Building Performance Tracking in Large Commercial Buildings: Tools and Strategies

Subtask 4.2 Research Report: Investigate Energy Performance Tracking Strategies in the Market

Submitted to:
California Energy Commission

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ABOUT THIS REPORT
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Executive Summary

The purpose of this research is to investigate the strategies and tools that building owners, energy managers, and operators use to track the energy performance of commercial facilities, and of office properties in particular. This report describes the methods, findings, conclusions, and recommendations for achieving best practices in energy performance tracking made under this research.

The research task (Task 4.2) is one of five tasks that make up a larger project funded by the California Energy Commission. The goal of the larger project is to facilitate a more rapid uptake of energy performance tracking methods, tools, and strategies into the marketplace by providing and disseminating technical research, case studies, and a Guide to successful energy performance tracking. The recommendations made in this report and in the reports from Tasks 4.3 and 4.4 will help inform the project’s primary output: a Guide for owners and operators to select the best-fit energy performance tracking management strategy and supporting technology for their buildings.

The team’s primary research methods for Task 4.2 included a comprehensive literature review, high-level phone interviews, and in-depth site interviews. The team reviewed current literature related to energy performance tracking and the persistence of existing building commissioning (EBCx) measures, including research reports, conference papers, webinars, and existing guidelines. The literature review provided a baseline understanding of current practices, benefits, barriers, and costs associated with performance tracking. To supplement the literature review, the team conducted 21 phone interviews with participants ranging from corporate executives to site-specific engineers to collect high level information on how performance tracking is performed in facilities. The team selected five of these sites to conduct an on-site interview and gain a deeper understanding of performance tracking in the field. Three case studies were created from the site visits to highlight particularly successful practices. The findings from this research were analyzed to produce recommendations for best practices in energy performance tracking.

From the research, the team identified five main categories of energy performance tracking tools:

1. Benchmarking
2. Building automation systems (BAS)
3. Energy information systems (EIS)
4. Energy anomaly detection (EAD)
5. Fault detection and diagnostic (FDD)

Benchmarking was the most commonly used method; benchmarking tools ranged from analysis of monthly utility bills (normalized for floor area and compared to a portfolio) to ENERGY STAR® Portfolio Manager. Among the interview participants, this approach worked well as long as well-defined processes and communication were in place to encourage follow-up action by staff when the tool identified an increase in energy use. Sites that used more complex EIS and EAD tools also showed substantial benefits; however, several sites had sophisticated tools that were not utilized due to challenges with management and the tool’s usability. The team found little mention or use of BAS as a primary energy performance tracking tool; however, most participants used the BAS to pinpoint the causes for degraded performance identified by another energy performance tracking tool (e.g. EIS). Similarly, our research was unable to locate many sites using FDD tools, even though these tools have been available for several years.

The research found that typical or standard quantitative costs and benefits were not available or cited for performance tracking tools. However, the research did identify general benefits cited for some installations, including:

- Energy cost savings
- Enhanced asset value from reduced operating costs
• Accurate measurement of energy savings from energy efficiency projects
• Identification of new energy saving opportunities
• Faster resolution of system performance issues
• Better understanding by operators of facility energy consumption

Many performance tracking tools were not being utilized to their full potential, primarily due to communication and management challenges. The primary barriers to successful performance tracking included:
• Vague internal policies and procedures
• Lack of resources and time
• Cost of tool installation and ongoing maintenance
• Limited communication among performance tracking team members
• Insufficient tool capabilities, such as data analysis or standardization of dashboards
• Insufficient availability of data, such as from lack of meters
• Lack of education on available tools and management strategies

Several key conclusions were drawn from the research findings. The team found that performance tracking is not widely used or well-understood. End-users typically underutilize the capability of their system, and education regarding the various types of strategies and available tools is generally lacking. The limited information that is available is focused on technical capabilities of the tools, and not on how end-users can effectively use the tools. Although some information is available on tool capabilities, there is no commonly understood and accepted framework for categorizing the landscape of energy performance tracking tools.

The team assimilated findings and conclusions from the literature review, phone interviews, and site visits to develop recommendations for achieving best practices in energy performance tracking. Choosing a performance tracking tool is an important step. Key recommendations for selecting a performance tracking tool include the following:
• Consider the needs of each stakeholder when selecting the tool and generating metrics. Higher-level metrics such as monthly whole building energy consumption (kWh/sq.ft.) may be sufficient for some stakeholders, while others may wish to see more detailed metrics such as chilled water plant efficiency (kW/ton).
• Determine whether the tool will automatically generate alerts or if data will be analyzed manually. For automatically generated alerts, set up the tool so that the alerts are timely, relevant, accurate, and actionable.
• Determine how the BAS can be leveraged to help support the tool. E.g., to diagnose identified anomalies.
• Ensure the tool has an intuitive user interface and sufficient data analysis capability.
• Integrate the tool with other processes and software wherever possible, including use of work orders to drive performance tracking-identified issues towards resolution.
• Remember that there are successful performance tracking programs based on simple tools such as ENERGY STAR Portfolio Manager.

Instituting management practices to support use of the performance tracking tool may be more important than the type of tool used. Key recommendations include:
• Develop clearly defined goals
• Develop a solid performance tracking process, including well-defined reporting protocols, specific team member responsibilities, and open lines of communication.
• Include both management and building operators on the team. Consider including tenants on the team.
• Ensure that each team member has sufficient time to carry out their duties successfully.
• Create clearly defined performance tracking goals or structure the program to help support existing goals.
• Provide incentives. Bonuses and recognition can help motivate team members.
• Report out periodically to stakeholders that are not involved daily, but would like to remain informed.

This research project gathered and distilled best practices for tools and management strategies to track building performance. While successful, there are still key research gaps that should be addressed to help energy performance tracking overcome barriers and move into mainstream practice. First, research on why owners and operators choose not to implement energy performance tracking is lacking. Second, the costs and benefits of implementing such practices need to be documented using a common methodology. Third, there should be further research on the best practices for specific management structures that maintain the motivations of all stakeholders. Finally, there is a need to develop performance tracking tools on the market to deliver the relevant functions for building owners with less effort and complexity, and with more effective integration of tools into management functions.
1 Introduction

1.1 PIER Energy Performance Tracking Project
Energy performance tracking is the process of monitoring and analyzing facility data on a regular basis to meet energy and performance goals. The benefits include energy and cost savings, accurate measurement of energy savings from existing building commissioning (EBCx) or monitoring based commissioning (MBCx) utility rebate programs, and increased awareness of facility performance. Energy performance tracking methods range in sophistication from monthly utility bill benchmarking to use of complex fault detection and diagnostic (FDD) tools.

This project is funded by the California Energy Commission. The goal of this project is to facilitate a more rapid uptake of energy performance tracking methods, tools, and strategies into the marketplace. This project will create a best practices Guide for owners and operators for selecting the best-fit energy performance tracking management strategy and supporting technology for their buildings.

The primary objectives of this project are to:

- Identify market and technical barriers to energy performance tracking, and create case studies to highlight identified best practices. (Task 4.2)
- Characterize the rapidly evolving performance tracking software tools in the market to inform and guide owner selection. (Task 4.3)
- Provide guidance for the implementation of performance metric tracking strategies in commercial and institutional buildings with best-practice analysis and easy-to-use guidance. (Task 4.4)
- Provide building owners and key market players with a comprehensive, easy-to-use, practical Guide for selecting the best-fit energy performance tracking management strategy and supporting technology for their building(s). (Task 4.5)

The project was originally designed to focus on best practices to achieve persistence of energy savings from existing building commissioning (EBCx). The project later expanded to cover energy performance tracking tools and approaches. The broadened scope reaches a wider audience, yet still achieves the goal of researching methods to track persistence of energy savings.

1.2 About This Sub-Task Report (Task 4.2)
This report summarizes work carried out under Task 4.2 between October 2009 and July 2010. Findings from Task 4.2 are included in this research report and will be used to develop recommendations that will be incorporated into a practical Guide for selecting persistence strategies (Task 4.5 deliverable).

provides an overview of the research process conducted under Task 4.2.


<table>
<thead>
<tr>
<th>Components of Task 4.2</th>
<th>Results</th>
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<tbody>
<tr>
<td>Literature Review</td>
<td>Twenty documents were reviewed to determine the state of the performance tracking industry, investigate the persistence of EBCx benefits, and identify any apparent gaps in previous work. Findings from the existing literature informed the questions posed to the participants in the phone and site interviews.</td>
</tr>
<tr>
<td>Phone Interview</td>
<td>Participants from twenty-one sites donated their time to discuss the performance tracking strategies and tools used by their respective companies.</td>
</tr>
<tr>
<td>Site Interview</td>
<td>The project team selected five sites from the phone interviews that appeared to be implementing best practices in performance tracking, and conducted onsite interviews with management and building operations staff to explore their performance tracking strategies in greater detail.</td>
</tr>
<tr>
<td>Case Studies</td>
<td>Case studies were developed from three of the site interviews to highlight best practices.</td>
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## 2 Literature Review

This section includes findings from a detailed review of literature related to energy performance tracking. The literature included research reports, conference papers, webinars, and existing guidelines. Many of the resources were academic in nature; however, a few resources included practical examples in the form of case studies. A few case studies included actual input from building operators which provided useful insights into the benefits and challenges of implementing and using energy performance tracking strategies. A detailed summary of the literature review is included in Appendix A.

### Energy Performance Tracking Strategies, Methods, and Tools Used

The material included in the literature review contained a variety of performance tracking strategies and tools. The project team identified five main tool categories used in the field, which include (ordered from least to most sophisticated):

1. Benchmarking
2. Building automation systems (BAS)
3. Energy information systems (EIS)
4. Energy anomaly detection (EAD)
5. Fault detection and diagnostic (FDD)

The term “tools” in this report refers to software that is either custom built, commercially available, or government provided.

**Benchmarking** most often normalizes energy consumption-based metrics such as weather or square footage to promote realistic comparisons with other similar buildings. In some cases, consumption from monthly utility bills is tracked to monitor the energy use at a single facility over time. Benchmarking provides a high level picture of energy use and was the most prevalent performance tracking approach mentioned in the current literature. EPA’s Portfolio Manager was mentioned often as a beneficial benchmarking tool.
Using **Building Automation Systems** for energy performance tracking most often requires the addition of energy meters and analysis or alarm capabilities. Previous PIER research projects resulted in guidelines describing how to incorporate energy monitoring into Siemens, Andover and TAC control systems (Sakurai and Culp, 2003). BAS vendors are just beginning to offer packaged solutions with integrated energy monitoring, but beyond the three former PIER guidelines, no other resources were identified that described the BAS as an option for energy performance tracking.

**Energy Information Systems** (EIS) are typically separate overlays to the existing building automation systems or stand-alone packages. EIS typically gather, store, process and display energy data, often through a web accessible interface. Most of the literature focused only on the tool capabilities while very few described how EIS were utilized by the end-users. One researcher mentioned that many of the features included in EIS packages are generally underutilized (Granderson, 2009).

**Energy Anomaly Detection (EAD)** systems provide analysis of consumption at the whole building level (top-down) by comparing whole building consumption to an expected energy profile established by simulations or by algorithms that use various measured inputs. EAD systems generate alarms when actual consumption deviates from expectations. Onsite staff must then determine the root cause of the alarms.

**Fault Detection and Diagnostic (FDD)** systems provide system-level fault detection and diagnostics (bottom-up). System level FDD typically utilize BAS points and “rule based” algorithms to detect faults at the component level. Alarms generated by FDD tools indicate system or component level faults, so building staff is directed to the problem.

**Costs and Benefits**

Quantitative costs associated with the performance tracking tools or the additional time investment required to use performance tracking systems were not widely found in the literature. One source stated that monitoring costs and required EIS upgrades were 40% of the $128,000 project (Brown, 2007). Another mentioned the most basic EIS was $2,500 to $4,000 with no other details provided (NBI, 2009). No other quantified costs were found.

The benefits listed in the literature were general in nature. Primary benefits listed included energy savings from more efficient operation and enhanced asset value due to reduced operating costs. Quantified benefits from performance tracking were not found. Assumptions such as “monitoring enhances performance” were made, but not supported by evidence. The discovery of 25% cost savings potential was mentioned in one study (Piette, 2001). However, the cost savings reported by Piette assumes that the building staff is able to act on every issue detected by the performance tracking system and that all the issues are valid. Another researcher mentioned that the use of FDD tools helped staff discover more potential improvements than were identified in the original EBCx investigation (Cunningham, 2008).

**Challenges and Barriers to Performance Tracking Adoption**

Several barriers to successful energy performance tracking were highlighted by the literature. The most prevalent barrier was stated as “time”, including the time required both to learn how to use performance tracking tools and to act on the information gathered from the tools. Resource and staffing constraints were cited as a limiting factor toward the full utilization of existing EIS tools.

A recent conference paper also noted the difficulty associated with the installation and continuous maintenance of EIS tools, which was mentioned by several resources (Eardley, 2007). Limitations in the existing BAS might also hinder the deployment of sophisticated FDD tools.
Researchers were uncertain about the ability of end-users to accurately interpret and act on data collected from an EIS (Granderson and Piette, 2009). A significant challenge also mentioned in a recent research paper was the difficulty decision-makers have in distinguishing sales information from actual usable features of performance tracking systems (Granderson and Piette, 2009).

A few of the documents from the literature review were analyzed under the original scope of persistence of existing building commissioning (EBCx) benefits. The findings from these sources apply to performance tracking in general and were included in this report. A detailed investigation into previous EBCx projects revealed a few common causes for lack of persistence, including limited operator support, poor information transfer, and lack of performance tracking (Friedman and Potter, 2002); occupant complaints caused operators to override the efficiency measures (SBW, 2010); and lack of time to track performance (Friedman, 2001).

2.1 Literature Review Conclusions
The initial goal of the literature review was to characterize the current state of energy performance tracking, identify best practices and determine any gaps in the available information. In general, the literature indicated that performance tracking was not widely used or even completely understood. Even after a performance tracking strategy was adopted and investments were made, end-users typically underutilized the capability of their system. Education regarding the various types of strategies and available tools was also generally missing. The information available was very technology-centric and not focused on the end-user. The literature available described the capability of the specific performance tracking tool but did not address the management or operational components.

Several sources recommended that any efficiency program should adopt a benchmarking strategy to gauge the impact of the program and compare future performance. To this end, EPA’s Portfolio Manager was the most widely recommended tool. Building operator training on maintaining energy performance was also recommended to achieve a successful performance tracking program. However, no single source of information was identified that provides a clear understanding of all the various energy performance tracking options for owners.

The identified literature did not cover the following topics:
- The performance tracking strategies and tools used in the industry
- The feedback from performance tracking that motivates corrective action
- Perceived cost/benefits of energy performance tracking
- Descriptions of the range of strategies available to owners

Based on these gaps and the results of the literature review, a series of questions were assembled to pose to users of various energy performance tracking strategies in a phone interview. The questions were designed to focus on areas not addressed in the existing literature. The information gathered from the interviewees was used to fill the gaps in the research to date and inform the content of an energy performance tracking guide.
3 Phone Interviews

The project team conducted 21 phone interviews to collect high level information on how energy performance tracking is achieved in the industry. The goal of the phone interviews was to build on the knowledge obtained from the literature review efforts and attempt to answer some of the observed gaps in current research. The participants were selected to cover a range of energy performance tracking methods and tools. The results of the phone interviews are presented and analyzed in this section.

The phone interview instruments are included in Appendix B. A summary of the participant responses is included in Appendix D.

3.1 Study Participants

The market segment mix of commercial office and institutional buildings that were included in the phone interview portion of the study are shown in Figure 1. The commercial office sector included a combination of portfolios and individual buildings and accounted for the majority of the interviews. Other building types included university campuses (institutional). Ten of the eleven non-portfolio candidates had been through an EBCx process in the past.

![Figure 1: Market Segment](image)

The phone interview participants ranged from national corporate executives to site-specific engineers as shown in Figure 2. During recruitment, the project team was often referred to higher-level employees to answer questions regarding performance tracking methodologies. These referrals accounted for a large percentage of corporate level and portfolio level contacts. Identifying the appropriate contact within an organization proved to be an unexpected challenge during recruitment of willing participants.
Many of the phone interview participants were responsible for overseeing the energy performance of a portfolio of buildings. As a result, specific building-related questions were not addressed. Participants were asked questions about specific buildings where applicable. Gathering a consistent data set from such a variety of respondents proved to be an unforeseen challenge. While questions related to specific buildings may have been glazed over when talking to the portfolio and executive level respondents, all participants were able to describe their energy performance tracking strategies.

**Performance Tracking Tools**

While a variety of energy performance tracking processes was observed from the participants, the top-down energy performance tracking approaches dominated. The top-down approaches, which analyze consumption at the whole building level rather than at the systems level, included various levels of sophistication that ranged from a simple manual analysis of monthly utility bills to whole building energy anomaly detection (EAD) software that compares actual to expected performance. Figure 3 provides the breakdown of the various strategies identified through this research phase. Figure 3 includes the primary tracking tool for each of the 21 participants (some sites utilized multiple strategies).
The strategies adopted by the interview participants were evaluated and classified under the categories described in Section 1 of this report (benchmarking, BAS, EIS, EAD, FDD).

The project team was not able to identify participants that currently utilize BAS for energy tracking. Several sites were identified where BAS tracking strategies were recently deployed, but none had the tracking strategy in place long enough to provide feedback for this project. Some BAS manufacturers had performance tracking ‘add-on’ packages to their core systems. However, there has been minimal uptake by the industry, which may be because it is a relatively new technology.

Sub-task 4.3 focused on system level FDD. Findings related to this category are presented in the sub-task 4.3 report.

In addition to the expected tracking strategies, the project team identified one additional category. The additional category has been classified as constant optimization. The constant optimization process used software algorithms to determine and modify system setpoints that would minimize system energy use while maintaining necessary performance.

As shown in Figure 3, the relatively simplistic approach of monthly utility bill tracking and whole building benchmarking was a prevalent performance tracking approach. The tools ranged from simple Excel based spreadsheets to EPA’s ENERGY STAR® Portfolio Manager. Surprisingly, these simple tools appeared to work well, as long as well-defined processes and communication structures were in place that supported and encouraged action related to the feedback received from the tool. One participant (a site engineer) mentioned that monthly energy data is collected and stored in a spreadsheet and sent to the energy manager, but from there he did not know how the information was used. There was no feedback to promote corrective action.

Sites that used the more complicated EIS tools for energy analysis and tools for energy anomaly detection also showed substantial benefits. However, the project team did notice several sites in which the sophisticated tools
were idle. Lack of time and lack of training were the reasons these tools were not utilized. One respondent warned not to invest in the tools if one did not have time to act on the information they provided.

Specific performance tracking tools and strategies used by the study participants, from the most simple to the most complex, include:

- Tracking monthly utility bills.
- ENERGY STAR Portfolio Manager, to monitor individual building performance and/or to benchmark against other buildings.
- Manual analysis of the last two years’ worth of energy bills, using a simple spreadsheet developed in-house.
- Monitoring real-time demand (kW).
- Software overlay of building’s main meter, to help display consumption patterns.
- Using monthly utility bills to set a benchmark ($ and kWh), which is normalized to degree-days. When consumption drifts from the benchmark, investigate the cause.
- Generating whole building usage load shapes based on utility interval data, and analyzing manually.
- Top-down fault detection system based on whole building usage and normalized to weather.
- Continuous automatic optimization software tied into the BAS for key building systems, to minimize the energy usage of those systems.

An interesting finding was the reliance on the existing BAS, even in facilities with sophisticated tracking tools and energy analysis packages. Operations staff tend to use the trending and graphical user interface functionality of their BAS to investigate alarms generated by the performance tracking tool since the most common tools typically do not diagnose the root cause of any anomaly in energy consumption. Further analysis and investigation was typically required, usually by the building operators, to determine the cause and take corrective action. One exception was the continuous optimization tool, which fed into the BAS for automatic control.

**Performance Tracking Management Practices**

While performance tracking tools provide the necessary framework and capability of the system, management practices were found to be an equally critical component to performance tracking. Goals and practices varied significantly among the participants and there was no single standout methodology. Each site adopted a practice that met their particular set of goals and motivations. Goals ranged from a general idea of the portfolio’s monthly to quarterly energy use to the desire for real-time feedback to immediately address any energy anomaly. The persons responsible for energy performance tracking ranged from onsite operators to national level energy managers.

Performance tracking strategies used by the study participants include:

- Energy manager reviews performance on a monthly basis, and meets with operators if usage increases.
- Energy manager reviews performance on a monthly basis, and has energy engineers investigate root causes. Technicians are then dispatched after the energy engineers identify the issue.
- Operators receive alarms directly from the tool continuously, and respond to them.
- Operators receive alarms directly from the tool on a daily basis, respond to them within a certain amount of time, and report back to energy manager.
- National energy manager receives alarms from the tool, and sends them to local / regional maintenance techs.
- Both the energy manager and the operators receive alarms from the tool, and the operators attempt to address the issue before they get the call from the energy manager.

The process and reporting structure for addressing alarms varied among the participants. Some participants have well-defined reporting processes for their performance tracking teams, with all members of the team informed.
when an issue is identified and resolved. Other participants use more close-ended reporting processes, where there is minimal accountability and follow-up related to detected performance anomalies.

**Costs and Benefits**

Participants were asked about the benefits related to performance tracking, but most did not have direct knowledge of the actual cost. Many of the benefits reported were also anecdotal. Many times, the energy savings quoted to the project team appeared related to other energy efficiency projects instead of the performance tracking strategy itself. One key finding was that performance tracking helps quantify the energy savings from these other projects. Another commonly cited benefit was that the tool helps operators visualize where energy consumption occurs in their building. Many participants reported improved operations of their building since the adoption of their performance tracking strategy.

Nearly all interviewees felt their tracking strategy resulted in energy savings for their building(s). Of the 15 participants that were asked if energy use had decreased due to energy performance tracking, 12 said that it had. The other three indicated that performance tracking itself did not reduce energy, but helped quantify the savings related to other efficiency projects and monitor performance over time. At the site with real time chiller optimization, implementation of the system had increased the efficiency of the chilled water plant from 1.2 kW/ton to 0.6 kW/ton.

**Keys to Success**

*Performance Tracking Tools*

The study participants noted that timely, accurate alerts from their performance tracking tools helps make their programs a success. Real-time alerts help the operators identify the core issues faster. Specific examples noted by the participants include:

- The tool assists with the quick identification of issues, and helps ensure persistence. Case study: natural gas consumption spiked at UC Davis, which turned out to be a leak upon further investigation.
- The tool generates automatic email alarms when thresholds are exceeded.
- Thresholds are set so that only the significant and relevant alerts are reported helps avoid false alarms.

Integration with other processes and software systems was also indicated as a best practice. The participants mentioned linking the tool with the computerized maintenance management system (so that a work order is generated when the tool detects an anomaly), and integrating the tool with their existing BAS.

Other keys to success cited by the participants include using accurate baselines (e.g., normalized to driving variables such as weather, and kept up to date), and allowing building tenants to log into the tool to see usage. Related to the latter, one participant indicated that occasionally the tenants call the property manager when they see red flags.

*Performance Tracking Management Practices*

The participants indicated that having a clearly defined performance tracking process, including reporting protocols and team member responsibilities, was a key to success. Participants cited the following features of their performance tracking management practices that helped achieve success:

- The reporting / tracking strategy was developed before the roll-out of the tool.
- The performance tracking process, including reporting protocols and team member responsibilities, was clearly defined.
- Lines of communication are kept open between end-users, maintenance staff, and the higher level administration.
Another key to success is the recognition that different stakeholders may demand different performance tracking methods to suit their needs. At one site, whole building monthly billing analysis was used alongside continual optimization software for key systems.

One site indicated that tenant involvement in the performance tracking process helped create a change in culture, which included Green Teams effective at fostering change and a more engrained desire for energy reduction. This participant believed that a successful performance tracking program required engagement with tenants.

**Challenges**

*Performance Tracking Tools*

Insufficient data analysis and data availability were the most common challenges cited by participants. One participant indicated that with their current tool, they lacked the ability to process or analyze data. This participant recognized that data not analyzed is useless in a successful performance tracking program. Another participant mentioned the difficulty in extracting data from the tool to conduct analysis or generate reports.

Data availability also proved to be an ongoing challenge for some participants.

- Obtaining data from the utilities proved difficult. One participant desired more proactive sharing of performance data by utilities.
- Participants expressed the need to track energy-related building inputs besides electricity (e.g., chilled water and steam usage) to capture all energy-related building inputs.
- Tools were using weather data from a non-representative location for normalizing the usage data.
- The day-after reports received from the tools were of minimal use for daily operations – real-time monitoring was more useful but not available.

*Performance Tracking Management Practices*

Many participants indicated that their performance tracking tools were not being utilized to their full potential due to challenges related to their performance tracking management strategies. Tools sat dormant because a process had not yet been established, or the tool was not integrated with work order systems. Participants noted that an installed performance dashboard did not guarantee day-to-day use in operations.

Management challenges cited by the participants often related to communication and resources. Participants indicated that limited communication among performance tracking team members hindered the success of performance tracking. For example, participants cited challenges when the performance tracking system was a corporate-based decision, with no warning to or input from engineering. In another example, goals and accountability were not established or communicated to the operations level. This indicates the need for buy-in from and communication to all stakeholders.

Insufficient dedication of capable resources can also hinder the success of a performance tracking program. As cited by the participants:

- Sufficient resources need to be devoted for analyzing alarms, taking corrective action, and reporting out.
- Non-technical energy managers without building operations experience may not be as valuable to a performance tracking program as technical energy managers.
- Policies from the top management must support performance tracking.

**Motivations for Performance Tracking**

Based on conversations with the participants, a successful performance tracking program requires clearly defined goals. These goals may tie into larger facility sustainability goals. A successful program also requires each team member to understand the benefits of performance tracking, and their role in helping to achieve those benefits.
The study participants listed several motivating factors related to performance tracking. The participants that used simple performance tracking strategies, such as benchmarking or monthly utility bill analysis, mentioned the following motivations:

- Comply with policies to save energy
- Implement good operational standards
- Achieve ENERGY STAR certification. One participant mentioned that buildings with ENERGY STAR scores just below 75 (i.e. near certification) receive special attention.
- Monitor general building performance.
- Track carbon footprint and greenhouse gas emissions.
- Increase asset value.

The participants that used more complicated strategies, such as top-down fault detection, mentioned the following motivations:

- Comply with policies to save energy
- Enact proactive energy management.
- Identify specific opportunities.
- Quantify benefits and monitor persistence of efficiency projects.

As indicated, participants with simple performance tracking strategies tend to have higher-level, more general goals (e.g. achieve ENERGY STAR certification, monitor general building performance) than those with more complicated strategies (e.g. identify specific opportunities, quantify benefits from specific projects).

Of the 14 participants that were asked if rewards were granted to staff for decreased energy use, only two responded positively. The first participant stated that spot bonuses and recognition were given to staff for reducing energy usage. Spot bonuses and recognition may be positive motivating factors that other organizations could implement to strengthen their performance tracking programs. The second participant cited that the reward for the staff member was he “keeps his job”. Operating staff at a separate site were also motivated to demonstrate energy savings since their jobs were affected by cutbacks at the organization. While not a “best practice”, job loss can be a motivator for energy performance tracking.

Participants also cited enrollment in utility programs (e.g. demand response) as a motivator. Utility programs may act as the initial catalyst for a new performance tracking program. Upcoming regulations and corporate level mandates were also cited as significant drivers for performance tracking.

### 3.2 Phone Interview Summary and Conclusions

The phone interview participants identified a number of attributes that help ensure the success of a performance tracking program. Related to performance tracking management practices, a well-defined process is key, with clearly defined goals, active communication and reporting among team members, and specific team member responsibilities. The process must address the motivations, needs, and capabilities of all stakeholders involved.

Sufficient resources need to be dedicated for performance tracking team members, especially for building operators – their involvement is key for investigating the root causes of performance anomalies and taking corrective action. Incentives and recognition can help motivate the performance tracking team. Building occupants are another group that should be considered – their involvement in performance tracking can help boost the success and buy-in of the program.

Related to performance tracking tools, their use can help quantify and monitor the benefits of specific efficiency projects in addition to helping identify performance anomalies. Integration of these tools with existing facility processes can help streamline a program and make it more widely accepted by all stakeholders. And finally, depending on specific goals of the organization, successful performance tracking programs can be based on...
simple tools such as ENERGY STAR Portfolio Manager. Complex performance tracking software is not always required.

Continuous optimization tools are a subset that did not fit within the original five categories described in section 2 (Literature Review) and deserve a separate classification. Continuous optimization tools go a step beyond system level FDD in capability and potential impacts.

4 Site Interviews

After the phone interviews were completed and the results were analyzed, the team conducted five on-site interviews to learn more about performance tracking tools and management practices being implemented in the field. The purpose of the site interviews was to build upon the phone interviews to obtain a more in-depth view of performance tracking in commercial office and institutional facilities, and to gain a deeper understanding of best practices in performance tracking. The results of the site interviews are presented and analyzed in this section.

The interview instruments used for the site interviews are included in Appendix C. A one-page summary of each site interview is included in Appendix E. Screenshots of the tools used by the site interview participants are included in Appendix F.

4.1 Study Participants

From the 21 phone interview participants, five were selected for additional site interviews. These five were selected because they had defined performance tracking programs in place and appeared to demonstrate best practices. Two of the five site interview participants were portfolio participants – the site interviews focused on the performance tracking program they had in place across their portfolio of buildings. Two other site interviews were conducted at large office facilities, and the fifth site interview was at a university campus.

During the interviews, the project team met with management and building operators, sometimes separately, to learn more about the role each played in their performance tracking programs, their motivations for performance tracking, and other information as indicated in the site interview instruments.

Performance Tracking Tools

The performance tracking tools used by management were varied among the five participants and provides a good range of performance tracking tools currently used in the industry. These tools included the following:

- Monthly utility bill tracking
  - Comparing current usage to previous month’s usage
  - Comparing current usage to previous month’s usage and usage of same period during previous year; investigating if usage is at least 30% greater
  - Benchmarking against their portfolio of buildings
- Whole building demand-based energy anomaly detection (EAD)
- Benchmarking the facility’s energy use against it’s own historical use and against the performance of peers with ENERGY STAR Portfolio Manager.
- EAD and performance-based fault detection based on the building’s main meter, sub-meters, and BAS points
- Building energy performance dashboard, with integration to BAS points
- Manual inspection of load shapes from interval meter data

Some sites used more than one tool to achieve different performance tracking program goals. These sites typically used one tool to monitor overall building performance (e.g. ENERGY STAR Portfolio Manager) and another for more actionable monitoring (e.g. EAD).
Even though ENERGY STAR Portfolio Manager was the predominant tool among the phone interview participants, only one of the five site interview participants used the tool. The reasons were varied. One site believed the normalization factors were incorrect in Portfolio Manager for their particular climate; another site preferred to look at raw consumption numbers rather than at a rating based on comparisons with other buildings; another site relied on their EAD system for monitoring whole building performance.

As indicated, management and building operators typically used different performance tracking tools. Management typically used tools that monitored overall building performance, while building operators used tools that targeted individual equipment performance. Tools used by the building operators among the five participant sites included the facility BAS and fault detection based on main meter, sub-meters, and BAS points. The building operators at every site used the BAS to help identify the root causes of identified issues.

Some participants also used their preventive maintenance (PM) programs to track equipment performance, rather than sophisticated software tools. For example, the building operators looked to their PM logs for indications of degraded equipment performance, cycled actuators regularly to help assure performance, or verified performance of dampers and electric heat elements.

Performance Tracking Management Practices

Each participant’s performance tracking management practices varied slightly. In three of the five sites, the process relied on performance anomaly alerts sent by the tool. The other two sites relied on manual inspection of reports from the tool to identify performance anomalies. The performance tracking practices in place at the five sites are described here:

Site #1 (130,000 sq.ft. office building with large data center): The tool emails the alerts to energy manager when monthly usage is 30% higher than expected. Energy manager then forwards alerts on to building operators. Operators use the BAS to investigate. No feedback to the energy manager.

Site #2 (82,000 sq.ft. office building with large library): One tool sends daily energy reports via email to both the energy manager and building operators. The operators look for increased usage in these emails. If they see increased or anomalous usage, they investigate using the BAS. Energy manager would like to see better reporting from the operators, to close the loop. Another tool is used by the manager for documenting and reporting overall energy usage.

Site #3 (250,000 sq.ft. office building): One tool continually and automatically optimizes the performance of the chilled water plant. Another tool, a utility billing service, analyzes monthly whole building energy consumption and sends an alert to management if consumption deviates by more than 7.5% from the previous month. If management can’t explain the cause, the issue is communicated to the site for further investigation.

Site #4 (Site #4: 253,000 sq.ft. office building with server rooms and small labs): Tool sends both operational-based and energy-based real-time alerts to onsite staff and corporate level staff. Onsite managers and engineers are paged and emailed when the system alarms. Engineers or facility manager then generate work orders to resolve any issues.

Site #5 (Site #5: 5,000 acre campus with 1,200 buildings and 14 million sq.ft. of floor space): The data analysis and reporting feature of the EIS are used by utility services to identify unusual spikes in electric and gas usage, via manual inspection, for both whole building and large circuits such as central plant equipment. The EIS does not send alarms, and reports must be generated manually. BAS is monitored by facilities services, as separate group, for operational alarms and equipment status. No formal process or consistent communication is set in place between the various groups.
As indicated, only one of the five participants does not have a formal performance tracking program in place. While the other four have formalized processes for investigating identified anomalies, none have a defined feedback loop to close open issues / alerts. Of the four with formalized processes, the performance tracking team includes both management and building operators. Responsibilities are clearly defined and understood at these sites.

**Costs and Benefits**

In general, the site participants’ responses to questions about performance tracking program costs and benefits suggested that their programs are a cost-effective way to help them meet their energy performance goals.

The cost of performance tracking tools can vary widely depending on the type of tool, the number of buildings, the depth of tracking, and other factors. Site #1, which uses a tool that sends email alerts to the energy manager when usage is higher than expected, indicated that their system cost about $300,000 to install for their 300 buildings. Another site said that their EAD system cost about $750-$2,000 per meter to install. This site also stated that the cost of the tool was absorbed by their utility budget.

The participants cited numerous benefits related to their performance tracking programs. In general, performance tracking helps the participants identify performance issues faster and quantify the benefits of energy projects. One energy manager also reported $120,000 in savings after correcting a billing error identified by the tool. Specific benefits cited by the participants include:

- The savings from the program helps to pay off the bond that was used to pay for the tool. The savings are mainly a result of other energy projects, some of which receive supporting data from the EIS.
- The company has seen 20% energy savings since the tool was installed and a 2.5 year payback related to use of the tools.
- The company is seeing high and increasing ENERGY STAR scores as a result of energy performance tracking.
- Savings from the automatic optimization tool (~$75,000) helped offset the reduced revenue from a large tenant moving out. Energy savings from installation of this tool was about 33%.

Each participant gave at least one example of a specific issue that was identified through tracking whole building, system, or equipment performance. An energy manager at one site gave an example of a non-energy performance issue identified through use of the tool. The manager noticed that monthly water usage was higher than normal, and then worked with the operators to identify and fix a broken float valve. The other sites gave at least one example each of the tool identifying an energy performance anomaly, then the staff drilling down to identify and correct the root cause. These include:

- After-hours energy usage was higher than expected. The root cause was excessive after-hours equipment operation, which was resolved.
- After seeing increased gas usage, the facility identified a kitchen booster heater being left on overnight, and resolved the issue.
- A chiller staging issue was identified after identifying increased chiller energy usage, which the operators hope to diagnose and correct when the weather warms up.
- The tool showed a spike in energy usage of a thermal energy storage chiller, which the operators intend to diagnose and correct.
- An airside economizer performance issue was identified as the reason for increased building power draw. The issue was investigated and resolved.

These five facilities not only use the tool to quantify and compare the overall energy performance of their facilities, they also proactively investigate identified energy performance anomalies to keep their buildings running efficiently.
The participants also cited some non-energy benefits. For example, one participant indicated that interval data output from the tool has helped design engineers with modeling, sizing equipment, and solar panel installations. Another mentioned that the daily emails from the tool are useful in giving a snapshot of the last day’s performance.

**Keys to Success**

*Performance Tracking Tools*

A key success cited by the participants related to their performance tracking tools is the careful set-up of the tool’s parameters. Specific examples include:

- Alarm ranges are set wide enough to minimize nuisance (false) alarms, yet narrow enough to identify the major anomalies and underperformers.
- Baseline models are normalized to the relevant independent variables.
- Baseline models are updated as needed to keep pace with changes in the building (efficiency projects, tenant churn).

Active use of the BAS was also cited as a success factor. One participant incorporated BAS points into their utility bill analysis tool, which helps identify the reasons for increased energy use. Another mentioned that the operators are typically able to identify issues before the energy manager sees them through his monthly utility bill analysis.

One participant indicated that the many meters being monitored and the tool’s sufficient capacity to store and analyze data help make their program a success.

*Performance Tracking Management Practices*

Related to their management practices, the participants cited a variety of successes. In general, the participants indicated that a well-defined process and open lines of communication are essential for a successful performance tracking program, echoing what was stated by the phone interview participants. Clear energy performance goals were also cited as both a motivating factor and justification for the performance tracking program.

The participants indicated that periodic reporting on energy performance (e.g., quarterly, annual) is helpful for stakeholders that do not need to be involved in performance tracking on a daily basis, but still would like to see information on progress to date. The energy manager at one site includes information on energy performance in her quarterly newsletter to building tenants. This energy manager also indicated that involving building occupants, organized as “green teams”, on the performance tracking team has helped make the program a success.

Two participants indicated that performance tracking helps ease the burden on building operators. One mentioned that performance tracking helps ensure proper building operation, which in turn helps free up operator time and allows operating staff to be more proactive. Another indicated that building operator resources have been freed up at the site that utilizes optimization software to minimize chiller plant energy usage, since a third party service monitors plant efficiency and contacts the operators when efficiency drops.

Building operators indicated that work orders are helpful in driving performance tracking-identified issues towards resolution.

**Challenges**

*Performance Tracking Tools*
Many of the participants would like to see more detailed building performance information than their current tools allow. Specific challenges cited by the participants include:

- Tool only monitors monthly whole building usage. Would like to also monitor performance of key metrics (e.g., kW/ton) and interval meter data for real-time tracking, and have tool send real-time alarms. The monthly monitoring does not allow for identification of faults.
- Tool does not incorporate end-use breakdowns.
- Operators would like to see more zone-level information at their BAS, for easier diagnosis of performance issues.

User interface and reporting was another challenge indicated by the participants. At one site, the interfaces for the various tools look different. Participants expressed the desire for them to look the same and be consolidated as much as possible. Another participant mentioned that the report generation functions are not intuitive. The team would like to be able to generate more reports from the system.

Limited data analysis capabilities were also mentioned by participants as a challenge, which is a similar challenge to that identified in the phone interviews. One participant mentioned that their tool does not have the capability to export data to a spreadsheet for further analysis. Another indicated that monthly data mining functionality in the tool is limited.

One participant indicated that the cost of the tool is a challenge. For this portfolio participant, the tool is only cost-effective for their larger facilities.

**Performance Tracking Management Practices**

The two main categories of challenges identified by the site interview participants echo those mentioned by the phone interview participants: insufficient communication and resources. Communication-related challenges cited by the site interview participants include the need for better communication between the different groups (e.g., utilities, facilities, sustainability manager, commissioning program manager), and for effective communication of energy usage information between building operators and occupants.

Resource-related challenges experienced by the participants include:

- Management sees much potential in the tool, but does not have enough time to use it. Building operators indicated the difficulty in keeping up with preventive maintenance tasks due to staff cuts (limited resources).
- For a performance tracking program to work, knowledgeable operations and maintenance staff need to look at the data. A quote from one participant: “Don’t put the money into it if you can’t dedicate the time.”
- There is more to invest than just the cost of the tool. A good tool does not itself make a good performance tracking program. A quote from one participant: “Software is the tool, not the solution.”

Participants also noted that vague policies and procedures can hinder the success of a performance tracking program. One site indicated that they do not have a set process for addressing alarms – i.e., who investigates the alarm, the timeline, the process for implementing corrective action, and how is the issue closed. Management recognizes that a process needs to be developed to allow more consistent reporting from the O&M staff, which would help demonstrate the value of the performance tracking program. Another site indicated that they do not have formal policies around energy performance. Vague and unrealistic policies reduce the effectiveness of the performance tracking program.

Other challenges noted by the participants include:

- Different stakeholders may wish to see different metrics. Metrics need to be relevant for each group.
• Building occupants have complained when an energy efficiency measure (EEM) impacts occupant comfort. Occupant comfort is a constant consideration when investigating and implementing EEMs.
• For a campus installation, one must have sufficient meters and the required communication pathways to access the data.

As indicated, there are many benefits and challenges related to performance tracking. The participants interviewed have had their performance tracking programs in place for some time, and thus have had enough experience to see that performance tracking programs may be beneficial, but still hold room for improvement.

**Barriers to Performance Tracking Adoption**

Participants were asked to consider the biggest barriers for owners in developing performance tracking programs. They noted the following:

• First cost. Need to understand the return on investment and avoided cost benefits.
• Ongoing costs. Need to devote time to the program, or it will not last over time.
• Lack of education. Commercial building managers need to ‘sell’ the performance tracking program to building owners.
• Tools should include more actionable outputs. A quote from one participant: “Information needs to be actionable.”
• Acceptability by the market. Many tools are ‘black boxes’, and there is a general lack of trust in them.
• Lack of incentives and motivation for staff.

The barriers listed by the interviewees cover a wide range of motivations and criteria, with no one clear barrier noted by all participants.

**Motivations for Performance Tracking**

Management and building operators have different motivations for performance tracking. These different motivations should be recognized, as they likely require different incentives for performance tracking team member participation. From saving money and documenting energy efficiency project results to complying with mandates and policies, management cited a number of motivating factors related to performance tracking:

• Save the company money on energy bills. According to one energy manager, energy performance tracking is secondary in his job. His first responsibility is to save money.
• Look for the energy reduction results of retrofit and EBCx projects in monthly utility bill analysis.
• Identify new savings opportunities.
• Participate in a utility monitoring-based commissioning program (this helped justify installation of the tool).
• Be accountable to tax payers and state mandates.
• Meet sustainability policies to reduce emission levels.

Building operators cited a lower number of motivating factors, which suggested that energy performance tracking is spearheaded more by management than by building operators. At one site, the operators are motivated to track performance in order to save their jobs. Operating staff has been cut, and keeping energy costs down will allow the current staff to keep their jobs. Operators at another site mentioned a sense of personal fulfillment by saving energy.

**4.2 Site Interview Summary and Conclusions**

The site interviews allowed the team to learn more about motivations related to performance tracking. None of the participants use performance tracking to monitor the performance of individual energy efficiency measures (EEMs) – they monitor ongoing performance of the building, or the results from energy efficiency projects, but not specific EEMs. In addition to quantifying the savings related to energy efficiency projects, performance
tracking helps the participants maintain building performance through identification of performance anomalies that, once diagnosed, can point to specific performance issues.

Different stakeholders have different motivations for energy performance tracking. These stakeholder groups can include energy managers, building owners, building operators, building occupants, and others that are either involved in or impacted by building performance. To meet the varying needs of these stakeholder groups, a variety of performance metrics may need to be monitored, and different types of tools may be required to meet these needs. For example, an energy manager may find monthly utility bill analysis most valuable for tracking building performance, while the building operators may find most value in using the BAS to monitor and maintain performance and diagnose identified anomalies.

The participants identified a variety of barriers that should be addressed when developing a performance tracking program, including first cost, ongoing cost, education, motivation, and incentives for performance tracking. Related to ongoing costs, sufficient resources must be dedicated to meet the established goals. Resources are required to both monitor performance and act on identified performance anomalies.
5 Project Sub-Task Summary and Recommendations

5.1 Overarching Research Themes
A number of common findings were identified from the literature review, phone interviews, and site interviews. The most common finding is that there are a great variety of tools and management approaches for energy performance tracking in the market. This research has helped to classify some of those approaches into a framework that can be used to help communicate the variety of options to owners and other stakeholders. The research also identified best practices in the field of performance tracking.

Performance Tracking Tools
Top-down tools, such as ENERGY STAR Portfolio Manager and whole-building EAD tools, were the most prevalent performance tracking tools discussed in the literature review and used by the phone interview participants. For the site interview participants, the managers typically use higher-level tools for monitoring overall building energy performance, while the building operators rely on tools that target specific equipment performance (e.g. BAS).

The project team had difficulty finding sites that were using FDD tools or the BAS as their primary tool for energy performance tracking. FDD is not being used successfully in many buildings, and most large BAS manufacturers have only recently begun offering energy performance tracking add-ons to their control systems. However, it is worth noting that while none of the participants use their BAS as their primary performance tracking tool, almost every participant uses their BAS as an integral part of their performance tracking program, for diagnosing issues.

Performance Tracking Management Practices
Management practices varied widely among the interview participants, including in the type of data analysis performed, the person with primary performance tracking responsibility, and the feedback process for closing the loop on identified anomalies. Four of the five site interview participants have a formal performance tracking process in place. All four have both management and building operators on the team and their responsibilities are clearly defined and understood. Each participant’s process begins with anomalies detected through use of the performance tracking tool.

Costs and Benefits
Quantitative costs were not widely discussed in the literature, and the interviews gave minimal specific anecdotal information about performance tracking costs. In general however, the interview participants indicated that their programs are a cost-effective way to help them meet their energy performance goals.

The literature review and the interview participants all indicated that energy performance tracking results in energy savings from more efficient operation. The interview participants emphasized that energy performance tracking helps them quantify the savings from energy efficiency projects. They also indicated that it not only helps them monitor overall building performance, but it also helps them visualize where energy consumption occurs in their buildings. None of the participants monitor the performance of individual energy efficiency measures.

Performance tracking also helps in faster identification of performance issues. However, these identified anomalies typically require additional analysis beyond that afforded by the tool (e.g. they use the BAS to identify the root cause).
Motivations
The phone and site interviews identified many motivations related to energy performance tracking. These included: complying with company policies, achieving ENERGY STAR certification, monitoring of general building performance, tracking carbon footprint, increasing their asset value, identifying specific energy saving opportunities, and quantifying the benefits of efficiency projects. On average, management cited more motivating factors than building operators, suggesting that energy performance tracking is typically spearheaded by management.

Challenges and Barriers
The literature review, phone interviews, and site interviews all identified lack of time, especially for building operators, as a significant challenge – time to monitor performance, investigate identified anomalies, and take corrective action. Only one interview participant indicated that performance tracking frees up operator time due to less trouble calls and more proper operation.

Related to challenges in general, the literature focused on tool capabilities, while the participants focused on their management strategies. The literature indicated that installation and continuous maintenance of the tools can be a challenge. Poor communication among performance tracking team members was a common challenge cited by the participants.

The literature and interview participants also indicated barriers related to turning identified anomalies into action – the literature said that the ability of end-users to accurately interpret and act on data collected from performance tracking tools can be a barrier, while the interview participants identified a lack of actionable outputs from the tools as a barrier.

Most of the interview candidates believed that their tracking tools and strategies resulted in energy savings but were typically not able to quantify the benefits. There is a lack of information related to quantifiable financial benefits for performance tracking, which is a challenge to stakeholders who have not yet adopted performance tracking and would need to financially justify such an investment.

Conversations with the interview participants identified a general lack of understanding of all tools and capabilities available. While some of the participants conducted detailed investigations into the various options available, several indicated they adopted the first tool identified by, or presented to, their team. Some of the participants were even surprised to hear that capabilities beyond their chosen tool were available.

5.2 Recommendations for Energy Performance Tracking
Stakeholders can choose from a wide variety of performance tracking tools and strategies to meet a particular set of goals. The literature review, phone interviews, and site interviews from task 4.2 identified key attributes that should be considered to design a successful performance tracking program. These include:

Performance Tracking Tools
Choosing a performance tracking tool is an important step. The type of tool used can have a significant influence on the overall program. Factors to consider when selecting, installing, and programming a tool include:

- Consider the needs of each stakeholder when selecting the tool and generating metrics. Higher-level metrics such as monthly whole building energy consumption (kWh/sq.ft.) may be sufficient for some stakeholders, while others may wish to see more detailed metrics such as chilled water plant efficiency (kW/ton).

- Set up the tool and alerts to be as actionable as required.
• Remember the BAS. While it may not be suitable for the primary energy performance tracking tool, it can be an integral part of the program, for diagnosing identified anomalies.

• Decide whether the tool should automatically generate alerts or if the data will be analyzed manually. For automatically generated alerts, set up the tool so that the alerts are timely (i.e., real-time), relevant (i.e., no false alarms), and accurate (i.e., use the right meters and normalizing factors).

• Ensure the tool has an intuitive user interface and sufficient data analysis capability to meet your needs.

• Integrate the tool with other processes and software wherever possible (e.g., CMMS, BAS).

• Keep it simple. Remember that there are successful performance tracking programs based on simple tools such as ENERGY STAR Portfolio Manager.

Performance Tracking Management Practices
As indicated by the interview participants, the management practices in place to support the tool may be more important to a successful performance tracking program than the type of tool used. Factors to consider when developing management practices include:

• Develop a solid performance tracking process, including well-defined reporting protocols, specific team member responsibilities, and open lines of communication. The process should address the motivations, needs, and capabilities of all stakeholders involved.

• Create clearly defined performance tracking goals or structure the program to help support existing goals.

• Recognize that different performance tracking team members may have different motivations. Team members are more motivated if each member has an understanding of the benefits of performance tracking. The process needs to be accepted by all stakeholders for the program to be a success.

• Include both management and building operators on the team. Also consider including building occupants on the team.

• Ensure that each team member has sufficient time to carry out their duties successfully. This includes time to monitor performance, investigate identified anomalies, and take corrective action.

• Provide incentives. Spot bonuses and recognition can help motivate team members.

• Consider including periodic reporting on energy performance for stakeholders that do not need to be involved on a daily basis, but would like to remain informed.

5.3 Future Research Needs
Throughout this task, additional research needs were identified related to energy performance tracking to help encourage wider adoption of successful performance tracking programs.

The interview participants were recruited for this research because they had already implemented an energy performance tracking strategy. As a result of this targeted recruitment, the research did not directly address reasons why other stakeholders choose not to implement energy performance tracking. Future research on the barriers related to implementing performance tracking programs would be valuable.
The lack of research on the quantified benefits and cost-effectiveness of performance tracking is a likely barrier to wider adoption. The interview participants did not mention the need to quantify benefits from a particular performance tracking investment, but rather used their tools to quantify benefits from other investments such as energy efficiency projects.

The literature review found little mention of management practices related to energy performance tracking, and the interviews identified a wide variation in management practices currently being implemented. Future research on identifying management best practices for energy performance tracking would help those that are developing an energy performance tracking program.

The research identified different motivations for different stakeholders related to performance tracking – management is typically motivated to keep energy use low, while operators are motivated to maintain occupant comfort and equipment reliability. Research into strategies for recognizing and maintaining motivations of all stakeholders and identifying where those motivations overlap would be valuable.

The interview participants indicated a desire to see more actionable outputs from their performance tracking tools. Identifying general performance anomalies is a crucial step, but identifying the reasons for those anomalies would be more valuable. Further development of tools that produce more actionable outputs would likely increase adoption of performance tracking.
6 Bibliography


### Appendix A: Literature Review Summary

The resources included in the literature review are described in more detail in the following tables. Key findings are indicated in **bold red**.

#### General Summary Table

<table>
<thead>
<tr>
<th>#</th>
<th>Title, author, year</th>
<th>Format</th>
<th>Intended Use / Audience</th>
<th>Overview of Study</th>
</tr>
</thead>
</table>
| 1  | Analysis of an Information Monitoring and Diagnostic System to Improve Building Operations, Piette, 2001 | Journal Article, *Energy and Buildings* | Demonstration of Information Monitoring and Diagnostic System (IMDS) technology | • Includes the installation of a prototype IMDS at one demonstration site to demonstrate the value of this technology to the industry. IMDS was a prototype technology demonstration (includes very high end, research grade sensors, and graphical software to plot lots of data). It doesn’t appear to have FDD capabilities, but allows users to manually find issues.  
• System operates in parallel with existing EMCS.  
• **Estimated 25% total energy savings potential was discovered for the site. Study focused on the technology and identification of issues; measure implementation was outside the scope of the study.** Appears that the operators identified the issues. |
| 2  | Evaluation of Emerging Diagnostic Tools for Commercial HVAC Systems, Friedman, 2001 | Conference paper, ICEBO | Intent was to provide a characterization of emerging tool sets to aid end users | • Includes an evaluation of six diagnostic tools commercially available at the time of publication:  
1. ENFORMA  
   ➢ Manual data acquisition, manual diagnostic aid, short term analysis  
2. Performance and Continuous Re-commissioning Analysis Tool (PACRAT)  
   ➢ Automated data acquisition, automated diagnostics, continuous analysis  
3. Whole Building Diagnostician (WBD)  
   ➢ Automated data acquisition, automated diagnostics, continuous analysis  
4. Universal Translator  
   ➢ Manual data acquisition, manual diagnostic aid, short term analysis  
5. Fan systems tools (UC Berkeley)  
   ➢ Manual data acquisition, manual diagnostic aid, short term analysis  
   ➢ Automated data acquisition, manual diagnostic aid, continuous analysis |
| 3  | Web-based Energy Information Systems for Large Commercial Buildings, Motegi, 2002 | Research paper, PIER sponsored | General overview of commercially available EIS systems. | • Applies an analytical framework to evaluate more than a dozen EIS with a focus on capabilities and limitations.  
• Potential use for long term applications toward energy efficiency and load management is discussed.  
• **Four general EIS categories are described:** Utility Energy Information Systems, Demand Response Systems, Enterprise Energy Management, and Web-base EMCS Interfaces |
| 4  | Investigation of the Persistence of New Building Commissioning, Friedman, Potter, 2002 | Research paper, PIER sponsored | Qualitative study on issues responsible for lack of savings persistence after Cx. | • Study includes a qualitative analysis of 10 buildings that were commissioned as new buildings  
• **The main reasons for reduced persistence are limited operator support / high operator turnover, poor information transfer from the Cx process, and lack of performance tracking**  
• Only measures and buildings with sufficient documentation from the Cx process were evaluated |
<p>| 5  | Contract and Beyond GEMnet Status and Accomplishments: GSA’s Energy and Maintenance Network, Piette, 2002 | Conference Paper, ACEEE | Paper presents the steps GSA has taken to improve building performance (including performance monitoring and RCx) | This paper focuses on building information technology activities within GSA’s Pacific Rim Region. Addresses the use of the GSA Energy and Maintenance Network, or GEMnet |</p>
<table>
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<th>Overview of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Development of an Enterprise-wide Energy Information and Utility Monitoring System in a Major Hotel Chain: Hyatt Hotels Corporation Experience, Burke, ~2003</td>
<td>Case Study, CACx</td>
<td>Reports on the deployment of a enterprise wide building performance tracking system</td>
<td>Describes the mandatory deployment of a utility tracking system to all Hyatt hotels. 55 are complete, all 120 will eventually be included.</td>
</tr>
<tr>
<td>8</td>
<td>Evaluation of Retrocommissioning Persistence in Large Commercial Buildings, Bourassa, 2004</td>
<td>Conference Paper, ICEBO</td>
<td>Quantitative study of savings persistence after the completion of RCx</td>
<td>• Review of savings persistence of a sample of buildings involved in the Sacramento Municipal Utility District Utility retrocommissioning program.                                                    • Measure savings persistence was evaluated using onsite inspections, staff interviews and whole building analysis.                           • Study shows the aggregate savings measured at the whole building level began to degrade at 4 years.</td>
</tr>
<tr>
<td>9</td>
<td>Using Energy Information Systems (EIS): A Guidebook for the U.S. Postal Service, Foster, Barbose, 2004</td>
<td>Guideline</td>
<td>Intended audience is the end-user of the EIS</td>
<td>• General overview of the postal service EIS, how it can be used and its benefits                                                                 • Provides guidance on how to use the EIS to achieve energy efficiency (e.g. monitor daily reports, look for patterns of irregularity, benchmark)</td>
</tr>
<tr>
<td>10</td>
<td>ASHRAE 1286-TRP Evaluation of Building Energy Performance Rating Protocols, Glazer, 2006</td>
<td>Research Paper</td>
<td>General research for policy implementers and guideline development</td>
<td>• Presents a review of five building performance tracking methods which were selected from a list of 47 identified during an extensive literature review                     • Building data was collected and applied to the selected rating methods</td>
</tr>
<tr>
<td>11</td>
<td>How Monitoring-Based Commissioning Contributes to Energy Efficiency for Commercial Buildings, Brown, 2007</td>
<td>Conference Paper, Revised from ACEEE 2006</td>
<td>Describes a monitoring-based commissioning program implemented at 25 UC campuses</td>
<td>• Provides program results to date (mid-cycle)                                                                 • Assumption is made that monitoring increases persistence, but does not indicate how much performance has been enhanced through monitoring. Details some issues that were identified, but would these have been found in normal RCx? • Does not address who monitors or responds to issues. • Program savings are similar to RCx savings reported in Mills study, 2004. Does not address how monitoring enhances savings or performance.</td>
</tr>
<tr>
<td>12</td>
<td>Persistence Tracking in a Retro-commissioning Program, Mike Eardley, 2007</td>
<td>Conference Paper, NCBC</td>
<td>Reports on persistence tracking results of two buildings</td>
<td>• A vital yet missing piece of retrocommissioning is to ensure that savings persist (this is not common practice, especially in utility-based programs)                                                     • Reports that benefits erode most often when occupants complain (thermal/airflow), or operators look for quick fixes instead of investigating root causes of issues   • Building 1: Schedule change persisted, not a single setpoint change persisted • Building 2: mechanical and detailed programming measures persisted as did condenser water reset. Again, the simple reset measures failed to persist. • Over half of measures failed to persist beyond the 2 month monitoring period. The author feels this is not uncommon.</td>
</tr>
<tr>
<td>#</td>
<td>Title, author, year</td>
<td>Format</td>
<td>Intended Use / Audience</td>
<td>Overview of Study</td>
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<td>----</td>
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</tbody>
</table>
| 13 | A Utility-Sponsored Incentive Program for Monitoring-Based Commissioning of Existing Buildings Using FDD Toolsets, Cunningham, 2008 | Conference Paper, NCBC | Presentation on a utility based MBPCx program. | • The paper presents information regarding a utility sponsored Monitoring-based Persistence Commissioning Program (MBPCx) and the fault detection and diagnostic (FDD) tools used in this process.  
• PACRAT and VPACC were the FDD toolkits chosen for this current program.  
• The program had not been active long enough to report on success of persistence. As of late 2009, a program evaluation had not yet been conducted on this program.  
• Owners receptiveness and use of the FDD toolkits were not addressed. Program paid for software tool licensing fees only during the project period. |
| 14 | ENERGY STAR®, Building Upgrade Manual, EPA, 2008 | Process Guidebook | Provides background information to assist a building operator/owner | • This guidebook provides direction in developing benchmark plans, investment analysis, and financing of building upgrades.  
• The process recommended is a staged approach which includes in order: the establishment of a baseline, RCx, lighting upgrades, load reduction strategies, and airside retrofits (upgrades).  
• Additional chapters discuss central plant O&M and retrofits, unitary systems, and building-specific energy use profiles, technical recommendations, challenges, and issues (K-12 schools, supermarkets, hotels and motels, retail). |
| 15 | BOMA Energy Efficiency Program, Courses 1-6, 2008 | Webinar | Building Operators | • Provides an overview of building energy efficiency fundamentals and highlights the financial reasons to pursue efficiency  
• The first recommended step in the pursuit of an energy efficient building is benchmarking using EPA’s Portfolio Manager  
• The benchmark can be used to track future progress toward an energy performance goal |
• Goal was to define and apply a characterization matrix to help understand current state of the technology and distinguishing characteristics  
• Case studies were conducted at four sites to help understand challenges, successes, and how information gathered from the EIS created action and led to energy savings |
| 17 | Advanced Metering and Energy Information Systems, NBI, 2009 | Report | Help regulators, program managers and others understand new trends and technologies in EIS | • Provides a breakdown of EIS basic components: meters, sensors, data acquisition system, gateway, remote database, software tools to display or analyze data.  
• Basic metering systems (whole building analysis) to enhancements (sub-meters/component level trends) are described |
| 18 | Annex 47: Cost-Effective Commissioning of Existing and Low Energy Buildings: Subtask C Final Report Commissioning Cost-Benefit and Persistence, Friedman, 2009 | Report | • Core purpose was to collect and disseminate info that could help to promote RCx.  
• Secondary goal is to define methods used to determine cost, benefits, and persistence of RCx | • Includes an extensive review of existing literature, analysis of past EBCx projects, and savings determination methods.  
• Strategies to enhance persistence were suggested: documentation, operator training, benchmarking, energy tracking, trend analysis (Enforma, PACRAT) and ReCx. |
| 19 | The High Performance Portfolio Framework, Northwest Energy Efficiency Alliance | Framework by Better Bricks | Provides guidance for owners of a large portfolio of buildings | • Guidelines to assist in the development of energy efficiency strategies. Main stages described are to assess, commit, plan, implement, and capitalize  
• Key: Planning stage, establish a multi-disciplinary team (need expertise in: operations, technical, building management, marketing, financial) Establish clear authority and accountability. Benchmark portfolio, scope and establish the energy plan  
• Key: Implement, establish incentives (financial, promotion, recognition). Improve and maintain through enhanced O&M, building tune-ups, equipment replacement. Track and monitor building energy use and equipment performance. |
<table>
<thead>
<tr>
<th>#</th>
<th>Title, author, year</th>
<th>Format</th>
<th>Intended Use / Audience</th>
<th>Overview of Study</th>
</tr>
</thead>
</table>
| 20 | **Final Report 2006–08 Retro-Commissioning Impact Evaluation, SBW, 2010** | EM&V report | Provides a summary of actual vs. predicted savings to regulators and utilities | • This report focused on 3 major components: realization rates, net-to-gross results, and effective useful life (EUL is related to persistence of benefits from energy efficiency measures)  
• The EUL analysis found that 22 of 96 measures investigated had failed since their installation three to four years ago. Failure was defined when less than 50% of the original savings still exist. |
## Detailed Summary Table

<table>
<thead>
<tr>
<th>#</th>
<th>Title, author, year</th>
<th>Types of Performance Tracking Strategies / Tools Discussed</th>
<th>Costs and Benefits</th>
<th>Successes, Challenges, and Barriers</th>
<th>Lessons Learned and Recommendations</th>
</tr>
</thead>
</table>
| 1  | Analysis of an Information Monitoring and Diagnostic System to Improve Building Operations, Piette, 2001 | • Reports included nine standard plots that demonstrate key performance trends. Plots not shown / defined in report.  
• Visualization software allows for the display and manipulation of a year of minute data for 8 points simultaneously.  
• 57 data points were tracked and stored, including temperatures, power, flow rates, and pressures.  
• Component, system and building level monitoring. | • Reduction of complaint calls.  
• Identification of control strategy adjustments to the EMCS to increase automation and reduce operator time requirements by an estimated 20%.  
• **Operator time savings alone provided a 5 year simple payback.**  
• Staff estimates $45,000 in savings per year  
• Estimate total cost of the system (hardware, software, installation) at $1 per square foot. | • Installation of the IMDS provided feedback on system performance that was not included in the existing EMCS.  
• The discovery of most deficiencies required high resolution, one minute intervals.  
• Building owner is not interested in supporting the high quality sensors used in this prototype system. | • The value of IMDS was found to be positive. Operators were required to spend significant time to learn how to work with the system, but gained a better understanding of their building operations which saves more of their time in the end.  
• Future deployments of IMDS were planned at the time of publication and continual monitoring of the pilot project to evaluate persistence of savings. |
| 2  | Evaluation of Emerging Diagnostic Tools for Commercial HVAC Systems, Friedman, 2001 | • Airside economizer was the most common diagnostic among all 6 tools.  
• All tools discussed include diagnostic capability at the system level (HVAC, central plant…) | Not discussed | • “Building operators and energy managers rarely have adequate training, time, or tools to continually assess performance” – common theme from the reviews  
• Key benefit is reducing data management and saving time in diagnosing operational issues.  
• Outlines strengths and limitations of each tool. | N/A (tool characterization only) |
| 3  | Web-based Energy Information Systems for Large Commercial Buildings, Motegi, 2002 | The systems reviewed included a range of energy inputs (utility meter tracking, sub-meter tracking, or EMCS). | Not discussed | Not discussed | EIS generally provides energy managers with information that helps visualize energy consumption patterns, evaluate cost reduction strategies, participate in DR programs and compare buildings through benchmarking. |
| 4  | Investigation of the Persistence of New Building Commissioning, Potter, Friedman, 2002 | n/a | Not discussed | • Documentation was a secondary benefit and often was not complete or sufficient  
• **Lack of performance tracking, lack of information transfer from the commissioning process and limited operator support hindered measure persistence.** | • Measures that involve hardware change or substantial re-programming tend to persist.  
• Measures that involve simple programming changes (e.g. setpoints or scheduling) were most at risk of non-persistence.  
• **Persistence is highly dependent on the working environment of the maintenance staff and engineers.** |
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</table>
| 5  | **Contract and Beyond GEMnet Status and Accomplishments:** GSA’s Energy and Maintenance Network, Piette, 2002 | • Remote monitoring and control of the BAS at the system level  
  • GEMnet includes the use of PACRAT  
  • Computerized Maintenance Management System (CMMS) software program in process | Benefits discussed broadly.  
  "…remote monitoring and control to reduce operational costs by improving energy efficiency, reducing peak demand, and optimizing maintenance in buildings.” | • GEMnet provides a common front-end to BAS, which should reduce dependence on BAS vendors  
  • Provides a framework for performance benchmarking, data analysis and building diagnostics | Future capabilities could include linking the model based diagnostic systems with maintenance management systems. |
  • Benchmarking tool determines key indicators (energy cost / m², kWh / m², m³ water / occupant), and compares with buildings in a similar population  
  • Diagnostic tool under development | Not addressed | Tools developed with the end-users constraints and needs in mind will be more successful. | • Building managers will be more motivated to improve the energy performance of their buildings if they can also improve their comfort level.  
  • The building manager needs some simple and flexible tools with different levels of details in order to let them assess their buildings performance from a top-down approach.  
  • The tools must be accessible via the Intranet of the ministry in order to be easily and widely accessible. |
| 7  | **Development of an Enterprise-wide Energy Information and Utility Monitoring System in a Major Hotel Chain:** Hyatt Hotels Corporation Experience, Burke, ~2003 | • Monthly, web-based benchmark reporting.  
  • Whole building metrics, electric, gas, water, along with local ambient conditions (OAT and RH) are collected. | • Good ROI mentioned qualitatively  
  • Preliminary financial study show positive savings (very cursory at the time of publication) | • Corporate policy promotes energy tracking  
  • Daily and monthly energy reports are sent automatically to the engineering manager. | None noted. Tracking system is still being rolled out to the facilities. |
| 8  | **Evaluation of Retrocommissioning Persistence in Large Commercial Buildings,** Bourassa, 2004 | Savings were tracked over time using EModel, Texas A&M’s proprietary statistical whole building modeling software. | Energy savings increased during measure implementation then began to degrade. At four sites with four years of post-RCx data, year four savings was 65% of peak post-RCx savings. | • The most cited negative aspect of RCx reported by building staff via the interviews was the extensive time requirement. However, all sites indicated a desire to RCx again in the future.  
  • Longer studies are needed to examine five year savings rates and beyond | Additional research is needed related to persistence of savings, and performance tracking tools. |
| 9  | **Using Energy Information Systems (EIS): A Guidebook for the U.S. Postal Service,** Foster, Barbose, 2004 | • Whole building electric utility meter data acquisition hardware, software, and communication systems. UtilityVision® (24 offices), KWickview Online Energy Monitor system (6 offices)  
  • Key Metrics: kW/day, kWh/month, kWh/yr, kW, load factor, base load kW, kWh/sqft/yr. | Benefits to monitoring using the EIS were described as the ability to identify inefficient schedules, identify peak demand reduction opportunities, verify performance in DR programs, and verify utility bills | N/A (Guidebook) | N/A (Guidebook) |
<table>
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• Whole building tracking methods | Consumption-based protocols such as ENERGYguide, ENERGY STAR, Arch and Cal-Arch, are available for use at no charge | Once poor energy performance of a building is identified, the energy professional must take additional steps to determine the root cause. | • A deep examination of the protocols revealed no single clear winner as the best approach overall  
• The report includes many recommendations for another future building energy performance rating system, based on ENERGY STAR.  
• Consumption-based protocols fail in providing good design guidance and feedback during the design process |
| 11 | How Monitoring-Based Commissioning Contributes to Energy Efficiency for Commercial Buildings, Brown, 2007 | Various monitoring suites (specific names not mentioned) were used depending on individual building/campus requirements. One project included parallel sensors tied into the EMCS. | Report notes 10% total source energy savings. MBCx program cost budget noted as $5.2 mil from utility and $0.5 mil from participants, over 7 mil square feet MBCx’d. For the 13 projects completed by the time of the study, median payback = 2.5 years, MBCx cost = $128,000 per project, and an average 40% of MBCx budget was spent on monitoring and EIS upgrades. | Paper presents program as successful (on target to meet goals). No specific challenges / barriers noted. | More selective screening can increase the number of projects with short payback periods. |
| 12 | Persistence Tracking in a Retro-commissioning Program, Mike Eardley, 2007 | BAS control points are used, but stored at an external database (separate from the BAS), measure-level tracking. Simple comparison of data is used to confirm the measure savings persist. | • Persistence tracking also allows for verification of proper ECM implementation  
• Continual monitoring might prevent the erosion of RCx benefits. | Coordination between multiple parties required to set up the tracking system was difficult. | • Even though the performance tracking system seemed simple by utilizing the BAS, setup and ongoing maintenance of the system was more challenging than expected.  
• If a measure has not held over time, it is likely that either implementation was not understood or the building operator made a conscious decision to abandon that measure |
| 13 | A Utility-Sponsored Incentive Program for Monitoring-Based Commissioning of Existing Buildings Using FDD Toolsets, Cunningham, 2008 | Program incorporates BAS monitoring and FDD toolkits in the RCx process. PACRAT and VPACC were the FDD toolkits chosen for this current program. | Not discussed | • The FDD toolkits identified more measures than were identified during the original RCx process  
• Extensive training is required to learn how to use FDD tools  
• The existing BAS must be robust enough to handle the additional trending and storage requirements of the FDD. | • FDD is most cost-effective in buildings with large energy savings potential, due to the costs associated with BAS trending and data harvesting activities.  
Screening building BAS systems for applicability to FDD is a worthwhile first step / expense.  
• Ensure that the BAS can handle additional trending related to FDD.  
• FDD can be deployed early in the RCx process (during investigation) |
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</table>
| 14 | ENERGY STAR®, Building Upgrade Manual, EPA, 2008 | • Performance tracking through benchmarking is discussed (specifically Energy Star, but the possibility of other protocols is mentioned)  
• Common performance metrics by application are mentioned. Examples are BTU/ft², BTU/employee, BTU/unit (assembly plant), BTU/pound (manufacturing), BTU/bed occupied (hospital or hotel), kWh/ft² (lighting), kW/ton (chiller efficiency), Watts/ft² (HVAC) | • The energy impact can be tracked through the upgrade process via benchmarking.  
• Other building specific benefits are mentioned, but the focus is on the upgrade, not performance monitoring. | • Challenges and successes are reported by building type, but the focus is on the building upgrade, not performance monitoring | • Train operators on maintaining persistence of savings. Plan for persistence at the start of RCx  
• The upgrade effort will be most successful if the senior management is committed to energy performance  
• Establish a new baseline after the upgrades are complete |
| 15 | BOMA Energy Efficiency Program, Courses 1-6, 2008 | • Recommends using EPA Portfolio Manager to benchmark and track energy consumption | • Generic benefits of energy efficiency are presented as reduced utility costs and increased asset value (specific financial examples are provided throughout) | • Case studies are presented throughout the webinar demonstrating specific project level successes.  
• Challenges and barriers are not discussed | • Start any efficiency process with benchmarking (EPA Portfolio Manager) and using the benchmark to compare future performance  
• Benchmark continually to track performance toward an energy performance goal |
| 16 | Building Energy Information Systems: State of the Technology and User Case Studies, Granderson, Piette, 2009 | Various commercially available EIS systems were characterized | Not addressed | • Resources and staffing were significant constraints which impacted the successful utilization of EIS data in every case studied | • The report mentions uncertainty around end-users ability to interpret and convert EIS data to performance enhancing actions  
• Feature-packed EIS systems are generally underutilized  
• Standardization of reporting formats will help facilitate the transfer of data to external sources which could encourage the development of physical models to aid in anomaly detection |
| 17 | Advanced Metering and Energy Information Systems, NBI, 2009 | • Mentions tracking EUI through Portfolio Manager  
• Two examples of tracking metrics mentioned: Chiller kW/ton, boiler efficiency BTU/BTU | • Costs for owner installed basic EIS: $2,500 to $4,000  
• FEMP training session cited in study notes that EIS is cost effective for buildings >$40,000 annual energy expenditure (>28,000 sq ft with average CBECs energy consumption)  
• 5% whole building savings from advanced metering is mentioned, based on interviews | • Costs are sometimes hard to estimate and benefits are not always understood  
• Separation between purchaser and benefactor leads to complication  
• Shortage of trained personnel | • Mentions MBCx type programs that use continual monitoring of performance to improve persistence of savings  
• Recommends that efficiency programs consider automated metering to acquire better and faster feedback on program results  
• Advanced metering and EIS provide opportunities to enhance benchmarking immediacy  
• A simple software tool is needed to improve cost effectiveness of EIS in smaller buildings |
<table>
<thead>
<tr>
<th>#</th>
<th>Title, author, year</th>
<th>Types of Performance Tracking Strategies / Tools Discussed</th>
<th>Costs and Benefits</th>
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<th>Lessons Learned and Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>Annex 47: Cost-Effective Commissioning of Existing and Low Energy Buildings: Subtask C Final Report Commissioning Cost-Benefit and Persistence, Friedman, 2009</td>
<td>Two performance tracking tools under development were described: 1. Automated Building Commissioning Analysis Tool (ABCAT): Whole building level FDD system, Excel based, advanced prototype as of 2007 2. Diagnostic Agent for Building Operation (DABO): includes a commissioning assistant and component level FDD from data base storage of trend data.</td>
<td>• TAMU case studies (EBCx mostly stable: 39% savings average after EBCx, 32% after 3 years)  • SMUD case studies (savings takes 2-3 years to fully manifest as measures are gradually implemented, some degradation after 3 years)</td>
<td>Data sets were highly research oriented: 9 of 12 data sets were research based- (university campus, labs), 2 of 12 were utility based</td>
<td>Recommendations noted in report are included elsewhere in this table (report references other papers / reports).</td>
</tr>
<tr>
<td>19</td>
<td>The High Performance Portfolio Framework, NEEA</td>
<td>Recommends benchmarking with Portfolio Manager</td>
<td>Noted benefits include enhanced net operating income (NOI) and asset value, reduced carbon emissions, improved tenant comfort and satisfaction, extended equipment life, and a revitalized corporate reputation for sustainability.</td>
<td>Includes countless tips and strategies to address challenges and barriers (including tenant pushback, buy-in, etc).</td>
<td>N/A</td>
</tr>
<tr>
<td>20</td>
<td>Final Report 2006–08 Retro-Commissioning Impact Evaluation, SBW, 2010</td>
<td>N/A</td>
<td>N/A</td>
<td>• The lack of detailed monitoring of measures at the study sites increased the level of uncertainty surrounding the percentage of savings still being achieved  • Reasons for lack of persistence (35%- perception that the measure compromised occupant comfort; 22%-unknown reasons; 22% lack of maintenance; 9%-operating hours changed; 12%-miscellaneous)</td>
<td>• Generally, the inconsistencies between utility EUL claims point towards the need for a more uniform and defensible basis for future EULs  • More data is needed to verify the results of this analysis.</td>
</tr>
</tbody>
</table>
Appendix B: Phone Interview Instruments

Building Staff Phone Interview Form

Introductions, thanks for taking the time to speak with us today. Then,

We are working on a research project for the California Energy Commission. The project is to develop an Energy Performance Tracking guideline for building owners & managers, taking a holistic view of management strategies and available tools, and the guideline will be accompanied by a few case studies to illustrate best practice. As background to this project we are conducting a series of interviews with building owners/managers/engineers to talk about their management approaches and the tools they use, and appreciate your taking the time to talk with us today.

Contact Information: (name, title, phone number, email address)
Date of contact: (Date of first call, left message, followed up with xxx)

Date of Interview:
Interviewer:
Other Contact Information: Use if there are additional staff are on the phone:

Recruitment Questions and Answers
Place any info that was gathered during recruitment here:

Other comments regarding information obtained during recruiting that will help during this interview:
<table>
<thead>
<tr>
<th>Building Staff Phone Interview Form</th>
</tr>
</thead>
</table>

**I. General**

1. **Building Name and Location:**

2. **Square Footage (note whether Conditioned, Gross, Rentable)**

3. **How long have you been associated with this building?**

4. **Does your building have any energy performance-related certifications such as LEED or Energy Star?**

5. **Is the building owner occupied, single tenant or multi tenant?**

6. **If not owner occupied, who pays the utility bills?**

**II. Building Performance History**

7. **Could you please give me a broad overview of your facility's HVAC and lighting systems, including how they are controlled.**
8. I'm going to list some assets related to building energy performance, please say yes or no if your building has a particular asset:

<table>
<thead>
<tr>
<th>Energy Management Control System</th>
<th>YES</th>
<th>NO</th>
<th>Year installed / upgraded:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type: Full pneumatic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full DDC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hybrid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If DDC, web-based?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lighting Controls for scheduling lighting</th>
<th>YES</th>
<th>NO</th>
<th>Year installed:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>VFDs on pumps</th>
<th>YES</th>
<th>NO</th>
<th>Year installed:</th>
</tr>
</thead>
<tbody>
<tr>
<td>List:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VFDs on Fans</th>
<th>YES</th>
<th>NO</th>
<th>Year installed:</th>
</tr>
</thead>
<tbody>
<tr>
<td>List:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Are there other assets that increase the energy efficiency of your building?

9. Do you have energy efficiency strategies programmed into your EMCS such as:
   - Optimum start
   - Temperature resets
   - Pressure resets
   - Economizer control
   - CO-based control of parking garage fans
   - CO2-based control of ventilation air
   - Daylighting / dimmable ballasts

10. Was your building commissioned when originally constructed?

   Has it ever been recommissioned or retrocommissioned by an outside CxP?

   If so, what were the primary benefits realized from Cx / EBCx?
11. Have you made any energy efficiency installations (retrofits) in the last five years such as a new high efficiency chiller, new boilers, VFDs on pumps or fans, lighting retrofits, a new EMCS? If yes, what?

III. Building Performance Staffing

12. Do you have an energy manager or a person with energy management responsibilities on staff? If yes, could you describe some of their main responsibilities?

13. How many building operators are on your team?

Do you regularly work with outside service contractors or commissioning consultants?

14. Do you have a regular training program for your building operators, or is training done as needed? (If they have a program, describe. If not, see next question.)
15. What might trigger a training class for one or more of your building operators?

<table>
<thead>
<tr>
<th>IV. Maintenance (Capacity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16. Do you have a computerized maintenance management system?</td>
</tr>
<tr>
<td>(If yes, ask how they use the system)</td>
</tr>
<tr>
<td>(If no, ask how they know when to perform maintenance on their equipment and systems)</td>
</tr>
</tbody>
</table>

| 17. What type of building documentation do you have available? (e.g., as-builts, original construction documents, systems manual, O&M manuals, controls documentation) |
| Do you have a process for updating your as-builts / building documentation as changes are made to your facility? |
| Are these documents kept in electronic or hard copy format? |

<table>
<thead>
<tr>
<th>V. Tracking Tools and Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>18. It sounds like you have made some good investments for improving the energy performance of your building. Could you describe how you track the performance of those systems, to help ensure that they are operating as expected?</td>
</tr>
</tbody>
</table>

<p>| 19. I’m going to list some tools and strategies for tracking and verifying the energy performance of your building and systems, please say yes or no if you have a particular tool or strategy: |</p>
<table>
<thead>
<tr>
<th>Question</th>
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<tbody>
<tr>
<td>An Ongoing Commissioning Plan?</td>
</tr>
<tr>
<td>A Recommissioning Plan?</td>
</tr>
<tr>
<td>Trend logging capability in your EMCS?</td>
</tr>
<tr>
<td>Periodic benchmarking?</td>
</tr>
<tr>
<td>Interval Meters (recording meters), utility or otherwise?</td>
</tr>
<tr>
<td>If so, are these linked to your EMCS?</td>
</tr>
<tr>
<td>Sub meters?</td>
</tr>
<tr>
<td>If so, are these on panels, or specific pieces of equipment?</td>
</tr>
<tr>
<td>An Energy Information System? (If yes, have them describe it and get brand name)</td>
</tr>
<tr>
<td>Fault Detection and Diagnostic tool (such as PACRAT)? (If yes, describe and get the brand name) (also note if they call it something other than ‘FDD’)</td>
</tr>
<tr>
<td>20. Are there any other tools or strategies you use to track and verify the energy performance of your building and its systems? If so, please describe briefly. (Some owners develop their own methods of tracking building performance, or may just review their utility bills)</td>
</tr>
<tr>
<td>What type of algorithms do your performance tracking tools use? Simple benchmarking (EUI), or more detailed (e.g., baseline model of equipment performance based on OAT)?</td>
</tr>
</tbody>
</table>
21. How did you select your PT tool (criteria, features)? How did you make the financial case for purchasing and using these tools? What type of information do you find most useful related to this effort?

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<thead>
<tr>
<th>VI. Tracking Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>22. It sounds like you have some good ways of acquiring energy performance data on your building. Is there someone responsible for analyzing the data and implementing solutions for energy performance issues revealed by the analysis? (refer to previous section for tools / strategies used, and address each)</td>
</tr>
<tr>
<td>23. How often does that person review the energy performance of your building? Who sees the performance tracking results (management, operations, tenants, public)?</td>
</tr>
<tr>
<td>24. After the performance data is analyzed, if energy usage is higher than expected, who is responsible for further investigation into the root causes? What is the process for this step (timeline, who reports to who)?</td>
</tr>
<tr>
<td>What is the process for evaluating the identified necessary improvements and implementing corrective action (costs and timeline)?</td>
</tr>
<tr>
<td>25. Conversely, if the data analysis shows that energy usage has decreased, is any action taken / rewards given?</td>
</tr>
</tbody>
</table>
26. Do you believe that your facility's energy use has decreased due to energy performance tracking? Please explain.

27. For what reasons do you monitor energy performance *(if not addressed above)*? *(prompts: to identify new savings opportunities, monitor general building performance, carbon tracking, monitor the performance of specific pieces of equipment, monitor the persistence of implemented measures)*

<table>
<thead>
<tr>
<th>VII. Closing</th>
</tr>
</thead>
</table>

28. Is there anything else you would like to tell us about how you preserve your building's energy performance?

29. We are developing a guide book for building owners on energy performance tracking tools and strategies as part of our project. Is there any information that you would like to see put into this type of a guide that would be particularly helpful?

(if building sounds like a good candidate for a site interview)

Would you be interested in participating in a follow-up onsite interview regarding your performance tracking practices? We'd like to get a better idea of your energy performance tracking practices.

30. May we contact you again, if we have further questions?

Thanks you for your time, etc.
Appendix C: Site Interview Instruments

Site Interview Guide

Prior to site interview:
- All of the general information on the building from the phone interview should already be in the site interview form such as: Facility name, square footage, number of stories, building age, interviewee contact information etc. Any missing information from the phone interviews will be obtained prior to the site interview.
- In some cases the phone interviews were done on the enterprise level and therefore have gaps in the site specific information. Most of this missing information in the phone interview form should be obtained from the building level participant (by phone) prior to the site interview in order to save time. However if this is not possible, the site interviews will attempt to fill in these gaps.
- Obtain permission to take photographs during the site interview. (For a building to be a case study we will need photographs.)
- Obtain permission for individuals from the company to participate in the site interview and let them know how much time will be needed from each participant. The site interview will include the person(s) most familiar with the buildings performance tracking tools such as the EIS, EMCS, FDD tools and other methods for ensuring that energy performance lasts.
- Set up a site interview kick off meeting with the building personnel and owner representatives who are scheduled to participate in the site interview.
- Develop a meeting agenda. The agenda will include such things as introductions, time to reiterate our project goals, the layout of the day (according to what’s been set up with them ahead of time – who will participate with you and when) etc. If it seems appropriate, do a short presentation on the outline for the Performance Tracking Guide and ask for feedback particularly on the “Checklist” approach.
- Time permitting for the participants, set up a site interview wrap-up meeting for the end of the day. If it seems appropriate and this was not done in the kick off meeting, do a short presentation on the outline for the Performance Tracking Guide and ask for feedback particularly on the “checklist” approach.

Site Interview:
- If it’s feasible, do the show-and-tell and questions for the person in charge of (or most involved with) the energy management of the facility first, and then a follow up walk through and questions with a building engineer who is most familiar with the controls system and energy performance methods.
- Take several high-resolution pictures of the exterior (an attractive angle of the front) and interior of the building. Take pictures of the persistence tools such as the EMCS, EIS, FDD tool including screen shots, etc. Also take shots of some newer large equipment such as a chiller (show off how clean and well maintained the mechanical areas are kept). Include people in some of the shots. More pictures are better.
Site Guide Checklist

The following is a checklist of the information that the site interview will attempt to obtain. Since each building is different as to what information has already been gathered in the phone interviews, once a building is selected for a site interview the information below should be modified with questions specific to that building.

**General Contact Information**
(This should be filled in ahead of time from the phone interview)

Interviewer:

Date:

Main Building Contact’s Name, Title and detailed contact information:

---

**General Building Information**
(This should be filled in ahead of time from the phone interview)

Facility Name:

Location (address):

Owner:

Facility size:

Age:

EUI (if available):

Type: (such as multi-tenant commercial office building with retail on ground level)

Building participants in site interview (Names and Titles):

Other: (Such as the roles and responsibilities of any third party entities involved in maintaining the building and the energy performance of the building)
**Management Level Information**

Show and tell about their energy tracking methods and tools used by management

(Fill out any information ahead of the interview, verify during interview)

- **What tools and methods do you use?** (Fill in from phone interview and verify during interview. Also, get information on any end-use metering that they use for tracking performance. Also note the terminology they use when referring to the tools – EIS? FDD? Or something else?)

- **What type output from the tool or method do you find most useful (why?)**

- **What are the criteria or metrics (KPIs) that trigger action (when does the operator need to know)?**

  - Who gets the alert and how long do they have to respond?

  - What’s the format for documenting the action?

- **Is there anything that you are particularly proud or in regards to energy savings strategies?**

- **What’s the biggest motivator for you to save energy?**

- **Do you have policies around energy performance? If so, are they written?** (It would be good if we could get a copy of the policy if we didn’t during the phone interviews but they may be confidential)
- Do you have plans such as an ongoing Cx plan, or energy management plan? May we see it? (It’s especially important to note whether they have a plan that includes performance tracking and what that says)

- Why did you choose this tool or this set of strategies to ensure energy performance?

- What was the biggest challenge for you in selecting the system(s) or method(s) for tracking energy performance?

- What are the lessons learned and challenge in using your current tracking system?

- What’s lacking in the methods or tools you have selected?

- Do you have plans for future improvements to your performance tracking systems and what are they?

- Over all, what do you think is the biggest barrier for owners in developing performance tracking strategies and obtaining tools to support performance tracking?

- Gaps to address, from phone interview (place important gaps or follow up questions for management under this item):
Specific questions for Case Study (fill in with any info. from phone interview):

☐ Can you quantify anything such as system cost and savings attributed to having a tracking strategy or method?

☐ Do they have a big story such as: As a result of using the energy tracking tool, we found X and that lead to Y amount of savings or cost avoidance?

☐ Did you receive any utility or government incentives to support energy tracking tools or other persistence methods and if so what?

☐ When you purchased the tool, how did you estimate or quantify the value of the system? How did you justify purchasing it?

Building Operator Level Information
Show and tell about energy tracking with the EMCS and FDD tools used by the building operators.

☐ Please show us your performance tracking tool(s) (We should know the brand name from the phone interview or follow up conversations, if not fill in the gap here)

☐ How do you use the tool? (What do they look at and for?)

☐ What are your biggest challenges in using the tool?

☐ Criteria or triggers for action. How do you know when to act on a problem that involves energy waste?

☐ If you act on something that has not come down through a work order or a manager, how do you document it and who do you tell?
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Do you feel the operation staff has adequate training on the energy performance tracking tools or methods used in the building?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Do you think the tools you have are adequate? (Why? Why not?)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>What’s the biggest motivator for you to save energy? (get the operator’s take)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>What are their biggest challenges in preserving the energy performance of the building?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Does your preventive (predictive) maintenance program include operational checks? (Give and ask for examples.)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Can you think of a time where you either stopped monitoring performance of an EEM, or noticed that an EEM wasn’t persisting and didn’t take action? What are some of the reasons?</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Please show us your control system (We should know the brand name from the phone interview or follow up conversations, if not fill in the gap here)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>What type of energy efficiency strategies are programmed into the system (list and see if they can show some of them).</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Do you use the system’s trend-log ability? (If so, have them explain how they use it – how often they look at and analyze the data)</strong></td>
<td></td>
</tr>
</tbody>
</table>
What are your biggest challenges in using the EMCS?

Gaps to address, from phone interviews:

**Third Party Level (if a third party has some responsibility for energy tracking)**

In some cases building owners and managers use third parties to track energy performance. In which case these question need to dovetail with questions above for both management and operating staff.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Show and tell about the third parting energy tracking methods including benchmarking (may be covered above)</td>
<td></td>
</tr>
<tr>
<td>□ Name of third party company (may be covered above)</td>
<td></td>
</tr>
<tr>
<td>□ Energy performance reporting methods to the owner</td>
<td></td>
</tr>
<tr>
<td>□ Criteria or triggers for reporting anomalies to the owner</td>
<td></td>
</tr>
<tr>
<td>□ Contractual agreements around energy performance and persistence (How do they know the third party is meeting expectations?)</td>
<td></td>
</tr>
</tbody>
</table>
Appendix D: Phone Interview Summaries

This Appendix includes an overall summary and key findings from each of the 21 phone interviews.
<table>
<thead>
<tr>
<th>Building type</th>
<th>Facility A</th>
<th>Facility B</th>
<th>Facility C</th>
<th>Facility D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance tracking (PT) system type</td>
<td>Benchmark</td>
<td>Benchmark</td>
<td>Monthly utility bill tracking</td>
<td>EIS 'ish (limited to computer power)</td>
</tr>
<tr>
<td>PT system name</td>
<td>Portfolio Manager</td>
<td>Benchmarking using monthly data and degree-day normalization</td>
<td>None</td>
<td>Verdium</td>
</tr>
<tr>
<td>PT strategy</td>
<td>Monthly tracking</td>
<td>Monthly utility bill tracking</td>
<td>EIS 'ish (with dashboarding capability - has some data analysis and reporting capability)</td>
<td></td>
</tr>
<tr>
<td>PT management structure / process</td>
<td>Along with Energy Star, they use a variety of home built excel based analysis tools. Generally these provide a quick comparison of energy bills at the site over the past 2 years.</td>
<td>Currently use utility bills to set a benchmark ($ and kWh) which is normalized to degree days. When consumption drifts from the benchmark, they investigate the cause. They are also rolling out a pilot for Enforma.</td>
<td>Originally identified for using Automated Logic, but turns out they use only the operational aspect of the system and not WebCTRL (no EIS functionality). Currently track monthly utility bill from SCE using internal staff. High bills = action/deeper investigation. The generally know when to expect higher than normal bills due to OAT, increased processes and overtime requests.</td>
<td>The PT method adopted is limited to computer energy management. Verdium, a client based software, is installed on every PC (19,000 in total across the state). Software can profile power consumption from any computer statewide and analyze by district/region from 1 sec to 1 year intervals. Can send instructions to PCs to sleep after a predefined idle time.</td>
</tr>
<tr>
<td>What aspects of PT system work best for them</td>
<td>Identified 12% reduction in consumption by tracking utility bills (simple analysis) Mostly from DR, T8 retrofits, central plant optimization</td>
<td>The systems also adds controllability to the computers on the network...allowing the enforcement of their energy policy (related to computers)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What aspects of PT system don't / didn't work for them</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consider for case study?</td>
<td>Y, when/if Enforma is installed and operational</td>
<td>N</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

**Notable findings:**
- ABM is a 3rd party O&M firm. They fully staff onsite maintenance for ~80% of their clients. ~10% include full facility management which included energy management. Their O&M focuses on equipment efficiency and reliability. **They see energy efficiency as a good service to provide their clients.**
- A reporting/tracking strategy was established before the roll out of Enforma.
- **No communication from the top down.** Vin submits monthly utility bills and doesn’t know how they are used. He has never been told how the data are used
- Monitoring provides proof of savings. Mentioned their Verdium system proves value of real time tracking. 1989 policy to turn off computers at night...believed ~30-40% complied, but had no way to verify. They benchmarked all computers in July and found 49% savings from baseline. Achieved another 19% savings from forced shutdowns. **Verdium dashboards the energy use of computers only.**
<table>
<thead>
<tr>
<th>Building type</th>
<th>Facility E</th>
<th>Facility F</th>
<th>Facility G</th>
<th>Facility H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance tracking (PT) system type</td>
<td>Large Office</td>
<td>various</td>
<td>Large office</td>
<td>various</td>
</tr>
<tr>
<td>PT system name</td>
<td>Custom-Intelligent Building Monitoring System (IBMS)</td>
<td>Vykon Energy Suite (Tridium)</td>
<td>Constellation, Energy Star</td>
<td></td>
</tr>
<tr>
<td>PT strategy</td>
<td>(Intelligent Building Monitoring System) contains alarming based on normalized operation defined by historical records (e.g. tomorrow’s forecast is compared with the 5 most similar days in the archive to create an expected baseline model)</td>
<td>Vykon Energy Suite is used to analyze historical energy usage. A corporate call center receives BAS alarms that are displayed on a dashboard. Automatic and escalating email alarms are created.</td>
<td>Continuous Optimization, 3rd party service- Constellation billing services with analysis- ABM for O&amp;M services</td>
<td></td>
</tr>
<tr>
<td>PT management structure/process</td>
<td>Operators respond to alarms generated by the PT system. They must actively look at the system to observe any alarms. A new feature is planned to create automatic work orders with any identified issues. George mentioned operators are work order driven and might not proactively watch the PT system for alarms.</td>
<td>Vykon generates load shapes using interval data for peak load analysis. The load profiles are inspected manually to identify any anomalies. The energy manager reviews load profiles of buildings quarterly. Operational alarms are dealt with as needed.</td>
<td>3rd party billing service- out of tolerance consumption results in a red flag and automatic warning to corporate. Corporate follows up and determines cause if possible, if not, informs property staff to identify and address</td>
<td></td>
</tr>
<tr>
<td>What aspects of PT system work best for them</td>
<td>Track benefits of efficiency projects</td>
<td>Automatic optimization has the plant operating very smoothly. There are very few issues that require reaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What aspects of PT system don’t/didn’t work for them</td>
<td>None addressed</td>
<td>Tracking appears to be in place, but no strong procedures to deal with the information are established. Seems like they track the data, but then don’t do anything with it yet.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consider for case study?</td>
<td>Yes</td>
<td>N</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Notable findings:</td>
<td>Most engineers/operators are maintenance/work order driven. Wants to encourage the workers to look at the systems more proactively. Currently, the alarming is a flashing screen and requires someone to watch in order to respond.</td>
<td>Also benchmarks using $/sf. Anything over $2/sf receives extra attention. Buildings with Energy Star Scores near 75 also get attention. A predictive model is developed. They are working to install threshold reporting alarms to the system, which would make their tracking a top-down FD method. Integration with their existing tridium Niagara AX system was a key driver</td>
<td>Utilizes multiple tiers in their performance tracking, from whole building to system level KPI’s. A billing service is used to flag anomalous monthly consumption and communicates any deviations from previous bills via automatic email alarms. ABM provides 3rd party O&amp;M services and has a strong focus on efficiency. The central plant was upgraded with OptimumLoop where the central plant operation is continually optimized and is monitored remotely by Optimum Energy staff. Any issues that affect central plant efficiency are communicated to onsite staff.</td>
<td></td>
</tr>
<tr>
<td>Follow-up questions to address during onsite interview</td>
<td>This was a very short phone interview that missed much of the building specific information. How are energy monitoring responsibilities delegated (energy manager, operators, etc)? Building maintenance section was skipped during the interview. How was the financial case made to pursue their current PT strategy? How does the PT information inspire action, what is the process when issues are identified?</td>
<td>When was DDC installed/upgraded? Was building Cx’d? When was bldg built. Do they compare monthly usage with last year’s usage for same month (for 2-5% error)? How was the financial case made for implementing a PT strategy? What do operators do when they receive an email from Carlos saying there’s an unaccountable increase in usage? Have savings from implementing PT been documented? Have performance issues been identified and corrected faster using the PT system than without?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Monthly invoices are the main tracking component. A national system is used but there is no main reporting structure established yet. They have kBtu/sf targets, but no policy to respond to signals from tracking. Larger buildings have PACRAT installed but it has pretty much sitting dormant for the last few years. VPACC is used and is tied to their CMMS to generate automatic work orders.</td>
<td></td>
</tr>
</tbody>
</table>

*Subtask 4.2 Research Report*
<table>
<thead>
<tr>
<th>Building type</th>
<th>Facility I</th>
<th>Facility J</th>
<th>Facility K</th>
<th>Facility L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance tracking (PT) system type</td>
<td>Various</td>
<td>large office</td>
<td>Hospital</td>
<td>Multiple</td>
</tr>
<tr>
<td>3rd party service</td>
<td>FD</td>
<td>dashboard</td>
<td>Multiple offerings (EIS used in some buildings)</td>
<td></td>
</tr>
<tr>
<td>PT system name</td>
<td>Energy Cap</td>
<td>Pulse</td>
<td>Power Monitoring System</td>
<td>Itron EEM Suite mentioned</td>
</tr>
<tr>
<td>PT strategy</td>
<td>Alarms are generated when monthly consumption increases above a 10% threshold. Engineers must respond to the alarms and inform the energy manager what caused the change from expected consumption.</td>
<td>Top-down fault detection</td>
<td>Monitor real-time power consumption. Data is hard to extract from the system. No analysis of data, therefore, this is not an EIS.</td>
<td>Varies by contract, but includes: utility bill tracking, load profile developed from interval data, live feeds. Energy Star is a primary tracker. Utilize Itron EEM Suite with some in-house modifications used for live feed services.</td>
</tr>
<tr>
<td>PT management structure / process</td>
<td>Alarms are sent to the energy manager and the chief engineers. Reasons for alarms are documented.</td>
<td>A facility manager is responsible for the energy use at the facility. He has been coached by an energy consultant from the BC Hydro program in using the Pulse PT system.</td>
<td>Monitoring focus is related to DR program only.</td>
<td>Lots of options to choose from...need to work with Will identify an appropriate CA site for more in-depth investigation. We should target a live feed facility that uses Itron.</td>
</tr>
<tr>
<td>What aspects of PT system work best for them</td>
<td>Monitoring helps identify systems/procedures that work and helped quantify how well they work</td>
<td>Quickly identify issues and ensure persistence. Tenants are able to log into the system and observe the building’s current demand. Sometimes the tenants call the property manager when they recognize red flags in the system</td>
<td>Works great for their DR capability. Provides an instantaneous snapshot of current demand and shows the immediate impact when a DR event is occurring.</td>
<td></td>
</tr>
<tr>
<td>What aspects of PT system don’t / didn’t work for them</td>
<td></td>
<td></td>
<td>Hard to extract data from the system</td>
<td></td>
</tr>
<tr>
<td>Consider for case study?</td>
<td>Energy Cap indicates abnormal conditions (deviations from normal operation) 10% deviation requires an explanation/investigation. ECAP is also a billing service. It does provide energy use graphs and charts. The engineers proactively respond to alarms from ECAP and attempt to have answers for the energy manager when an alarm is received (the energy manager calls the engineers to investigate alarms).</td>
<td>Enrolled in BC Hydro’s continuous optimization program. 10 of 14 buildings will have Pulse installed. After RCx, they noticed a 23% energy reduction portfolio wide. The main pulse dashboard is used, not the energy reports. Pulse already helped ID a building warm up mode during summer</td>
<td>They use their own meters (power monitoring system). Monitor energy use on the fly. Motivation for the power monitoring system was to look into energy use and enroll in DR. Dashboard can show the 3 levels of DR that can be activated when needed.</td>
<td>Yes</td>
</tr>
<tr>
<td>Notable findings:</td>
<td></td>
<td></td>
<td></td>
<td>Very high level information from multiple perspectives, more building specific information can be gathered once an appropriate site is identified. An in-house Cx program was mentioned-more details?</td>
</tr>
<tr>
<td>Follow-up questions to address during onsite interview</td>
<td>Limited time for interview</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building type</td>
<td>Facility M</td>
<td>Facility N</td>
<td>Facility O</td>
<td>Facility P</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td></td>
<td>Large Office</td>
<td>State Library with office</td>
<td>Large Office</td>
<td>Large office</td>
</tr>
<tr>
<td>Performance tracking (PT) system type</td>
<td>FD</td>
<td>FD-whole building analysis with fault detection</td>
<td>FD</td>
<td>FD-whole building monitoring with fault diagnostics</td>
</tr>
<tr>
<td>PT system name</td>
<td>MACH Energy</td>
<td>Energy Expert</td>
<td>Pulse</td>
<td>Stonewater</td>
</tr>
<tr>
<td>PT strategy</td>
<td>Top-down fault detection</td>
<td>Whole building tracking</td>
<td>Whole building top-down fault detection</td>
<td>Real time whole building kW-based.</td>
</tr>
<tr>
<td>PT management structure / process</td>
<td>Auto email alarm is sent to the operator, property manager, and corporate owners</td>
<td>Energy coordinator looks at portfolio level indicators (EUI). Building operators focus on daily energy use reports from Energy Expert</td>
<td>Energy and Sustainability Manager is the sole user of the Pulse front end. He keeps the dashboard running in the background and monitors throughout the day.</td>
<td>PT system generates an alarm when kW is higher than expected (time of day / day of week-based baseline, not OAT-based). Bldg operators and nat'l energy manager are notified. Operators have ~3 days to give reasons for increased demand to energy manager. If they can't figure it out right away, operators look to BAS trends.</td>
</tr>
<tr>
<td>Consider for case study?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Notable findings:</th>
</tr>
</thead>
<tbody>
<tr>
<td>MACH Energy used to be the PT tool at this site, but the operator didn't like the system. They have since transitioned to EnerNOC for demand response. This interview was to discuss the reasons they didn't like their original tool. Main reasons the engineer didn't like MACH were the delayed response time (1 day lag for alarms, nuisance alarms (threshold was too narrow), alarms generated based on inaccurate weather data (SFO data for downtown a building)).</td>
</tr>
<tr>
<td>The coordinator keeps lines of communication open between end-users, maintenance and the higher level administration. They need to show energy savings or risk losing positions. Their budget was cut and they agreed to make up the difference via energy savings instead of layoffs. Tenant involvement seemed to help create a change in culture. Energy reduction is now engrained throughout the department. Quarterly nighttime audits for all occupied buildings</td>
</tr>
<tr>
<td>The utility appears to fund the energy manager. He mentioned the need to show energy savings/progress to validate his position. The energy manager actively monitors the main energy dashboard (keeps it on his main screen) and actively pursues information from operators when deviations are observed. During early deployment, the system generated lots of tolerance alarms. Now that it's been running for a while, fewer alarms are received (not sure if this is due to a shifting baseline, or improved operation)</td>
</tr>
<tr>
<td>Joe would like a copy of the report when available.</td>
</tr>
<tr>
<td>How is information transferred to/from the utility manager? A third party billing service was mentioned, how does this service factor into PT. Is the utility manager a software or person? How is the CMMS (FC 7) used?</td>
</tr>
<tr>
<td>Year of DDC install, lighting control install, fan VFD install.</td>
</tr>
<tr>
<td>Building type</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>Performance tracking (PT)</td>
</tr>
<tr>
<td>PT system name</td>
</tr>
<tr>
<td>PT strategy</td>
</tr>
<tr>
<td>PT management structure / process</td>
</tr>
<tr>
<td>What aspects of PT system work best for them</td>
</tr>
<tr>
<td>What aspects of PT system don't / didn't work for them</td>
</tr>
<tr>
<td>Consider for case study?</td>
</tr>
<tr>
<td>Notable findings:</td>
</tr>
<tr>
<td>Follow-up questions to address during onsite interview</td>
</tr>
</tbody>
</table>
Appendix E: Site Interview Summaries

This Appendix includes an overall summary and key findings from each of the five site interviews.

Site #1: 130,000 sq.ft. office building with large data center

Location: Sacramento, California

**Highlights**
- Energy manager (EM) uses EIS tool to track monthly whole building energy performance of his 300 facilities, to identify major underperformers.
- EM has incorporated some BAS points into the EIS.
- Operators don’t use the EIS. They use the BAS to monitor building performance.

**PT Tool**

EEM Suite, by McKinstry (formerly Itron).
- EM uses EEM Suite to track monthly utility usage of 300 facilities, and benchmark his portfolio of buildings
  - Site #1 is one of the largest of those 300
- EM would like to:
  - Incorporate interval meter data for real-time tracking
  - Alarm on hourly data using interval meter data and BAS points. He’s already incorporated some BAS points into EEM suite
  - Communicate energy usage info more effectively with building operators and occupants
  - Find time to use the tool to its full potential

EM sees upfront and ongoing costs as barriers for owners implementing PT programs

**Overview of PT Process**
- Energy-related alerts are emailed to EM when usage is 30% higher than either the previous month’s usage, or the same period during the previous year.
  - The 30% threshold is set so high to eliminate nuisance alarms
  - EM only wants to identify major underperformers
- Operators use the BAS (JCI system), they don’t use EEM Suite. They have a few key screens they reference (e.g., AH-1), to get an idea of system performance

**Management PT Process**
- The EM forwards energy alerts on to the engineer responsible for the related building
  - Beyond that, there’s no set process
- For ESCO projects, EM would like to get away from looking for results at the meter
  - He’d rather track performance of KPIs

**Building Operator PT Process**
- Operators monitor equipment performance and space temps through the BAS. They’d like to monitor more zone-level info through the BAS.
- Operators don’t track energy performance
- At this facility, operators say they identify issues before the EM sees them at EEM Suite. For this particular facility, the operators have never received an alert email from the EM about high energy usage
- Operators have a tough time keeping up with their PMs due to staffing cuts
- They do some operational checks, but mostly rely on the mfr’s O&Ms
Site #2: 82,000 sq.ft. office building with large library
Location: Salem, Oregon

**Highlights**
- O&M staff uses the EIS to monitor overall building performance and the BAS to diagnose the root cause of problems
- EM uses a quarterly newsletter and building green teams to promote behavior change
- Clear energy performance goals and sufficient, capable staff make the program successful

**PT Tool**
The EM uses three tools, and the O&M staff use two tools. EM uses:
- Utility Manager for benchmarking against buildings internally.
- Energy Manager (Itron EEM) for kWh info and load factors.
O&M staff use:
- BAS and loggers for identifying causes of increased usage as detected by Energy Expert.
EM finds Utility Manager most useful, the O&M staff finds Energy Expert most useful. Re. Energy Expert, both the EM and O&M staff said, “The tool helps us find problems faster.”

**Overview of PT Process**
Energy Expert delivers daily emails to EM and O&M staff. O&M staff look for increased usage in these emails. They also look at real-time power draw through Energy Expert. When they see an increase, they use BAS trends to identify the root causes.

2.5 year payback related to EPT. Their EPT system helps them meet their energy goals. They have a sustainability plan in place.

**Management PT Process**
EM develops a quarterly newsletter, which includes usage data. EM relies on green teams to spread the word of energy conservation. These teams are also involved in night energy audits.

Per the EM, for a successful EPT program:
- O&M staff need to have time to look at the data / reports. “Don’t put the money into if if you can’t dedicate the staff time.”
- You need people who understand the data they’re looking at and know what to do with it.

EM would like to better demonstrate the value of the system through better O&M staff documentation of adjustments made after receiving alerts from Energy Expert.

**Building Operator PT Process**
- EPT examples: O&M staff identified an equipment scheduling issue and an airside economizer issue after receiving increased energy usage alerts from Energy Expert.
- Staff is motivated to monitor usage to help save their jobs. Energy reduction is in their budget. O&M staff doesn’t monitor specific EEMs, only overall building performance.
- O&M does routine operational checks. E.g., dirty coils, quarterly economizer damper checks (damper open / closed, sequences), nighttime checks of equipment on/off.
Site #3: 250,000 sq.ft. office building
Location: La Jolla, California

**Highlights:**
- Continual optimization of the central plant setpoints and 3rd party monitoring ensures continued performance
- Open lines of communication from the top down and bottom up
- Top level support for energy efficiency
- kW/ton is a KPI used at this site

**PT Tool**
The onsite engineer maintains the efficiency of the central plant through:
- OptimumLoop and Optimum MVM (central plant)
- Manual inspection of monthly DR-100 reports (interval data)
The corporate level uses:
- Constellation (monthly billing service with analysis and alarms)
- Energy Star Portfolio Manager

**Overview of PT Process**
OptimumLoop is used for the central chiller plant to continually optimize setpoints to increase chiller plant efficiency. 3rd party services are used to monitor and ensure chiller plant efficiency, inspect utility bills for abnormal deviations, and to conduct O&M.
- Corporate uses Portfolio Manager to track and compare building benchmarks

**Management PT Process**
Management looks primarily at portfolio level tools (Portfolio Manager is used most)
- Utility billing service includes data analysis with automatic alarms when monthly consumption deviates by more than ~7.5% (month to month – not weather normalized).
- Corporate investigates alarms and determines the cause
  - Mainly extreme ambient conditions or major tenant movement
  - If corporate can’t explain the cause, the issue is communicated to the site to investigate
Management would like:
- Energy use breakdowns included in Optimum Energy services

**Building Operator PT Process**
OptimumMVM is a 3rd party monitoring service that flags issues with chiller plant efficiency. When the plant efficiency drifts from expected levels, staff engineers from OptimumEnergy attempt to diagnose and communicate the alarms to the building engineer. Chiller plant operation is optimized automatically.

The building operator:
- Uses hardcopies of monthly interval data to look for anomalies in consumption
- Uses the Optimum Energy dashboard and responds to drift in plant efficiency
- Had the controls contractor develop a custom display on the Alerton BAS
  - No graphics, just main points for primary systems (his preference)
- Conducts a daily building walk-through and records main meters
Site #4: 253,000 sq.ft. office building with server rooms and small labs
Location: San Francisco, California

**Highlights**
- Data from primary electric sub-meters are monitored and trendable
  - Visual display of main meter consumption allows operators to understand where energy is used at the facility
- The EIS has capability to display/track nearly any KPIs (very customizable)
- Onsite staff appear mainly operational driven, not energy focused
- Onsite staff responds to alarms from the tool, but don’t seem to track any KPI’s

**PT Tool**
IBIS: Intelligent Building Interface System is a building energy dashboard
- Custom built for Site #4 by Integrated Building Solutions

IBIS is a building level dashboard that displays key information. Sub-metered energy data and main BAS points are collected and available. Reports can be created from the main data, though the operators mentioned the process is not very intuitive.

IBIS provides a dashboard view of:
- Sub-metered energy use data (data center, mechanical, lighting & plugs, kitchen)
- Operational points from primary equipment (temps, RH, status, tons)
- Lighting occupancy per floor

Alarms received are operational based (space temperature/humidity) but can also be triggered by high energy (compared to historical usage at similar conditions – database lookup)
- Operational alarms were most common
  - Months since the last alarm event was received
- Alarms are emailed to onsite staff and corporate level staff

**Overview of PT Process**
Building performance is maintained primarily through a focus on operations. The EIS is primarily used to identify alarms such as out of tolerance zone temperatures and excessive energy use. The process appeared reactive instead of proactive; however, the last alarm was received several months before this site interview.

**Management PT Process**
Accountability is incorporated into the overall PT process. Corporate level employees receive emailed alarms from the tracking tool and follow up with the local staff to ensure the issue is resolved. The local staff appeared motivated to prevent any such follow-ups from corporate.

**Building Operator PT Process**
The operators mentioned the building operates very well and reported no major challenges
- Two operators occasionally keep an eye on the dashboard
- They respond to alarms received from the system

Operators discovered 150-200 kW spikes in the kitchen after hours using IBIS – someone left the booster heater on at night.
Site #5: 5,000 acre campus with 1,200 buildings and 14 million sq.ft. of floor space
Location: Davis, California

Highlights
- Utilities office (CHW, steam, and high voltage supply) tracks balance in the primary loop and power quality
- A dashboard pulls data from Pi and is mainly used by staff/tenants, especially those billed for utilities. The dashboard is not used by utilities or maintenance staff for PT
- Operators use EMS to monitor operational performance. Firewalls block access to Pi.

PT Tool:
OSIsoft Pi – data collection, storage and primary analysis tool. Aggregates data points from control systems, turns into metrics and reports.

- Current use: (Staff use/generate custom reports to identify anomalies in key systems)
  - Found unusual spikes in demand from the large central plant equipment
  - Found a spike in NG use in housing through the tool (caused by a leak)
  - Discovered utility customers were undercharged for by ~$750,000/yr
  - Dashboard used only by end-users, especially those that are billed for their utilities

Overview of PT Process
- No set process among operators or Utilities groups. Little communication between Utilities, Building Maintenance, Environmental Stewardship and Sustainability, and Project Management offices

Management PT Process
- Utilities mentioned that providing motivation for energy savings is “a senior management issue to drive down prerogatives to staff.”

Areas needing improvement:
- Time/capacity/fund limitation prevents full advantage of all the tool’s capabilities.
  - LEED helped by requiring extended M&V times – provides long term motivation.
- Some buildings don’t have the proper meters; some buildings don’t have the required communication pathways to access the data.

Funding has helped:
- There was no drive to push for efficiency measures when there was no $ for investment. Motivation increased when funding became available. Now the savings from the portfolio of projects is used to pay off the funding source (bond)

Building Operator PT Process
- Their primary focus is operation. They don’t look at the high level performance metrics. They have a central control room with 3 split screens and projectors to display the DDC system.
- They look for alarms, track equipment status, and dig deeper when the need arises.
- Would like to see integration with the Pi system to provide the group with a bigger picture. Firewall is the problem.
- Proper operation frees up time and allows his staff to be more proactive rather than reactive.
- Biggest challenge for operators is funding.
Appendix F: Tool Screenshots

This section includes screenshots from the performance tracking tools used by the site interview participants.

Site #1: 130,000 sq.ft. office building with large data center
Tool: McKinstry EEM Suite
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...END...
Site #2: 82,000 sq.ft. office building with large library
Tools: Utility Manager; Northwrite Energy Expert; Energy Manager
Highest kBtu/SqFt

Year Ending 12/2009

kBtu/SqFt Ranking Graph (Highest) -- Printed by: 

on 04/27/2010 at 2:59 PM -- Data prorated into calendar month according to billing from and thru dates

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Currently you do not have any default view. Select a view from "All Views" and add it to "My Views" as default view.
Site #3: 250,000 sq.ft. office building
Tool: OptimumEnergy
Site #4: 253,000 sq.ft. office building with server rooms and small labs
Tool: Intelligent Building Interface System