# INTERNET-BASED BUILDING PERFORMANCE ANALYSIS PROVIDED AS A LOW-COST COMMERCIAL SERVICE

KRISTIN HEINEMEIER, PH.D, P.E.
PROGRAM MANAGER
HONEYWELL, INC.
MINNEAPOLIS, MN

WILLIAM KORAN, P.E.
SENIOR ANALYST
HONEYWELL, INC.
PORTLAND, OR

## ABSTRACT

Internet-based monitoring services can play a very important role in reducing the energy consumed in commercial buildings. They can provide the information needed to identify improvements that should be made in the operation of particular buildings or pieces of equipment, and to justify the expenditures needed to make those improvements. This type of information has typically been very difficult to obtain from a facility manager's position. There is a need for services such as these in the marketplace, although some of the considerations that must be made in designing, marketing, and providing a cost-effective and reliable service are not always apparent to buildings researchers. This paper describes some of those considerations, and shows an example of how one service already in the market has addressed them.

## INTRODUCTION

Monitoring, performance analysis, performance metric tracking, and fault detection/diagnostics are all very promising technologies. The potential benefits of such technologies are attractive: reduced energy use and costs, as well as reduced operating and maintenance costs and more effective energy management practices. Information technologies can enable information-based applications to make very substantial improvements in the performance of commercial buildings. While the Internet is an important enabling technology, it is merely the communication backbone upon which real value-based services rely. In order to make a commercially viable product or service based upon Internet technologies, significant focus must be placed on the applications provided; on clarifying and maximizing the benefits to the customer, as well as minimizing the cost to the provider of providing the product or service.

This paper identifies the potential benefits from Internet-based building information, monitoring, and performance analysis services. It also discusses the constraints that must be addressed for these types of services to become common-practice. Some of the issues that must be addressed include clearly defining the intent of the system and what its role is in supporting decision making, identifying reliability requirements, user interface and notification mechanisms, and evaluating overall life-cycle system costs and benefits.

As an illustration of these benefits and constraints, the paper describes one service that is currently available to provide these kinds of enhanced information-based benefits. The service is a cost-sensitive monthly subscription service aimed at large chains of relatively simple buildings. By subscribing to this service, customers can view up-to-date performance, weather, and benchmark data in graphical and report formats. Service center analysts also view and analyze these same data and recommend operational changes to improve performance. Several types of analysis tools are brought to bear in making these recommendations, including automated data review and notification routines, on-line analytical processing technologies, advanced graphics, and modeling techniques.

The paper describes the hardware needed, the overall system architecture, and the operational processes required to deliver the service. Special emphasis is paid on how monitored data are reviewed and analyzed to provide concrete savings for customers. The analysis process is discussed, along with identification of the analysis applications developed to support the process.

## BACKGROUND

Researchers have proposed and demonstrated that information-based applications are an important tool in managing energy costs in commercial buildings and to reduce energy consumption and its associated environmental impacts (see for example, Brambley and Pratt, 2000; Claridge et al., 2000; Fryer 1996, Komor 1996, Olken et al., 1996; and Piette et al., 2000).

Such monitoring and information-based services can provide substantial benefits to customers, including reduced energy consumption, reduced maintenance costs, and improved decision support. You can't manage what isn't measured, so monitoring is an essential part of modern energy management. Monitored data can support many building activities such as commissioning, fault detection and diagnostics, load disaggregation, utility load aggregation, and enterprise energy management.

The next step in the advancement of this area of research is to insert these technologies into commercial practice: commercial vendors must begin to find ways to sell this technology at a profit if they are to have any impact on the state of the art. However, providing these kinds of products or services profitably on a large scale requires a vendor's attention to many different issues that have not been addressed by smaller pilot studies or demonstrations.

Customer

Who is the customer (i.e., purchaser)? Are you targeting the right customer set (size, complexity of buildings, organizational structure, incentive placement)? Do you understand the needs of the customer?

Product

Is it a product or service? Who will use it (manager, building engineer, outside expert)? What information does it provide to the user? Can it be used to implement identified changes?

Cost

What is the cost to the customer (one-time or recurring)? What does it cost the vendor to supply the product or service? What are the costs for hardware, software development, installation, configuration, maintenance, analysis, and communication? Who pays for what? Can it be offered on a shared savings basis?

Equipment

What equipment is installed? Can existing equipment be used (e.g., existing Building Management Systems—BMSs)? If existing BMSs are used, how will the different proprietary communication protocols be handled? How will data be retrieved from the site at the lowest cost?

Information Provided

What information is of interest to the customer? What data must be monitored to provide this information? Is raw data or analyzed information provided? To whom is it provided? Is it provided via canned reports or an ad-hoc tool for customer use? Is it provided as tables, graphs, and reports? What context is needed to interpret the information? How much detail is provided? Is current information needed, or historical summaries? Is an outside expert required to help the user interpret the information?

User

Who is the user? Do you understand the needs of the user? What decisions does the user make that require support from an information-based tool? Can the user act on the information that is provided to improve operations?

Central Analysts

If central experts are used to evaluate data, how will they get contextual information about the site? If they identify improvements that should be made, can they make changes, or will they convey the opportunities to the customer? How will they communicate to customers what they have found or done? What kind of analyses will they carry out? What types of situations will they be able to detect?

Software

What type of preprocessing must be done on the data before it can be analyzed by a program or by a person? How can data quality be assured? How will data be stored? How much configuration is required? How easy is it to develop new applications?

Scalability

What kind of architecture and equipment will be required to ensure that the system will have adequate performance with the expected number of customers? What if the number of customers doubles—how will the system have to be altered?

Maintainability

What kind of staff will be required to maintain the system, including both equipment installed at individual sites, equipment in the central monitoring site, and data and software? It must be designed for redundancy to provide 24/7 availability. What kind of redundancy is required to ensure that downtime is minimized? Will you have the ability to monitor large-scale system health for troubleshooting?

Security

The system must ensure the confidentiality, privacy, and integrity of information. How can you ensure that no one can access customer data? How will you manage the users that are allowed to use the system?

If these types of issues can be adequately addressed, a vendor can expect that there will be a substantial market for this service. The next section presents an example of an internet-based monitoring service that has addressed some of these considerations.

## A CURRENTLY AVAILABLE MONITORING AND ENERGY INFORMATION SERVICE

There is one service that has recently become available that addresses many of these concerns. The Honeywell Atrium™ service monitors all of a customer's facilities, and helps to manage energy costs enterprise-wide. The key phrase used in marketing this service is "Rise high enough to look down," indicating that this service provides information at a detailed level for decision makers at every level in an organization, who typically lack such detailed information presented in a useful way. This service is being marketed to chains of buildings, which are unique in the complexity of the task of managing energy enterprise-wide, if not in the complexity of individual buildings.

This service is provided on a subscription basis: customers pay a monthly fee for each site monitored. Equipment is installed at each facility to monitor energy consumption via installed energy meters, and building operational parameters via a gateway to the BMS. The monitoring equipment and other aspects of the system architecture are described in more detail in the next section. There is a one-time setup fee for this monitoring equipment. From that point on, building owners, facility managers, corporate energy managers are all able to view the performance of each building within their responsibility on a website, over the internet.

The information on this website is provided in a number of ways. A report on the main page identifies the items most relevant to the customer for all the buildings in his or her domain: year-to-date energy costs, energy and operational savings, and the best- and worst-performing buildings in terms of energy costs and alarms received. These summary indicators lead to a series of informative reports that summarize the data and put them into a format that will be most helpful to users at any given level of responsibility. There is also a charting tool that allows users to view the trends and relationships in performance indicators for individual buildings or aggregations of buildings at any of a number of different timescales (see Figure 1). The website also has information on individual pieces of equipment at each facility, including a graphical depiction of the equipment along with the points associated with it (see Figure 2). On this page, the customer has the ability to view current status and historical alarms and override settings at the site. There are also links to software applications for utility bill tracking and vendor management, enabling managers to manage this information as well.

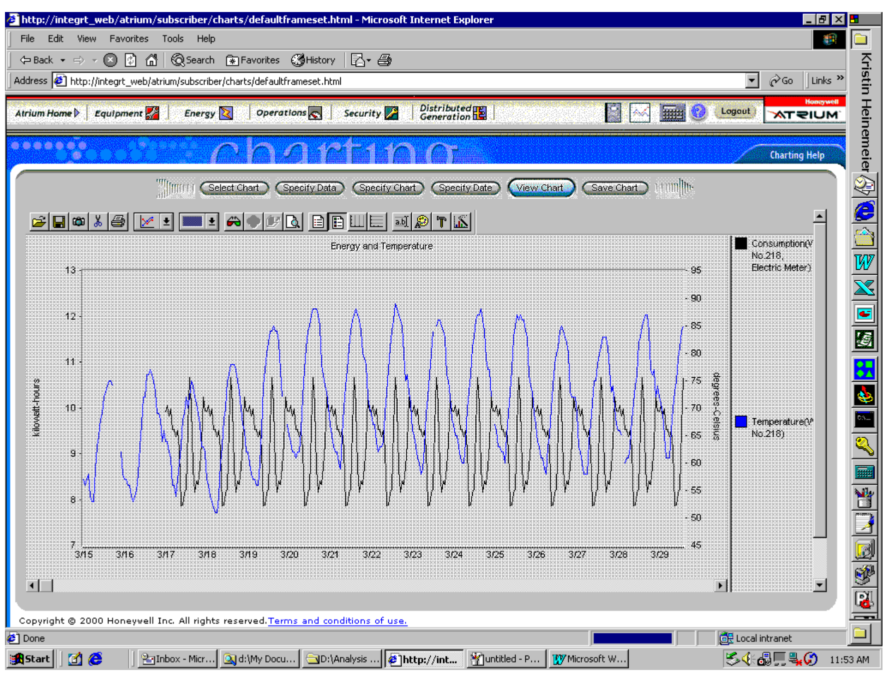


Figure 1. Charting Data on Customer Website.

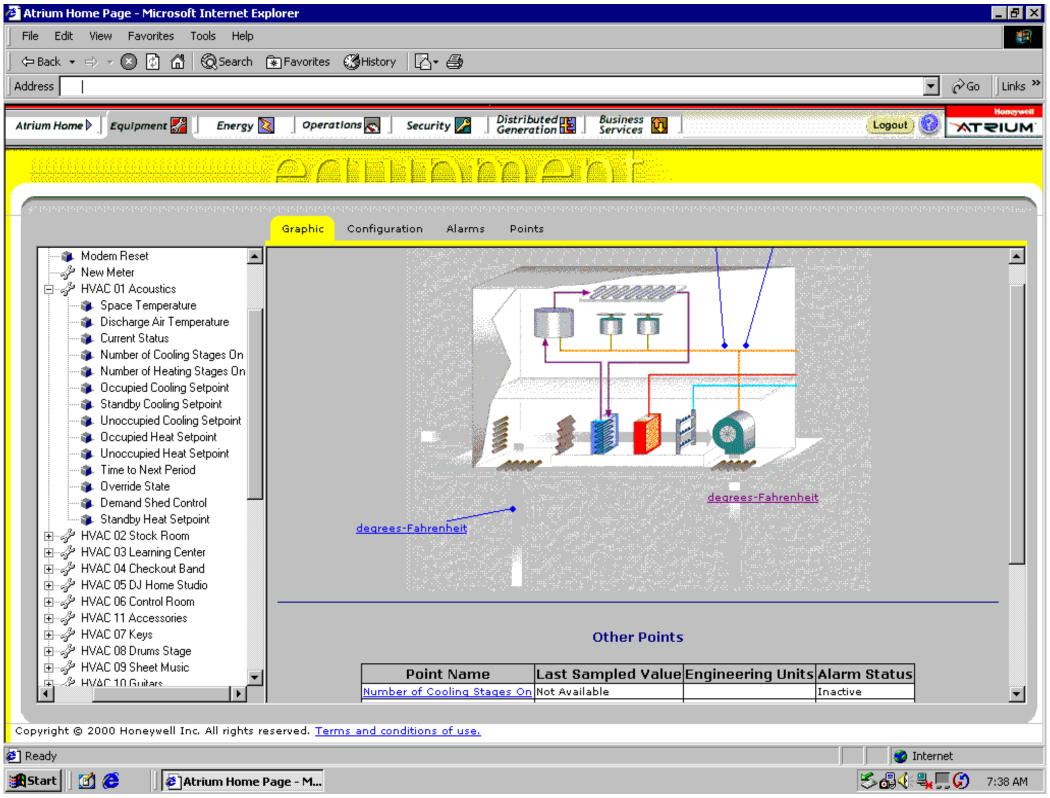


Figure 2. Equipment information on Customer Website.

Aside from this Customer Website, one of the most important aspects of this service is a staff of expert analysts who review the data coming from the buildings, and recommend changes to the building and its operation that can save energy or operational costs. These analysts all have a background in facility management, energy retrofit, building equipment, and building energy analysis. They have more experience in data analysis than the typical building engineer, and have access to advanced tools to help them analyze the collected data. When they identify a change that would save costs at a facility, they communicate this to the customer via a report on the customer's web page.

If additional services are required, such as building commissioning, more detailed audits and surveys, implementation of the improvements identified by the analysts, or inclusion of additional datastreams, these services can be provided at an additional fee.

This service uses advanced tools (described later) to take the mounds of data that can be collected at a building and make them more useful to building personnel. They give those responsible for buildings the information that they need at the level they need it in order to make better decisions. Armed with this information, facility managers can readily identify which buildings to focus on at any given time, and can review their progress towards goals. Building staff can take this information and identify the best ways to save energy. This service can also cut maintenance costs.

Despite the obvious value this service has to customers, it is key that this service offering be provided at a low price. Efforts made to keep the costs low included minimizing the cost of the monitoring hardware installed at each site and the cost of the software development. By far, however, the most important element in keeping costs low is streamlining the process for delivering the service. This process includes installation of equipment at each site, collection and input of site information needed for data analysis (this includes information on users, customer structure, building information, equipment, and points), maintaining the monitoring and web server infrastructure, and analyzing the data to determine potential improvements in operations, and communicating recommendations to customers.

SYSTEM ARCHITECTURE

It is one thing to provide an information-based service for one or two buildings in a prototype or demonstration environment. But providing a reliable information service to thousands of customer sites requires a very well engineered system that is maintainable, available, scalable and secure. Figure 3 shows the system providing these attributes for the service.

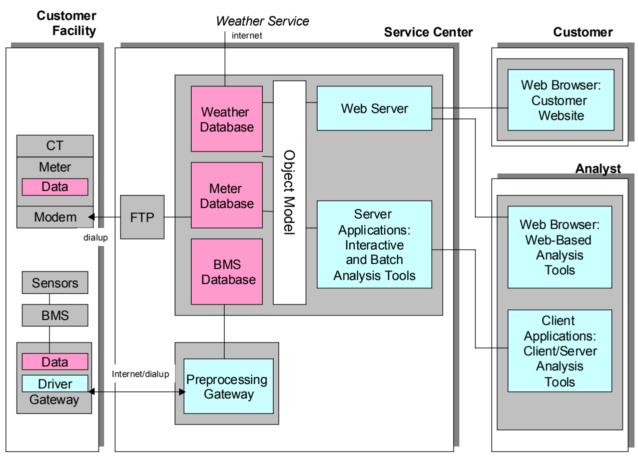


Figure 3. Description of System Architecture

## Data Collection

At each facility monitored with the system, data may be collected from meters and/or from a BMS. For power measurement, special meters are installed that integrate sensors, transducers, data storage, and communications. Meters are also available to measure gas consumption, or to count pulses off of existing utility electric meters. The data are stored for as long as needed (within limits), and on a programmable schedule, they communicate to the data collection center. This communication is accomplished via a dialup connection or via the internet if such a connection is available. If necessary, the central data collection center can also initiate the communication for collecting data.

Building operational information is obtained through a link to the existing BMS. This is done by installing a gateway at each facility. A gateway is essentially a small, low cost, single-purpose computer that communicates with the BMS, stores data, and communicates with the data collection center via a dialup or internet connection. To do this, it must have a driver for each BMS supported. Trend data are collected and automatically sent to the data collection center on a programmable schedule. Real-time alarm data are automatically sent as soon as they are received. Since customers have the ability to override settings, two-way communication is provided.

Weather data are obtained through a third-party weather service. Every day a file containing the prior day's weather data for all weather stations is downloaded to the data collection center.

## Data Preprocessing

One often-overlooked step yet essential step in providing a service such as this is the preprocessing of the data. Automation of this preprocessing is required if the delivery of the service is to be streamlined. Manual processing would be costly and inefficient. Preprocessing in this system consists of putting the information into a standardized format, regularizing the time-series data, and ensuring data quality.

In an effort to make the system more open, this system collects data in a standardized format, which is based upon BACnet. This software gateway translates information collected at each site in its own proprietary format into a format that is standardized across sites. This can be quite challenging, since different BMSs not only speak different languages, but also represent information in such different ways. The translator must often interpret the information to fit it into a standardized format.

When data are collected, they are often not collected at a regular time interval (or often, not reliably so). The data preprocessing also includes a mechanism to manipulate energy, weather, or BMS data to provide information at regular intervals. This can include averaging (or taking a maximum in the case of demand) over short time intervals, or interpolation over longer time intervals. It also includes translation of change-of-value data (where data are collected whenever the value changes by a specified amount, regardless of the time interval) and subtraction of cumulative energy values to obtain interval consumption. When the units of measure that are collected do not match the units desired in the database, a unit conversion takes place in this preprocessing.

Finally, the quality of the data must be assessed during this preprocessing stage, to ensure that all energy, BMS, and weather data in the database are of sufficient quality to support presentation on the customer website or evaluation by the analysts. In these algorithms, missing data are filled, if possible, with reasonable values, and data that are deemed incorrect are replaced with values that are more reasonable. It is challenging, yet essential, to determine whether a suspicious reading is erroneous or correctly represents peculiar operation at the building. Some simple filters are used in this data cleaning, such as defining thresholds of reasonable values and allowable spikes. However, it was necessary to invoke more sophisticated modeling to determine allowable values based upon historical relationships between different variables and engineering judgement. In some cases, this requires input of data at the configuration stage, or tuning of the model parameters. This type of human input must be minimized, however, to streamline the configuration process. Any time a value is filled or replaced, an indicator is set so that analysts can determine whether the data they are analyzing are real or synthetic.

### Data Storage

The core of the system is the database, which serves as a repository for all the collected data and a source of data for all the applications used by the customer or the analysts. This database uses the most modern database technologies, and is designed to be scalable as more and more customers are added to the system. Its performance will have a large impact on the performance of the rest of the system.

One of the most unique aspects of the data storage in this system is the object model that was created. This object model contains the structure necessary to describe the relationships between different data included in the database, in the form of objects (such as buildings, customers, pieces of equipment). For example, there is an object called "chiller," and all configuration and monitored point data related to that chiller are associated with this object. This greatly facilitates navigation of the data by the customer and analyst, and facilitates the development of applications that make use of the data. For example, if a user wishes to chart the whole-building consumption of all buildings in the western region, this could be done very easily, without needing to specify which buildings are in that region, which meters are whole-building meters, which point on the meter represents consumption, and the physical address of that point on the gateway. As another example, a neural net model could be assigned to determine expected whole-building consumption as a function of outdoor air temperature and other site variables, without a tedious process of assigning which variables to look at. This requires a significant level of effort in the configuration stage, although it more than pays back when it comes to streamlining the analysis stage and providing a usable website for customers.

### Applications

Having high quality data stored in a database using a detailed object model, the task of developing applications to make use of the data is greatly simplified. The customer website and some of the analysis tools are based upon state-of-the-art web development tools. Some of the other tools used by the analysts follow a client/server architecture, based upon the latest distributed computing technologies. Whenever possible, third party components are used to provide parts of the software. For example, charting is based upon components provided off-the-shelf by a third-party vendor. This enables the development team to focus on specific aspects that will provide value to the customer, while relying upon others to create and upgrade these other components.

## ANALYSIS PROCESS AND TOOLS

While customers will find the reports and charts on the customer website useful in understanding the composition of their energy costs, the detailed analysis done by the central analysts is a crucial element in providing concrete savings. By manually reviewing the collected data and applying automated review tools, the analysts will be able to detect buildings that are not performing as expected and provide recommendations for how this performance can be improved. This section describes how the expert analysis process is structured, and the tools that are brought to bear on this problem.

### Process Overview

The responsibility of the central analysts includes configuring new customers, analyzing collected and input data, and making recommendations for operational improvements. Since this is a cost-sensitive service, however, analysts must respond quickly and do not have the option to "mull over" the data or to conduct analysis that takes much user intervention or configuration information that is not available. Therefore, the tools are as simple to use as possible, and they were designed to operate together. An emphasis is placed on presenting and reviewing the data in a concise and meaningful form to allow isolation of buildings that require more detailed analysis, and then applying an appropriate level of analysis to accomplish the objective of providing meaningful recommendations to customers.

The process includes configuration of new customers, review of performance metrics such as annual EUI and demand intensity to detect buildings of interest, interactive use of online analytical processing tools to further detect buildings with problems that can be resolved, setup and running of automated detection and notification routines, creating alternative operational scenarios and estimating their impact on energy; estimating the financial impacts of operational changes, and communicating the recommended changes to the customer. This section describes the tools that are used to carry out each of these tasks.

New Customer Configuration

Each new customer must be entered into the database with the appropriate information. Customers are treated as hierarchical data: customer; region, building, equipment, point. Most information is entered at the building level. Building-level data include data necessary for analysis, such as square footage and schedule. It is also possible to define unique building features that are in common for a subset of the customer's buildings. Regions are provided to provide flexibility in grouping buildings according to each customer's requirements. There are also sub-levels between each major level to provide additional grouping flexibility.

Initial Evaluation of Buildings

The analyst first establishes performance metrics for each customer. These typically are common metrics such as energy use indexes (kWh or Btu per square foot per year), base load Watts per square foot, and cost indexes ($ per square foot per year). Other, more specific metrics can also be used, such as base load during unoccupied hours.

The metrics chosen depend upon the level of information available prior to the initiation of data collection through the monitoring system. If a customer has only utility bill information, simple metrics such as EUI are used. If the customer has a history of meter data available, then all of that data is transferred into the database to use in the initial evaluation.

The purpose of the initial evaluation is to prioritize the buildings for analysis. Obviously, the buildings that are both high use and high cost get the initial attention from the analyst.

Benchmarking Tool.

With the benchmarking tool, the analyst selects whether to compare buildings based upon energy/floor area, energy cost/floor area, or demand/floor area. For energy and energy cost, the user will have a choice of electricity, gas, or total.

The tool selects buildings from an "external" data source that match the building's characteristics. The source of data includes public data--CBECS-plus the customer's other buildings, and other comparable buildings within the system that match the building's characteristics. The characteristics criteria include business type, CDD and HDD, operating hours per week, and square footage.

The analyst can omit any buildings he or she does not think are sufficiently representative.

Online Analytical Processing

Another step in reviewing the mass of data to identify buildings that require additional analysis is performing "Online Analytical Processing," or OLAP. OLAP facilitates interactive review of data, by preprocessing the data and storing them in an intermediate database (referred to as a multi-dimensional "cube"), which can be queried by an end-user much more easily than the original database. This permits "slicing and dicing" the data, via aggregation and disaggregation across any defined "dimensions" or groups of dimensions. Dimensions are different views of the data—independent ways that data values can be aggregated or disaggregated. For example, an analyst might need to look at the demand of all of an owner's buildings together, or just the total demand for the owner's buildings in Texas. The analyst might wish to only look at operation for ambient temperature between 50 and 60 °F.

The ability to compare benchmarks is facilitated by OLAP. The values for the common performance metrics are calculated using automated OLAP Tools. Figure 4 shows a histogram of energy use that is one way that an analyst reviews the overall performance of a customer's buildings. (The benchmarking tool generates a similar histogram, but includes buildings outside the customer's data set.) For example, the histogram in Figure 4 was generated for the customer's stores in only one state, using the following criteria: all occupancy, all temperature bins, all daytypes, all times of day, year 2000, month March, all dates.

There is flexibility to generate the histogram for just occupied hours, particular daytypes or day of week, for a particular date range, or even for a temperature bin. This flexibility assists comparisons with a reference data set.

Exploring the data by changing the criteria and regenerating charts helps the analyst understand the

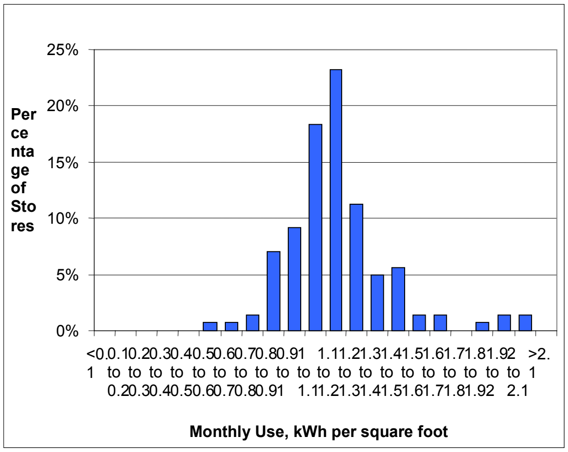


Figure 4: Histogram Presented in Online Analytical Processing Tool

similarities and differences between the customer's buildings. With this understanding, the analyst is better equipped to move on to the next step, which is to set up the criteria for routines that automatically detect unusual or energy-intensive behavior.

Automated Alarming and Notification

Another way to identify buildings that require additional analysis is to set up automated reviews of the data, with notification upon detection of discrepancies. A sophisticated data review and alarming tool was built to accomplish this. This tool periodically takes cached data from multiple buildings, and looks for deviations from specified criteria. When events occur, the tool notifies the analyst via e-mail.

All element definitions allow some kind of a comparison and a duration that must be met, i.e., Point1 is more than 10 °F higher than Point2 for longer than 30 minutes. All Event definitions also allow optional checking against occupancy status, time-of-day range, and day of week or month of year. The tool also permits the user to request notification in the event that a point is more than *x* standard deviations from the mean, and the time period over which the mean is calculated can also be specified..

For example, Figure 5 shows a sample screen shot from the alarming and notification program, in which the user has defined a condition where the instantaneous demand point's value is more than 12 kW above the mean value of the average demand point over the previous three days. Not shown is the configuration page where the duration of 30 minutes is selected. The program will evaluate this condition every day with the previous 24 hours of data, detect cases where the condition persists for more than 30 minutes and notify the analyst.

The analysts initially create conditions that are universal across the customer's buildings. For example, the analyst could use the OLAP tools to generate typical load profiles showing the range of normalized demand for different hours of the day, for different daytypes, and for different temperature bins. Then, the analyst would use the alarm and notification tool to create events to be notified whenever demand was high for the combination of hour of day, daytype, and ambient temperature. After more experience with individual buildings, these general events are modified to a narrower tolerance for each building, and additional events are defined as required.

Automated Pattern Matching and Notification

Another tool used to automatically detect unusual behavior of the monitored buildings is an automated pattern matching and notification tool. This tool allows the user to define expected "shapes" for the data. If the data collected from a building matches this prototypical shape within a specified variation in amplitude and duration, and to a specified "goodness of fit," then the analyst is notified by email. Alternatively, it can be configured to notify the analyst if the shape *does not* match the reference shape.

The tool can also be used interactively, and the matches for multiple data sources can be viewed simultaneously. Via this tool, pattern matching can also be used as criteria within the alarming and notification tool.

Shapes to be matched can either be defined manually—through a graphical interface—or can be defined by browsing through collected data to determine either normal or abnormal behavioral patterns. Shapes can be stored in a library for use with other data.

A sample screen shot from interactive use of the pattern-matching program is shown in Figure 6. Here a suspicious pattern in the data has been highlighted by the user, and the data from other buildings will be evaluated for similarity to this shape. If the user decides that this pattern is one of interest, he or she can save it and those buildings' data will be automatically reviewed every day, and the user will be notified of any matches.

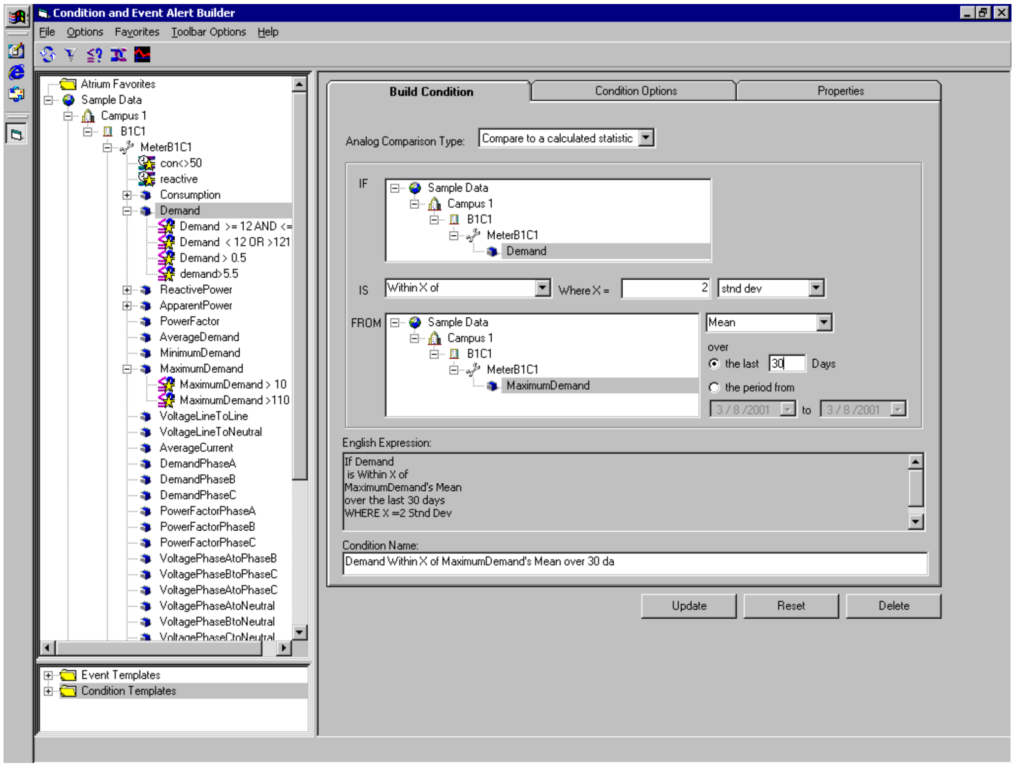

Figure 5: Alarming and Notification Tool

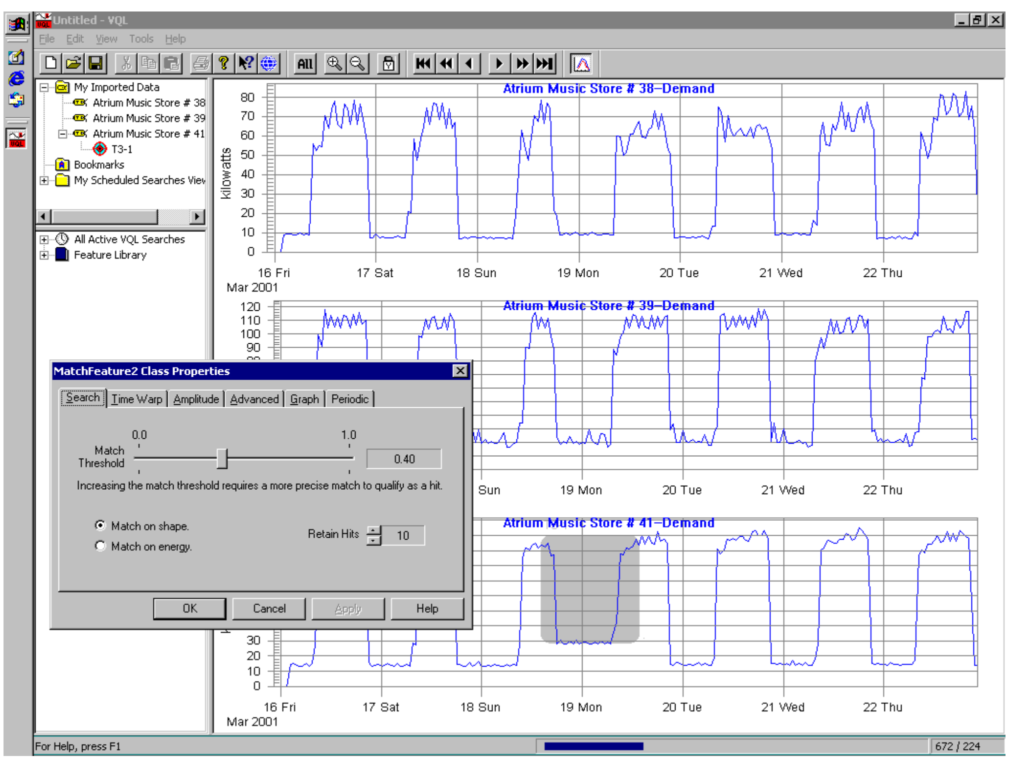

Figure 6: Pattern Matching and Notification Tool

Energy Impact

Once abnormalities in a particular building have been identified, the analyst estimates the impact that this behavior is having on the building's energy use—or the energy savings that could be achieved if the performance were improved. This is done by modeling the impact of any improvements to the equipment's or building's operation. To facilitate estimating the financial impact of changes, the modeled impact must be output as a modification to the building's daily load shape, and doing the bookkeeping of summing these daily impacts over a typical year. Daytypes, weather, and other available parameters affecting energy use are accounted for as appropriate. This impact assessment might be considered very rudimentary, but this level of calculation is appropriate given the overall objectives and constraints of the service.

Financial Impact

After calculating the energy impacts, the next step is to estimate the financial impacts of improvements to the building's operation. This is done using a "rates engine" to enter the rate structure for a particular utility, and inputting interval load data. Two techniques are used for financial impact assessment in this service. In both methods, two hourly load shapes are entered for a given building, for a month: as-measured, and a synthetic loadshape. Two cost calculations are performed, and the difference is the savings.

In the first method, the synthetic loadshape is determined from the modeling in the Energy Impact Tool. In the second method, a hypothetical loadshape is created representing a set percentage savings in any of the billing determinants—consumption tiers, time-of-day rates, etc. The marginal savings for that percentage is the result of the difference between the two rates calculations. Expected cost savings for a particular cost-saving measure will be estimated by applying the appropriate percentage to these marginal savings.

There are several important issues related to rates calculations. First is the challenge of keeping a rates database up-to-date. In this service, rates libraries are maintained by a third party. The second issue involves the desire to do real-time financial calculations. It is sometimes desirable to calculate costs mid-month. This can be done, although it must be recognized that energy costs have little meaning except on a monthly basis, since demand and tiered energy charges often require a full month of data, and ratchet charges may require a year of data.

Recommendations

Since central analysts are not responsible for implementing potential improvements, but merely to communicate them to customers, the final step in the process is to accomplish that communication.

Analysts use an online tool to enter recommendations for operational improvements into the database. Each analyst can input or view all the recommendations for a single customer, for a region, or for a single building. For each new recommendation, the analysts record their observations and attach supporting evidence. They then enter the recommended action. Finally, they enter the expected gross savings by month, and the number of months the improvement is expected to provide savings. Since the analyst has no way of knowing when throughout the year the improvement will be implemented, a full "prototypical" year of savings is entered.

From their website, customers can review all the recommendations that have been made, and record the implementation date for those that have been implemented. The relevant months of savings are extracted from the "prototypical" year of savings to report on expected savings, which is made available to be included in some of the other management reports available on the website. Actual savings are not tracked or reported, since that is beyond the scope of the service. From this page, the customers can also send an email to analysts, communicating their impressions of the recommendations.

Notes

One final tool used by analysts is a note-taking tool. This allows the analyst to record memos to him or herself, to help in subsequent evaluations of the building's performance. These notes are stored in the database along with other building information, so that other analysts also have access. Some notes are also published to the customers, allowing them to get information from analysts other than recommendations. This is an important mechanism to let customers know what is happening with their data, even when no anomalies are found.

All of these tools help organize the process of analyzing buildings. Of course, many other tools are used in a more ad-hoc basis by analysts, but one of the big requirements of the system is that multiple tools can be used together with minimal reconfiguration or re-entry of data. This has been accomplished with the current architecture.

## CONCLUSIONS

Information technology is one of the fastest evolving technologies in the U.S. economy, and one of the most important new technologies for energy management in commercial buildings. The explosion of internet-based commerce and information applications is beginning to make its way into the buildings sector. Fryer (1996) and Komor (1996) provide excellent reviews of the applications that are possible. Researchers have made great strides in demonstrating the potential of these types of technologies for reducing the operating costs of buildings. The next step in developing a technology such as this is ensuring the entry of associated products and services in the marketplace. Researchers look to industry to provide the knowledge of how to make successful products based upon the applications they have developed.

The considerations that must be made in designing and delivering an internet-based monitoring system include: identifying the appropriate customer set, defining the nature of the product or service, identifying all the costs and who will bear them, defining the equipment that must be used, elaborating on the information that will be provided, identifying the user, defining the need for central analysts, and what considerations they will require, addressing software concerns, ensuring scalability in the system, ensuring maintainability in the solution, and ensuring security of customer information.

Considering these issues in the early stages of product development will ensure that the product that is presented to the market will be successful. These issues can also be addressed by researchers as they develop prototypes and engage in demonstration projects, to help in attracting the interest of potential commercializers.

An example was presented of a service that was recently made available to the market. This service is an internet-based information service provided to commercial building owners and managers—especially to enterprises consisting of multiple distributed facilities. It consists of installation of meters and gateways to existing BMSs (for equipment operation information). Data collected from the sites via dialup or internet connections are stored in a scalable database. This database features a detailed object model that facilitates configuration and application development. For a monthly service fee, customers at any level of the organization can access information from their site over the internet. The customer's web page provides a manager's summary, more detailed reports of all key indicators, a view of equipment operation, and an ad hoc graphing tool. In addition, this service includes central analysts, who evaluate the data collected from the building, and use more advanced tools to analyze performance and make recommendations on possible improvements.

So far, this service has been very successful in the market. Customers have recognized the value of the service, and the unique perspective the service will provide them. Its long-term success, however, will depend greatly on how well the delivery of the service addresses considerations such as those presented in this paper.

## REFERENCES


Brambley, M.R., and R.G. Pratt. 2000. *Using Automated Diagnostic tools to Provide Energy Services*. ACEEE Summer Study on Energy Efficiency in Buildings, Asilomar, CA.

Claridge, D.E., C. H. Culp, M. Liu, S. Deng, W.D. Turner, J.S. Haberl. 2000. *Campus-Wide Continuous Commissioning™ of University Buildings.* ACEEE Summer Study on Energy Efficiency in Buildings, Asilomar, CA.

Fryer, L. 1996. *Tapping the Value of Energy Use Data: New Tools and Techniques."* E-Source Report SM-96-3.

Komor, P. 1996. *Online Energy Services for Commercial Energy Services*. E-Source Report SM-96-4.

Olken, F., C. McParland, M.A. Piette, D. Sartor, and S. Selkowitz. 1996. *Remote Building Monitoring and Control.* ACEEE Summer Study on Energy Efficiency in Buildings, Asilomar, CA.

Piette, M.A., S.K. Khalsa, and P. Haves. 2000. *Use of an Information Monitoring and Diagnostic System to Improve Building Operations*. ACEEE Summer Study on Energy Efficiency in Buildings, Asilomar, CA..