LBNL-2899E

ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

Building Energy Information Systems: State of the Technology and User Case Studies

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November 2009

DISCLAIMER

All reported findings are based on vendor-supplied information at the time of the study. Current capabilities are subject to change, and readers are encouraged to confirm information based on their specific needs. Moreover, the EIS that were selected for evaluation are representative of the market, but not comprehensive, and inclusion in the study does not imply endorsement.

Please cite this report as follows:

Granderson, Jessica, M. A. Piette, G. Ghatikar, and P. Price. 2009. Building Energy Information Systems: State of Technology and User Case Studies. Lawrence Berkeley National Laboratory. LBNL-2899E.

Table of Contents

Executive Summary

The focus of this study is energy information systems (EIS), broadly defined as performance monitoring software, data acquisition hardware, and communication systems used to store, analyze, and display building energy data. At a minimum, an EIS provides hourly whole-building electric data that are web-accessible, with analytical and graphical capabilities [Motegi 2003a]. Time series data from meters, sensors, and external data streams are used to perform analyses such as baselining, benchmarking, building level anomaly detection, and energy performance tracking.

Energy information systems are viewed as a promising technology for a number of reasons. There is widespread recognition that there is often a large gap between building energy performance *as designed* and measured post-occupancy energy consumption, and a growing body of evidence indicates the value of permanent metering and monitoring [Brown et al. 2006; Mills et al. 2005; Mills 2009; Piette et al. 2001b]. Energy information systems are also well aligned with current trends toward benchmarking and performance reporting requirements, as in recent federal and state mandates.

Dozens of EIS are commercially available, yet public domain information is often vague,and demonstration software may not be available. In addition, a lack of common terminology across vendors, and a significant degree of salesmanship, makes it difficult to discern *exactly* what functionality the tools offer, what the hardware requirements are, or what makes one product more effective than another. This study was designed to extend and update an earlier report [Motegi and Piette2003], andit is guided by three high-level objectives:

1. To define a characterization framework of EIS features that provides a common terminology and can be used to understand what EIS are and what they do.
2. To apply the framework to EIS products to achieve a better understanding of the state of the technology, its distinguishing capabilities, and its leading-edge functionality.
3. To conduct case studies, to begin to understand the interplay between common features, diagnostics, and energy-saving actions.

EIS State of the Technology

The EIS characterization framework was developed iteratively, beginning with the features identified in prior work and a scoping of current technologies. In its final form the framework compriseseight categories with five to ten features each. This framework was then applied to characterize approximately 30 EIS. Key findings that are related to distinguishing capabilities, leading edge functionality, and the general state of EIS technology are presented in the following list, grouped by major feature category.

Business models (General)

- EIS are most commonly offered through an Application Service Provider (ASP) with no hardware, or optional hardware based on client needs.
- Optional or bundled services are nearly universally offered.

Display and visualization

- Features have converged to a near common set. Data can be viewed over user-defined intervals of time, trended variables can be aggregated into totals, and the user can overlay multiple datasets on a single plot.
- X-y scatter plotting is offered in only half of today's EIS solutions.

Energy analysis

- Two-thirds of the EIS feature greenhouse gas analysis, or provide custom or configurable options to do so. Most apply a simple energy/carbon dioxide (CO_2) relationship, but almost half account for regional differences in generation or other standards.
- Nearly every EIS permits the user to quantify an energy consumption baseline, however weather normalization is rare.
- Every tool that was evaluated supports (or will soon support) multi-site benchmarking.Distinguishing aspects include:
  - Composition of the comparative cohort: buildings within the user's enterprise; comparison to buildings from the vendor's database;or less commonly,national data sets.
  - Display of results: static reports versus dynamically accessible functions; results depicted in tables, plots, or charts.

Advanced analysis

- About three-quarters of the EIS address data quality, and they do so via three principal means: flagging or summative reporting, cleansing and/or correction, and linking to external or third-party software packages.
- Anomaly detection is typically trend-based and accomplished by identifying departures from normal energy consumption patterns.
- More than half of the EIS forecast near-future loads, usually by coupling historic trends and weather data; very few provide model-based capabilities.
- The large majority of EIS accommodate some form of measurement and verification (M&V) or the ability to track the impact of operational changes.

Financial analysis

- Energy costing is supported in nearly all of the EIS, and more than half have implemented model- or tariff-based calculations.

Demand response

- Demand response (DR) capabilities have advanced since early 2000 and have converged to a common set of features.
- Automated response to DR signals is supported in all but three of the DR systems that were characterized.

Remote control and management

- Just over half of the EIS surveyed report the ability to control according to a program, and just under half report internet-capable direct remote control.

The EIS product evaluations indicated that, overall, visualization and analytical features are distinguished by the degree to which they accommodate dynamic user-defined selections versus statically defined reporting, calculation, and plotting parameters. Rigorous energy analyses that include normalization, standards-based calculations, anomaly detection, and forecasting are robustly integrated in some EIS products, but less so in others.

EIS User Case Studies

The case studies included in the scope of this study attempted to answer questions related to energy savings and actions attributable to EIS use, performance monitoring challenges, and successful implementation models.Wal-Mart, Sysco, the University of California (UC) Berkeley, and UC Merced were selected, representing commercial enterprises and campuses with a diversity of performance-monitoring technologies, commercial building types, and portfolio sizes, as described in Table 1. These cases encompass buildings that range from Wal-Mart and Sysco's relatively repeatable warehouse and retail designs, to UC Berkeley's legacy and historic sites, to UC Merced's very-low energy new construction.

Case	Type, size (square feet)	Controls	Performance Monitoring
UC Merced	Campus (800,000)	Automated Logic Corporation WebCTRL	Automated Logic Corporation WebCTRL Utility bills
UC Berkeley	Campus (15.9M)	Barrington Some ALC, Siemens	Obvius Utility bills
Sysco: Stockton, California Sygma site	Refrigerated/dry warehouse (52 M, Stockton 95,000)	DOS-based refrigeration control	NorthWrite Energy WorkSite Utility bills
Wal-Mart	Retail/grocery (675M)	Novar Danfoss Emerson CPC	Energy ICT EIServer Utility bills

Table 1: Characteristics of case study sites

UC Merced

The UC Merced case illustrated the challenges in using a web-based energy management and control system (EMCS)as an EIS, the web-EMCS as enabling critical information links, and realization of the campus as a living laboratory.Typically, WebCTRL use at UC Merced is dominated by operational EMCS investigations, however, WebCTRL meter data are used annually to track energy performance.Gas, electricity, hot water, and chilled water consumption are quantified at the campus level and for critical buildings.On a monthly basis, the campus energy manager uses the web-EMCS data to determine utility recharges for non-state buildings, and he reports a high level of satisfaction with WebCTRL. He emphasizes that UC Merced trends extremely large volumes of data and that intensive monitoring needs to be undertaken deliberately, with close attention to a spectrum of issues including wiring, system programming, network architecture, and hardware selection.

Sysco

The Sysco case highlighted: (1) enterprise-wide EIS use and information sharing, both vertically and horizontally throughout the corporation,(2) limited, yet powerful, on-site use of the EIS, and(3) use of EIS technology to ensure persistence in savings and energy accountability. Sysco adopted a three-part approach to achieve portfolio savings of 28% in under three years: expert site visits to conduct tune-ups and identify low-/no-cost energy-saving measures; customization of the EIS to accommodate and map to Sysco's goals; and continuous communication and collaboration between corporate managers, energy services contractors, and on-site "energy champions."Sysco performs both site-specific and portfolio analyses on a monthly basis.Managers coordinate monthly group reviews with each site's "energy champion," who is accountable for energy use. The energy champion who was interviewed reports that the EIS is most highly valued for its role in supporting and encouraging accountability and staff motivation, so that efficiency gains might persist over time.

Wal-Mart

Wal-Mart is a case of "siloed" EIS use by specific groups or individuals for a few key purposes. A group of internal supporters champion the use of the EIS technology and maintain a vision for how its use might be expanded throughout the organization, yet regular operational analytics are not yet widespread vertically or horizontally within the enterprise.The EIS features a custom module for M&V tasks that has been used extensively, although it has been used on an ad-hoc basis, to determine the effectiveness of energy efficiency improvements. The wholesale power procurement and demand response group also uses the EIS intensively, making considerable use of forecasting and normalization.The EIS is also used to gauge the performance of new designs, particularly at "High Efficiency" supercenters. Each month, the benchmarking analyst identifies the twenty poorest-performing sites; however,custom benchmark models and downloading constraints in the interface require that EIS data be exported to conduct this portfolio tracking.

UC Berkeley

There is no central EIS at UCBerkeley; it is a contrasting case that is included to illustrate the challenges that are encountered in the absence of a campus-wide performance monitoring system. Although there is no campus EIS, there is a large volume of energy and system performance data, yet it comes from disparate sources and is used by different staff groups. The utility group uses utility bills and monthly manual meter reads to manage the purchase and billing of all campus energy, performing reviews for approximately 200 utility accounts. The EMCS group uses a web-accessible interface to oversee the campus Barrington control systems. Independently, a number of efficiency and commissioning interventions have implemented remotely accessible electric interval metering at approximately 30 buildings, totaling 11 million gross square feet. UC

Berkeley's energy manager identified several energy management priorities including: more remote-access metering to reduce the resources dedicated to manual meter reads, submetering beyond the whole-building level, and access-controlled public data for researchers and special projects.

Conclusions

Resources and staffing were a significant constraint in every case studied, and clearly affect the extent to which energy data are successfully used to identify energy-saving opportunities. They also directly affect a site's ability to make meaningful use of submetered data. With the exception of Sysco, where current levels of engagement with the EIS are viewed as sufficient to meet efficiency goals, each organization expressed a strong desire to engage more with measured data in order to improve efficiency.

Reliable, high-quality data are a critical aspect in automated analysis of building energy performance, and can have a significant impact on EIS usability. The Merced case shows that particular attention must be paid to wiring and hardware integration, system programming, and network communications. In contrast, Wal-Mart and Sysco did *not* report significant dataquality issues, probably for two reasons: EIServer has embedded validation estimation error checking (VEE) routines, and data quality is usually a concern only in cases of submetering and energy sources other than electric. In the four EIS cases that were studied, the most common energy-saving actions related to fixing incorrect load scheduling, performing measurement and verification (M&V) tasks, and identifying and fixing inefficient operations. Reported savings resulting from these improvements were on the order of 20%–30% for measures applied at the end-use and whole-building level.

The degree to which a site uses embedded analytical capabilities depends on the particular performance metrics and benchmarking data that are utilized. Our cases showed that the more tailor-made the calculations, the more likely it is that the data will be exported for analysis in third-party modeling or computational software. Although EIS offer a wide range of features, actual use of these features can be very limited, and it is not clear that users are always aware of how to use the capabilities of the technology to generate energy-saving information.

Future Needs

Future research needs concern four key areas:

1. Features and usability
2. Anomaly detection and physical models
3. Technology definitions and scalability
4. Successful use and deployment models

Questions concerning the most useful features, potentially useful but underutilized features, and energy savings attributable to EIS use merit further attention. For instance, a more extensive set of typical actions and associated energy savings, as well as documented records of building consumption before and after EIS implementation, would enable stronger conclusions on the range of expected savings from EIS use. Closely related to features and usability, there is considerable analytical potential in linking EIS anomaly detection methods to physical models. Today's EIS algorithms rely purely on empirical historic performance data to detect *abnormal* energy consumption. However, they do not provide a means to identify *excessive* energy consumption relative to the design intent, or to realize model-predictive control strategies.Standardizing the format and structure of information at the data warehouse level could encourage such advancements, as could the development of features to configure exported data files into formats that can be used by modeling tools such as Energy Plus or DOE-2. Standard formatting of EIS data would also facilitate the transfer of energy information from the building to outside entities, supporting and aligning with current developments in demand side management, and the smart grid.

From a technology standpoint, definitions and scalability require further study. The question of whether a given system is or is not an EIS is not trivial. This study defines EIS broadly, stipulating whole-building energy analyses, graphical capabilities, and web accessibility.Therefore, many technologies that were included in the study are EMCS or DR tools that are less immediately thought of as EIS, but that *can be used* as an EIS. Scalability is a concern that may provide insights as to where to draw the line between EIS and related technologies. In the future it will be necessary to understand the tradeoffs between diagnostic capabilities, trend volume and number of points monitored, and the resulting burden on the system's underlying hardware and communication networks.

Finally, there remains much to learn about effective EIS use within organizations. A common view is that EIS are primarily the domain of in-house staff, and that services are used to a minimal degree during installation and configuration. However, the general prevalence of staffing constraints, Sysco's successful efficiency gains through partnership with service providers, and the number of EIS vendors that offer analytical services indicate the potential for alternate models of successful EIS use. Additional research is needed to understand the full spectrum of approaches to data-centered energy management. Large enterprises and campuses have cost-effectively implemented EIS, yet for other organizational sizes, commercial segments, and building ownership models the appropriate balance between on-site analysis, technology sophistication, and expert services is not well understood.

Chapter 1. Introduction

The focus of this study is energy information systems (EIS), broadly defined as performance monitoring software,data acquisition hardware, and communication systems used to store, analyze, and display building energy data. Time-series data from meters, sensors, and external data streams are used to perform analyses such as baselining, benchmarking, building-level anomaly detection, and energy performance tracking. Newly adopted initiatives such as the Energy Information and Security Act, the zero-energy Commercial Building Initiative, and the Smart Grid have brought building energy performance to the forefront of the national energy dialogue. At the same time, national energy use intensities across the commercial sector increased 11% between 1992 and 2003 [CBECS 1992, 2003], marking a trend that must be quickly reversed in order to meet national net-zero building energy goals. It is clear that a multiplicity of solutions will be required to effect deep efficiency gains throughout the nation's building stock, and analogous to home energy displays, building EIS have received significant attention as a technology with the potential to support substantial energy savings.

Energy information systems are viewed as a promising technology for a number of reasons. There is widespread recognition that there is often a large gap between building energy performance *as designed* and measured post-occupancy energy consumption. A growing body of evidence indicates the value of permanent metering and monitoring [Piette et al. 2001], particularly in the context of monitoring-based and continuous or retrocommissioning [Brown et al. 2006; Mills et al. 2005; Mills 2009]. Also pointing to the value of monitoring, researchers have increasingly documented the positive behavioral impacts of making energy consumption visible to building occupants and residents [Darby 2006; Petersen et al. 2007]. Energy information systems are also well aligned with current trends toward benchmarking and performance reporting requirements. For example, recent federal and state mandates require benchmarking of public buildings, and many corporations now participate in greenhouse gas (GHG) emissions reporting. While these requirements can be met through utility bill tracking, EIS can certainly simplify the process through increased levels of automation.

This work is motivated by two closely related, yet unproven concepts. First is the idea that buildings are complex, dynamic systems, and that realizing optimal energy performance requires higher-granularity data and more timely analysis than can be gained from monthly utility bills. Second is the notion that EIS are critically important because they can process data into *actionable information*, and thereby serve as the informational link between the primary actors who affect building energy efficiency. This concept is illustrated in Figure 1, using the following example. Time-series data from electric interval meters and weather information services are analyzed by the EIS, which displays information in the form of weekend versus weekday energy consumption. The EIS user is then able to take action based on this information, for example, ensuring that weekend schedules are properly implemented. Further, since the EIS is implemented in software, the energy manager who might detect the mis-scheduling is able to share this information with the operators who are responsible for equipment settings and controls, and with owners or other decision makers who might need to authorize such changes, or to track energy costs. Clearly, as one transitions from the whole-building focus of EIS to component or system level fault diagnostics, there is a spectrum of what is considered "actionable information." For example, EIS do not typically generate information as specific as, "third-floor damper stuck open." Rather, the current state of the technology is such that a knowledgeable operator can use the visualization and analysis features to derive information that can be acted upon.

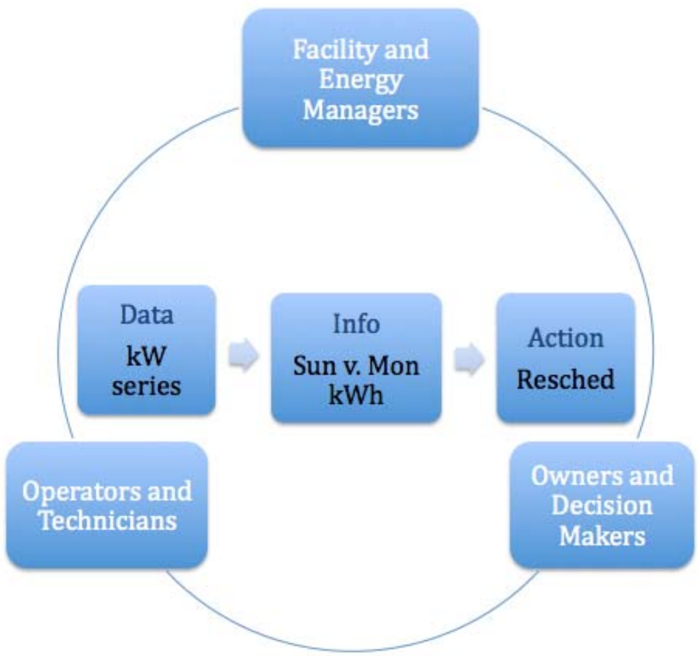

Figure 1: EIS translate data into actionable information and link the actors who impact building energy

There is not an extensive body of prior work or literature from which to draw an understanding of contemporary EIS technology or the energy savings that they might enable. Dozens of EIS are commercially available, yet public domain information is often vague,and demonstration software may not be available. In addition, a lack of common terminology across vendors and a significant degree of salesmanship makes it difficult to discern *exactly* what functionality the tools offer, what the hardware requirements are, or what makes one product more effective than another. These questions must be better understood before it is possible to evaluate the energy saving potential of EIS. What is the full spectrum of analyses and diagnostics that EIS support? Which capabilities are standard in EIS, and which denote more sophisticated functionality?What are users' experiences with EIS, and how do they leverage embedded features to improve energy performance?

Correspondingly, this study is guided by three high-level objectives:

1. To define a characterization framework of EIS features that provides a common terminology and can be used to understand what EIS are and what they do.
2. To apply the framework to EIS products to understand the state of the technology, distinguishing capabilities, and leading-edge functionality.
3. To conduct case studies to reveal critical aspects of EIS usability and begin to understand the interplay between common features, diagnostics, and energy-saving actions.

While the body of prior work dedicated to EIS is sparse compared to other aspects of building control and diagnostics, there are several studies and key articles that merit attention. Two books published in 2005 and 2007 contain editors' compilations of articles that document the implementation of web-based building control and automation systems and their use for enterprise or site energy analysis [Capehart and Capehart 2005, 2007]. This year, at the request of the U.S. Environmental Protection Agency (EPA), the New Buildings Institute published a report that considers EIS in the context of advanced metering technologies[NBI 2009].The Lawrence Berkeley National Laboratory (LBNL) has a long history of researchaddressing EIS,as well as system-specific performance monitoring and diagnostics [Motegi and Piette 2003; Piette et al. 2001, 2001b]. This study extends and updates the outcomes of research published by LBNL in 2003, which comprised a smaller-scale evaluation of features and EIS products [Motegi and Piette 2003].Finally, a substantial body of work is dedicated to the use of building automation systems (BAS) and energy management and control systems (EMCS). However, it tends to focus on leveraging heating, ventilating, and air conditioning (HVAC) data for applications external to the EMCS, and on HVAC performance diagnostics [Friedman and Piette 2001; Heinemeier 1994; Webster 2005]. In contrast, this work considers EMCS only in terms of their utility in whole building energy monitoring.

In the remainder of the report, Chapter 2 details the content and structure of the characterization framework and findings from our review of commercial EIS. In its totality, the framework represents the full range of analytical, diagnostic, and visualization features that EIS support. In addition, each major feature category is discussed with a focus on typical offerings versus more sophisticated or more rare ones. It is important to emphasize that all reported findings are based on vendor-supplied information at the time of the study. Current capabilities are subject to change, and readers are encouraged to confirm information based on their specific needs. Moreover, the EIS that were selected for evaluation are representative of the market but not comprehensive, and inclusion in the study does not imply endorsement.

The case studies are presentedIn Chapter 3, and Chapter 4 is dedicated to conclusions and future work. The appendices contain the characterization framework, EIS evaluations, a technical discussion of baseline methods, and case study narratives.

Chapter 2. EIS Characterization Framework and Evaluations

As depicted in Figure 2, EIS are defined as products that combine software, data acquisition and storage hardware, and communication systems to store, analyze, and display building energy information. At a minimum an EIS provides hourly whole-building electric data that are web-accessible, with analytical and graphical capabilities [Motegi and Piette 2003]. Data types commonly processed by EIS include energy consumption data; weather data; energy price signals; and demand response (DR) information. These data are processed for analyses such as forecasting, load profiling, and multi-site and historic benchmarking.Energy information systemsmay also provide submeter, subsystem, or component-level data, as well as corresponding analyses such as system efficiencies or analysis of end uses, yet these are not requirements.

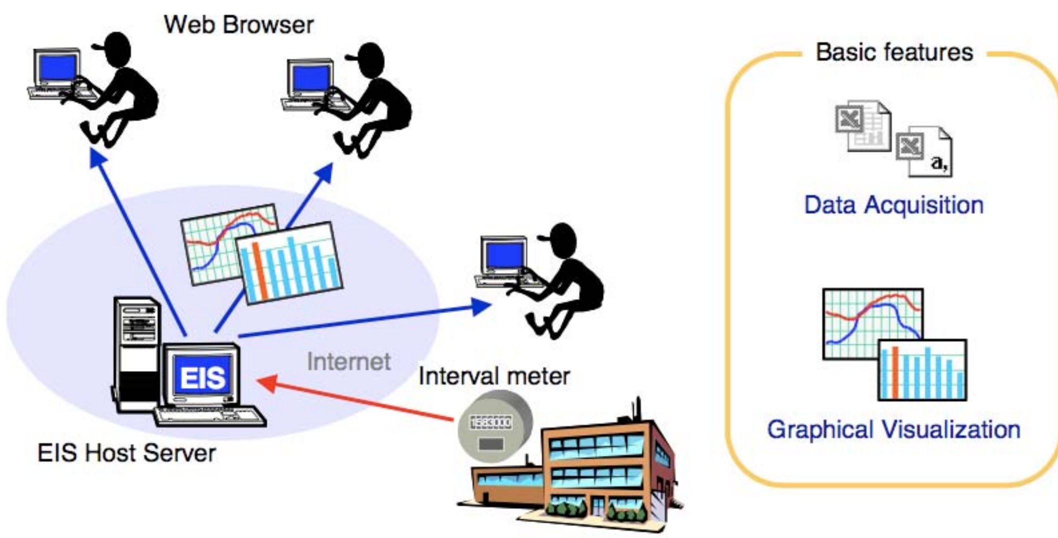

Figure 2: Basic Energy Information System [Motegi and Piette 2003]

Four general types of EIS were identified in prior work:(1) utility EIS, (2) DR systems, (3) web-based energy management and control systems (web-EMCS), and (4) enterprise energy management (EEM) tools [Motegi and Piette 2003].As indicated in Figure 3, EIS consist of the intersection of support tools from a number of domains.

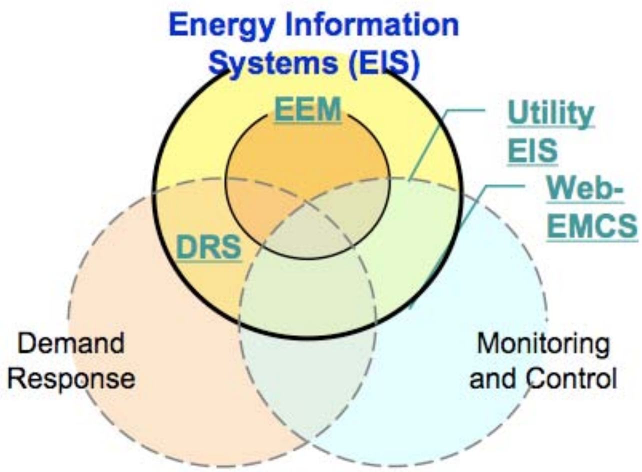

Figure 3: Types of EIS and overlapping functional intent [Motegi and Piette 2003]

The distinction between what is and what is not an EIS is better understood using EMCS as an example. While their traditional design intent is to monitor and control building systems, EMCS *can* integrate whole-building utility meters and weather sensors. In turn, these data can be used to define energy performance metrics that can be included in plots, calculations, and reports. In addition, some EMCS are web-accessible. If the monitoring-focused features of an EMCS are implemented and used in this manner, the web-based EMCS can be considered an EIS. That is, the functionality of some EMCS can be applied to whole-building data in such a way that the software serves as an EIS, although scaling issues for data management and storage may be encountered in large enterprises. On the other hand, conventional EIS may not have control capability or subsystem data, but rather embody a design intent to understand patterns of whole-building energy use. Energy information systemsprovide support for benchmarking, baselining, anomaly detection, off-hours energy use, load shape optimization, energy rate analysis, andretrofit and retro-commissioning savings. In this way, traditional building automation or control systems, and equipment specific diagnostic software tools do not fall within the scope of EIS.

In contrast to EIS software, we treat information "dashboards" according to the traditional definition: single-screen graphical displays of the most critical information necessary for a job or task, commonly used to communicate business information [Few 2006]. Dashboards have recently gained popularity in energy applications, because of their ability to distill a large volume of complex data into a summative set of graphics that can be interpreted at a glance. Common graphical elements in dashboards include gauges and dials evocative of a vehicle dashboard, as well as graphs and charts that are often color-coded to map quantitative measures to qualitative terms. There is clearly overlap between the two technologies—for example, EIS may include dashboard views or layouts—however, we consider EIS to be full-featured software offerings with a variety of menu, display, and analytical options.

It is tempting to attempt to provide a more constrained definition of EIS that goes beyond a general set of use contexts and an accompanying set of technology capabilities. For example, one may seek a specific minimal set of features that must be offered in order for a specific technology to qualify as an EIS.This study targets technologies that are commonly considered EIS, that are used as EIS, or that could arguably be considered EIS. The immediate objective is to identify the full set of features that are supported, in order to provide a common framework for understanding and discussing this diverse set of technologies. This framework could be used in the future by an industry standards group to then determine by consensus an appropriate set of capabilities that could serve as the criteria for a given technology to qualify as an EIS.

2.1 EIS Characterization Framework

The EIS characterization framework was developed iteratively, beginning with the features that were relevant in 2003. That set of features was augmented to better fit today's systems based on preliminary knowledge of industry advances and a cursory scoping of current systems. Feedback from a technical advisory group and a small number of vendors was solicited and incorporated in revisions. In its final form, the framework consists of eight categories with five to ten features each (see Appendix A).

The categories within the framework (and associated features) include the following:

- Data collection, transmission, storage, and security
    - Accepted energy inputs, storage capacity, minimum trend interval, upload frequency, supported protocols and interoperability, archived and exported data formats, and security measures
- Display and visualization
    - Daily, summary, or calendar plotting intervals, daily and trend display overlays, three-dimensional plotting, DR status and reduction, and x-y plotting
- Energy analysis
    - Averages, high/lows, efficiencies, normalization, carbon tracking, multi-site, historical, and standards-based benchmarking
- Advanced analysis
    - Forecasting, fault detection and diagnostics (FDD), data gaps, statistics, on-site generation, renewables, and load shape analysis
- Financial analysis
    - Simple and tariff-based energy costing, meter/bill verification, estimation of savings from capital or operational changes, bill processing/payment, and end use allocation
- Demand response
    - Signal notification, event response recording, manual vs. automated response, opt out, blackout, test dates, response analysis, and quantification
- Remote control and management
- General information

- Browser support, purchase and subscription costs, intended user, number of users, vendor description, traditional and newly targeted markets

This framework characterizes standard out-of-the-box functionality across a broad spectrum of EIS technologies. Depending on the specific software under consideration, not every feature may be applicable. The framework is most applicable to systems that target end users at the facilities level, with a minimum level of bundled or optional services. However, even tools with a number of options can be characterized with a bit of annotation beyond simple yes/no assignments. In interpreting product-specific evaluations, it is important to recognize that within the context of a given product's target and objectives, ”no” responses do not necessarily indicate a less-powerful overall solution; conversely ”yes” responses do not automatically signify increased usability or effectiveness. In terms of specific products, the framework should be understood as a high-level starting point from which to gain an understanding of any particular offering. Demonstrations and direct conversations with vendors are required to fully understand the appropriateness of any one tool for a given facility and its associated energy management needs.

2.2 Commercial EIS Evaluations

Following formalization of the framework, approximately 30 EIS (listed in Table 1) were characterized, with a description of intended users. Out-of-scope products included most EMCS, energy information ”dashboards” for occupants or owners, GHG footprint calculators, batch analysis tools, and general building environment tools.

Vendor	EIS	Intended Users or Facility Types
Agilewaves	The Resource Monitor	Energy managers, operators
Apogee Interactive	Commercial Energy Suite	Facility managers
Automated Energy		Commercial, enterprise, utility customers
Automated Logic	Web-CTRL	Data center, commercial
Chevron Energy Solutions	Utility Vision	Energy managers
Energy Connect	Web Connect	DR participants, energy and facility managers
EnergyICT	EIServer and modules	Enterprises, utilities, multi-site
EnerNOC	Power/CarbonTrak	Internal use, commercial and government DR participants
Envinta	ENTERPRIZE.EM	Enterprises, utilities
FactoryIQ	eMetrics	Large commercial, industrial
	Green Energy Management System (GEMS)	
Gridlogix	Automated Enterprise Management	Enterprise
Interval Data Systems	EnergyWitness	Enterprises, facility managers
Itron	EEM Suite	Energy managers
Matrikon	Operational Insight	Enterprise
NorthWrite	Energy WorkSite	Commercial, industrial, utility customers
Novar		Internal use, big-box retail enterprise
Noveda	Facilimetrix	Facility managers
Powerit Solutions	Spara EMS	Facility managers
PowerLogic	Energy Profiler Online	Commercial
PowerLogic	Ion EEM	Enterprise, industrial
Richards Zeta	Mediator	Commercial
SAIC	Enterprise Energy Dashboard (E2D)	Enterprise and industrial facility, energy managers
Small Energy Group	Pulse Energy	Managers, owners, occupants
Stonewater Controls	InSpire	Enterprise, utilities, government
Tridium	Vykon Energy Suite	Facility and energy managers, owners, energy service providers
Ziphany	Energy operation, energy information, and DR platforms	Energy service and DR providers

Table 1: EIS evaluated according to the characterization framework

Each system in the study was reviewed based on publicly available online material and demos. It is not possible to fully characterize an EIS offering based purely on brochures and website information, so vendor feedback and input was included in the evaluation. Where possible we characterized features through interviews with the vendor, although in some cases the vendors preferred to evaluate their offering independently, and they then provided us with their evaluations.

General findings concerning the state of the technology are presented in the remainder of Chapter 2.2, with product-specific evaluations provided in Appendix B. It is clear that product-specific yes/no responses taken over a family of capabilities do not directly lead to an understanding of key differentiators and driving trends. To better understand those differentiators and trends, the body of EIS that were characterized is analyzed from a number of perspectives, corresponding to primary feature categories in the framework. Specific products are referenced only to illustrate the conclusions that are drawn.

2.2.1 Business Models

It is quite difficult to map the diversity of EIS offerings to traditional software business models. The array of optional services, varying degrees of customization or configuration, and alternatives for data and IT management and pricing quickly blur the lines that define common software models. Nevertheless, some of the familiar structures are useful in attempting to understand the EIS market.

Standard software products are typically purchased with a one-time fee, are licensed according to number of installations, and include limited support with no additional services. **Enterprise client-server applications** are commonly licensed based on the number of users, and include one-time fees as well as support and upgrade subscriptions. **Application Service Providers** (ASP) offer solutions in which the ASP owns operates and maintains the software and servers for web-based applications that are usually priced according to monthly/annual fees. **Turnkey solution providers** offer fullypackaged solutions that include pre-installed software, hardware, and accessories in a single ”bundle.”

Although it is rare to find an EIS vendor that cleanly fits into a single model, EIS offerings and providers can be differentiated according to the following considerations:

- ASP or traditional ownership: who houses, owns, and maintains the servers and software application?
- Bundled or optional services: data and IT management, interface customization, and energy-specific data analysis
- Intended end user: energy service providers, aggregators, operators, facilities managers, corporate enterprise managers, utilities, and systems integrators
- Hardware requirements: does the offering include specific or proprietary hardware, no hardware, or hardware only as necessary for the clients’ objectives?
- Payment options: per site, per user, billing frequency, subscription or one-time fee

A minimum number of tools included in this study are offered as traditional enterprise client-server applications, with the user responsible for on-site IT management (e.g., Energy Witness). More commonly, EIS are offered via ASP with no hardware, or optional hardware as might be dictated by client needs (e.g., Facilimetrix, Energy WorkSite, EEM Suite, Pulse Energy). Just as frequently, EIS are offered via ASP with optional or bundled services (e.g., Automated Energy, Ziphany, E2D). In a limited number of cases the EIS software is offered free of charge(e.g., PowerTrak, Novar, Web Connect), as its primary end users are service providers.

Solutions that feature software bundled with hardware tend to include web-EMCS by definition, in addition to some of the DR tools (Web-CTRL, The Resource Monitor, Spara EMS). Finally, it is important to understand that EIS can be intended for diverse user groups. The tool may be intended directly for the on-site or enterprise end users or for third parties to offer to their own clients. For example utilities, aggregators, energy consultants and service providers, and systems integrators may develop or customize applications for on-site end users.

2.2.2 EIS Architectures

The discussion of business models naturally leads to a review of the architectures underlying common EIS tools and services. Figure 4 illustrates the hardware, subsystems, and software that comprise or are utilized in a typical EIS.

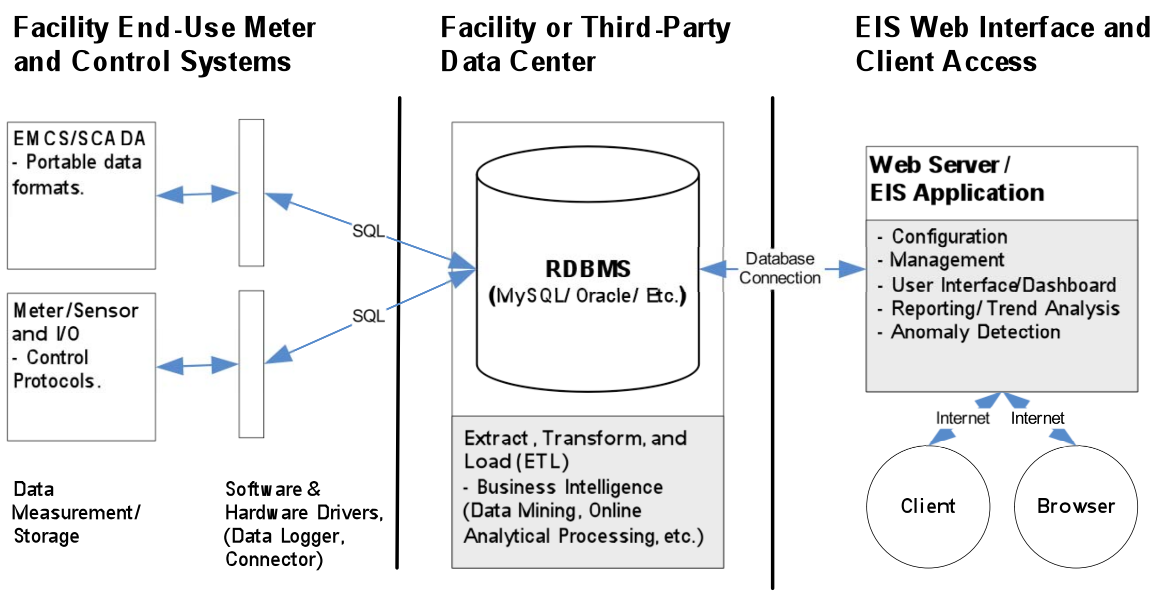

Figure 4: Hardware, subsystems, and software that comprise or are utilized in typical EIS

Note: SCADA = supervisory control and data acquisition; SQL = Structured Query Language; RDBMS = relational database management system

From left to right in the figure, the three hierarchical levels underlying the data acquisition and controls, storage and analysis, and display functionality of EIS are:

1. **Facility End-Use Meter and Control Systems:** These systems measure and monitor using variety of communication protocols such as BACnet, and Modbus.
2. **Facility or Third-party Data Center:** This is typically a data warehouse within a facility or third-party (service provider) location.

3. **EIS Web Interface and Client Access:** The front-end application is used to configure, manage, and display EIS data. Remote internet access is provided via web browsers or other clients such as mobile devices.

At the data center or facilities storage level detailed in Figure 5, monitored information is posted to a data warehouse. Typically, a relational database management system (RDBMS) stores and archives the data, although online analytical processing (OLAP) is sometimes used. The RDBMS might follow a variety of database offerings, including those such as MySQL, Microsoft SQL Server, or Oracle, as well as proprietary solutions. Structured Query Language (SQL) or variations such as Procedural Language SQL (PL/SQL) are standard communication languages to query and post information between meter sources and databases.

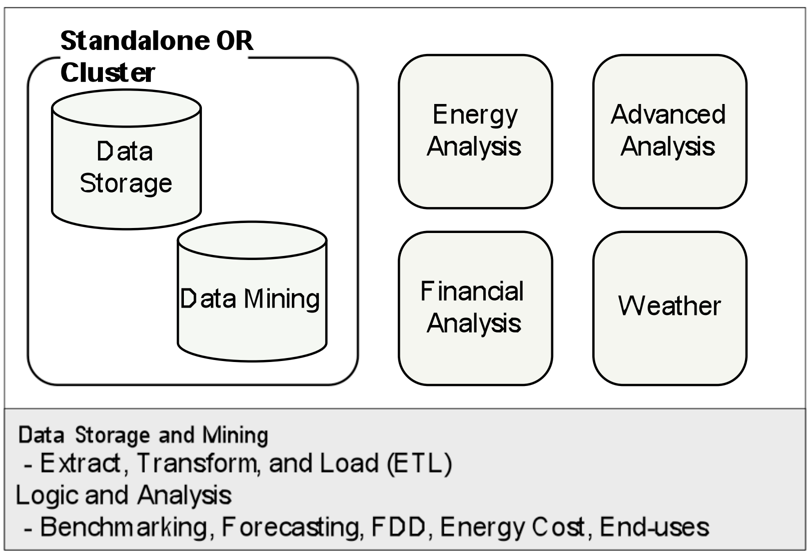

Figure 5: Detailed view of the data center level of EIS architectures

The EIS data warehouse can be a standalone server or a high-volume cluster, and can be physically located at the site or at the EIS provider's (third-party) data center. For the purposes of EIS, data are processed in three major steps: transmission to the data center, data cleansing or filtering (if provided), and database archiving for post-processing. Archived data are the basis of facility-specific analyses, including energy, finances, weather modeling, and others. Algorithms for baselining, load forecasting, fault detection, energy costing, are applied to processed data. Finally, for front-end web interfaces to display and report information, EIS application programmers make use of database connection drivers such as Java Database Connectivity or Open Database Connectivity.

2.2.3 Display and Visualization

Since 2003 there have not been significant changes in display and visualization features. Across all of the EIS that were evaluated, load profiling and point overlay display capabilities are largely accommodated. With a few exceptions trends can be viewed over user-defined intervals of time, be it years, months, or minutes of data; trended variables can be aggregated into totals (e.g., kilowatt-hours [kWh] last week); and features that allow the user to overlay multiple trends on a single plot are nearly universal. Slightly less common, but still standard is the ability to overlay trends for different time periods on a single plot (e.g., Monday kW and Saturday kW).Flexibility is one aspect of visualization that is found to vary from tool to tool. Display parameters might be dynamically altered "on-demand" as user need arises, or more statically defined within configurable options. For example all tools will display a plot with multiple trend overlays, but in some implementations these trends must be predefined in reports settings, while others allow the user to plot any value on the fly.

Similar to trend display and overlay features, the ability to show DR event status and reduction levels is almost universally supported, as it was in 2003. Three-dimensional surface plots in contrast are *not* common, and were encountered in just a handful of the tools that were reviewed. This finding is not surprising, as it is unclear how additional dimensionality enhances the ability to process, understand, or analyze energy information. X-y scatter plotting was not a common or standard visualization capability in 2003, and while it has grown some, it remains an under-supported feature in today's EIS solutions. Given their power in facilitating diagnostic troubleshooting, it is discouraging that only half the tools surveyed include x-y plotting. Those tools that do include it usually accommodate the feature through correlation analyses. The EIS that originated in the industrial sector are especially likely to support x-y or correlational plotting, due to the historic demand for site-specific key performance indicators. As for the more general display features discussed above, an important distinction in evaluating x-y plotting is whether it is dynamically defined by the user or statically defined in configured graphics.

2.2.4 Energy Analysis

Features related to GHG analysis did not appear in the 2003 study, but they are an element of the EIS framework. Two-thirds of the EIS that were reviewed feature carbon tracking and analysis as a standard capability or provide custom or configurable options to do so. The majority of analyses apply a simple energy/carbon dioxide (CO_2) relationship; however, about half account for regional differences in generation or other standards. For example:

- PowerTrak uses EPA's eGRID (emissions and generation resource integration) database paired with client zip codes.
- Ion EEM determines emissions factors based on Scope 1 and 2 of the GHG Protocol, a GHG accounting framework used in standards and programs such as the International Standards Organization and the Climate Registry.[1]
- Automated Energy, EIServer, and Energy Witness apply knowledge of utility-specific fuel mixes.
- Energy WorkSite uses Department of Energy values for state-by-state emissions.

[1] http://www.ghgprotocol.org/

Time-varying GHG intensities are not yet frequently addressed. Time variance is expected to be a useful feature for sites that perform load shifting, for example via thermal energy storage systems. The few exceptions that were encountered include EPO and ION EEM, both of which permit the definition of multiple emissions factors, and Commercial Energy Suite, which cites time-variance as an optional feature. Energy Witness reports that the feature is under development for upcoming releases.

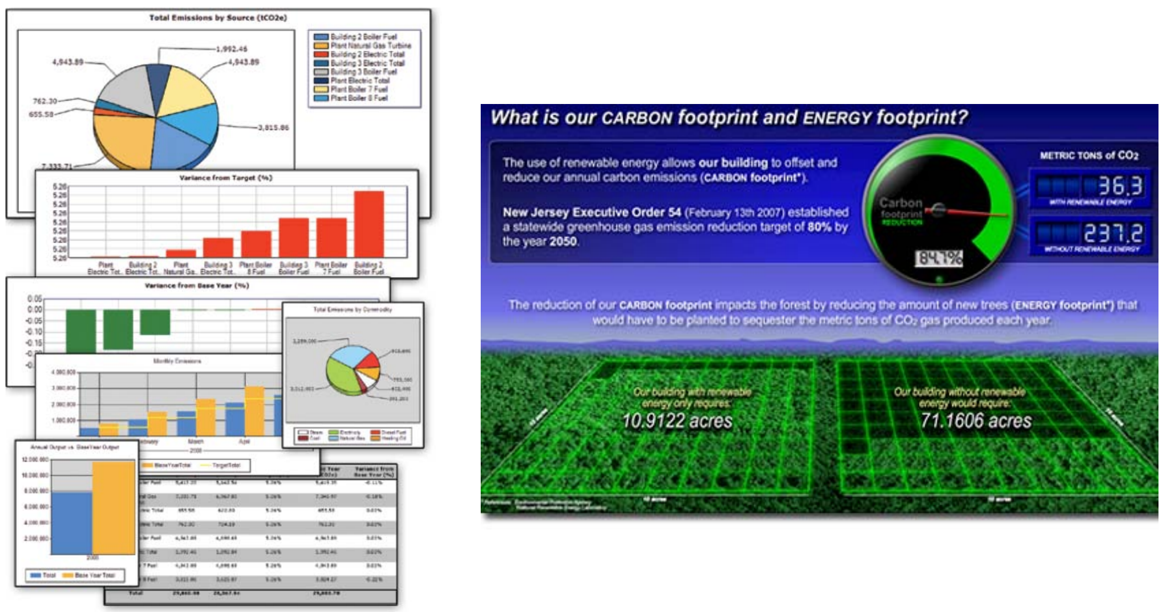

Figure 6: ION EEM emissions reporting module[2] and Noveda Carbon Footprint Monitor[3]

Normalization is an important feature of energy analysis that is widely accommodated, although at diverse levels of rigor. Only a handful of tools report that they offer no means of normalization (e.g., Utility Vision, EEM Suite, The Resource Monitor, Web Connect, InSpire), or require that data be exported to third-party software such as Excel to do so. Normalization capabilities may be offered via reporting options or definable arithmetic calculations (monthly kWh divided by monthly degree days) or plottable trend points created from other trends (e.g., ION EEM, Operational Insight). Weather normalization may make use of environmental sensors that are integrated into the EIS database, external sources of weather data (e.g., Automated Energy uses Accuweather), or manual entry within calculation functions.

Quantification of a building's historic energy performance baseline is supported in nearly every EIS in the study. The majority implement trend-based or report-based solutions, while weather-normalized baseline models or implementation of standard methodologies are far less prevalent. Some exceptions include the ION EEM energy

[2] http://www.powerlogic.com/literature/3000HO0603R1108_IONDemand.pdf
[3] http://www.noveda.com/en/page/105?l1=3&l2=5&l3=0

modeling module, as well as Powerit Solutions and Novar, who integrate expert knowledge and heuristics.

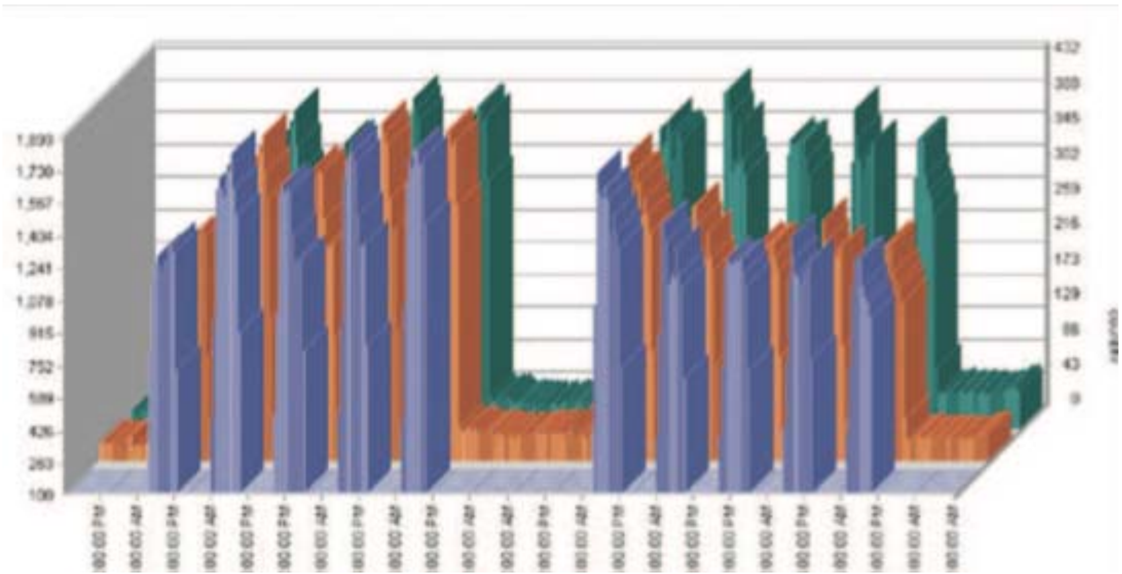

Figure 7: EEM Suite[4] baseline and metered consumption, with total production

Multi-site benchmarking is used to relate one building's energy performance to that of other buildings, for comparative purposes. Every tool that was evaluated for this study supports some form of benchmarking, currently or in upcoming version releases. Distinguishing aspects of EIS benchmarking functionality include the following:

- Composition of the comparative cohort: buildings within the end user's enterprise, other clients from the vendors databases, or data sets such as the Commercial Buildings Energy Consumption Survey (CBECS)
- User access: embedded in static reports or dynamically accessible functions
- Display of results: numerically in tables or graphically in plots or charts

Two examples of benchmarking against national data sets include Energy Witness' use of CBECS data and Energy WorkSite's calculation of Energy Star rankings.

2.2.5 Financial and Advanced Energy Analyses

The ability to identify corrupted or missing data is critical in EIS, given the number of performance calculations that are automated based on trended historic data, as well as the large volumes of data that are stored. Three-quarters of the systems that were evaluated accommodate this capability, via three principal means: identification through flagging or summative reporting; actual cleansing and/or correction; and linking to external or third-party software.

- Utility Vision, Automated Energy, Energy Witness, and ENTERPRIZE.EM identify gaps/corruption by flagging, reporting, or e-mail notification

[4] www.**itron**.com/asset.asp?region=sam&lang=en&path=products/specsheets/itr _008021.pdf

- Energy WorkSite automates error checking, data cleansing, and interpolation
- Energy ICT, PowerTrak, and Ziphany make use of validation editing and estimation standards (VEE)
- Vykon offers configurable cleansing options in reports and documents communication faults to identify potentially corrupted data sets
- eMetrics provides data cleansing as a service

Depending on the tool and the extent to which the vendor offers services, data filtering and correction is purchased for additional fees, custom-defined, or out-of-the-box.

Some EIS provide building-level anomaly detection, or departures from normal consumption or trend patterns, howeveras expected based on the whole-building emphasis of EIS, automated fault detection and diagnostics at the component level is not typical. The exceptions include a few tools that link to external software packages or to dedicated, compatible FDD modules. For example EEM Suite recommends linking to Metrix IDR to identify corrupted data and to perform FDD, and Operational Insight links to an FDD module separate from the EIS.

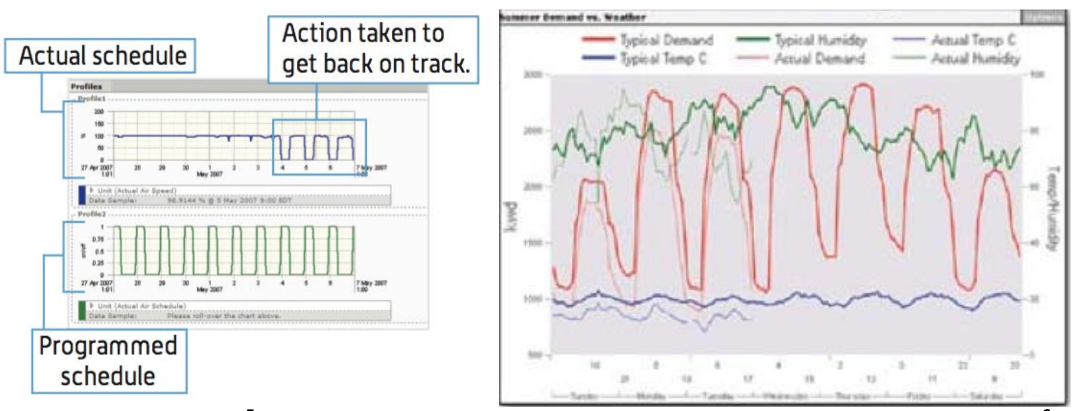

Figure 8: PowerTrak's[5] departure from normal/programmed schedule (left); ION EEM[6] trend overlay to compare typical and actual trends (right)

Over three-quarters of the EIS that were reviewed are able to provide simple estimates of the energy cost of operating the building, and the majority of those that do so also handle model-based or tariff-based costing. It is not surprising that the DR tools tend to offer the most robust energy cost estimates. In addition to estimating energy costs, more than half of the tools evaluated report the ability to forecast near future load profiles, typically by coupling historic trends with weather data and perhaps pricing or cost data (e.g., Automated Energy, Energy Witness, Facilimetrix).In those tools that are bundled with services, the level of forecasting sophistication is largely dependent upon the needs of the client (e.g., E2D, Novar). Few solutions feature model-based or algorithmic forecasting, although Energy ICT applies neural networks, Energy WorkSite employs a bin methodology, and Pulse Energy uses a proprietary method of weighted

[5] http://www.enernoc.com/pdf/brochures/enernoc-mbcx-brochure.pdf
[6] http://www.powerlogic.com/literature/3000HO0603R1108_IONDemand.pdf

averaging. Although forecasting, anomaly detection, and benchmarking are separate features in the framework, it is important to recognize that these functions often rely upon a single underlying baseline method. Appendix C contains a technical overview of several approaches to baseline calculation that are found in EIS, and discusses how baselines are used for prediction, M&V, benchmarking, and anomaly detection. It was not possible to learn the precise baseline methods used in each and every EIS in the study, therefore this discussion detailsgeneral approaches, with three specific examples.

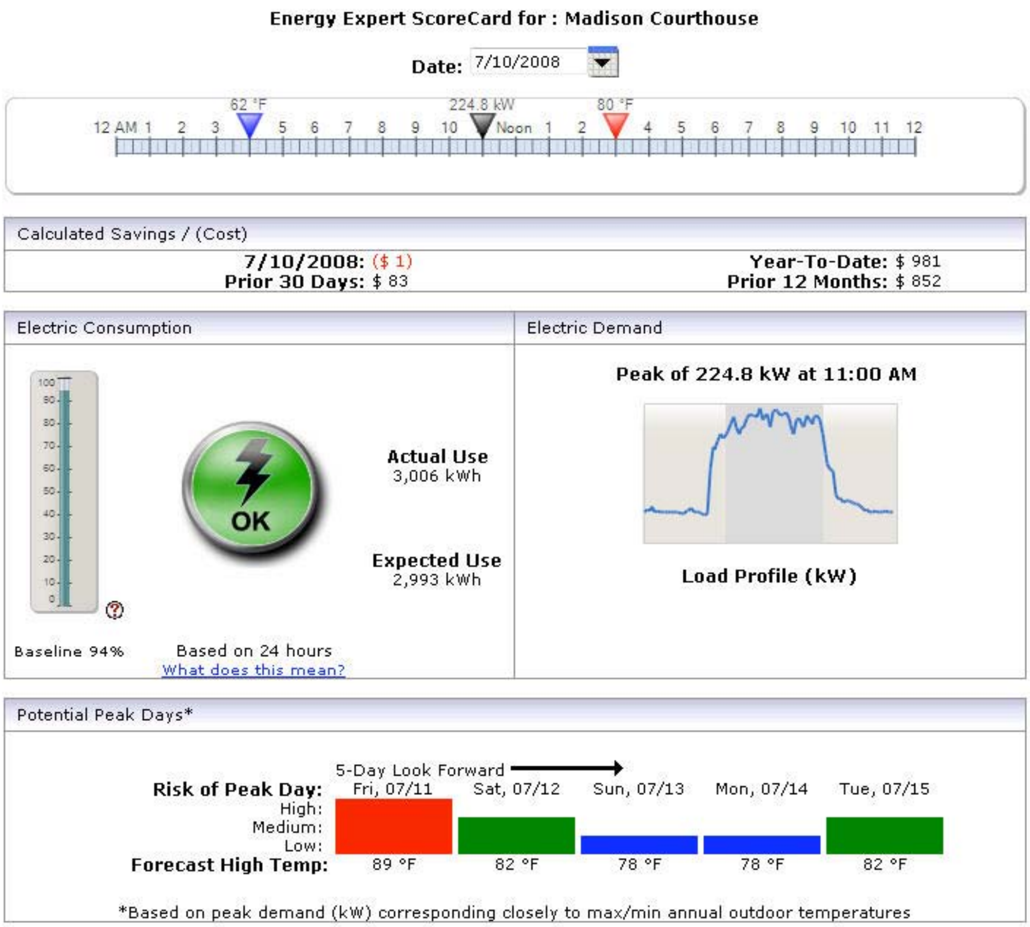

Figure 9: NorthWrite display of actual and predicted use, costing, and forecasting

Closely related to energy costing and forecasting is the ability to calculate or predict savings from retrofit operational strategies, or EIS use. As with energy costing, roughly three quarters of the EIS that were reviewed support this feature in some form, and EIS that do not support costing do not tend to calculate or predict savings from operational changes. Determination of savings from retrofits is one of the more common applications of M&V efforts, and in theory it is possible to facilitate M&V through the baselining, normalization, user-defined arithmetic, and tariff-based costing in an EIS. However it may be difficult to configure an EIS to conform to specific M&V protocols, e.g.,the International Performance Measurement and Verification Protocol (IPMVP), that may require baseline or routine adjustments via regression modeling of independent variables or minimum monitoring periods. In fact, at least one large utility reports that many EIS vendors who offer comprehensive feature sets are unable to configure their systems to provide an acceptable M&V methodology.

Approximately half of the EIS accommodate the comparison of meter readings and utility bills to verify accuracy, but the feature may not be fully automated. As one might expect, the EEM systems often provide more sophisticated or robust financial analyses, as they are designed to address corporate/executive needs in addition to energy monitoring.

2.2.6 Control and Demand Response

Energy information systems control and management capabilities commonly appear in two varieties: (1) control according to a program via gateway or EMCS, or (2) remote control over the internet [Motegi and Piette 2003]. Just over half of the EIS surveyed report the ability to control according to a program, and just under half report internet-capable remote control. Remote control is intimately related to demand response capabilities, which have advanced since 2003, converging to a common set of features.

- Automated response is possible in all but three of the DR systems that were evaluated (Commercial Energy Suite, PowerTrak, and EPO are limited to manual DR.
- E-mail, phone, pager, and alarm notifications of DR event status are all standard, although not every tool implements all four contact methods.
- All of the tools surveyed calculate baselines according to utility program formulas, allow testing events, and support response recording/documentation. Recording may be formalized and structured or simply captured in historic trend logs.
- All of the systems evaluated permit selection of opt out and blackout dates. One exception is PowerTrak; as with the automation feature, this is an artifact of the specific service they offer, rather than a software limitation.

Figure 10: Ziphany's load curtailment platform for utilities[7]

[7] http://www.ziphany.com/Files/drp-utilities.pdf

While the features detailed above are standard across all DR systems, the ability to predict savings from a given response is a key distinguisher of EIS capability. The near uniformity in features offered in today's DR systems begs the question of what would expand today's response capabilities? One potential advance is to allow for several increasingly severe DR strategies that could be implemented if the primary strategy were not effecting large enough demand reductions to meet the target. In addition, calculation of DR potential or expected savings might be enhanced through model-predictive or intelligent algorithms. Ultimately, as automated DR becomes commonplace in commercial buildings, post-event rebound will become more critical, and DR systems that address rebound will be an advantage.

Chapter 3. EIS User Case Studies

While exceptionally useful in building an understanding of the state of the technology, individual product characterizations and conclusions regarding software capabilities do not answer questions of usability and real-world utilization. Correspondingly, four case studies were conducted to answer questions such as: Which features have proved most useful in attaining energy savings? What actions are taken based on the information provided via an EIS? How much of a building's low energy use or energy savings can be attributed to the use of an EIS? What are common challenges encountered in whole building performance monitoring? What are successful, realistic EIS implementation and use models?

The existing body of case studies documenting EIS use is modest, and is typically comprised of vendor-authored publications or literature from the commercial building energy community. Vendor-authored case studies are typically written to publicize successful implementation of a specific EIS, and as such are inherently biased to emphasize positive aspects of the technology that the vendor wishes to advertise. Vendor case studies are usually posted on the website, as is true of a number of the EIS that were evaluated in Chapter Two.[8,9,10,11] These profiles tend to emphasize cost savings over energy savings, although a number do include both metrics. The case studies conducted for this project are markedly different, in that they present users' technology challenges as well as successful savings. Further, they document EIS use based on the user's perspective, rather than the vendor's.

Case studies from the building energy community are more objective in their assessments and more varied in content and level of detail. Integration and installation, and the use of EMCS data, tend to be more frequently addressed [Capehart and Capehart 2005, 2007; Webster 2005]than the relationship between software features, actions taken, and resulting energy savings [Motegi et al. 2003].When features, actions, and savings are addressed in the literature, the overall topic is usually not whole-building EIS diagnostics, but rather equipment and system-level operational diagnostics.The cases presented in this chapter offer several unique contributions. First, they are coupled to the framework and EIS evaluations, providing a structured context from which to relate overall technology capabilities to real-world uses. Second, they cover a range of commercial building sectors and types. Finally, they target the less commonly explored aspects of EIS use at a high level of detail.

Wal-Mart, Sysco, the University of California (UC)Berkeley, and UC Merced were selected for case study based on the following criteria: users with a high level of

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[8] http://noveda.com/en/page/130?l1=5&l2=0
[9] http://www.enernoc.com/customers/case-studies.php
[10] http://www.intdatsys.com/pdfs/EnergyWitness-Hospital_Case_Study.pdf
[11] http://www.pulseenergy.com/category/case-studies

engagement with energy data and a role in energy management; aggressive savings or high-efficiency performance; and willingness to participate in three to four hours of interviews and site visits, location permitting. The UC Merced case study was conducted with the campus energy manager, and the UC Berkeley case included the associate director of sustainability and engineering services, and members of her staff groups. The Sysco case study was informed by the energy services provider and the person who is accountable for energy performance at a Northern California warehouse site. The Wal-Mart case combined discussions with a benchmarking analyst from the Energy Department, the Electrical Engineering Manager from Prototypical Design/Construction Standards, and the Senior Manger of Energy Systems and Technology Development. As summarized in Table 2, the four cases that were chosen represent commercial enterprises and campuses with a diversity of performance-monitoring technologies, commercial building types, and portfolio sizes. These cases encompass buildings that range from Wal-Mart and Sysco's relatively repeatable warehouse and retail designs, to UC Berkeley's legacy and historic sites, to UC Merced's very-low energy new construction.

Case	Type, (square feet)	Controls	Performance Monitoring
UC Merced	Campus (800,000)	ALC WebCTRL	ALC WebCTRL Utility bills
UC Berkeley	Campus (15.9M)	Barrington Some ALC, Siemens	Obvius Utility bills
Sysco: Stockton, California Sygma site	Refrigerated/dry warehouse (52M, Stockton 95,000)	DOS-based refrigeration control	NorthWrite Energy WorkSite Utility bills
Wal-Mart	Retail/grocery (675M)	Novar Danfoss Emerson CPC	Energy ICT EIServer Utility bills

Table 2: Case study sites and characteristics

Chapters 3.1 through 3.4 detail case-specific findings and the particular research themes that each case illustrates. For example, UC Merced exemplifies the challenges of using a Web-EMCS as an EIS, and the value of a web-accessible dense data set. Sysco, on the other hand, is a case of classic enterprise-wide EIS use, and use of the EIS to ensure persistence of savings and corporate accountability for energy performance. The final section in the chapter summarizes the energy savings and challenges that were documented for each case. The UC Merced and Sysco cases are presented in deeper detail in the narratives in appendices D and E.

3.1 UC Merced

Opened in 2005, UC Merced is the newest University of California campus. Prior to opening, the campus made a strong commitment to energy-efficient building design, and energy conservation plays a fundamental role in campus objectives. Campus energy activities focus on three areas:[12] building energy performance targets; ongoing monitoring of energy use; and climate neutrality. The University of California at Merced uses custom benchmarks for UC/California State University (CSU) campuses [Brown 2002] and has set targets ramping over time from 80% to 50% of average performance.

In support of these efficiency requirements and three focal activity areas, standardization of the campus control systems was made to be a priority during the design and construction phases, and Automated Logic Corporation's WebCTRL was selected. The University of California at Merced features a uniquely dense metering and monitoring infrastructure, already trending over 10,000 points at three academic buildings, the central plant, and smaller auxiliary buildings. Custom benchmarks and deep monitoring capability with a sophisticated web-EMCS are central to the main themes embodied at the campus: (1) the challenges in using a web-EMCS as an EIS, (2) the web-EMCS as enabling critical information links, and (3) realization of the campus as a living laboratory. These themes are visible in typical uses of the web-EMCS, site-specific data and technology challenges, and energy-saving opportunities identified in the data.

3.1.1 UC Merced Web-EMCS Uses

Typically, WebCTRL use at UC Merced is dominated by operational EMCS investigations, rather than EIS energy performance diagnostics.The technology is used most extensively to respond to trouble calls. In addition to troubleshooting problems that have already been brought to attention, WebCTRL is also regularly used to verify that individual buildings are operating as expected. Use of the web-EMCS for more traditional EIS analyses directed at campus and whole-building energy performance has been complicated because the EMCS and monitoring instrumentation was not explicitly commissioned for EIS diagnostics. The metrics used to track energy performance are more complicated than simple energy use intensities [Brown 2002], and the logic-based arithmetic in WebCTRL was not configured to perform the associated calculations. For example, allocations from the central plant, based on chilled water consumption, are added to the whole-building electric meter data, as are allocations for campus road lighting. Therefore, building and campus energy data are commonly exported to spreadsheet software for additional computation, cleansing, and computation. WebCTRL meter data are used annually to track energy performance; gas, electricity, hot water, and chilled water consumption are measured at the campus level and for critical buildings, as summarized in Table 3.On a monthly basis, the campus energy manager uses the web-EMCS data to determine utility recharges for non-state buildings (that is, buildings that are located on campus but are differently financed, requiring that they "reimburse" the campus for utilities).

[12] UC Merced, http://administration.ucmerced.edu/environmental-sustainability/energy

Web-EMCS	Annual Building Metrics	Data Sources	Benchmarks
Automated Logic Corporation WebCTRL	Peak electric demand Total electric use Peak chilled water demand Total gas use (incl. steam and HW)	Building electric meter Central plant electric submeters Central plant gas meters Building gas meters Building chilled/hot water flow, and supply/return temperature Utility bills	UC/CSU weather and building-type normalized energy use intensity [Brown 2002]

Table 3: UC Merced metrics, benchmarks, and data sources

The campus steam system provides two examples of the use of the web-EMCS to inform operational changes leading to energy-savings. Gas trends at the central steam plant showed significant gas use throughout the night, when the system was not intended to operate; at the same time, steam trends at the central plant revealed non-zero operating pressures at night. The energy manager shared the data with the superintendent, who returned the system to true zero overnight pressure, securing 30% reduction in average daily gas consumption (therms/day) at the steam plant and an estimated $4,500 monthly savings. In the lower portion of Figure 11 the change to zero overnight pressure is plotted; in the upper portion the resulting drop in overnight gas use is shown. In addition, the energy manager is in the process of combining gas trends from the steam plant with temporary steam use logging at the building level to confirm the efficiency of the steam plant. Knowledge of the plant efficiency will direct a decision to continue centralized steam production or move to a distributed supply.

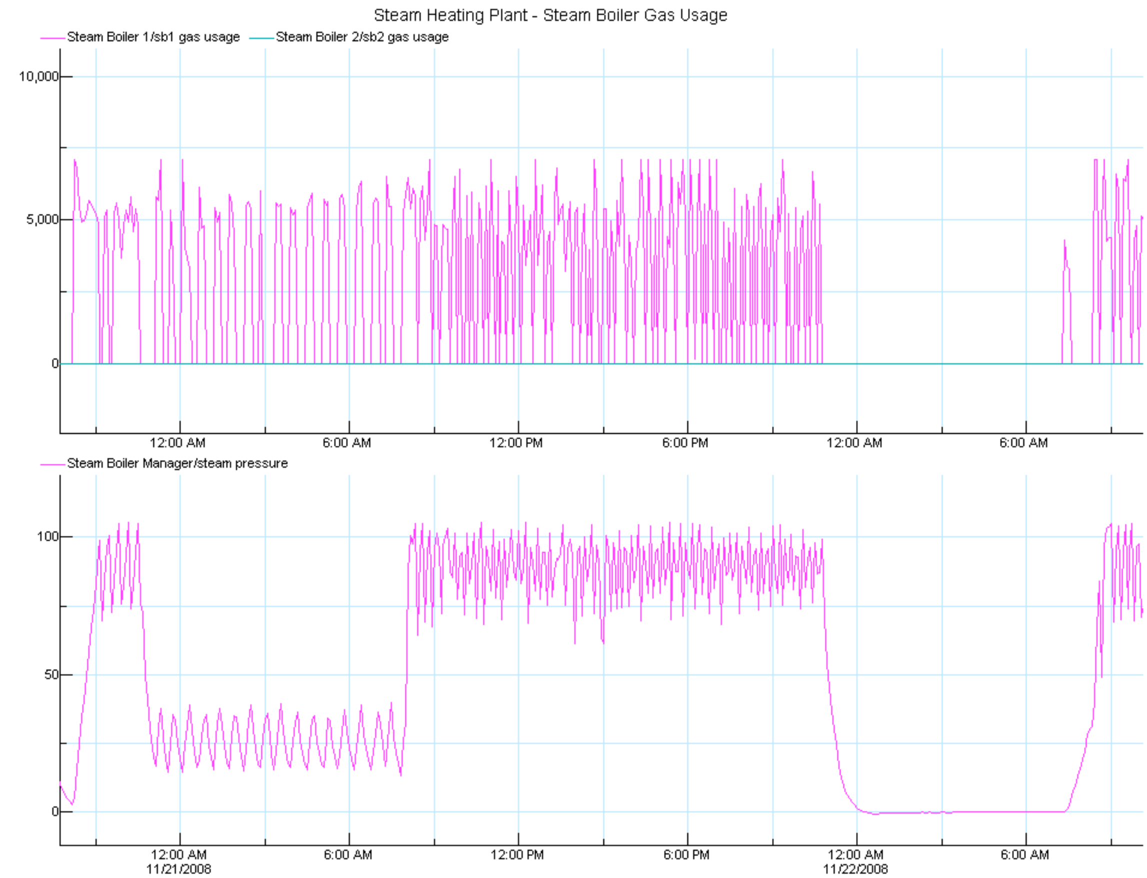

Figure 11: Web-EMCS trends and energy-saving operational change at UC Merced,showing overnight drop in gas use from zero overnight pressure."

In addition to providing a rich set of operational and energy consumption data, the web-EMCS has also facilitated the realization of the campus as a *living laboratory*. The campus energy manager emphasizes that this has been a tangiblebenefit of the WebCTRL system, and that the living laboratory concept is of critical importance, particularly at an academic institution. To this end the web-EMCS data are used in engineering thermodynamics course modules that the energy manager teaches; to inform student and faculty research efforts; and in short- and long-term research and demonstration collaborations with the external buildings research community. For example, the U.S. Department of Energy and the California Energy Commission have sponsored research at Lawrence Berkeley National Laboratory that focuses on using EMCS data to: develop and pilot model predictive control strategies at the chilled water plant; design a real-time diagnostic tool based on comparing meter data to calibrated building energy models; and analyze how the campus demand response potential is affected by the thermal energy storage system.

3.1.2 UC Merced Challenges and Needs

Data quality issues arise in a number of contexts at UC Merced, further challenging the use of the EMCS for automated analyses.Networking and connectivity problems have led todropped or miscommunicated values that generate errors, lock out equipment, and cause large volumes of false data and cascading false alarms. This has been a significant problem in using and maintaining WebCTRL at UC Merced, however network communications are viewed as affecting operations more than energy monitoring, and over time many of these challenges have been addressed.

While not attributable to the capabilities of the EMCS, meter or sensor calibration and configuration errors also affect data quality, thereby affecting the ability to use the EMCS as an EIS. With the exception of whole-building electric data, significant resources were required to manually validate the EMCS data quality and to quantify the campus energy performance relative to benchmark. Manual validation included inspections to trace the physical meter point to its representation in WebCTRL, as well as energy and mass balances to confirm accuracy of logged data and interpolation or estimation of missing data. To date, manual validation has affected building science researchers more than WebCTRL users at UC Merced, but it does have implications for advanced use of the data within the living laboratory context.

Staffing and resources are a recurrent theme that arises in the case studies. At UC Merced, the energy manager has not been able to investigate building and submeter trends to the full extent desired, and campus-wide it has taken some effort to transition from reactive to proactive use of the data.For example, the central plant operators have begun performing hourly reviews of WebCTRL trends according to a defined check-sheet, and the reviews are documented and commented. This process was implemented as a structured way for the operators to be able to leverage the web-EMCS technology. Analogously, more routine campus and building-level energy diagnostics based on web-EMCS trends has been somewhat hindered by constraints on the energy manager's time. Note that prior research in the use of building management systems at government buildings identified similar challenges in proactivity, resources, and energy management [Webster 2005].

There are no embedded features in the software that are unused at UC Merced or that are considered superfluous or too time-consuming or difficult to learn. Although addressing trouble calls may dominate use of the web-EMCS, these operational efforts have allowed the energy manager to maintain exceptional energy performance. Were the metering infrastructure better calibrated and commissioned, and were the EMCS configured to track key performance metrics, it might be used more easily for EIS-like analyses.

In spite of outstanding needs and imperfections with the technology, the energy manager reports a high level of satisfaction with WebCTRL and what it has enabled him to accomplish. He emphasizes that UC Merced trends extremely large volumes of data and that intensive monitoring needs to be undertaken deliberately, with close attention to a spectrum of issues including wiring, system programming, network architecture and hardware selection. Further, Automated Logic Corporation has been particularly accommodating, working with UC Merced and other large institutions to develop a revised network and hardware infrastructure.

3.2 Sysco (Sygma)

Sysco has implemented a three-year corporate-wide energy efficiency program that targets a 25% reduction in energy consumption across a portfolio of one hundred forty-three distribution centers in the United States and Canada. Sysco has a long-standing energy services and consulting contract with Cascade Energy Engineering, with whom a collaborative three-part approach was adopted: (1) site visits by expert refrigeration engineers and technicians to perform tune-ups and identify low-/no-cost energy-saving measures; (2) customization of NorthWrite's Energy WorkSite EIS to accommodate Sysco's goals; and (3) continuous communication and collaboration between corporate managers, Cascade Energy Engineering, and on-site "energy champions." This approach has enabled Sysco to outpace its goal, reaching 28% savings in kilowatt-hours per thousand square feet (kWh/ksf)before the end of the program period. This amounts to roughly 18,000,000 kWh savings each month.

While the UC Merced case revolved around the particular constraints and power of a densely populated, sophisticated web-EMCS platform, the Sysco case highlights the following themes: (1) classic enterprise-wide EIS use and information sharing; (2) limited, yet powerful, on-site use of the EIS; (3) use of EIS technology to ensure persistence in savings and energy accountability. These themes are reflected throughout the organization in typical uses of the EIS and in the ways in which the 28% energy reductions were achieved.The first 12–18 months of Sysco's efficiency program were dedicated to site visits, control tune-ups, and installation of the EIS meters and software. A combination of EIS data, expert assessments, and on-site staff insights was used to gain 18% savings from no-/low-cost measures. Over the remainder of the program a further 10% savings in total energy use were gained through capital improvements such as variable frequency drives (VFDs), lighting retrofits, and HVAC upgrades.

3.2.1Sysco EIS Uses and Challenges

Sysco performs both site-specific and portfolio analyses on a monthly basis, using Energy WorkSite's embedded reporting capabilities. Cascade Energy Engineering inputs utility billing invoices into the data warehouse, and portfolio benchmark rankings are generated as listed in Table 4. Managers coordinate monthly group reviews with each site's "energy champion," who is accountable for energy use. Monthly rankings are compared based on a metric called the *efficiency factor,* which takes into account wet bulb temperature, the total volume of frozen and refrigerated space, total and daily energy consumption, and weather predicted energy performance. While not deeply understood by energy champions and managers, the efficiency factor is a metric that was custom defined for Sysco's portfolio of refrigerated warehouses, and preconfigured within Energy WorkSite reporting options, as in Figure 12. In addition to serving as the basis for portfolio rankings, each site's efficiency factor is tracked over time as a means of ensuring accountability for performance and persistence of savings. Although the predictive algorithms that form the basis of efficiency factor are not well understood, it is understood that the metric is a unit-less number and that larger magnitudes indicate excessive use.

EIS	Performance Metrics	Data Sources	Benchmarks
NorthWrite Energy WorkSite	Unit-less efficiency factor kWh/ksf	Electric utility meter Utility invoices Weather feed	Portfolio rankings based on efficiency factor Pre-program consumption [kWh/sf]

Table 4:Sysco metrics, benchmarks, and data sources

Site	kWh	Wet-Bulb Temp	kWh / day	Total Frozen cu-ft	Total 28-55°F cu-ft	Total Dry cu-ft	Weighted Volume Cu-ft	Space Weighted Eff Factor	Weather Predicted Eff Factor	New Effiency Factor
Sygma - Denver	1,902,060	41.9	10,337	891	971			2.66	4.52	.666
Sygma - Southern California	2,587,710	48.4	14,064	920	1,142			3.01	4.76	.732
Sygma - Northern California	1,855,050	52.3	10,082	748	595			3.01	4.9	.756
Sygma - Kansas City	1,077,360	47.7	5,855	340	641			3.43	4.74	.775
Sygma - Illinois	3,558,070	46.4	19,337	1,680	1,043			3.66	4.69	.835
Sygma - Oklahoma	1,391,650	52.8	7,563	498	392			3.61	4.92	.844
Sygma - Portland	1,277,340	48.1	6,942	425	442			3.62	4.75	.863
Sygma - Detroit	1,567,380	45.2	8,518	384	407			3.32	4.65	.927
Sygma - Dallas	3,397,560	56.6	18,465	919	1,083			4	5.06	.930
Sygma - Boston	1,390,940	43.7	7,559	445	383			3.85	4.59	1.037
Sygma - Georgia	2,341,800	55.6	12,727	388	584			4.67	5.02	1.043
Sygma - Florida	3,333,500	64.5	18,117	794	824			5.09	5.35	1.110
Sygma - Carolina	2,899,140	53.7	15,756	685	592			4.86	4.95	1.111
Sygma - Pennsylvania	2,689,120	47.3	14,615	597	884			4.36	4.72	1.152
Sygma - San Antonio	5,479,980	59.7	29,783	924	936			7.43	5.17	1.532
Sygma - Columbus	5,816,070	45.3	31,609	1,006	942			7.09	4.65	1.677

Figure 12: Efficiency factor report for Sygma distribution centers

The Sysco site visit was conducted at the Stockton, California, Sygma distribution center. The visit was based on Cascade Energy Engineering's experience that the Stockton energy champion is one of the most highly engaged EIS users, with one of the higher-performing sites. Stockton ranks highly in the Sysco portfolio, and has reduced site energy 36% since the start of the efficiency program. In this case, daily use of the EIS was limited but inarguably powerful.The energy champion makes near-exclusive use of the "meter monitor" view for his most energyintensive building's utility meter. As shown in Figure 13, this view contains a two-point overlay comparing the current week's or day's kilowatt time series to that of the prior week, a summary of cumulative kilowatt-hour for both time periods, the average ambient temperature, and the percent change in consumption and temperature.

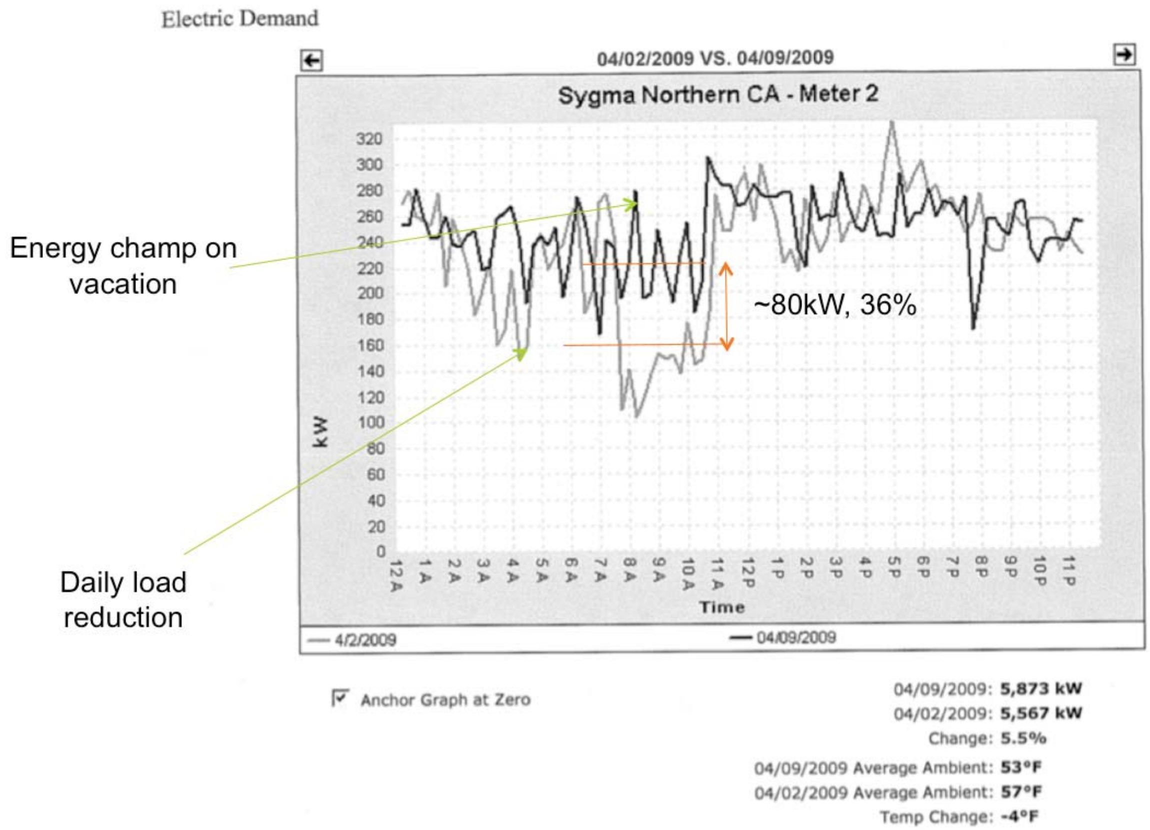

Figure 13: Energy WorkSite's "meter monitor" and the Stockton Sygma efficiency strategy

Use of the EIS to monitor the meter dedicated to refrigeration loads has allowed the energy champion to implement a powerful daily energy efficiency strategy, with datato confirm its effectiveness. The existing controls do not permit it; however, the frozen goods can tolerate fluctuations in temperature between -5°F to 10°F for short periods of time without compromising quality. In response, upon arriving in the morning, he accesses the DOS-based control programs for ten refrigerationunits via dial-up modem and manually raises the setpoints to force the compressors to shut down. Throughout the morning he monitors the temperature of the conditioned spaces and the metered power consumption, returning the setpoints to their original levels around 11 a.m. The lighter-colored trend in Figure 13 reflects an instance of this daily strategy, whereas the darker line reflects a day in which the energy champion was on vacation and the strategy was not implemented. In spite of a four-degree temperature increase, the energy champion effected an average load reduction of approximately 35% throughout the morning, relative to a day in which the strategy was not implemented.

The Stockton Sygma site contains five utility meters and accounts, and while the meter dedicated to refrigeration loads is the primary focus of EIS use, minor energy management tasks are performed with the remaining four meters. Unanticipated, unexplained spikes in consumption are plotted and shared with equipment technicians, and deviations from expected profiles are investigated and remedied. For example, the energy champion has noted instances in which loads did not decrease as expected after the final shift of the day, and based on knowledge of the building end uses was able to determine that lights were not being turned off. Staff reminderswere sufficient to correct the situation. Over time, the EIS has played an especially useful role identifying such behavioral impacts on site energy consumption, and it has served as a motivational benefit to prevent backsliding performance. The energy champion perceives that staff behavior is now well aligned with site efficiency goals.

End users of the EIS and Cascade Energy Engineering did not bring up challenges in data acquisition and quality until explicitly asked to do so during the case study interviews. Sysco monitors electric utility meters and has not pursued submetering, with the result that aside from infrequent minor glitches in cellular communications, data quality has not been a critical challenge. Timely entry of utility invoices into the EIS data warehouse is a challenging aspect of the services contract, since the provider manually inputs the billing data for storage in the central data warehouse. As a result the Stockton site relies on personal spreadsheets, forgoing Energy WorkSite's comprehensive embedded utility modules. In fact, the Stockton site visit revealed that much of the EIS functionality was unused and unexplored. It was difficult for the energy champion to navigate outside of the default meter monitor view; for example, to identify the previous year's total consumption or the previous year's peak demand.

Although NorthWrite offers on-demand training, their clients do not commonly request it, revealing one of the more compelling case study findings. The highly customized implementation of the EIS configured to meet Sysco's needs and the collaboration with expert service providers has resulted in a notion that deep diagnostics from on-site energy champions are not necessary to attain energy savings. Successful measures implemented during the initial stages of the program, accountability based on monthly reporting, and an emergent corporate culture of competition have precluded the perceived need to use the more powerful features of the EIS. It may be that refrigerated warehouses pose limited opportunities for extensive whole-building performance diagnostics, and as such present a special case for EIS. In contrast to other building types, a full 50% of the load is dedicated to refrigeration, and another 20% to lighting. At the Stockton site the EIS is most highly valued for its role in supporting and encouraging accountability and staff motivation, so that efficiency gains might persist over time.However, it is possible that additional energy savings have gone unidentified because energy champions have not seen the value in the full set of EIS capabilities. For example, what added savings could be gained at the Stockton site if the energy champion made of use of the "daily scorecard" to compare predicted to actual consumption, or to view month-long load profiles to identify historic trends? How might forecasting feature be leveraged to optimize the daily efficiency strategy that is currently based on implicit heuristic knowledge?

3.3 Wal-Mart

Wal-Mart maintains a portfolio of 67 million square feet of commercial retail space, and uses Energy ICT's EIServer to collect and monitor energy consumption data. Wal-Mart's decision to implement an EIS was motivated by an overarching business philosophy that holds that with billion dollar utility expenses, energy information limited to sixty- or ninety-day billing cycles is wholly insufficient. Wal-Mart's Energy Systems and Technology Development manager and building design engineers analogize that they would never base retail decisions on sixty-day old sales data, and that energy considerations are just as critical. Motivated by this viewpoint, Wal-Mart determined that the organization required access to real-time data at the electric submeter level, and issued a request for EIS implementation proposals in which functionality and cost were prioritized.Ultimately, EIServer was selected for the ability to forecast near-future time series using neural networks. At that time, around 2003, Wal-Mart found that competing technologies either did not provide model-based forecasting, or they were far less willing to share the details behind their specific methodology. Further, Energy ICT was willing to customize applications for Wal-Mart, and their final quotes were lower in price.

The central themes highlighted in the Wal-Mart case contrast markedly to those at Sysco. Rather than integrated EIS use throughout the enterprise to meet portfolio goals, as at Sysco, Wal-Mart is a case of "siloed" use by specific groups or individuals for a few key purposes, among various departments and teams in the enterprise. A group of internal supporters champion the use of the EIS technology and maintain a vision for how its use might be expanded throughout the organization, yet regular operational analytics are not yet widespread vertically or horizontally within the enterprise. In addition, the Wal-Mart case illustrates that even the more-sophisticated EIS may not satisfy all of an organization's analytical and energy performance monitoring needs. For uses such as measurement and verification (M&V), EIServer's embedded functionality is well suited to user needs, while for others such as portfolio benchmarking, the EIS data are exported to third-party software for analysis.

3.3.1 Wal-Mart EIS Uses and Challenges

EIServer features a custom module for M&V tasks that has been used extensively at Wal-Mart, although on an ad-hoc basis, to determine the effectiveness of energy efficiency improvements. "Project Tracking" is used at a given site or group of stores to quantify the savings associated with efficiency measures. Regression analyses establish weather-normalized baseline forecasts against which actual measured consumption data are compared. Wal-Mart does not have a dedicated M&V analysis team, although the software tool is available to any project. The wholesale power procurement and demand response group also uses the EIS intensively. This group makes considerable use of EIServer's forecasting and normalization features, with experience indicating that the technology is sufficiently accurate for week-ahead predictions, and accurate to within to within 1% for hourly time intervals.

Wal-Mart's EIS data comes from independent meters that "stand alone" from the building management systems. HVAC, lighting, and refrigeration mains are the most metered, however some stores do monitor gas and water as well. Real-time data from a subscription weather feedare imported into the EIS.Store and portfolio performance metrics are summarized in Table 5.

EIS	Performance Metrics	Data Sources	Benchmarks
Energy ICT EIServer	Weather and sales normalized kWh/sf M&V for energy saving measures	Building and submetered electric Some gas and water Subscription weather feed ICT project tracking	Portfolio rankings Pre-measure baseline

Table 5: Wal-Mart metrics, benchmarks, and data sources

At the individual store level, the EIS is used to gauge the performance of new designs, particularly at ”High Efficiency” supercenters. Beginning in 2007 four series of high-efficiency prototype designs have been constructed, targeting 20%–45% savings compared tothe typical Wal-Mart store [Wal-Mart 2009]. New stores are tracked to ensure that the design performance is met. One user reports that High Efficiency stores are best analyzed by exporting EIS data for use in Virtual Environment models, because of the ability to run computational fluid dynamics, solar thermal, and daylighting simulation modules. Due to usability constraints and the use of custom benchmark models, EIS data are also exported to for portfolio tracking. From a usability standpoint it is too cumbersome for the analyst to select trend data meter by meter, for the entire portfolio. More critically, Wal-Mart applies a custom model-based approach to calculate weather and sales-normalized energy use intensities. Each month, the benchmarking analyst identifies the twenty poorest performing sites, and refers them for further investigation at the operations and maintenance level. In some cases the benchmarking analyst delves into the data for an individual store; however, she does not rely upon the EIS normalization capability, preferring to ensure validityby comparing stores from similar climates.

Measurement and verification and benchmarking activities provide two examples of energy savings attributable to Wal-Mart’s use of the EIS. Non-functional dimming is one of the more common problems that are detected with the EIS. As shown in Figure 14, high energy consumption at a store in Texas was traced back to a 225 kW static lighting load due to a failed dimming control module. The benchmarking analyst identified the problem, corrected it, and avoided thirty-five thousand dollars of additional energy costs.Avoided waste due to failed hardware also arose in a VFD retrofit program. There, the EIS Project Tracker module was used to identify several sites in which a failed or incorrectly installed VFD prevented actual energy savings.

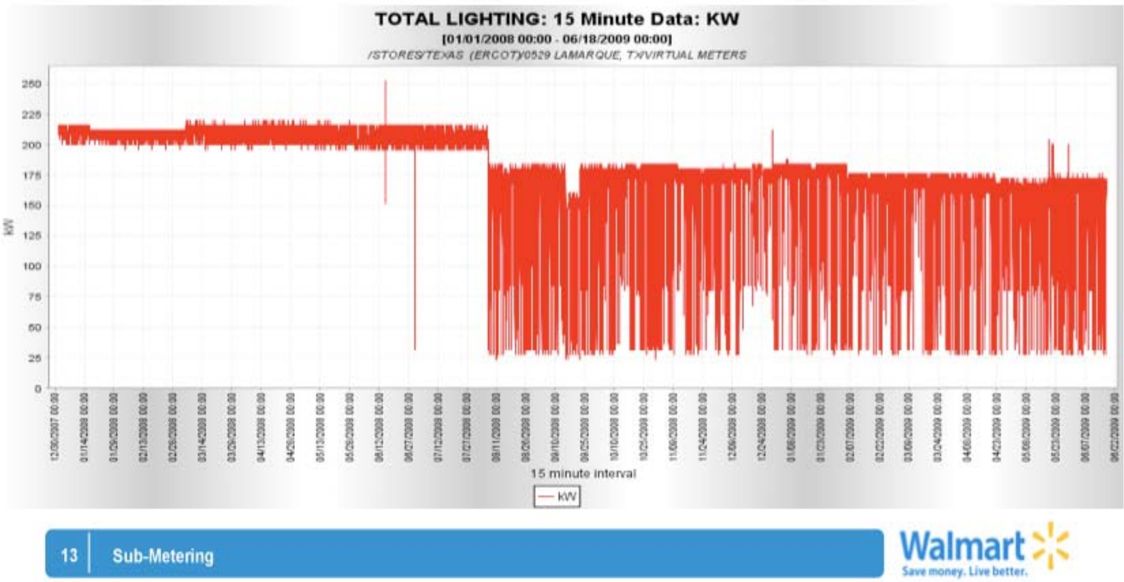

Figure 14: Non-functional dimming module at Wal-Mart identified with EIServer, and then fixed

Wal-Mart's EIS challenges are largely independent of the EIS technology itself. Submetering has been difficult because it has not been financially feasible to meter each store to the degree desired by the corporation's internal EIS champions. Given that the average supercenter contains a dozen submeters, consistency in the quality of contracted installations has also been a concern. More central to understanding real-world EIS use, Wal-Mart has faced difficulty integrating regular EIS use into standard daily activities, particularly during the current economic downturn. For example, believers in the power of the EIS technology would like to see, at a minimum, that all staff have access to the system through web-based executive reporting. Similarly, one person currently performs benchmarking tasks every thirty days, whereas the vision is to support a benchmarking group that would engage with the data on a daily basis.

3.4 UC Berkeley

The University of California at Berkeley (UC Berkeley) is a 140-year-old, 15.9 million square-foot campus with a wide diversity of building ages, types, and sizes. This accounting includes off-campus buildings and non-state buildings such as the health center. Campus energy performance has been prioritized to differing degrees throughout the last decade, and Berkeley is currently experiencing a period of renewed attention to efficiency. Following a two- to three-year gap, the campus energy management position has been re-staffed. There is no central EIS at UCBerkeley; it is a contrasting case that is included to illustrate the challenges that are encountered in the absence of a campus-wide performance monitoring system. It also provides insights as to the information needs and energy management desires of a specific energy manager, when a large, aging campus is tasked with reducing its climate impact.Although there is no campus EIS, there is a large volume of energy and system performance data. As summarized in Table 6 however, the data come from disparate sources and are used by different staff groups.

Data Sources	Number	Users, uses
Utility bills	Gas, electric	Invoicing, utilities staff
Whole-building electric meters, monthly manual reads	>200	Invoicing, utilities staff
Whole-building gas meters, monthly PGE bills	<100	Invoicing, utilities staff
Whole-building steam meters, monthly manual reads	<50	Invoicing, utilities staff
Web-accessible Obvius whole-building electric meters	20	Commissioning interventions
Prototype building performance monitoring website		
Barrington EMCS – control settings, states, equipment energy consumption	61 bldgs. 40K points	Four-person EMCS staff

Table 6: Sources of energy data and user groups at UC Berkeley

3.4.1 UC Berkeley Data Uses

The utility group uses utility bills and monthly manual meter reads to manage the purchase and billing of all campus energy. They process all invoices, and perform accounting reviews for approximately 200 utility accounts, including water, electric, gas, and steam. UCBerkeley uses an in-house DOS-based database program to store manual meter reads, which are exported to spreadsheet software for analysis. In addition to utility recharges, manual meter records are maintained to provide data for building energy analysis. Although there are not dedicated energy analysts on the energy manager's staff, from time to time the group receives external requests for building data, for example from staff who are responsible for cohorts of buildings, students conducting research projects, and developers of the campus Strategic Energy Plan.

The EMCS group at UC Berkeley uses Broadwin's WebAccess Project Manager to remotely access and oversee the campus' Barrington control systems.Fifteen to twenty servers are managed exclusively by the EMCS group to monitor sixty-one buildings, with approximately forty thousand trend points. Each day eight person hours are dedicated to building-by-building HVAC equipment checks. Beginning with the graphics screen pictured in Figure 15, appropriate on/off status and setpoints are verified. When problems are detected, the staff delves further into time-series plots of relevant trend data.

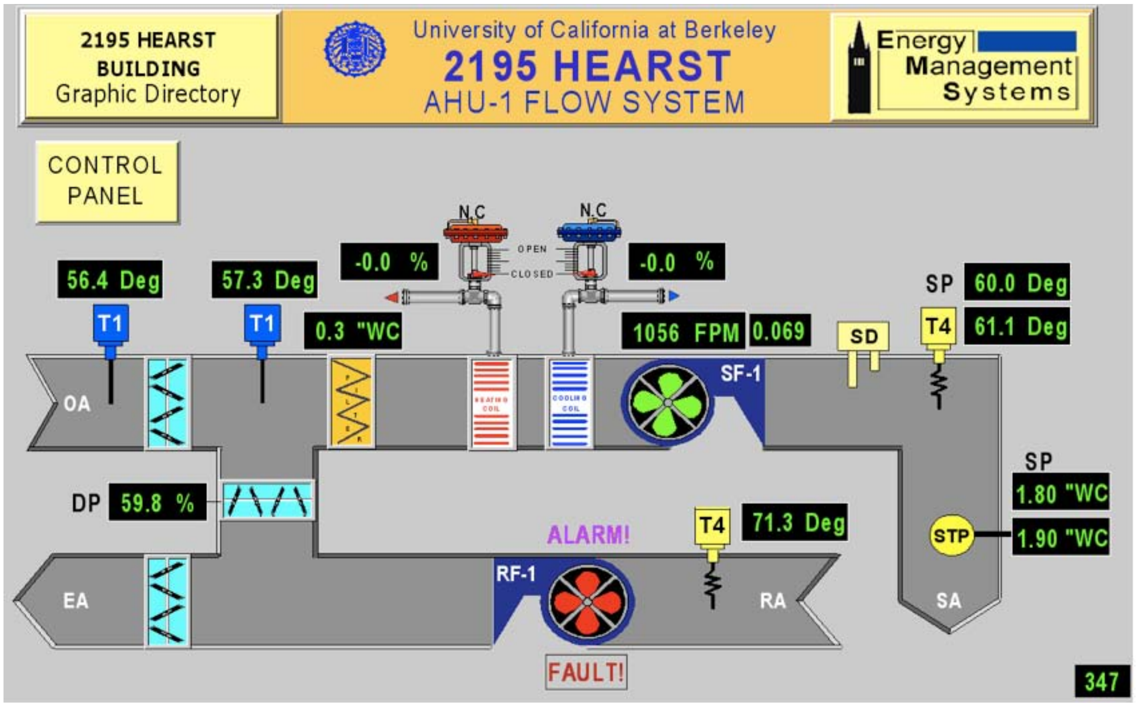

Figure 15: Air handler graphic from UC Berkeley's Broadwin Web-EMCS

A number of campus efficiency and commissioning interventions have implemented remotely accessible electric interval metering at approximately 20 buildings, totaling 11 million gross square feet. Obvius field devices acquire 15-minute pulse outputs and upload the data to an off-site data warehouse daily. Meter data can be visualized, plotted, or exported via a web application maintained by Obvius. While the data are continuously acquired and constantly available, it has been used most extensively for specific projects on short-term bases. It is worth noting that a potentially useful tool is under development in a student-funded research project that pairs Obvius meter data with monthly utility data. The *Building Energy Dashboard* includes monthly representations of energy, water, and steam, as well as real-time displays of meter data from Obvius devices. Although it is still under development and the final version may be quite different, a prototype was made accessible for the purpose of this report. Figure 16 shows a "live data plot," which contains a zoom-able representation of the most recently uploaded data from Obvius field devices; Figure 17 shows a "detailed building plot" in which this week's consumption is plotted against the previous week, with minimum maximum and average demand.

Figure 16: UC Berkeley Building Energy Dashboard prototype, "live data" view

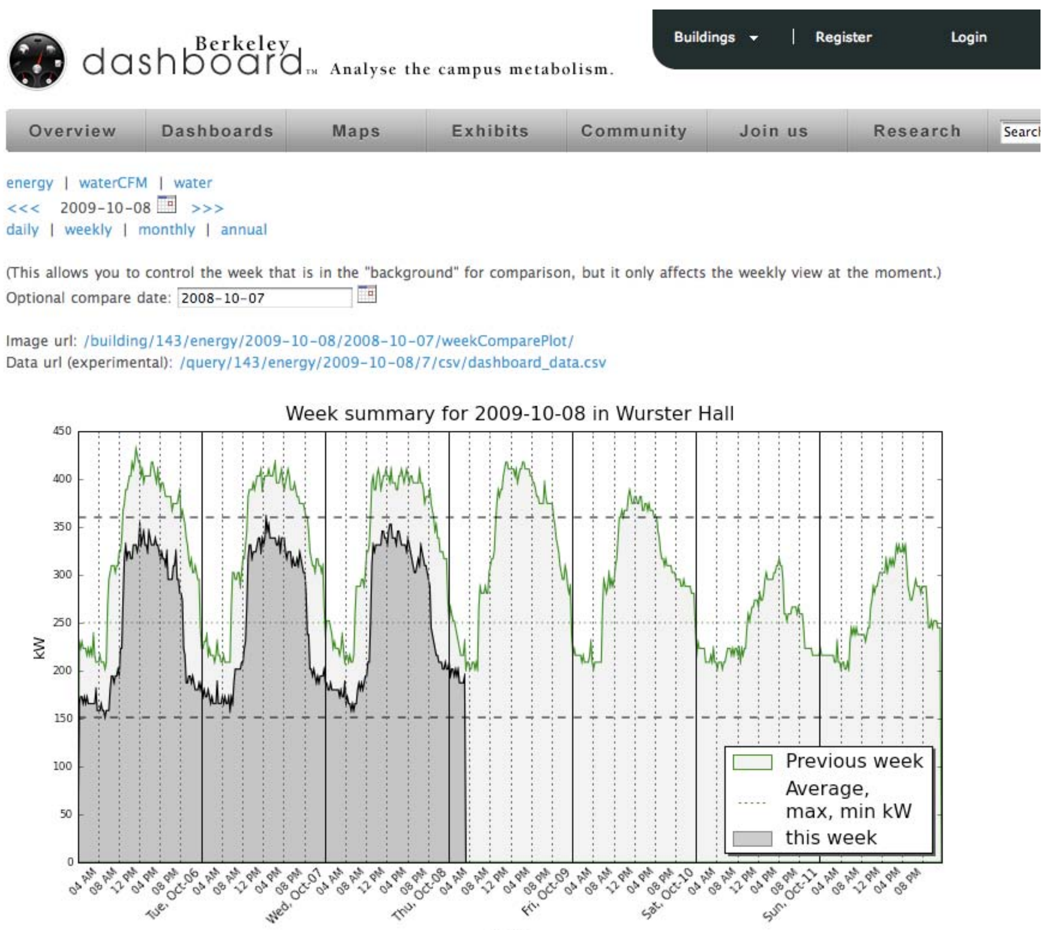

Figure 17: UC Berkeley BuildingEnergy Dashboard prototype, "detailed building plot"

The *Building Energy Dashboard* targets occupants, and it is primarily intended to inform faculty, staff, and students [Berkeley Campus Dashboard 2009]. While the software is still under development, anecdotes of student trials revealed an instance in which excessive operation of the ventilation system and over-illuminationin the architecture building were identified. Based on these observations, the ventilation schedule was reduced by six hours per day, and a lighting retrofit was conducted, resulting in a 30% reduction in total energy use.The two trends in Figure 17 show the whole-building power before and after these changes were made. Because the dashboard combines data from the utilities group with interval data that are currently used only on a limited basis, the application might be useful for the campus energy management team, as well as for building occupants.

3.4.2 UC Berkeley Energy Management Needs

Similar to the other cases in the study, resources were cited as a challenge at UC Berkeley.In particular, the energy manager prioritizes tracking performance at the building level and providing feedback to building coordinators, EMCS and HVAC staff, and technicians. The energy manager also emphasizes that continuous maintenance is a critical element of any efficiency program, noting that healthy equipment is a precursor to optimal energy performance.

Regarding energy information and data, Berkeley's energy manager identified several priorities. More remote-access interval metering, with near-real time (as opposed to daily) uploads would reduce the resources dedicated to manual meter reads and increase the resolution of existing building data.Submetering beyond the whole-building level is desired to support improved decision making related to building technology, operations, and proposed use or space changes.Finally, access-controlled public data would simplify the process of satisfying data requests from researchers and special projects. While she did not cite an EIS as an outstanding need, the manager's challenge in processing the existing data, her desire for remote-access permission-based meter data, and increased density of electric metering does imply the need for an analysis-rich EIS.

3.5 Summary of Energy Savings and Challenges

Table 7 summarizes actions that were taken based on building energy data in each of the cases studied, and where available, the associated energy impacts. The most common actions and observations that were encountered concerned incorrect implementation of scheduled loads, M&V, and inefficient or excessive operations. Table 8 summarizes the challenges, needs, and successes that were found. Note that in this respect each case truly is different, and that one case's success may represent another's challenge.

Site	Observation/Action	EIS Data Points	Energy impact
UC Merced	Excessive overnight gas use due to non-zero pressure at steam boilers	Steam plant pressure, gas	30% reduction in average daily gas use, $4,500/mo avoided costs
UC Merced	False peaks in observed chilled water demand at buildings, due to central plant operations	Building chilled water flow, supply and return temperature Central plant chilled water supply temperature	
Sysco	Lights left on after hours at Stockton Sygma	Building electricity	
Sysco	Multi-hour daily energy efficiency strategy at Stockton Sygma	Building electricity, control system setpoints and temperatures	35% demand reduction *Single observation
Sysco	Identification of low-/no-cost savings opportunities, e.g., retro-commissioning and refrigeration tune-ups	Warehouse electric meters	18% reduction in portfolio energy use 36% reduction in Stockton site energy
UC Berkeley	Excessive ventilation and over illumination identified, leading to lighting retrofit and ventilation schedule change	Whole-building electric meter	30% reduction in whole building energy use
UC Berkeley	Multi-week chiller lockout that prevented shut-down	Control system setpoints	
Wal-Mart	Static 225kW load at dimming control submeter	Submeter electricity	$35,000/yr avoided costs
Wal-Mart	Failed or disconnected VFDs used in retrofit programs		Avoided zero savings at program sites

Table 7: Summary of actions taken based on building energy information

Site	Challenges/Needs	Successes
UC Merced	Network communications – largely resolved Meter/sensor configuration, and commissioning Resources, staff, proactive use of data Commissioning the Web-EMCS as an EIS Metering aligned w/ metrics – e.g., sampling, vs. totalization	Living laboratory realization Dense instrumentation and data Meeting energy performance goals
Sysco, Stockton Sygma	Timely integration of utility data On-site knowledge and use of EIS features	Network reliability and data quality Portfolio-wide energy reductions Persistence of energy savings Accountability in energy performance Enterprise information sharing
Wal-Mart	Resources, staffing for more intensive EIS use Enterprise-wide use of EIS Portfolio benchmarking within the EIS Ensuring quality of submetering installs	EIS forecasting for DR and purchasing M&V of energy saving measures EIS for large portfolio data acquisition
UC Berkeley	Resources, staff to use energy data Central energy information system External requests for energy data Continuous maintenance	In-house EMCS IT management Utility invoicing, whole-building meters Volume of distributed building data Efficiency intervention meter monitoring

Table 8: Summary of performance monitoring challenges, needs, and successes

Chapter 4. Conclusions and Future Work

Energy information systems encompass a diverse set of technologies that are sold under an array of business models, with a complicated mix of features, architectures, and optional or required services. The sheer number and variety of options, in combination with rapidly advancing analytical and IT capabilities makes it difficult to distinguish one product from another or to understand the general state of the technology. Vendors' public domain information is typically vague, demonstration software is often not available, and vendor-documented use cases tend not to critically evaluate the technology usefulness. In response, a framework to characterize today's EIS market was developed and applied to several dozen commercial products. The framework provides common nomenclature, as well as a structured classification of existing functionality, while the evaluations permit characterization of the state of today's technology. In addition, four case studies were conducted to explore how the various features and technologies in the framework and evaluations are actually used to achieve energy savings.

4.1 EIS Characterization Framework and Technology Evaluations

The categories in the framework comprise the highest-level functions and uses of the technology, such as graphics and visualization or energy and financial analysis. They also include aspects related to purchase and implementation, such as data transmission, storage and security, and general business and licensing models. The sets of features associated with each category are based on typical capabilities as well as leading edge functions that may not yet be widely implemented, for example time-varying analysis of GHG emissions. These findings represent a snapshot of the state of the technology in a quickly changing field with frequent shifts in offerings and ownership, and they should be interpreted in this context.

The EIS product evaluationsindicated that overall, visualization, and analytical features are distinguished by the degree to which they accommodate dynamic, user-defined selections versus statically defined reporting, calculation, and plotting parameters. Rigorous energy analyses that include normalization, standards-based calculations, actionable anomaly detection, and forecasting are either more or less robustly integrated, depending on the specific product. The fact that EIS capabilities are largely distinguished by flexibility in parameter selection, dynamic versus static options, and robustness of analyses reveals the single most difficult aspect of the EIS evaluations. Although out-of-the-box capabilities were stressed as the focus of the study, vendors were quite reluctant to differentiate between embedded ”clickable” functionality and actions that the user *conceivably could* perform based on the software features. For example, one EIS might have dedicated modules specifically for M&V investigations, whereas another might report that M&V is supported through no-limit trend storage, aggregate totaling functions, and configurable arithmetic.

The following summarizes specific evaluation findings according to the different categories in the framework:

Business models (General)

- EIS are most commonly offered via application service provider (ASP) or software as a service (SaaS), with no or optional hardware based on client needs
- Optional or bundled services are nearly universal across EIS technology solutions

Display and visualization

- Supported features have converged to a near-common set, including the ability to display load profiles, point overlays, aggregation into totals, etc.
- X-y scatter plotting remains under-supported and relatively uncommon, given the potential for powerful diagnostics
- 3-D surface plotting is among the least common features

Energy analysis

- GHG analysis is a newly emergent feature in EIS; the majority apply a simple energy/carbon relationship, but just under half include knowledge of regional generation or other standards
- Nearly every EIS permits the user to quantify an energy consumption baseline, but weather-normalization is rare
- Benchmarking is widely supported, provided that a portfolio of meters is included in the historic data warehouse; only two EIS in the study used national data sets for comparison

Financial analysis

- Energy costing is supported in nearly all of the EIS, and more than half have implemented model or tariff-based calculations

Advanced analysis

- About three-quarters of the EIS handle corrupted or missing data, and do so via three principal means: flagging or summative reporting; actual cleansing and/or correction; and linking to external or third-party software packages.
- Anomaly detection is typically trend-based, and is accomplished by identifying departures from normal energy consumption patterns
- More than half of the EIS forecast near-future loads, usually by coupling historic trends and weather data; very few provide model-based capabilities
- The large majority of EIS accommodate some form of M&V or the ability to track the impact of operational changes

Demand response

- DR capabilities have advanced since early 2000 and have converged to a common set of features
- Automated response to DR signals is supported in all but three of the DR systems that were characterized.

Remote control and management

- Just over half of the EIS surveyed report the ability to control according to a program, and just under half report internet-capable direct remote control.

The EIS that supports the most features is not necessarily the most powerful solution for a given building. Identifying the most suitable EIS for a commercial implementation must begin with a purposeful consideration of the site's operational and energy goals.

Once the immediate and longer-term needs are understood, high-priority features and functionality can help narrow the options, and the most appropriate technology can be selected. For example, an organization that uses custom benchmark models to gauge performance might prioritize flexible definition of metrics and calculations over a dynamic configuration; a geographically diverse enterprise that requires proof of savings from large retrofit initiatives may require robust baselining, data cleansing, and tariff-specific energy costing. Similarly, a business with a history of energy awareness that has implemented a phased, multi-year energy plan is likely to have different needs than a business that has just begun to consider building energy performance.

4.2 EIS Case Studies

While exceptionally helpful in gaining an understanding of the state of the technology, individual product characterizations and conclusions regarding software capabilities do not answer questions of usability and real-world utilization. The case studies included in this study attempted to answer questions related to energy savings and actions attributable to EIS use, performance monitoring challenges, and successful implementation models. Because the associated findings overlap considerably, they are grouped into organizational impacts and success factors, and usability and analysis.

4.2.1 Organizational Impacts and Success Factors

The existence of data or performance monitoring software does not guarantee shared knowledge or actionable information. Enterprise-wide EIS use at Sysco has encouraged persistent savingsand a corporate culture of energy accountability, awareness, and competition. Similarly, extensive use and sharing of energy data at UC Merced has contributed to highly efficient operations and energy performance, and it has supported the realization of the living laboratory concept. On the other hand, Wal-Mart and UC Berkeley are both working toward more extensive use of data to reduce energy consumption.

Resources and staffing were a significant constraint in every case studied, and those factors clearly limit the extent to which energy data are successfully used to identify energy-saving opportunities. They also directly affect a site's ability to make meaningful use of submetered data. With the exception of Sysco, where current levels of engagement with the EIS are viewed as sufficient to meet efficiency goals, each organization expressed a strong desire to engage more with measured data in order to improve efficiency.

A common view is that EIS are primarily the domain of in-house staff, and that services are used to a minimal degree during installation and configuration. At the alternate end of the spectrum, EIS may be primarily intended for use by third-party energy service consultants and providers. However, the general prevalence of staffing constraints, Sysco's successful efficiency gains, and the number of EIS vendors that offer analytical services indicate the potential for alternate models of successful EIS use. For example, Cascade Energy Engineering is seeking opportunities for inclusion in utility energy efficiency programs, confident that careful application of engineering expertise, services, and software-based performance tracking will prove a guaranteed pathway to deep energy savings for enterprises. The varying degree to which these cases were successful in leveraging energy data emphasizes that factors such as organizational resources, commercial subsector, size, and resources have a critical impact on the most effective balance between on-site analysis and expert services.

4.2.2 Usability and Analysis

Reliable high quality-data are a critical aspect in automated analysis of building energy performance, and those data significantly affect EIS usability. At UC Merced, failure to commission the instrumentation and web-EMCS for EIS analytics has impacted the ability to track and diagnose building performance. More generally, usability at UC Merced is affected by a number of challenges specific to implementation of an intensive monitoring infrastructure and the acquisition and storage of extreme volumes of trend data. The UC Merced case shows that particular attention must be paid to wiring and hardware integration, system programming, and network communications—not all of which lies wholly in the domain of the EMCS developer. In contrast, Wal-Mart and Sysco did *not* report significant data quality issues, which is likely for two reasons: EIServer has embedded validation estimation error checking (VEE) routines, and data quality is usually a concern only in cases of submetering and energy sources other than electric.

The degree to which a site uses embedded analytical capabilities depends on the particular performance metrics and benchmarking data that are utilized. Our cases showed that the more tailor-made the calculations, the more likely it is that the data will be exported for analysis in third-party modeling or computational software. In addition, users may develop personal analyses or spreadsheets that prefer to the EIS, even when the EIS provides similar or more powerful functionality. These cases indicated that sophisticated EIS normalization and forecasting methods are not universally understood across users and technology champions. Even so, these methods are commonly used to great success, in a “black-box” manner.

Finally, although EIS offer a wide range of features, actual use of these features can be very limited, and it is not clear that users are always aware of how to use the capabilities of the technology to generate energy-saving information. As evidenced in the Sysco case, partial use of analytical features can result in very powerful outcomes; however,it is possible that further potential savings have gone undetected. In the four EIS cases that were studied, the most common energy-saving actions were related to incorrect load scheduling, M&V, and inefficient operations. The actual savings attributable to these actions are expressed in a number of ways (if at all) depending on a site’s standard performance tracking procedures and metrics. Avoided costs or energy consumption, percent reductions in component or end-use loads, reductions in portfolio consumption, and total site energy or power reductions are examples of the diverse measures that each site used to quantify EIS savings.

4.3 Future Research

Taken together, the EIS characterization framework, technology evaluations, and user cases studies have resulted in a complementary set of findings, to be extended in future research. These findings and future research needs concern four key areas:

1. Features and usability
2. Anomaly detection and physical models
3. Technology definitions and scalability
4. Successful use and deployment models

While the four case investigations generated useful insights as to the value of EIS, questions concerning the most useful features, potentially useful but underutilized features, and energy savings attributable to EIS use merit further attention. For example, a more extensive set of typical actions and associated energy savings, as well as documented records of building consumption before and after EIS implementation, would enable stronger conclusions on the range of expected savings from EIS use.In addition, typical EIS actions and associated features can be linked to a classification of standard EIS uses such as M&V for retrofit support, continuous building-level anomaly detection, or GHG emissions reporting. Specific building ownership models may also affect these standard uses, as geographically diverse enterprises likely have different organizational objectives than do medium-sizedtenanted offices or government-owned buildings.

Closely related to features and usability, there is considerable analytical potential in linking EIS anomaly detection methods to physical models. Today's EIS algorithms rely purely on empirical historic performance data to detect *abnormal* energy consumption. However, they do not provide a means to identify *excessive* energy consumption relative to the design intent, or to realize model-predictive control strategies. Standardizing the format and structure of information at the data warehouse level could encourage such advancements, as could the development of features to configure exported data files into formats that can be used by modeling tools such as Energy Plus or DOE-2. Standard formatting of EIS data would also facilitate the transfer of energy information from the building to outside entities, supporting and aligning with current developments in demand side management and the smart grid.

From a technology standpoint, definitions and scalability require further study. The question of whether a given system is or is not an EIS, is not trivial. This study defines EIS broadly, stipulating whole-building energy analyses, graphical capabilities, and web accessibility.Therefore, many technologies that were included in the study are EMCS or DR tools that are less immediately thought of as EIS, but that *can be used* as an EIS. The UC Merced case illustrated some of the challenges in using an EMCS as an EIS, indicating an outstanding research question: can an EMCS serve as a robust EIS, reliably adding whole-building energy analyses to management and control functionality? Scalability is a concern that may provide insights as to where to draw the line between EIS and related technologies. In the future it will be necessary to understand the tradeoffs between diagnostic capabilities, trend volume and number of points monitored, and the resulting burden on the system's underlying hardware and communication networks. These considerations become especially relevant as a campus or owner's portfolio of buildings grows, or as a user moves to increased levels of submetering or subsystem monitoring and analysis.

Finally, there remains much to learn about effective EIS deployment and use models within organizations. The Sysco casereveals a potentially powerful approach in which in-house use and expert services are combined. This is critical when facility managers have limited time to devote to energy analysis. Additional research is needed to better understand where this approach is most useful and to determine alternate success models that are appropriate to a diversity of organizational sizes, commercial segments, and building ownership models. Neither the EIS evaluations nor the case studies delved very deeply into the costs of EIS. Not surprisingly, vendors were very reluctant to provide price details, and the case studies were primarily focused on the use of EIS features to achieve energy savings. Future investigations into successful EIS use models will be most informative if they are able to link features, whole-building energy savings, the role of services, and EIS cost. The outcomes of the work in this report and prior researchwill provide the foundation forabroader set of case studies sponsored by the Department of Energy. They will be pursued in collaboration with the New Buildings Institute, beginning in 2010.

ACKNOWLEDGMENT

Vendor participation was critical to the success of this study, and the authors wish to acknowledge their generosity and willingness to be included in this work. This work was supported by the California Energy Commission and the California Institute for Energy and Environment under Contract No. MUC-08-04, and by the U.S. Department of Energy, under Contract No. DE-AC02-05CH11231.

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Appendix A: EIS Characterization Framework

Category	Main Feature	Feature Details	Feature Description
Data Collection, Transmission, Storage and Security	Accepted energy inputs	Electricity	Does the EIS accept metered electricity data?
		Water	Does the EIS accept metered water data?
		Hot water	Does the EIS accept metered how water data?
		Natural gas	Does the EIS accept metered natural gas data?
		Oil	Does the EIS accept metered oil data?
		Steam	Does the EIS accept metered steam data?
		Chilled water	Does the EIS accept metered chilled water data?
		Liquefied petroleum gas	Does the EIS accept metered LPG data?
		Utility billing data	Does the EIS accept utility billing data?
	Storage capacity	Months, years, memory limit, duration	What are the storage limits?
	Manual data entry		Can the user manually input the collected data (via GUI)?
	Minimum trend interval	Daily, hourly, near real-time, real-time	What is the minimum resolution of interval data?
	Upload frequency	Daily, hourly, near real-time, real-time	How often does the EIS retrieve data?
	Upload type/connectivity	Phone, cellular, internet	Does the EIS use internet or telecommunication?
	Data sources	Interval meter (building), submeter	Does the EIS provide submeter in addition to building data?
	Data transmission standards, protocols, interoperability	BACnet, LonMark, MV 90, IP, OPC	What transmission protocols or standards does the EIS use/interoperate with?
	Archived data	SQL, .net, XML, CSV, .xls	How is data archived (relational database, flat file, binary proprietary)?
	Exported data	ASCII delimited (ex. CSV, TDL), XML	What export formats are supported for archived data?
	Security	Https encryption, VPN, pgp, authentication	What security protocols/procedures does the EIS use?

Category	Main Feature	Feature Details	Feature Description
Display, Visualization	Load profile	Calendar	It is possible to display a month of time series in calendar form?
		Daily	Is it possible to display time series in hour-long intervals or less?
		Summary	Is it possible to display aggregated usage (daily, weekly)?
	Overlay	Day	Is it possible to overlay multiple days' trend on a single plot?
		Point	Is it possible to overlay multiple time series-points on a single plot?
	3-D graphics		Is it possible to generate 3-D surface plots?
	X-y plots		Can the user plot one trended data point vs. another?
	DR status		Is it possible to display whether a DR even is occurring and event/communication details?
	DR reduction		Is it possible to graphically display DR load sheds (vs. load-shape baseline)?

Category	Main Feature	Feature Details	Feature Description
Energy Analysis	Performance indicators/metrics	Averages	Does the EIS calculate hourly, daily, weekly, or monthly average consumption?
		Highs/lows	Does the EIS calculate the highest/lowest hourly, daily, or weekly consumption?
		Efficiency	Does the EIS calculate system (plant) or component (chiller) efficiencies?
		Load duration	Does the EIS calculate load duration: number of hours at a set of demand levels, usually annually
		End-use breakdown	Does the EIS estimate energy consumption by end use? (w/o submeter data)
	Normalization	Cooling degree days (CDD)	Does the EIS normalize consumption by CDD?
		Heating degree days (HDD)	Does the EIS normalize consumption by HDD?
		Outside air temperature (OAT)	Does the EIS normalize consumption by OAT?
		Square feet (sf)	Does the EIS normalize consumption by sf?
	Carbon	Standards-based, relational	Is carbon analysis standards-based (CA AB 32), or is an energy/CO_2 relationship applied?
		Time-varying intensity	Does the carbon analysis account for time-varying intensity?
	Benchmarking	Multi-site comparison	Is it possible to comparatively analyze one building's use with respect to another?
		Historical	Is it possible to analyze a building's use with respect to a historic benchmark?
		Standards-based	Does the EIS benchmarking analysis rely upon standards such as Energy Star or Labs 21?

Category	Main Feature	Feature Details	Feature Description
Advanced Analysis	Forecasting	Algorithm, trend-based, model-based, neural net	Does the EIS forecast near-future load profiles?
	Fault detection and diagnostics (FDD)		Does the EIS perform FDD?
	Data gaps/faults		Does the EIS identify corrupted data or gaps in trends?
	Statistics	Regression	Does the EIS perform regression analysis?
		Percentiles	Does the EIS calculate percentiles within a defined cohort?
		Deviation	Does the EIS calculate standard deviation and/or variance?
	Renewables	Solar, wind	Does the EIS provide analysis modules/functions for data from renewable energy sources?
	On-site	Cogeneration	Does the EIS provide analysis modules/functions for data from on-site energy generation?
	Load shape		Does the EIS identify base load, peak demand, and other (weather-based) consumption patterns?

Category	Main Feature	Feature Details	Feature Description
Financial Analysis	Simple energy cost prediction	Estimation	Does the EIS perform simple energy cost estimates?
	Model-based costing	Rate tariff, dynamic (online), or static	Does the EIS include specific rate tariffs in energy cost analyses?
	Bill and meter verification		Does the EIS compare meter readings to utility bills to validate billing and metering accuracy?
	Savings estimation		Does the EIS calculate/predict savings from retrofits, operational strategies, EIS use
	Bill outsourcing		Does the EIS transmit data sufficient to outsource bill processing/payment? (campus recharges)

Category	Main Feature	Feature Details	Feature Description
Demand Response	Automation type	Manual, semi-auto, auto	How does the system respond to DR signals - manual initiation of load-shed, or automatic based on utility signal?
	DR signal notification	Pager, e-mail, phone, fax	How is the operator notified of DR events?
	Real-time DR response		Is the load-shed quantified in real-time?
	Analyze DR		Does the product calculate energy and/or $ savings due to event response?
	Baseline		Does the product calculate a DR baseline according to a utility program formula?
	Savings		Does the product predict expected savings from a response?
	Opt-out		Can the operator choose to ignore a DR event signal?
	Black-out dates		Can the operator pre-specify dates to ignore DR signals?
	Test		Can the operator test DR events (simulate DR signals)?
	DR recording		Does the product record DR data: time received, actions performed?
Control, Management	Automated		Is the EIS capable of controlling building systems according to a program (either through gateways or EMCS)?
	Internet remote Management		Does the product offer remote control and/or management of buildings via the internet?

Category	Main Feature	Feature Details	Feature Description
General, Meta	Browser support	Internet Explorer, Mozilla Firefox, Safari	Are all three current major web browsers supported?
	Upgradeability		Are upgrade modules available (vs. full version purchases)?
	Purchase cost	Hardware	What are the associated hardware costs?
		Software	What is the product software cost?
	Ongoing costs (if any)	Software fee	What is the cost of annual or monthly licensing fees?
		System usage fee	What is the cost of annual or monthly system usage fees?
		Service and maintenance	What are the annual or monthly service and maintenance costs?
	Lifespan		What is the expected product lifespan before major upgrades are recommended?
	Target market	Commercial, industrial, school, etc…	Which market segments does the product/company traditionally target (historic versus newly targeted)?
	Intended user	Building manager, facility manager, enterprise/multi-site	Who are the intended users (most common, as opposed to all-that-apply)?
	Number of users		Approximately how many customers currently use the product?
	Company profile	System integrator, control vendor, software, energy service provider, utility	Which descriptor best characterizes the company?
	EIS product type	Software only, software and hardware	Does the product offering include hardware in addition to software?

Appendix B: EIS Technology Evaluations

This appendix contains the specific vendor evaluations that were used to inform the state of the technology findings presented in this study. The appendix comprises a spreadsheet that can be downloaded from: http://eis.lbl.gov.

All reported findings are based on vendor-supplied information at the time of the study (November 2008–April 2009). Current capabilities are subject to change, and readers are encouraged to confirm information based on their specific needs. The EIS that were selected for evaluation are representative of the market, but not comprehensive, and inclusion in the study does not imply endorsement.

Appendix C: Selected EIS Baseline Methods

Energy information systemsuse baseline energy consumption models to perform measurement and verification (M&V) or savings tracking, historic performance tracking, multi-site benchmarking, anomaly detection, and near-future load forecasting. In this context, the term *baseline* refers the typical or standard energy consumption. To ensure fair comparisons and consistency across time, climate, and buildings, baselines shouldbe normalized to account for weather, time of day or week, and other factors.

- M&V analyses compare post-measure energy consumption to the baseline. Similarly, historic performance tracking compares recent or current consumption to the baseline.
- Multi-site benchmarking is accomplished by comparing one building's appropriately normalized baseline to that of a cohort of buildings. The cohort might be other sites in a portfolio, other sites in a vendor's databases, or national or state databases such as the Commercial End Use Survey (CEUS) or Commercial Buildings Energy Consumption Survey (CBECS) or ENERGY STAR.
- Anomaly detection is accomplished by predicting would-be consumption by inputting current/recent conditions into baseline models, and then comparing the predicted and actual consumption.
- Near-future load forecasting is accomplished by inputting current/recent and forecasted conditions into baseline models.

Linear regression and non-linear estimation techniques are common approaches to quantifying baselines in EIS. The following susbsections describe these methods, and their relative strengths and weaknesses. Linear regression pairs historic energy trends and weather data to determine a functional relationship between the two. In regression models, explanatory variables (e.g., humidity, air temperature and day of week) are used to determine the value of the dependent variable (e.g., demand). Baseline models differ according to:

- the number of explanatory variables included
- the resolution of weather data , e.g. daily high, or hourly air temperature
- the resolution of the baseline, e.g. daily peak, or hourly peak demand
- the goodness of fit between the model and the data

Three non-linear estimation techniques that were evaluated in the study are used in the EIS. Energy WorkSite uses a bin methodology, Pulse Energy uses weighted averaging, and EIServer uses neural networks.

Bin method used in Energy WorkSite

The bin method predicts the energy consumption at a given time to be equal to the average consumption at times when conditions were similar. To understand the bin method, consider the case in which air temperature, relative humidity, and time of week are the explanatory variables and are used to estimate energy. The three-dimensional space of explanatory variables is ”binned,” or broken into mutually exclusive volumes. For example, temperature might be binned into five-degree intervals, time of week into weekend and weekday, and relative humidity into five percent intervals. Energy consumption data are placed into the appropriate bins, as in Figure 1.

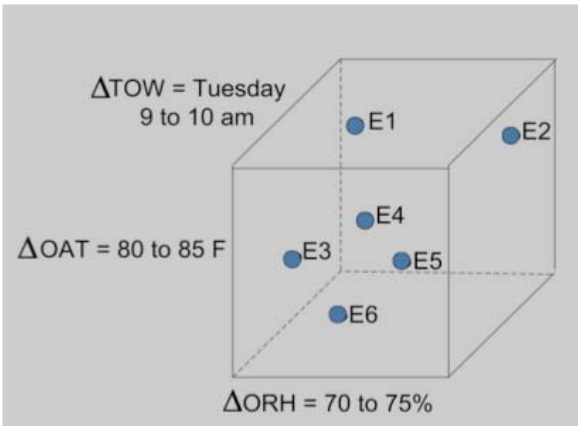

Figure 1. Energy Worksite bin methodology[13]

Once the bins are sufficiently populated with historic data, the explanatory variables are used to identify which bin corresponds to the current conditions. The predicted energy consumption for the current conditions is then taken as the average consumption across the historic data in the bin. The bin method has proven effective in building energy analysis, as well as component systems, but it breaks down as the number of explanatory variables grows: beyond 3–5 variables, the number of bins becomes too large.[14] With a very large number of bins, the current state of the system will often correspond to an empty bin, or one with few data points, and in these cases averaging the energy consumption of the points that are in the bin will often not yield good predictions. For example, there may never have been a previous period in which, at 10:30 a.m. on a Tuesday morning in summer, the outdoor temperature was between 75°F and 80°F, the relative humidity was between 55% and 60%, the sky was cloudy, and the wind was strong from the south.

Advantages of the bin approach are that it is simple to explain and understand, and it works well when only a few input variables are important. Disadvantages are that the approach can only handle a small number of input variables, and that bin models may be unable to predict, or may provide inaccurate predictions for conditions that have occurred rarely or never before. Also, some bin implementations use fixed bin boundaries; in these cases there can be problems when current conditions are closely aligned to bin boundaries, e.g., if outdoor air temperature is 84.9 °F and bins are defined

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[13] Image from Energy Expert: A Technical Basis, available from http://www.myworksite.com/energyworksiteMBS/htmlArea/files/documents/244_eetechdesc.pdf.

[14] Energy Expert: A Technical Basis, p.5

by 80–85 °F and 85–90 °F. (Energy Worksite's implementation does not have this problem: it dynamically redefines bin boundaries so that current conditions are always in the middle of the bin).

Pulse Energy

The method used by Pulse Energy applies the same basic principle as the bin method: the predicted energy consumption is the average consumption during similar periods. The method creates a metric to describe the degree of similarity between the current conditions and similar conditions at other times. It then takes a weighted average of the energy performance at these similar times to determine the predicted Typical Performance for the current time. The weights used in calculating the average depend on the degree of similarity, with highly similar conditions receiving a high weight. Pulse uses a proprietary patent-pending method to define the metric that quantifies the degree of similarity between current conditions and conditions in the database. This metric can be building-specific. For example, if for a particular building, wind speed turns out to be unusually highly correlated with energy consumption, the metric for this building will be more sensitive to wind speed than it is in other buildings.

As with bin-based methods, a method based on a weighted average of values during similar conditions can suffer if the current conditions have rarely or never been encountered before. However, the predictions are bounded by the lowest and highest values that have been historically recorded so the predicted values will always be physically possible values, which is not true for some other methods. Pulse Energy developers are working on extrapolation methods to be able to make predictions for conditions that have not occurred before.

Advantages of the Pulse Energy approach are that the basic principle is easy to understand, and that there is no limit on the number of input variables that can be used effectively. In contrast to bin methods, the Pulse Energy approach allows input variables to be differently weighted, potentially improving accuracy. Similar to bin methods, a disadvantage of the approach is that it may provide poor predictions for conditions that have rarely or never occurred before.

Neural Network method used inEIServer

Artificial neural networks are so named because they simulate some of the behavior of neurons in the central nervous system. Input variables such as outdoor temperature and humidity are mathematically processed to create a potentially large number of secondary, or "hidden," values. These hidden values are then processed to generate a (usually small) number of output values, such as predicted energy consumption (see Figure 2.) The mathematical functions that process the input values and the hidden values have adjustable parameters known as *weights,* so that the effect of every input value on every hidden value is adjustable, as is the effect of every hidden value on every output value. Neural networks "learn" by adjusting the weights so that the outputs are as close as possible to their desired values, for a large set of "training" data. For example, data from several weeks or months of building operation can be used to train the network to predict energy consumption, given input data such as temperature, humidity, and time of day.

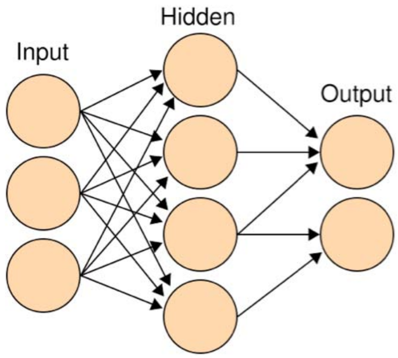

Figure 2: Graphical representation of a neural network[15]

EIServer beings with a simple model, adding additional input variables only if the network generates inaccurate outputs. Once the initial training is complete, the system can perform energy forecasts. EIServer features a built-in scheduling system to retrain the model occasionally as more data become available. Neural networks have the advantage of being able to handle a large number of input variables, and the large number of automatically adjusted parameters can provide accurate predictions. However, the concept is difficult to understand, and if the network behaves poorly even experts can be challenged in identifying improvements. Finally they may not perform well for conditions that differ greatly from those in the "training set."

Outstanding questions

Each of the three systems discussed above has advantages and disadvantages compared to the others. Unfortunately we do not have enough information to judge which system or systems work best, and it is even possible that some methods will work well in some buildings and poorly in others. As far as we know, there has never been a comparison of how the different approaches work in the same set of buildings.

All of the methods discussed above may make poor predictions when conditions differ substantially from those in their database, which can be a problem for periods on the order of one year after the system begins operating: all of the systems need to accumulate at least a few weeks of data in the cooling season and the heating season, and may still have problems making accurate predictions when conditions are extreme (such as the coldest or hottest weeks of the year, the most humid week of the year, and the cloudiest week of the year). Some of the methods may perform better than others when conditions are outside those in the historical data, but we are not aware of any studies that have investigated this issue.

Many systems for estimating baseline energy consumption or for recognizing anomalous behavior can fail to recognize a slow creep or shift in use, in which at any given moment the energy consumption is not greatly different from normal, but over time the

[15] Image from: http://en.wikipedia.org/wiki/File:Artificial_neural_network.svg

consumption creeps up or down. Since the systems continue to incorporate new data as they become available, the baseline can slowly shift with time, without any particular data point appearing anomalous. Some of the EIS provide approaches to recognizing or quantifying this issue, for example by comparing predictions using the system's current model to the predictions that would have been generated using last year's model. The effectiveness of these approaches is not known.

Appendix D: UC Merced EIS Case Study Narrative

1.0 Case Background and Introduction

Opened in 2005, UC Merced is the newest University of California campus. Prior to opening, the campus made a strong commitment to energy-efficient building design, and energy plays a fundamental role in campus objectives targeting environmental stewardship and high-quality, affordable instruction, research, and employee working environments. At UC Merced, campus efficiency requirements have been developed to:[16]

- reduce operating costs toward minimizing life-cycle cost of campus facilities,
- achieve maximum subsidies for energy efficiency,
- contribute as many points as practical to facility LEED™ ratings,
- minimize infrastructure costs,
- minimize impact of the campus on the environment and on the energy infrastructure, and
- maintain high-quality energy services in campus facilities.

Campus energy activities focus on three areas:[17]

- **Building energy performance targets,** to ensure that new buildings are significantly more efficient than required by code or compared to other university buildings in California.
- **Ongoing monitoring of energy use,** to facilitate continuous improvement in campus operational efficiency and design, as well as serve as a primary component of UC Merced's "living laboratory" for the study of engineering and resource conservation.
- **Climate neutrality,** to pursue use of renewable energy resources and other strategies to reduce and offset greenhouse gas emissions with an eventual goal of climate neutrality.

In support of these efficiency requirements and three focal activity areas, standardization of the campus control systems was made to be a priority during design/construction, and the campus control was bid as a full package. This is in contrast to many UC campuses in which building controls are bid on an individual basis, and it is common to encounter a diversity of solutions. Automated Logic Corporation's WebCTRL was selected, largely for the internet/intranet connectivity and control capabilities. The UC Merced staff and the engineering company both found it especially useful to log in to the system remotely throughout the campus design and commissioning processas new buildings were constructed and opened for full-time use.

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[16] UC Merced, http://administration.ucmerced.edu/environmental-sustainability/energy

[17] Ibid.

1.1 Installation and Configuration

Because UC Merced was newly constructed, integration with existing systems was not an issue, as is often the case when an EIS is purchased. Automated Logic distributors are responsible for system installation, configuration, programming control sequences, and desired monitoring points. In addition, UC Merced holds a small ongoing maintenance contract with their distributor.

2.0 Energy Savings and web-EMCS Use

Approximately twenty people use the WebCTRL system at UC Merced, including:

- central plant operators,
- HVAC technicians,
- building superintendents,
- the campus energy manager, and
- electricians, on occasion.

In addition, twenty internal and external researchers use the software for building energy research projects. Relative to other professional and technical software applications, UCMerced WebCTRL users have found the system easy to learn and to use. For example, in contrast to the maintenance management software, the campus energy manager does not feel that there are capabilities that he does not understand or not know how to use. Only 2–3 other users at Merced understand the system at the same level of detail as the energy manager, however that is more an artifact of job structuring and responsibilities than of usability.

2.1 Specific Web-EMCS uses

At UC Merced WebCTRL is most extensively used as a troubleshooting tool in response to trouble calls. During the initial year of operation, problems involving the reliability of the air handler units (AHUs) arose 2–3 times a week. The AHUs would commonly trip off, causing a severe rise in buildings and IT room temperatures. The facilities staff and energy manager found that the only way to consistently solve the problems was to build up diagnostic trends that would permit identification of the source.

In addition to troubleshooting problems that have already been brought to attention, WebCTRL is also regularly used to verify that the individual buildings are operating as expected. Roughly 10 multiple-trend ”operational plots” were defined, for example, for the hot and chilled water bridges, AHUs, and a representative array of individual zones. Figure 1 contains an example of the AHU plot, including trends for supply air temperature and setpoint, outside and return air temperatures, damper and valve positions, supply and return VFD power, and other factors.

Figure 1: Diagnostic AHU trends

The central plant operators have begun performing hourly reviews of WebCTRL trends according to a defined check-sheet, and the reviews are documented and commented. This process was implemented as a structured way for the operators to be able to leverage the tool and be more proactive. The campus energy manager views this as their first successful step in moving beyond reactive use of the EIS which is limited to responding to trouble calls and alarms.

On a monthly basis WebCTRL meter data are used to determine utility recharges. Twelve-month snapshots are also compiled for annual analyses of campus and building-level energy performance with respect to California campus benchmarks. These include hot water, chilled water, electricity, and gas. In addition laboratory $/cfm (cubic feet per minute) and cooling plant $/ton are calculated on annual bases. Finally, WebCTRL data are used on an as-needed basis, to generate diagnostic variable air volume (VAV) summaries in the form of trends or reports. For example, there has been some difficulty keeping the dining facilities warm in the winter. In response, the energy manager used a summative report of every VAV in the space in combination with trends of temperatures and flows relative to setpoints, to characterize the number of zones not meeting setpoint. From that knowledge he was able to isolate problem areas to be serviced by technicians. These reports and plots are shown in Figures 2-4 below.

VAV Summary Report

Location: University of California / Merced Campus / Kolligian Library: 0201 / HVAC: 0201 Run Date: 10/28/2008 2:24:22 PM

Name	Zone Temp	Htg Setpoint	Clg Setpoint	Setpt Adj	Air Flow	Airflow Stpt	% of Flow Setpoint	Cool Req	Heat Req	HW Valve	CO2 Lev
VAV-130 MDF	73.8	65.0	74.0		440.0	410.0	107.3	0.0	0.0		
VAV-122 MDF M1-2	81.6	63.0	72.0		1,480.0	1,500.0	98.7	3.0	0.0		
VAV-131 U1-2,3	72.0	72.0	76.0		530.0	520.0	101.9	0.0	0.0	52.0	
VAV-101 RM-101	72.1	72.0	76.0		280.0	300.0	93.3	0.0	0.0	0.0	
VAV-102 RM-107A,B,E	73.4	74.0	78.0		70.0	60.0	116.7	0.0	1.0		
VAV-103 RM-107,C,D	73.4	72.0	76.0		120.0	100.0	120.0	0.0	0.0	0.0	
VAV-104 RM-108	72.0	68.0	72.0		1,550.0	1,600.0	96.9	1.0	0.0		
VAV-105 RM-108	72.8	68.0	72.0		950.0	1,000.0	95.0	1.0	0.0	0.0	
VAV-106 RM-106A	71.2	71.0	74.0		100.0	100.0	100.0	0.0	0.0		
VAV-107 RM-106B	72.3	69.0	73.0		100.0	100.0	100.0	0.0	0.0	0.0	737.0
VAV-108 RM 108-D,E	71.0	68.0	71.0		130.0	130.0	100.0	0.0	0.0		
VAV-109 RM-109	72.3	70.0	74.0		220.0	230.0	95.7	0.0	0.0	0.0	
VAV-110 RM-113	69.1	67.0	73.0		30.0	60.0	50.0	0.0	0.0	0.0	
VAV-111 RM-117	70.9	69.0	73.0		20.0	20.0	100.0	0.0	0.0	0.0	619.7
VAV-112 RM-119	72.4	72.0	76.0		0.0	40.0	0.0	0.0	0.0	0.0	807.3
VAV-113 RM-122	75.9	71.0	75.0		1,410.0	1,500.0	94.0	1.0	0.0	0.0	
VAV-114 RM-122	72.5	70.0	74.0		180.0	290.0	62.1	0.0	0.0	0.0	
VAV-115 RM-122A	71.8	70.0	73.0		100.0	100.0	100.0	0.0	0.0		
VAV-116 RM-122B	73.5	70.0	74.0		120.0	110.0	109.1	0.0	0.0	0.0	666.6
VAV-117 RM-122C,D,E,F	73.5	70.0	74.0		90.0	100.0	90.0	0.0	0.0		
VAV-118 RM-122G	73.6	72.0	79.0		120.0	120.0	100.0	0.0	0.0		

Page 1 of 10

Figure 2: Diagnostic VAV summary report

Figure 3: Diagnostic trends of VAV zone temperatures

Figure 4: Diagnostic trends of VAV zone flows

UC Merced was designed for low energy use and energy-efficient performance. Manual diagnostics based on EMCS data have been used to manage energy use over time as the campus grows. For example, actual operating data from the EMCS were used to verify that campus energy performance has in fact exceeded ambitious targets. For the 2007–2008 fiscal year, UC Merced used only 48%–73% percent of the energy used at other campuses. That is, it was operated 27%–52% more efficiently than average.

	Performance vs. Benchmark
Peak Electric Demand*	48%–63%
Annual Electric Use	68% source, 69% site
Annual Gas Use	73%

*With and without use of the Thermal Energy Storage system

Table 1: UC Merced campus energy performance, 2007/2008 fiscal year

2.2 Data quality

Data quality issues arise in a number of contexts at UC Merced, further challenging the use of the EMCS for automated analyses.Networking and connectivity problems have led to dropped or miscommunicated values that generate errors, lock out equipment, and cause large volumes of false data and cascading false alarms. This has been a significant problem in using and maintaining WebCTRL at UC Merced; however, network communications are viewed as affecting operations more than energy monitoring, and over time many of these challenges have been addressed.

While not attributable to the capabilities of the EMCS, meter or sensor calibration and configuration errors also affect data quality, thereby affecting the ability to use the EMCS as an EIS. With the exception of whole-building electric data, significant resources were required to manually validate the EMCS data quality and to quantify the campus energy performance relative to benchmark. Manual validation included inspections to trace the physical meter point to its representation in WebCTRL, as well as energy and mass balances to confirm accuracy of logged data and interpolation or estimation of missing data. To date, manual validation has affected building science researchers more than WebCTRL users at UC Merced, but it does have implications for advanced use of the data within the living laboratory context.

2.3 Future web-EMCS use

Looking to the future, there are several measures that the energy manager would like to implement. Currently the data are in the form of single-point samples acquired every 15 minutes, however the energy manager would also like to make use of 15-minute averages to more accurately reflect standard monitoring protocols. Similarly, in an effort to reduce the volume of data to be processed, he would like to identify the minimum sampling frequency necessary to accurately reflect the energy parameters that are continuously tracked. The energy manager would also like to enhance the operational plots and fully integrate them into the daily routines of the HVAC technicians. The ability to review a standard set of plots and data each time there is a problem has proved to be a valuable time saver, but it is not yet a habit.

The metrics that quantify energy performance with respect to benchmark are currently calculated annually, by exporting WebCTRL data to third-party software for computation. Ideally, these metrics would be calculated directly within WebCTRL. For instance, building-level metrics could be combined with a range of Central Plant efficiencies (actual vs. best-practice) and a basic annual load shape. This would make it possible to determine for example, if three months into the year the campus was on-track to meet the annual performance targets. The energy manager expects that these calculations can be defined using the WebCTRL's logic, but that actually programming the logical sequences will require the expertise of the distributor.

In addition to enhanced metrics and calculations and performance tracking, the energy manager would like to delve further into the building electrical submeters to better understand building end uses, and to inform and justify proposed changes. For example, the exterior zones of the library and science buildings currently feature banks of lights that are switched on/off according to daylight, in addition to scheduled on/off operation. The energy manager reports significant hassle with the setup and maintenance of such controls, and suspects that increased personal control options combined with vacancy sensing may be more effective and more efficient. Regular tracking of end use data, which is currently acquired and stored but configured for display, would permit quantitative comparison of different conditioning strategies.

In addition to facilities staff, the energy manager would like to make end-use data available to building occupants. In the summer of 2008 the campus participated in a single-day manual demand response event that relied in part on building occupants to reduce their electric demand. The most valuable result of that event, beyond the savings that were achieved, was that the campus community became engaged and began to think about building energy in new ways and ask questions of facilities. As a result, the energy manager has expressed interest in making the WebCTRL data publically available so that during the next event occupants can view the load reductions in real-time and assist in participation at their building. Analogously, there is a desire to use WebCTRL data for a newly constructed 1-megawatt solar panel, in combination with a front-end panel graphical user interface to encourage public awareness and engagement with efficiency measures.

3.0 Usability and Enhancement

Overall, UC Merced WebCTRL users are quite satisfied with the system's plotting and graphical capabilities. In contrast to some tools such as Excel, WebCTRL offers a simple, clean way to graph and zoom in and out over very large sets of data. However, it was noted that it would be useful to have an easy way to run basic statistical analyses (un-accommodated in logical programming blocks) and identify gaps in historic trend logs.

There are no embedded features in the software that are unused at UC Merced or considered superfluous by the facilities' end users. There are however, features that are not included that would be very useful for enhanced energy analysis and performance monitoring. The ability to create x-y scatter plots was highlighted as the single-most useful, yet absent, feature in WebCTRL. The University of California at Merced has experienced significant seasonal difficulty in tuning nested proportional-integral-derivative (PID) control loops, and x-y capability would permit visual and numerical troubleshooting that is not possible today. Expanded data analysis options would also be useful; there are limits to the calculations that can be automated via logic, such as identification, filtering, or interpolation of gappy meter data.

At UC Merced, the energy manager did not have decision-making power over what type of performance monitoring to use, because WebCTRL was pre-selected as the campus-wide operational and control tool. Despite not being involved in the selection, the energy manager feels that the overwhelming majority of analytical and operational tasks he would like to implement are easily accommodated within WebCTRL. Furthermore, WebCTRL's capabilities have been instrumental in complementing the realization of UC Merced as a ***living laboratory***.

Early in the design process, campus stakeholders opted to heavily instrument the campus to support the link between research, instruction, and facilities operations. This concept is very highly valued by the energy manager, who asserts that every academic institution should support such connections. WebCTRL data have been used to facilitate several conversations between facilities and faculty in the department of Engineering, resulting in research proposals to the California Energy Commission, a thermodynamics curriculum that includes a module to quantify the performance of the chilling plant, student employment or project work, and collaborative research projects with the U.S. Department of Energy and Lawrence Berkeley National Laboratory.

3.1 General EIS Perspectives

Regarding general perspectives independent of vendor-specific solutions, the energy manager at UC Merced has a strong preference for multi-option, user-configurable designs over pre-configuredquick-access displays of the variety commonly see in information ”dashboards.” In terms of specific features, the energy manager believes that carbon tracking and alignment with benchmarking and other standards will be of increased importance in the future, though especially challenging due to the need to anticipate how people will use software to comply with reporting requirements. It was noted that the campus reports to the California Climate Registry are based on monthly utility bills, but that it would be ideal to use WebCTRL data to automate the reporting process. Data quality, filtering, and fault detection were also highlighted as critical features that will remain critical to any EIS, meriting increased levels of sophistication.

Understandably, the features and capabilities of a single EIS are not likely to support each and every diagnostic or analytical procedure that especially engaged operators and managers may wish to conduct. Ultimately, it may be necessary to export data to third-party software with more robust graphical and visualization or data processing and manipulation capabilities. At UC Merced, the preference is to rely upon a single system in spite of its inherent constraints, rather than attempting to leverage the capabilities of a suite of software tools. For example, Pacific Gas and Electric’s Universal Translator offers a convenient means to synchronize, filter, and analyze data from loggers and energy management systems,[18] and it could prove quite valuable to UC Merced, given the history of non-uniform sampling configurations and data corruption. Ultimately however, the prospect of adding another step to the WebCTRL-based monitoring procedures outweighed the potential advantages. Moreover, Web-CTRL has recently developed an integrated plotting and visualization module that is expected to enhance use of the EMCS for monitoring purposes.

In terms of powerful features that are not accommodated in contemporary EIS, UC Merced would benefit most significantly from embedded functionality to link performance analysis and maintenance. The energy manager emphasized that rather than deeper analysis he would like to see current analytical capabilities merged with knowledge of operations. At UC Merced, efficiency is not perceived as a stand-alone goal in and of itself, but rather as an aspect of an ongoing need to ensure that the

[18] http://www.pge.com/mybusiness/edusafety/training/pec/toolbox/tll/software.shtml

campus operates and performs as it should. Therefore the energy manager believes that the EIS should enable facilities to conduct decision-making that will protect the campus efficiency investment. For example, reports would indicate when a technician should be dispatched in order to maximize system performance and minimize costs. That is, what should be done today to improve tomorrow's performance? It is important to note that the energy manager believes that this absence of EIS capability is rooted in a lack of understanding within the industry, rather than in software development challenges. Finally, although less critical, the ability to better detail IT capacity and energy demands to equipment performance and long-term growth planning would also be of great use to enterprises or campuses such as UC Merced.

Appendix E: Sysco EIS Case Study Narrative

1.0 Case Background and Introduction

Sysco has implemented a corporate-wide energy efficiency program that targets a 25% reduction in energy consumption across a portfolio of over one hundred distribution centers in the United States and Canada. Two-and-a-half years into the three-year program Sysco has exceeded its goal, achieving 28% energy savings. Sysco has a long-standing energy services contract with Cascade Energy Engineering, but did not make use of an EIS prior to beginning the efficiency program. When the energy targets were determined, a three-part approach was adopted in collaboration with Cascade Energy Engineering: (1) site visits by expert refrigeration engineers and technicians to perform tune-ups and identify low/no cost energy-saving measures,(2) implementation of an EIS to accommodate Sysco's performance monitoring need and energy savings goals, and (3) continuous communication and collaboration between corporate managers, Cascade Energy Engineering, and on-site "energy champions."

The first 12–18 months of the program were dedicated to site visits, tune-ups, and installation of the EIS meters and software. A combination of EIS data, expert assessments, and on-site staff insights was used to gain 18% savings from no-/low-cost measures. Over the remainder of the program period, a further 10% savings were gained through capital improvements such as variable-speed drives, lighting retrofits, and HVAC upgrades. In addition, Sysco experienced significant growth over the program period and was able to successfully apply energy-saving recommendations to new facilities. Throughout the enterprise, the performance tracking metric is daily savings per thousand square feet. Current monthly savings with respect to the program baseline amount to nearly 18,000,000 kWh. The success of the initial three-year energy efficiency program has encouraged adoption of a second phase in which underperforming sites will form the focus to achieve enterprise savings of 30%–35%.

Sysco uses NorthWrite's Energy WorkSite EIS, and it serves as an interesting example of an EIS that was at least in part developed to support the specific needs of a large client with a complementary vision of EIS technology, use, and design. With the exception of the Energy Expert module, key configurations in reporting, benchmarking, and utility billing utility modules were defined based on the needs of the Sysco efficiency project. In addition to a willingness to collaboratively define the EIS information content, look, and feel, the NorthWrite system was selected for usability and relatively low cost. While it did not perform an extensive screening process, Cascade was able to determine that relative to competing technologies, NorthWrite was intuitive, learnable, and presented a sufficient but not overwhelming number of configurations and user-selected options.

1.1 Installation and Configuration

Interoperability between the EIS and preexisting systems and controls was not a notable challenge in the case of the Sysco implementation. This was largely due to the nature of refrigerated warehouse energy consumption and Sysco's specific program needs. Gas is not a significant portion of total energy use, and with approximately 50% of energy consumption devoted to refrigeration, and 20% to lighting, even minor operational changes are reflected in whole-building electric meters. Because most Sysco warehouse sites contain multiple utility meters but do not feature submetering beyond the whole-building level, the monitoring aspect of the efficiency program did not require extensive integration with existing control systems or equipment-level metering. Several sites expressed interest in NorthWrite's ability to integrate submetering, but ultimately they were unable to justify the additional associated costs. Across the enterprise, 15-minute interval pulse outputs are uploaded to the NorthWrite central data server via cellular communication.

2.0 Energy Savings and EIS Use

The NorthWrite EIS is used throughout the Sysco organization. The energy champion at each site interacts with the EIS to varying degrees, depending on individual work styles and site-specific operational concerns. Additionally, site energy champions attend monthly meetings to discuss their site ranking relative to others in the portfolio and to share successes and ensure accountability. At the executive level, monthly reports that aggregate site performance into portfolio savings are regularly reviewed.

Sysco's Northern California Stockton SYGMA affiliate was studied for this case, including a site visit and interview with the energy champion. Typically, the energy champion is the only staff member that regularly uses the EIS, as is the case at the Stockton distribution center. The title of "energy champion" is not a dedicated assignment, but rather a responsibility that is assumed in addition to the traditional aspects of their role in the organization. In Stockton, and throughout the enterprise, Sysco's contract with Cascade Energy Engineering precluded significant involvement of on-site staff in the identification of reporting options, trend resolution, tracked performance metrics, and other configurable options within the software.

2.1 Specific EIS Uses

The Stockton site was selected for this case study because of the reported degree to which the energy champion engages with the EIS, and because of his energy performance relative to his peers in the organization. Stockton ranks highly in the Sysco portfolio, and it has reduced site energy 36% since the start of the efficiency program. The energy champion makes extensive daily use of the "meter monitor" view that contains a two-point overlay comparing the current week's or day's kilowatt time series to that of the prior week. In addition to time series overlays this view contains a summary of cumulative kilowatt-hours for both time periods, the average ambient temperature, and the percent change in consumption and temperature between the two overlaid time periods. This view is illustrated below in Figure 1.

The Stockton Sygma site contains five utility meters, and while the meter dedicated to refrigeration loads is the primary focus of EIS use, minor energy management tasks are performed with the remaining meters. Unanticipated or unexplained spikes in consumption are plotted and shared with equipment technicians, and deviations from expected profiles are investigated and remedied. For example, the energy champion has noted instances in which the lights were not shut off following the last shift of the day, and has responded with staff reminders. Over time, the EIS has played an especially useful role identifying such behavioral impacts on site energy consumption, and has served as a motivational benefit to prevent backsliding performance. The energy champion perceives that have staff behavior is now well aligned with site efficiency goals.

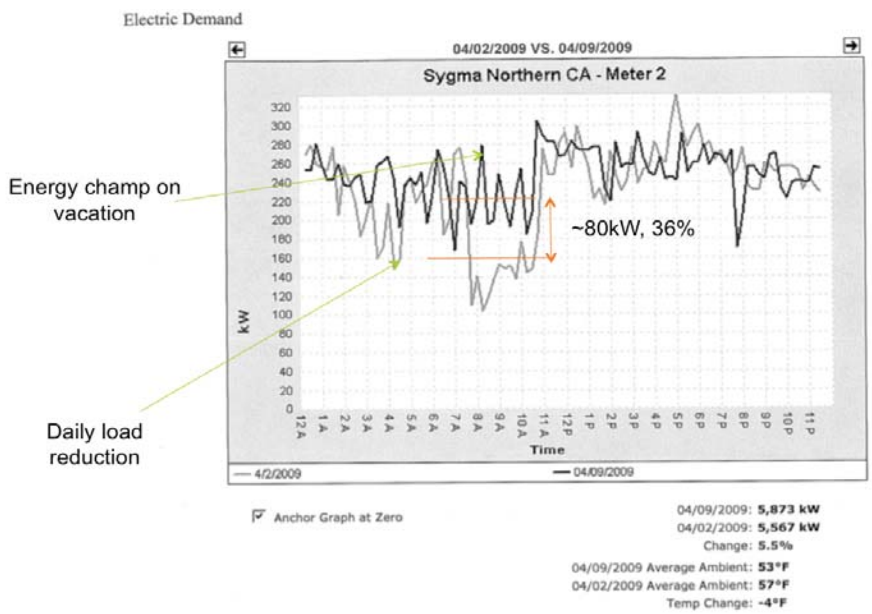

Figure 1: NorthWrite meter monitor and Stockton Sygma daily efficiency strategy

In addition to the analyses embedded in the meter monitor, which are utilized daily, several analyses are performed in monthly reporting runs. Cascade Energy Engineering inputs utility billing invoices into the data warehouse, and monthly reports are used to generate portfolio benchmark rankings. Within the network of SYGMA affiliates, the Ohio-based project manager coordinates monthly group reviews with each site's energy champion. Each energy champion's access is limited to their own site; however, executive level staff have portfolio-wide account permissions. Comparative benchmark rankings are based on a metric called the *efficiency factor,* which takes into account wet bulb temperature, the total volume of frozen and refrigerated space, total and daily energy consumption, and weather predicted energy performance. Report-generated ranking tables and efficiency factors are shown in Figures 2 and 3 below.

Ranking Table Report - January 2009

North Central

Rank	Site	Efficiency Factor
1	GRAND RAPIDS	0.521
2	KNOXVILLE	0.525
3	CINCINNATI	0.577
4	BARABOO	0.676
5	CLEVELAND	0.687
6	ROBERT ORR	0.712
7	ASIAN FOODS - Chicago	0.738
8	E. WISCONSIN	0.742
9	INDIANAPOLIS	0.763
10	KANSAS CITY	0.811
11	MINNESOTA	0.829
12	ROBERTS	0.849
13	HARDINS	0.858
14	NORTH DAKOTA	0.864
15	DETROIT	0.865
16	IOWA	0.867
17	ST. LOUIS	0.920
18	LOUISVILLE	0.956
19	PEGLER	0.959
20	CHICAGO	1.118
21	CENTRAL OHIO	1.500
22	ASIAN FOODS - St. Paul	1.665
	AVERAGE	**0.864**

SYGMA

Rank	Site	Efficiency Factor
1	Sygma - Denver	0.625
2	Sygma - Southern California	0.663
3	Sygma - Northern California	0.671
4	Sygma - Portland	0.822
5	Sygma - Oklahoma	0.864
6	Sygma - Dallas	0.867
7	Sygma - Kansas City	0.926
8	Sygma - Detroit	0.982
9	Sygma - Illinois	0.983
10	Sygma - Georgia	1.015
11	Sygma - Boston	1.059
12	Sygma - Pennsylvania	1.070
13	Sygma - Florida	1.097
14	Sygma - Carolina	1.125
15	Sygma - San Antonio	1.555
16	Sygma - Columbus	2.209
	AVERAGE	**0.955**

Figure 2: Energy performance ranking tables for Sysco North Central and Sygma affiliate distribution centers

Site	kWh	Wet-Bulb Temp	kWh / day	Total Frozen cu-ft	Total 28-55°F cu-ft	Total Dry cu-ft	Weighted Volume Cu-ft	Space Weighted Eff Factor	Weather Predicted Eff Factor	New Effiency Factor
Sygma - Denver	1,902,060	41.9	10,337	891	971			2.66	4.52	.666
Sygma - Southern California	2,587,710	48.4	14,064	920	1,142			3.01	4.76	.732
Sygma - Northern California	1,855,050	52.3	10,082	748	595			3.01	4.9	.756
Sygma - Kansas City	1,077,360	47.7	5,855	340	641			3.43	4.74	.775
Sygma - Illinois	3,558,070	46.4	19,337	1,680	1,043			3.66	4.69	.835
Sygma - Oklahoma	1,391,650	52.8	7,563	498	392			3.61	4.92	.844
Sygma - Portland	1,277,340	48.1	6,942	425	442			3.62	4.75	.863
Sygma - Detroit	1,567,380	45.2	8,518	384	407			3.32	4.65	.927
Sygma - Dallas	3,397,560	56.6	18,465	919	1,083			4	5.06	.930
Sygma - Boston	1,390,940	43.7	7,559	445	383			3.85	4.59	1.037
Sygma - Georgia	2,341,800	55.6	12,727	388	584			4.67	5.02	1.043
Sygma - Florida	3,333,500	64.5	18,117	794	824			5.09	5.35	1.110
Sygma - Carolina	2,899,140	53.7	15,756	685	592			4.86	4.95	1.111
Sygma - Pennsylvania	2,689,120	47.3	14,615	597	884			4.36	4.72	1.152
Sygma - San Antonio	5,479,980	59.7	29,783	924	936			7.43	5.17	1.532
Sygma - Columbus	5,816,070	45.3	31,609	1,006	942			7.09	4.65	1.677

Figure 3: Efficiency factor report for Sygma distribution centers

In addition to use in determination of monthly site rankings, efficiency factors are tracked over time. As reflected in Figure 4, the Ohio project manager generates tabular reports that show monthly efficiency factors for each site, over a rolling period of more than a year. Each cell is color-coded to indicate increases and decreases relative to the previous month. Changes in efficiency factor between the previous year and year-to-date are also carried in this table.

SYGMA Operations Tracking Report

Occupancy

FY 09 Period 9

Energy Efficiency Factor (EEF) - through Period 7

	LY thru Period 7	YTD thru Period 7	% Change FY06 FY09	% Change LY - YTD	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07
Boston	1.005	1.037	-23.3%	3.2%	0.892	0.975	1.032	1.044	1.020	0.958	0.927	0.999
Carolina	1.246	1.111	-59.6%	-10.8%	1.286	1.286	1.299	1.260	1.265	1.217	1.237	1.190
Columbus	1.671	1.677	-19.9%	0.4%	1.558	1.572	1.631	1.590	1.587	1.600	1.691	1.752
Dallas / Dallas North	0.940	0.930	-12.0%	-1.1%	0.929	0.943	0.953	0.984	0.981	0.956	0.910	0.905
Denver	0.797	0.666	-21.0%	-16.4%	0.760	0.700	0.772	0.796	0.786	0.779	0.770	0.866
Detroit	1.135	0.927	-36.9%	-18.3%	1.183	1.272	1.297	1.293	1.292	1.211	0.872	0.939
Florida	1.059	1.110	-15.9%	4.8%	1.176	1.151	1.146	1.163	1.084	0.962	1.025	0.999
Georgia	0.902	1.043	-9.3%	15.6%	0.980	0.947	1.012	0.933	0.893	0.887	0.898	0.838
Illinois	1.051	0.835	-5.6%	-20.6%	0.880	0.852	0.936	1.169	1.398	0.839	0.973	1.032
Kansas City	0.685	0.774	-	13.0%			0.672	0.696	0.761	0.602	0.600	0.738
Northern Cal	0.955	0.756	-35.5%	-20.8%	1.115	1.141	1.113	1.065	0.983	0.904	0.892	0.881
Oklahoma	1.070	0.844	-33.2%	-21.1%	1.021	1.050	1.089	1.148	1.092	1.047	1.006	1.016
Pennsylvania	1.208	1.152	-21.6%	-4.6%	1.187	1.236	1.224	1.207	1.256	1.125	1.371	1.043
Portland	1.131	0.863	-32.9%	-23.7%	1.139	1.144	1.122	1.136	1.150	1.142	1.143	1.128
San Antonio	1.601	1.532	-13.8%	-4.3%	1.593	1.532	1.528	1.678	1.644	1.613	1.608	1.597
Southern Cal	0.914	0.732	-	-19.9%	0.872	0.863	0.862	0.896	0.888	0.913	0.952	0.949
OVERALL	1.113	1.022	-22.9%	-8.2%	1.105	1.111	1.112	1.122	1.130	1.047	1.055	1.080

	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09
Boston	1.020	1.023	0.961	0.912	1.024	1.042	1.100	1.107	1.041	1.034	0.950	0.960	1.059
Carolina	1.252	1.229	1.204	1.180	1.182	1.197	1.145	1.135	1.091	1.110	1.104	1.068	1.125
Columbus	1.797	1.748	1.725	1.574	1.527	1.456	1.485	1.497	1.457	1.604	1.707	1.757	2.203
Dallas / Dallas North	0.893	0.853	0.857	0.873	0.928	1.034	1.004	0.954	0.948	0.929	0.903	0.894	0.867
Denver	0.834	0.839	0.797	0.750	0.716	0.713	0.673	0.662	0.611	0.641	0.638	0.693	0.625
Detroit	1.089	1.076	0.993	0.873	0.953	1.154	1.053	1.019	0.966	0.915	0.842	0.880	0.932
Florida	1.038	1.030	1.074	1.127	1.148	1.169	1.169	1.163	1.149	1.121	1.081	0.992	1.037
Georgia	0.854	0.840	0.838	0.884	0.962	1.039	1.028	1.038	1.071	1.104	1.050	1.018	1.015
Illinois	0.999	0.934	0.799	0.736	0.768	0.737	0.753	0.764	0.767	0.814	0.862	0.897	0.938
Kansas City	0.730	0.726	0.670	0.674	0.724	0.770	0.795	0.755	0.652	0.656	0.747	0.873	0.925
Northern Cal	0.850	0.845	0.821	0.851	0.840	0.875	0.865	0.853	0.785	0.749	0.685	0.676	0.671
Oklahoma	1.090	0.988	0.963	0.873	0.871	0.890	0.932	0.886	0.798	0.781	0.795	0.858	0.864
Pennsylvania	1.239	1.224	1.211	1.177	1.301	1.295	1.275	1.281	1.184	1.143	1.058	1.054	1.070
Portland	1.096	0.977	0.989	0.964	0.920	0.964	0.938	0.898	0.882	0.845	0.805	0.852	0.822
San Antonio	1.641	1.533	1.519	1.632	1.535	1.526	1.554	1.562	1.443	1.431	1.433	1.592	1.555
Southern Cal	0.965	0.876	0.910	0.825	0.833	0.865	0.852	0.822	0.766	0.656	0.655	0.695	0.663
OVERALL	1.050	1.030	1.000	0.972	1.027	1.012	1.005	1.045	0.944	0.929	0.908	0.931	0.955

Improvement from previous month

Increased usage by 0.050 or more

Figure 4: Efficiency factor tracking over time

The NorthWrite EIS includes a module called *Utility Bill Manager,* and under Sysco's contract all utility invoices are to be entered into the system by Cascade Energy Engineering. However, the Stockton site has experienced several months lag in the data entry process, perhaps due in part to the larger number of meters at the site—most Sysco sites do not have multiple meters. Therefore, the Stockton energy champion uses a personally designed spreadsheet to track energy expenditures. He also uses this personal tracking to produce documentation in support of his annual employee performance review. An example is provided in Figure 5.

2009 / 2008 BLENDED kWh RATES COMPARISON (P-9)

Meter #	Provider	2009 kWh used	2009 Total $ billed	2009 True kWh cost	2008 kWh used	2008 Total $ billed	2008 True kWh cost
OR2235	PG&E	3,491	$ 237.78	$ 0.0681	3,397	$ 247.77	$ 0.0729
OR2235	Sempra	3,491	$ 431.27	$ 0.1235	3,397	$ 294.84	$ 0.0868
PG&E / Sempra Combined >		***3,491***	***$ 669.05***	$ 0.1916	***3,397***	***$ 542.61***	$ 0.1597
C38928	PG&E	124,681	$ 4,808.34	$ 0.0386	164,841	$ 7,109.32	$ 0.0431
C38928	Sempra	124,681	$ 15,450.39	$ 0.1239	164,841	$ 14,277.79	$ 0.0866
PG&E / Sempra Combined >		***124,681***	***$ 20,258.73***	***$ 0.1625***	***164,841***	***$ 21,387.11***	***$ 0.1297***
Bldg A Total >		***128,172***	***$ 20,927.78***	***$ 0.1633***	***168,238***	***$ 21,929.72***	***$ 0.1303***
63P886	PG&E	2,830	$ 379.24	$ 0.1340	2,822	$ 362.57	$ 0.1285
6M9291	PG&E	19,760	$ 2,678.15	$ 0.1355	17,040	$ 2,121.14	$ 0.1245
9M4491	PG&E	15,418	$ 1,789.34	$ 0.1161	14,309	$ 1,557.09	$ 0.1088
Bldg B Total >		***38,008***	***$ 4,846.73***	***$ 0.1275***	***34,171***	***$ 4,040.80***	***$ 0.1183***
36P844	PG&E	2,294	$ 310.56	$ 0.1354	2,787	$ 358.58	$ 0.1287
6M9304	PG&E	29,000	$ 3,653.23	$ 0.1260	22,993	$ 5,576.94	$ 0.2425
28P847	PG&E	3,222	$ 739.29	$ 0.2295	10,569	$ 1,376.47	$ 0.1302
Bldg C Total >		**34,516**	***$ 4,703.08***	***$ 0.1363***	**36,349**	***$ 7,311.99***	***$ 0.2012***
Total ALL		**200,696**	***$ 30,477.59***	***$ 0.1519***	***238,758***	***$ 33,282.51***	***$ 0.1394***

PERIOD 9	*kWh usage*	*Invoice Amounts*	*Blended Rate*
2009	*200,696*	*$ 30,477.59*	*$ 0.1519*
2008	*238,758*	*$ 33,282.51*	*$ 0.1394*
$ Increase from last year			*$ 0.0125*
% Rate increase from last year			*8.94%*
Variance due to rate increase from prior year			*$ 2,500.87*

Variance in kWh useage from last year	*(38,062)*
% Change from last year	*-15.94%*

Figure 5: Analysis of utility billing data based on exported meter data and utility invoices

Daily use of the EIS to monitor the meter dedicated to refrigeration loads has encouraged and confirmed the effectiveness of operational changes implemented by the energy manager. The existing controls do not permit it; however, the frozen goods can tolerate fluctuations in temperature between -5°F to 10°F for short periods of time without compromising quality. In response, the energy champion implements a daily energy-efficiency strategy. Upon arriving in the morning, he uses a dial-up modem to access DOS-based control programs for ten freezer units and manually raises the setpoints to force the compressors to shut off. The energy champion observes the temperatures and metered power consumption throughout the morning, and reduces the setpoints to their original levels around 11 a.m. The lighter trend in Figure 1 reflects this daily strategy; whereas, the darker line reflects a day in which the energy champion was on vacation and the strategy was not implemented. In spite of a four-degree temperature increase, the data for these days show approximately 35% reduction in load when the energy manager was present to execute the strategy.

In addition to site-specific uses, the NorthWrite EIS was an integral component in the identification and pursuit of the low- and no-cost measures that resulted in 18% energy savings across Sysco's portfolio. To begin the three-year program, Cascade Energy

Engineering and expert refrigeration engineers and technicians conducted three-day site visits to over 100 distribution warehouse centers. They used the NorthWrite EIS information to support retro-commissioning and tune-up activities, and to support the implementation of low-cost measures. For example, occupancy sensors were installed at the Stockton sitefor bathroom and break room lighting, and locked-out digital thermostats were placed in conditioned staff areas. The ”Projects and Tasks” tool within the EIS was used to track these measures for savings, cost, and persistence, and to provide administrative task checklists.

Across the portfolio, Cascade Energy Engineering reports that approximately one-third to one-half of energy champions engage with the EIS data on a daily or weekly basis, typically making use of the meter monitoring view, as at the Stockton site. Also similar to the Stockton case, a typical use of the EIS is to verify that consumption dips during off or sleep-mode hours of operation. In addition, most Sysco sites have a refrigeration operator who uses whole-building trends to optimize setpointsand number of active compressors if site performance should slip.

2.2 EIS Data Quality

Data quality is managed by Cascade Energy Engineering, who report that in general NorthWrite’s pulse acquisition and cellular relay hardware is quite reliable. Further, the Sysco sites monitor at the utility meters only, removing the quality issues commonly encountered in submetered installations. When data feeds do drop out, Cascade Energy Engineering receives the alarm notification, and notifies the specific site to service the acquisition devices. There are also occasional glitches in cellular transmission of the data; however, these are perceived more as annoyances than critical problems, particularly given that cellular solutions are quick and relatively straightforward to install.

3.0 EIS Usability and Enhancement

As might be expected, given his emphasis on daily energy efficiency in refrigerated spaces, the Stockton energy champion reports that the most useful feature in the EIS is the ability to monitor meter trends and changes in total electric use, as illustrated in Figure 1. In his experience, this is the only analytical support he requires to maintain good performance at his site. After the initial site tune-ups and low-cost measures were implemented, the EIS software has proven most useful at the site for motivation, awareness, and accounting and verification of persistence in savings. In this sense, the Stockton energy champion has also found monthly comparison rankings and corporate accountability meetings especially valuable. The identification of an energy champion, provision of the EIS software to prevent backsliding, and accountability for performance have resulted in a corporate culture of energy awareness and competitiveness relative to energy efficiency.

In contrast to other commercial implementations of EIS, the Stockton Sygma case revealed limited exploration most of the analytical features offered. While the energy champion does not feel that he could not manage energy performance as successfully *without* the NorthWrite technology, and while he uses it to implement a powerful efficiency strategy, he had difficulty navigating beyond the meter monitoring view that he accesses as a default. For example, it was a challenge to locate performance indicators such as total kWh last year, an entire month of time series, or the annual peak for the most critical refrigeration meter. Similarly, analyses beyond those automatically included in monthly reports are largely unused and in some cases misinterpreted.

Throughout the enterprise, the energy champions have identified a set of recommended improvements to the NorthWrite EIS, as currently configured for the Sysco portfolio. Utility billing graphs will be modified to allow extrapolated data points to be displayed for projected energy use and costs based on month-to-date data. In addition, a real-time metering graph will be added to show this week versus last year, with an option to display today versus last year. A monthly report addressing underperformers has also been requested. This report is to include the two least efficient sites in each benchmark group; the ten sites portfolio-wide that have improved the least, relative to pre-program baselines; and sites that have backslid more than four percent relative to the prior fiscal year. Backsliding sites may ultimately have the option to undergo recommissioning with Cascade Energy Engineering.

3.1 General EIS Perspectives

Sysco has achieved significant energy savings by coupling corporate goals and accountability methods with Cascade Energy Engineering's expertise and the performance-tracking capabilities of the NorthWrite technology. In addition to the Sysco program, Cascade has recently initiated a program with Super Value centers, reaching 9% energy savings in the first nine months. Cascade Energy Engineering therefore views this as a compelling model that promises widespread traction for enterprise energy-saving initiatives, and it has begun to seek opportunities for formal inclusion in utility programs. They are optimistic that careful application of engineering expertise and energy services, combined with software-based tracking and performance documentation within a context of corporate promotion of efficiency goals, will prove a reliable pathway to secure, low-cost, deep energy savings.