version of the tool.

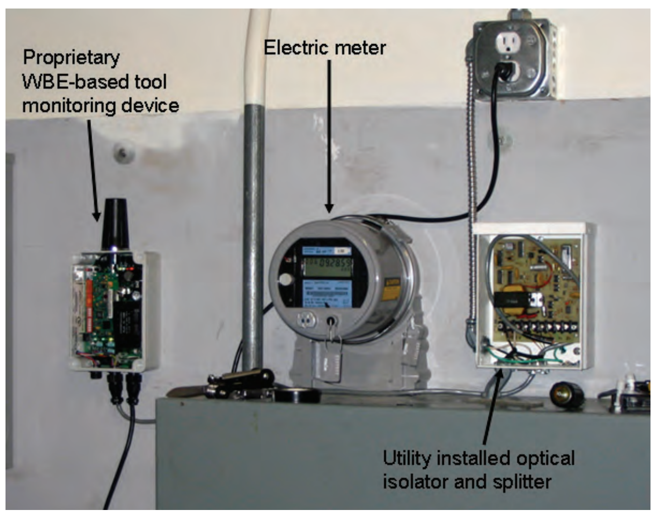


Figure 8.9.1. Installed wireless monitoring system for WBE-based system

Photo courtesy of NorthWrite, Inc., Minneapolis, MN.

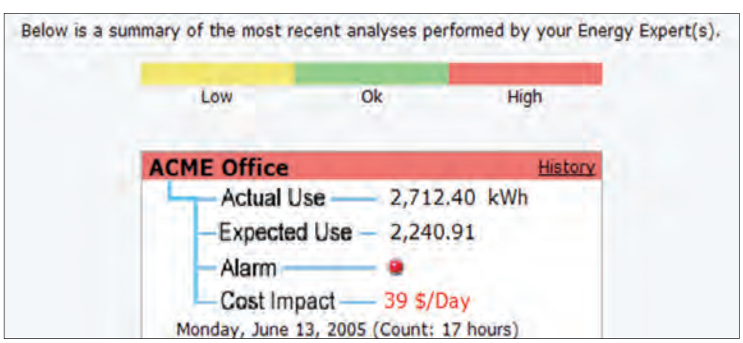
The WBE module tracks energy uses at the building level – in this case, the total electric and natural gas use. The values of expected energy consumption are generated by empirical models of the building, which are automatically developed by the WBE. In general, the model uses time of week, outdoor air dry-bulb temperature, and relative humidity as independent variables. The WBE then graphically provides building operators alarms for unexpected usage to identify major changes in energy consumption (PNNL 2005).

As part of the demonstration project, NorthWrite, Inc., partnered with FEMP to make the web-enabled WBE module available to the Madison Courthouse as part of an overall suite of operations and management tools. The Madison Courthouse is a 100,000-square-foot building in Madison, Wisconsin. The building spaces include court rooms, chambers for the judges, jury rooms, holding cells, and offices for the Clerk of Courts, Bankruptcy Courts and U.S. marshals. Daily building occupancy includes approximately 120 full-time employees plus daily visitors.

The one-year demonstration started in May 2005 with the installation of the electric pulse meter and a monitor device, which reads pulse outputs from the meter and sends them wirelessly to a network operations center, needed to support the web-enabled WBE (Figure 8.9.1). A gas pulse meter was installed in July 2005. Summary of costs to purchase, install, and operate the metering system at the Kastenmeier Federal Courthouse is as follows:

- $1,000 to purchase and install the electric and gas meters (approximately $500 each)
- $3,500 to install the proprietary WBE-based tool hardware
- $2,500 to train agency staff on the use of the commercial web-based suite of tools (which included the WBE-based tool as well as additional site maintenance management functionality)
- $100 per month for the monitor service
- $250 per month to subscribe to the WBE-based tool and commercial maintenance management services suite of tools.

The reports and graphics generated by the WBE module are reviewed daily by the building mechanic as part of the morning startup, with an emphasis on verifying that peak usages do not vary unexpectedly (Figures 8.9.2 and 8.9.3). These daily reviews of the data have been helpful in diagnosing:



Screenshots courtesy of NorthWrite, Inc., Minneapolis, MN.

Figure 8.9.2. Sample screen capture for a generic building showing an alarm or high-energy using condition. Included is an estimated cost impact associated with the higher than expected electricity use.

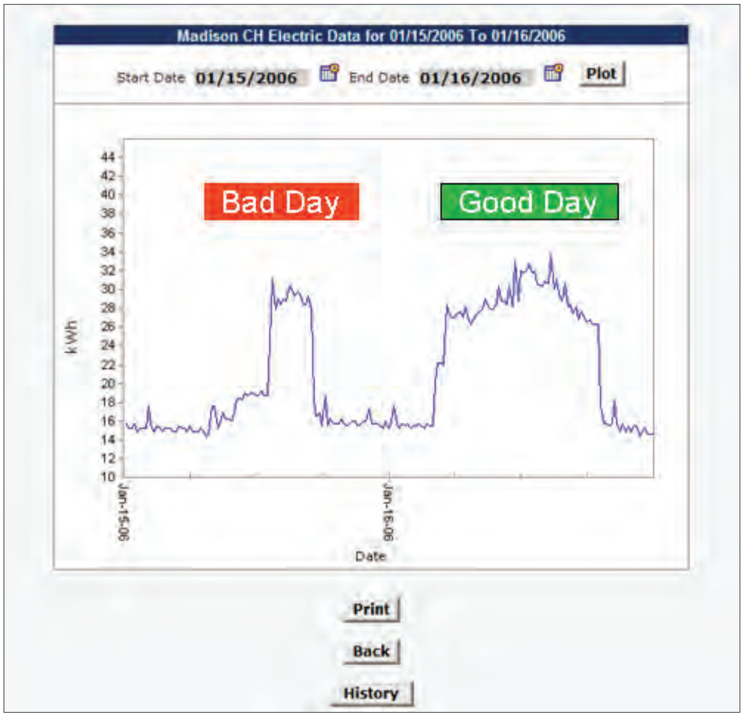


Figure 8.9.3. Data from the monitoring device provides a comparison of 2 days of electricity use for Sunday, January 15, 2006, and Monday, January 16, 2006. Figure shows unexpected off-hour usage on the 15th, while electricity consumption on the 16th was as expected.

- Incomplete reprogramming of schedules on the building automation system (BAS) following a time change
- Improper boiler sequencing operations
- An air-handler operating 24/7 instead of on the schedule as programmed by the BAS
- Belt slippage due to wear on a large horsepower motor
- Refrigerant leaks in rooftop compressors.

The WBE module also lets the General Services Administration (GSA) staff observe the effects of variable-speed drives and direct-expansion cooling operations, including occasional spikes in electrical consumption, and verify that energy-intensive IT downloads are completed during off-hours.

Since this is a web-based system, the GSA regional energy office in Chicago is able to access and review the system data. This second set of eyes works to alert the Madison staff of other possible emerging trends.

Lessons Learned:

- Metered data were instrumental in identifying high or abnormal energy use, and assisted in diagnosing inefficient equipment and systems operations at the Kastenmeier Federal Courthouse.
- The ability to view data at multiple, including remote, locations allowed for expanded assessment capabilities.
- Metering natural gas consumption, while not required by EPAct 2005, proved beneficial. Metering natural gas consumption is now required by EISA 2007.

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