Using Key Performance Indicators To Manage Energy Costs

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ABSTRACT

Modern management systems rely heavily on information technology to set goals, track performance, and communicate results. Energy management approaches (such as those offered by the US Department of Energy and Natural Resources Canada) and measurement and verification protocols (such as IPMVP 2001) often highlight the importance an information system has in maximizing results. The increasing adoption of energy information systems has led, however, to an interesting paradox: while it is now cost-effective to collect much more data than ever before, many energy managers find themselves drowning in the volume of data generated.

Business information systems faced a similar challenge a decade ago, and it is now common practice to use key performance indicators (KPIs) to summarize volumes of data into a few critical "nuggets" of actionable information. These KPIs provide both the metrics that will be used to determine the success of a business plan as well as the timely information managers need to track performance and make adjustments to ensure success. A similar approach can be used in the practice of energy management, where KPIs can be designed to measure the success of key elements in an energy management plan and provide energy managers with the timely "nuggets" of information they need to ensure success.

This article describes how to define and use KPIs to track the performance and measure the success of an energy management plan. A framework is provided to assist in selecting measurable goals from an energy management plan and determine the raw data and processing required to generate the associated KPIs.

INTRODUCTION

Energy management practice has traditionally focused exclusively on technologies that increase the energy efficiency of key energy-consuming processes and equipment. Although there is little doubt that upgrading equipment and processes is a key ingredient to increased energy efficiency, there have always been concerns that traditional deployment practices have not resulted in consistent (and long-term) energy savings.

Many energy managers are familiar with the challenges that are associated with these wide variations in energy savings. Projects designed to reduce energy consumption can involve significant capital investment and changes to operating procedures, which means such projects will inevitably be elevated for executive review and approval. Many different projects will be competing for funding at this level, and executives will expect and demand at least an assessment of the risk involved in realizing the projected savings. Such an assessment can be challenging for energy efficiency projects because consumption is often strongly linked with variable factors like outdoor temperature and production volume, making it difficult to attribute the savings realized by these projects.

Executive teams familiar with modern management practices such as those found in ISO 9000 and Six Sigma programs will often insist that energy efficiency projects follow the management philosophy outlined in those programs. These quality management programs highlight the importance of measuring baseline performance, setting goals, and tracking performance against those goals. This approach can be adopted and applied to energy management practice, and in fact there are standards and best practices designed to increase the performance of energy efficiency projects and make the savings realized more predictable and repeatable. The International Performance Measurement and Verification Protocol (IPMVP), for example, provides best-practice methods for measuring and verifying the results of energy efficiency projects in commercial and industrial facilities [1]. MSE 2000, an energy management standard developed by the Georgia Institute of Technology and accredited by ANSI, specifies a management infrastructure for increasing energy efficiency and reducing costs [2].

One key aspect of these management approaches is their focus on setting goals and measuring performance against those goals. It is not uncommon to see organizations build a comprehensive information system to support their quality management program, and similar information systems can be built to support energy management programs. These energy information systems can be designed to collect relevant data, compensate for external factors such as weather and production volume, and provide the supporting information required to monitor the performance of energy management projects and keep them on track.

DATA OVERLOAD

Although it would seem clear that an energy information system can play an important role in reducing energy consumption and costs (and maintain those savings over time), it is also true that such systems can overwhelm their users with the volume of data they generate. The cost per monitored point within energy information systems is steadily decreasing, and it is becoming cost effective in a number of applications to build systems with hundreds of monitored points. Such systems can, however, become unusable without careful consideration of which data to collect, how often to collect it, and how to present the data collected. All too often an energy information system is simply configured to capture as much data as possible, as quickly as it can, "just in case it is needed." If only a handful of monitored points are involved, this "catch everything" approach will simply make finding useful information in the data inconvenient; if several hundred monitored points are involved, it becomes impossible to find anything of value at all!

A well-designed energy information system starts by considering which "nuggets" of information are required to support the key goals of an energy management plan. Modern business management practice refers to such nuggets of information as *key performance indicators*, and these indicators are normally defined well in advance of any data collection in order to determine the scope of data collection activities. The sections below describe how this same approach can be applied to the selection of performance metrics that support energy management practice.

KEY PERFORMANCE INDICATORS

Although it is often tempting to start planning an energy information system by considering which data to collect, it is more important (and usually more difficult!) to start by considering how the information system will support key goals in the energy management plan. If these goals are the best expression of what an organization hopes to achieve in managing its energy, then the first step is to convert those goals into key performance indicators (KPIs) that can be measured and tracked.

As an example, consider this goal statement from Executive Order 13123, *Greening the Government Through Efficient Energy Management*, targeted at U.S. federal industrial and research facilities:

> *Through life-cycle cost-effective measures, each agency shall reduce energy consumption per square foot, per unit of production, or per other unit as applicable by 20 percent by 2005 and 25 percent by 2010 relative to 1990.*

This goal states the key measurement of interest (energy consumption) and provides target levels and time frames (20 percent by 2005, 25 percent by 2010) as well as a baseline year (1990) as a reference. If data regarding total energy consumption and production volume were available for a particular facility, the following sample KPI definition could be used:

1. The baseline energy consumption for 1990 will be determined using consumption data from electricity and natural gas utility bills for the entire facility (in units of MBtu).

2. The baseline production volume for 1990 will be determined using production data from the facility manufacturing resource planning (MRP) information system (in units of tons).

3. The baseline measurement for 1990 will be energy consumption per unit of production, expressed as MBtu/ton. This value will be reduced by 20 percent to set the 2005 target (expressed in MBtu/ton) and reduced by 25 percent to set the 2010 target (expressed in MBtu/ton).

4. Metering shall be installed on electric and natural gas service points to measure total facility energy consumption. The metering data collected will be converted to MBtu and summed on a monthly basis. These monthly values shall be aggregated into an annual sum for reporting against the target levels.

5. Production volume will be reported by the MRP information system on a monthly basis. These monthly values shall be aggregated into an annual sum for reporting against the target levels.

6. At the end of each year, the energy consumption and production data described in items four and five will be combined to generate the energy consumption performance metric. This metric will be combined with others into the annual energy management performance report and presented to the executive team.

A performance metric definition like the one above provides the foundation required to determine which data to collect, how often to collect them, and how to present them. This sample definition is also careful to state the assumptions made so that everyone involved understands exactly what is being measured. Note, however, that the sample above is designed to provide only a summary performance metric that can be reported as part of an annual energy management performance report. This example definition could be further expanded to selectively provide the richer details that an energy manager would need to investigate deviations from the target goal and help keep the energy management plan on track.

Continuing with the example above, consider the expanded performance metric breakdown for energy consumption shown in Figure 1. This breakdown highlights different levels of additional detail that an energy manager can "drill down" into to understand what is driving the behavior of the defined performance metric. In this example, energy consumption is broken down into electricity and natural gas consumption (measured on a monthly basis). These measurements are further broken down into major consuming categories (such as motors, heaters, and an "other" category for electricity). In addition to breaking down consumption by type and category, greater detail may be offered in the form of shorter measurement intervals, with monthly totals breaking down into daily or even hourly intervals. The criteria for selecting which measurement details to highlight is determined by understanding the underlying drivers of the performance metric and knowing which details will give energy managers the information they need to correct deviations from target goals.

Once performance metrics have been defined and any supporting detailed measurements selected, the next step is to determine how the required data will be collected.

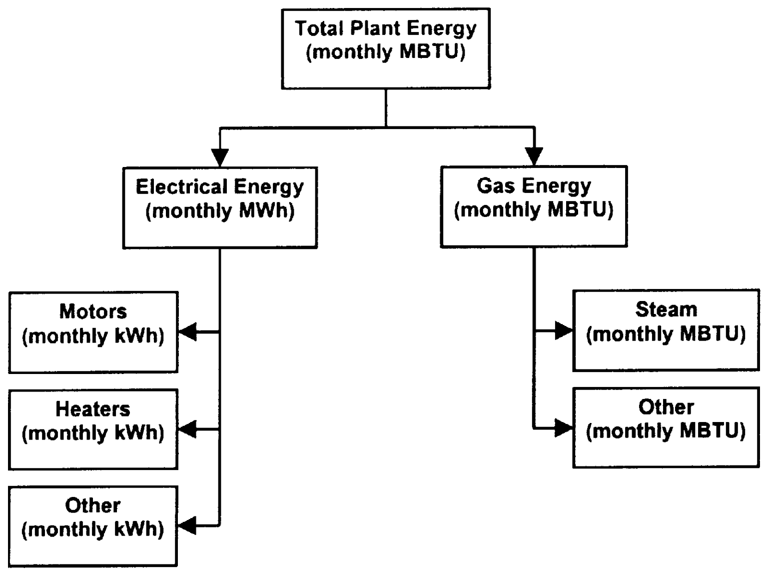

Figure 1. Expanded KPI breakdown for energy consumption

DATA COLLECTION

Compared to the potential volume of data that many energy information systems can generate, the volume required to support defined KPIs can easily be an order of magnitude less. This is not to say that energy information systems should never collect detailed data at all; it is more accurate to say that such an information system should be designed to capture just the right amount of detailed data required to accomplish the primary goals of the system.

The data that a performance metric design process (like the one in the previous section) might specify tend to fall into one of two main categories:

- *Static data such as facility floor space and equipment ratings*. This type of data is often collected as part of an initial energy audit of a facility and is typically used to normalize measurements for benchmark comparisons.

- *Dynamic data such as energy consumption, external temperature, and production volume*. This type of data needs to be collected at regular intervals and processed to generate the desired performance metrics.

Although both categories of data need to be collected, parameters in the dynamic data category tend to be more expensive to manage because there is some continuous effort involved in acquiring and processing this data. This category of data will also take up the vast majority of the total storage space in an energy information system. The cost and effort associated with dynamic data would suggest that selecting which data to collect should be done with care. Modern building or industrial automation systems may make it tempting to add a large number of measurements "just in case they are needed," but unless it serves a purpose in supporting the KPIs described above, these data will only consume unnecessary cost and effort.

Once the measurement parameters required have been selected, there are a variety of potential data sources to consider:

- *Energy consumption from utility bills*. Energy consumption totals can be keyed in from utility bills, but many utilities will also offer billing data in electronic form to their larger accounts. In addition to energy consumption totals for a billing period, some utilities will also offer load profile and other interval data.

- *Energy consumption from "shadow" metering*. If detailed energy consumption data are required but not available from the utility, a separate meter can be installed at the utility service point to "shadow" the utility meter.

- *Energy consumption from sub-meters*. Data for an expanded performance metric breakdown of energy consumption can be obtained by installing meters on major loads or points within an energy distribution system.

- *Energy consumption from existing automation systems*. Some building and industrial automation systems have the ability to integrate with basic energy meters and transducers, acquire data from these, and communicate it to an energy information system.

- *Temperature data from publications*. Public sources such as the National Oceanic and Atmospheric Administration (http://www.

noaa.gov) and the Meteorological Service of Canada (http://www.weatheroffice.ec.gc.ca/) publish a variety of temperature data.

- *Temperature data from live, online sources*. Weather services such as Weather.com (http://www.weather.com) offer live access to current and forecasted temperatures.

- *Temperature data from local measurements*. A variety of products exist that allow you to take your own temperature measurements, ranging from inexpensive thermometers to sophisticated weather stations with interval data logging.

- *Production data from existing automation systems*. Nearly all manufacturing organizations record production volume using some form of information system, ranging from "process historians" in process control systems to shipment data in material resource planning (MRP) systems.

Once the required data parameters have been defined and sources for these parameters selected, the next step is to build basic models that highlight the relationship between energy consumption and the primary driver of that consumption.

BASIC MODELING

Modeling energy consumption is a critical step on the path to constructing KPIs that accurately reflect the impact of actions taken to manage energy. Modeling building or process energy usage normally involves determining the relationship between energy consumption data and some variable (such as temperature or production activity) that represents the *primary driver* of that energy consumption. For buildings, there is normally a direct relationship between the energy consumed by a building and outdoor temperature. For production processes where energy use is largely determined by the physics of the process (such as heat-based and chemical processes), there is normally a direct relationship between the energy consumed and production volume.

The process of building basic models involves the following steps:

1. Select a *baseline period* of energy and primary driver data from the historical data collected;
2. Create and test a *baseline model* of energy vs. the primary driver; and
3. Create one or more *target models* to track the performance of an energy management plan.

Figure 2 illustrates the process and data flow involved in selecting a baseline data set and building both baseline and target models. Each of these steps is described in more detail below.

It is important to note that the modeling process described here is quite basic and will not generate robust energy consumption models in all circumstances. More sophisticated techniques for modeling industrial and commercial energy consumption are available, one example being the change-point models described in ASHRAE RP-1050, *Inverse Modeling Toolkit: Numerical Algorithms*.

Baseline Period

The data set selected over a defined length of time to represent the energy consuming behavior of some load (which may be a building or manufacturing process) before an energy management plan is

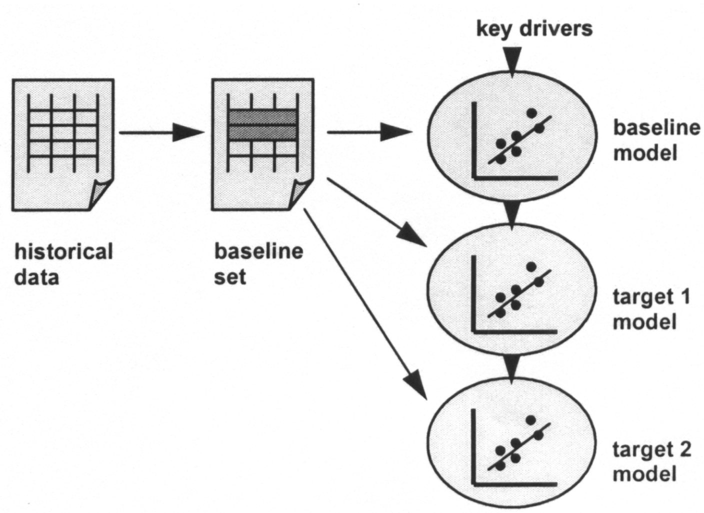

Figure 2. The process and data flow of building baseline and target models.

implemented forms the *baseline period*. This data set normally consists of two main variables: the energy consumption of a load and the primary driver associated with that energy consumption (which can include parameters such as temperature and production volume). The data collected for both of these variables will be expressed in a common interval; if energy consumption is totaled on a daily basis, for example, then production volume or temperature data needs to be expressed as a daily value as well.

To obtain the most accurate model possible, the length of this baseline period should encompass the time period required for the load being studied to cycle through its entire operating range. In the case of a building, the baseline period will normally be at least one year in length to capture the energy consuming behavior of the building across all seasons. In the case of a production line, the baseline needs to be long enough to capture normal variations in production volume.

Baseline Model

Once baseline period energy consumption and key driver data have been selected, the next step is the creation of a *baseline model* that will highlight the relationship between these two variables. A "visual" method of building this model involves the following steps: (a) create a scatter plot of baseline energy consumption and key driver data, and (b) plot a line that is the "best fit" for the points on the scatter plot. In many cases, there is a strong linear relationship between energy consumption and the key driver, and the equation for this "best fit" line can be easily determined through *linear regression* analysis.

To see how this modeling process works, consider the scatter plot of electrical energy consumption (in MWh/day) vs. production volume (in tons/day) shown in Figure 3. In this example, the energy consumption and production volume data set for the baseline period have been plotted on a chart, with production volume on the x axis and the associated energy consumption on the y axis. Modern spreadsheet software makes the creation of such charts quite straightforward—the sample chart shown in Figure 3 was created using Microsoft Excel.

The chart in Figure 3 also includes a straight line that best fits the points on the scatter plot, along with the equation (in the form of $y = \boldsymbol{m}x + \boldsymbol{b}$) that describes this line. In this equation, the constant $\boldsymbol{m}$ represents the slope of the line and the constant $\boldsymbol{b}$ represents the intercept of the line. The *correlation coefficient* (R-squared) indicates the strength of the re-

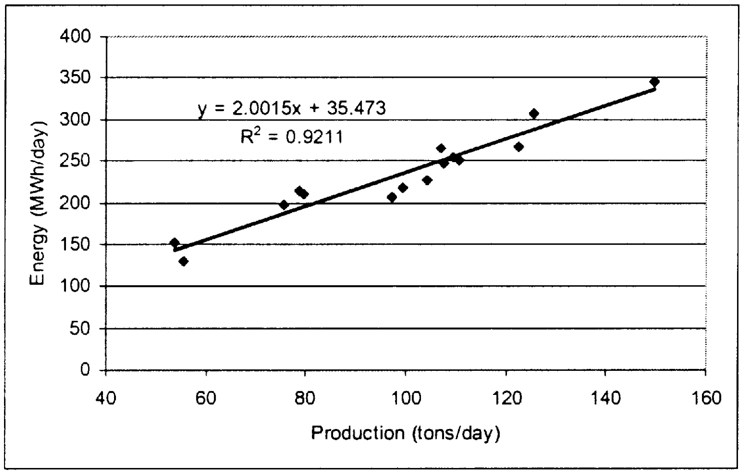

Figure 3. Scatter plot of energy consumption vs. production volume for an industrial process

lationship between energy consumption and production volume, where a value of 1.0 indicates a perfect correlation between variables. Modern spreadsheet software can be used for this linear regression analysis and will generate the straight-line equation and correlation coefficient.

Although linear regression analysis of data within a baseline period will generally result in a straight-line model with a high R-squared value, there are cases where the variables involved may not have a strong, linear relationship. The following Action Energy (http://www.actionenergy.co.uk) guides offer detailed information about the creation of baseline models and examples that demonstrate how to interpret non-linear results:

- *Degree Days for Energy Management* [GPG 310]
- *Monitoring and Targeting in Large Companies* [GPG 112]

Target Models

The role of a baseline model in generating KPIs is to provide a reference model that describes energy consumption before energy management activities are implemented. The role of target models in generating KPIs is to provide the "yardsticks" by which the success of energy management activities will be measured. These models are constructed by applying the key goals embedded in the performance metrics identified above against the baseline model to generate the reference model that ongoing measurements will be compared against.

The following examples demonstrate how two typical goals can be converted into target models:

- *Reduce energy consumption to 20 percent of 1990 levels by 2005*. Given energy consumption and primary driver data for 1990, we can select a baseline period and create a baseline model of energy consumption, as described above. The straight-line equation for this baseline model is in the form of $y = \boldsymbol{m}x + \boldsymbol{b}$, and by reducing the slope and intercept constants by 20 percent, we can create the straight-line equation for the 20 percent energy reduction model.

- *Reduce energy consumption to best practice levels within one year*. Best practice metrics are often expressed in normalized units relevant to a particular industry or application (e.g. MWh/ton for a particular manufacturing process). Assuming these normalized metrics hold true across a range of primary driver values (e.g. varying tons of production), a simple straight-line equation can be crafted to create a target model.

Figure 4 demonstrates the energy reduction target model concept by combining a sample baseline model with the Executive Order 13123 target reductions. The 20 percent and 25 percent reduction models can be expressed as straight-line equations, and these models can be used to generate a variety of charts and displays that energy managers can use to actively track the performance of an energy management plan.

Once baseline and target models have been constructed, they can be used, along with current measured data, to track the performance of an energy management plan.

TRACKING PERFORMANCE

Our final step in constructing KPIs that support an energy management plan is to build information displays using the data we have collected and energy consumption models we have created. The displays we will create typically fall into one of two main categories:

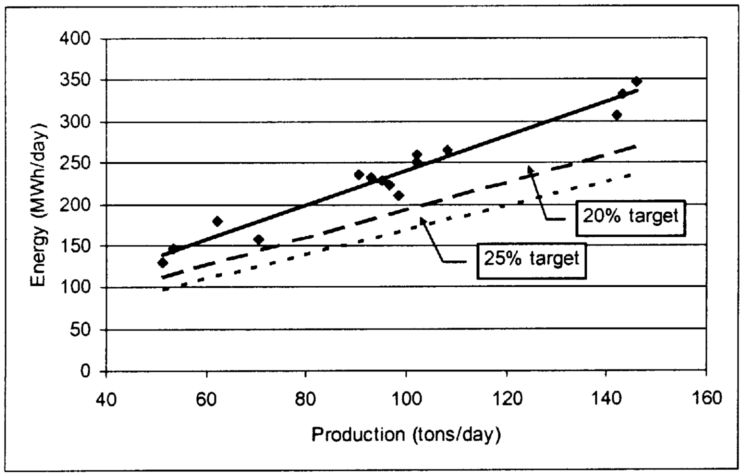

Figure 4. Scatter plot of energy consumption vs. production volume showing 20 percent and 25 percent reduction targets

- *High-level overviews of a KPI.* These concise views are designed to help an energy manager "see the forest for the trees" and are meant to provide a general indication of energy management performance.

- *Detailed drill-down view of the data behind the KPI.* These views work in concert with high-level overviews of KPIs, providing additional details about the behavior of the data behind the KPIs. These details can help an energy manager understand why an energy management plan is starting to go off track.

There are a variety of ways to display performance metric information and detailed data, and the choice of which display method to use depends on what information is being conveyed and how this information will be used. Some examples include:

- *KPIs in a table.* A table is often the best way to organize and display the high-level target numbers that support a particular KPI. A metric specifying a target goal of 10 kWh/square foot/year within four years, for example, might be shown as a table of declining target values for each of the four years.

- *KPIs in a bar chart*. Current and past performance can be visually compared against target goals using a bar chart. Such a chart may show month-by-month actual values vs. target values for the performance metric.

- *Drill-down data in a time-series chart*. To gain an understanding of what is driving a particular KPI value, a time-series chart can provide a detailed view of the data behind the KPI. Both actual and target values can be plotted over time to help an energy manager see where any deviations from plan are taking place.

To complete our Executive Order 13123 example above, consider the information displays shown in Table 1 and Figures 5 through 7. Table 1 shows possible KPI target reductions over five years that will bring energy consumption to the 20 percent reduction goal in the sixth year. Figure 5 is a bar chart comparing these target reductions against measured values on a year-by-year basis. The measured value for 2003 exceeded the target reduction for that year, and Figure 6 is a bar chart that breaks out this year into individual months. Finally, it is apparent from the bar chart in Figure 6 that the measured energy consumption exceeded the target reduction in February. Figure 7 provides a detailed time-series chart showing measured vs. target consumption on a day-to-day basis. It is also clear from this time-series chart that much of the deviation from the target goal occurred on the third and fourth days of that month.

Table 1. Possible performance metric target reductions over five years

Year	Target (MBtu/ton)
2000	27
2001	25
2002	24
2003	23
2004	22
2005	21

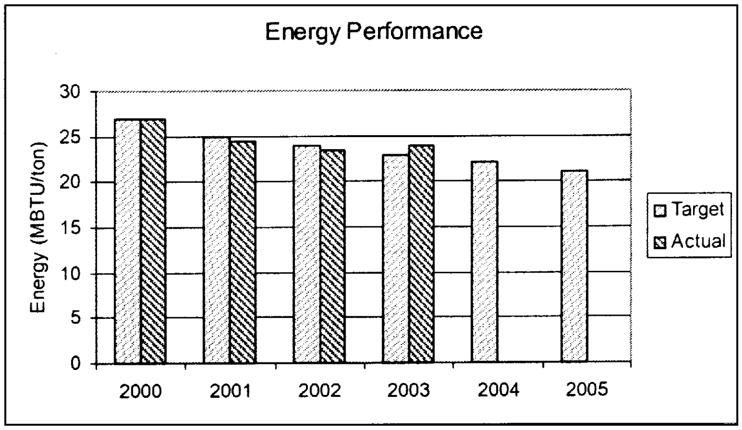

Figure 5. Annual measured and target energy consumption levels

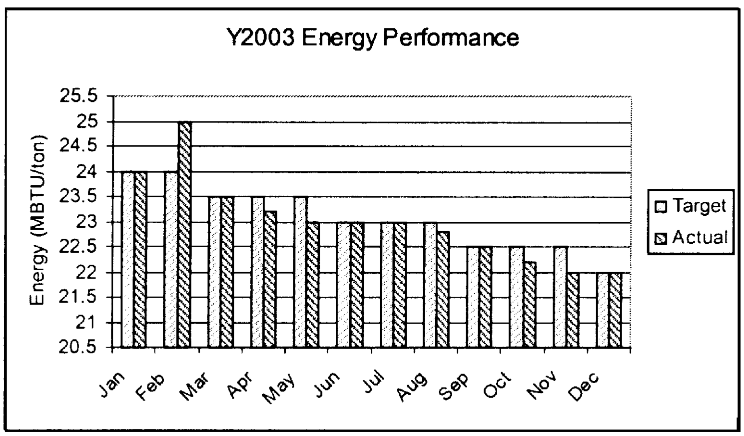

Figure 6. Monthly measured and target energy consumption levels for 2003

It is important to note that the information displays described above, moving from Table 1 to Figure 5 through to Figure 7, progress from a high-level overview of energy management performance to increasing levels of detail. By reviewing high-level KPIs first and drilling down into details only when there are deviations from target goals, an energy manager can avoid searching though thousands of data points to find the few that are of interest. This is not to say, however, that the data captured while KPIs are on track are without value; these data

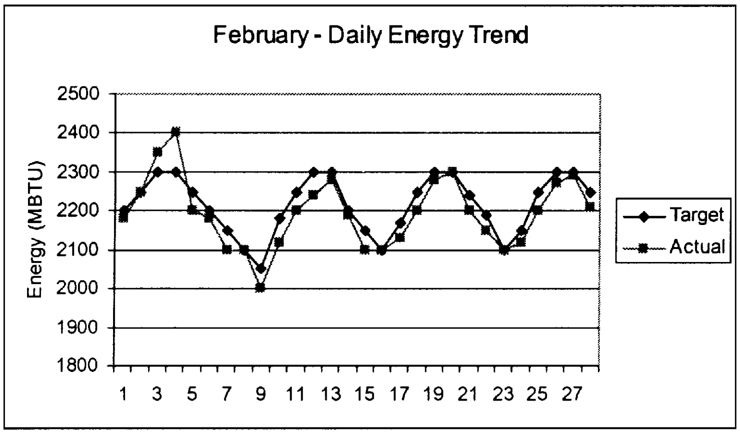

Figure 7. Daily measured and target energy consumption levels for February 2003

can be used for a variety of other tasks, including the development of operating "profiles" for monitored equipment.

It should also be noted that there can be different audiences within an organization for the different information displays described above. All stakeholders participating in the energy management plan will be interested in the high-level KPIs, and the core energy management team will be the primary audience for detailed drill-down views that help them understand deviations from planned target levels. It is also likely that the energy manager will make use of both the high-level KPI displays and select detailed displays when presenting updates to executives.

CONCLUSIONS

Energy management practice has traditionally put greater emphasis on the technology involved in energy efficiency efforts than it has on the management of those efforts. There is no question that new technology plays an important role in helping organizations increase their energy efficiency, but it is also true that projects can see increased (and more consistent) savings by adopting the performance management approach integral to modern quality and energy management programs.

Information systems are becoming a key part of modern energy management practice, especially as the hardware and software components that make up these systems become more widely available. In the past such energy information systems were often prohibitively expensive, but advances in recent years have been steadily decreasing the cost involved to monitor an increasing number of measurements. As the costs involved in automating data collection continue to drop, the "total cost of ownership" for these systems will increase on the data management and information processing side of the equation. The value of future energy information systems will not be in the quantity of data they can collect, but rather in the quality of insight they can deliver.

References

[1] *IPMVP 2001 [Volume I]*, International Performance Measurement & Verification Protocol, http://www.ipmvp.org

[2] *MSE 2000: A Management System for Energy*, Georgia Tech, http://www.industry.gatech.edu/energy/

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