Subcontractor Report

Advanced Utility Metering

Period of Performance:
April 23, 2002—September 22, 2002

Architectural Energy Corporation
Boulder, Colorado

NREL

National Renewable Energy Laboratory

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NOTICE

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Executive Summary

In support of federal agencies considering the approach to utility metering appropriate for their facilities, the U.S. Department of Energy Federal Energy Management Program offers this publication as an overview of options in metering technology, system architecture, implementation, and relative costs. It provides advanced metering systems information to help potential users specify, acquire, use, and expand systems. It addresses basic security issues and provides case studies and information resources.

The following are some effective uses for metering:

- **Revenue billing** (the way utilities are paid), also useful for managing costs and energy-use metrics

- **Time-of-use metering** and real-time pricing, which allow for smart management of peak load use and demand cost savings

- **Load aggregation** for streamlined service acquisition and lower rates

- **Submetering** for analyzing the distribution of loads and equitably billing tenants

- **Energy use diagnostics** to spot problems and improve operations

- Detection and documentation of **power quality**

- Real-time feedback allowing response to **curtailment** and power-related **emergencies**

- Collecting, reducing, and presenting information for **planning** and **reporting** requirements.

Each agency is likely to have several guiding priorities that will serve in the decision to invest in a metering system. To address the wide range of metering needs and uses across the federal government, this publication emphasizes an approach based on setting clear objectives and continuously extracting maximum value from the meter information. The approach has four key elements:

- Identify the metering needs

- Identify the uses for metering

- Clarify the metering maintenance plans

- Consider possible system expansion.

Basic components are described for collecting, storing, analyzing, and presenting data. Systems can be developed for use on a single piece of equipment that manually collects the data for a single building, between several buildings at a facility using an Intranet, or across a network of remote facilities communicating using the Internet. The advanced metering industry was once a boutique industry. Now collaboration with the telecommunications industry, with higher volume and lower cost, makes the sharing of such information a low-cost commodity.

To effectively manage energy systems, some level of monitoring is necessary. Success lies in making use of the metering information. To ensure that the metering system is used perpetually and the maximum benefit is being derived, we include recommendations and information on continual assessment of use and savings. Case studies from the U.S. Department of Defense and General Services Administration facilities exemplify federal applications.

Advanced Utility Metering

Background

With volatile energy rates and a need to control costs, federal agencies are interested in technologies to meter utility use and manage utility information. Agency leadership is interested in goal setting and performance metrics. Facility managers need to allocate utility costs and obtain feedback on energy management practices and diagnosis of problems. All agencies respond to existing legislative requirements, and recent legislative initiatives would require each agency to meter or submeter the energy use in all its federal buildings, industrial processes, and energy-using structures.[1]

The purpose of this publication is to provide information to potential users of advanced metering systems. Simply stating that more detailed metering information is required at federal facilities is not the approach here. Rather, this report will help managers determine why the metered information is needed and how it will be used to design and implement the most effective metering system. Planning for system maintenance and expansion is critical.

A wide range of facility types and metering goals is possible within federal facilities. Similarly, there is a wide range of possible uses for metered data. Some of those uses will be presented here to provide context for developing a concise performance specification.

A large campus that has a single utility meter and that houses multiple agencies might require submetering to equitably allocate utility costs. Other uses for the data could include energy-use diagnostics, demand control, and response to real-time pricing. A very different example is an agency that operates buildings in separate locations. In this case, providing an on-line data display may fill the need. Providing day-old data may be acceptable to reduce data collection costs. The costs of these two systems would be substantially different, but each meets the specific requirements of the sites. Choosing the best solution for a specific site may reduce up-front costs, while still meeting needs.

This publication describes various metering purposes that may be needed at federal facilities and provides an overview of metering technology. The technology is categorized into meters, data collection, archiving, analysis, and presentation. This report discusses system architecture, implementation, and relative costs and provides basic information about security issues. Finally, the document presents general guidelines, provides case study examples, and lists providers of equipment, software, and services. Appendices include additional information and resources.

General Metering Purposes

Revenue Billing

Probably the most common use of metering is for billing purposes: utility companies install meters to charge customers for the amount of electricity they use. The data provided by a basic revenue meter are usually not very detailed, often consisting of nothing more than a monthly total of energy use and, perhaps, information on peak demand. More complicated rate structures can also require power factor or time-of-use information. Only utilities collect and use this information, but the same metering system could be used to provide customers the energy-use information they need to plan their activities and manage costs.

Time-of-Use Metering

Many utilities and regulators are moving toward time-of-use rates, which charge more for energy use that contributes to the system peak demands. They also provide an incentive for utility customers to shift demand off peak. Time-of-use rates require special meters.

Real-Time Pricing

This is somewhat similar to time-of-use metering in data requirements. A customer who receives power under a real-time pricing (RTP) contract has energy prices that change dramatically from season to season, and even hourly during periods of high system demand. Being able to adjust purchased energy use in response to these fluctuations in energy prices can save substantial amounts of money.

Load Aggregation

Agencies may want to combine geographically separate facilities to acquire and bill utility services. Such aggregation can often result in lower utility rates than a separate utility account for each site.

Submetering

The utility generally installs a single revenue meter for an entire campus of buildings. This serves the purposes of the utility company, but does not provide any information about the distribution of the load among buildings within the campus. Information about the loads at individual buildings can be used to equitably allocate energy costs.

Without submetering, a utility bill is often allocated according to the square feet of building space that is occupied by tenant agencies or by some other technique that uncouples payments from the amount of energy used. For federal facilities, a fundamental principle should be that payments for utilities be based on measured use, so there is an incentive to conserve utility resources and a consequence for wasting them.

An issue of equity comes up when allocating utility costs. For example, an end or top unit in an apartment building will have more heat loss than a central one. It is important to take into account factors that are beyond occupants control, so as not to impose an undue financial burden on those unfortunate to be in space that uses more energy as a consequence of its condition.

Energy-Use Diagnostics

Understanding the way energy is used in a building can lead to changes in operation that reduce energy consumption. For example, a large nighttime load may indicate that equipment is running unnecessarily. Similarly, shifting equipment schedules can sometimes reduce demand charges from the utility companies by eliminating coincident and unnecessary equipment demands during peak periods. Other simple energy-use diagnostics are related to a comparison of energy-use indices (EUIs), such as the amount of kilowatt-hours used per square foot (kWh/ft^2). EUIs can be compared between similar buildings to determine whether a building is using more energy than it should or can be compared to historical data for the same building to determine whether the building energy use has increased. Observations in energy-se trends over time can indicate when equipment is in need of service.

Power Quality

Advanced meters can capture electrical anomalies such as transients, voltage disturbances, power factors, and harmonics to troubleshoot power quality problems. This can be especially useful

when monitoring sensitive loads. Transients can cause printed circuit boards in computers and other electronic equipment to fail prematurely. Improper power factors can result in surcharges from utility companies. High harmonics can shorten the life of transformers. Using advanced meters allows power quality problems to be detected and documented so solutions can be developed and implemented.

Emergency Response

During an electrical power emergency (such as the one experienced in California in 2000 and 2001) or during other utility shortages (such as a drought in 2002), the manager of a federal facility may need real-time information to make decisions regarding plant closure or interruption of noncritical loads. He or she may also need to determine whether the directions to staff to reduce power use are being followed and are achieving the required results.

Planning and Reporting

Managers of facilities that are distributed geographically may benefit from an advanced metering system that allows them to view and record energy use via the Internet. An advanced metering system could be designed to collect, reduce, and present information that would describe agency energy use and progress toward goals set by legislation and Executive Order or other goals set by utilities. For example, one advanced metering offering plots facility energy use against the "20/20" goal set by California utilities (reduce energy use by 20% from the previous year and be rewarded by an additional 20% reduction in costs). Carefully designed reports from advanced metering systems can help an agency plan how to meet these goals.

Metering System Components

Metering systems consisted of the following basic components:

- meters
- data-collection system
- data storage
- data analysis and presentation.

These components are found in even the simplest monthly manual-reading system, where the meter has a visual display and is read and manually recorded by a human meter reader. This information is then manually entered into the billing system and presented in a monthly bill. For this discussion, the manual activities need to be replaced by automated processes, and the data analysis and presentation need to provide much more detailed information about the nature of energy consumption. Depending on the needs, real-time or near-real-time data presentation may be necessary.

Each basic component is discussed in the following sections.

Meters

Nearly all the electric meters suitable for remote data communications are solid state as opposed to electromechanical. At the most basic level, they provide energy and demand information. At the most sophisticated level, they provide information on power quality, log a substantial number of data, and provide a wide variety of communication options, such as hosting Web pages for presenting meter data. Table 1 lists three classes of meters and their associated characteristics: commercial/industrial (C/I) meters, advanced meters, and sub-meters. Most meters can be modified with options, so distinctions between these classifications are not always clear. For

example, C/I meters can have several options that make their capabilities similar to those of advanced meters.

Some meters can be installed in utility socket-mount/switchboard cases; others are designed to be installed in panels. Meters can vary in type, size, shape, and accuracy. Meters used for revenue applications need to comply with specific requirements.

Metering functionality is also available integrated with other devices, such as circuit-breaker trip units and protective relays. Technology improvements allow many manufacturers to offer devices with metering capabilities that include communications plus optional power quality information. This can be very cost effective for submetering and cost-allocation applications in new equipment installations.

Table 1. Meter Characteristics

Characteristic	Basic C/I Meter	Advanced Meter	Submeter
Configuration	Utility Socket	Utility Socket Panel	Panel Stand-alone
Energy and Demand	Yes	Yes	Yes
Power Quality Analysis	No	Yes	No
Data Logging	Option	Option	Option
Output Type	Pulse; Digital	Digital	Pulse
Communication Capabilities	Pulse RS-232 Modem	RS-232/485 Ethernet Modem	Pulse RS-232 Modem
Alarm and Control	No	Available	No
Revenue Metering Capable	Yes	Yes, in utility socket configuration	Not intended use
Industry Examples	ION 8300 Siemens[2] Square D[3] POWERLOGIC / Schlumberger Sema Q1000	ION 8500 Siemens Maxsys Square D POWERLOGIC CM4000T / CM3000	Square D POWERLOGIC Power Meter / Energy Meter / Enercept EMON[4] ION 6200[5]

The meter classifications shown in Table 1 do not indicate the meter application. For example, an advanced meter can be used in a submetering application, if advanced capabilities such as power quality monitoring are required. Similarly, a relatively basic meter can be used for utility revenue billing if only basic energy information is required. The following are key to proper meter selection:

- determine the required information

- select a meter that can support the data required to provide this information.

Advanced meters include substantial computing power that can be used for a variety of communications and processing tasks. These features provide options well beyond metering electricity use. Their applicability to the overall goals of metering should be considered when developing the requirements for an overall metering system.

Gateway

Meters that have Ethernet communications capabilities can act as gateways for other devices. For example, meters can accept Modbus communications from other devices that can then be accessed over the Ethernet. In addition, dedicated gateways can be used to tie the Modbus meter communications to an Ethernet system. However, when public Ethernet (Internet) is used and the data must be passed out of a building to another location, security becomes an issue. Security is discussed in more detail later in this report.

Push Data Transfer or E-mail

Sending data from a meter or a gateway through a LAN (Local Area Network) takes advantage of established infrastructure for data transfer. This can be accomplished in the form of a "push" transfer of data or by electronic mail (e-mail). Transferring data through a push method involves the use of an embedded system gateway that can act as both a gateway and server, enabling it to also host a variety of historical data from multiple meters. Data can also be transferred via e-mail, thereby taking advantage of the mail server,[6] which provides a secure method of communicating through firewalls (a system or group of systems that enforces an access control policy between two networks). Power Measurement Company has developed an integrated e-mail feature into several of its meters called MeterM@il[®].[7] This provides the security features of e-mail within a single meter.

Web Server

Meters that can act as Web servers can serve meter data that can be accessed over a LAN (Figure). This allows access to the meter information by using standard browser software and can easily viewed by anyone on the enterprise-wide LAN. To allow access to this meter from the Internet requires a firewall. The firewall must be configured to allow access through a port specific for that meter. As with any connection to the Internet, the proper security must be maintained.

Some manufacturers provide Ethernet to serial gateways that fully support the published standards for Modbus and Modbus over TCP/IP. These gateway products provide Web-based utilities for device configuration, as well as the ability to serve real-time and historical data across a LAN using HyperText Transfer Protocol. This capability provides access to real-time information about a facility from any PC within the facility, using an industry standard Web browser.
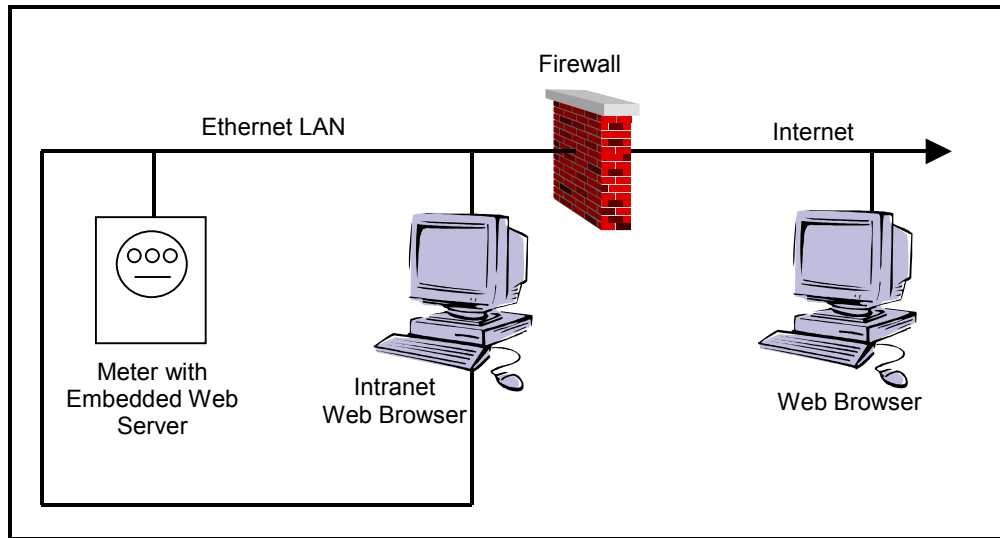
Figure 1. Meter with Web server feature

Control

Some meters have digital outputs that can be used to control other devices or loads. This feature could have applications in load control and be used to reduce demand during peak periods. For example, software designed to track peak demand could notify an energy manager of an impending peak that would exceed a threshold and trigger an increased demand charge. Upon notification, the energy manager could either shed load or dispatch generation capacity to avoid exceeding the threshold. Also, the software could be configured to automatically shed load or dispatch generation.

Data-Collection System

The data collection system is used to access the electric meters. Traditionally, the data collection system was a manual process, where meter readers would visually read the meter register and record the data in a notebook. Automated Meter Reading (AMR) has been developed to reduce the labor associated with manual meter reading. AMR systems range from an extension of manual meter reading, such as radio-based walk-by and drive-by meter reading systems, to more sophisticated systems consisting of wireless networks that can remotely read meters. Figure 2 is a general depiction of a data collection system for a single meter. The data recorder would be required for a relatively basic meter that has no storage capabilities. It would store pulses from the meter for retrieval by the data collection system.
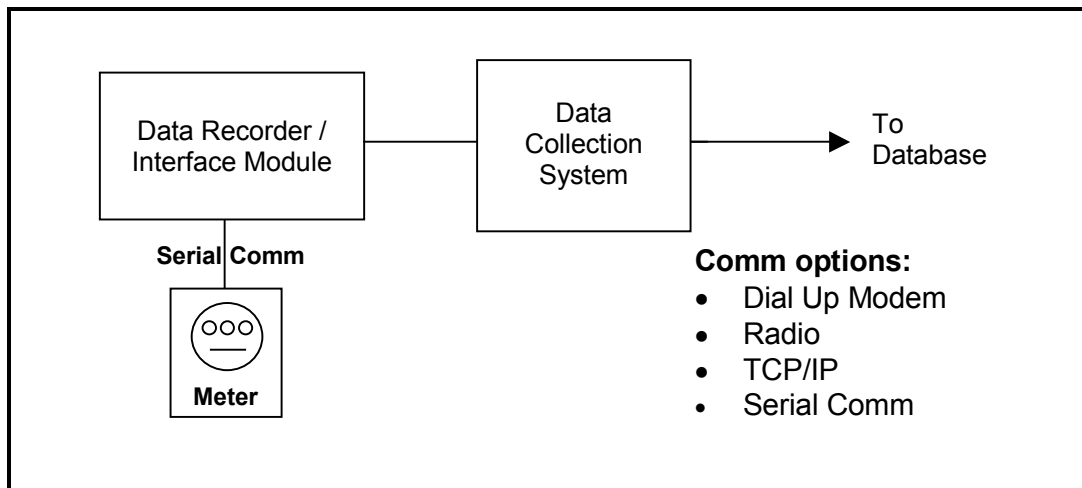
Figure 2. Single meter data-collection system

Once the data are read from the meter, they are stored in a database for further processing and analysis. The utility industry *de facto* standard for data collection and storage systems is the MV-90. This system was developed so meters from different vendors could be read and the data stored consistently. Meter manufacturers have developed their own communication protocols, data formats, and proprietary software to communicate primarily with their own meters. So that utilities with many different meter brands and types in their service territory could avoid having to use many versions of proprietary software, the MV-90 was developed so a single software package could be used. Once the data were converted into a standard format, they could be transmitted to a database for storage in MV-90 format.

The original MV-90 data collection concept consisted of a module located near the meter that communicated with the meter using its native communications protocol and with the main MV-90 system through a dial-up modem. The collected data were then stored in MV-90 format.

Variations on this concept include wireless data collection through drive-by or walk-by radios, use of fixed wireless networks, dedicated wide-area networks, and other communications methods, such as the Internet, to communicate between the meter communications module and the main MV-90 system. Because utilities have traditionally been the target market for MV-90, it has a variety of software applications to meet their requirements.[8]

There are other multivendor approaches besides MV-90. Another system is marketed by Stark North America,[9] which is marketed toward smaller enterprises that need a multivendor solution.

Proprietary data collection software designed to work with specific manufacturers' meters is also an option if all the meters are compatible with the software. Nearly all proprietary software can communicate with meters that support the Modbus® protocol, which can provide basic energy and demand information. However, more advanced meter features may require proprietary data collection software to take full advantage of a meter's specific features.

Communications Methods and Protocols

There are many ways to communicate the meter information to the storage servers. Each has advantages and disadvantages; some are described here.

Phone/modem. A modem is a "modulator/demodulator" that converts digital data to analog frequencies and back to digital, so that digital data can be transmitted by analog radio frequencies

over wires (Dial-up, Digital Subscriber Line [DSL], Cable) or the air (Wireless). A modem and a dial-up phone line offer a simple and effective communication method if the data refresh rate is relatively slow. For example, the system can dial into the modem located at the electric meter each day and request 24 hours of data. The consumption data may be stored on the meter or the local components of the data collection system on a 15-minute or faster interval, but would only be updated to the database once per day. Depending on the location of the central database, phone modems may incur long-distance charges.

Internet. Internet communication is an innovation in meter communication that provides nearly real-time access to meter information over public networks. Some meters can act as Web servers, providing data in HTML (Hypertext Markup Language) or XML (Extensible Markup Language). The data from these meters can be viewed directly by a standard Web browser or imported directly into another system using XML data labels. The Internet can provide communication between the meter and the data-collection system, although security can be an issue.

Intranet. Intranet communication is similar to Internet communication. However, some security issues are eliminated because everything happens behind a firewall and the network is not public.

Private wireless networks. Wireless fixed networks can be used to continuously collect data from distributed electric meters and have been implemented for residential data collection. SchlumbergerSema CellNet is one example of such a network.

Power line carrier. A power line carrier can be used to transmit data between devices over power lines. It is often used within buildings on the user side of the utility meter. Its advantages are that no additional communication cable is required, and it is relatively inexpensive. A major disadvantage is that data transmission is not reliable across unmodified transformers. Because of this issue, and for highest reliability, all communications must be on the same side of a transformer.

Modbus. Modbus is an open communication protocol that can be used for communications between electric meters and data-collection devices. It allows flexible communications that can avoid the use of proprietary software and protocols. However, there may be meter capabilities that cannot be accessed when using Modbus, depending on how elaborately the manufacturer has implemented the Modbus protocol. However, all meters that talk Modbus will be able to communicate energy-consumption data. Modbus was originally designed for communications over serial buses such as RS-232 or RS-485. As the Ethernet has become more prevalent, Modbus TCP/IP was developed to take advantage of the available Ethernet network.

A description from Modbus.org:

> Modbus Protocol is a messaging structure developed by Modicon in 1979, used to establish master-slave/client-server communication between intelligent devices. It is a *de facto* standard, truly open and the most widely used network protocol in the industrial manufacturing environment.

> In order to move Modbus protocols into the 21st century, an open Modbus TCP/IP specification was developed in 1999. Combining a versatile, scaleable, and ubiquitous physical network (Ethernet) with a universal networking standard (TCP/IP) and a vendor-neutral data representation (Modbus) gives a truly open, accessible network for exchange of process data.

Wireless communication methods. Several wireless communication methods suitable for meter data collection are described here. Table 2 compares costs and capabilities of several of these wireless communication methods.

Cell modem. This method would be used like a telephone line, but with a wireless cell modem. Cell service is typically more expensive than a land line, but may be more convenient if cell service is available, because installation is quicker.

CDPD modem. CDPD ("Cellular Digital Packet Data") modems allow continuous Internet connection. They provide connectivity similar to that of a LAN, although at a slower baud rate. CDPD modem service is more expensive than cell modems and is available in a smaller geographic area. It employs an additional server connected to the normal Cellular Network, which keeps track of the modem. Because the technology does not have a second server to keep track of a dynamic IP address, it requires a static IP address. Today, that poses a problem in that networks are assigned a limited number of IP addresses in blocks for use by customers. CDPD sends digital packets of data to the Cellular systems, which are placed in between transmissions of analog (voice) data so that the network can serve both types of transmissions simultaneously.

Pager. Pager technology can be used to transmit relatively few data using a network such as Skytel. A data transceiver, such as those produced by SmartSynch, is required to communicate between the meter and the pager network. A typical data-gathering approach using this system is to communicate with the meter once per day to download the previous 24 hours of 15-minute consumption data, although it is also possible to communicate with the meter more frequently. SmartSynch has developed an overall data collection system for using the pager network, partnering with Siemens and SkyTel.

Private Wireless Networks. Wireless fixed networks can be used to continuously collect data from distributed electric meters and have been implemented for residential data collection. SchlumbergerSema CellNet is one example of a private wireless network.

Wireless Radio Frequency (RF) communications may be subject to regulations on military sites. The frequency coordinator for a specific site should be consulted to determine requirements or whether RF communication is possible. Similarly, sites with equipment or processes sensitive to RF radiation may prohibit RF.

Table 2. Wireless Communications Summary[10]

Parameter	Cellular Control Channel	CDPD	Paging, 1-2 Way	Spread Spectrum Radio	Satellite
Example Providers	Aeris.net MicroBurst Cellemetry	AT&T, Verizon[a]	Skytel	DataRadio Microwave Data	Qualcomm Orbcomm
Wireless Radio Cost	$100 to $125	$250 to $350	$350 to $400	$1,200 plus private radio network	$700 to $1,500
Monthly Service	$5 to $10	$50 plus use	$10 to $40 plus $0.02 to 0.12 per message	$0[c]	$20 plus $0.10 per message
Data Capacity	8 to 25 digits[b]	2,400 to 9,600 baud	2,400 to 9,600 baud	2,400 to 9,600 baud	2,400 to 9,600 baud
Coverage	Wide availability in North and South America	Limited Metro Areas only	Availability around Metro Areas	Line of site within radio network	Near 100%
Latency	<10 seconds	<10 seconds	15 to 270 seconds	<10 seconds	<10 seconds
Primary Application	Telemetry, Monitoring & Control	Telemetry, Monitoring & Control	Telemetry, e-mail, PDAs	Telemetry, communi-cations Modem	Telemetry, communi-cations Modem

[a]Roaming charges can be expensive, annual contract required

[b]Aeris.net has announced Vburst, with a capacity of 1024 digits

[c]Radio maintenance and infrastructure costs not included

Data Storage

Data accessed by the data-collection system must be stored in a database for analysis and archiving. There are many different database vendors and types, and their advantages and disadvantages will not be discussed here. The focus of this discussion is on data storage location.

Choosing the best location for data storage is important for the overall system architecture. Data can be stored on a computer dedicated to the data-collection and storage task when all the data are used on-site and the infrastructure is in place. For an enterprise-wide system where meter data are collected at multiple locations, data will likely be centrally stored. Another option is the embedded system gateway. It is a self-contained server and can collect energy data and

automatically send it over the Web. Such a device can be a stand-alone system providing local monitoring or part of a corporate enterprise

For enterprise-wide systems, the data can be stored and hosted either by an information technology (IT) department that can host, archive, and serve data, or a third party can use an application service provider (ASP) business model. An ASP would collect and archive the data and provide reports and analysis tools to the user, most likely through a standard Web-browser.

An ASP is also responsible for software maintenance. A subscription fee is typically associated with the service, but using an ASP can eliminate the need to maintain a database and multiple versions of software locally. The ASP often can provide other services such as analysis and reporting.

Data Presentation and Analysis

Presentation and analysis are necessary to effectively process and present the data gathered by the collection systems. Manual methods are expensive, time consuming, and error prone. Custom software developed for each site for analyzing data, again, can be very expensive to develop, maintain, and—depending on their underlying architecture—difficult to expand. Thus, choosing a system that meets current requirements and can be easily expanded is important.

Software packages are available from meter manufacturers and from third-party software vendors. Packages developed by meter manufacturers are designed to work seamlessly with their own meters, often communicating in their native protocols. The software can exploit features of the meters that may be available only in the native communications protocol. If all meters in a system are compatible with this software, this can be a suitable solution for data presentation and analysis, assuming that the analysis capabilities of the software meet the analysis needs of the facility. However, to ensure compatibility with other vendors' meters, manufacturers' software usually can talk in Modbus or another standard protocol. Power Measurement ION$^®$ Enterprise,[11] Square D POWERLOGIC System Manager™,[12] and Siemens WWW100 Internet Information System[13] are examples of meter manufacturers' software.

Third-party software vendors also provide solutions for data presentation. They are usually integrated with the data-collection system and provide a vendor-neutral method of collecting and presenting data. Although architecture can vary, these packages are usually intended to be owned and operated by the end user.

Another approach to data presentation is through the ASP model. An ASP collects all the data into their servers, then provides access to reports and analysis tools through a standard Web browser. In this model, the ASP archives the data, maintains all software, and provides additional services. An example of an ASP is Automated Energy, a Oklahoma-based company that provides tools for trending data, aggregating multiple sites, analyzing utility rates, and managing energy information.

Analysis

Collected data must be processed and presented in an easily interpreted form. This has often been a manually intensive process, where data are requested from the database using database queries, then processed in spreadsheets or other tools. Specialized tools have also been created that can interrogate the database directly. Different types of analysis software are available for users. However, it is important to identify analysis needs for each facility.

Some potential analysis needs were listed at the beginning of this document and are repeated here with discussion of their data presentation and analysis requirements.

Revenue billing. Usually, revenue billing is the responsibility of the utility company. Most federal facilities purchase power from the utility company, which provides the bill. Therefore, federal agencies generally do not perform revenue billing, because they are not in the generating business. However, they can verify bills by processing the energy consumption data through a "rate engine" that shadows the rate calculation performed by the utility company. The energy use data can also be processed through alternate rate structures to determine whether another rate will result in lower costs. Similarly, by performing these calculations, the effect of load shifting or peak reduction on the monthly energy cost can be determined.

To perform these activities, candidate software should contain rate engine tools, the ability to import current rates and perform "what-if" rate analyses, and to perform bill verification calculations.

Load aggregation. Agencies may want to aggregate energy consumption from geographically separate facilities to acquire and bill utility services. Clearly, these facilities will have separate utility meters. Billing can be aggregated when all the facilities are within the service territory of a single provider, but generally not when facilities are in different service territories. Nevertheless, the issues of collecting and aggregating data from geographically separate meters would be similar regardless of territory.

The capabilities of candidate software should provide tools to aggregate any number of meters to provide an overall energy-consumption profile.

Submetering at building or department level. Often a single utility meter is used for an entire plant, which can contain many buildings or departments. If these buildings or departments are submetered, information is available about the energy consumption of each. This information can be used to allocate the cost of consumed energy to departments, which is more equitable than basing energy costs per square foot or by some other arbitrary method.

Submetering can also be used to identify buildings with higher-than-normal energy consumption to allow corrective action to reduce their energy consumption. The actions can be as simple as turning off equipment or lights.

The capabilities of candidate software should provide tools for analyzing submetered data for allocation. Similarly, some methods for identifying buildings with high energy consumption should be available.

Energy-use diagnostics. Energy-use diagnostics can be performed at multiple levels. When submetering at the building level, EUIs such as kWh/ft^2 can be used to determine whether a building is performing at a reasonable level. If a building appears to be using too much energy, manual methods are often used to examine its load shape. The load shape can be compared to historical use patterns to determine whether a change has occurred. Similarly, the load shape can be compared to the occupancy or use schedule of the building to determine whether there is excessive use when the building is unoccupied. If equipment is submetered, its energy consumption can be tracked to help determine when energy is being used and whether equipment performance may be deteriorating.

The capabilities of candidate software should provide tools for the following functions:

- calculating EUIs for buildings

- comparing EUIs with historical use

- analyzing load shapes.

Power quality. Power quality issues can be presented in various forms. One of the more useful methods is to provide alarms when power quality has deteriorated and may damage equipment or processes. Providing periodic power quality summaries may also be valuable. The capabilities of candidate software should provide tools for analyzing waveforms and power disturbances. Also, some type of alarming to warn of problematic issues is useful.

Report Generation

To display the results of an analysis, the software will provide reports that may consist of trend plots, tables, or a combination that most effectively presents the results. During "browsing" activities, where a user may simply be interested in plotting variables, the user interface that instantly displays the results graphically may be sufficient, especially for interim results. Ultimately, however, a concise report displaying the analysis results will be necessary. This section discusses methods of report delivery and creation—rather than specific report types, which depend on the type of analysis.

An end user or an ASP can automatically generate and "push" reports to users through e-mail. This approach can be useful when a user would like to have a daily report showing performance on the previous day or if a monthly report is desired. By receiving an automatically prepared report, the user's job is easy: no effort is required to set up or generate the report.

When all users are on the same LAN, static HTML reports can be generated and posted on a server. Users can access these reports by entering the Web address for the report in a standard Web browser. In an enterprise system, an embedded system gateway can be used to push data to a password-protected website. This allows users at multiple locations who are not on the same LAN to access these reports.

For real-time or near-real-time data reports, the user must have immediate access to the data for diagnostics, response to real-time pricing, or some other need that requires current data. For these users, tools for automatically generating plots or reports are necessary. To streamline these tasks, report templates can eliminate the need to recreate report formats.

System Architecture and Implementation

Integrating the components of metering, data collection, data storage, and data presentation and analysis into a system that meets the needs of the users is a substantial task. Security is a consideration when using public networks such as the Internet. Communication across firewalls requires solutions that do not compromise security, yet allow functionality.

Nearly all meter and software vendors can provide services to implement their systems. However, special consideration is required for integrating a new system with existing infrastructure and requirements. Meters from many vendors may need to be accessed. If metering systems have been previously implemented at different sites, the databases will likely be different and distributed.

Sharing data between different systems or applications can be difficult. Extensible Markup Language (XML) is a simple, very flexible, text format that can simplify the task. It is like HTML (uses tags to identify types of data), but HTML is only focused at presentation (how the report

should look) rather than the data structure and content. XML separates the actual data content from the presentation. The benefits include easy access to data, easy alteration of the presentation, data presented in multiple formats, easy searching/querying of data, etc. Unlike HTML, XML does not have any fixed set of tags (hence is extensible!) This provides a consistent interface for data transfer. It avoids the necessity of directly understanding different database structures and the need to develop different database queries for different databases. These issues are important when data from different meter data-collection systems must be processed and viewed and should be considered when developing an overall plan for metering systems.

There are several levels of architecture, depending on the facility and the data needs. A relatively simple system that has few security issues is shown in Figure 3. Meters communicate with a gateway that serves as a simple Web server for the meters. Web browsers connected to the Intranet (LAN) can access this Web server and view data. No access is available from outside the LAN.

When meters from a variety of vendors are within one facility, a common method of communicating with these meters is required. A common communications method is to use Modbus, as shown in Figure 4. The Modbus protocol can be implemented on RS-485 serial communications bus or be implemented on TCP/IP, where Ethernet would be used rather than a serial communications bus.

As the requirements for communications and analysis capabilities extend beyond simple configurations, the need increases for secure communications and a server that has greater computing power to provide better processing throughput.
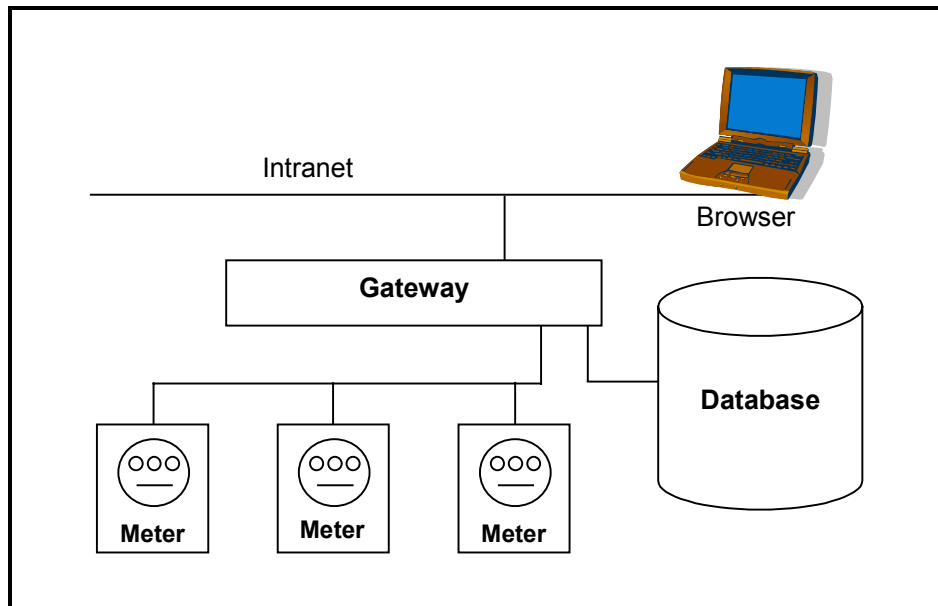
Figure 3. Intranet-based architecture
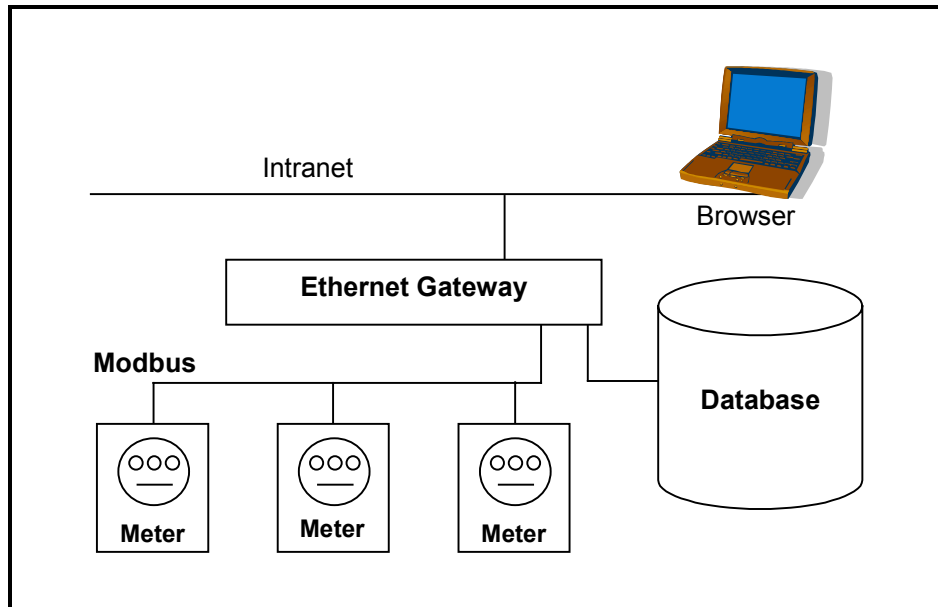
Figure 4. Modbus-networked meters

Metering Cost Drivers

The costs of an entire metering system vary dramatically. Here are some of the drivers that affect costs:

Meter type and quantity

A basic submeter can cost as little as a few hundred dollars; an advanced meter with Internet communications capability can cost as much as several thousand dollars. A relatively basic C/I meter will cost less than $1,000. Users should choose the most appropriate meter, while considering future needs to minimize initial costs.

Data-collection software

Data collection costs include the software required to collect the data, as well as the costs of the hardware required to connect the meter to the data collection computer. Software that is designed for large data-collection systems works very well, but is more expensive than software scaled for smaller systems.

Data-collection hardware

Using an established infrastructure for data collection can reduce costs. The infrastructure can include a facility LAN or phone lines. Adding wireless networks or relying on other wireless systems can increase costs when the infrastructure can access the meters, although wireless systems can be good solutions when properly applied.

Frequency of data collection

Depending on the data-collection hardware and software, fast data collection that provides near-real-time data can be more expensive if the data-collection system operating costs are based on the frequency or number of data transferred, such as in the case of long-distance phone calls, cell modems, and other public wireless networks. However, for hard-wired meters on a LAN, the frequency of data collection will only affect costs in the quantity of data stored.

Data-presentation software capabilities

Very expensive and capable software platforms provide detailed information about energy use. Similarly, modest systems are also available. Choosing the right level of capability for the data presentation software is an important decision, as it provides the ability to efficiently turn vast amounts of time-series data into useful information.

Number of allowable users

Software is available for a single user (residing on a single computer) or multi-user (client-server) configurations. Also, software is available where the users are "thin clients," requiring only a standard Web browser. The larger the number of "power" users or users who interact with the software, the higher the cost. However, providing links to these reports gives casual users access to the resulting reports.

Level of user support

When buying a system, support will be required during initial installation and throughout its life for updates, problem solving, user training, etc. These costs are often higher than the cost of the software.

Monitoring all loads is not practical. Metering and communication costs can be greater than the savings attributable to the metering information. A rule of thumb for installing an advanced meter is to avoid metering loads of less than 200 kW demand.[14] Another is to consider the "value" of the energy consumed by the load. The "value" rule of thumb is to consider metering loads that consume at least $1,000/yr in electricity.[15] There can be other considerations besides energy consumption and cost when determining when to add meters, such as a need for specific information such as power quality, or a need to submeter loads for cost allocation.

Using an ASP may reduce the up-front costs of implementing a metering system and eliminates the need to maintain data archives and software updates. The ASP supports all these activities and typically charges a monthly fee for providing the services. The monthly fee will vary depending on the number of meters monitored, the "freshness" of the data, (i.e., day old versus near-real-time) and other services provided. Initial meter installation or access costs will need to be considered.

Security

Security must be considered whenever public networks are used. Security is a process that must continuously evolve and includes access control; private secure communications (standard IPSec), network intrusion tools to diagnose the vulnerability and risk and to detect intruders, firewall, authentication to assure that users are who they say they are; and encryption. Access is controlled by user names and passwords, although without encryption they can be intercepted and used to access the meter.

There are two components to a meter data-collection and presentation system: communication between the meter and the database (data collection) and communication between the database and the end user (data presentation). Some of these systems work over private networks, others use the Internet. Private networks, such as phone systems, greatly reduce the possibility of unauthorized access. When the Internet is used, security elements such as authentication of systems or users, firewalls, and access control are critical to protect the data and meters.[16] Data presentation involves many of the same security issues.

A smart gateway can communicate securely with the end point through a virtual private network, where the gateway computer encrypts all traffic from the meters and tunnels the data to the point of destination.

The U.S. Department of Defense has standards and procedures for information security. These should be consulted for specific requirements.[17]

Codes and Standards

When creating a performance specification, the key is to provide information on WHAT needs to be accomplished, not HOW it is to be accomplished. For construction specifications, all applicable standards should be listed. However, when creating performance specifications, listing too many standards may actually limit the possible solutions to HOW goals are accomplished. In general, if codes and standards are included, they should be used to inform, not limit, solutions.

Because codes and standards must be met for a specific site, language such as the following is appropriate:

> Design of the metering system will incorporate all applicable codes and standards. Regulations that are in effect for the specific site at the time the specifications are prepared shall be incorporated.

Codes address safety and good building practices. Because metering systems involve electricity, in all practical cases they will have to meet the National Electric Code (NEC), NFPA 70. The NEC focuses on the proper installation of electrical systems and equipment to protect people and property from the potential dangers of electricity. In most cases, local building codes will require compliance with the NEC.

Electricity meters have a variety of standards. Revenue-class meters comply with applicable American National Standards Institute (ANSI) C12 metering standards, such as the following:

- ANSI C12.1 - American National Standard Code For Electricity Metering

- ANSI C12.4 - American National Standard For Mechanical Demand Registers

- ANSI C12.5 - American National Standard For Thermal Demand Meters

- ANSI C12.6 - American National Standard For Marking And Arrangement Of Terminals For Phase-Shifting Devices Used In Metering

- ANSI C12.7 - American National Standard For Watt-hour Meter Sockets

- ANSI C12.8 - American National Standard For Test Blocks And Cabinets For installation Of Self-Contained A-Base Watt-hour Meters

- ANSI C12.9 - American National Standard For Test Switches For Transformer-Rated Meters

- ANSI C12.10 - American National Standard For Electromechanical Watt-hour Meters

- ANSI C12.11 - American National Standard For Instrument Transformers For Revenue Metering, 10 kV BIL Through 350 kV BIL

- ANSI C12.13 - American National Standard For Electronic Time-Of–Use Registers For Electricity Meters

- ANSI C12.14 - American National Standard For Magnetic Tape Pulse Recorders For Electricity Meters

- ANSI C12.15 - American National Standard For Solid-State Demand Registers For Electromechanical Watt-hour Meters

- ANSI C12.16 - American National Standard For Solid-State Electricity Meters

- ANSI C12.17 - American National Standard For Cartridge-Type Solid-State Pulse Recorders For Electricity Metering

- ANSI C12.18 - American National Standard For Protocol Specification For ANSI Type 2 Optical Port

- ANSI C12.19 - Utility Industry End Device Tables

- ANSI C12.20 - For Electricity Meters 0.2 and 0.5 Accuracy Classes

- ANSI C12.21 - Protocol Specification for Telephone Modem Communication

- ANSI C62.41: Surge Immunity.

The Institute of Electrical and Electronics Engineers (IEEE) has standards related to electromagnetic immunity including:

- IEEE C.37-90.1-1989: IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems (ANSI). All inputs tested, except for the network communications port.

ANSI is a member of the IEC (International Electrotechnical Commission), which has adopted the following standards related to metering:

- IEC1000-4-2 (EN61000-4-2/IEC801-2): Electrostatic Discharge (B)

- IEC1000-4-3 (EN61000-4-3/IEC801-3): Radiated EM Field Immunity (A)

- IEC1000-4-4 (EN61000-4-4/IEC801-4): Electric Fast Transient (B)

- IEC1000-4-5 (EN61000-4-5/IEC801-5): Surge Immunity (B). Certified by American Electric Power (AEP)

- IEC1000-4-6 (EN61000-4-6/IEC801-6): Conducted Immunity

- IEC 60687 0.2S, section 4.6.1, 4.6.2, 4.6.3.

The Federal Communications Commission (FCC) also regulates electromagnetic emission:

- FCC Part 15 Subpart B, Class A: Class A Digital Device, Radiated Emissions. d. IEC Compliance.

Other organizations might impose local requirements. For example, the California Independent System Operator (ISO) has standards and protocols for installing, reading, and maintaining meters on the system including:

- ISO MTR1-96: Engineering Specifications for Polyphase Solid-State Electricity Meters for Use on the ISO Grid.

Clearly, most of these standards address specific features that may not apply to all meters. Before such standards are listed, their ramifications should be considered. Specialized consultants could ensure that standards are appropriately applied without unnecessarily limiting options. At the performance specification level, it is most appropriate to specify the metering goals (revenue-class submetering, power quality monitoring, etc.), rather than to specify the meter standards.

Metering Guidelines

The following guidelines are presented based on information from federal agencies that have completed monitoring projects, metering and energy information software manufacturers, and industry experts. Although the types of metering systems will vary from site to site depending on the needs, budgets, and character at each facility, the process and issues encompassing each project are basically the same.

The general procedure recommended for federal agencies is summarized here. The following guidelines provide criteria that should be considered when developing a site-specific project:

1. Identify the goals and objectives of the metering program and determine data requirements to meet these goals and objectives

2. Identify technical criteria and analyze established systems for compatibility issues

3. Develop criteria for evaluating system costs, benefits, and impacts on site personnel

4. Develop performance specifications and procurement requirements

5. Develop an implementation priority and schedule to maximize the early benefits from the program

6. Provide a plan for using, maintaining, and evaluating the program. The maximum cost-savings are realized by using the long-term results of the metering program.

A flowchart (Figure 5) describes the general procedure recommended for developing a metering system. The process is iterative, where the costs, benefits, goals, and project budget are evaluated and adjusted during each step to ensure project success.

Metering programs will vary greatly among federal agencies. Some may have substantial submetering requirements to equitably allocate utility costs. Others may need to ensure superior power quality, requiring high-end meters and data-collection systems. Therefore, the same type of metering program to meet the needs of both facilities would result in a system that would either be too expensive for one facility or provide an ineffective solution for the other.

Following the metering guidelines described in this section will help ensure a successful metering program. An organization cannot control what is not measured, so some level of monitoring is necessary.

Establish Overall Goals and Data Requirements

Before a metering system can be specified, its purpose and use must be established. Specifying hardware without understanding the overall needs may result in an inadequate system. Different departments within an organization may have different goals for the metering program. For example, the financial controller may need to allocate utility costs among tenants, while the planning department may need load information to plan improvements to the distribution system. A team representing each interest should identify a single metering program that satisfies all identified goals.
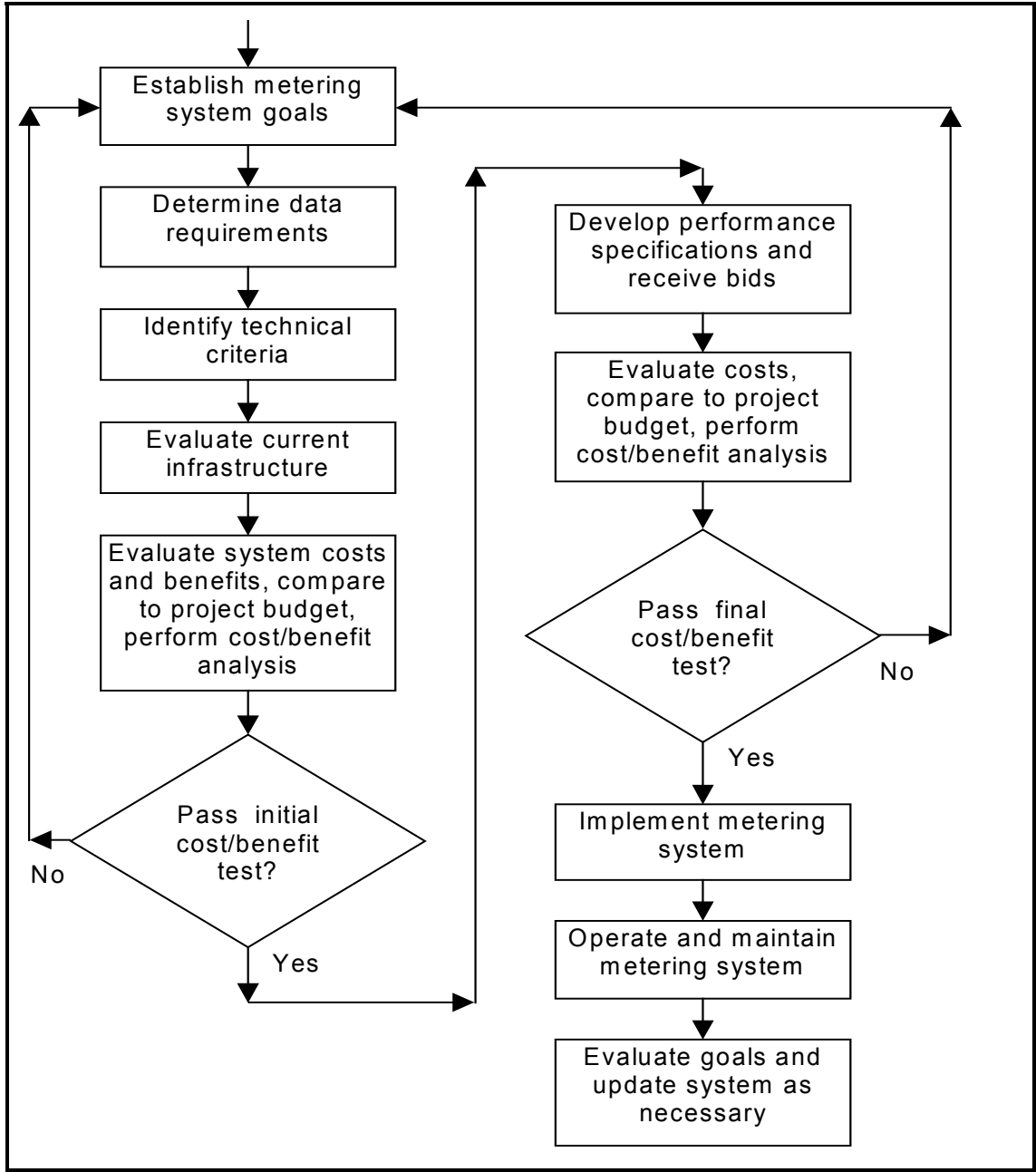
Figure 5. Recommended development process for a metering system

Overall Goals

Examples of goal categories and specific goals within those categories may include the following:

Financial goals such as cost allocation, billing, and energy purchasing:

- Allocate utility costs among users. Perhaps the most common goal of federal organizations is to connect utility cost to utility consumption, thus giving tenant agencies an incentive to use resources more efficiently.

- Aggregate loads. Combining loads in different locations by assembling the metering data may help agencies negotiate better utility rates.

- Analyze alternative utility procurements. Meter data can be used to determine whether costs would be lower on another utility rate schedule or in a deregulated environment from another utility provider.

- Evaluate utility outages and power quality to enforce the requirements of a utility contract.

Energy system diagnostics

- Identify savings opportunities. Meter data can be used to determine the cause of high utility costs and pinpoint priorities for retrofit projects or changes in occupant behavior, such as rescheduling large demands to reduce costs.

- Measure leakage to determine whether someone is using too much water or power between measured points in a system. This often occurs in federal facilities, where taps were added before cost-allocation systems were established.

ESPC Monitoring and Verification

- Establish baseline energy use and post-retrofit savings to determine payments under energy savings performance contracts.

Design Information

- Establish historical load information for the design of new electrical or mechanical systems or to design renewable energy or distributed generation systems.

Reporting Requirements

- Provide reports according to federal mandates and guidelines on progress toward energy efficiency goals.

- Provide quick feedback to department heads or upper-level command on whether instructions to reduce energy use are heeded during an energy emergency.

Determine Data Requirements

Once goals have been identified, the data requirements must be established by determining the format and content of the data products and reports. Metering and data-collection requirements can thus be more easily developed.

To review, the process develops in three parts:

- establish goals

- determine necessary reports or other products

- identify the metering and data requirements needed to generate the data products.

Examples of data requirements that support the goal categories mentioned above are included in Table 3.

Table 3. Example Data Requirements

Goal	Metering Points	Data Interval	Minimum Update Rate
Cost Allocation	Demand and energy for each tenant or agency to be billed	As frequent as required to support utility rate	Monthly
Load Aggregation	Demand and energy for each facility to be included in the aggregation	As frequent as required to support utility rate	Monthly
Utility Rate Analysis	Demand and energy	As frequent as required to support utility rate	Monthly, or as required to support analysis
Power Quality	Suggested: Amps, volts, VAR, harmonic data	As frequent as required for waveform capture	Daily More frequently for real-time analysis and reporting
Energy System Diagnostics	Depends on types of diagnostics, use demand and energy for consumption-related diagnostics	Suggestions: • 15 minutes • Shorter intervals for end use diagnostics involving cycling analysis	Daily More frequently for real-time analysis and reporting
ESPC Monitoring and Verification	Demand and energy	As frequent as required to support M&V requirements. Hourly may be sufficient	Monthly
Design Information	Demand and energy	Hourly or daily	As required for design projects
Management Reporting Requirements	Depends on reporting requirements; demand and energy for consumption-related reporting	Depends on reporting requirements	As required for reporting frequency

Many data requirements cannot be clearly stated because they depend on defining specific goals. For example, cost allocation may require only monthly energy and demand data, if the utility bill has no time-of-use component. However, time-of-use rates require that energy-consumption data be captured into the different time periods. These types of variations dictate that specific goals be clearly stated so that the correct data are collected from the proposed metering system.

The practicality of accomplishing certain goals must be evaluated against the implementation cost. For example, one objective may be to monitor the energy consumption of every energy-consuming device at a facility or military base. This would be very expensive and may have an insignificant impact on reducing overall energy consumption. For that reason, guidelines for evaluating the costs and benefits of the project need to be established. Regardless of the goals and data requirements, starting with a relatively small metering program that allows for flexibility and scalability is prudent. Standardizing, where possible, may save time and money.

Identify Technical Criteria

Once the goals and data products have been established, the technical criteria associated with collecting, processing, and presenting the data must be identified. The technical criteria should be developed in a top-down fashion (i.e., examine the needs from the final product, the reports or other data products, down to the meters). In this way, the system is designed to support the goals.

When identifying technical criteria, future requirements and scalability of the system should also be considered. For example, current requirements may require a daily data interval with monthly database updates, but future needs may dictate 15-minute or even 1-minute data intervals with near-real-time database updates. Also, options and upgrades to the initial system that would be costly additions later may be worth considering. A good example is meter memory, which is relatively inexpensive when added at the factory. However, adding memory to equipment already in the field involves pulling meters and adding the upgrade, creating service disruptions and increasing labor costs.

Budget constraints will typically limit the type of system that is procured. Acquiring all the desired features and hardware quantities may not be possible during the initial project implementation. A scalable system is recommended and provides the opportunity to start by metering some loads and grow as its usefulness is proven. If funds are limited, one strategy is to focus initial metering on the buildings or equipment systems with the highest energy use. Using a phased approach provides the opportunity to modify metering goals and data requirements accordingly.

Technical Criteria Categories

These include technical criteria associated with the main metering system components.

Data presentation/analysis/reporting. Users interact with the data presentation, analysis, and reporting functions of the metering system more than any other component. These functions are essential for users to achieve the metering system goals. The features that provide the proper analysis and reports (user access and software capabilities) are important to consider.

Aspects of user access include the following:

- The overall system structure should support the number of potential users.

- The number of allowable simultaneous users accessing the data should support system goals. Increasing that number unnecessarily may increase costs.

- Security and authorization requirements for site access will vary, depending on facility data security requirements. Permission criteria for different levels of site access and control need to support these requirements.

- Client/server software should support all access and security requirements and be easily maintained.

The analysis and reporting software must support all reporting and analysis tasks required for meeting goals and objectives. For instance, if near-real-time pricing information is needed and the software does not support that functionality, the user will be unable to manage expectations. All technical criteria should be specified when the data products are defined.

Data-collection system/data archive. The data-collection and storage system is used to retrieve data from the meters and store information in an easily accessed database. Here are some criteria for this system.

Frequency of data updates. Several methods are available for communicating and collecting data from meters. Some are designed primarily for monthly meter reading; others collect data at 15-minute intervals, while others provide near-real-time data. Table 3 shows examples of the minimum update rate for various goals, which should always be established to help define frequency requirements.

Number of meters. A data-collection and archive system capable of reading thousands of meters may be excessive when the goals of the metering program require fewer than 100. However, flexibility for expansion should be considered when specifying system requirements.

Database structure and accessibility. The performance and robustness of the database are critical to overall system performance. Slow response times and unstable systems will frustrate users.

Database maintenance issues. Project managers should interact with in-house IT personnel regarding possible locations for the metering system database and server (if it has a dedicated server), activities surrounding data backup and archiving, and ongoing maintenance. Security requirements should also be discussed.

Communications. Several methods are available for communicating between the meters and the host computer. The communication method should be selected based on its cost, future scalability, and ability to meet the overall goals of the metering system. Important questions include:

- How many meters are planned?

- Will the proposed meters be located in relatively dense or remote locations?

- Do the data need to updated continuously or monthly?

- What are the barriers to installation?

Meters. The technical requirements of the meters used to measure electricity consumption and other parameters need to be identified. The load should be defined. Although site conditions will affect metering appropriateness, some considerations may include defining the metering application (tenant building, remote facility, temporary load); identifying the number, type, and size of the loads; and classifying the level of metering accuracy required. Also, maintenance personnel may need to reset meters from time to time and verify accuracy. A few general guidelines are as follows:

- meter buildings with demands larger than 200 kW

- meter buildings with energy costs more than $1,000/month

- to realize the full benefit of the metering system, the monitored loads should be manageable or controllable either manually or with an automated system unless they are monitored for reporting purposes only

- metering tenant spaces may be difficult because of constant changes in space configurations

- display local information on the meters for manual verification and troubleshooting.

Evaluate Current Infrastructure

After identifying the technical criteria, metering equipment should be inventoried for a general idea of the IT infrastructure. The number of utility meters and submeters should be audited and wiring diagrams obtained to understand which areas the meters are monitoring. From the wiring diagrams, determining sensible ways to select areas to monitor and meter locations may be easy.

Valuable time can be saved talking to IT staff about communication options and networks. Ethernet or DSL systems may already be in place. Dedicated phone lines may be required. Computer servers may have excess capacity or database systems with scheduled backup and archive activities may be available. For most agencies, security regarding LANs, authorization levels, and Internet access have been addressed and simply need to be discussed and implemented.

Staffing levels should also be evaluated. The hardware and software of a metering system do not provide a turnkey solution for resolving power quality issues and implementing energy efficiency changes. Dedicated personnel must manage the data and provide results.

Develop and Evaluate Costs and Benefits

The traditional way to evaluate the cost effectiveness of any capital investment is to perform a life-cycle analysis of the costs versus the benefits. Evaluating the benefits of implementing a metering system may be more difficult than a project such as replacing standard lighting with energy-efficient lighting. Through metering, a better understanding of the way energy is used can help identify substantial opportunities for reducing energy costs. The value of this understanding is difficult to quantify, but significant. The benefits of a metering system must be carefully examined, because many are synergistic. For example, metering can also provide metrics for activities such as operations and maintenance.

Case studies have shown that utility costs can be reduced by 25% or more by identifying energy savings opportunities through metering. A less aggressive estimate is approximately 5%. An initial estimate may be formulated through an energy audit. Also, preliminary screening criterion can be applied to eliminate some buildings from consideration. An example screening criteria might evaluate the life-cycle costs of metering a building versus the potential energy saving, which is a function of the building load. Building load may not be known, because of a lack of load data; therefore, estimates can be based using typical EUIs for buildings of similar type and location. Typical EUIs are available from the Energy Information Administration Commercial Building Energy Consumption Survey (http://www.eia.doe.gov/emeu/cbecs/). Estimates of the potential energy reductions will vary, depending on the condition of the building and the ability to perform any load control or reduction. The metering data can be used to reduce facility downtimes, size electrical equipment, and save on labor costs.

After the potential benefits are evaluated, the costs of metering a building need to be estimated. Metering costs will vary, depending on the feature set selected. For instance, meters with capabilities can cost $5,000; a relatively simple meter costs less than $1,000. Similarly, the cost of the metering system infrastructure (servers, software, communication equipment, etc.) will

vary depending on the overall size of the installation. When the monitoring of a specific building is evaluated, the additional cost of the metering system infrastructure should be considered.

A substantial cost is the labor to evaluate and respond to the reports. To realize any cost savings from metering, staff involvement at many levels, including maintenance, energy purchasers, and facility managers should be accounted for in the cost estimate. Additional time will have to be allocated to various activities to achieve maximum benefit, especially during the initial stages of the project.

After estimating the costs and benefits of the metering program, the cost/benefit analysis can be performed. If the analysis shows that the costs are greater than the benefits over the life cycle period, the metering program, as currently specified, may not be appropriate or should be respecified to reduce costs or increase benefits. For example, reducing the number of buildings to those with the greatest consumption or specifying meters that collect only energy consumption data and not power quality information may improve the financial analysis.

Develop Performance Specifications

After the metering program is fully defined, the system requirements can be specified in documents used for requesting technical and price proposals where best value is selected. Performance-based, rather than product-based, specifications are recommended to provide flexibility for vendor response. A performance specification outlines the performance attributes of the system, but does not list the specific hardware and software that must be used for compliance. For example, meters can be specified to meet minimum accuracy requirements and data-storage capabilities, but a specific manufacturer's model is not generally included. However, these can be included as necessary to meet a facility's specific requirement. A metering system can be very complex, and developing a comprehensive performance specification may require input from experts in various disciplines. However, clearly developing a detailed performance specification will avoid confusion. An example of a performance specification that the University of New Mexico used when developing its comprehensive metering system is available for review.[18] Such a sample can be useful, but should not be used to supplant the process of first understanding the goals, then developing the requirements that form the basis for specifications.

Implement Metering System

Implementing the metering system may create many challenges. Suggestions from other federal agencies include the following:

- outsource the entire installation to contractors or leverage in-house staff when possible

- develop protocols for all aspects of handling the meters (set, repair, and calibrate meters and ensure meters are wired properly)

- define IT support, warranty issues, and training needs for the metering software

- update and add users and meters to the metering system

- understand RF issues for remote metering locations that require wireless modems. Military bases require approval for RF and can take as long as 1 year. Government frequencies may be required. The key is to interface with the frequency coordinator for each service and each area.

- coordinate and schedule excavation work and connections to electrical distribution panels. Be aware that wiring and meter setting work may require disruption in electrical service to the facility.

Implementation issues are best identified during the development of the metering program when various departments and facility personnel are solicited for their input.

Plan for Continuous Use and Evaluation

After all the planning and implementation are complete and energy information is seamlessly arriving at users computers, a plan should be established to ensure that the system is used perpetually and the maximum benefit is derived. Constant assessment is recommended. The following questions should be asked:

- Are people using the system?

- Are the right types of data being gathered and presented?

- Are the savings from using the system data to reduce energy costs, improve operations, and increase reporting productivity being documented?

- Are warranty, training, and maintenance issues being addressed?

- Would system expansion be beneficial?

For many agencies facilitating the development and implementation of a metering system, the process is rigorous and time-consuming, but the opportunities for rewards are great.

Case Study #1

DOE Site Expands Metering System

Background

In the mid-1990s, the U.S. Department of Energy's (DOE) Waste Isolation Pilot Plant (WIPP) embarked on a power metering program at its multifaceted facility in the desert near Carlsbad, New Mexico. The WIPP personnel wanted a metering system to document energy use, investigate power quality issues, audit utility bills, and identify energy efficiency opportunities. As a result, facility engineers effectively identify power quality issues by adding meters and acquiring energy data that have been used to achieve an estimated 30% reduction in energy costs and countless savings.

Owned by DOE and operated by Washington TRU Solutions (WTS), a division of Washington Group International, the site is the nation's first underground repository for transuranic waste or clothing, tools, and other items contaminated by radioactive material during the research and development of nuclear weapons. Permitting for the site began in 1988, and the WIPP received the first shipment of waste in 1999.

The facility encompasses roughly 270,000 ft^2 of conditioned space, more than 60 buildings, and an enormous underground storage area situated in a salt formation at 2,150 ft below the Earth's surface. Annual utility costs for the site in 2001 were approximately $755,000; consumption averaged 18 million kWh/yr.

Metering Presents Opportunities

The driving force behind the installation of power metering at the WIPP has been the federal mandates to reduce energy consumption in buildings, laboratories, and processes and the need to provide ongoing documentation. Before the metering program began, facility staff had difficulty monitoring and documenting baseline energy use and efficiency gains from utility meters located at the main delivery point—a high-voltage substation. By installing power metering at strategic locations, engineering personnel were able to monitor and document energy use from selected loads.

Beyond the main utility metering point, the WIPP owns and maintains 11 electrical substations aboveground and three medium-voltage distribution switchgear, two substations, and six portable power centers belowground to provide power for operating the numerous buildings and various industrial processes. The site is organized around the different industrial processes required for handling the waste aboveground and storing and maintaining the material in the underground cavities.

The electrical engineers wanted a metering system that could do the following:

- monitor all electrical parameters

- monitor power quality

- capture abnormal event information

- remotely monitor status of switching devices and relays

- remotely control switching devices.

The engineers hoped to use the metering data to audit the energy bills from the local electric utility. Finally, trend data and load profiles would be developed from the metering system to help identify on-site load shedding and energy efficiency opportunities.

Special Requirements

Beginning in 1993, the WIPP received seed money from the DOE headquarters to fund various energy efficiency activities and establish the framework for the metering system. Engineering personnel evaluated different metering options ranging from installing canned watt-hour meters with minimum capabilities to using sophisticated electronic metering with communication protocol. The costs for the options were $800 to $5,000 per meter.

Regardless of the meter type selected, the project would be labor intensive and require cooperation among numerous departments. No overhead electrical lines are permitted at the WIPP site and ground excavations cost approximately $150/ft. Also, work such as adding wiring and setting meters on the electrical distribution system cannot be performed when the system is "hot" or energized. De-energizing a substation or process to install metering would require extensive scheduling and coordination among numerous personnel.

In addition, the facility operates under stringent technical requirements and has specific equipment needs because it handles transuranic waste. For instance, locations where waste is present require negative differential pressure. This includes underground storage, which has specific ventilation requirements. All requirements had to be identified and considered for the metering system to be effective.

Standardization

The senior engineer from the start of the project, James Hedin, determined that the management, design, coordination, and labor required to install a metering system would constitute approximately 80% of the total cost. The other 20% of the project cost would depend on the products and vendors selected. Hedin decided to look for a server-based software system that could access meters remotely from a personal computer, provide a multiseat operation over a network, and meet all identified facility goals.

Hedin and senior engineers Jorge Alva and Al Boyd decided to standardize its metering program using one vendor's products: Power Measurement's ION® class meters and associated software. The meters communicate using native protocol over the WIPP Ethernet and provide energy data for authorized personnel through the ION Enterprise™ software. The hardware and software system provides trend data and load profiles for analyzing energy use and establishing baselines; complex power data, including waveforms, voltage, and electrical distribution data for power quality investigations; and shadow billing reports for verification of utility charges.

Most of the installation work for the metering project has been "piggybacked" or included with major renovation or maintenance projects that already included excavation work and scheduled downtimes for the electrical systems. The "piggyback" approach has allowed the engineers to minimize construction costs, where possible, and concentrate funds on purchasing more hardware. Facility personnel have expanded the system from 0 to 16 meters monitoring mostly industrial processes to 40 meters currently monitoring all the substations, numerous processes, and several individual buildings. The present system also includes four wireless RF modems that send data from meters installed at remote sites.

Security has not been an issue. The metering system software has its own dedicated server that is only accessible over the WIPP Intranet system. Firewalls protect against unauthorized access. The system is password protected with different functionality available depending on a user's authorization level. Having the metering system operate on a dedicated server also provides

reduced traffic and robust performance. The system may become Internet accessible in the future.

Benefits for the WIPP

Hedin says the metering program has already paid off by providing energy information for the following areas:

Load shedding and energy efficiency opportunities have been identified. Recently, facility engineers began a commissioning program. One of the first projects included using metering data to commission new direct digital controls (DDCs) and occupancy sensors. The metering data quickly identified that the controls and sensors were not operating properly and adjustments have been made. Also, facility engineers now establish baseline energy use in areas where energy efficiency or load-shedding projects are planned.

Investigation and documentation of power quality issues have improved. The facility experienced a failure in one substation, resulting in downtime until the fault could be identified. Using waveforms captured from the metering system and fault analysis, the WIPP staff proficiently determined the cause, saving significant time and effort. In addition, salt and sand are constant foes of the electrical distribution system. Staff uses the power data from the metering system to identify weaknesses in the power distribution and substation design and recommend modifications.

Energy-use documentation has been enhanced. For energy reporting purposes, lighting and heating, ventilation, and air conditioning needs to be differentiated from the industrial processes dealing with the waste. With the current system, 40 meters are used to distinguish building from process loads, making reporting more efficient.

Auditing of utility bills has been enhanced. The software has provided shadowing of utility billing activities that enables the WIPP personnel to more effectively audit utility costs and detect discrepancies.

Conclusion

Over the past several years, the WIPP personnel have seen the economic and operating advantages from the metering program. Significant issues have been identified and changes implemented after metering points are brought on-line at the facility.

Hedin's near-term goal is to reach 60 meters, continuing to separate process from building loads where possible. However, he envisions the process of adding meters and gathering and using data to continue indefinitely.

Project Information:

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Case Study #2

GEMnet System Shines

Background

Approximately 3 years ago, the U.S. General Services Administration (GSA) Pacific Rim Region launched GEMnet (GSA Energy and Maintenance Network) to assist in energy efficiency and maintenance activities for its massive building stock. GEMnet is a collection of information technology applications using a common database and operating system that integrates various facility management functions and communicates over the Internet.

The GSA is the federal government's landlord, owning and operating more than 250 million ft^2 of federal building space in North America. GSA's mission is to help federal agencies better serve the public by offering superior workplaces, expert solutions, acquisition services, and management policies at the best value. The Pacific Rim Region is the largest geographic area of the GSA and is responsible for managing roughly 20 million ft^2, consisting mostly of office space in California, Nevada, Arizona, Hawaii, and the Pacific territories.

GSA priorities are to do the following:

- manage assets responsibly

- operate efficiently and effectively

- ensure financial accountability .

GSA personnel thus envisioned developing a common data platform with support personnel and applications. The system would provide information to users that would help preserve the building portfolio, support the energy efficiency policy goals outlined in Executive Order 13123, and identify cost-effective opportunities for improvements.

Development of GEMnet

With a history of using innovative building technologies, the Pacific Rim Region developed the GEMnet system for centralized tracking of building maintenance and monitoring of building energy systems throughout their building portfolio. The system also provides the capability to participate in California's demand-response programs during times of market and supply volatility.

The system is based on an IT infrastructure with an open protocol design and integrates the following functions:

- centralizes maintenance and management activities into one system

- provides a platform for fault detection and diagnostics

- supports remote programming and optimization of building automation systems (BAS)

- presents a common front-end to users for various BAS

- maintains and updates a central database for maintenance services and equipment inventories

- provides a platform for remote control and demand-reduction activities

- uses the Internet to provide easy access for users.

The GEMnet system can interface real-time applications with a common database management system. For example, work orders for equipment malfunctions can be generated based on system alarms detected from BAS or other fault detection systems.

By linking real-time data to static equipment inventories and work records, the GSA personnel are able to strengthen maintenance programs, mitigate tenant service calls, and identify potential energy-savings opportunities.

Technology Overview

The GSA designed the GEMnet system using two concurrent paths:

- At the regional level, personnel develop and support the various applications that reside on a centralized server, maintain the database engine, and supply the application service provider infrastructure.

- At the building level, personnel provide troubleshooting and quality assurance for BAS.

A retro-commissioning program is being implemented using GEMnet data. Other applications are also being integrated into the regional computerized maintenance management system (CMMS).

For a typical building in the Pacific Rim Region, the GEMnet system starts with BAS communicating over the Internet to the regional infrastructure using DSL. The standardized open protocol for the system is BACnet. If the BAS is BACnet capable, a gateway/router provides the communication link; if not, a bridge device is used to translate the GEMnet protocol to the legacy protocol.

In most cases, whole-building power is measured from the main power feed using the BAS. A separate power monitoring system has been installed in one building, with tentative plans for expansion to other buildings. Limited submetering is currently provided through the BAS and is fielded through the power monitoring system. Overtime systems, such as rooftop chillers, are commonly metered through the BAS. More systematic submetering may be implemented in the future.

One of the GEMnet applications is a Web-based BAS front-end, used primarily as a data collection platform. The data are polled according to set intervals, date and time stamped, and transmitted to the regional server via the Internet on request or when memory limitations require transfer. The data collected from the individual buildings and stored by the centralized server can be viewed and downloaded by any Web site user.

Applications are based on an ODBC (Open Database Connectivity) database management system. With the infrastructure based on open protocol, communication links between various networks (Figure 6) should be possible with minimal difficulty. Security is managed primarily through password protection (deep links protected), and Internet server firewall protections.

The open protocol design enables the GSA to support continued competition from vendors regarding future applications, hardware, and services for the GEMnet system. The common interface enables GSA staff and contractors to train and operate consistently on one scheme.

Current Activities

At this time, the GEMnet BAS front-end application has been fielded to 11 buildings (three are temporarily off-line pending resolution of a network issue), with three more following in the immediate future. The degree of data acquisition, monitoring, and control activities varies at each
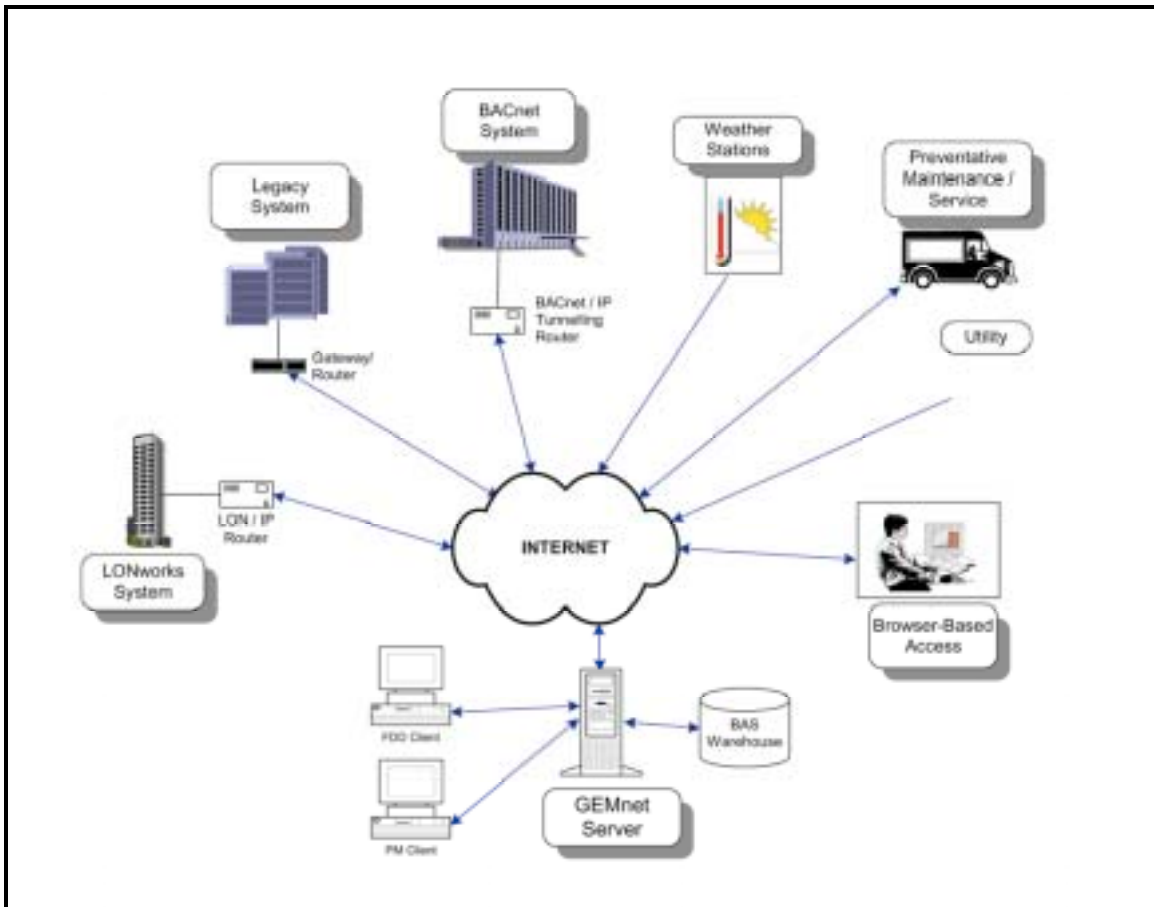
Figure 6. The data transfer configuration for GEMnet system enables communication links between various networks

site, partly because of differences in BAS, facility maintenance and operations staffing, and building management teams. The GEMnet program is designed to be cooperative, adaptive, and responsive to requests from building management teams.

The buildings range in size from less than 10,000 ft^2 to more than 1 million ft^2. Encompassing a wide variety of climates, the energy-use intensity for the sites varies from 22 to 83 kBtu/ft^2/yr (thousand British thermal units), and the associated energy costs vary from a low of \$0.54 to a high of \$2.06 per ft^2/yr.

In the summer of 2001, the Pacific Rim Region used GEMnet to participate in a Demand Relief Program administered by the California ISO for reducing peak energy demand during times when electricity supplies were minimal. GSA personnel used the system to raise space temperatures in two buildings, offsetting about 1 MW of demand and receiving financial compensation based on achieved reductions.

Improvements to the building BAS are frequently necessary for improved operation and efficiency and to ensure accurate instrumentation to provide data to the system. One large federal building has been almost entirely reprogrammed. A systematic retro-commissioning program is now underway.

Another application the GSA personnel are developing at the region level is the CMMS program, which tracks preventive maintenance and inspection schedules and issues work orders. One

function that is being added to the CMMS program is the ability to allow GSA building tenants to directly enter and track work order requests. If the request is related to an occupant comfort issue (temperature too hot or cold), the CMMS program will automatically display the temperature in the space based on the BAS at the time of the request.

Benefits of System Expanding

The GEMnet system is helping the Pacific Rim Region to reduce operating costs, improve the efficiency of building energy systems, reduce peak energy demand, and enhance maintenance services at 13 GSA sites.

Within the infrastructure of GEMnet, the CMMS for asset and maintenance tracking has been created, energy and maintenance data are continually being warehoused to provide performance benchmarking and data analyses, and field operations are becoming automated with centralized support available.

Pacific Rim Region employees continue to expand the number of buildings, the variety of applications, and the number of uses of the system. Additionally, GSA is developing guidelines regarding networks, communications, and applications for new BAS projects. Overall, the Web-based information system represents the integration of various technologies to advance asset management and energy efficiency activities for the federal government's largest landlord.

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Appendix A: Legislation Information

The following legislative information is based on a presentation to the August 27, 2002, Federal Utility Metering Panel, held in Golden, Colorado, by Deb Beattie of the National Renewable Energy Laboratory.

Federal Energy Mandates, Directives & Standards

- Law: Energy Policy Act, 1992

- Executive Order: EO 13123 Greening the Government through Energy – Efficient Management, 1999

- Regulation: 10 CFR Subpart D - 434.401 Electrical Power and Lighting Systems (Replaced 435 October 8, 2001)

Subpart D - Building Design Requirements – Electric Systems and Equipment

434.401 Electric Power and Lighting Systems

- Single tenant building with service >250 kVA

- Tenant spaces with connected load >100 kVA

Shall have provisions for check metering of electrical consumption subdivided for

- Lighting and receptacles

- HVAC systems and equipment.

Shall have provisions for check metering of electrical consumption subdivided for

- Systems >20 kW
  - Service Water Heating (SWH)
  - Elevators
  - Special occupant equipment and systems

- Tenant-shared HVAC and SWH.

Subdivided feeders shall contain provisions for portable or permanent check metering including the following:

- Safe access

- Sufficient space for clamp-on meters or split core transformers

- Identification

- Schematics.

107th Congress: Terminated ~ Comprehensive Energy Legislation

- House drafted Interval Data legislation

- Senate accepted metering legislation as an amendment to H.R. 4 on April 25, 2002

- Legislation is now in Joint House – Senate Conference Committee

House Language

Sec. 126 Use of Interval Data in Federal Buildings

NLT Jan. 1, 2003, agencies shall use, for the purposes of efficient use of energy and reduction in cost of electricity, interval consumption data that measure in real time or daily basis the consumption of electricity; agencies to develop plans to meet the requirement including responsible personnel.

Terminated ~ Comprehensive Energy Legislation

SEC. 912. ENERGY USE MEASUREMENT AND ACCOUNTABILITY.

Section 543 of the National Energy Conservation Policy Act (42 U.S.C. 8253) is further amended by adding at the end the following:

Metering of Energy Use

(1) DEADLINE- By October 1, 2004, 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 submetered in accordance with guidelines established by the Secretary under paragraph (2).

Metering of Energy Use ~ Deadline

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.

Metering of Energy Use ~ Guidelines

(2) Guidelines-

(A) IN GENERAL- Not later than 180 days after the date of enactment of this subsection, the Secretary, in consultation with the Department of Defense, the General Services Administration and representatives from the metering industry, utility industry, energy services industry, energy efficiency industry, national laboratories, universities and federal facility energy managers, shall establish guidelines for agencies to carry out paragraph (1).

Metering of Energy Use ~ Guidelines

(B) REQUIREMENTS FOR GUIDELINES- The guidelines shall--

(i) take into consideration--

(I) the cost of metering and submetering and the reduced cost of operation and maintenance expected to result from metering and submetering;

(II) the extent to which metering and submetering are expected to result in increased potential for energy management, increased potential for energy savings and energy efficiency improvement, and cost and energy savings resulting from utility contract aggregation; and

(III) the measurement and verification protocols of the Department of Energy;

Metering of Energy Use ~ Guidelines

(ii) include recommendations concerning the funding and trained personnel necessary to gather and use the metering information to track and reduce energy use;

(iii) establish date(s), not later than 1 year after the issuance of the guidelines, on which the requirements specified in paragraph (1) shall take effect; and

(iv) establish exclusions from the requirements specified in paragraph (1) based on the minimum quantity of energy use of a federal building, industrial process, or structure.

Metering of Energy Use ~ Plan

(3) PLAN- No later than 6 months after the date guidelines are established under paragraph (2), in a report submitted by the agency under section 548(a), each agency shall submit to the Secretary a plan describing how the agency will implement the requirements of paragraph (1), including (A) how the agency will designate personnel primarily responsible for achieving the requirements and (B) demonstration by the agency, complete with documentation, of any finding that advanced meters or advanced metering devices, as defined in paragraph (1), are not practicable.

Federal Restructuring Legislation

Bill Number: H.R. 4
Short Title: Securing America's Future Energy Act
Introduced: July 27, 2001
Sponsor: Congressman W. J. (Billy) Tauzin (R-LA)
http://www.eia.doe.gov/cneaf/electricity/page/restruct_bills/hr4.html

Purpose: To enhance energy conservation, research, and development and to provide for security and diversity in the energy supply for the American people, and for other purposes.

Summary: Expresses the sense of Congress that the U.S. should take all actions necessary in the areas of conservation, efficiency, alternative source, technology development, and domestic production to reduce the U.S. dependence on foreign energy sources from 56 percent to 45 percent by January 1, 2012, and to reduce U.S. dependence on Iraqi energy sources from 700,000 barrels per day to 250,000 barrels per day by January 1, 2012.

Appendix B: Glossary of Terms

Access—Allowed availability to information on a network

Actual Peak Load Reductions—The actual reduction in annual peak load (measured in kilowatts) achieved by consumers. It reflects the real changes in the demand for electricity at a consumer's site resulting from load shedding or load-reduction programs that are in effect at the same time the utility experiences its peak load, as opposed to the installed peak-load reduction capability. It should account for the regular cycling of energy efficient units during the period of peak load.

Address—Reference number assigned to an interfaced device

Application Service Provider (ASP) —Third-party entities that manage and distribute software-based services and solutions to customers across a wide-area network from a central data center

Automated Meter Reading (AMR)—AMR is a form of advanced (or enhanced) metering that uses communications devices to communicate data from the meter to the meter data-management provider. AMR may be used to transmit simple energy-use data from the meter, or to transmit more complex measures of energy recorded in the meter, or to implement advanced functionality, such as outage detection or remote programming.

Baud Rate—The rate of speed at which information is transmitted over communications lines; expressed in bits per second

Bits—A contraction of binary digits, the smallest unit of information in binary notation. A bit has the value of a zero (0) or a one (1). For example, the binary number 0110 consists of four bits.

Btu (British thermal unit)—A standard unit for measuring the quantity of heat energy equal to the quantity of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit.

CDPD—The Cellular Digital Packet Data sends digital packets of data to the Cellular phone system; these packets are placed in between transmissions of analog (voice) data.

Coaxial Cable—A cable consisting of an outer conductor concentric to an inner conductor, separated from each other by insulating material

Circuit—A conductor or a system of conductors through which electric current flows

Daisy Chain—The physical method of cabling devices in series

Demand (electric)—The rate at which electric energy is delivered to or by a system, part of a system or piece of equipment, at a given instant or averaged over any designated period of time

DSL—Digital Subscriber Line

Electric Utility—A corporation, person, agency, authority, or other legal entity or instrumentality that owns and/or operates facilities within the United States, its territories, or Puerto Rico for the generation, transmission, distribution, or sale of electric energy primarily for use by the public and files forms listed in the Code of Federal Regulations, Title 18, Part 141. Facilities that qualify as cogenerators or independent power producers under the Public Utility Regulatory Policies Act (PURPA) are not considered electric utilities

Energy—The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks.

Electrical energy is usually measured in kilowatt-hours, whereas heat energy is usually measured in British thermal units.

Energy Efficiency—Refers to programs that are aimed at reducing the energy used by specific end-use devices and systems, typically without affecting the services provided. These programs reduce overall electricity consumption (reported in megawatt-hours), often without explicit consideration for the timing of program-induced savings. Such savings are generally achieved by substituting technically more advanced equipment to produce the same level of end-use services (e.g., lighting, heating, motor drive) with less electricity. Examples include high-efficiency appliances, efficient lighting programs, high-efficiency heating, ventilating and air conditioning (HVAC) systems or control modifications, efficient building design, advanced electric motor drives, and heat recovery systems.

Ethernet—A specification for local communication networks that employs cable as a passive communication medium to interconnect different kinds of computers, information processing products, and office equipment at a local site

Extensible Markup Language (XML)— Specification that allows designers to create their own customized tags, enabling the definition, transmission, validation, and interpretation of data between applications and between organizations

Fiber Optics—A medium that uses light conducted through glass or plastic fibers for data transmission

Firewall—A system designed to prevent unauthorized access to or from a private network. Firewalls can be implemented in both hardware and software, or a combination of both.

Firmware—Operating system and/or program within a device

Gateway—In LANs, a computer system and its associated software that permit two networks using different protocols to communicate with each other. A gateway translates all protocol levels from physical layer up through applications layer and can be used to interconnect networks that differ in every detail

Hourly Metering—Hourly metering is a type of interval metering where the measurement or recording of customer use is collected in 6-minute intervals. The competitive metering model is based upon the implementation of hourly metering of customers or the application of load profiles, which average customer use over hourly periods.

HyperText Transfer Protocol—The underlying protocol used by the World Wide Web. HTTP defines how messages are formatted and transmitted and what action Web servers and browsers should take in response to various commands.

Interface—A device that allows communication between systems or ports of systems

Interval Metering—Interval metering is the measurement of customer energy use by fixed time periods or intervals. Typically, the interval time period is 15 minutes, but can vary according to the customer or T&D system needs. Today, interval metering is provided to commercial and industrial customers and some residential customers. In the future, in an unbundled environment, the residential market may require more frequent interval measurements.

IP Address—Internet protocol address. See also *Ethernet* and *address*

KiloWatt (kW)—One thousand watts

KiloWatt-hour (kWh)—One thousand watt-hours

Load Aggregation—Aggregation of energy consumption from facilities that are geographically separate from each other for purposes of acquiring and billing utility services

Local Area Network (LAN)—Computer network that spans a relatively small area

MegaWatt (MW)—One million watts

Mixed-mode—Supporting both POWERLOGIC and Modbus devices on the same communication daisy chain

Modem—Modulator-demodulator. A device or program that enables a computer to transmit data over telephone lines

Modbus® Protocol—A messaging structure developed by Modicon in 1979, used to establish master-slave/client-server communication between intelligent devices. It is a *de facto* standard, truly open, and the most widely used network protocol currently available

Multipoint Communications—A method of communication in which a single device can communicate to multiple devices

MV-90—The utility industry *de facto* standard for data collection and storage systems. This system was developed so that meters from different vendors could be read and the data stored in a consistent manner

NEMA Standards—Property characteristics adopted as standard by the National Electrical Manufacturers Association

Network—A group of computing devices that are connected to each other by communications lines to share information and resources

Non-volatile Memory—Memory that retains its contents when power is lost

Peak Demand—The maximum load during a specified period of time

Point(s) of Delivery—Point(s) of interconnection on the Transmission Provider's Transmission System where capacity and/or energy transmitted by the Transmission Provider will be made available to the Receiving Party. The Point(s) of Delivery shall be specified in the Service Agreement

Power Line Carrier (PLC)—Communication system that transmits data between devices over power lines

Programmable Logic Controller (PLC)—A solid-state control system that has a user programmable memory for storage instruction to implement specific functions such as I/O control logic, timing, counting, arithmetic, and data manipulation

Protocol—A standardized procedure for establishing a communications link between devices and that is based on such elements as word structure or word length

Radio Frequency (RF)—Refers to alternating current (AC) having characteristics such that, if the current is input to an antenna, an electromagnetic (EM) field is generated suitable for wireless broadcasting and/or communications

Real-Time Metering—Metering that records consumer use in the same time frame as pricing changes in the market, typically hourly or more frequently

Real Time Pricing (RTP)—The instantaneous pricing of electricity based on the cost of electricity available for use at the time the electricity is demanded by the customer

RS-485 Serial Communications Bus— An Electronics Industry Association (EIA) standard for multipoint communications. RS-485 is similar to RS-422 but can support more nodes per line because it uses lower-impedance drivers and receivers.

TCP/IP—Abbreviation for Transmission Control Protocol/Internet Protocol, the suite of communications protocols used to connect hosts on the Internet. TCP/IP uses several protocols, the two main ones being TCP and IP. TCP/IP is built into the UNIX operating system and is used by the Internet, making it the *de facto* standard for transmitting data over networks.

Time of Use—The pricing of electricity based on the estimated cost of electricity during a particular time block

Thin Client—In client/server applications, a client designed to be especially small so that the bulk of the data processing occurs on the server

Server—A computer or device on a network that manages network resources. For example, a file server is a computer and storage device dedicated to storing files

Watt—The electrical unit of power. The rate of energy transfer equivalent to 1 ampere flowing under a pressure of 1 volt at unity power factor

Watt-hour (Wh)—An electrical energy unit of measure equal to 1 watt of power supplied to, or taken from, an electric circuit steadily for 1 hour

XML—Extensible Markup Language is a simple, very flexible text format

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Appendix D: Representative Metering Manufacturers

This section describes the offerings of selected manufacturers. It is not intended to be an exhaustive list, but instead provides a short description of some of the major suppliers. Because of the nature of the technology, capabilities of equipment and software change at a rapid rate and, as a result, Web addresses of each company are listed to enable access to their latest product and service offerings

Siemens Metering

Siemens Metering manufactures a range of products suitable for metering loads from substations to commercial/industrial loads. It also markets software for data presentation and analysis and a wireless AMR product.

http://www.ptd.siemens.com/meters/00_meters.html

http://www.ptd.siemens.com/meters/autometer.html

http://www.ptd.siemens.com/meters/www100.html

Since 1847, Siemens has been recognized as a global leader in electrical engineering and electronics. Headquartered near North Carolina's Research Triangle Park, Siemens Power Transmission & Distribution, Inc., (Siemens PTD) was established in 1997 to serve the needs of the electric power industry.

Currently, 1,800 employees are creating comprehensive solutions for the complex challenges facing the United States and international energy infrastructure. In 2000, Siemens Corporation generated more than 7,000 patents, ranking ninth overall in the United States for patent generation.

Power Measurement

Power Measurement provides electricity meters and enterprise energy management systems for energy suppliers, service providers and large consumers. Its ION® Web-ready software and intelligent metering and control devices comprise a complete, real-time information-and-control network that helps manage complex energy contracts, improve power quality, reduce energy costs, and keep operations running enterprise-wide, 24 hours a day.

ION® metering products fully address the enterprise energy management needs of energy suppliers and consumers. All products are based on patented ION technology that provides powerful "out of the box" functionality, while allowing devices and software to be customized to suit any application, and features to evolve, as needs change. Solutions are highly scalable, allowing customers to start small and grow to very large enterprise-wide systems.

http://www.pwrm.com/default.asp

Square D/PowerLogic

Square D Power Management (Square D) is a global leader in providing enterprise energy reduction and reliability solutions. For more than a decade, the POWERLOGIC® and POWERLINK® Systems have provided a proven return for Square D and continue to help customers realize significant advantages in productivity and profitability.

Web-enabled POWERLOGIC Systems provide savings through reduced utility costs, effective power equipment management, and increased power system reliability and downtime avoidance.

Square D's commercial and industrial power distribution expertise spans from single buildings to geographically dispersed enterprise systems. It offers a dedicated team of sales, service, and system engineers, with the application experience to analyze, clearly define, install, and commission the complete project.

http://www.powerlogic.com/

E-MON

E-MON, L.P., manufactures solid-state electronic kilowatt-hour meters, submeters, automatic meter reading equipment, and load profilers. E-MON's products are installed worldwide for tenant billing, cost allocation, demand-side management, and load profiling in skyscrapers, shopping centers, airports, factories, office buildings, and apartment complexes, as well as industrial, governmental, and educational facilities.

After several years of research and development, E-MON brought the first fully electronic kWh submeter to market in 1983. This product, the E-MON D-MON, quickly became the industry standard, making E-MON the leader in the submetering market. Since that time, E-MON has continued to expand its product line with state-of-the-art technology in demand profile analysis and energy consumption aggregation.

http://www.emon.com/

Itron

Itron/UTS has a series of products built around its MV-90 multivendor translation software to provide data collection and analysis capabilities to automatic meter reading.

Itron's solution portfolio includes automatic meter reading systems to meet the requirements of all customer classes and service environments, Web-enabled workforce management solutions, as well as transmission and distribution system design solutions and services. Itron also provides advanced software solutions and consulting services for collection, analysis, and application of load profile data including enterprise-wide data access, data warehousing, load research, complex billing and settlement, and Web-based data access and exchange.

http://www.itron.com/

eMeter

eMeter's mission is to ensure (1) that every consumer has access to his or her own detailed hourly electric-use data so, as an informed buyer, he or she can make the right energy choices; and (2) that electric utilities have access to the data so they can deliver power more efficiently.

eMeter envisions an electric industry with real-time metering of power and Internet access to every electric socket for all electricity customers. Time-based metering empowers and informs energy users, enabling them to combat the market power of wholesale generators through peak demand response. Automatic demand response through remote control of equipment, thermostats, and appliances makes it simple and easy for customers. The Internet makes possible low-cost, powerful display of data and implementation of equipment, thermostat, and appliance controls.

eMeter uses public networks and industry standards. It delivers its solution in partnership with utilities and via a consortium of California-based and global companies.

http://www.emeter.com/

Silicon Energy

Silicon Energy provides enterprise energy management software solutions that enable interaction between energy providers and energy users to reduce energy use, lower energy costs, and optimize energy procurement processes. Their EEM Suite™ uses an Internet-based software platform to integrate geographically dispersed energy-management systems and equipment into an enterprise-wide network. It combines powerful analysis tools, external data sources, advanced data visualization, and Internet-based monitoring and control of energy assets to allow energy users and providers to transform information into meaningful cost and risk reduction and improved operational efficiency.   Rather than manufacture meters, Silicon Energy provides software to extract information from meters and present useful results.

http://www.siliconenergy.com

Automated Energy

Automated Energy (AE) provides an integrated system that allows businesses to know and understand their energy consumption use, enterprise wide. Here are some of the capabilities it provides:

- consumption data gathering and load profiling

- metered load data collection for all facilities

- view load profile information

- cost comparisons from rate and price offers

- bill estimate calculations from what-ifs

- real-time Web-enabled power monitoring

- Application Service Provider (ASP) where AE hosts and manages provisioned software applications; coordinates the ongoing support, maintenance, and upgrades of those applications; and delivers them to customers via the Internet

- data-management systems integration, allowing access to multiple metering and communications technologies

- outage detection and reporting

- enterprise-wide analysis.

http://www.automatedenergy.com

SchlumbergerSema

CellNet: SchlumbergerSema CellNet technology provides a unique approach to wireless communications that leverages open standards, delivers state-of-the-art management systems, and offers the multiple levels of security required for wireless communications. Data can be collected cost effectively from hundreds to thousands of end points because of the scalability of the network. This provides an economic edge to customers by delivering cycle-based and real-time, up-to-the-minute information more easily, quickly, and cost effectively than ever before possible.

Using a distributed, object-oriented, three-tiered client/server network architecture, the network provides a powerful, integrated system for collecting, processing, and delivering valuable information quickly and reliably. The system is designed with two-way communications

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capabilities across all levels of the network that are scalable, reliable, and economical. An open, standards-based architecture at the wide-area network level ensures system flexibility and smooth, easy integration with utility, energy service provider, and commercial systems.

UtiliNet: SchlumbergerSema UtiliNet is a two-way wireless data communication system combining spread-spectrum, connectionless mesh architecture, and packet-switching technologies to ensure high-speed and accurate data transmission. The UtiliNet technology is based on a network of programmable intelligent radios that create a dynamic multipoint-to-multipoint communication grid. The result is an extremely efficient, autonomous network that quickly and consistently provides accurate information and reliable network answers for remote telemetry and distributed control applications.

The UtiliNet wireless fixed network not only enables utilities to communicate with end devices in the field, it provides distributed control throughout the network. Utilities stay in touch, minute-by-minute, with critical customer information and functionality to help companies achieve both operational and financial efficiencies.

http://www.slb.com/utilities/technologysolutions/RTEM/fixednetwork.html

Endnotes

[1] For existing legislation see Appendix A; new initiatives include Federal Facility Energy Management Act of 2001 (Introduced in Senate)[S.1358.IS] 8/3/2001 Referred to Senate committee. Status: Read twice and referred to the Committee on Energy and Natural Resources.

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17 Information Systems Security Services are available to our customers in order to support their missions. For further information or assistance with any of these services, please contact the Navy INFOSEC Technical Assistance Center (ITAC) Toll-Free 1.800.304.4636 or DSN: 588-5426/4286.

18 University of New Mexico Comprehensive Integrated Metering and Monitoring System (CIMMS) Specifications. The University of New Mexico CIMMS contract and specifications are available for download at the address provided below. These should be used as a case study and sample, as they were developed to meet specific goals and criteria at the University of New Mexico. http://www.appa.org/energy/unm.html
Further discussion of the project resulting from these specifications is available in the following case study, provided by Square D, who provided much of the electricity metering system. http://www.powerlogic.com/pdf/cs34.pdf

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13. ABSTRACT *(Maximum 200 words)*

In support of federal agencies considering the approach to utility metering appropriate for their facilities, the U.S. Department of Energy Federal Energy Management Program offers this publication as an overview of options in metering technology, system architecture, implementation, and relative costs. It provides advanced metering systems information to help potential users specify, acquire, use, and expand systems. It also addresses basic security issues and provides case studies and information resources.

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