California Energy Commission
Public Interest Energy Research Program

LBNL-52510
(HPCBS No. E5P2.2T1b5)

HPCBS

High Performance Commercial Building Systems

Web-based Energy Information Systems for Energy Management and Demand Response in Commercial Buildings

Element 5
Project 2.2
Task 1

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April 18, 2003

LBNL-52510
CD-484

Web-based Energy Information Systems for Energy Management and Demand Response in Commercial Buildings

Final Report

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Lawrence Berkeley National Laboratory

Sponsored by the California Energy Commission's
Public Interest Energy Research Program and the US Department of Energy

High Performance Commercial Building Systems
Element 5 – Integrated Commissioning and Diagnostics

Task 2.2.1- Fault Detection and Diagnostics Tools and Techniques

This work was supported by the California Energy Commission, Public Interest Energy Research Program, under Contract No. 400-99-012 and by the Assistant Secretary for Energy Efficiency and Renewable Energy, Building Technologies Program, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

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Executive Summary

Energy Information Systems (EIS) for buildings are becoming widespread in the U.S., with more companies offering EIS products every year. As a result, customers are often overwhelmed by the quickly expanding portfolio of EIS feature and application options, which have not been clearly identified for consumers. The object of this report is to provide a technical overview of currently available EIS products. In particular, this report focuses on web-based EIS products for large commercial buildings, which allow data access and control capabilities over the Internet.

EIS products combine software, data acquisition hardware, and communication systems to collect, analyze and display building information to aid commercial building energy managers, facility managers, financial managers and electric utilities in reducing energy use and costs in buildings. Data types commonly processed by EIS include energy consumption data; building characteristics; building system data, such as heating, ventilation, and air-conditioning (HVAC) and lighting data; weather data; energy price signals; and energy demand-response event information.

This project involved an extensive review of research and trade literature to understand the motivation for EIS technology development. This study also gathered information on currently commercialized EIS. This review is not an exhaustive analysis of all EIS products; rather, it is a technical framework and review of current products on the market.

This report summarizes key features available in today's EIS, along with a categorization framework to understand the relationship between EIS, Energy Management and Control Systems (EMCSs), and similar technologies. Four EIS types are described:

- Basic Energy Information Systems (Basic-EIS)
- Demand Response Systems (DRS)
- Enterprise Energy Management (EEM)
- Web-based Energy Management and Control Systems (Web-EMCS)

Within the context of these four categories, the following characteristics of EIS are discussed:

- Metering and Connectivity
- Visualization and Analysis Features
- Demand Response Features
- Remote Control Features

This report also describes the following technologies and the potential benefits of incorporating them into future EIS products:

- Benchmarking
- Load Shape Analysis
- Fault Detection and Diagnostics
- Savings Analysis

1. Introduction

1-1 Introduction to Energy Information Systems

Energy Information Systems (EIS) refer to software, data acquisition hardware, and communication systems administered by a company, partnership, or collective to provide energy information to commercial building energy managers, facility managers, financial managers and electric utilities. Data types commonly processed by EIS include energy consumption data; building characteristics; building system data, such as heating, ventilation, and air-conditioning (HVAC) and lighting data; weather data; energy price signals; and energy demand-response event information. This report summarizes key features available in today's EIS, along with a categorization framework to understand the relationship between EIS, Energy Management and Control Systems[1] (EMCSs), and similar technologies.

For this report, we make a distinction between two types of Energy Information Systems: "web-based" and "non-web-based". Web-based EIS products access and manipulate building facility data via the Internet, while non-web-based EIS manipulate data stored onsite. In this report, we focus only on web-based EIS products.

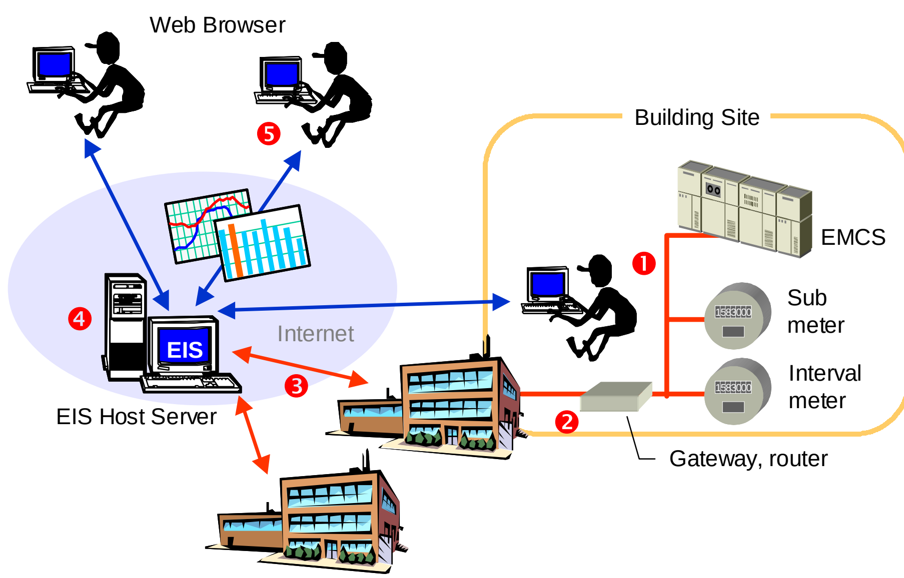


Figure 1-1. Typical Architecture of an EIS

In a common EIS architecture, shown in Figure 1-1, (1) building energy consumption data are collected by metering devices installed at building sites, and (2) dispatched via a gateway or other communication device (3) through an internet connection or telephone line to a database server located at an EIS service provider's physical site. (4) The offsite database server stores and archives this data and (5) EIS users access the database server remotely using a web browser. The application program installed on the database server provides a user-friendly interface to

[1] EMCSs, also known as EMS (Energy Management Systems), BMS (Building Management Systems), or Building Automation Systems (BAS) are systems that, through a series of sensors and controllers, allow operation of end-use equipment within a facility, usually HVAC equipment. These control centers are often run from a centralized workstation, and in some cases may be remotely controlled over an Internet web page (Xenergy and Nexant, 2002). Because the majority of currently installed EMCS are not web-based, we use the term EMCS to refer to conventional EMCS without Internet connections unless indicated.

facilitate energy management and utility programs. The software commonly provides data visualization and may include additional features such as the ability to download raw data.

Although EIS have been in development since only the middle of the 1990's (Levy, et al., 2001), their capabilities have been improved and expanded to include a wide variety of operability and connectivity. To cope with electricity reliability problems in recent years, major utility companies have created Demand Response (DR) programs, which offer customers cash incentives for reducing peak loads. To make the DR programs feasible and efficient, utility companies have adopted and promoted EIS products as communication systems between utilities and their customers.

Today, EIS are used by utility companies, energy service companies (ESCOs), and facility owners and operators. Because these different users are likely to use EIS for different purposes, it can be confusing for them to choose the most appropriate EIS from many similar products.

1-2 Benefits of EIS for Operators

The primary benefit of an EIS is to assist facility operators, owners, and other decision makers to manage building energy use. An EIS helps operators and energy managers understand the energy use patterns of their building or buildings, including issues such as:

- Timing and magnitude of peak electric demand
- Daily load shapes
- Historic baseline energy use
- Unexpected operation schedules
- Cost variations by hour, day, week, month, and year

Real-time or daily updating of hourly energy consumption data allows users to evaluate building performance issues that have been difficult to observe. It also enhances the retro-commissioning process (Price and Hart, 2002). Since most EIS products provide real-time or daily updates of hourly trend data, facility operators can check the impact of an operational strategy immediately following or within a day of the operation. In the absence of an EIS, an impact evaluation would have to be postponed until the monthly utility bill arrived. An EIS also allows facility operators to see the hourly detail of the impact, whereas a monthly utility bill would show only the monthly total. With Internet capabilities, an EIS can help manage hundreds of geographically spread sites. Although energy managers may be able to assemble and organize monthly utility bill data for hundreds of sites, this work is painfully time-consuming. EIS products can facilitate such multi-facility energy management tasks.

EIS are also strongly coupled with demand-response programs and strategies. Some EIS products allow energy managers to participate in DR programs and execute shedding strategies. Most of these systems also provide immediate feedback on demand reduction events.

1-3 Project History

Lawrence Berkeley National Laboratory (LBNL) has conducted a series of research projects on building commissioning and diagnostics, both by developing tools and frameworks for analyzing tools, and by demonstrating advanced techniques and systems in actual buildings. In 1999 and

2000, LBNL worked with a multi-institutional team to develop and evaluate the Information Monitoring and Diagnostic System (IMDS) for large commercial buildings, further described below (Piette, et al., 1999; Piette, et al., 2000).

The Commercial Buildings Systems group at LBNL is currently involved in a project to assist the General Services Administration (GSA) in developing and testing the GSA Energy and Maintenance Network (GEMnet) (Levi, et al., 2002). At the same time, the Electricity Markets and Policy Group at LBNL is conducting a series of research projects on DR programs across the country, which include technology reviews and user feedback on EIS products that are related to DR program operation (Goldman, et al., 2002).[2]

This report is part of a larger research effort funded by the California Energy Commission (CEC) and the US Department of Energy, called the High Performance Commercial Building Program (HPCBP).[3] The research effort described in this report is one of many commissioning and diagnostics tasks constituting the HPCBP. This report was developed under a task to assess fault detection and diagnostic tools for building operators.

Prior to this EIS study, LBNL reported on the capabilities of emerging HVAC diagnostic tools (Friedman and Piette, 2001). During 2000 and 2001, the CEC made significant investments in EIS as a response to the electricity crisis in California, culminating in an investment of over $30 million in demand-responsive HVAC and lighting systems (AB 970).

1-4 Literature Review and EIS History

A recent report by Levy Associates describes EIS development history from the view of metering technologies and applications (2002). This report surveyed the historical development of automated meter reading (AMR) with a focus on the customer interface and hardware systems, including EIS. According to the report, utility metering and information practices have not changed much in the last 50 or 60 years. Standard metering systems were designed to measure only total monthly electricity usage and provided little or no value to the customer. Some utilities, however, were aware that metering information could support highly valued customer services. Ensuing utility field trials, such as those at Georgia Power and Kansas City Power and Light, repeatedly demonstrated valuable meter and EIS data applications for every type of customer.

In 1996, E-SOURCE released a series of reports outlining the basic capabilities of EIS products available at that time. Their first report categorized data sources and defined key features of EIS products, complete with practical examples and graphics (Fryer, 1996). Later E-SOURCE reports covered technical specifications, potential benefits, market strategies, and prospects of EIS for large commercial energy-consumers, ESCOs and utility companies (Komor, 1996). The EIS industry was (and still is) premature, and the variation and use of EIS products have further developed since then.

In recent years, the capabilities of EIS have improved, increasing the functionality from visualization to remote control. A recent article in the ASHRAE Journal noted an increasing market for energy-related information services (Kintner-Meyer and Burns, 2001). In this research, the authors briefly introduce some of the advanced capabilities of EIS products, including

[2] See http://eetd.lbl.gov/EA/EMS/
[3] See http://buildings.lbl.gov/hpcbs/

dynamic utility rate analysis (for time-of-use[4] or real-time-pricing[5] rates), remote control, energy efficiency analysis, and DR program bidding capability.

To assist in the recent California energy crisis, numerous new DR programs were developed and promoted. To enhance DR program participation, the CEC released a guidebook for demand response technologies (Xenergy and Nexant, 2002). This guidebook familiarizes facility and operations managers with enhanced automation technologies including EIS and EMCS as well as HVAC and lighting controls technologies. The guidebook provides cost and savings estimates for common enhanced automation options. It presents strategies for system selection, project planning, and implementation.

1-5 Project Objectives

The main objective of this report is to provide a review of the capabilities of EIS products available in the United States. Based on current markets and available technologies of EIS, we categorize EIS types and provide a definition for each category. Because most EIS products have specific target markets, the types of clients and markets are also categorized. Through this categorization framework, we review key sections of EIS technology, from system architecture to software application. This report emphasizes software products rather than hardware products and does not rate or rank the individual EIS products. Furthermore, this is not an exhaustive review of all EIS products. Such a review is extremely difficult because of the quickly changing nature of EIS technologies and commercial partnerships.

The objectives of this report are to:

1. Provide a review of the basic capabilities of various types of EIS products
2. Define and categorize EIS products and key market segments
3. Provide a review of EIS technology from system architecture to application
4. Review prospects for future use and capabilities of EIS products

This report is intended for multiple audiences. First, it is intended for use by potential EIS users such as building operators and energy managers, so they might better evaluate which EIS functions may be most useful to them, considering trade-offs such as capabilities and complexity. Second, this report is intended to assist utility companies and policymakers by providing them with a review of the current state of the technology. Third, this report is intended to assist EIS vendors with a review of current EIS capabilities, to enable them to compare their own products to those of their competitors. Finally, building technology researchers may find this report useful in understanding how such tools can be used to reduce energy use and peak demand in buildings.

[4] Tme-of-use (TOU) rates charge preset rates for energy and demand that are lower during off-peak and higher during seasonal/daily peak demand periods. TOU is often mandatory for very large customers and voluntary for smaller customers (Xenergy and Nexant, 2002).

[5] Real-time pricing (RTP) is hourly pricing of electricity where the cost per kWh varies by hour and by day. For example, the utility gives customers a 24-hour price forecast each day for the following days, allowing them to adjust usage daily to minimize costs. Typically, RTP is tied to the wholesale market price (Xenergy and Nexant, 2002).

1-6 Methodology

LBNL conducted an analysis of 20 EIS products by compiling information on EIS technology and DR programs throughout the country. We collected information using the following methods:

- **Literature Search –** We reviewed research papers, journals, magazines and other related literature.
- **Website Review –** Most EIS developers have well-developed websites that provide product information and the company's background. Some of them describe their product's technology and capability in detail. Others describe only abstract benefits of their products.
- **Online Demonstrations –** Some websites have comprehensive demonstrations of their products, where users can test functionality via the Internet. Some developers also provided passwords to access test sites.
- **Phone Interviews –** Where additional information was required, we conducted phone interviews and Web meetings.
- **E-mail Questionnaires –** After summarizing and comparing the EIS products, we emailed a report to the EIS developers for review. The EIS developers verified the information reported in Table 3-1.
- **Meetings –** Several EIS vendors visited LBNL to present their technology and services, and LBNL made several site visits to California-based EIS developers.

By investigating these products, we developed an EIS categorization framework. Each featured EIS is reviewed and introduced individually. In the latter half of this report, system architectures and capabilities of EIS products are discussed and compared. It is important to identify the characteristics of each EIS to understand the primary purpose and unique advantages of each. This report is primarily based on developer/vendor-side information, and does not include user interviews or feedback. We briefly discuss emerging technologies for EIS products, some of which are the subject of current research.

This report does not include a detailed cost and benefit analysis of EIS products, nor an analysis based on user interviews or feedback. Such research is beyond the scope of this report, but will be included in future research (see Chapter 6). The report does not confirm the functionality reported by the EIS vendors; rather, we attempt to characterize the features that have been developed and are on the market today.

1-7 Report Organization

This report provides definitions of EIS types, and comprehensive comparisons of system architectures and capabilities.

- **Chapter 1** – briefly summarizes the background and history of EIS
- **Chapter 2 –** categorizes and defines the typical types of EIS and EIS clients
- **Chapter 3** – presents short descriptions of featured EIS products on their capabilities. (Specific EIS features are listed in Appendix C)
- **Chapter 4** – compares the system architectures and capabilities among several EIS products. Connectivity and particular application capabilities are discussed separately. Capital and operations costs are also discussed.
- **Chapter 5** – reviews and discusses some emerging technologies, such as forecasting and benchmarking, and discusses the potential for their adaptation to EIS products.
- **Chapter 6** – shows summary and future direction of this research.

An earlier summary version of this paper was presented at the 10th National Conference on Building Commissioning (Motegi and Piette, 2002).

2. Market Categorization

Energy Information Systems have evolved out of the electric utility industry in order to manage time-series electric consumption data. EIS products have been developed quickly with various features and complexities in order to satisfy the wide variety of client needs. In this chapter, the market for EIS is characterized into several categories by client and by EIS type. Each layer of technology is described.

2-1 Client Categorization

EIS features and capabilities have been designed to serve a variety of markets and different types of customers. The key segments of customer groups are:

- Multi-Site Clients
- Individual Buildings
- Energy Providers
- Energy Service Companies (ESCOs)

Figure 2-1 shows a classification of the EIS clients.

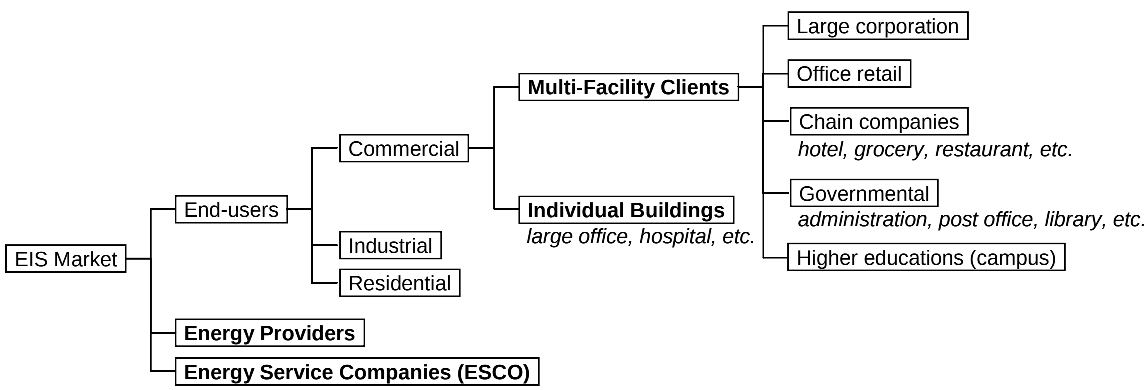


Figure 2-1. Classification of EIS Clients

2.1.1 Multi-Site Client Market

Multi-site clients are defined to be organizations that manage multiple buildings. These clients include large corporations, retail chains, restaurants, office buildings, governmental organizations, and educational facilities. This is a key market segment for EIS products. One advantage of an EIS is the ability to easily look at, and optionally control, multiple sites spread over a large geographical area. In this report, we use the term “site” to mean either a standalone building or a retail space within a larger building.

EIS are reported to be cost-effective tools for multi-site clients, since a single EIS covering multiple sites is typically less costly than having an operator at each site. For example, chain grocery stores, which generally do not have a facility operator or energy management systems, often waste energy due to inefficient operation, system malfunctions, or unnecessary scheduling. Today most multi-site clients have only a few energy managers to oversee hundreds of sites.

Another option for multi-site clients is to save significant expenses on human resources by using off-site energy managers to manger their buildings remotely.

2.1.2 Individual Buildings Market

Most buildings have limited data acquisition, visualization and management tools, which can be powerful tools for facility managers to understand their building energy consumption trends. Some EIS products provide large volumes of energy and related data, including whole-building electricity usage information, but also end-use energy consumption, temperature, on/off status, or other system condition data, in hourly or shorter intervals. In most cases, however, energy managers and facility operators are too busy to look at such detailed data. Advanced EIS products allow processing and simplification of this data, allowing the operator to save time by reviewing simplified metrics and key criteria. For clients needing more detailed diagnostic analysis, some EIS vendors also offer remote manual diagnostic services.

2.1.3 Energy Providers and Electric Utility Markets

An EIS can provide powerful interactive communication between customers and energy providers. EIS vendors sell customized products to energy providers. The energy providers then redistribute the EIS to their customers as an optional service, or they may provide it free to participants of their load management programs.

An EIS can be used by electric utilities to manage DR programs that request customers to reduce load when the electric grid is taxed and energy supplies are limited (Goldman ,et al., 2002). Major energy suppliers in California, including Pacific Gas & Electric, Southern California Edison, San Diego Gas & Electric, and Sacramento Municipal Utility District (SMUD), purchased EIS products to operate their customized peak demand programs. While the implementations were successful, these utilities are still exploring capabilities and benefits of EIS in the current California energy markets context.

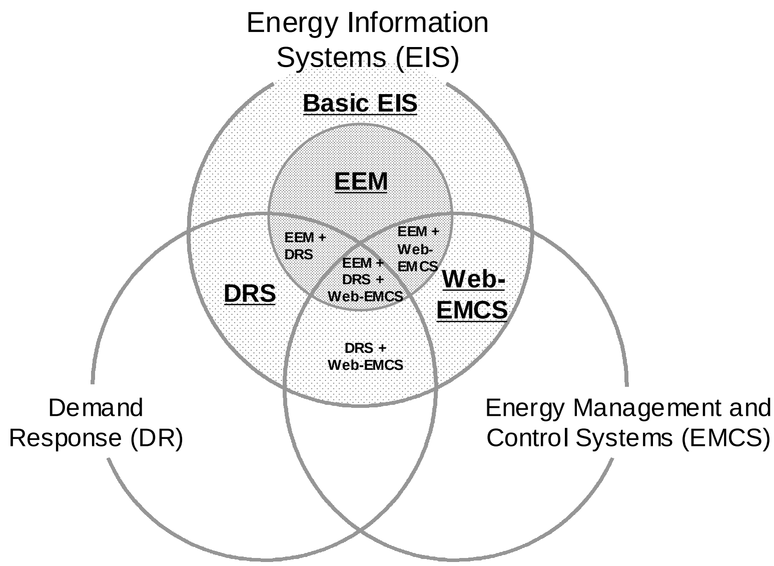
2.1.4 Energy Service Companies Market

Energy service companies (ESCOs) typically provide two major services to their clients: building diagnostics and performance contracts. An EIS can help with both of these tasks. By using an EIS, ESCOs can diagnose their clients' buildings remotely and in real time, instead of repeatedly visiting sites as is required in the absence of an EIS. This saves both time and human resources.

For performance contracts, ESCOs track building energy use to verify energy savings against the baseline. They also track any changes in environmental conditions and occupational settings such as occupancy schedules, temperature setpoints, and equipment runtimes, to assist the building operator in planning future curtailments. The EIS is an essential tool for tracking such data.

2-2 Types of EIS

Web-base Energy Information Systems have evolved out of the electric utility industry in order to manage time-series electric consumption data. However, the other energy management technologies have also expanded their functionalities, and have partly come to merge with EIS technology. Since EIS products are relatively new technologies, they are changing quickly as the market unfolds.



Basic Energy Information Systems (Basic-EIS)	Gather, archive, summarize, and display whole building electricity data.
Demand Response Systems (DRS)	Communicate between utilities and customers to facilitate demand response programs.
Enterprise Energy Management (EEM)	Manage overall energy costs by facilitating energy benchmarking and procurement optimization over a business enterprise.
Web-Based Energy Management and Control Systems (Web-EMCS)	Integrate multiple building systems (e.g. HVAC, lighting, generation), and/or monitor and control building systems at the component-level by communicating with a EMCS via the Internet.

Figure 2-2. Types of EIS and Related Fields

Figure 2-2 is a Venn diagram showing the relationships between EIS and related fields. The "demand response" field has developed systems that enable utility-operated demand response programs or other demand curtailment measures (e.g. responsive thermostat[6], direct load control devices[7]). The "EMCS" field has developed energy management and control systems including non-web-based systems. The technologies in these fields are different from each other, yet there are a number of overlaps between the fields.

[6] A thermostat that can receive external signals and respond by adjusting temperature settings.
[7] Devices that allow the utlity system operator to interrupt power to individual consumer appliances or equipment.

In this report, EIS are categorized into four types shown in Figure 2-2. Demand Response System (Xenergy and Nexant, 2002) and Enterprise Energy Management (Friend, 2002; Thompson, 2002) are commonly used terms. Basic-EIS and Web-EMCS are terms used by the authors to assist in comparing the key attributes of various EIS.

Many EIS products are designed to perform various functions overlapping multiple fields. DRS, which provide both EIS and DR functionality, fit in the overlap between EIS and DR fields. Web-EMCS, which have both EIS and EMCS features, fit in the overlap between those fields. Most EEM, which are considered to have functions of Basic-EIS, fit in the EIS field. Some EIS may fit into more than one category, but an EIS with many features and overlapping categories is not necessarily more advanced. Some EIS products that include only one feature may be more advanced and complex than those with multiple features.

2.2.1 Basic Energy Information Systems (Basic-EIS)

In this report, "Energy Information Systems" are defined as a broad range of web-based tools to monitor, archive and analyze building energy data, and control building systems; however, common industry terminology for "Energy Information Systems" refers to a narrower range of systems that provide only fundamental data acquisition, management and visualization of utility electric metered data (Xenergy and Nexant, 2002). To distinguish the common industry terminology from wider range of EIS products, we define the fundamental tools as "Basic Energy Information Systems (Basic-EIS)".

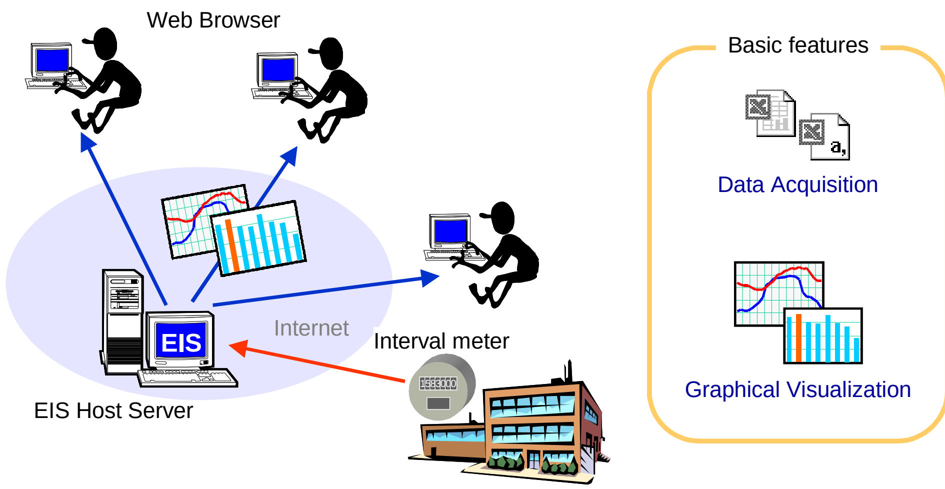


Figure 2-3. Basic Energy Information Systems

The capabilities for Basic EIS are:

- Whole building electricity data collection
- Hourly or 15-minute interval data collection
- Data acquisition
- Historical and real-time data visualization

Basic-EIS emerged early in EIS development. Some traditional Basic-EIS products were provided by utilities to their customers to offer easy access to historical energy consumption data as a value-added service.

A Basic-EIS retrieves and plots hourly or sub-hourly trend data, but does not provide detailed data analysis or allow remote system control. If such functionality is desired, users must scan the data plots for inconsistencies and manually adjust building systems as needed. Because of the simplicity of Basic-EIS products, their main advantage is that they are less expensive than other EIS products.

2.2.2 Demand Response Systems (DRS)

Demand Response Systems (DRS) are notification and response[8] tools used to simplify the execution of DR programs offered by electricity providers (Xenergy and Nexant, 2002).[9] DRS basically work as real-time communication gateways between energy providers and their customers. For customers with multiple facilities, DRS enable energy managers to organize their energy data simultaneously and remotely, and enable users and program managers to implement control strategies and then verify the participants' demand savings (kW reduction). Recent rapid development of EIS products was partly due to the sudden need for DRS products in 2001 during the California electricity crisis.

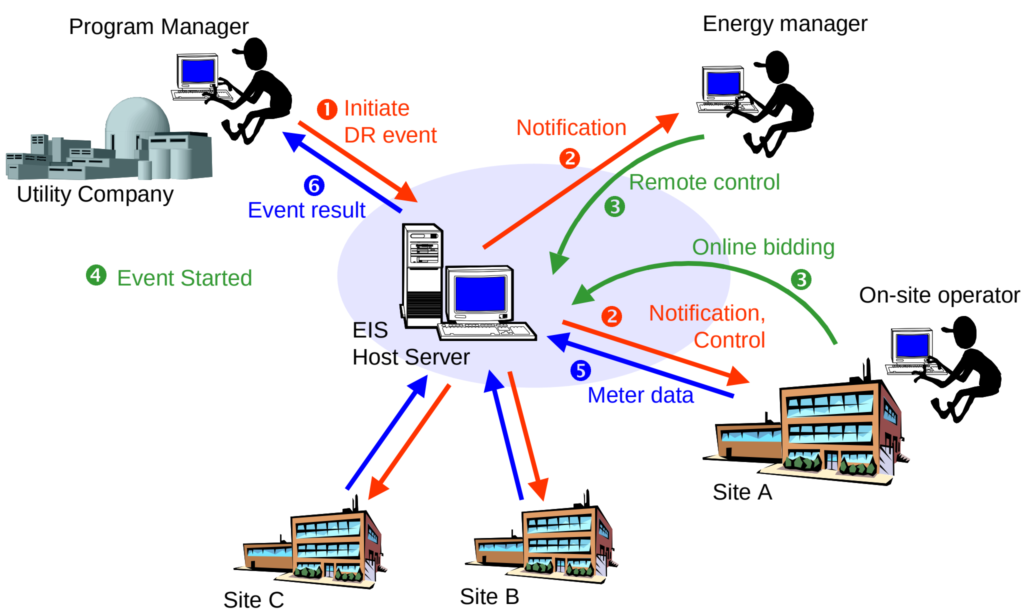


Figure 2-4. Demand Response Systems

Here we provide an example of how a DRS might be used in a "demand bidding" type DR program. When a demand curtailment event occurs, the utility company program manager

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[8] The notification-and-response communication is often called "two-way communication". The monitoring and control function is also called "two-way communication" (in this case, monitoring-only function is called a "one-way function"). This report does not use the term "two-way communication" to avoid this confusion, though it is very common industrial terminology.

[9] For example, with a single click, an energy manager can respond to a DR event in hundreds of buildings simultaneously, according to a preset start time, duration time, and load response.

notifies DRS users via e-mail, pager, fax, phone or other method. The users can then respond to the event via a password-protected EIS website. Users decide whether to participate in the demand reduction event (in case of a voluntary program), and if they accept, they can bid how much they will shed and at what price. Since most DRS products possess the data acquisition and visualization features of a Basic-EIS, users can monitor their demand reductions in real-time. This trend data is also used for curtailment verification after the event is over.

DRS products facilitate the implementation of DR programs, which can benefit both energy providers and customers. The utility, as an energy retailer, meets electric demand by producing or purchasing electricity at or near cost. During peak demand periods, the utility is often forced to purchase supplemental electricity at a more expensive rate. To avoid purchasing such expensive electricity, the utility offers rewards for customers to reduce their demand during the peak period. A large customer with a number of buildings in the affected area can pool demand reductions from these buildings to affect a large aggregate reduction and reward. Such a large reduction potential can even qualify a customer as a small power producer in the electricity wholesale market.

There are many different types of DR programs. “Pay-for-performance” programs offer participants a utility-determined price for kW reductions below a historical baseline. “Demand bidding” programs allow participants to bid the price at which they would be willing to forgo the electricity, and the utility can then compare between the available DR and supply bids. DR program participants benefit both from the DR program rewards and from energy cost savings at the standard rate. Such programs require complex communications between the utility and the DR program participants. Thus, the notification-and-response communications provided by DRS products play important role in DR program implementation.

In addition to the notification-and-response communication features, many DRS products have remote control functionality. A large number of DRS clients are multi-site facilities that do not maintain an operator at each site. For such facilities, the remote control capability of DRS products is necessary for energy managers to participate in DR programs. Loads commonly targeted for monitoring and remote control include chillers, fans, thermostats and lighting. These devices can be controlled individually or via a gateway installed at each site. Popular control strategies include modifying thermostat settings, disabling or reducing chiller or fan operation, and dimming interior lighting (Levy, 2001).

Another important feature of DRS is the verification and analysis of DR events using baseline or forecasting techniques. Baseline techniques require calculation of an energy consumption reference to estimate demand savings. Forecasting techniques predict future energy consumption to plan demand response or peak avoidance. The two calculation techniques can be similar in method, and can vary from simple averages to complex algorithms. These features are discussed and compared in detail in Chapter 5.

2.2.3 Enterprise Energy Management (EEM)

Enterprise Energy Management (EEM) products integrate multiple business processes involved in energy decision-making into a consistent information infrastructure (Friend, 2002), and are capable of multi-site aggregation (Thompson, 2002). In this report EEM is defined as an EIS that facilitates energy benchmarking and energy procurement optimization manually or automatically over several sites.

There are typically four major components to EEM products:

- Energy analysis, to help make decisions about retrofits or energy saving investments.
- Energy procurement, in terms of negotiating contracts to satisfy plant requirements.
- Energy management in plant operations, to optimize energy costs.
- Evaluation of energy costs, to ensure that energy contracts are being applied correctly.

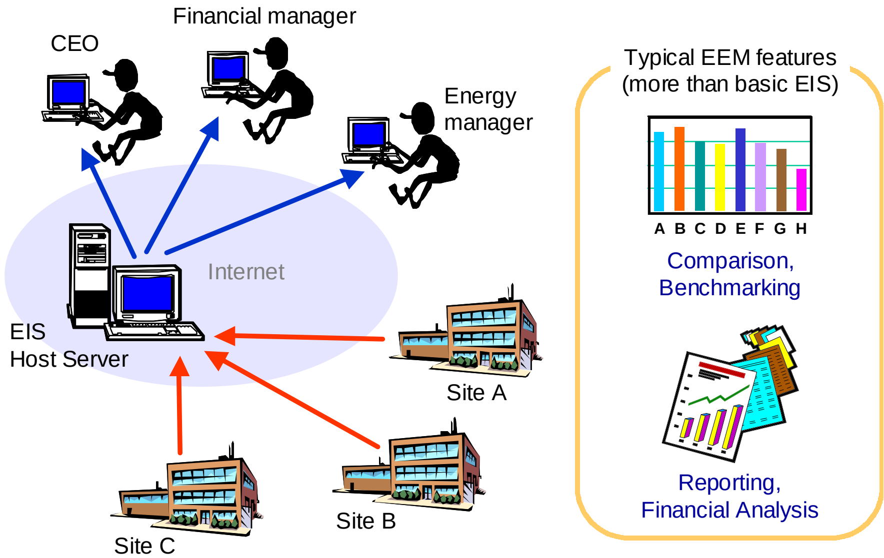

Figure 2-5. Enterprise Energy Management

Multi-site clients are the major target users of EEM products. Many multi-site facilities consists of medium to small buildings or retail spaces. Since they rarely have interval meters installed by utility companies, they are often required to install their own electric meter at each site.

EEM products are used to compare and benchmark energy use among a portfolio of sites by plotting energy-use data for multiple buildings and normalizing by area or weather. These normalized comparisons allow operators and energy managers to determine how buildings compare to each other. They also indicate if a month, day, or hour has high energy-use or unusual operation relative to a baseline.

Another common EEM function is financial analysis. EEM products integrate energy use, rate, cost, procurement and related information, and generate reports that are easy to understand. Since EEM users may include non-technical personnel as well as energy managers or operators, EEM features have to be user-friendly.

2.2.4 Web-based Energy Management and Control Systems (Web-EMCS)

Approximately 75 percent of commercial and industrial facilities over 50,000 square feet have Energy Management and Control Systems (EMCSs) (Xenergy and Nexant, 2001). EMCSs are control systems to optimize operations of end-use equipment, usually HVAC, through a series of sensors, communications, and controllers. Unfortunately, EMCS data are rarely utilized for optimizing operations, mainly because they do not have adequate data analysis infrastructure. The main limitation of many EMCS products is the lack of interoperability among building systems. Today's building systems are becoming increasingly complex, integrating the needs of

HVAC systems, lighting systems, and on-site electricity generation. However, many EMCS are designed to control HVAC only, and have limited capabilities in integrating with other building systems via the Internet.

In this report, we define a Web-EMCS as an EIS that emphasizes system integration capabilities and has the ability to monitor and retrieve data from an EMCS or similar system via the Internet. Thus, Web-EMCS products:

- Monitor and control building systems at the component-level by communicating with EMCS or similar technology via the Internet.
- Integrate multiple building systems such as HVAC, lighting, generation, and security using a gateway[10] or similar technology.

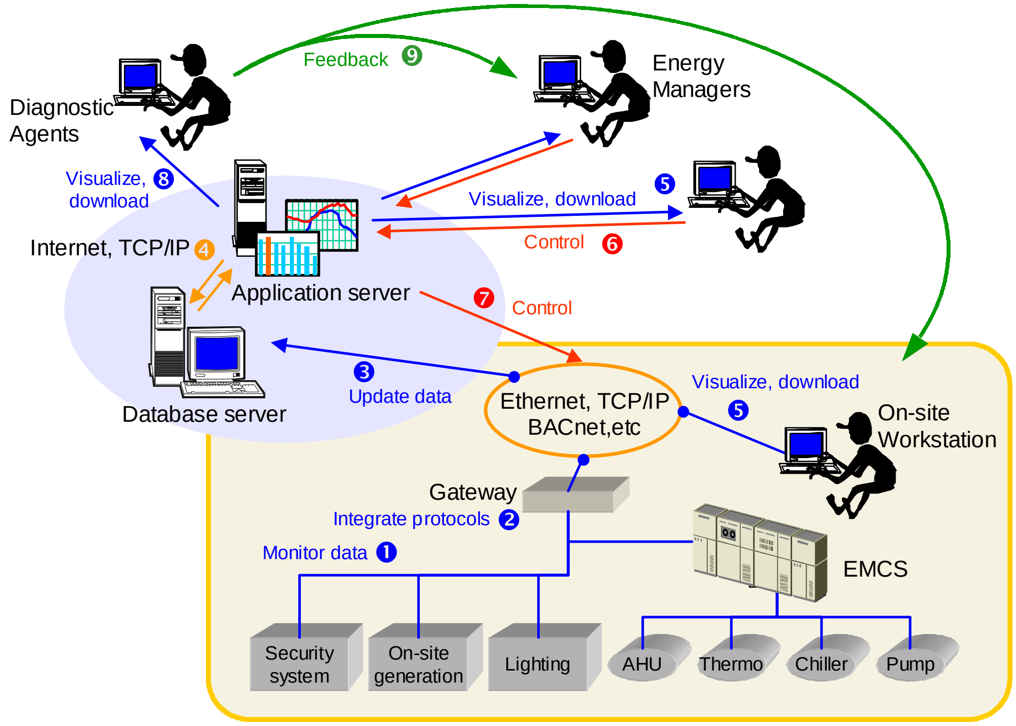

Figure 2-6. Web-based Energy Monitoring and Control Systems

The system architectures of Web-EMCS products range from simple to complex. A simple system might consist solely of a meter that sends and receives signals to monitor and control the equipment on which it is installed. A more complex Web-EMCS might integrate multiple systems, including meters, lighting, security systems, on-site generation, and EMCS. Systems with a gateway can translate different protocols to an open protocol such as BACnet. Where systems use the same protocol, a simple router can be used instead of a gateway. One important distinction is how deep into the building systems the web-based control systems reach. Some Web-EMCS provide a single contact point to an EMCS or other controller, while others provide deeper levels of control access to individual buildings systems such as air handlers or perhaps even zone controls.

[10] Most existing systems use proprietary protocols. A conventional EMCS is unlikely to have an open protocol such as BACnet or LonWorks, so gateways are typically capable of translating between various proprietary and non-proprietary protocols.

Gateway systems can be divided into monitoring-only and monitoring-and-control types. Monitoring-only (one-way) gateways translate data from devices or systems to a form usable by the EIS database, but are not capable of translating the other way. Monitoring-and-control (two-way) gateways can translate in both directions. Web-EMCS products that focus on underlying system connectivity can work as a system platform for other EIS products that focus on visualization and/or data analysis applications. In such cases, the EIS application will be highly customized, allowing integration with the other EIS application products.

Like their EMCS cousins, many Web-EMCS products control building systems automatically according to user-programmed algorithms. This feature can be useful for responding to DR program events. DR program participants with a Web-EMCS can program the system to automatically modify thermostat settings, reduce chiller or fan loads, and dim lighting when a curtailment call is received. In this sense, Web-EMCS product functionality can overlap that of DRS products.

Web-EMCS can enhance real-time and continuous building diagnostics and commissioning, though it is not yet common. Building systems data typically targeted for monitoring and diagnostics include chiller power, air temperature, airflow, and end-use electric loads. With the data visualization capabilities of Web-EMCS, these detailed data can be utilized for component-level system diagnostics. Web-EMCS products can provide graphics to analyze time-series data to help facility operators analyze their building systems, but such activities are time-consuming. While most Web-EMCS have analysis[11] and reporting capabilities, these capabilities do not actually diagnose or make decisions. This is the common limitation of EIS in general.[12] To make up for this limitation, some EIS vendors and ESCOs provide manual diagnostic services for Web-EMCS clients.

2-3 Layers of Technology

EIS is a combination of technologies spanning the distance between metering and user-interface. Each EIS has its own emphasis and unique characteristics. For instance, an EEM tends to focus on user-friendly visualization software, while a Web-EMCS tends to focus more heavily on system integration. These pieces of technology can be divided into stages of data transfer from metering data at each component (sensors and measurement) to transferring the trend data to a data server (connectivity) to storing and archiving the data (server configuration) to analyzing and displaying the data for users (application). These EIS technologies are further described in Figure 2-7.

[11] These analysis capabilities will be described in Chapter 4.

[12] A few Web-EMCS products (to be introduced in later chapters) automatically select optimized control without human interaction, but these advanced capabilities are not common.

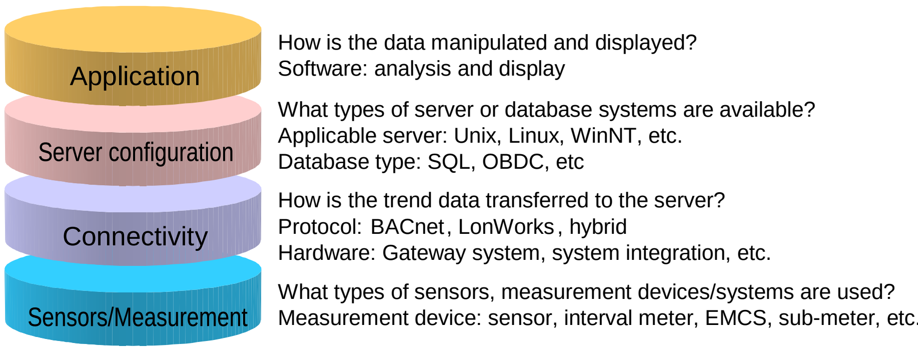

Figure 2-7. Technology Layers of EIS

Sensors and measurement – Sensors and measurement refers to the equipment used, the method of collecting data, and the type of data collected. Common data sources include electric interval meters, EMCSs, and sub-meters. Whole-building power data can sometimes be read from utility meters; however, end-use monitoring requires additional meter installation. Data can be collected and stored by the existing EMCS, by the EIS, or by some other secondary monitoring system. At a minimum, whole-building power data are required by EIS, while some also use end-use power data and weather data.

Connectivity layer – The ability of an EIS server to communicate with existing building systems is a key factor in the adoption of the technology. Three networking scenarios apply to EIS:

- Single meter: A meter sends/receives signals directly to/from the Internet server.
- EMCS: The Internet server communicates with the EMCS to monitor and control building systems.
- Gateway: A gateway (or router) integrates multiple building systems.

Without a common communications protocol, the EIS cannot communicate with the EMCS. In this case, a gateway is required to translate the protocols and integrate multiple systems used by the EIS. If all the systems to be controlled are using same protocol, a router, which is less expensive than gateway, can be used to integrate the systems. Communication between systems may be monitoring-only or monitoring-and-control. Communication between an EIS and the Internet is accomplished through standard communications pathways including Ethernet, telephone line, or wireless communication.

Server configuration layer – The two main database server configuration options are (1) the database type (e.g. ODBC, Microsoft SQL, developers proprietary system, etc.), and (2) the PC environment the database system can accommodate (e.g. Unix, Linux, WinNT, etc).

Application layer – Application software accesses and manipulates historical data stored in the database server. The application software can be installed on the user's PC; however, most EIS application software is stored on the database server so users can access it from any PC. Methods of visualization and analysis vary widely depending on users' needs. Rate analysis, other financial analysis features, and DR event analysis are also included in this layer.

2-4 Summary of Common EIS Features

Table 2-1 summarizes common EIS features described in the previous sections. Each feature can be briefly categorized in the layers of technologies defined. The features listed in this table are described in detail in Chapter 4.

Table 2-1. Common Features of EIS

Metering	
Internet download	Download data via Internet.
EMCS download	Download data from EMCS (e.g. electricity, temperature, tons, flow).
Sub-metering	Electricity metering of portions of sites (e.g. individual end-uses).
Real-time	Update at least every 15 minutes.
Connectivity	
DR Notification	Notification of DR signal for manual response.
Internet control	Control thermostat or other HVAC settings via Internet.
Integration	Integrate systems that have different protocols, manufacturers, and other configurations.
Application	
Load profile	Display hourly electricity usage.
Summary	Aggregate by week or month.
Benchmarking	Compare among multiple buildings or historical data.
Rate analysis	Estimate and/or predict energy costs based on the existing tariff.
Forecasting	Forecast near-future load profile.
Diagnostics	Automatically diagnose building systems.
Automated Control	Automatically control building systems according to a preprogrammed strategy.[13]

Table 2-2 summarizes between common EIS features by EIS type. These are not restrictive categories and there is significant variation among the various systems. This framework allows us to understand the general nature of these tools as they currently exist on the market and the key features driving the architecture of each tool.

Table 2-2. Feature Summary of Each EIS Type

Type of EIS	Metering				Connectivity			Application						
	Internet download	EMCS download	Sub-meter	Real-time	DR Notification	Internet control	Integration	Load profile	Summary	Benchmark	Rate analysis	Forecasting	Diagnostics	Automated control
Basic-EIS	●			◐				●	●		●			
EEM	●							●	●	●	●			
DRS	●			●	●	◐		●			◐	◐		◐
Web-EMCS	●	●	●	●		●	●	●	◐				◐	◐

●: Usually covered ◐: Optional [14]

[13] For example, the EIS may be programmed to respond to a DR signal. In advanced systems, the EIS can schedule optimized operations according to monitored or forecast data (described in Chapter 4).

3. EIS Products and Descriptions

Table 3-1 lists various EIS products available today, developer information, types of EIS and product information sources. Many EIS fit more than one category. Most EIS have Basic-EIS features, which consist of hourly data acquisition and visualization as well as DRS features. The recent rapid development of EIS is largely due to increasing needs of demand response programs. Developers new to the EIS business are more likely to be DRS-oriented; whereas many long-time vendors come from energy service companies, utility companies, or monitoring/control engineering firms.

Table 3-1. Featured EIS and Vendor Information

			EIS Types				Information sources					
Software	Acronym	Vendor / Developer	Basic-EIS	EEM	DRS	Web-EMCS	Website	Other research	Online demo	Phone interview	E-mail ques.	Meeting
Utility Manager Profiler Utility Manager Online	UM Profiler UM Online	Save More Resources		✓			✓		✓	✓	✓	
Enerlink	-	SCT Corp.	✓				✓	✓		✓	✓	
PLISEM	-	Plurimi	✓				✓		✓			
Demand Exchange	DEMX	Apogee Interactive			✓		✓	✓	✓	✓	✓	✓
Energy Profiler Online	EPO	ABB	✓		✓		✓	✓	✓		✓	✓
Intelligent Use of Energy	IUE	WebGen Systems	✓	✓	✓		✓	✓	✓	✓	✓	✓
Readmeter Loadcontrol	-	Cannon Technologies	✓		✓	✓	✓		✓	✓	✓	
Energy Partner Web	EP Web	ELutions	✓		✓		✓		✓	✓	✓	
eMAC	-	Pentech Solutions	✓		✓	✓	✓			✓	✓	
UtilityVison	-	CMS Viron	✓			✓	✓	✓	✓	✓	✓	✓
Automated Energy	-	Automated Energy	✓		✓	✓	✓		✓	✓	✓	
Facility Explorer	FX-TEM	Johnson Control	✓	✓	✓	✓		✓			✓	
EnterpriseOne	-	Circadian Information Systems	✓			✓	✓		✓	✓	✓	
Enterprise Energy Management Suite	EEM Suite	Silicon Energy	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Vykon	-	Tridium	✓	✓	✓	✓	✓		✓	✓	✓	✓
GSA Energy and Maintenance Network	GEMnet	GSA, Automated Logic, Polarsoft, and others	✓	✓		✓		✓	✓		✓	✓
Information Management and Diagnostic System	IMDS	Electric Eye, Enflex				✓	✓	✓	✓		✓	✓

[14] Each feature marked with a black circle is critical to the EIS functionality and is usually covered. Features marked with a half-circle are not critical to the functionality of the EIS, but may be offered as an enhancement.

The following list describes each EIS product, emphasizing the unique characteristics of each product without attempting to cover all product capabilities. We review detailed feature descriptions in Chapter 4. A compilation of yet more detailed information on each EIS is listed in Appendix C.

Utility Manager Profiler/Utility Manager Online (UM Online/UM Profiler)
Utility Manager Online (UM Online) is a web-based utility bill reporting and auditing tool that helps energy managers manage thousands of sites. UM Online visualizes and analyzes monthly utility bill data via the Internet.[15] Like most EEM products, UM Online has a series of site comparison reports and graphs. Utility Manager Profiler (UM Profiler) retrieves 15-minute interval meter data. Save More Resources, the EIS developer, also offers additional data analysis services.

Enerlink
Enerlink started with electric bill analysis in 1988, and was commercialized with Basic-EIS capabilities in 1992 (Hyde, 1996).

PLISEM
PLISEM, which was specifically designed for DR program participation, has user-friendly data analysis and visualization features.

Demand Exchange (DEMX)
Demand Exchange (DEMX) enhances interaction between utility program managers and building energy managers by allowing manual trading of day-ahead demand curtailment. DEMX not only accepts or rejects the DR event, but also enables building energy managers to bid in prices for the curtailed demand.

Energy Profiler Online (EPO)
Energy Profiler Online (EPO), which has one of the largest shares in DRS products, is a communication gateway for load curtailment program participation. EPO also allows commercial and industrial customers to better understand their energy usage.

Intelligent Use of Energy (IUE)
By applying neural network technology, IUE "learns" the typical interactions of system components and predicts future energy usage. Based on the energy usage forecast, IUE's Intelligent Agent deploys specific conservation strategies to minimize energy usage. IUE constantly schedules consumption during normal conditions, in advance of weather or pricing changes. IUE attempts to achieve energy savings while maintaining thermal air comfort and air quality conditions.

Readmeter/Loadcontrol
Readmeter collects data directly from revenue meters and Loadcontrol provides direct and/or indirect control of customer-side loads. Readmeter/Loadcontrol platforms on Yukon, the underlying system architecture, which communicates with various legacy systems[16] and enhances system integration.

[15] UM Online is an example of a Utility Accounting System, which facilitates or automates monetary transactions between utilities and customers and provides utility bill data via the Internet. While it does not fit the definition of EIS, it is introduced here as an example of a related tool. UM Profiler does fit the description of an EIS.
[16] In most cases an existing EMCS with proprietary protocols.

Energy Partner Web (EP Web)
EP Web collects data from many different types of logging devices and meters located at the customer's facility. It also provides real-time, device-level consumption reporting and control. EP Web has a set of comprehensive data visualization/analysis features and basic DRS capability. EP Web also provides professional diagnostic services as an option.

eMAC
eMAC is an energy end-use monitoring and control tool. eMAC is usually applied for multi-facility clients that have hundreds of small buildings. eMAC is installed to each roof-top HVAC unit and carries out automated diagnostics and control. eMAC also provides monitoring, control, and diagnosis for lighting, electric-vehicle chargers, and other end uses.

UtilityVision
UtilityVision was initially developed for performance contract activities. While energy savings verification under conservational performance contract procedures can take months, UtilityVision can provide results immediately using EIS technology. Its FacilityVision module is a diagnostic tool that monitors and diagnoses data according to a rule-based algorithm.[17] UtilityVision also facilitates manual or automated curtailment during DR events.[18]

Automated Energy
In addition to providing basic EIS functionality, Automated Energy calculates bill estimates using "what-if" analysis. Automated Energy estimates monthly bills under different rate schedule and/or usage pattern scenarios, and compares results to the current bill. Automated Energy also has a forecasting fucntion that enables estimation of future loads based on current consumption patterns.

Facility Explorer (FX-TEM)
Facility Explorer for Total Energy Management (FX-TEM) can be used to fully automate the collection, storage and analysis of energy cost and usage data. Facility Explorer has an automated anomaly detection capability that detects abnormal energy consumption[19] (Seem, 2002).

EnterpriseOne
EnterpriseOne assists building managers and factory engineers in monitoring and reducing energy costs. It is designed to process, analyze and report on energy data for the purposes of diagnostic testing, sub-metering, and performance verification. EnterpriseOne has various flexible reporting engines and system diagnostic tools.

EEM Suite
The main focus of EEM Suite is enterprise energy management. EEM Suite enables interaction between energy providers and energy users to reduce energy usage, lower energy costs, optimize energy procurement processes, and implement DR programs. Though EEM Suite has variety of functionality on whole building energy and cost analysis for multiple buildings, it can also monitor detailed data to help users perform component-level system diagnostics.

[17] FacilityVision is now under field testing, and not yet commercialized.
[18] The automated curtailment function is now under field testing.
[19] Details of the abnormality detection of Facility Explorer will be described in Chapter 5.

Vykon/Niagara Framework

Vykon is an energy management application that runs on top of Niagara Framework, both developed by Tridium. Vykon has various and flexible visualization features. The Niagara Framework is a system integration platform that integrates legacy systems including EMCS, lighting, and on-site generation. Niagara Framework (with or without the Vykon application) can work as a system platform for many other EIS product applications.

GEMnet

GEMnet (GSA Energy and Maintenance Network) is being developed for energy management and building maintenance of Federal buildings in the Pacific Rim Region. GEMnet provides a platform for manual building system diagnostics, and is capable of analyzing trends in equipment performance, diagnosing problems and equipment/system deterioration, and recommending remedies. It is one of the first systems in which multiple BAS products communicate via the Internet to a high speed DSL installed at each building (Levi, et al., 2002).

IMDS

The IMDS (Information Monitoring and Diagnostic System) is one of the earliest web-based monitoring systems. It was developed and evaluated as a collaborative effort among researchers, building property managers, and private industry (Piette, et al., 2000). The IMDS consists of a monitoring and data acquisition system with high-quality sensors. Its trending points include component-level electricity consumption data and many other data types that are typically not available from an EMCS.

4. EIS Product Comparison

This chapter compares and contrasts the features and capabilities of the EIS products introduced in Chapter 3. Since the main purpose of this report is to understand the functions and user-friendliness of different EIS products, we focus on discussing and comparing the application capabilities. However, knowledge of metering and connectivity technologies is also important to gain more insight into underlying technologies enabling the application. Table 4-1 shows the correlation between the EIS features discussed in this section and the technology layers categorized in Chapter 2.

Table 4-1. EIS Features and Technology layers

		(Technology Layers)		
		Sensors and Measurement	Connectivity	Application
▪ **Metering and Connectivity**	(4-1)	✓	✓	
▪ **Application Capabilities**	(4-2)			
→ **Visualization**	(4.2.1)			✓
→ **Demand response**	(4.2.2)		✓	✓
→ **Remote Control**	(4.2.3)		✓	✓
→ **Financial analysis**	(4.2.4)			✓

In this chapter, we compare the capabilities and characteristics of EIS products by each of these features. For each feature, EIS capabilities are described and an overall summary including current capability and limitation is presented. Because some application capabilities are closely related to connectivity technology, connectivity variations are also discussed occasionally. We do not discuss EIS hardware requirements because they vary widely depending on the client's existing system and data needs.[20] Finally, we present rough cost estimates for the four EIS types, but do not present costs for each individual EIS product.

The detailed features of each EIS product change quickly. In particular, data visualization and demand response features are currently changing quickly. Therefore, we cannot guarantee that the EIS products discussed in this chapter will continue to have same capabilities and limitations several months into the future. Generally, these features are continuously being improved, so this report reflects only a snapshot of EIS products as they exist today.

[20] For example, if a client site already has an EMCS communicating with BACnet protocol, it is easy to install web-based communication to the site. If the site's EMCS is a proprietary system, the client is required to purchase an additional gateway system.

4-1 Metering and Connectivity

4.1.1 Data Sources

In a recent paper on EIS, Fryer explained three types of data sources: monthly billing data, whole-building electric interval data, and sub-metered component or EMCS data (2002):

> ***Monthly billing data*** *– Monthly bills are good for figuring out which buildings are the most expensive to operate (perhaps normalized for area, weather, occupancy, or production units). This seemingly simple task turns out to be difficult for most companies, who don't formally even collect data, let alone enter it into a database. Yet, data are accumulating nonetheless: namely, the meter data. At a minimum, monthly use and cost are available.*
>
> ***Whole building electric interval data*** *– This provides much more information than monthly bills alone. Many larger facilities are equipped with interval meters, which record data every 15 minutes. The resulting load profiles show peaks and high use times which can often explain high energy costs*
>
> ***Submetered component or EMCS data*** *– End use data provides the most information, however, it is the most expensive to collect because it requires dedicated monitoring equipment and the most complex to analyze because of the high volume of data. It is at this level that real diagnosis of specific problems can be done.*

As described in the California Energy Commission's "Advanced Metering Scoping Study" (Levy, 2001), whole-building-electricity metering systems can be divided into three types based on their communication capabilities (Table 4-2). Conventional manual/electric keypad and remote meter reading systems, which don't support communication capabilities and whose data are only available once in each billing cycle (28-32 days), are the dominant systems in place today. However, automated meter reading and interval metering are required to support EIS capability. Because most sites with EIS products have hourly or 15-minute interval meter data, we do not discuss monthly bill data or software in this report.

Table 4-2. Metering Systems Classification (Levy, 2001)

Type of Meter System	System Features
Conventional Manual/ Electric Keypad	▪ Limited to single kWh usage value each billing cycle. ▪ Cannot collect hourly interval data. ▪ Data only available once in each billing cycle.
Remote Meter Reading	▪ Support collection of multiple kWh register values of TOU rate. ▪ Cannot collect hourly interval data. ▪ Data only available once in each billing cycle.
Automated/Network Meter Reading (Interval meter)	▪ Meter connected to data repository by telephone, paging, Internet, or other communication technologies. ▪ Full compliment of interval and other meter data. ▪ Stored meter reading can be collect on a fixed schedule, on demand, or real-time.

One problem with EMCS data is that the trend data may not be sufficiently accurate for historical data analysis if the meters and sensors are not properly commissioned. Temperature, flow, and pressure data may be used in the EMCS for control that were not commissioned for performance analysis (Stein, et al., 2000). Recent research projects in this area have included additional sensors and meters that are more accurate than typical EMCS monitoring (Piette, et al., 2000).

To obtain better accuracy, some vendors prefer to install their own sub-meters instead of using the EMCS. These vendors install sub-meters on critical points, which are different for each client. For example, refrigeration power consumption is most important for grocery stores, while HVAC systems are most important for commercial office buildings. Since connectivity characteristics are different between sub-meters and EMCS, sub-meter and EMCS data are categorized separately in this report.

Table 4-3. Metering and Connectivity

Software	Type of EIS[21]				Data Source			Trend Interval	Update freq.	Notification /Response	Monitoring /Control
	Basic-EIS	DRS	EEM	Web-EMCS	Interval	EMCS	Sub meter				
UM Online			✓		✓			1 month	monthly		
UM Profiler	✓				✓			15 min	daily		
Enerlink	✓				✓			5 min	daily		
PLISEM		✓			✓			-	real-time		
Demand Exchange	✓	✓			✓			15 min	real-time	✓	
EPO	✓	✓	✓		✓			1 hour	real-time	✓	
IUE	✓	✓	✓	✓	✓	✓	✓	2 min	2 min	✓	
Readmeter	✓	✓		✓	✓			15 min	daily	✓	
EP Web	✓	✓		✓	✓	✓	✓	15 min	real-time	✓	
eMAC				✓			✓	15 min	daily		✓
UtilityVison	✓	✓		✓	✓		✓	15 min	daily	✓	✓
Automated Energy	✓		✓	✓	✓	✓	✓	15 min	daily		✓
EnterpriseOne	✓		✓	✓	✓	✓	✓		real-time		✓
EEM Suite	✓	✓	✓	✓	✓	✓	✓	15 min	real-time	✓	✓
Vykon	✓		✓	✓	✓	✓	✓		real-time		✓
GEMnet				✓	✓	✓		1 min	real-time		✓
IMDS	✓			✓	✓		✓	1 min	real-time		✓

* If there are options in trend interval or updated frequency, the basic interval is noted.

Most EIS products have access to interval meter data, and most Web-EMCS products have access to EMCS data, but [22] some EIS products also have unique data sources, as shown below.

Examples of Data sources

eMAC	The eMAC system collects 26 different data points (e.g. chilled water temperature, water flow, fan kW) for each roof-top unit. The controller sends and receives wireless signals to monitor and control the roof-top unit.

[21] Refer to Chapter 2 for the definitions of each type of EIS.
[22] A Web-EMCS may use submeter or sensor data detailed enough to perform component-level diagnostics instead of EMCS data.

IMDS	IMDS has additional sensors that are more accurate than typical EMCS sensors.

Trend Interval
EIS products typically provide interval data with at least one-hour resolution to develop daily electric load profiles. Shorter intervals provide better data detail, but are more expensive to operate and require more data storage capacity. The typical trend interval is 15 minutes. In general, 15-minute intervals are detailed enough for whole building electricity analysis (hourly intervals are also acceptable). Unlike whole-building energy consumption, some component data such as chiller tons and fan airflow fluctuate sharply. Therefore Web-EMCS, which perform component-level analysis, often trend data in intervals even shorter than 15 minutes.

Update Frequency
There are two ways for EIS products to retrieve data, daily upload and real-time upload. Daily uploads are frequent enough to be used for building energy management diagnostics, and benchmarking. On the other hand, real-time upload is common in DRS. For manual control systems, the DRS user has to check the demand frequently during a curtailment event. Fifteen-minute upload is generally called "near real-time", while "real-time" is considered to be at least every 1 or 2 minutes. Since 15-minute upload is insufficient to track the dynamic changes of peak demand, monitoring frequencies are often shorter than trend intervals.[23] Although many "real-time" EIS products upload meter data every few seconds, the server may archive data only once every 15 minutes to reduce disk space.

4.1.2 Connectivity

Most EIS directly communicate with metering devices. As mentioned earlier, a building site has to be equipped with an interval meter to support EIS services. The technology needed to acquire interval meter data is easily cost-justified for large commercial and industrial customers, and is often already in place or readily upgraded (Levy, 2001). Interval meters are commonly installed in large commercial buildings using time-of-use and/or other customer service options. Major utility companies in California have provided free installation of interval meters for customers participating in DR programs.[24]

Interval meters almost always have data storage capability. In systems where the data collection interval is more frequent than daily upload, the meter needs to store the interval data until data upload. The data upload is usually scheduled once a day, during the night or early morning. In some cases, meters dispatch trend data directly to the host server in real-time, so storage capacity is not necessary.

Daily uploads are less expensive than real-time uploads because they can use telephone line to send data. Real-time data transfer usually requires a fast Internet connection, which is relatively expensive. Real-time data transfer is critical for DRS or automated control, but daily upload is sufficient for manual diagnostics by offsite professional engineers. The decision between daily upload and real-time data transfer should be made carefully, depending on the customer's needs. Communication methods for individual sub-meters are the same as for that of interval meters.

[23] In case of manual control during a DR event, an onsite operator changes equipment setpoints or on/off manually. The operator needs to know how much kW the building is using in real-time, to meet the target kW reduction. Using 15-data may not reveal increases in usage, and risks failing to meet the DR target.
[24] In 2001, the California legislature passed AB970 which provided incentives to energy providers to enhance DR program participation of their customers.

Where there are multiple sub-meters at one site, sub-meter data may be integrated in a terminal device, and then sent to the data server via the Internet. This data transfer can be done daily or in real-time.

Web-EMCS products generally have more advanced connectivity than other EIS products. They emphasize system integration using gateways or similar technology to integrate multiple systems. Some Web-EMCS products work only as an underlying system integration platform for other, more applications-focused EIS products. GEMnet and IMDS are two examples of technology combinations that compose Web-EMCS products, as described below. More connectivity issues are discussed later in remote control features.

Examples of Applications Software and System Integration Platform Combinations

GEMnet	GEMnet relies on Web-CTRL as its underlying system integration technology. In the GEMnet project, some application technologies are tested at different sites and programs led by different institutions. The National Institute of Standards and Testing (NIST) is developing Variable-Air-Volume box diagnostics. LBNL is performing on-going analysis of the BAS data and developing model-based diagnostic techniques for implementation in GEMnet. GEMnet is also planning to include the use of PACRAT[25].
IMDS	IMDS uses Enflex for its underlying system integration technology, and is equipped with ElectricEye as its visualization application.

EIS products commonly use one of two types of communication methods. The most commonly used is telecommunication, which includes telephone line and wireless cell phone communication. Telecommunication can be used only when data transfers are small. Most daily-upload EIS products use telecommunication, and upload at night when the communications pathways are relatively idle, to avoid fatal data loss during data transfer. Telecommunication is widely used because it is economical and easy to install.

The second most commonly used EIS communication method is Internet access. Using high-speed Internet connections, large volumes of data can be transferred rapidly. Web-EMCS products often use high-speed Internet connections because they transfer such large volumes of data. While the use of high-speed Internet access is not yet widespread as an EIS communication method, it is quickly becoming more common, because of the recent rapid advancement of information technology industries.

[25] PACRAT and other diagnostic tools are explained in detail by Friedman and Piette (2001).

4-2 Application Capabilities

EIS applications span a wide variety of purposes and features. We categorized these application features into four different capabilities, including data visualization, demand response, automated control, and financial analysis.

4.2.1 Data Visualization

Most EIS products have data visualization capabilities, some more complex than others. Data visualization features can be roughly divided into two categories, time-series visualization and analytic visualization.

Time-series visualization

One of the most common ways that building operators view EMCS data is through simple time-series graphs. With EIS, building operators and remote users have access to more sophisticated time-series plots, such as daily overlays, averages, highs and lows, point overlays, and 3D charts – all of which are combinations of different daily profiles or different layouts of the same time-series data. The main use of time-series visualization is to quickly analyze data trends. Some common time-series visualization features are described below and time-series visualization examples are shown in Figure 4-1.

- **Daily profile –** Time-series daily load profiles are displayed with time, in intervals of an hour or less, along the horizontal axis and load along the vertical axis. This is the most common EIS function for visualizing energy consumption data. It can be used to verify operation schedules, identify peak hours, and develop baseline load profiles. Incorrect scheduling of equipment (air-conditioning, lighting, etc) can be quickly determined from the daily profile.
- **Day overlay –** Overlay plots display multiple daily profiles on a single 24-hour time-series graph. Daily overlays are useful for finding abnormal days that would otherwise be difficult to find in a single daily profile and can also be used to obtain a quick estimate of the average.24-hour load profile of a building.
- **Average –** The Average function calculates the average hourly energy consumption values for selected days and displays an average daily profile, which can be used for baseline reference.
- **Highs and lows –** Indicates maximum and minimum hourly consumption values for the day, or plots a daily profile of the maximum and minimum day within selected days.
- **Point overlay –** Allows viewing of multiple time series data points on the same graph. This is useful for finding the most energy-consuming sites (for multiple sites) or components (for sub-meters). It is also useful to overlay highly correlated data, such as power and outside air temperature. Some EIS products offer online access to real-time and forecasted temperature data.
- **3D chart –** Three-dimensional surface charts often display the time of day, date, and variable for study. These charts can be used to quickly determine which time-periods might be problematic. For example, a 3D chart might indicate peaks occurring at unexpected time periods over a month. A user finding an abnormality in a 3D chart can then study a 2D daily

profile in more detail, or examine other detail graphs for that day; i.e., it is useful for a top-down diagnostic approach.[26]

- **Calendar profile –** View up to an entire month of consumption profiles on a single screen as one long time series. The calendar profile displays the historical sequences of daily profiles and weekly trends.

Analytic visualization

Analytical visualizations help with benchmarking and diagnostic analysis. Common analytical visualization features are described below and examples are shown in Figure 4-2.

- **Summary –** The data summary feature is used to aggregate data by day, week, month, or other selected time period. Data typically are displayed in bar charts and/or tabular summary statistics. Summary statistics are useful for analyzing the historical sequence of energy usage (for single buildings) over time, since monthly or yearly summary statistics can be compared. This is commonly found in EEM and Basic-EIS.
- **Energy use breakdown –** Energy usage breakdowns show energy use for individual or multiple buildings, either by energy source (electricity, gas, oil, etc) or by end use (lighting, chiller, refrigeration, etc). Breakdowns by energy source are easier to obtain as data are collected separately. End use breakdowns require meters for every end use that is to be reported. It is common to meter the end uses that use the most energy, such as cooling equipment.
- **Multi-site comparison –** Multi-site comparison is a crucial feature for enterprise energy management systems that typically are used by multi-facility customers. The typical method of comparison is to plot whole-building energy consumption for each building in a bar chart. This is helpful in targeting sites for energy saving measures or retrofit.
- **Normalization –** Typically a client's sites differ in many respects. In order to make a fair comparison between buildings, some EEM products utilize normalization techniques. Some normalization factors include building area, number of occupants, outside air temperature (OAT), and cooling or heating degree-days (CDD, HDD). Expressing the data in terms of energy use per square foot normalizes energy use data to account for variations in building size. Weather normalization techniques usually involve a more complex method such as a regression model.
- **Load duration –** A load duration curve indicates the percentage of time the load persisted at the defined levels of magnitude, in kW. If the curve is relatively flat, it indicates the energy consumption is steady. If the curve spikes up at the left side of the graph, it indicates that the peak demand is high and infrequent against the baseline, and the client may have to pay a high peak demand charge.[27]
- **X-Y scatter –** X-Y scatter plots are useful for visualizing correlations between two variables. Some common X-Y plots used in chiller diagnostics are chiller tons vs. kW/cooling ton and fan CFM vs. power. For whole-building energy analysis, daily or monthly energy use may be plotted against outside temperature for buildings with power consumption dependent on

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[26] The method of building diagnosis that analyzes whole-building-energy first, finds a suspicious energy trend, and narrows down the suspicious part to identify the cause of the energy trend is called "top-down approach". This is useful for identifying the largest energy saving opportunities. On the other hand, the method that analyzes component-level data first, sums up the energy saving of each solution to the problem, and finally estimates total energy saving, is called a "bottom-up approach".

[27] The demand charge is related to the maximum demand for electricity (kW) in the monthly billing period.

weather conditions. This is useful for users interested in managing peak load under high-temperature conditions.

Most Basic-EIS products provide simple tabular and graphical visualization of interval meter data. These time-series visualization features often include daily overlay, average plot, and high/low indication. Table 4-4 shows the visualization features available for each EIS product. Figures 4-1 and 4-2 show examples of visualization featured in this section.

Table 4-4. Visualization Features

Software product	Time-series visualization							Analytic visualization					
	Daily profile	Day overlay	Average	Highs/lows	Point overlay	3D chart	Calendar profile	Summary	Energy-use breakdown	Multi-site comparison	Normalization	Load duration	X-Y scatter
UM Profiler/UM Online	✓	✓		✓				✓	✓	✓	✓		
Enerlink	✓		✓	✓	✓	✓		✓			✓		✓
AMICOS	✓				✓			✓					
Demand Exchange	✓	✓	✓	✓	✓			✓				✓	
EPO	✓	✓	✓	✓	✓			✓		✓		✓	
IUE	✓	✓			✓		✓	✓	✓	✓		✓	
Readmeter	✓			✓	✓							✓	
EP Web	✓		✓	✓	✓	✓	✓	✓		✓			
UtilityVison	✓	✓	✓	✓	✓			✓					
Automated Energy	✓				✓			✓		✓			
EnterpriseOne	✓	✓	✓		✓		✓	✓	✓	✓	✓		✓
EEM Suite	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
IMDS (Electric Eye)	✓	✓		✓	✓	✓					✓		✓

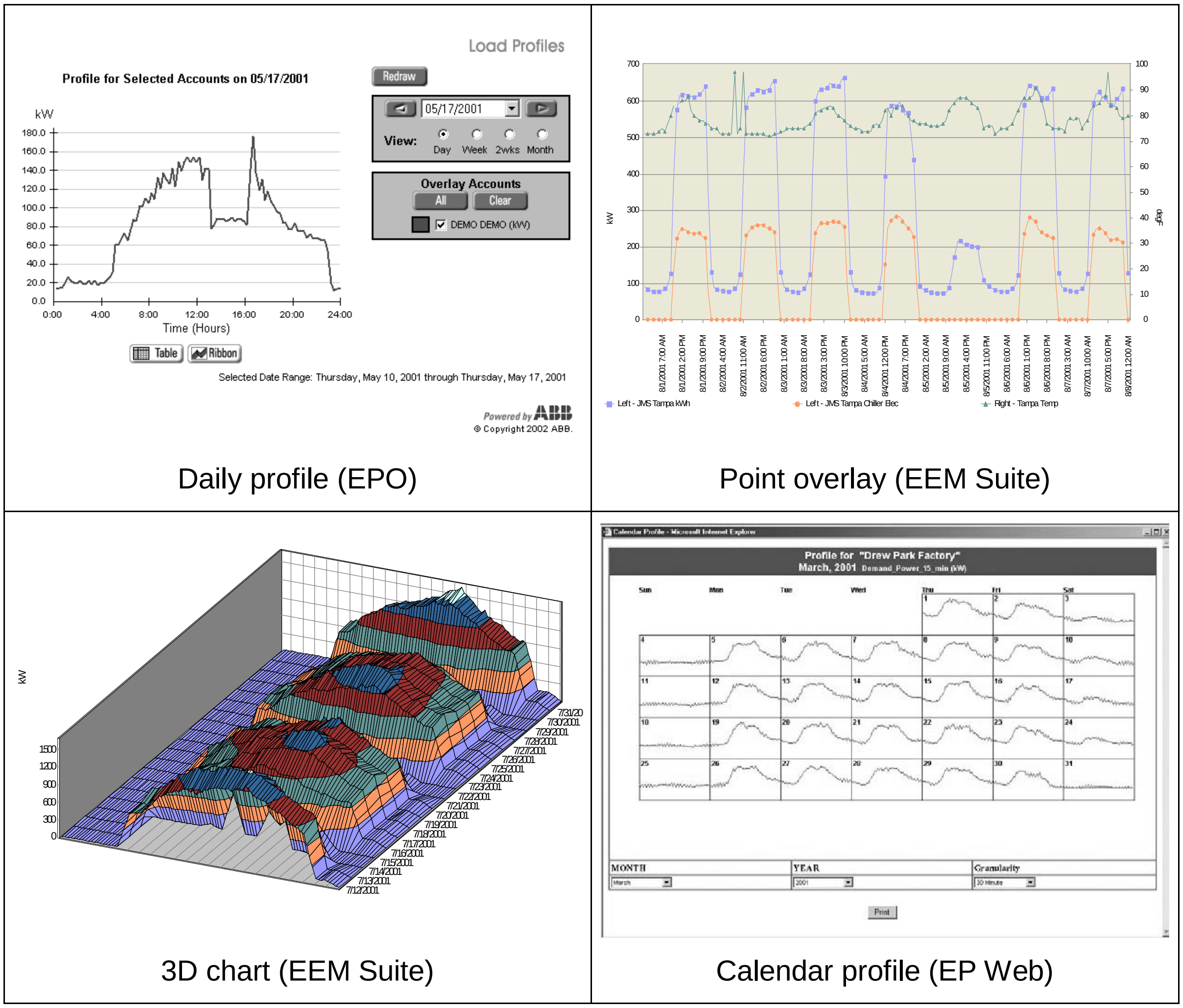


Figure 4-1. Time-series Visualization Examples

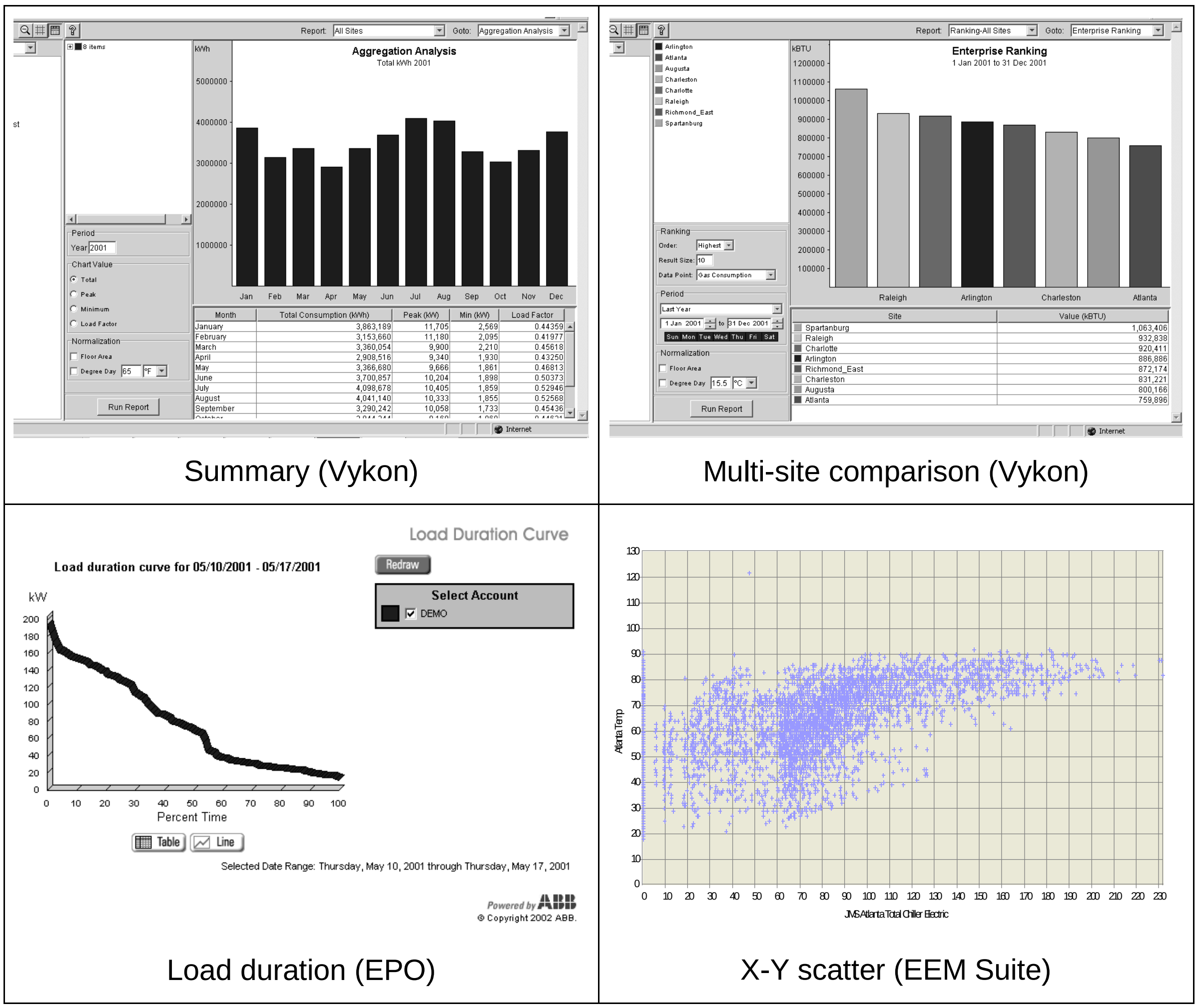


Figure 4-2. Analytic Visualization Samples

Some EIS products have analytical visualization features that help users summarize historical energy usage and diagnose problems that are difficult to detect using simple time-series visualization. Summary functions are more often found in EEM products, while diagnostic functions are more often found in Web-EMCS products. Historical energy analysis includes data summaries, energy usage breakdowns, comparisons of multiple accounts, and normalization. Below are examples of advanced data visualization features.

Examples of Energy Usage Breakdown

EnterpriseOne	EnterpriseOne combines multiple energy sources by automatically converting each unit into Mbtu.
EEM Suite	EEM Suite has an energy use breakdown chart for systems with end-use sub-meters.

Examples of Normalization

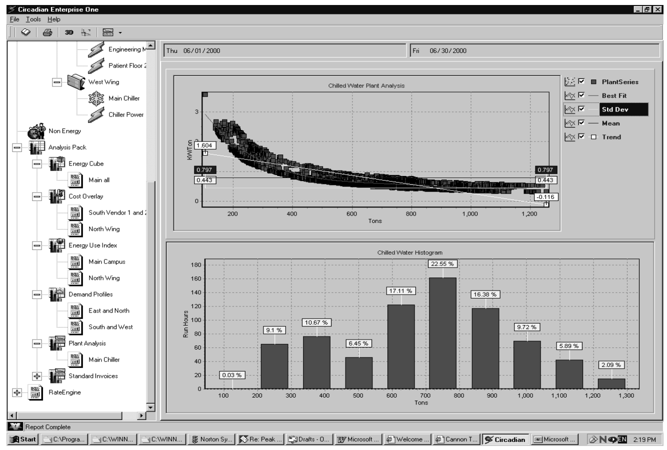
Enerlink	Enerlink has area normalization (per square feet).
EnterpriseOne	To ensure the facility is operating to specifications, EnterpriseOne helps normalize energy usage to account for weather changes by using weather data tracked by the EMCS. EnterpriseOne also normalizes by area.
EEM Suite	The EEM Suite's Energy Analyst module can normalize by area, CDD, HDD, and production unit.
IMDS	Electric Eye has a math function that creates a new point from any other points. Using the function, the user manually can create a normalized point.

Diagnostics

Detecting and diagnosing problems in buildings can lead to improved control and occupant comfort, prolonged equipment life, and lower energy use and maintenance costs. The data visualization and analysis features described above are useful for analyzing detailed trend data to detect operational problems; however, human expertise is required to determine which data points are to be plotted and what patterns in the data or graphs indicate a problem. Even knowledgeable users may find this to be time-consuming; moreover, user selections will not be consistent among all sites and over time. Pre-defined diagnostic graphs designed for specific variables may still require that the user interpret the information, but can save valuable time. Commonly-viewed plots such as chiller tons vs. tons/kW could be prepared as built-in charts. Below are some examples of pre-defined charts.

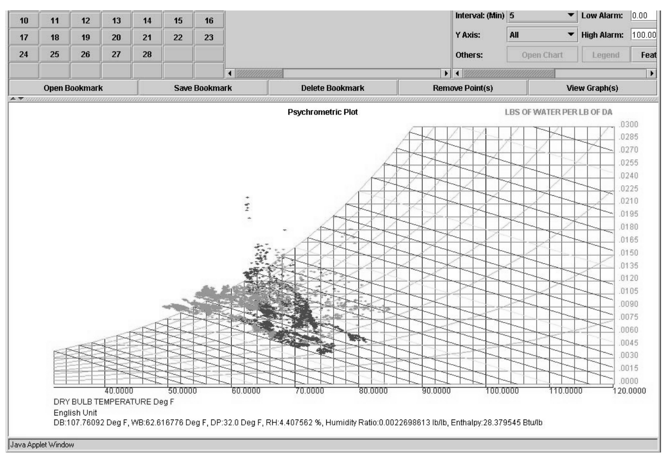
Examples of Pre-defined diagnostic graphs

EnterpriseOne EnterpriseOne has specific pre-defined analysis features including chiller diagnostics chart of the tons vs. tons/kW chart and tons histograms.



Chiller ton vs kW/ton, Chiller Histogram

IMDS IMDS with Electric Eye has Psychrometric chart. This chart represents the interrelation of air temperature and moisture content, which indicates indoor/outdoor air comfort.



Psychrometric chart

Automated diagnostics[28]

Sophisticated building energy information systems have the potential to deploy automated fault detection and diagnostic analysis. Although many EIS products provide alarm features that produce alarms according to simple algorithms such as maximum/minimum limit, this is not sufficient to detect many HVAC problems. Some EIS, however, do have automated diagnostics functions. These more advanced tools will run algorithms to search for anomalous data representing potential faults and suggest possible causes and solutions. Diagnostic tools integrated with an EIS, EMCS, or other data acquisition system provide a greater opportunity for real-time analysis and a greater level of automation because data can be automatically transferred

[28] Automated diagnostics are discussed by Xu and Haves (2002).

from the EIS into the diagnostic application. Automated diagnostic procedures can be run continuously or periodically, requiring user action only when a fault is detected. This saves a great deal of time and the embedded expertise allows less-experienced users to perform high-level assessments (Friedman and Piette, 2001).

One type of automated diagnostics is rule-based diagnostics, in which system failures and operational problems are detected by rule-based algorithms[29], and the diagnosis presents potential causes and recommendations to alleviate a problem. While these automated diagnostics features are emerging in EIS, they were originally developed as EMCS data diagnostic tools (Friedman and Piette, 2001). Here are some examples of EIS that have automated diagnostics either in practice or in progress.

Examples of Automated Diagnostics

eMAC	eMAC has a rule-based diagnostic algorithm in its on-site controller, and diagnoses rooftop units in real-time. If the controller detects an abnormality, it immediately sends an alarm with estimated cause via e-mail, pager, and/or some other method(s).
UtilityVision	UtilityVision's FacilityVision module uses PowerNet as its automated diagnostics platform (for PowerNet details, see Chapter 5). Professional agents operate FacilityVision, and provide diagnostic solutions to their clients.
EEM Suite	EEM Suite includes a rule-based exception analysis and web reporting capability to alert personnel to abnormal equipment, process and/or facility operating performance. Expected energy consumption and/or electrical demand are compared to actual values to identify anomalies within commercial facilities or industrial processes.
FX-TEM	Statistical methods are applied to hourly time-series data to detect anomalous values which are usually an indication of faulty equipment operation or scheduling problems (Seem, 2002).
GEMnet	The National Institute of Standards and Testing (NIST) is developing Variable-Air-Volume box diagnostics. LBNL is performing ongoing analysis of the BAS data, along with developing model-based diagnostic techniques for implementation in GEMnet. GEMnet will also include the use of PACRAT (Friedman and Piette, 2001).

Forecasting

Forecasting functions use historical time series data to predict future values. In EIS this function typically consists of a 2- to 5-day forecasts of electricity consumption. The methods and the parameters used for the forecast vary in each EIS. The primary use of forecasts is to plan future operational schedules, including DR program participation. When the forecast indicates high peak demand, the users can plan for a DR program curtailment or schedule peak avoidance strategies. A limitation of the forecasting feature in most cases is that human intervention is required to determine and implement operational changes in response to forecasts. Here are some examples of forecasting capability.

[29] For example, an algorithm can be programmed to send an alarm if the supply fan air pressure passes a minimum setpoint. This is only a very simple example, but an algorithm can be very complex by combining multiple sub-routines or calculating a parameter from multiple data with mathematical formulas.

Examples of Forecasting

IUE	IUE automatically forecasts end-use-level, time-series electricity consumption by assessing device consumption data in conjunction with variables that drive energy use and cost, such as: external weather, space occupancy and temperature, RTP data, and market demand. These forecasts can be viewed at both the building and the portfolio level. IUE's Intelligent Agents utilize data feeds every 2 minutes to learn building consumption patterns and their reactions to change. IUE can predict future energy usage for any period of time - 1 hour, 2 days, and more than 30 days. Accuracy of the forecast, however, depends on the accuracy of weather forecasts and other data inputs.
Automated Energy	Automated Energy incorporates data from AccuWeather, the Internet weather provider, into its system so that weather can be factored into the forecasting.
EEM Suite	EEM Suite's Forecasting module uses its own proprietary algorithm based on historical load and weather data to forecast 24- to 48- hour energy usage. Alternatively, other customer-derived algorithms can be deployed. Various statistical analysis techniques are used to calculate expected consumption or demand on an hourly or daily basis. Techniques include facility and profile cluster analysis, weather and production normalization, day-type normalization and hybrid statistical-neural network modeling.

4.2.2 Demand Response

All the Demand Response Systems (DRS) have some demand response (DR) features. The general purpose of DRS is to allow users to participate in DR programs and manage their participation as operable and feasible. Increasingly, other EIS are also equipped with DR features. DR features can be briefly separated into following three parts:

- **Notification and Response**
- **Analysis (Event report, Baseline)**
- **Remote control (Manual control, Automatic control)[30]**

Notification and Response

Notification-and-response communication is fundamental to DRS. Typical notification-and-response communication systems are described in Chapter 2, though the procedures of DR program participation vary widely depending on clients' (energy providers) needs. The California ISO orders investor-owned utilities to initiate interruptible load programs, either mandatory or voluntary. Table 4-5 shows DR and remote control features of each EIS. In this table, only EIS categorized as DRS are featured.

[30] Though described in 4.2.3, the remote control capability is an important feature of demand response.

Table 4-5. Demand Response / Remote Control Features

Software product	Notification-and-Response		Analysis			Control	
	Notification	Response	Event report	Baseline	Saving analysis	Manual control	Automated control
PRISEM	✓	✓	✓				
Demand Exchange	✓	✓	✓	✓	✓		
EPO	✓	✓	✓		✓		
energy1st	✓	✓	✓	✓		✓	
IUE	✓	✓	✓	✓	✓	✓	✓
Loadcontrol	✓	✓	✓	✓		✓	
EP Web	✓	✓	✓			✓	
UtilityVision	✓		✓			✓	✓*
Automated Energy	✓	✓	✓	✓		✓	
EEM Suite	✓	✓	✓	✓	✓	✓	✓

* Under field test.

Definitions:

Notification:	Notification of DR event via web-site, e-mail, phone, pager, cell phone, etc.
Response:	Capability to bid DR event via web-site[31].
Event report:	Track and report kW savings and cost for all events.
Baseline:	Calculate baseline according to utility program formula.
Saving analysis:	Cost estimation of expected utility bill saving using forecast and/or utility tariffs.
Manual control:	Execute demand-shedding operation remotely by operators.
Automatic control:	Execute demand-shedding operation automatically.

Some DR programs are based on bids placed the day before or the day of curtailment. All the DRS featured in Table 4-5 are capable of real-time notification and demand bidding. **PRISEM** is focused on the real-time notification-and-response communication features, though it does not have graphical visualization of load profiles or other sophisticated visualization/analysis features. On the other hand, the **Demand Exchange**'s perspective is more traditional. **Demand Exchange** operates on day-ahead basis wholesale market, though it also has real-time bidding option.

Most commercial customers' energy consumption is highly temperature sensitive, and is not a large component of their business. Therefore, they rarely have interest in being in the DR market on a daily basis. However, there are other customers, such as large aluminum and steel mills, which are less temperature-sensitive and use an enormous amount of energy on a regular basis. They are either in the business themselves or they designate an agent to operate on their behalf. According to Borska and Lynch-Blanc, **Demand Exchange** is the product of energy consultants developing a software platform, while **PRISEM** and other real-time DRS products are Internet platforms developed by Internet people for the energy industry (2000).

Savings analysis

Savings analysis features are designed to verify curtailed peak demand (kW) for DR program contracts, and to plan future DR programs. For the former purpose, DR verification, the baseline calculation capability is indispensable. A baseline is a forecast used to predict what power consumption would have been in the absence of a curtailment. The amount of curtailed peak demand during a DR event is calculated by subtracting actual measured demand from the baseline.

[31] Refer 2.2.2 to see how the transaction between a utility company and a client works.

Each DR program has its own baseline calculation method. For example, the California ISO 2001 Summer Demand Reduction Program used the "Highest 10-of-11-Day Average" as its baseline method. The simple calculation methods used by DR programs are less accurate than the more sophisticated forecasting methods offered in some EIS. Section 5-4 includes additional discussion on measuring demand reduction and energy savings. Below is an example of baseline setting of DRS.

Example of Savings Analysis

EEM Suite	EEM Suite's Curtailment Manager calculates 10-day baselines for savings verification, which can be customized to adjust to variety of baseline formats. Pacific Gas & Electric deploys Curtailment Manager, which is adjusted to the California ISO baseline method.

While the remote control features are substantial to implement DR programs, they have wider capabilities and opportunities for energy management as well. Most EIS developers offer a wide range of customized products and solutions.

4.2.3 Remote Control

EIS users can send remote control signals manually (or EIS applications can send signals automatically). Control devices and EMCS receive these control signals directly from the Internet or through a gateway at the site. Each device or gateway has to have monitoring-and-control communication. EIS products that have remote control capability are mostly categorized as Web-EMCS. The typical system architecture for remote control functionality is described in the definition of Web-EMCS (Section 2.2.4).

Manual control

Manual control refers to functionality that allows a user to manually submit control commands via EIS in response to a DR event or other critical condition. The advantage of using an EIS for control is that a user can operate multiple buildings at once over the Internet. This allows an energy manager to act promptly on DR events.

Manual control capabilities have various degrees of facilitation. For example, the user can customize a range of demand-shedding strategies for each site, and execute the strategies remotely when a curtailment event occurs. An example of a hypothetical demand-shedding strategy is shown below.

Site A	Level-1:	Thermostat setting up to 76 deg-F
	Level-2:	Thermostat setting up to 82 deg-F
Site B	Level-1:	60% load chiller operation
	Level-2:	30% load chiller operation

Popular control strategies are chiller load reduction, load rotation, thermostat reset, supply air temperature reset, and dimmed lighting. The levels to select depend on the level of curtailment needed. These preset control commands facilitate DR event participation and other energy saving strategies, so that a user can easily execute load shedding across all sites. Below is an example of manual control functionality.

Example of Manual Control

UtilityVision	Each site has its own load curtailment settings ranging from level 1 to 5. These curtailment settings include chiller shedding, dimming lights, and changing temperature setpoints. The user sets the start time, duration, and curtailment level. When the start time comes, UtilityVision automatically controls the facilities according to the user's manual settings.

Automated control

In addition to these manual controls, some EIS have automated control capabilities. Some Web-EMCS products work like an EMCS by automatically controlling building facilities in response to monitored building conditions. Such products have control algorithms in their gateway devices, and automatically control without manual operation.

These automated control technologies using real-time control algorithms are used for DR programs, so that even energy managers do not need to respond to an alert in real-time. In this case, these EIS products respond to curtailment requests or energy prices, and automatically deploy specific control strategies to avoid high demand peak. Here are some examples of automated control capabilities.

Examples of Automated Control

IUE	IUE's Intelligent Agents automatically deploy proprietary, pre-defined intelligent conservation strategies to minimize energy usage. Based on a forecast, energy-saving strategies are aimed at permanent load reduction, peak load management (avoidance and reduction), and voluntary and emergency curtailment. Specific tactics include: set point optimization, supply air temperature optimization, 24-hour-7-day-a-week load shed, and load rotation. A pre-cooling strategy is now in development. All of the strategies that are automatically and manually deployed can be viewed in real-time online.
eMAC	Unlike many Web-EMCS prodcuts, eMAC comes with predefined but customizable control strategies. eMAC has several modules specified for rooftop units, lighting and refrigeration. This "component-specific" design reduces the system variation of their products and lowers the production cost.
UtilityVision	UtilityVision deploys load curtailment according to a proprietary energy forecast system. The user inputs peak demand to respond, curtailment duration, and target demand shed. UtilityVision automatically starts up a curtailment event, and chooses the appropriate curtailment level. Currently this automation feature is under field test at some sites with on-site electricity generation (using photo-voltaic cells).
EEM Suite	Using the Universal Calculation Engine module, a user can create a control algorithm that calculates energy conditions and automatically sends alarms or controls equipment in real-time. In combination with its Forecasting module, it can also implement "forward-basis" control strategies.
Vykon	Niagara Framework, the underlying platform of the web application Vykon, integrates existing control algorithms in legacy systems and also creates new algorithms. These algorithms are not modifiable via Vykon.

Unfortunately, these automated control capabilities are rarely utilized, partly because clients are not fully convinced of their usefulness and reliability. Further demonstrations and user education will be required to popularize the use of these capabilities.

4.2.4 Financial Analysis

Energy managers generally do not have time to incorporate energy usage information into their companies' financial strategies. Financial analysis is powerful tool for energy managers to identify costly energy behavior, plan cost-saving procurement, or assess economical profitability of DR events. Common features of financial analysis are defined as follows.

- **Rate tariff** – Software contains a series of rate tariffs to fit to clients' utility rates. Users can compare energy procurement alternatives or estimate DR event benefits.
- **Online rate tariff** – Rate tariff data can be dynamic according to real-time price structure downloaded from the Internet.
- **Bill validation** – Utility bills are compared to meter readings to validate accuracy of bills.
- **Real-time tracking** – Calculates electricity costs every day or hour using real-time meter reading and rate tariffs.
- **Breakdown summary**[32] – Breaks down monthly utility bills by day or hourly profile. Identifies the highest cost day or hour. This combines aspects of real-time tracking and rate tariff features; however, a breakdown summary may also be performed using downloaded or historic data that is not necessarily provided in real time.
- **End-use allocation** – According to user-defined parameters and algorithms, estimates end-use energy consumption from whole building energy. Generally used for cost allocation to building tenants. A common parameter definition is energy use per square foot.

Rate tariff features are often included in Basic-EIS offerings from utility companies. The breakdown summary shows the product of rate and hourly load profile, which may indicate more striking results than electricity consumption data alone. Final results depend on the hourly rate, demand charge, and other rate features. These charges can comprise a large part of the total utility bill, so the breakdown summary, a cost structure approach, has significant energy cost-saving potential. Though end-use allocation is not an energy-saving measure, it is useful to fairly allocate the utility bill to the tenant and can help the building managers understand where they use energy. This feature can be found in EEM. Below are some examples of financial analysis capabilities.

Examples of Financial Analysis

EP Web	EP Web has the basic features of financial analysis, including rate tariff, bill validation, real-time tracking, and end-use allocation. These features can be applied to any monitored or logged value.
Automated Energy	Automated Energy estimates upcoming bills using load forecasting and "what-if" scenario analysis.

[32] The breakdown summary is a combination of the real-time tracking and the rate tariff. The only slight difference between the real-time tracking and the breakdown summary is that the breakdown summary doesn't have to be real-time, so weekly or monthly download of interval data can be applicable.

EnterpriseOne	The RateEngine module compares purchasing options from multiple energy providers and verifies cost/benefit analyses by third party energy service companies.
EEM Suite	EEM Suite has wide variety of financial analysis, including the financial analysis functions listed above.
UtilityVision	UtilityVision integrates performance contract procedures into the EIS, showing a monthly summary of energy savings with baseline, target savings, utility rate, and estimated cost savings.

4-3 Cost Comparison

EIS costs vary widely depending on their systems and services. Cost structures depend on the type of EIS clients, and can be briefly divided into two types. In one type, an EIS vendor contracts with an energy provider or an energy service company. Costs of EIS software and monthly fees are paid to the vendor by the utility. The utility has the discretion to pass through all, some, or none of the fees in any number of ways across its customer base. In another type, an EIS vendor contracts directly with end-users. A recent CEC report summarizes EIS cost structures for energy providers and end-users separately (Xenergy and Nexant, 2002).

Costs for Energy Providers
There are three basic fee structures when contracting with a vendor for EIS platforms:

Overall set-up or licensing fees – This fee varies based on whether the utility or the customer is being charged. It is heavily dependent on what type of metering technology a site has or needs to interface with the vendor's network platform. Utility charges can include licensing fees, platform system maintenance, or information service access.

Monthly Fees – In most cases, monthly fees assessed to customers include 24-hour, 7-day-a-week access to vendor assistance and data center resources. In those cases, the structure and amount of those monthly fees is site and equipment capability specific and is negotiated on a case-by-case basis.

Transaction Fees – When the company participates in a DR program, transaction fees are charged per event. This transaction fee generally covers notification-and-response communication, and in some cases, verification and settlement of load is included as well.

Cost for End-Users
Costs for end-users, including multi-facility clients and individual buildings, can be explained by the types of EIS. The above-mentioned CEC report reported end-user costs by levels of EIS for DR Program in their definition (Xenergy and Nexant, 2002). The costs are divided into hardware hook-up, such as devices at the meter and wiring; software licensing and initial system installation; system usage or licensing via application service provider; and other fees, which include service and maintenance (Table 4-6).

Table 4-6. End-User Costs of Varying Levels of EIS (Xenergy and Nexant, 2002)

EIS levels	Hardware Hook-up (per site)	Costs to acquire or use energy information software and systems		Service, maintenance & other costs or fees (monthly/site)
		Software licensing & initial system installation (&/or annual fee)	System usage (ASP) or licensing (monthly site)	
Notification (Basic-EIS)	$0 – $3,000	$3,000 (&/or > $500/yr)	$25 - $100	$0 -$50
Notification & analysis (DRS)	$3,000 or more	$5,000 - $10,000 (&/or > 1,000/yr)	$100 - $250	$100 - $150
Notification, analysis & response (DRS, Web-EMCS)	$5,000 - $15,000	$25,000 - $50,000 (&/or > $1,200/yr)	$400 - $1,000	$400 - $1,200

5. Emerging Methods

Analysts and engineers have a variety of tools and techniques that are currently available and in use, but those tools and techniques are not commonly found in EIS. In this section we discuss related tools that provide functionality not commonly integrated into EIS. In general, increased automation of these tools is likely to increase their ease of use and acceptance.

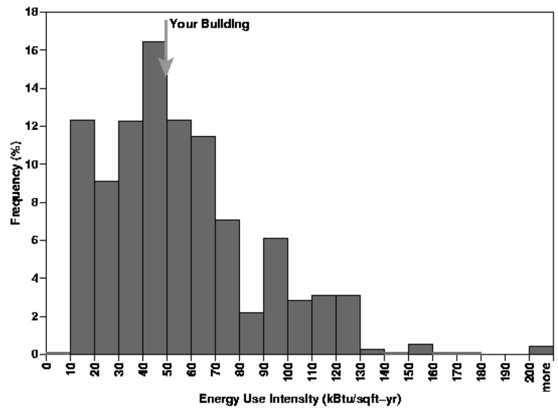
5-1 Benchmarking

Benchmarking refers to the comparison of energy use in a building to energy use in other buildings. It can be useful in energy audits and for targeting buildings for energy-saving measures in multiple-site audits. Energy service companies and performance contractors may use "best practice" and "typical" benchmarks such as annual energy use intensities (EUIs) to communicate energy savings potential. On the other hand, control companies and utilities track actual energy usage and compare to historical data and/or combined data from multiple buildings. Energy managers and building owners have an ongoing interest in comparing energy performance to other similar buildings (Kinney and Piette, 2002). Integration of benchmarking information in EIS provides the users with constant information on the relative performance of their buildings relative to each other, and to other similar buildings.

Benchmarking features are becoming common in EEM-type EIS (Section 2.2.3); however, they are less frequently seen in other EIS. The benchmarking features found in EEM typically allow you to compare energy use between different buildings and loads connected to the EEM. A few of the EIS tools are starting to provide industry benchmarks or comparisons to public survey data or industry benchmarks; however, this type of comparison usually requires separate analysis.

There are a number of free online benchmarking tools that could easily be linked or integrated into any other online EIS. For example, Silicon Energy is providing benchmarking information to its California customers by sending queries to LBNL's Cal-Arch benchmarking tool. The results can be viewed within their own software environment. Currently a list of online benchmarking tools is maintained at LBNL website (http://poet.lbl.gov/cal-arch/links/). Most national benchmarking tools we have found are based on DOE's CBECS (Commercial Building Energy Consumption Survey). Two examples of benchmarking tools are Cal-Arch and Energy Star Portfolio Manager.

Cal-Arch	Cal-Arch is an online benchmarking tool that provides distributions of actual energy use in California buildings. It is based on California's Commercial End Use Survey, which has data on approximately 2000 buildings. Users can compare the energy use in a building to other buildings in the database and have the option of comparing by size, climate zone, and building type. The results are displayed as histograms and summary statistics of the energy use for the buildings contained in the database (LBNL, 2002).



Cal-Arch Benchmarking Plot

Energy Star	Energy Star's Portfolio Manager is the most commonly used national tool. Portfolio Manager also allows users to track multiple buildings over time and calculate Energy Performance Ratings (EPR). Eligible buildings with an EPR higher than 75 are said to be among the top 25 percent in terms of energy performance and qualify for an Energy Star buildings label. The scores are developed from complex regression models developed using CBECS data. Separate models and scoring systems were developed individually for several different building types (US EPA, 2002).

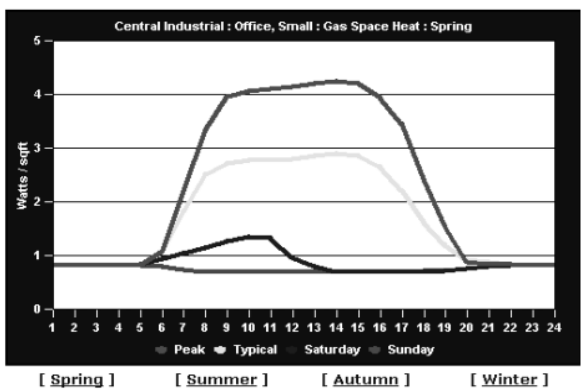
5-2 Load Shape Analysis

Historically, load shape analysis has referred to tools utilized by electric utilities for end-use forecasting and customer energy consumption analysis. Now load shape analysis is widely used for end-users as a basic method to analyze energy consumption of their buildings. Load shape analysis identifies base load, peak demand, and other energy consumption patterns. We describe some examples of load shape analysis tools.

SitePro

SitePro is a load-shaping tool utilizing the eShape library developed by Regional Economic Research (RER) working with the Electric Power Research Institute (EPRI). Prototype load shapes in its database are modified according to key factors to produce an accurate estimation of a load shape for a particular user. They have also developed tools to access large libraries of load shapes by building type, heating, and cooling fuels, for each U.S. State. End-use load shapes are also available.

A subset of the library can be downloaded for free from the RER website or purchased on CD for ten U.S. regions. The eShape browser is included. On their website, a simple browsing tool allows different 16-day load shapes by commercial/industrial sector, region, building type, spaceheat type, energy type, and season. As shown below, a different load shape is given for a peak day, typical weekday, Saturday, and Sunday. Additional programs and data must be purchased, including state-level, end-use, industrial, and custom eShapes (RER, 2002).

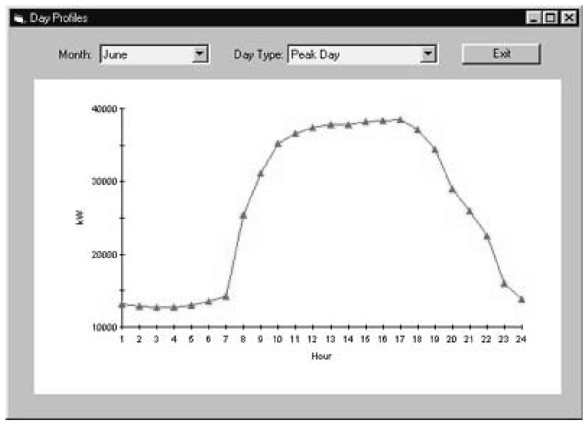


Site Pro

Shape-IT/ Compare-IT

Shape-IT is a load shaping tool that constructs load profiles for a group of buildings based on factors including energy and peak demand, floor area, building type, climate zone, fuel type, and vintage. Statistical algorithms are used to apply models from its library to the user's data.

Compare-IT is used to compare the load profile of one or more facilities with past performance and similar facility benchmarks. The components of the tool include a library of DOE-2 models for the user's target market and normalized load shapes to be used for benchmarking. Since it is model-based, a building model can also be compared to a model of a potential retrofit to the building to evaluate energy impacts.



Shape-IT (RLW, 2002)

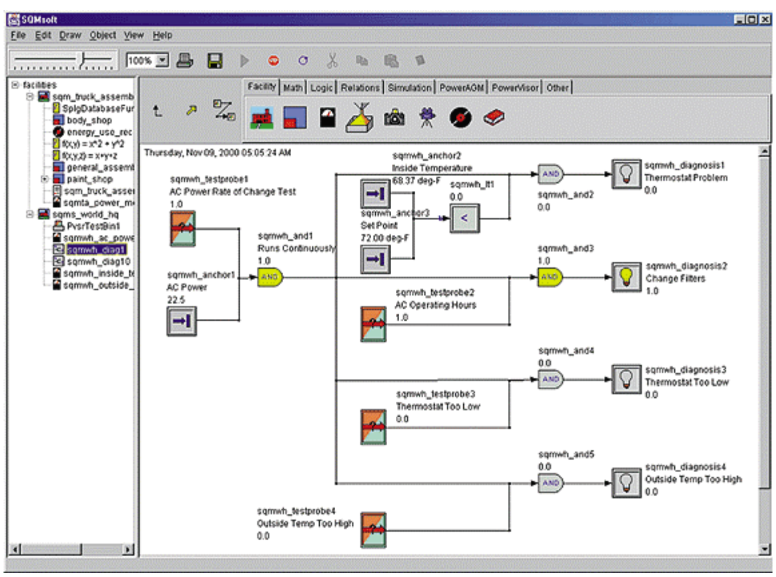
5-3 Fault Detection and Diagnostics

Section 4.2.1 describes data visualization features in EIS that are useful for manual diagnostics. Diagnostics in EIS are generally focused on whole-building energy. There are many other different types of diagnostics procedures, with other system components and faults diagnosed using automated methods. A range of diagnostics tools exist that facilitate data collection, visualization, and analysis, enabling building operators and energy engineers to continuously assess building performance. At a minimum, a diagnostic program for building analysis will process data and provide summaries of relevant performance metrics and common diagnostic plots for manual analysis.

Friedman and Piette (2001) discuss diagnostics in greater detail and compare several diagnostic tools. The automated diagnostics covered in their analysis include Pacific Northwest National Laboratory's Whole Building Diagnostician and Facility Dynamic's PACRAT. The other tools described provide a range of information useful for performing manual diagnostics. These include Enforma (Architectural Energy Corp.), Universal Translator (Pacific Gas and Electric), and diagnostics developed at UC Berkeley, as well as the EEM Suite and IMDS described here. Here we describe a platform for implementing custom automated diagnostics, an automated anomaly detection procedure, and a manual diagnostic method used at LBNL.

PowerVisor

PowerVisor provides a platform for creating and running diagnostic routines. While some commonly used routines are provided in the software, the user or administrator is free to program custom routines with a built-in graphical programming language. When routines trigger an alarm, the alarms can be sent to a web page, pager, or email address along with recommendations and related information (PowerNet Software, 2002).



PowerVisor Facility Diagnostic Network

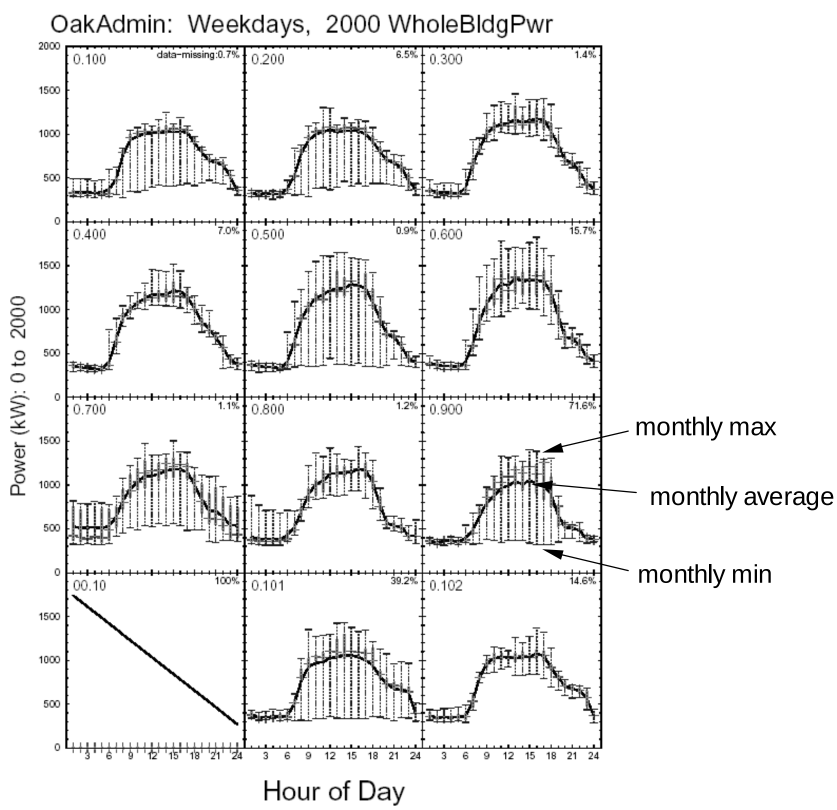
Facility Explorer	This product includes an automated anomaly detection algorithm. This detects abnormal energy consumption based on daily energy consumption and peak load. Energy consumption for a particular day is compared with recent energy consumption for up to 30 days of the same 'day type'. Days with similar consumption profiles are considered to have the same day type. For example, data may be grouped into weekdays and weekends/holidays. First, data are sorted by day type using a pattern recognition algorithm, or manually, by the operator. Once data are grouped based on day type, outliers are identified using a statistical method called the "generalized extreme studentized deviate many-outlier procedure". Depending on the selected significance level and upper bound placed on the number of potential outliers, this algorithm is used to identify observations that appear unusual relative to other observations in the same sample. Lastly, a modified Z-score is calculated for each outlier based on the standard deviation and mean of the non-outlier observations. This quantifies the amount and direction of the deviation of the potential outlier from the mean value of the non-outlier observations (Seem, 2002).

AHS Plots

Annual Hourly Statistical Plots (AHS Plots) were developed to aid in the analysis of data collected over several years in the Energy Edge project carried out by LBNL and Bonneville Power Administration between 1986 and 1993. The plots have continued to be useful in commissioning and diagnostics research for viewing whole-building power, end-use power, weather, and other related data.

An AHS Plot is actually 12 plots displayed on a single page, one plot for each month in a year. Each monthly plot is generated from monthly time series data. Each month is divided into hours between 0 and 23, and for each hour, the mean, median, maximum, minimum, and quartiles are calculated and displayed on the graph.

Displaying a year of data on one graph is advantageous as it allows you to pick up several bits of information at a glance. It is also useful to filter out days that are not of interest, for example, we are primarily interested in weekdays only, though weekend energy use should not be ignored. Some examples of information that can easily be read off the graphs include scheduling errors, startup control, and peak usage.



AHS Plots

5-4 Savings Analysis

After a retrofit, emergency demand reduction, or other change in building operation, building owners and operators are often interested in knowing how much energy was saved or how much demand was reduced. Here we elaborate on savings analysis for demand reduction and describe a specialized analysis tool useful for estimating energy savings.

Demand Response Systems, as tools designed for demand reduction program participation, typically include a savings analysis feature as described in Section 4.2.2. The demand reduction is measured by predicting what the power usage would have been in the absence of a demand reduction event, typically referred to as a baseline. The amount of the reduction is estimated to be the difference between the baseline and actual power use as monitored by the electricity provider. The baseline calculation methods used by many DR programs are based on an averaging formula using recent power usage data. Recent research reviewed baseline procedures (Xenergy and Nexant, 2002). Other forecasting methods can be used to obtain better estimates of demand reduction.

Emodel	Some tools have retrofit analysis tools included directly in the software. Ideally such tools would include weather normalization in the savings analysis. One example of the tool for such an analysis is Emodel. Such a tool could ideally be included directly in EIS. Emodel is particularly useful in measuring energy savings obtained from a retrofit. It can also be used to determine baseline energy consumption to identify operational problems. It has built in functions to construct simple and multiple regression models, as well as change-point models. The change-point model function is particularly useful for commercial buildings as change-point models are typically a better representation of the relationship between power and temperature than simple regression models. Energy savings are calculated by applying separate regression models to pre-retrofit and post-retrofit data (Kissock,, et al., 1994; Claridge, 1998).

6. Summary and Future Directions

This report summarizes key features and capabilities of web-based Energy Information Systems. Throughout this report, we discussed various features and roles of EIS with categorization frameworks and comparison of example EIS products.

One important issue this report does not evaluate is the costs and benefits of EIS. Many EIS include large numbers of metering points, control functions, real-time Internet connections, and a wide variety of visualization capabilities. The energy savings from the use of an EIS will vary, as will how effectively the operators and energy managers use the technology. The benefits of EIS extend beyond energy cost savings. Significant human resources savings and an improvement in the energy management process can also be anticipated, though these benefits are often difficult to quantify, but can be characterized in qualitative terms.

This report also describes new technologies and features of EIS. For instance, integration of automated control and automated diagnostics into EIS system is still under development in some cases. In this report we introduced the capabilities of each EIS product already in use in many customers' sites, unless otherwise indicated. However, some marketing information of EIS may be ambiguous and theoretical, especially for the new advanced technologies.[33] Prospective EIS users have to understand the detailed functionality of the EIS.

Currently DRS features are emphasized in many parts of the US as an integral part of aggressive electric demand response programs. It is likely there will be a growing value in the use of EIS for commissioning and diagnostics. Emerging advanced analysis techniques and automated fault detection and diagnostic features will make growing use of EIS data.

LBNL has an ongoing interest in developing, evaluating, understanding, and demonstrating how advanced energy information systems can help reduce energy use, peak demand, and energy costs in buildings. LBNL is beginning a new project with the California Energy Commission to evaluate automation in demand-responsive buildings using EIS and related technologies. This project will build on the technologies characterization work of this study, but will also cover communications systems, control strategies, and demand-shedding savings analysis. LBNL also has an ongoing interest in commissioning and diagnostics. Related research will continue to explore how to best utilize data of the type collected by EIS to detect and diagnose building performance problems.

[33] Many marketing brochures say "this EIS can detect system malfunctions", but in fact the EIS may only visualize data and the user has to know exactly how to look at the data.

References

Borska, Diane, and J. Lynch-Blanc, August 2000, *"New Economy Market Mechanisms"*. Energy eBusiness.

Claridge, D.E., 1998. *A Perspective on Methods for Analysis of Measured Energy Data from Commercial Buildings*. Transactions of the ASME, 120:150-155.

Friedman, Hannah, and M. A. Piette, 2001. "*Comparative Guide to Emerging Diagnostic Tools for Large Commercial HVAC Systems"*, Final Report for the California Energy Commission, Public Interest Energy Research Program, High Performance Commercial Building Systems Program, LBNL Report #48629.

Friend, William R., 2002. *"Energy Management – The Last Untamed Resources"*. Food CIO Forum. http://www.siliconenergy.com/newsroom/articles.htm.

Fryer, L., 1996. *"Tapping the Value of Energy Use Data: New Tools and Techniques"*. E SOURCE Exclusive Reports on Energy and Efficiency Strategic Memo. SM-96-3.

Fryer, L., 2002. *"Retrocommissioning-on-demand: Using Energy Information to Screen Opportunities"*. Proceedings of the 10th National Conference on Builiding Commissioning.

Goldman, Charles A., Michael Kintner-Meyer, and Grayson Heffner, 2002. *"Do "Enabling Technologies" Affect Customer Performance in Price-Responsive Load Programs?"*. Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings.

Hyde, Frank, 1995. "Software Helps Keep Customers Tied to the Line. (Enerlink)", Electrical World v209, n2: 43.

Kinney, S. and M.A. Piette, 2002. *"Development of a California Commercial Building Energy Benchmarking Database"*. Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings.

Kinter-Meyer, Michael, M. Burns, August 2001. "Energy-Related Information Services". Building Connections Article, ASHRAE Journal.

Kissock, K., X. Wu, R. Sparks, D. Claridge, J. Mahoney, and J. Haberl, 1994. Emodel Version 1.4d. Texas Engineering and Experiment Station, Texas A&M University; College Station, TX.

Komor, Paul, May 1996. "Online Energy Services For Commercial Energy Users". E SOURCE Exclusive Reports on Energy and Efficiency Strategic Memo. SM-96-4.

Lawrence Berkeley National Laboratory, 2002. Cal-Arch Building Energy Reference Tool. http://poet.lbl.gov/cal-arch/.

Levi, Mark, D. McBride, S. May, M.A. Piette and S. Kinney, 2002. *"GEMnet Status and Accomplishments: GSA's Energy and Maintenance Network"*. Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings. LBNL Report #50733.

Levy Associates, August 2001. *"Advanced Metering Scoping Study"*, California Energy Commission.

Piette, M.A., S. Kinney, and H. Friedman, 2001. *"EMCS and Time-Series Energy Data Analysis in a Large Government Office Building"*, Proceedings of the 9th National Conference on Building Commissioning, and LBNL Report #47699.

Piette, M.A, S. Khalsa and P. Haves, 2000. *"Use of an Information Monitoring and Diagnostic System for Commissioning and Ongoing Operations"*, Proceedings of the 2000 ACEEE Summer Study on Energy Efficiency in Buildings. LBNL Report #48284.

Piette, M. A., S. Khalsa, P.Haves, P. Rumsey, K. L. Kinney, E. L. Lee, A. Sebald, K. Chellapilla, and C. Shockman, 1999. *"Performance Assessment and Adoption Processes of an Information Monitoring and Diagnostic System Prototype"*, Report to California Energy Commission, LBNL Report # 44453.

Price, Will and Reid Hart, 2002. "Bulls-Eye Commissioning: Using Interval Data as a Diagnostic Tool". Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings.

Regional Economic Research, 2002. http://www.rer.com.

RLW Analytics, 2002. http://www.rlw.com.

Seem, J. E., 2002. *"Using Intelligent Data Analysis to Detect Abnormal Energy Consumption in Buildings"*.

Smothers, Fredric, and K. Kinney, 2002. *"Benefits of Enhanced Data Quality and Visualization in a Control System Retrofit"*. Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings.

Stein, Jeff Ross, Aditi Raychoudhury, Charles Eley, 2000. *"The Jury is (Halfway) In: New Building Performance Contracting Results"*, Proceedings of the 2000 ACEEE Summer Study on Energy Efficiency in Buildings.

Thompson, Olin, 2002. "Enterprise Energy Management Software - The Key to Effective Energy Utilization". TechnologyEvaluation.com.

U.S. Environmental Protection Agency Energy Star Program, 2002. Benchmarking/Portfolio Manager. http://yosemite1.epa.gov/estar/business.nsf/.

Xenergy, Inc., 2002. Protocol Development for Demand Response Calculation - Draft Findings and Reccomendations. Consultant Report to the California Energy Commission, Sacramento, CA.

Xenergy and Nexant, 2002. *"Money and Energy Saving Resources from the Enhanced Automation – Technical Options Guidebook"*. California Energy Commission publication #400-02-005F. http://www.consumerenergycenter.org/enhancedautomation.

Xu, Peng., P. Haves, 2002. *"Field Testing of Component-Level Model-Based Fault Detection Methods for Mixing Boxes and VAV Fan Systems"*. Proceedings of the 2002 ACEEE Summer Study on Energy Efficiency in Buildings. LBNL Report #50678.

Acknowledgements

The authors are grateful for assistance from Grayson Heffner (LBNL), and our sponsors Martha Brook, California Energy Commission (CEC), and David Hansen, US Department of Energy (DOE). This work is part of LBNL's High Performance Commercial Building's Program, Element 5 (Integrated Commissioning and Diagnostics). This program is supported by the CEC and by the Assistant Secretary for Energy Efficiency and Renewable Energy, Building Technologies Program, of the U.S. DOE under Contract No. DE-AC03-76SF00098. We also thank the following people for their assistance.

Blum, Hannah	Pentech Solutions
Bomrad, Phil	Tridium
Crews, Tom	Pentech Solutions
Eng Lock, Lee	Electric Eye Pte. Ltd.
Friedman, Hannah	Portland Energy Conservation, Inc.
Fryer, Linn	Platts
Graves, Cody	Automated Energy, Inc.
Hummel, Leslie	Silicon Energy, Inc.
Hyde, Frank	SCT Corporation
Kinney, Kristopher	Engineered Web Information Systems
Kubaiak, Edward	Tridium
LaCombe, Ron	CMS Viron Energy Services
Levi, Mark	General Services Administration
Losleben, James	Cannon Technologies, Inc.
Mahling, Dirk	Prof. Dr., University of Pittsburgh, WebGenSystems, Inc.
Manley, Gerard	eLutions, Inc.
Mimno, Gerald	AES Corporation
Reid, Beth	ABB, Inc.
Rognli, Roger	Cannon Technologies, Inc.
Seem, John	Johnson Controls, Inc.
Stell, Christine	Circadian Information Systems
Tillman, Deborah	Southern California Edison
Ulibarri, Keith	Save More Resources, Inc.
Watson, Eric	Apogee Interactive, Inc.

Appendix A. Acronyms

AMR	Automated Meter Reading
BAS	Building Automation Systems
CBECS	Commercial Building Energy Consumption Survey
CDD	Cooling Degree Days
CEC	California Energy Commission
DOE	Department Of Energy
DR	Demand Response
DRP	Demand Response Programs
DRS	Demand Response Systems
DSL	Digital Subscriber Line
EEM	Enterprise Energy Management
EIS	Energy Information Systems
EMCS	Energy Management and Control Systems
EMS	Energy Management Systems
EPA	Environmental Protection Agency
EPR	Energy Performance Rating
EPRI	Electric Power Research Institute
ESCO	Energy Service Company
EUI	Energy Use Intensity
GSA	General Services Administration
HDD	Heating Degree Days
HVAC	Heating, Ventilation and Air-Conditioning
ISO	Independent System Operator
LAN	Local Area Network
LBNL	Lawrence Berkeley National Laboratory
OAT	Outside Air Temperature
PV	Photovoltaic
RTP	Real Time Pricing
SAT	Supply Air Temperature
SMUD	Sacramento Municipal Utility District
TOU	Time-Of-Use
VFD	Variable Frequency Drive

Appendix B. EIS and related field company list

Company Name	Product Name	Website
ABB Energy Interactive	Energy Profiler Online	www.energyinteractive.com
AES IntelliNet		www.aes-intellinet.com
Apogee Interactive	Demand Exchange	www.apogee.net
Automated Energy	Automated Energy	www.automatedenergy.com
Cannon Technologies	ReadmeterLoadcontrol	www.cannontech.com
Circadian Information Systems	EnterpriseOne	www.circadianinfosystems.com
CMS Viron	UtilityVison	www.cmsenergy.com/MST/
Consumer Energy		www.consumersenergy.com
Converge		www.comverge-tech.com
Datapult	Datapult Central	www.datapult.com
Electric Eye	Electric Eye	www.eeye.com.sg
Electrotek		www.electrotek.com
eLutions	Energy Partner Web	www.elutions.com
Enerlink	Enerlink	www.enerlink.com
Enerwise	Energy Manager	www.enerwise.com
Engage Network Solution	Active Energy Management	www.engagenet.com
Excel Energy		www.excel-energy.com
GSA	GEMnet	
Honeywell	Atrium	atrium.honeywell.com
Johnson Control	Facility Explorer	www.jci.com
LBNL	IMDS	eetd.lbl.gov/BTP/iit/diag/
Metering Technology Corp.		www.metertech.com
MMSI		www.mmsi.com
Obvius	Building Manager Online	www.obvius.com
Optimum Energy Products	Metrix	www.optimumenergy.com
Pentech Solutions	eMAC	www.pentechsolutions.com
Plurimi	PLISEM	www.plurimi.com
POWERnet Software	POWERnet	www.powernetsoftware.com
PowerPact		www.power-pact.com
RER		www.rer.com
Save More Resources	Utility Manager Online	www.smr.tv
Silicon Energy	EEM Suite	www.siliconenergy.com
Sixth Dimensions	6D iNET	www.sixthdimension.com
Southern California Edison	AMICOS	www.edisonamicos.com
Southern Company	Energy Direct	www.energydirect.com
Stonewater Control Systems	energy1st	www.stonewatercontrols.com
Tridium	Vykon	www.tridium.com
TXU Energy	Gateway	www.txuesgateway.com
Utility Data Resources		www.udri.com
WebGen Systems	Intelligent Use of Energy	www.itswebgen.com

- This is a list of companies found during research, and not entire list of all companies. Many other products beside these exist. A product does not constitute endorsement.
- Shaded items are not featured in the report.

Appendix C. EIS Product Information

- This is product information data sheet of EIS featured in this report.
- The information is based on telephone interview to or meeting with company representatives.
- Features and capabilities described were current as of date of the project and may have changed. A product does not constitute endorsement.

Utility Manager Profiler / Utility Manager Online

Developer Information

Developer	Save More Resources, Inc.
Background	Utility accounting system Energy service provider
Foundation	1992
Company location	Grand Junction, CO
Website	www.smr.tv

Tool Market Information

Service area	All over US
Service started	EnAct (off-line utility accounting system) since 1992. UM Online (on-line utility accounting system) since 2002. UM Profiler (15-minute interval data EIS) since 1999.
Cost	
Target market	Large corporations, Grocery chains, Government and Municipalities, School Districts
Target users	Facility operators, energy managers, SMR's engineers.
Commercialization	N/A

Data Access

Trend interval	UM Profiler: 15-minute UM Online: Monthly
Update frequency	UM Profiler: Once a day UM Online: Monthly
Data sources	UM Profiler: Installed meter UM Online: utilities' database
System requirement	Internet Explorer 4.0 or greater, or Netscape 4.7 or greater.
Configuration	UM Profiler The installed meter sends pulse to the on-site data logger which has little data storage capacity. SMR's server (UM Server) retrieves data from the data logger typically once a day and stores it in its database. Users can access the UM Server via internet. UM Online Access to utilities' database server. Not all utilities provide the database access services. PG&E, SCE have this capability.

Operational Capability

Main focus, Unique features, etc	

Enerlink

Developer Information

Developer	System and Computer Technology Corporation (SCT Corp.) (Originally a subsidiary of Southern Company)
Background	Software company
Foundation	
Company location	Georgia
Website	www.enerlink.com

Tool Market Information

Service area	All over North America
Service started	
Cost	
Target market	Utility company
Target users	
Commercialization	More than 5,000 users and 40 utility customers across North America

Data Access

Trend interval	5 minutes
Update frequency	
Data sources	Interval data collected by remotely accessing customer-site meters Meters are queried daily, weekly or monthly on a read-only basis
System requirement	
Configuration	A database of current and historical information is built and stored on a secure server.

Operational Capability

Main focus, Unique features, etc	▪ Multiple channels display. ▪ Meter independent with protocols for many meters. ▪ Creation of baseline load from historical data. ▪ Different intervals available from 5 to 60 minutes. ▪ Overlay load profiles with weather data. ▪ Energy usage information can be downloaded and imported into spreadsheets. ▪ Print-ready graphics and reports. ▪ Customizable graphics options – choose colors, bar, line, or 3-D graphic styles.

PLISEM

Developer Information

Developer	Plurimi
Background	Real-time, Web-based demand response solutions
Foundation	
Company location	San Francisco, CA
Website	www.plurimi.com

Tool Market Information

Service area	Allover US
Service started	
Cost	
Target market	Energy providers
Target users	Program manager (energy provider), energy manager (customer)
Commercialization	

Data Access

Trend interval	15 min
Update frequency	Daily. Optionally 5 min for large customers.
Data sources	Interval meter, and any electric meter
System requirement	
Configuration	

Operational Capability

Main focus, Unique features, etc	**Demand Response Program management tool for energy providers** ▪ Alert hundreds, or even thousands of customers via email, telephone, wireless and pager about upcoming curtailment events. ▪ Broadcast details of demand buyback, interruptible, and system reliability events in a matter of minutes. ▪ Enterprise-level administration means only authorized users can initiate events and commit to curtailments, but all stakeholders receive the information they need to implement any necessary changes. ▪ Customize your events, including price splits, timing, usage thresholds, or government regulations. ▪ Target communications by service area, type of program, or individual customer using sorting and filtering capabilities. ▪ Track and report all curtailment requests, responses and commitments on both an aggregate level and by individual customer.

Demand Exchange

Developer Information

Developer	Apogee Interactive, Inc.
Background	Software, consulting, e-learning
Foundation	1994
Company location	Tucker, GA
Website	www.apogee.net; www.demx.com

Tool Market Information

Service area	All of North America and New Zealand
Service started	1998
Cost	Significant variation based upon customized configuration. Ranges from $30k to $250k
Target market	Investor-owned utilities, power authorities, municipals, and cooperatives.
Target users	Electricity traders, marketing department
Commercialization	Few dozen clients, over one thousand end-users

Data Access

Trend interval	Typically 15-minute
Update frequency	Typically once per day
Data sources	All
System requirement	Interval data monitoring
Configuration	Master database resides on server, applications reside on separate server

Operational Capability

Main focus, Unique features, etc	• Demand response - price responsive, demand bidding, and mandatory curtailment • RTP programs • Baseline generation • Dynamic group creation for event notification • Online settlement • Counter-offering • Interval meter data presentment • Baseline evaluation services

Energy Profiler Online (EPO)

Developer Information

Developer	ABB, Inc.
Background	Software manufacturing E-business
Funding Parent cooperation	Formerly ABB Energy Interactive.
Foundation	
Company location	Oakland, CA
Website	www.abb.com/bmsus

Tool Market Information

Service area	All over US
Service started	1998
Cost	
Target market	Energy service providers, utilities
Target users	Energy manager, operator
Commercialization	

Data Access

Trend interval	15 min
Update frequency	10 sec
Data sources	Interval meter
System requirement	Interval meter installation
Configuration	

Operational Capability

Main focus, Unique features, etc	Simple but well-selected features. ▪ Multi-account comparison/management ▪ Demand responsive program application **Visualization/Analysis** ▪ Comparison Statistics – Compares several accounts in tabular view. ▪ Load Duration Curve ▪ Load Profiles, Summary, Average Profiles ▪ Usage History – Plots daily, weekly, and monthly usage (kWh) and peak demand (kW) for single point. **EPO Curtailment Module** ▪ Notify utility curtailment event via e-mail, pager, etc. automatically. ▪ Posts of prices for voluntary curtailment programs. ▪ Allows customers to opt in or out of any specific event. ▪ Calculates baseline usage according to configurable rules. ▪ Provides settlement reports both to the customer and internal users.

Intelligent Use of Energy (IUE)

Developer Information

Developer	WebGen Systems
Background	Power generation networking
Foundation	2000
Company location	Cambridge, MA
Website	www.itswebgen.com

Tool Market Information

Service area	US
Service started	2001
Cost	
Target market	Large commercial, Academic, Governmental customers
Target users	Operator, Energy manager, Financial manager
Commercialization	4 ongoing cases

Data Access

Trend interval	2 minutes (60 days), storing 15 minutes data for 1 year
Update frequency	2 minutes
Data sources	Interval meter data, EMCS data Directly communicate with EMCS, acquiring data and controlling system remotely.
System requirement	Accessed via any web browser IE version 5 or 6 preferable. The monitoring and control software runs on top of NT, IIS.
Configuration	Readily available protocols to connect to BMS/EMS are: BacNet, OPC, FTP, AEM (Engage Networks) proprietary, Silicon Energy proprietary, PML proprietary

Operational Capability

Main focus, Unique features, etc	Unlike the other EIS which merely facilitate energy analysis but require human intervention to plan and act on it, IUE takes action automatically and immediately by using neural network technologies, and minimizes energy consumption and cost not only during peak-time but also under normal conditions.

Readmeter/Loadcontrol

Developer Information

Developer	Cannon Technologies, Inc.
Background	Automation hardware and software development
Funding Parent cooperation	Westinghouse Electric Company
Foundation	1987
Company location	Golden Valley, MN
Website	www.cannontech.com

Tool Market Information

Service area	Allover US
Service started	Standalone, closed network services since 1987. Web-base system since 1999.
Cost	N/A
Target market	Utility
Target users	Utility program operators
Commercialization	300 utility companies including old version users

Data Access

Trend interval	15 min
Update frequency	Daily. Optionally 5 min for large customers.
Data sources	Interval meter, and any electric meter
System requirement	
Configuration	

Operational Capability

Main focus, Unique features, etc	**Readmeter** ▪ Lower cost real-time meter data collection. ▪ Real-time meter data aggregation for multiple meters. ▪ Peak demand and load factor for aggregated loads. ▪ Meter data display on web pages that appear to reside on your server. ▪ Real-time dispatch of distributed generation resources and other loads. ▪ Consolidated data for billing. ▪ Interfaces to customer-owned energy control systems. ▪ Interfaces to utility-owned control systems to drive load management and/or real-time pricing. **Loadcontrol** ▪ Build and execute control strategies. ▪ Reconfigure individual load control receivers. ▪ Control or cycle individually or by group. ▪ Create as many groups as you need.

Energy Partnership Web (EP Web)

Developer Information

Developer	eLutions (Joint venture of: Invensys Building Systems (building control) Engage Networks (network device and software)
Background	Energy management service and software Controlling device manufacturer
Foundation	2000
Company location	Tampa, FL
Website	www.elutions.com

Tool Market Information

Service area	All over US
Service started	2000
Cost	
Target market	
Target users	Energy manager, operator
Commercialization	More than 130 domestic IBS field offices and 500 Invensys global field offices

Data Access

Trend interval	15 minutes
Update frequency	
Data sources	SAM Meter (solid-state power sub-meter, eLusions products), produced by Revenue meter (utility interval meter), EMCS data
System requirement	EPIM (Ethernet Pulse Input Module, by Engage Networks), LPIM (once-a-day telephone connection device), or PM6000 (Ethernet and telephone connection device, enabling real-time and sub-meter level monitoring)
Configuration	Software platform: Active Energy Management (Engage Network), AEM requires host server on customers' site, but EP Web has its own server on eLusion side, and customer access the server remotely from their sites. Data storage and archiving in a SQL server database.

Operational Capability

Main focus, Unique features, etc	▪ Power Quality Analysis ▪ User-Defined Alarming (Pager, Email) ▪ On-line Web-Based Reporting ▪ Real-Time and Historical Data Profile Analysis ▪ Aggregate Multiple Sites ▪ Cost Allocate to Sub-Groups ▪ Rate Comparisons

eMAC

Developer Information

Developer	Pentech Solutions
Background	Manufacturer, energy service provider
Foundation	1994
Company location	San Diego, CA
Website	http://www.pentechsd.com

Tool Market Information

Service area	All over US
Service started	Provide products to utility companies since 1994. Provide services to commercial buildings through ESPs since 1999. Provide energy saving service since 2001.
Cost	Hardware eMAC controller: $695 (+$595 install) /unit Service $12~15 /month-unit $80/month.unit (with diagnostic services)
Target market	Multi-facility clients who have hundreds of small/medium buildings Energy service providers
Target users	Energy managers, Pentech's diagnostic agents.
Commercialization	

Data Access

Trend interval	15 min
Update frequency	15 min
Data sources	eMAC controller (wireless meter produced by Pentech Solutions)
System requirement	
Configuration	

Operational Capability

Main focus, Unique features, etc	

Automated Energy

Developer Information

Developer	Automated Energy
Background	Energy information service
Funding Parent cooperation	Private
Foundation	1999
Company location	Oklahoma City, OK
Website	www.automatedenergy.com

Tool Market Information

Service area	All over US, Canada. UK is intended in future
Service started	Dec 2000 ~ early 2001
Cost	$30/month, +$20/submeter (Commercial), $3/month (Residential)
Target market	Consumers, energy companies, retail energy marketers, energy service companies
Target users	Operator, budget manager, etc.
Commercialization	More than 1500 customers across North America
Major users	Hertz (car rent) City of Oklahoma City SMG (facility management)

Data Access

Trend interval	15 minutes (5 min is also available but 15 min is popular.)
Update frequency	Daily or more (Real-time monitoring is not necessary for most of the cases. Daily update is enough for day-ahead pricing.)
Data sources	Interval data collected by remotely accessing customer-site meters. Meters are interrogated daily, weekly or monthly on a read-only basis.
System requirement	Interval metering. If site doesn't have Interval meter, AEI requests utility company to install the meter.
Configuration	A database of current and historical information is built and stored on a secure server.

Operational Capability

Main focus, Unique features, etc	**Saving Analysis** ▪ Estimate bills using bill engine ▪ Find coincident demand at sub-metering ▪ Compare to historical load pattern to identify savings opportunity. **Rate Analysis (Rate Engine)** ▪ Rate schedule ▪ Rate library ▪ Calculate energy bills based on schedule and rate library **Load Forecasting** ▪ Forecast load profiles for next 5 days ▪ Estimate from historical load patterns and local weather forecasting.

Enterprise One

Developer Information

Developer	Circadian Information Systems (subsidiary of R.G. Vanderweil Engineers)
Background	Engineering, Plumbing
Foundation	1996
Company location	Boston, MA
Website	www.circadianinfosystems.com

Tool Market Information

Service area	Mostly in East coast. HQ in MA, NJ, and DC
Service started	1996
Cost	$4995 (basic package, 10-meter license)
Target market	Large company, campus
Target users	Energy engineers, managers
Commercialization	16 companies, mainly campuses and hospitals.

Data Access

Trend interval	
Update frequency	
Data sources	BAS (Andover Controls, Power Management Limited, TRANE, Johnson Controls, CSIv), Utility invoice, Sub-meters.
System requirement	
Configuration	Metasys Interface for Circadian Applications

Operational Capability

Main focus, Unique features, etc	**Real-Time Analysis** – See up-to-the-minute energy consumption, including mean, trend analysis and peak analysis for a single meter or group of meters. **“What If” Rate Analysis –** Use exclusive Rate Engine to compare purchasing options from multiple energy providers. **Cost Overlay** – Overlay energy usage and cost so that user can identify unusual mismatch between energy and cost. **Energy Use Index** – Compare multiple energy resources and benchmark your facility’s total MBTU consumption per unit area. Show Total Energy, MBTU/SF, and Cost/SF. **Plant Analysis** – Shows kW/ton vs Tons scatter chart and Chilled water usage histogram (Run Hours at each Ton Usage). **Standard Invoice** – Verify the accuracy of the utility’s invoices before receiving it via mail and explore multiple utility rates to evaluate the benefits of switching.

EEM Suite

Developer Information

Developer	Silicon Energy
Background	Software development Engineering
Foundation	1997
Company location	Alameda, CA
Website	www.siliconenergy.com

Tool Market Information

Service area	All over US and Canada,
Service started	1998
Cost	Software: $50K-250K includes: installation, training, configuration, maintenance and support.
Target market	Energy service providers, commercial, government, higher education, industrial, and utility sectors
Target users	Energy manager, purchasing, facility management and engineering
Commercialization	Commercialized in 1998. Over 10,000 facilities are directly connected, and over 5 million meters are managed with energy providers.

Data Access

Trend interval	15 min is typical, can support 1 minute
Update frequency	Real-time to daily
Data sources	Meter, utility bill and/or EMCS data
System requirement	EDI and/or on-site gateway
Configuration	SQL databases on remote server. OLAP (on-line analytical processing) technology – roll data into hourly, daily, and monthly bins. Third-party charting tool.

Operational Capability

Main focus, Unique features, etc	Integrated financial and budget management, operation & maintenance and procurement applications for decision-support and management reporting. Operations & Maintenance ▪ Performance monitoring ▪ Demand Management ▪ Price/Use Optimization Financial & Budget Management ▪ Bill Validation ▪ Cost Allocation ▪ Budget Variance Procurement & Sourcing ▪ Best rate analysis ▪ Retail commodity purchasing ▪ Wholesale commodity purchasing

Vykon

Developer Information

Developer	Tridium, Inc.
Background	Software company
Foundation	1996
Company location	Richmond, VA
Website	www.tridium.com

Tool Market Information

Service area	Global installations and offices. Target service companies and end-users.
Service started	1996
Cost	Software: Priced Per JACE Monthly running cost: None
Target market	Government facilities, K-12, Universities, hospitals, chain accounts.
Target users	Energy manager, facility manager, maintenance manager, operations.
Commercialization	We have over 10,000 instances of our software installed globally.

Data Access

Trend interval	Tridium can log and archive the data in any increment longer than 1-minute.
Update frequency	
Data sources	Extensive capability to communicate with existing systems.
System requirement	JACE is essentially a web-server and using a peer-to-peer distributed architecture.
Configuration	Available for use in multiple environments.

Operational Capability

Main focus, Unique features, etc	True real-time, two way control from any web browser, not 15-minute delayed.