

An Algorithmic Approach to Enterprise Energy Management: Developing an Integrated Energy Solution Utilizing Real-time Data Collection and Predictive Modeling Capabilities

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This paper explores an aggregated, enterprise-wide methodology for energy engineering and management. In addition to developing a design and architecture for the integrated enterprise energy management system, this paper uses examples from several system implementations to validate the methodology and demonstrate the possible efficiency gains.

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Abstract

Conventional plant and facility energy management systems have focused on providing interval or utility-bill tracking to isolate energy use and analyze consumption patterns. While these tools can be used to find system inefficiencies, such conventional tracking methods fail to provide the comprehensive perspective required to optimize energy production and consumption decisions. Energy managers seeking to maximize efficiencies are often inhibited by data gaps, disparate data sources and complicated systems interfaces, making real-time analysis of energy data difficult. These difficulties impede the decision-making process by forcing energy managers to function retrospectively. A more robust energy-management solution, however, leverages predictive modeling capabilities to facilitate proactive decision making and maximize system efficiencies.

This paper explores an aggregated, enterprise-wide methodology for energy engineering and management. The requirements of an integrated enterprise energy management (EEM) system are developed using an algorithmic approach, which leverages real-time and historical data to predict performance trends and evaluate response options. Utilizing this holistic approach, energy managers can realize higher visibility into ongoing operations, achieve the capacity to isolate potential issues, and employ preemptive action procedures based on upcoming events such as weather, schedule or energy-price changes. In addition to developing a design and architecture for the integrated enterprise energy management system, this paper uses examples from several system implementations to validate the methodology and demonstrate the possible efficiency gains.

Keywords: Energy management, energy efficiency, energy benchmarking, energy modeling

1 Introduction

Conceptually, energy management has a broad scope that encompasses activities ranging from managing electrical production and distribution to tuning complex building automation systems to purchasing fuel oil or gas. Despite this variety, the facets of energy management have a notable common requirement: the need for advanced data collection and analytical tools that facilitate energy-efficient practices.

The objective of this paper is to explore the potential of an enterprise energy management (EEM) system that was developed based on a commercially available, business-intelligence platform that provides a comprehensive function set for data collection and sophisticated analytical capabilities designed to reduce the complexity of energy-related operational decisions. The fundamental requirements for the EEM include connectivity to disparate data sources, energy modeling for real-time benchmarking of energy data, analytical capabilities to support ongoing systems commissioning, and accessible visualization of energy data. Although some of these system requirements have been explored previously, the holistic approach to EEM described in this paper adds new dimensions to the field of energy management and allows energy operations to achieve higher levels of efficiency. The following sections review the capabilities of previously documented systems and research and then compare these capabilities to the comprehensive function set that constitutes an EEM system.

1.1 Data Source Connectivity

Energy data comes in many forms and from many different sources. From a software perspective, the widely used concept of energy information systems has generally been divided into two subcategories: energy management control systems (EMCS) and measurement and verification systems. An EMCS is typically a collection of direct digital controllers (DDC) and devices that control energy supply equipment, such as chillers and boilers, as well as energy demand equipment, such as lighting and heating ventilation and air conditioning (HVAC) systems [1]. As such, the data available in the EMCS depends on the systems the EMCS controls.

A measurement and verification system collects energy data to quantify and report energy savings accurately. The predominant standard for measurement and verification systems is defined in the International Performance Measurement and Verification Protocol (IPMVP). The IPMVP specifies four methods for measuring and verifying energy conservation: partially measured retrofit isolation, retrofit isolation, whole building, and calibrated simulation. A proper method is selected depending on the energy conservation measure being performed and the data granularity required for validating energy savings [2].

1.2 Energy Modeling and Benchmarking

Benchmarking of energy data has been used for years to normalize and compare energy data sets across different time periods and conditions. Because many variables – such as weather conditions, occupant activities, and schedule – affect a facility’s energy consumption, establishing benchmarking and modeling methodologies provides validation of whether energy savings in the facility actually occurred.

Various approaches to energy benchmarking have been documented. In 1997, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) published a decision diagram for the selection of an energy benchmarking model. In this diagram, ASHRAE rated modeling techniques by the categories of usage, difficulty, time scale,

calculation time, variables, and accuracy of the model [3]. For the EEM system implementations discussed in this paper, two models of different degrees of complexity and accuracy were used to develop energy benchmarks: a multiple linear regression model and an artificial neural network (ANN) model. Both modeling methods have been used in other studies in recent years.

Chung et al. used multiple linear-regression modeling to investigate the relationship between commercial building energy-use intensities (EUIs) and an assortment of exogenous variables, such as building age, occupancy, occupants' behavior, energy systems, and degree-day weather normalization [4]. In a similar study, Westphal and Lamberts also used a multiple regression model to simulate the electrical consumption of several buildings based on design and weather parameters. While these models resulted in high coefficients of determination, indicating a good fit, they noted the limitations of regression models over time and indicated that the method was best suited to evaluating the energy performance of new buildings during the initial design and commissioning stage [5].

Yalcintas used the ANN method to create energy benchmarks for buildings in a tropical climate with high air-conditioning loads. This investigation found the ANN model was highly correlated to the actual data and determined ANN was a useful means for making EUI predictions at both the plug and whole-building levels [6]. In another analysis, Yalcintas and Ozturk compared the mean-squared error of benchmarking using an ANN against a multiple regression model. They found the ANN method provided more accurate predictions against actual energy consumption data than the regression model [7]. Cipriano et al. also used the ANN method to predict energy consumption and the potential for energy savings based on various retrofitting measures. Using variables for seasonal weather change, building age, occupancy, and equipment, this investigation found the ANN method provided an even better fit than Yalcintas and Ozturk found, and also concluded that ANN modeling can be used to predict potential energy savings from retrofitting measures by creating reference models against which to benchmark existing systems [8].

1.3 System Commissioning

For more than a decade, building commissioning has received attention as one of the principal methods for reducing building energy consumption. ASHRAE in 1996 [9] and the U.S. Department of Energy in 1999 [10] developed building commissioning guidelines, which outlined fundamental best practices for commissioning. While these commissioning approaches tend to be labor intensive and focus on bringing building systems in line with design specifications, more recent developments concentrate on automating and optimizing the commissioning process. This optimization is described and documented in a guidebook for the Federal Energy Management Program, which introduced the concept of Continuous CommissioningSM. Continuous CommissioningSM involves constant monitoring and analysis of building mechanical systems and occupant needs [11].

Similar to Continuous CommissioningSM, the monitoring-based commissioning (MBCx) process, developed by Lawrence Berkeley National Laboratory and the University of California system, has resulted in significant energy savings by facilitating enhanced system scheduling, control tuning, equipment maintenance, and other operational efficiency measures [12],[13]. Some of the motivation for developing these commissioning methods comes from research showing that new buildings incorporating LEED design standards and state-of-the-art building management technology still experience rapidly degrading energy performance

[14]. So without real-time system monitoring and analytics, even buildings thought to be energy efficient can perform well below their design specifications.

1.4 Energy Visualization

Energy visualization methods don't only differ by the data available, but also by the group for which the data is intended. An energy engineer may want to view HVAC performance data using engineering metrics, a facility administrator may be most interested in energy costs per square foot, while a facility occupant might want to know how energy consumption translates into carbon dioxide (CO²) emissions. Lawrence Berkeley National Laboratory has developed a specifications guide for performance monitoring systems that details some fundamental visualization methods for energy data, such as trending time-series data, XY plots, and data tables [15].

University campuses have used other types of graphical displays to communicate relevant energy information for students and encourage energy conservation. At Indiana University Bloomington, an energy-challenge competition website featured dynamic and highly graphical displays of energy data that informed students of accumulated energy and water savings using equivalences ranging from CO² reductions to the number of avoided toilet flushes [16]. At Dartmouth College, the Green Lite project utilizes an animated polar bear to show whether a building's energy use is above or below normal [17]. These projects demonstrate the potential for reducing energy demand when real-time data connections are combined with meaningful visualization methods. As automated collection of energy data increases, more efficient and evocative ways to communicate and display that data will require powerful and flexible visualization tools, such as those offered in an EEM system.

2 EEM System Design and Implementation Results

From the review in the previous sections of existing literature, it is clear that various amounts of research have been performed in each of the fundamental functional areas of the EEM system: connecting to data sources, energy modeling and benchmarking, systems commissioning, and energy data visualization. This section provides a more detailed description of how the EEM system offers a comprehensive function set that connects these functional areas into a single, business-intelligence platform, allowing the EEM system to leverage a holistic, enterprise-wide approach to energy management. This section also discusses some of the energy-efficiency gains from these capabilities as experienced across EEM system implementations.

2.1 EEM System Connectivity

While the EMCS (incorporating control-system data) and the measurement and verification system (incorporating various levels of metered energy data) have been the standard repositories of energy data, the EEM system connects these and other data sources together to abstract the complexities of the individual data sources and create a coherent, unified view of all relevant data. As shown in Table 1, the EEM approach provides connectivity to important data sources beyond the standard EMCS and energy meter data.

Table 1. Potential data sources in the EEM system’s architecture.

Data Source	Data Description
Energy Management Control System Data (EMCS)	Building data from automation systems, HVAC, lighting systems, boiler, chiller, turbine, and other equipment
Energy Meter Data	Data from energy meters and submeters, which can include electricity, chilled water, steam, gas, fuel, water and other metered resources
Enterprise Resource Planning (ERP)	Enterprise-level business data, such as supply-chain, asset, financial, project and others
Data Historian	A historical data repository that efficiently stores data from manufacturing process, facility metered, or other types of historical data
Weather Data	Temperature, pressure, humidity, and other weather data
Building Data	Building type, design specifications, and square-footage data
Web Data	Various internet data sources such as DOE or EIA energy databases or forecasted weather data
Billing Data	Incoming and outgoing utility billing data, which may also come from the ERP system
Scheduling Data	Line schedules, room schedules, facilities schedules, personnel schedules and others
Excel Data	Historical spreadsheets and reports of Excel data

Although not every EEM implementation connects to all the data sources described above, Table 1 demonstrates the connection possibilities and the range of data available for analysis. By providing connectivity to this diverse array of disparate systems and by abstracting the data sources, the EEM system allows users to minimize the time spent searching for data and maximize the time spent analyzing the data.

2.2 EEM System Modeling and Baselineing

Once a facility has the relevant data sources available, modeling and benchmarking of energy and performance data provide the foundation of the EEM system’s analytics. As mentioned, existing EEM system implementations have used both multiple linear regression models and ANN models. In a different approach from the previous energy modeling and benchmarking work discussed, the EEM system provides a continuous baseline that both benchmarks current performance and allows for predictions about future energy consumption in real time.

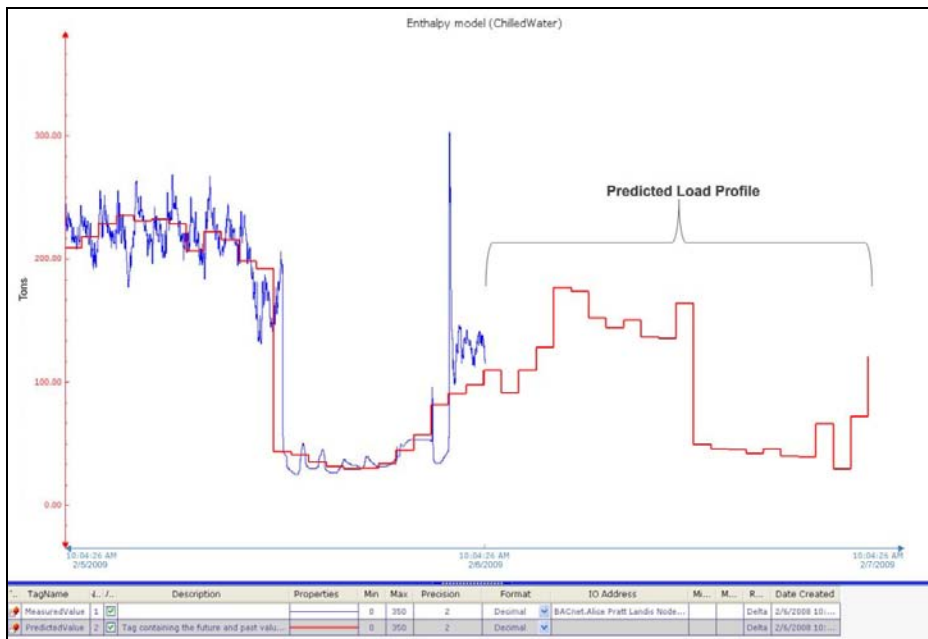


Figure 1. A building’s chilled water meter showing the actual (blue) data with the real-time baseline (red) data.

The trend displayed in Figure 1 shows the actual and modeled baseline data for a building’s chilled water meter. The baseline was developed using a multiple linear regression model. This regression model normalizes historical meter data with weather data, including temperature, pressure, and humidity, which are aggregated to produce an enthalpy factor. Because building a model for each meter across large facilities or campuses can be time consuming, the EEM system includes an automated model generation algorithm. The algorithm includes data processing functionality to identify sections of bad meter data and can automatically create a new baseline for any new meter.

One of the most important aspects of the baseline functionality comes from having energy consumption data put into context. While other applications can present energy usage in reports and trends, these tools can fail to show how much energy should have been used. In essence, systems without the meter-baseline model provide a lot of data but little analytical power for interpreting that data. By contextualizing the data from each meter, the EEM system provides an overview of the building systems’ current situation and allows for rapid identification of buildings that are experiencing operational issues.

Another important feature displayed in Figure 1 is the EEM’s 24-hour, predicted-load profile. This profile is generated for each meter using forecasted weather data. The ability to model and predict future loads provides several notable benefits. Using concurrent external data, such as the cost of energy and fuels along with the predictive model, EEM system users have negotiated contracts that more accurately reflect predicted consumption. Therefore, they are empowered to buy more energy when prices are low and less energy when prices are high. In addition, central plant managers use the forecasted load functionality to anticipate total demand across facilities, allowing them to plan equipment and personnel operations accordingly. Several current EEM installations have also found that the predictive load capability creates an opportunity to implement closed-loop, advanced process control (APC) systems for turbine, boiler, and chiller optimization. While the pilot implementations of these

APC systems show promising results, further investigation is ongoing to demonstrate the scale of energy savings possible.

2.2.1 Artificial Neural Network Baseline Models

The existing EEM system implementations have used a multiple linear regression method for creating the meter-baseline model. While this regression tactic has produced accurate models, some work has been done on using an ANN to develop models that can more easily handle a large number of variables. Several meter baselines have been created using a commercially available ANN software program.

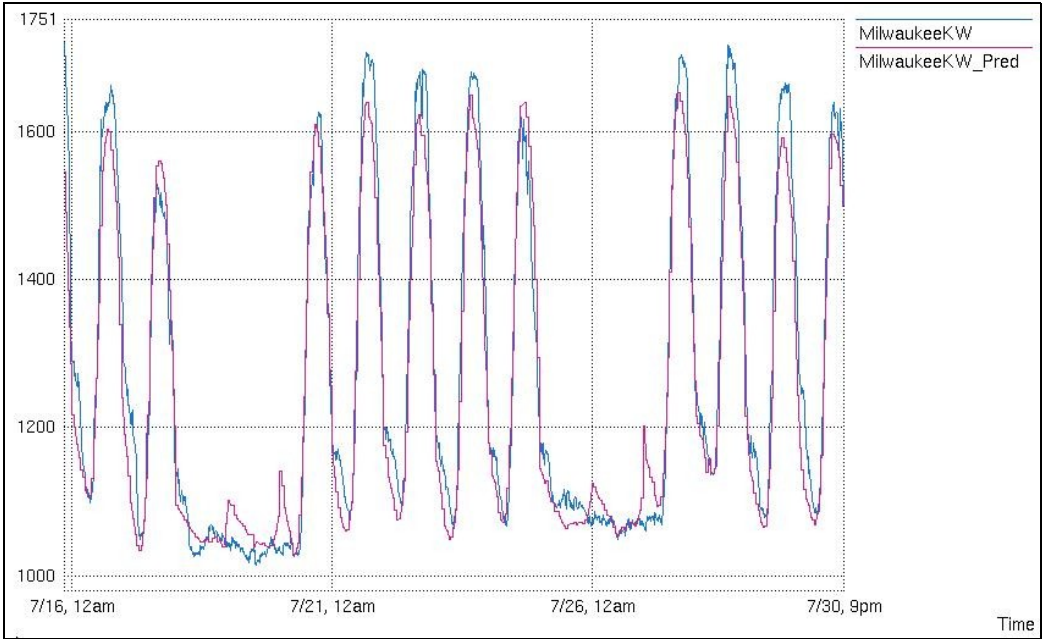


Figure 2. An actual versus predicted baseline model created using the ANN modeling tool.

The trend in Figure 2 shows an actual versus predicted baseline model of electricity consumption that was created using an ANN model. The ANN model was developed as a function of the following variables: historical energy data, temperature, dew point, wind speed, wind direction, relative humidity, time of day, weekday, weekend, and holiday. While the fit of these initial ANN baselines is relatively well correlated to the actual data, further adjustments are required to achieve a fit that exceeds the accuracy provided by the multiple linear regression models.

Other efforts to fine-tune the ANN model involve integrating with advanced scheduling databases that include specific-use and occupancy data for individual buildings and creating baselines on the sub-meter level to model specific manufacturing processes against input and output data. One preliminary attempt on the manufacturing level incorporated variables for energy, production batch, schedule, and process data to create a model of the dollar cost per batch of production for several products. This method of process modeling is made possible using the ANN and facilitates attempts to manage energy costs similarly to many firms' efforts to manage raw materials, equipment, or human resources. Integrating energy costs into manufacturing processes in this manner can help firms make more intelligent decisions about production equipment, operations, and scheduling that help reduce both energy consumption and production costs.

2.2.2 Multiple Baselines

Along with searching for an optimal-fit baseline methodology, another use of a baseline is to demonstrate energy savings over time while continually providing ongoing analysis of energy consumption. Simultaneously achieving both goals becomes complex when only one energy baseline is created. As energy-saving activities are implemented, the actual energy use begins trending below the predicted baseline, allowing real-time quantification of energy savings but reducing some of the contextual benefits of the baseline.

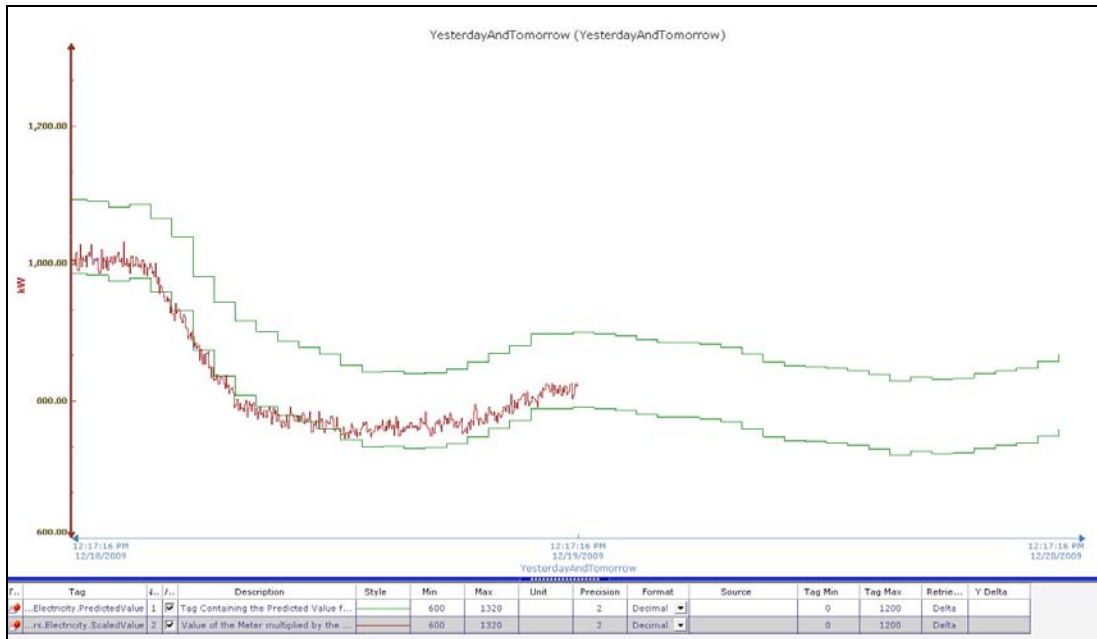


Figure 3. An electric meter with an original baseline and a second baseline that fits the actual data.

The solution to this dilemma is to allow the EEM system to have multiple baselines for any given meter. When the EEM system is first commissioned, a best-fit baseline for the existing historical data is produced. As energy efficiencies are found and the actual consumption begins to trend below the original baseline, the EEM system's automated-baseline function allows the generation of a second baseline that is tuned to the shifted energy data. Figure 3 shows an electric meter with both original and new baselines. In this case, the original baseline provides a model of what the electrical consumption would have been, had energy-saving activities not reduced the total energy consumption. This method of multiple baselines allows the EEM system to calculate energy savings automatically against the original baseline and still provides contextual analysis using the new baseline.

Although the multiple-baseline method solves the dilemma of savings quantification versus context, some issues still remain. The most complicated issue is determining when an energy meter requires a new baseline. To some extent, an algorithm can be used to solve this problem, as well. By setting threshold values around a baseline, it becomes relatively easy to track when actual consumption is consistently outside the baseline's threshold. But this method still requires some level of operator interaction and review before a new baseline is generated. Over time, more advanced algorithm development, along with trial and error, should produce some best practices for baselining and re-baselining meters based on whether

the deviation from a baseline is temporary or represents an actual trend toward a different level of energy consumption.

2.3 EEM System Commissioning and Intelligence Capabilities

Beyond the baseline functionality, applying the EEM system’s business intelligence platform to energy and related data creates a new array of analytical options for finding energy efficiencies in campuses, large facilities, or manufacturing processes. Because baselines allow for the real-time quantification and evaluation of energy data, higher-level reports can quickly show energy managers and operators where the problem areas exist.

Hourly Utilities												
	Consumed			units per k-Sq Ft			Dollars			Total		
	Ton-Hours	mmBtu	KWH	Ton-Hours	mmBtu	KWH	Ton-Hours	mmBtu	KWH	\$/hour	\$/ksq ft	
MAIN CAMPUS (WEST)												
BOWEN SCIENCE BUILDING	5.79	20.73	819.28	0.02	0.06	2.51	\$0.92	\$311.13	\$61.12	\$379.16	\$114	
BOYD LAW BUILDING		2.17			0.01		\$0.00	\$32.51	\$0.00	\$32.51	\$0.17	
CARVER BIOMEDICAL RESEARCH BUILDING	3.08	5.03		0.02	0.04		\$0.47	\$75.55	\$0.00	\$76.05	\$0.56	
CARVER-HAWKEYE ARENA		2.85			0.01		\$0.00	\$42.74	\$0.00	\$42.74	\$0.20	
COLLEGE OF MEDICINE ADMINISTRATION	7.82	0.40		0.23	0.01		\$1.20	\$6.03	\$0.00	\$7.24	\$0.21	
DENTAL SCIENCE BUILDING	6.81	6.99	253.61	0.03	0.03	1.26	\$0.90	\$104.97	\$18.82	\$124.79	\$0.62	
ECKSTEIN MEDICAL RESEARCH BUILDING	18.99	5.20	608.10	0.14	0.04	4.42	\$2.93	\$77.99	\$45.87	\$126.29	\$0.92	
FIELD HOUSE		5.79	265.34		0.02	0.79	\$0.00	\$86.88	\$19.79	\$106.68	\$0.32	
HARDIN LIBRARY FOR HEALTH SCIENCES		2.06	363.55		0.02	4.16	\$0.00	\$30.95	\$27.12	\$58.07	\$0.66	
HILLCREST		4.77			0.02		\$0.00	\$71.54	\$0.00	\$71.54	\$0.27	
HYDRAULICS LABORATORY		0.30	66.11		0.01	1.95	\$0.00	\$4.49	\$4.98	\$9.42	\$0.28	
KINNICK STADIUM		3.50			0.01		\$0.00	\$52.50	\$0.00	\$52.50	\$0.14	
MEDICAL EDUCATION BUILDING	0.74	2.28	53.78	0.01	0.03	0.63	\$0.11	\$34.29	\$4.01	\$38.42	\$0.45	
MEDICAL EDUCATION RESEARCH FACILITY	9.46	8.70	719.39	0.04	0.04	3.95	\$1.46	\$130.63	\$53.67	\$185.76	\$0.87	
MEDICAL LABORATORIES	11.12	17.78	701.03	0.06	0.09	3.56	\$1.71	\$266.98	\$52.80	\$320.99	\$1.65	
MEDICAL RESEARCH CENTER	25.70		186.04	0.27		1.95	\$3.96	\$0.00	\$13.88	\$17.84	\$0.19	
MEDICAL RESEARCH FACILITY	2.78	0.31	73.14	0.08	0.01	2.13	\$0.43	\$4.66	\$5.46	\$10.54	\$0.31	
MUSIC WEST - INTERIM BUILDING	8.88	0.64	22.24	0.12	0.01	0.90	\$1.36	\$9.57	\$1.66	\$12.59	\$0.17	
NURSING BUILDING	0.48	1.60	61.79	0.01	0.02	0.80	\$0.08	\$24.08	\$4.61	\$28.77	\$0.37	
PHARMACY BUILDING	79.42	7.23		0.56	0.05		\$12.29	\$108.46	\$0.00	\$120.69	\$0.84	
QUADRANGLE		5.94			0.04		\$0.00	\$89.13	\$0.00	\$89.13	\$0.64	
RECREATION BUILDING	0.00	2.23	150.21	0.00	0.01	0.98	\$0.00	\$38.46	\$11.21	\$44.67	\$0.29	
RIENOW HALL							\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	
SLATER HALL		2.32			0.02		\$0.00	\$34.77	\$0.00	\$34.77	\$0.30	
SOUTH QUAD		0.25	19.60		0.01	0.70	\$0.00	\$3.70	\$1.47	\$5.17	\$0.18	
THEATRE BUILDING	1.94	1.02	58.10	0.02	0.01	0.72	\$0.21	\$15.26	\$4.33	\$19.80	\$0.24	
WENDELL JOHNSON SPEECH AND HEARING		1.12	66.39		0.02	1.01	\$0.00	\$16.86	\$4.95	\$21.82	\$0.33	
WESTLAWN	21.63	2.06	138.58	0.15	0.01	0.98	\$3.33	\$30.88	\$10.34	\$44.54	\$0.31	
Totals ----->	204	113	4628	0.11	0.03	1.79	\$31.30	\$1,700.02	\$345.13	\$2,076.46	\$0.47	

Figure 4. An all-building summary report using color coding to display energy consumption deviations.

As shown in Figure 4, an all-building summary report provides timely analysis across a number of facilities. In the sample report in Figure 4, each building’s consumption of chilled water, steam, and electricity is shown in terms of total consumption, units per thousand square feet, dollars per thousand square feet, and totalized numbers for dollars per hour and dollars per thousand square feet across all the utilities. Because these numbers are updated hourly and each energy meter is baselined, the report automatically flags areas of high consumption by coloring those cells yellow or red. Areas of low consumption are flagged using different shades of blue. Using this report, energy managers can target areas of above-normal energy usage based not only on total consumption but also on which buildings are costing the most money due to their problematic behavior, simplifying issue prioritization.

Using a similar methodology to the all-building summary report, other real-time commissioning reports can provide system information with even more granularity. An air handler exception report, for example, shows the temperatures, valve positions, and damper positions of each coil to determine whether they are heating and cooling a space at the same time for all the air handlers in a building. This report can take the temperature at every stage and compare it to the valve position for that stage. So if a valve sensor says that a heating coil is shut, the system should not see a significant temperature increase after the heating coil. If

such an increase is identified, a color-coded notification, such as those used in the all-building summary report, is used to flag the issue.

Other similar commissioning reports can also provide sophisticated diagnostics on critical building or manufacturing systems. So when an energy manager determines from the all-building summary report that a certain building requires closer examination, the manager can quickly see if an air handler, VAV box, heating, cooling, or other system is causing the problem. Drilling down into specific systems allows for real-time commissioning, similar to the continuous and MBCx processes, but with the benefits of more systems connectivity and flexible analysis and visualization tools that can be adapted to the meet needs across different facilities.

2.4 EEM System Data Visualization

As previously reviewed, visualization of energy data is a critical component of finding energy savings. The EEM system provides several methods of data visualization, including report generation using Microsoft[®] Excel spreadsheets, publication of reports to the Internet using a web portal; data trending; XY analysis tools; and interactive, highly graphical dashboards and key-performance indicators (KPIs).



Figure 5. A graphical building dashboard displaying energy consumption and emissions information.

A sample graphical building dashboard is shown in Figure 5. The dashboard provides the end user with various historical and real-time data for any building across the institution's facilities. The data in the dashboard includes historical data for the past month for each metered utility in the building and for total utilities in terms of dollars above or below their baseline trend data; real-time energy data KPIs for each metered utility and for total utility data along with threshold values for in-specification (green), warning limits (yellow), and out-of-specification (red) conditions; building heating versus cooling data that shows if heating and cooling loops are conditioning the building at the same time; CO² emissions for the past

24 hours by utility; total CO² emissions for the past 24 hours; and total population density across the campus and CO² emissions for the past 24 hour per person.

This type of building dashboard can provide information not only to energy managers but also to building occupants. Because automated collection of energy data makes the visualization of that data an essential part of an energy system, graphical dashboards provide a useful method for doing this and can be adapted for different audiences to communicate the relevant data in the most meaningful way.

3 Conclusion and Recommendations

This paper has reviewed the fundamental requirements of an EEM system's design and has offered discussion on various components from several EEM system implementations. Although each system implementation had a unique project scope, the objective has been the same – driving energy efficiencies. Further documentation is required to provide details for specific EEM system implementation results, but the outcome from utilizing an EEM system for energy management has typically shown first-year reductions in energy consumption at campuses, large facilities and manufacturing plants in the range of 10 to 23 percent. In addition, EEM systems allow for facilities to sustain the savings achieved and to continually obtain more energy efficiency from buildings and equipment each year. These sustained savings have frequently led to a payback period for the EEM system in less than a year, although this also needs to be examined and discussed in detail in future documentation.

While the aspects of the EEM systems described have already gone through several evolutionary iterations, further development is still required. Of particular importance for future work will be establishing best practices for the development and maintenance of energy baselines and models. Although past work has provided a solid starting point for a general benchmarking methodology, the type of real-time baselining the EEM system makes possible, as described in this paper, requires new discussion and research. Other work remains to examine the specific system designs that are best suited to different types of operations, such as campuses, large facilities and commercial buildings, and for manufacturing plants, in particular. Providing manufacturers with the fundamental EEM system functionalities can help industrial companies significantly reduce energy consumption per good or batch produced. Regardless of a facility's purpose, it is clear that because an EEM system integrates the connectivity of disparate data systems with modeling, commissioning, analytical, and visualization functionality, it offers a powerful set of business intelligence tools for achieving energy-efficiency goals.

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