Synthesis of Year Three Outcomes in the Smart Energy Analytics Campaign

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Executive Summary

As building energy and system-level monitoring becomes more common, facilities teams are faced with an overwhelming amount of data. These data do not typically lead to insights or corrective actions unless they are stored, organized, analyzed, and prioritized in automated ways. Buildings are full of energy savings potential that can be uncovered with the right analysis. With analytic software applied to everyday building operations, owners are using data to their advantage and realizing cost savings through improved energy management.

The Smart Energy Analytics Campaign (smart-energy-analytics.org) is a public–private-sector partnership program focused on supporting commercially available Energy Management and Information Systems (EMIS) and monitoring-based commissioning (MBCx) practices for commercial buildings. Monitoring-based commissioning is an ongoing commissioning process that focuses on monitoring and analyzing large amounts of data on a continuous basis. EMIS tools are used in the MBCx process to organize, present, visualize, and analyze the data. The Campaign couples technical assistance with qualitative and quantitative data collection. Participants are encouraged to share their progress and may receive national recognition. After three years in operation, the Campaign now includes 96 commercial organizations across the United States, totaling 518 million square feet of gross floor area and more than 5,900 buildings, making this the most comprehensive dataset available on analytics installation and use. This report presents a characterization of EMIS products, MBCx services, and trends in the industry based on data from the Campaign.

Study participants with energy information systems[1] (EIS) achieved a median energy savings of 4 percent ($0.04/sq ft) and participants with fault detection and diagnostic tools[2] (FDD) achieved a median savings of 9 percent ($0.24/sq ft).[3] Comparing the most recent year for which data are available to the baseline year before the EMIS installation, 45 participants saved 2.6 trillion Btu/year and $59 million/year. These savings demonstrate the reduction in energy use achieved at buildings that are utilizing EMIS. However, the savings cannot be attributed solely to the operational improvements achieved with the support of the EMIS, since energy savings are determined at the whole building level, and other energy-impacting projects may be occurring simultaneously. With cost reporting from 67 participants, median costs and resource requirements by EMIS type are as follows:

- **EIS:** Software installation and configuration is $0.01/sq ft, annual recurring software cost is $0.01/sq ft, and the annual in-house labor is one hour per month per building.
- **FDD:** Software installation and configuration is $0.05/sq ft, the annual recurring software cost is $0.02/sq ft, and the annual in-house labor is 9 hours per month per building.

An initial cost-effectiveness analysis showed a 1- to 2-year simple payback period. Table ES-1 below summarizes Campaign results to date using data collected from 96 participating organizations. The high level of participation in the Smart Energy Analytics Campaign points to a growing national trend in the use of analytics in commercial buildings. The Campaign supports an expansion in the use and acceptance of EMIS, helping organizations transition to building operations that are continuously informed by analytics.

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[1] Energy information systems (EIS) are the software, data acquisition hardware, and communication systems used to store, analyze, and display building energy data.

[2] Fault detection and diagnostic (FDD) tools are the software that automates the process of detecting faults and suboptimal performance of building systems and helps to diagnose their potential causes.

[3] Energy savings reported from sites with at least two years of EMIS implementation. The median savings are determined by comparing energy data from the second year after EMIS implementation with the baseline year before the EMIS was installed.

Table ES-1: Summary of EMIS Use by Smart Energy Analytics Campaign Participants, through July 2019

EMIS Category	Energy Information Systems (EIS)	Fault Detection and Diagnostics (FDD)
Used by	Energy managers	Facility operations teams, energy managers, and service providers
Used for	**Portfolio management** • Portfolio key performance indicators (KPIs) / prioritization of properties for improvements • Energy use tracking and opportunity identification (mainly heat maps and load profiles) • Emerging tool for public/occupant communications and measurement and verification (M&V)	**Detailed system analysis** • Reducing preventative maintenance program costs • Improving comfort with zone-level diagnostics • Finding hidden waste and maintaining savings (participants shared that retrocommissioning [RCx]) savings did not persist without MBCx)
Typical installation	Whole building energy meters by fuel for large buildings in a portfolio, either with utility-provided interval data or an owner-installed meter. Submetering is less prevalent.	Installation focuses on fault detection and diagnostics (FDD) for problem HVAC areas (central plant, air handling units [AHUs]), or variable air volume (VAV) terminal boxes.
Common analytics *n = 96 organizations* *Floor area:* *518 million sq ft* *5,950 buildings*	• Energy use intensity (kBtu/sq ft) • Heat map • Load profile, filtered by day type • Predictive models for energy use	• Chiller plant operations and setpoint optimization • Air handlers (simultaneous heating and cooling, economizers, valve leak-by) • Terminal unit operation • Detecting failed sensors
Top measures implemented through the MBCx process *n = 74 organizations* *Floor area:* *452 million sq ft*	• Improve HVAC scheduling • Share energy information with occupants • Adjust space temperature setpoints	• Improve HVAC scheduling • Improve economizer operation • Reduce overventilation • Reduce simultaneous heating and cooling • Adjustment of space temp setpoints • Reset supply air temp and duct static pressure • Tune control loops to avoid hunting
Energy Savings* *n = 45 organizations* *2,627 buildings* *Floor area:* *224 million sq ft*	Median energy savings (whole building, all fuels) after two years of EMIS installation: EIS: 4%, ($0.04/sq ft); range: -6% to 31%; FDD: 9%, ($0.24/sq ft); range: -2% to 26% ** Savings are not specifically attributed to operational measures. Savings may include changes to the buildings that are not related to analytics.*	
Cost* *n = 67 organizations* *Floor area:* *484 million sq ft*	Median base cost (software + installation): EIS $0.01/sq ft; FDD $0.05/sq ft Median annual recurring cost: EIS $0.01/sq ft per year; FDD $0.02/sq ft Median in-house labor hours/month per building: EIS one hour; FDD nine hours ** Base and recurring cost data have been provided in $ and normalized by floor area.*	
Cost-effectiveness *n = 24 organizations* *Floor area:* *198 million sq ft*	Median simple payback period: EIS: 1.5 years (n = 7; 30 million sq ft) FDD: 1.1 years (n = 17; 168 million sq ft)	

1. Introduction and Background

Buildings are full of hidden energy savings potential that can be uncovered with the right analysis. With sophisticated software to inform and assist in building operations, building owners now are reducing energy and improving operations using building data analytics.

The cornerstone of successful building data analytics is the ability to extract accurate and actionable insights from large amounts of data. Modern building automation systems (BAS) monitor hundreds of points per building, and an owner may have a portfolio generating many thousands of data points every hour. The BAS can provide alarms for points out of range, but the analytical capabilities fall well short of helping achieve an optimized system. Further, common analysis tools for energy meter data tend to manage the monthly bills but do not support hourly interval data. Energy management and information systems (EMIS) are software that provide the needed analytical horsepower to building owners as they work to find meaning from data. This section highlights the benefits and challenges in using EMIS for continuous energy management.

What are EMIS and MBCx?

EMIS are the broad and rapidly evolving family of tools that monitor, analyze, and control building energy use and system performance. The data generated from EMIS tools enable building owners to operate their buildings more efficiently and with improved occupant comfort by providing visibility into and analysis of the energy consumed by lighting, space conditioning and ventilation, and other end uses. EMIS tools are used in the monitoring-based commissioning (MBCx) process to organize, present, visualize, and analyze the data.

There is no consensus definition of EMIS, but a broad categorization framework has been developed (Granderson et al. 2015). Figure 1 describes a framework for classifying EMIS functionality in meter-level analytics and system-level analytics. An EMIS product may have attributes in multiple categories.

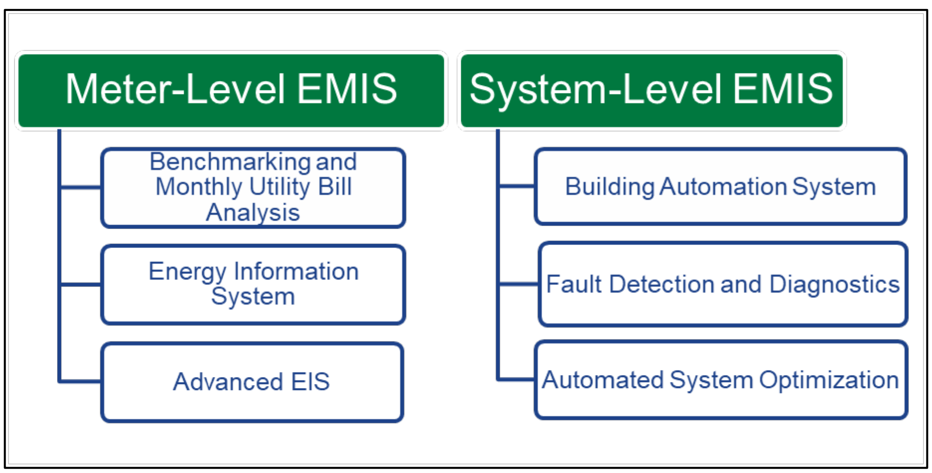

Figure 1: Energy Management and Information Systems (EMIS) Framework

While monthly bill management software and BAS are classified as the first tier of EMIS, this paper is focused on the more advanced EMIS as the industry moves toward in-depth analytics.

BAS are used to control building heating, ventilation, and air-conditioning (HVAC) systems, and in some cases, building lighting and security systems. The BAS is excellent at maintaining indoor temperature, humidity, ventilation, and lighting conditions; however, BAS often lack the ability to answer questions such as: how much energy is consumed at different times of the day? Does the economizer behave appropriately? What is the optimal air handling unit supply air temperature setpoint? EMIS tools such as energy information systems (EIS), fault detection and diagnostics systems (FDD), and automated system optimization tools (ASO) supplement the BAS to facilitate analysis and management of building energy use.

Descriptions of the more in-depth EMIS technologies that are the focus of this report are as follows:

- **Energy information systems / Advanced EIS:** The software, data acquisition hardware, and communication systems used to store, analyze, and display building energy data. EIS are a subset of EMIS that are focused on meter-level monitoring (hourly or more frequent, at whole building or submeter level). These meter data are not yet commonly integrated with BAS. Advanced EIS incorporate automated opportunity analysis that typically includes predictive energy models using interval meter data.
- **Fault detection and diagnostic systems:** Software that automates the process of detecting faults and suboptimal performance of building systems and helps to diagnose their potential causes. FDD are a subset of EMIS that focuses on system-level monitoring (using BAS data). An FDD system is different than a BAS alarm. Alarms typically detect sensor value deviation associated with a specific point based on real-time conditions. They don't typically allow for sophisticated logic that interrelates multiple data streams and performs rule-based or model-based diagnostics. FDD tools are typically applied as a separate software application that pulls data from the BAS and may provide a report of the duration and frequency of faults, cost and/or energy impacts, and relative priority levels.
- **Automated system optimization:** Software that continuously analyzes and modifies BAS control settings to optimize HVAC system energy usage while maintaining occupant comfort. These tools read data from the BAS and automatically send optimal setpoints back to the BAS to adjust the control parameters based on data such as submetered energy use and energy price signal. Two-way communication with the BAS distinguishes ASO solutions from FDD.

EMIS can be implemented individually or in combination and are intended to support facility staff and management efforts to meet higher levels of comfort and performance. EMIS help to prioritize efforts toward optimal system performance, as opposed to reactively fixing what is broken. Previous research includes a complete description of the components of EMIS and details how organizations can plan and implement for successful EMIS use (Granderson et al. 2015).

While EMIS are powerful tools, any tool needs a process that utilizes it to have impact. Commissioning is a process that "focuses on verifying and documenting that all of the commissioned systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements" (ASHRAE 2013), and this process can be augmented using EMIS. MBCx is an ongoing commissioning process that focuses on monitoring and analyzing large amounts of data on a continuous basis, and EMIS are an integral part of streamlining analysis and automating the MBCx process. MBCx is a type of existing building commissioning (EBCx), which is defined as "…a systematic process for investigating, analyzing, and optimizing the performance of building systems through the identification and implementation of low/no cost and capital-intensive Facility Improvement Measures and ensuring their continued performance" (Building Commissioning Association Best Practices 2018). Traditionally EBCx was implemented by commissioning providers manually analyzing a short-term data snapshot of building performance in a process called retrocommissioning (RCx). The advent of EMIS has enabled these commissioning providers to provide automated analytics in real time.

MBCx may be used during an RCx process to streamline and automate data analysis during the investigation process and after RCx to track whether energy savings persist and find additional opportunities over time. Figure 2 illustrates the three main elements of MBCx, showing how tools like FDD and EIS are incorporated into the MBCx process.

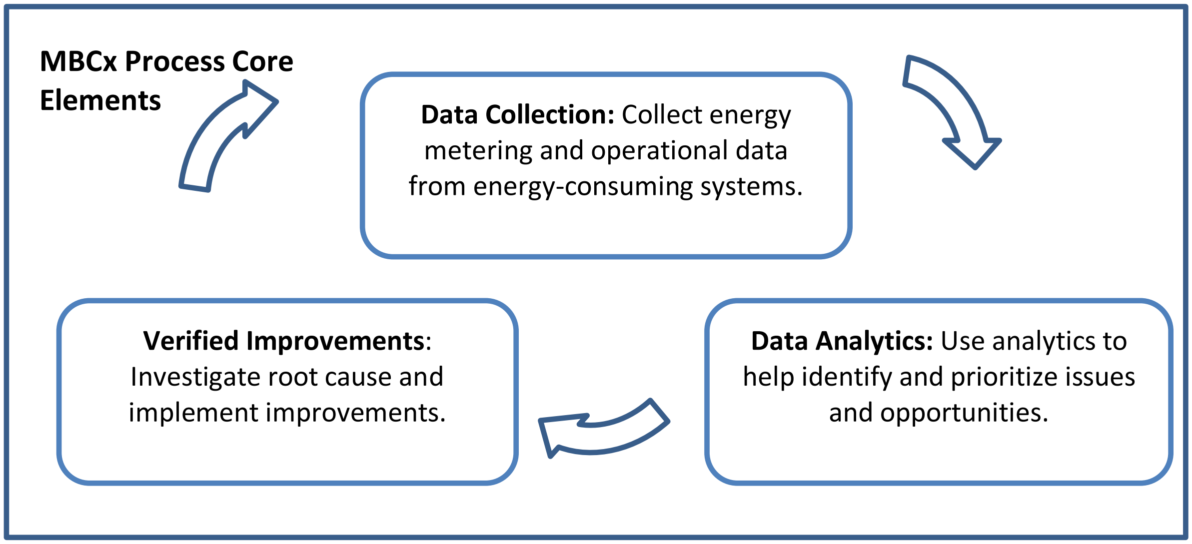

Figure 2: Monitoring-Based Commissioning Process

While MBCx is a recommended best practice, many organizations have successfully implemented EMIS without a formal MBCx process. In the absence of formal MBCx, the EMIS may be integrated into daily building operations, helping to drive facility management processes and enable data-driven decision making.

EMIS Technology Benefits

Energy and cost savings are often a driving factor in the decision to implement an EMIS. The number of commercially available EMIS has increased dramatically over the past decade, driven by the increased availability of higher-granularity energy (generally 15-minute to hourly) and BAS time series data. Building staff can leverage these data to continuously monitor building performance and automate analysis through EMIS, leading to energy savings, peak demand reduction, and a reduction in service calls. Further, analytics can help owners move from the reactive to the proactive by detecting equipment cycling issues and avoiding unnecessary wear and tear that can reduce equipment life. To support owners in these aims, Lawrence Berkeley National Laboratory (LBNL) created a resource that summarizes how both EIS and FDD can be used to identify energy saving opportunities in commercial buildings (Lin et al. 2017). In addition to operational improvements, EMIS can be used to verify energy savings for many measures.

EMIS are most often implemented as a part of an overall energy management approach that includes retrofits and commissioning. Thus, the benefits of using EMIS are difficult to isolate from other actions. In one EIS-focused study of 28 buildings and 9 portfolios across the United States, energy savings ranged from -3 to 47 percent with a median of 17 percent for individual buildings, and from 0 to 33 percent with a median of 8 percent for portfolios (Granderson and Lin 2016). Study participants reported that this performance would not have been possible without the EIS. A wide range of costs were also found, with total costs of EIS software ranging over two to three orders of magnitude.

Research results on the costs and benefits of commercialized FDD products are less available than those for EIS. A study on FDD for commercial buildings provided a thorough characterization of functionality and application for 14 FDD technologies (Granderson et al. 2017); however, the study scope did not include quantification of costs or benefits. Based on an analysis of the most common faults in building systems, studies estimate that the energy savings achievable from addressing these faults range from 5 to 30 percent whole building savings (Fernandez et. al 2017; Roth et. al 2005). FDD software costs have not been published in research to date. With significant diversity in costs for both EIS and FDD in an evolving market, additional data are needed to better characterize costs. This system-specific cost data will continue to be collected through the research, with initial results available in this report.

Historical Challenges in EMIS Use

With numerous vendors and feature packages available, it becomes difficult for owners to determine which type of EMIS will support their needs and meet thresholds for return on investment. Even if there is adequate energy metering in place, it is common to have problems integrating the data into the EMIS due to legacy data sources, varying communications protocols, and cybersecurity needs. It can be difficult to get disparate data collection systems into a single database to integrate with the EMIS.

In addition to metering and data management hurdles, a common challenge is the lack of staff time to review the EMIS dashboards and reports, and to investigate and implement recommended findings. Staff may experience data overload if their EMIS is not configured properly, or if there is not enough automation of the analytics. With EIS, there may be difficulty in pinpointing opportunities in the data, and even with FDD there are often challenges definitively isolating root causes. For example, the FDD software might detect a problem with the outside air economizer not bringing in enough air for free cooling and recommend that the damper actuator be checked, as well as temperature sensor calibration and the air handler control sequence. As with all enabling tools, the EMIS itself does not directly produce savings, but requires action upon the analytic results. There is a growing body of service providers to help owners manage their data and analytics and implement findings.

Smart Energy Analytics Campaign

In response to these challenges in implementing and utilizing EMIS systems, a research and industry partnership program was formed in 2016 (Smart Energy Analytics Campaign 2018). The Smart Energy Analytics Campaign targets the use of a wide variety of commercially available EMIS technologies and ongoing monitoring practices to support data collection and analysis that support energy savings. This program provides expert technical support to commercial building owners in implementing in-depth analytics, and the program recognizes owners with exemplary deployments.

As a part of the program, participants are offered technical assistance and engagement with a peer network. Participants share data about their progress that are analyzed by the program to report the latest in EMIS savings, costs, and trends in implementation. This research report expands and builds upon previously published research based on an earlier version of the dataset (Kramer et al. 2019). As of July 2019, there were 96 participating commercial organizations across the United States, totaling more than 500 million square feet of gross floor area and 5,900 buildings, making this the most comprehensive dataset available on analytics installation and use. The Campaign launched in 2016, and this report is the third annual summary of findings. The final report of the Campaign will be completed in September 2020.

2. Methodology

The findings in this paper are based on data that originates from four main sources:

- **Campaign participant data:** Quantitative data were collected on floor area with EMIS, annual energy use, and EMIS costs. Campaign participants self-reported qualitative information such as the type of EMIS installed, how the EMIS has been used, and the most frequently implemented improvements in which they utilized the EMIS.
- **Prior EIS study:** Energy savings and EIS costs from a prior study of nine portfolio owners (Granderson and Lin 2016) was combined with Campaign participant data. This integration of datasets was possible because the cost and savings methodologies were the same, with the exception that the prior study did not collect estimates of the time in-house staff spent using the EMIS. The cost and energy savings results were similar as well. By combining these data sources, more conclusive findings can be drawn because the dataset is larger. Throughout the Campaign results, the data from this study have been referred to as "2013 EIS study participants."
- **Campaign participant and industry partners survey:** An online survey was used to obtain additional information about enablers, barriers, and future technical needs associated with EMIS.
- **Ongoing interviews:** Participants are interviewed to better understand their current EMIS and MBCx implementation, then participate in activities such as individual and group technical support. The information gained from these activities has been used to categorize EMIS implementations and determine the barriers and enablers to successfully implementing EMIS.

As new participants join the program and existing participants continue their EMIS implementation, new data are added, and the research results are updated each year. Almost all participants implemented or planned to implement EIS or FDD. While two participants with ASO are in the study cohort, there are not enough data to report savings and costs for this technology.

2.1 Energy Savings

To understand energy and cost savings benefits achieved by owners using EMIS technologies, participants are asked to provide annual energy consumption before and after EMIS implementation. These energy savings achievements are attributable to several energy efficiency activities including, but not limited to, use of the EMIS. Participants provide data only for buildings with active use of EMIS. Energy savings achieved since EMIS installation are determined in four ways.

1. **Interval data analysis**: Pre-EMIS (baseline year) interval data are used to develop a model of building energy use. Energy use is projected using the baseline model and compared with actual energy use during the period after installing EMIS. This method utilizes the International Performance Measurement and Verification Protocol (IPMVP) Option C methodology.
2. **Annual energy use analysis:** Pre-EMIS (baseline year) energy use is compared to the most recent full year of energy use. Energy cost savings are calculated using national average energy prices. Sometimes the data are normalized for weather using ENERGY STAR Portfolio Manager. When the participant uses ENERGY STAR Portfolio Manager for their buildings with EMIS, we ask for their data through standard ENERGY STAR reports, so we can gather weather-normalized usage. If participants do not utilize ENERGY STAR Portfolio Manager, then we do not weather-normalize the change in energy use.

3. **Engineering calculations:** This system analysis approach for estimating energy savings may use BAS trends or short-term measurements as baseline data. Spreadsheet calculations are based on engineering equations that often utilize temperature or load-based bin analysis.
4. **Building energy simulation**: Modeling whole facility energy use is a system analysis approach that uses energy simulation software such as eQUEST, EnergyPlus, Trane TRACE, or Carrier HAP.

2.2 Costs

Costs to implement an EMIS and perform MBCx are gathered from participants in the three categories shown below: base cost, recurring EMIS cost, and in-house labor cost. Cost data are provided by participants in dollars for the base cost and annual software cost, and then normalized by floor area.

Technology and measure identification costs:

1. **Base cost:** Costs for the EMIS software installation and configuration, including EMIS vendor and service provider costs. They do not include additional costs such as the cost of energy metering hardware and communications, adding points to the BAS for EMIS monitoring purposes, additional data servers, retrocommissioning, or retrofits.
2. **Recurring EMIS cost:** Annual recurring costs broken out into two categories: software cost and MBCx service provider cost.
    a. **Annual software cost:** The recurring annual cost for a software license or software-as-a-service fees.
    b. **Ongoing MBCx service provider cost:** The average annual cost to MBCx service providers or other consultants for support in analyzing and implementing EMIS findings.
3. **In-house labor cost:** Labor costs broken out into two categories: EMIS installation/configuration and ongoing EMIS use. In-house labor costs are reported both in hours and estimated cost. The labor cost estimate is determined using the reported hours utilizing the EMIS and $125/hour as an average labor rate.
    a. **EMIS installation and configuration:** Approximate total labor hours spent by in-house staff to support installation and configuration of the EMIS.
    b. **Ongoing EMIS use:** Approximate time spent by in-house staff reviewing EMIS reports, identifying opportunities for improvement, and implementing measures (average hours spent per month).

2.3 Cost-effectiveness

Determining the cost-effectiveness of EMIS implementation is not straightforward since EMIS is an enabling tool—installation of the software does not directly create savings. Rather, savings are achieved by acting upon the information that the technology provides (i.e., the improvement opportunities that are identified). The only type of EMIS that achieves direct savings is ASO, since the optimization is performed directly by the ASO software.

Attributing savings to an EMIS can be difficult since not all measures that an organization implements are due to use of the EMIS but may come from other things like capital upgrades or projects that would have happened without the EMIS. Even so, EMIS is often used to help identify the need for retrofits and measure the performance of those retrofits.

To develop estimates of EMIS cost-effectiveness, first-year costs and first-year savings are determined for all participants in which the data are available, using the following methodology:

1. **First-year cost:** The estimated first-year median cost includes base EMIS implementation cost (software + installation), in-house labor cost to support installation, in-house labor cost to use the EMIS for one year, and an estimated cost to implement operational measures found using the EMIS. The Campaign does not collect data on hard costs for implementing measures (e.g., replacing a variable frequency drive), therefore an estimate of these hard costs must be used. RCx measures are consistent with the measures identified and implemented through use of EMIS software, so we use the median RCx implementation cost as an estimate for EMIS measure implementation costs from a recent commissioning study (Crowe et al. 2018). In the commissioning study, typical RCx measure implementation costs are reported as approximately one-third of the total RCx cost. With a median RCx cost reported in the commissioning study of $0.27/sq ft, we selected $0.11/sq ft as a conservative implementation cost estimate for operational measures related to the EMIS.
2. **First-year savings:** The median savings are determined by comparing energy data from the first full year after EMIS implementation with the baseline year before the EMIS was installed.
3. **Cost-effectiveness calculation:** For each participant that reported costs and energy use, the first-year costs are divided by the first-year savings to determine a simple payback period. The median simple payback for participants with EIS and FDD are reported separately. As a cross-check, we compare the Campaign cost-effectiveness results with other public sources cost-effectiveness data documented in EMIS case studies.

3. Findings

In this section, we summarize data collected through the Campaign based on reporting to date from 62 participating organizations representing more than 404 million square feet. Fourteen participants had not yet implemented their EMIS, and therefore did not have data to report. We had different reporting rates for different data requests, and the number of participants (n) and square footage are reported for each finding. The findings provide an overview of the types of activities, analytic tools, and energy management processes that Campaign participants use. The section also summarizes EMIS and MBCx benefits, costs, and cost-effectiveness results.

3.1 Participant Characterization

Current Campaign participation includes 96 public and private sector organizations, representing a total gross floor area of 518 million sq ft and more than 5,900 buildings. Participants are mainly in the office and higher education market sectors, with healthcare and government laboratories also represented (Figure 3). The most common portfolio size is between 1 million and 5 million sq ft (Figure 4).

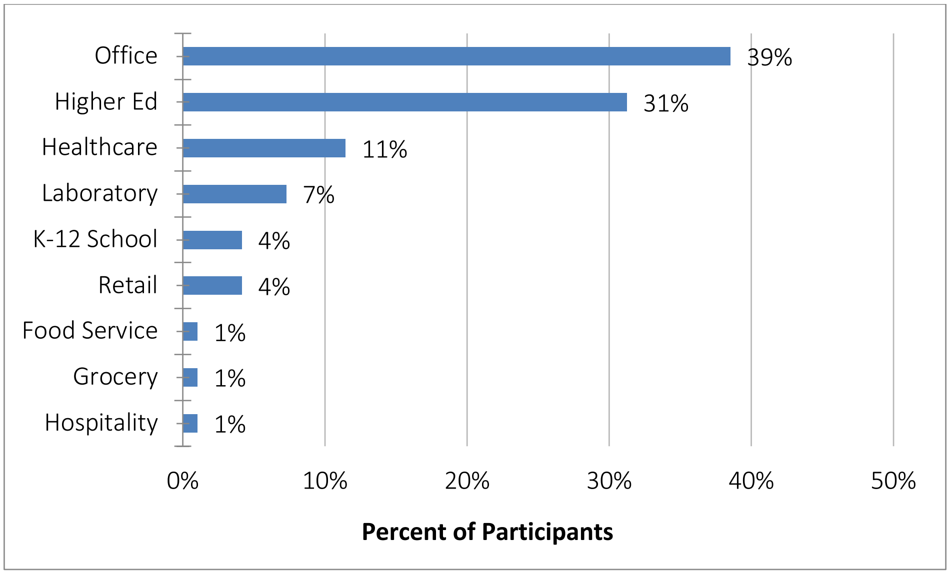

Figure 3: Participants by Primary Market Sector (n = 96)

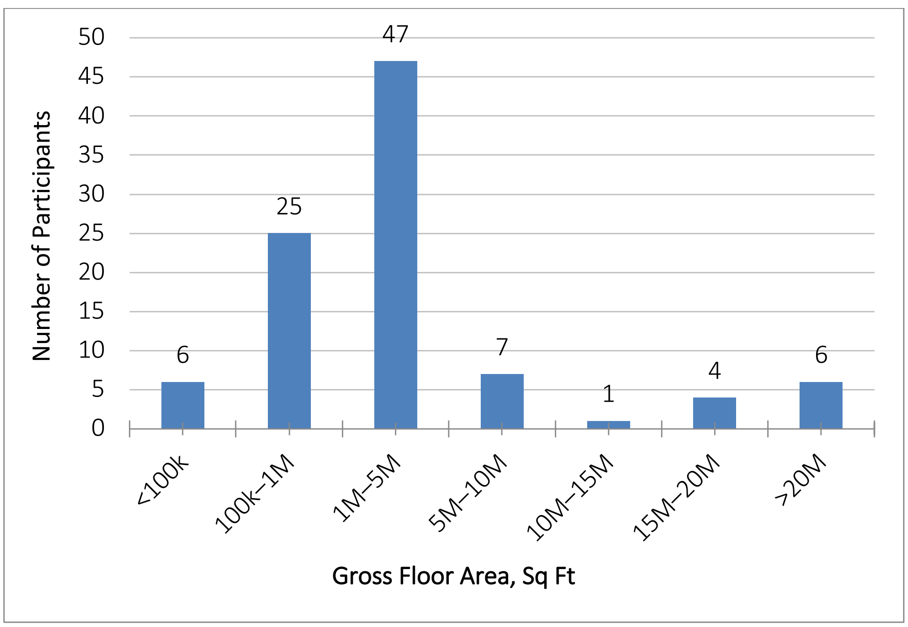

Figure 4: Distribution of Gross Floor Area for Participants with Planned or Installed EMIS (n = 96)

Almost all Campaign participants have access or are gaining access to whole building hourly data in addition to their monthly utility bill data, and 40 percent of participants have submeter data for tenants or other end uses. Those who don't have whole building hourly data are FDD users who have not integrated meter data into their FDD software. The most common analysis tools used are the BAS, ENERGY STAR Portfolio Manager, spreadsheets, and EIS. Campaign data shows that where EIS and FDD have been implemented, operators benefit from expanded analysis capabilities, well beyond these common analysis tools. About one-third of participants are installing or have installed a new EMIS during the Campaign, one-third are using an existing EMIS, and one-third are upgrading their EMIS to deploy in more buildings or add additional functionality. Of those planning to install, 40 percent plan to install an EIS, 33 percent plan to install FDD, and 26 percent plan to install both EIS and FDD technologies.

Figure 5 shows the breakdown of EMIS type chosen by Campaign participants.

- Sixty-one percent of participants are implementing EIS to analyze hourly (or more frequent) interval data.
- More than half of participants are implementing FDD to identify HVAC operational faults.
- The 31 percent of participants that implement both EIS and FDD almost exclusively analyzed these data within the FDD software package. A few participants had separate EIS and FDD software.
- ASO is not yet prevalent in the market generally, or among Campaign participants. Two participants are using ASO, and they also have EIS and/or FDD installed. We do not report costs or savings for ASO since there are only two data points.
- To date, approximately 15 participants have not yet installed their EMIS and are either researching and specifying their system or in procurement.

EIS functionality is most utilized by energy managers. Participants with both FDD and EIS tended to focus on the FDD functionality within their building operations teams due to its ability to provide detailed recommendations. The FDD implementations that integrate meter data analytics are categorized as EIS + FDD in Figure 5. However, since the software applications are primarily FDD solutions, we have combined FDD and EIS + FDD categories for cost and savings analysis in the remainder of this report.

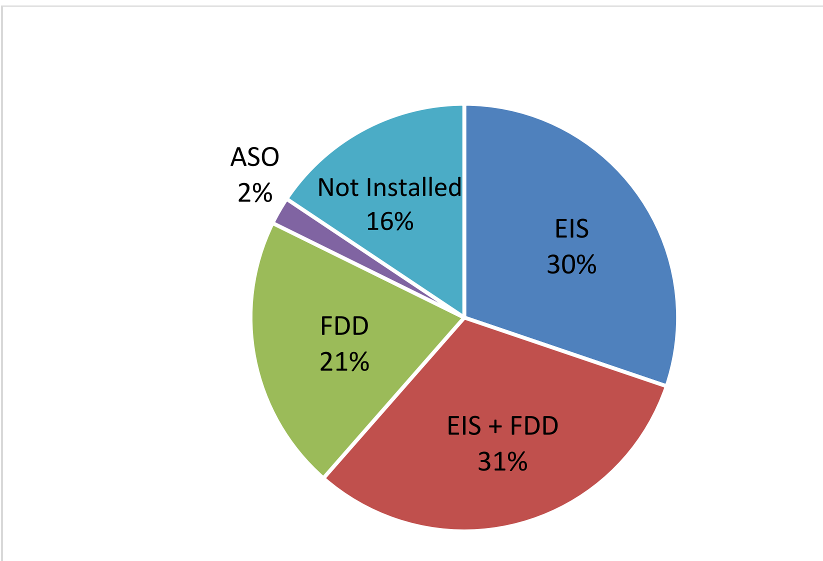

Figure 5: Type of EMIS Installed by Participants (n = 96)

Most participants needed less than six months to install and configure their EMIS. A few participants experienced significant challenges getting meters connected and properly communicating, with multiple years required to get all the issues resolved and the EMIS in use. For example, a large campus may be integrating meters and sub-meters for multiple fuels (electric, natural gas, chilled water, hot water, steam), with many different meter vendors and vintages across the campus.

The use of data and software in combination with an overarching defined energy management process is critical in realizing the value of EMIS. Almost all participants have an energy management team mostly made up of facility engineers or technicians and energy managers. The energy managers tend to lead the analysis process and are sometimes supported by a consultant or service contractor. Just over half the participants contracted with a service provider to support their use of EMIS, and more than half of the energy management teams are using a formalized MBCx process that includes continuous analysis (rather than periodic review).

Participants implementing MBCx provided information on their scope of activities:

- **Common MBCx activities**: in-house review of EMIS analysis and reporting to identify issues, commissioning the EMIS to verify data accuracy and configuration, implementing a management process for taking action to correct issues, and using the EMIS to document energy and/or cost savings
- **Less common MBCx activities**: a program for staff or occupants to recognize energy savings and an EMIS training program for in-house staff to maintain ongoing energy management processes

An approximately even number of participants reviews their EMIS daily, weekly, or monthly, as shown in Figure 6. FDD users most commonly review the outputs weekly, whereas EIS users most commonly review outputs monthly or daily. The EIS is used both to conduct daily electric load analysis and to prepare for monthly energy team meetings and reports.

While a review frequency of daily or weekly is desirable to benefit from the real-time results of analytics, constraints on operations and maintenance (O&M) staff time may lead to monthly review, either in-house or through an MBCx service provider. Since notification of emergency-type faults are generally available through the BAS directly (e.g., a chiller is off-line), the issues found through an FDD may not be urgent from a safety and comfort perspective. The FDD software can assess the severity of the faults and determine how long they have occurred, so that responses can be prioritized for whatever frequency of action is desired.

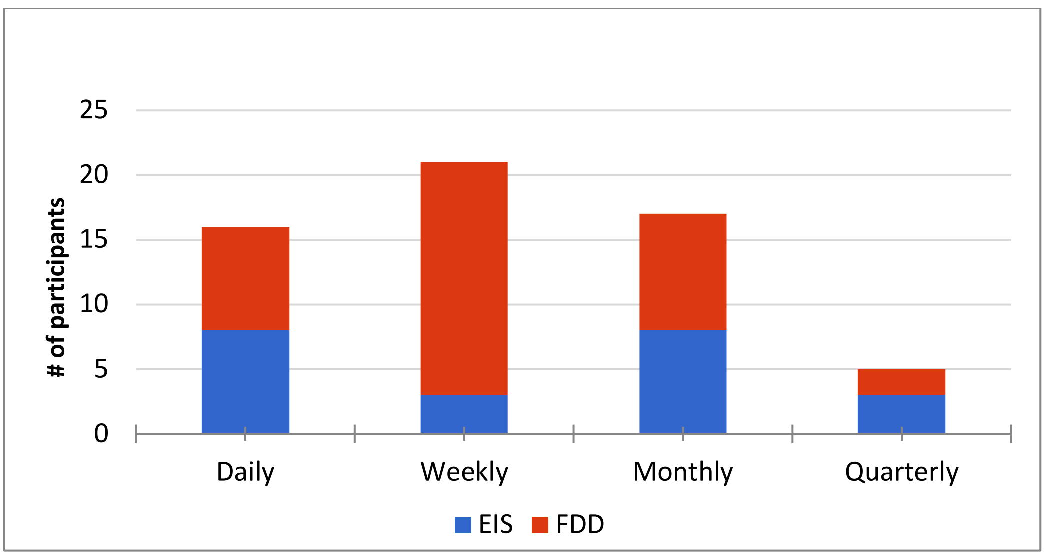

Figure 6: Frequency of EMIS Review by EMIS Type (n = 59)

3.2 Cost and Benefit Findings

This section reports on the results of data collection around motivation for EMIS, measures implemented using the EMIS, energy savings, and costs.

3.2.1 Benefits Motivating EMIS Implementation

Energy and cost savings are almost always a driving factor in the decision to implement an EMIS, as shown in Figure 7.

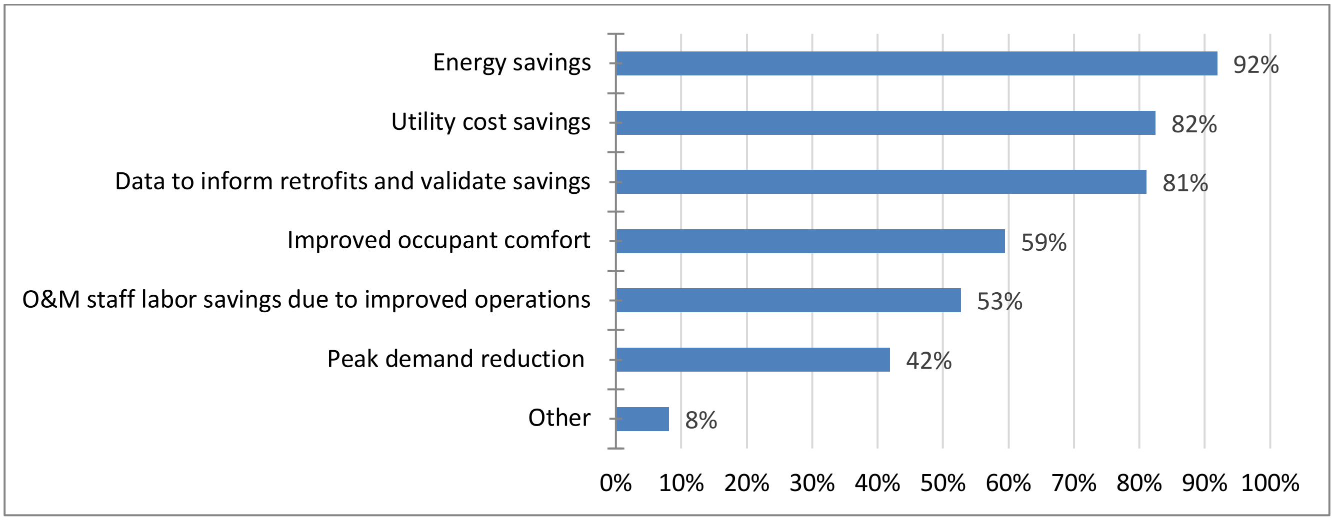

Figure 7: Benefits of Implementing EMIS (Percent of time benefit was chosen by participant, may select multiple benefits)

The wide range of benefits indicated by participants provides multiple motivations to install an EMIS, and value from multiple perspectives: owners, energy/facility managers, and building operators. While energy cost savings is a common driver, it is noteworthy that 81 percent of participants consider the EMIS a benefit for informing retrofits or validating project savings. Occupant comfort and improved operations are additional benefits considered important by more than half of participants.

3.2.2 Top Measures Implemented

Campaign participants were asked to indicate up to 10 of the most frequently implemented measures that they identified using their EMIS from a list of 26 common operational improvement opportunities. Figure 8 shows the frequency that measures were selected.

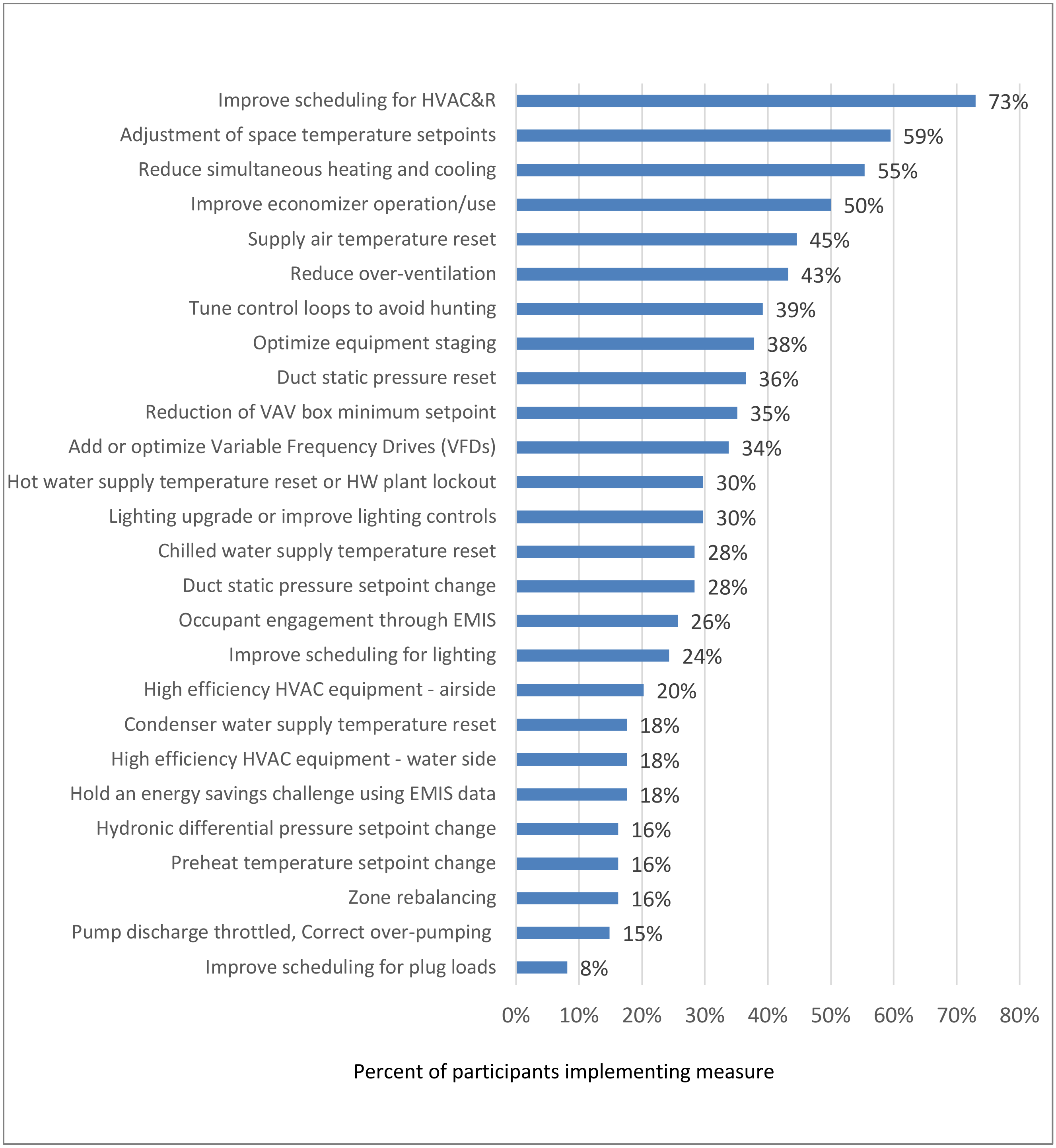

Figure 8: Measures Implemented with EMIS Support (respondents may indicate multiple measures; n = 74)

The measures in Figure 8 are consistent with typical measures implemented during RCx. The higher education and office sectors focused more than the other market sectors on occupant behavior through sharing energy information with staff and students. FDD supported identification of simultaneous heating and cooling, economizer operation, reset schedules, and control loop hunting, among other measures. Both EIS and FDD supported identification of improved schedules and setpoints. The ways in which EIS and FDD support the identification of these measures are summarized in Table 1 and Table 2 below.

Table 1: Summary of Commonly Used EIS Metrics and Analyses

Common Metrics and Analyses	Used to Identify
Energy use intensity (EUI), kBtu/sq ft	• High energy use relative to the portfolio
Heat maps	• Scheduling improvements • Baseline reduction opportunities
Load profiles	• Scheduling improvements • Baseline reduction opportunities • Peak demand reduction opportunities • Energy use by hour relative to modeled prediction

Table 2: Summary of Common Faults Detected by FDD technology

Common Faults Detected	FDD Tool Analysis
Controllers (actuators/valves/speed drives)	• Compare controller output setpoints to the actual condition to find failed devices. • Determine the stability of controllers.
Dampers (air handling units, terminal units)	• Identify if a damper is stuck open, closed, at a fixed position, or leaking. • For example, compare mixed air temp to return air temp with the outdoor air damper closed.
Cooling/heating valves and coils	• Identify if a valve is stuck or leaking. • Identify a fouled or blocked coil. • For example, a temperature difference exists across a coil when a valve is shut or not achieving a desired temperature drop across a coil when a valve is open.
Economizer operation/use	• Detect if the rooftop unit (RTU) or AHU is not economizing when it should. • Detect if the RTU/AHU is economizing when it should not (i.e., calculate the relevant theoretical outdoor air ratio with outdoor air temperature, return air temperature, and mix air temperature). • Detect if the economizer lockout setpoint is too high or low.
Simultaneous heating and cooling	• Detect if unnecessary heating, economizer cooling, and/or mechanical cooling happen at the same time.

3.2.3 Energy Savings

As described in the methodology, the energy savings since installation of an EMIS were determined in three ways (Figure 9).

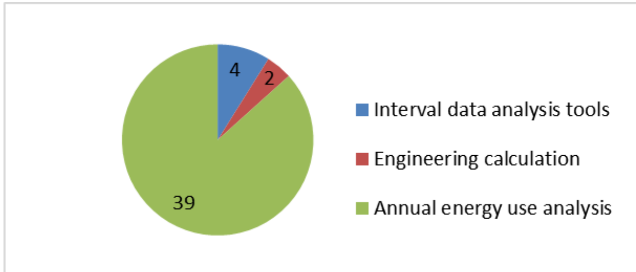

Figure 9: Distribution of Energy Savings Calculation Methods (n = 45, 224 million sq ft)

Four participants reported savings results determined from interval data analysis tools. Two participants estimated savings using engineering calculations. The energy savings from the other 39 participants were calculated by LBNL using annual energy use analysis. None of the participants used building energy simulation to estimate savings.

With annual energy use data from 19 participants[4] implementing EIS, and 26 participants implementing FDD, the sub-cohorts were large enough to report energy savings for each EMIS type. The EIS + FDD implementations (16 organizations) were primarily FDD solutions that integrated some meter data analytics and were combined with the FDD-only implementations (10 organizations). Figures 10–11 show the median savings across the buildings in each participant's portfolio, for each year of implementation. Figure 10 corresponds to EIS users, and Figure 11 corresponds to FDD implementations. In each plot the gray line represents a single participant's portfolio of buildings, and the y-axis represents percent savings relative to the year before the EMIS installation, referred to as the "baseline year." The red line indicates the median savings across all participants.

The results indicate that savings generally increase over time for the participants that had EMIS installed for multiple years. The decrease in savings for EIS in years 3 and 4 is likely an artifact of skew in the small number of data points (fewer than five participants had three or more years of post-installation energy use data).

[4] EIS energy use data were reported by 11 participants in the Campaign and eight participants in the "2013 EIS study" (Granderson et al. 2013).

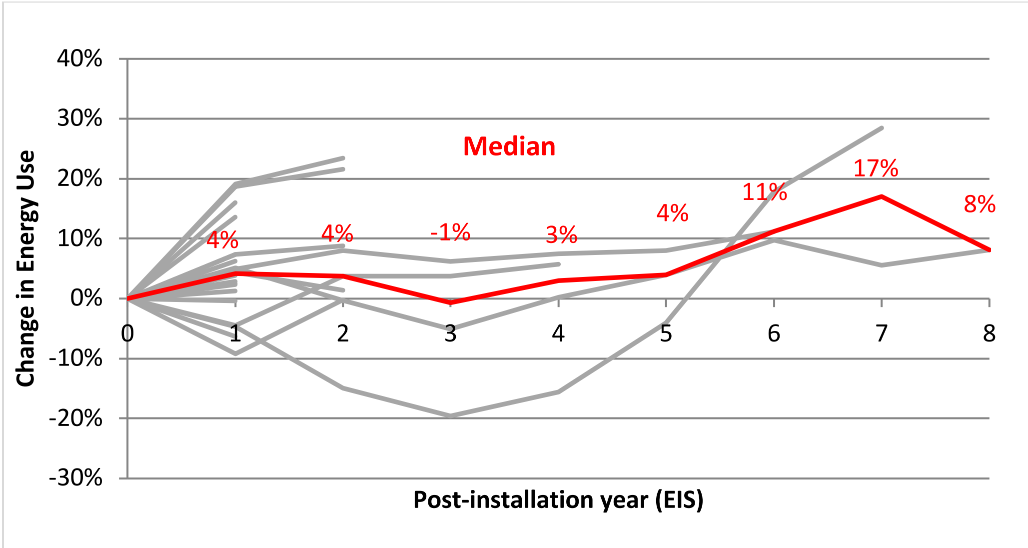

Figure 10: Percent Change in Participant Energy Use Relative to the Year before EIS Installation (n = 19 in Year 1).

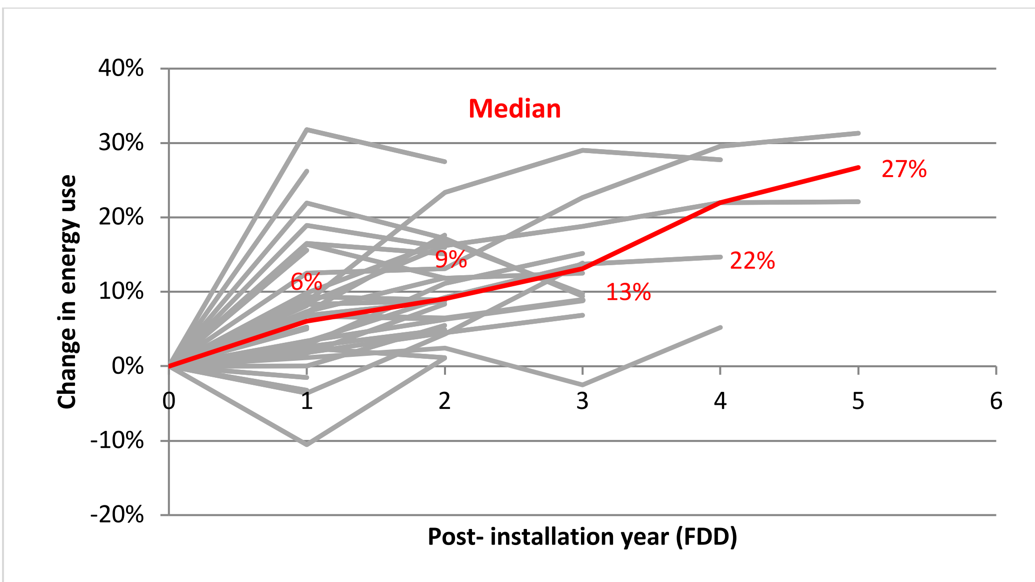

Figure 11: Percent Change in Participant Energy Use, Relative to the Year before FDD Installation (n = 26 in Year 1).

Tables 3 and 4 show median savings since the EMIS was installed, in percentage and dollars per square foot per year. In some cases, the EMIS had been installed for more years than the energy data were provided. It is important to note the number of participants with energy data available for each year after EMIS implementation. Where the number of participants is five or fewer, the savings reported are not a large enough dataset to reference, therefore these data are shown in gray.

Table 3: Summary of Energy Savings for Participants with EIS

EIS	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Number of participants	19	9	4	4	3	3	2	1
Floor area (millions of sq ft)	126.8	79.9	47.4	47.4	42.2	42.2	4.5	3
Median savings (%)	4%	4%	-1%	3%	4%	11%	17%	8%
Median savings ($/sf/yr)	$0.13	$0.04	$-0.05	$0.03	$0.11	$0.41	$0.47	$0.23

Table 4: Summary of Energy Savings for Participants with FDD

FDD	Year 1	Year 2	Year 3	Year 4	Year 5
Number of participants	26	18	10	5	2
Floor area (millions of sq ft)	97.5	78.3	50.1	36.8	3.4
Median savings (%)	6%	9%	13%	22%	27%
Median savings ($/sf/yr)	$0.17	$0.24	$0.38	$0.37	$0.88

Study participants with energy information systems have made improvements to their buildings, achieving a median second-year energy savings of 4 percent ($0.04/sq ft) and participants with fault detection and diagnostic tools installed achieved a median savings of 9 percent ($0.24/sq ft). In total, these 45 participants are saving 2.6 trillion Btu/year and $59 million/year, comparing the most recent year for which data are available to the baseline year before the EMIS installation. These energy savings achievements are attributable to several energy efficiency activities including, but not limited to, use of the EMIS. Section 3.2.2 reports the top energy saving measures identified and implemented through use of the EMIS; additional measures may also have been implemented.

3.2.4 Costs

With cost data from 35 participants[5] implementing EIS and 32 participants implementing FDD, the sub-cohorts were large enough to report energy savings separately for each EMIS type. The results for median base cost and recurring cost per square foot are presented in Figures 12 and 13 by EMIS type, with a separate bar for each participant, as well as using box and whisker plots. The box and whisker plots show minimum, maximum, quartiles (25th percentile and 75th percentile), and median (where the orange and green quartile boxes meet). Most participants have large portfolios; therefore, the costs normalized by floor area reflect these economies of scale, with lower cost per square foot than would typically be found for smaller scale implementations. As stated in the methodology, the base cost includes the software and installation costs, and the recurring cost includes the annual software fees and any MBCx service provider fees (as applicable).

[5] EIS cost data were reported by 18 participants in the Campaign and 17 participants in the "2013 EIS study" (Granderson et al. 2013).

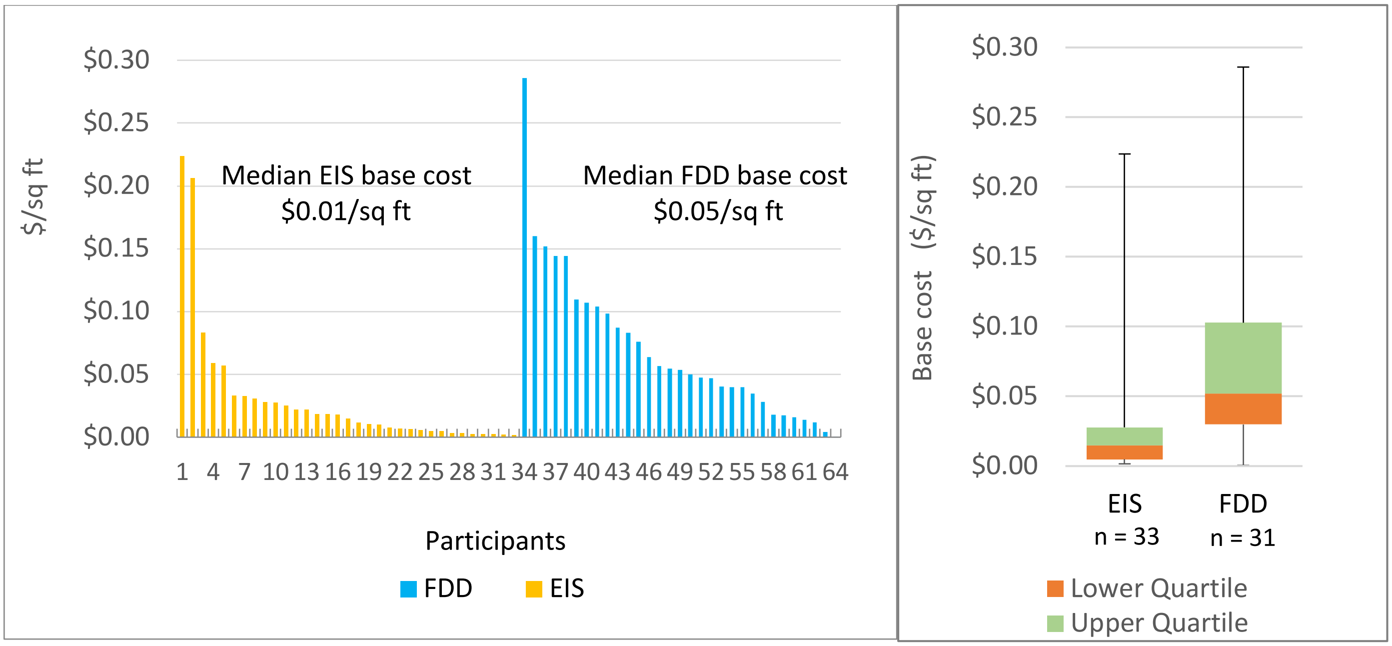

Figure 12: Base Cost by EMIS Type

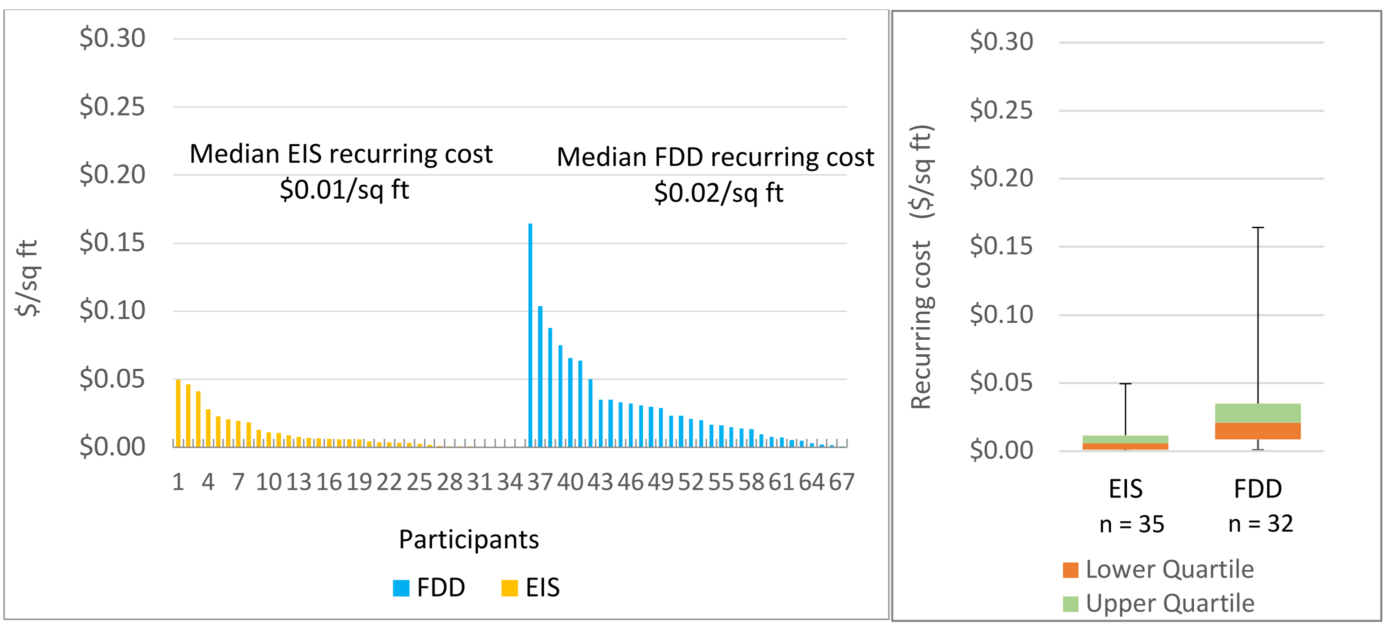

Figure 13: Recurring Software and MBCx Service Cost by EMIS Type

Base costs and recurring costs for FDD are higher than for EIS. This cost difference is due to the complexity of mapping hundreds or thousands of BAS points, writing rules or tuning existing FDD rules to the organizations' HVAC systems, and interpreting diagnostic results. While the base costs for FDD were more than for EIS overall, there are instances of variability and overlap. For example, there are two EIS implementations in the top three highest base costs. FDD recurring costs are also higher than EIS recurring costs, with similar instances of variability and overlap.

In addition to normalizing costs by floor area, costs were normalized by number of points (e.g., meters and sensor data from the BAS) and number of buildings. These metrics are shown in Table 5. The EIS cost per point (in this case, per meter) is $333, and the recurring cost is $149/meter. This cost does not include the cost of the meter itself, only the cost to integrate existing meters and configure the EIS software. There are, on average, four meters per building connected to the EIS. Costs per point for FDD are low since typically over 1,700 BAS points per building are integrated.

The median cost per building to implement FDD is more than eight times higher than that to implement EIS, however the median building size is about twice as large for FDD than EIS. FDD is more often implemented on larger buildings because the type of FDD used by Campaign participants are focused on addressing issues in complex HVAC systems. Other FDD products exist for packaged HVAC, however the Campaign participants generally did not utilize these smaller HVAC products. EIS are implemented across a wide range of building sizes since whole building meter data is the minimum necessary input.

Table 5: EMIS Cost Summary

Type of Costs, by EMIS Type	Median Costs		
	Per point	Per building*	Per sq ft
EIS (n = 35)			
Base software and installation (one-time cost)	$333	$1,500	$0.01
SaaS + MBCx service provider ($ per year)	$149	$408	$0.01
FDD (n = 32)			
Base software and installation (one-time cost)	$8	$12,500	$0.05
SaaS + MBCx service provider ($ per year)	$5	$3,503	$0.02

* For each participant, a 'per building" cost was established. This column represents the median of those values. Since the median participant in the 'per building' and 'per sq ft" columns have different building sizes, the 'per building' and 'per sq ft' costs do not scale.

When considering the price of EMIS software it is important to consider the full picture of base and recurring costs. For example, with the study cohort, there are instances where the base costs are low, but the recurring costs are much higher than average. There are also instances where the base cost is high but there is little to no recurring cost, as the software is hosted and managed in-house. While we've calculated costs per point, per building, and per square foot, vendors price their systems in various ways. Some EMIS vendors price by groups of points (e.g., cost per 10,000 points), while others price by building or floor area.

Last, we summarize the time it takes for in-house staff to use the EMIS to identify and follow up on issues. Figure 14 shows bars by participant and box and whisker charts. Participants used their EIS a median of one hour per month per building and their FDD a median of nine hours per month per building. It is not surprising that owners spend more time using their FDD software than their EIS software, due to the complexity and detailed recommendations included with FDD implementation. Additionally, the median building size is almost twice as large for buildings with FDD compared to buildings with EIS.

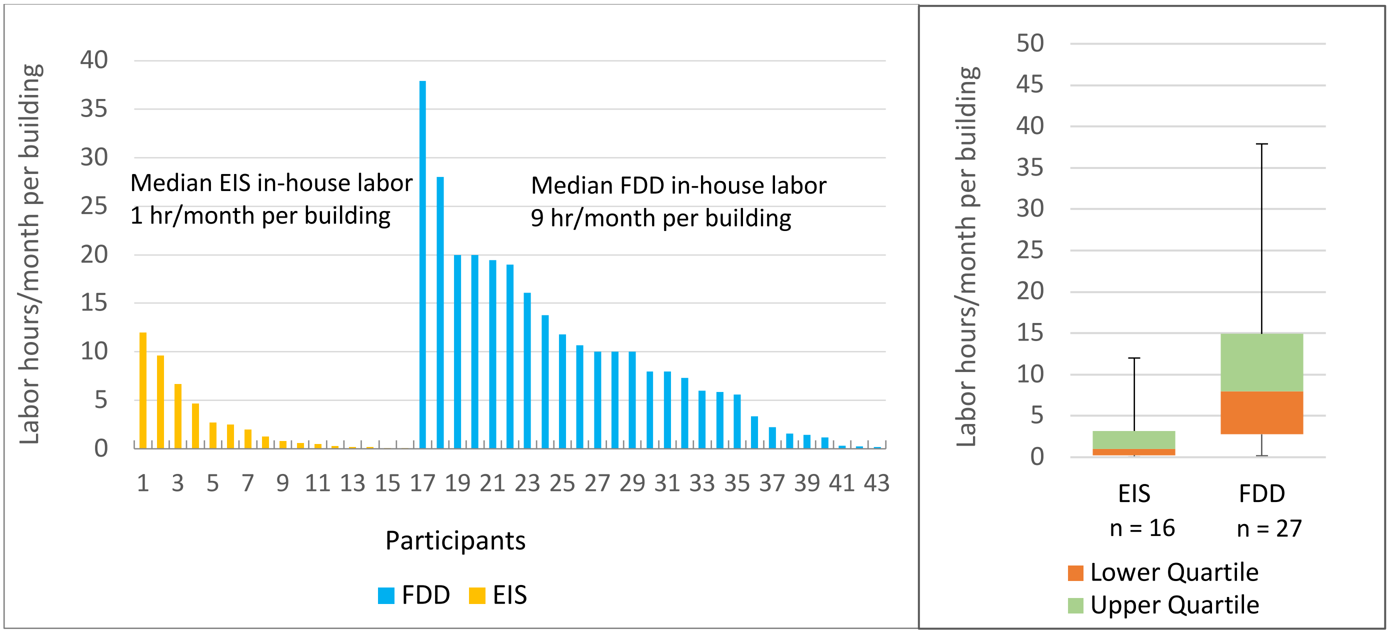

Figure 14: Estimated In-House Labor Cost by EMIS Type

3.2.5 Cost-effectiveness

Using the cost-effectiveness methodology described in Section 2, we calculated cost-effectiveness for EIS and FDD by participant, then report the median, as shown in Figure 15. The one-year cost includes base EMIS software and installation cost, in-house labor cost, and an estimate of implementation costs for operational measures found using the EMIS.

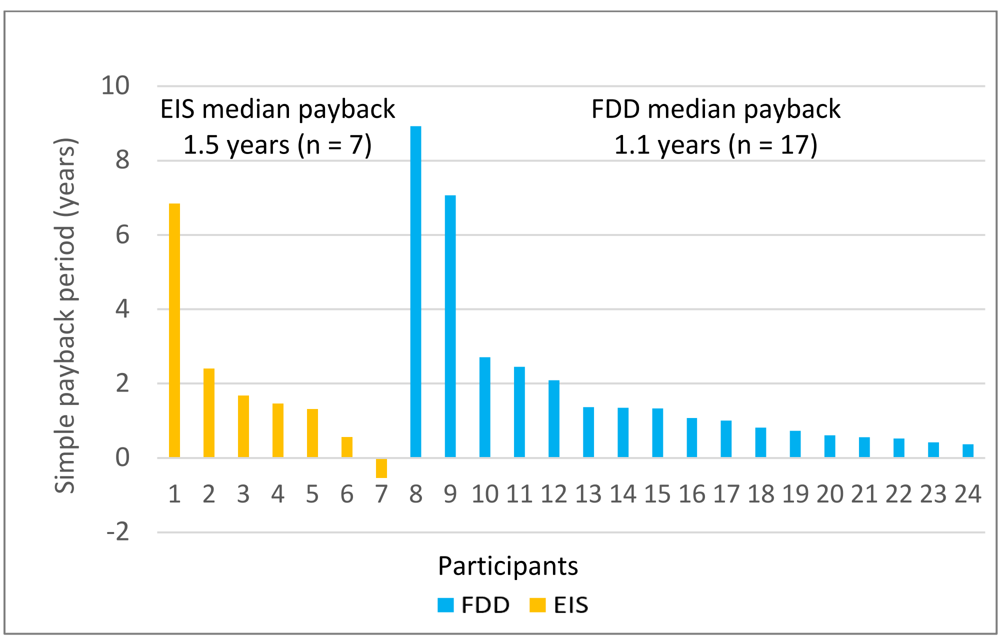

Figure 15: Estimated Simple Payback Period by EMIS Type

We compared these cost-effectiveness estimates with published EMIS cost-effectiveness results for EIS or FDD. We found only one study that quantified cost-effectiveness for EMIS or MBCx. An MBCx program was implemented for the University of California and California State Universities, which supported implementation of EIS and MBCx through incentives provided by California's investor-owned utilities. The MBCx program resulted in 11 percent site-level energy savings and a median simple payback time of 2.5 years for 24 buildings, representing 3.2 million sq ft (Mills and Mathew 2009). The MBCx program result is comparable to the 1.5-year simple payback found through the Campaign dataset for sites with EIS installed. Note that we did not find studies with cost-effectiveness published for commercialized FDD technologies.

3.3 Enablers and Barriers to EMIS Implementation

Through the course of technical assistance and qualitative data collection from Campaign partners, we have evaluated and summarized enablers and barriers to successful EMIS software and MBCx process implementation. These are provided in Table 6. Three of the most significant barriers to successful EMIS software and MBCx process implementation include the following:

- Lack of staff time to review the EMIS dashboards and reports, and to investigate and implement findings, as well as challenges getting operation staff to accept and use EMIS as a tool
- Difficulty making the business case to management to fund the EMIS
- Lack of metering in place, data quality problems, and problems integrating data into the EMIS

One driver of EMIS investment is to have corporate-level energy savings or carbon emissions reduction goals because implementing an EMIS is viewed as a tool to help monitor progress and achieve these goals. Beyond securing funding, one of the most important enablers to successful implementation is getting building data streams organized and brought into a central location for analysis by the EMIS. Further, participants that have institutionalized the use of data analytics in their standard meeting and reporting processes are finding their MBCx process to be valuable, from both cost savings and building comfort perspectives.

Table 6: Enablers and Barriers to Successfully Implementing EMIS and MBCx

Category	Enablers	Barriers
EMIS Specification and Selection	• Focus RFPs where there is the most interest in using the data (i.e., operations staff may desire FDD for specific faults, while energy managers may desire EIS to simplify energy tracking and reporting).	• Users are not clear on which EMIS product features they need. • Lack of clarity on differences between EMIS products. • Long procurement process through RFP and/or vendor interviews.
EMIS Installation and Configuration	• Integrating disparate data streams into a central location for EMIS analysis. • EMIS service providers support data integration and setup, then if desired, manage the FDD process. • Commissioning the EMIS installation avoids problems later. • Data warehouses provide a single location for all relevant data streams.	• Data integration problems include difficulty extracting data from older BAS, disparate naming conventions, and difficulty bringing all the data into a single database. • Data quality problems (gaps in data, incorrect meter readings). • Lack of existing metering in place.
Analytic Process	• Metrics and charts that summarize performance at a glance. • Analytics are implemented to address specific operational challenges, rather than implementing all analytics possible. • Vendors and service providers implement an existing FDD rules library.	• Users experience data overload instead of gaining actionable insights. • There is difficulty in pinpointing measures/opportunities in the data. • There is difficulty in finding root causes of fault conditions. • A lack of an M&V process in place to verify savings.
MBCx Organizational Process	• Staff that routinely use EMIS tend to find value. • Energy savings and carbon reduction goals drive EMIS use. • Integration of EMIS with work order systems helps drive implementation. • Ability to reinvest energy cost savings.	• Difficulty maintaining persistence of savings without a robust MBCx process (with only a periodic review after EBCx, savings may degrade). • Staff overrides of BAS and a desire to operate in manual mode leads to energy waste.

4. Discussion

This section discusses the cost and benefit findings of the research and presents trends in EMIS product and services delivery. Using data gathered through Campaign interactions, enablers and barriers to implementation and industry needs are also summarized.

4.1 Energy Savings and Other Benefits

FDD users achieved 9 percent median savings after the second year of implementation, compared to 4 percent median savings for EIS users after the second year. In the first year, savings may be increasing as the tools are better utilized; second-year savings are a good representation of the benefits that EMIS provides. With ongoing use and operational integration, savings can increase over time, and the use of EMIS supports persistence in savings. After the second year, other projects may be initiated, and the savings may be increasing due to the EMIS or due to other projects. While we report 17 percent median savings at organizations with EIS after seven years and 27 percent median savings at organizations with FDD after five years, we do not attribute this level of savings solely to EMIS.

In addition to helping identify savings opportunities, EMIS gives owners the ability to monitor their energy savings progress over time, which is invaluable to all energy saving efforts. Further, more than 80 percent of organizations reported using their EMIS to inform retrofit strategies at their facilities, including identifying retrofits, sizing equipment, and verifying savings (see Figure 7).

Although non-energy benefits are not the primary motivator for implementing EMIS, these benefits play a key role in garnering O&M staff support for EMIS use. Analytics can identify issues before they grow into occupant complaints or equipment failures. For example, operators generally do not have time to perform preventative maintenance on all terminal units; operations are typically assessed when there are comfort complaints. Using FDD, building operators can evaluate terminal unit performance proactively at a broad scale in a fraction of the time it would take to check all the boxes. Cycling equipment is another common operational issue identified through EMIS; eliminating cycling improves equipment life.

While a portion of the energy savings documented for Campaign participants may be due to changes in their buildings not related to the use of EMIS, almost all Campaign participants show a decrease in whole building energy use during the time the EMIS has been implemented.

4.2 Costs

The range of costs observed in the Campaign data reflects the scope or depth of service provided with the EMIS installation. For example, an FDD installation that includes ongoing turnkey measure implementation by the MBCx service provider resulted in the highest FDD recurring cost reported. Some FDD installations included all available BAS points and FDD rules, while others focused on certain key systems. For example, the lowest base cost for FDD was for a large participant that focused on FDD for their central plants (base cost = $0.004/sq ft).

Base cost: Among reporting participants, the base cost for installing and configuring FDD software was five times that of EIS. There is significantly more work required to integrate the BAS data into the FDD software than to integrate meter data into EIS software, because there are more BAS data and a variety of points must be mapped for use in the FDD software. The high end of the base cost occurred at sites where the FDD was installed at greater depth or on more complex systems. Data integration across the BAS and many devices drove the higher base cost. The low end of the base cost generally occurred when there were fewer points brought into the EMIS. For FDD implementations greater than 1 million sq ft in size, costs flatten. Large portfolios gain benefits in implementing EMIS across their portfolio, including the ability to use EIS to benchmark their buildings, manage energy use from a single location, and sometimes control building systems remotely through an operations center.

Recurring cost: EIS recurring software fees are equal to the median base cost (both are $0.01/sq ft), and FDD recurring software costs ($0.02/sq ft) are half of the FDD base cost. These recurring costs include two components: the annual licensing/software-as-a-service (SaaS) fee and ongoing MBCx service provider fees. The breakout of these two components is arbitrary, as some vendors include MBCx services within their SaaS fees, so we have not reported the breakout. For EIS, both the upfront and ongoing effort is lower than FDD, and this is reflected in the pricing. Typically, participants with only EIS do not utilize MBCx service providers, and about half of participants with FDD are contracting with MBCx service providers for additional support.

In-house labor cost: The time it takes in-house staff to utilize the EMIS is a significant portion of overall EMIS costs. While the labor cost is a different type of cost, since it may be embedded in the existing staff workload (and thus may not require additional funding), estimates of the labor cost from building staff were significantly higher than the recurring costs for FDD. The high end of the labor cost was reported from sites in their first year of FDD installation, during which time many faults were detected that may have existed for some time. Not surprisingly, the highest labor costs occurred at sites that implement MBCx in-house without service providers. Some participants' annual labor costs are quite low per square foot, either due to outsourcing to an MBCx service provider or a lack of engaged use with their EMIS. Levels of support from the integrators and vendors in installation and configuration varied widely, from mostly in-house EMIS installation by operations staff with a low level of vendor support to full-service installation with vendor support to analyze findings. Both the extent of engagement with the EMIS and the varying level of contracted MBCx support affected the estimated in-house labor cost.

Overall, the total cost of use and ownership for EIS is lower than that for FDD. With easier installation, EIS is often the point of entry for an owner new to EMIS. While there is not a previous study from which to compare the FDD cost results, FDD implementations have more data streams and complexity in implementing diagnostics, therefore higher costs than those associated with EIS were expected.

4.3 Cost-effectiveness

Organizations in the Campaign used their EMIS as part of an integrated energy management strategy, informing operational improvements, the need for retrofits, and retrofit sizing. Determining cost-effectiveness of an EMIS (a tool in the MBCx process) is akin to determining the cost-effectiveness of any business-specific software - the software is one of many tools needed to effectively perform the job. However, cost effectiveness of EMIS can be estimated by comparing the energy savings they enable to the costs to procure and use them.

Using Campaign participant data, the payback for EIS was estimated at 1.5 years, whereas that for FDD was approximately one year. While these estimates entail an inherent degree of uncertainty, they are based on more data than have previously ever been available from actual EMIS installations. Moreover, they are well within the 2- to 4-year payback requirements that drive most energy efficiency decision making. Figure 15 demonstrates mostly cost-effective EMIS implementations but are only a few of the many participants in the Campaign. We will continue to collect cost and savings data through the next year to update this cost-effectiveness analysis.

4.4 EMIS Products and Selection

Given the wide variety of available features, selecting an EMIS can be a challenging task. Most Campaign participants knew whether they wanted to start with implementing EIS or with FDD. Whether they start with EIS or FDD, almost all participants want to design an EMIS that is flexible for future additions. Some participants wanted as many energy management features in one tool as possible, to avoid multiple software interfaces.

Participants either went through a request for proposals (RFP) process or chose an EMIS based on vendor demonstrations. In either case, there were a variety of different reasons for choosing their vendor; for example, the desire to program the software using in-house labor, ease of implementation within existing maintenance processes, and known use by peers.

The Campaign team developed a list, shared on the website, that currently contains 63 EIS products, 31 FDD products, and 8 ASO products.[6] Twenty vendors offer both an EIS product and an FDD product. To date, Campaign participants have implemented approximately 40 of the products on this list. Through the process of developing and maintaining the EMIS products and services list, several insights emerged.

- New EMIS tools are continually being developed, with some vendors consolidating or acquiring products. The field is crowded, with vendors working to differentiate their products based on feature sets, market-sector focus (i.e., small to medium businesses), and partnerships with other EMIS vendors for integrated suites of products.
- Some EMIS products are being embedded in other EMIS products. For example, SkySpark is the analytic engine for several other FDD products. The white labeled products are generally combined with the EMIS service provider's ongoing analytic support. The software value-add from the service provider may include enhanced project management and fault prioritization capabilities.

While almost all participants have hourly whole building energy use available in their EMIS, the use of advanced meter-data analytics such as automated load shape analysis and automated M&V using interval meter data is not yet common. Over a dozen EMIS products in the market currently have automated M&V capability built into their products (Granderson and Fernandes 2017); however, the use of this feature has not been widespread by Campaign participants. Simpler ways to estimate savings are generally used, including monthly utility bill comparisons and use of the ENERGY STAR Portfolio Manager.

Some FDD installations focused their systems on monitoring hundreds of VAV boxes that they otherwise could not monitor manually. Owners with experienced in-house teams often received training from the FDD vendor to program and tune the FDD rules on their own. Some owners develop a "core" set of rules to roll out across a portfolio and tweak them for each unique building's situation. While most FDD software has built-in estimation of the energy cost waste of each fault to use as a means of prioritization, calculation of cost waste is not standard across tools.

The need to use both EIS and FDD technologies is clear. We have seen participants who only implement FDD and do not know how much energy they are using or saving. Conversely, those that implement only EIS tend to focus mainly on schedules, baseload, and peak demand, and may miss the more nuanced operational opportunities identified through FDD. EIS and FDD can work together to provide both a top-down and bottom-up analysis of a building's energy use and systems.

4.5 MBCx Process and Service Providers

A compelling evolution in the industry is the expansion of market delivery of FDD through MBCx service providers using the tools to provide added value to their customers. This contrasts with earlier models that relied on in-house direct organizational use, and from analysis-as-a-service provided by the FDD vendor. MBCx service providers tend to be commissioning firms expanding into MBCx, controls vendors with MBCx service offerings, or EMIS software vendors that also provide services. The expansion in service offerings has the potential to make the use of EMIS achievable for building owners that do not have large in-house facility

[6] This products list is a representative snapshot of vendors and providers and is not comprehensive; inclusion does not indicate endorsement by the U.S. Department of Energy (DOE), LBNL, or the University of California.

teams. Some service providers are national organizations, but most are likely to serve regional markets, as they are the outgrowth of regional engineering firms.

FDD users were most active in implementing findings when they had support from MBCx service providers in analyzing and prioritizing faults, and a routine process was in place for following up on faults with operations teams. Once established across a portfolio, FDD fault alerts can number in the hundreds or even thousands, therefore there is the need to filter and prioritize. While many FDD software platforms have built-in estimation of the energy cost of each fault to use as a means of prioritization, many participants valued the role of MBCx service providers in diagnosing the root cause of faults highlighting the most important measures for immediate action. In some cases, the owner might seldom or never access their EMIS directly, only the service provider's reports or online dashboard.

Most commonly, once the EMIS was in place and providing benefits, organizations received stable funding for their MBCx process with top management buy-in. In other organizations, the cost of MBCx and the EMIS software had to be justified annually. One participant created a detailed business case documenting the degradation of savings from RCx and the resulting benefits of MBCx (Gregory 2015).

Figure 16 illustrates different ways to implement EMIS with the support of service providers. The most limited support for in-house staff is installation support from EMIS vendors or service providers. Additional support in prioritizing and reviewing the output of the EMIS can be provided by EMIS vendors or MBCx service providers. The highest level of assistance includes on-the-ground implementation support from an MBCx service provider.

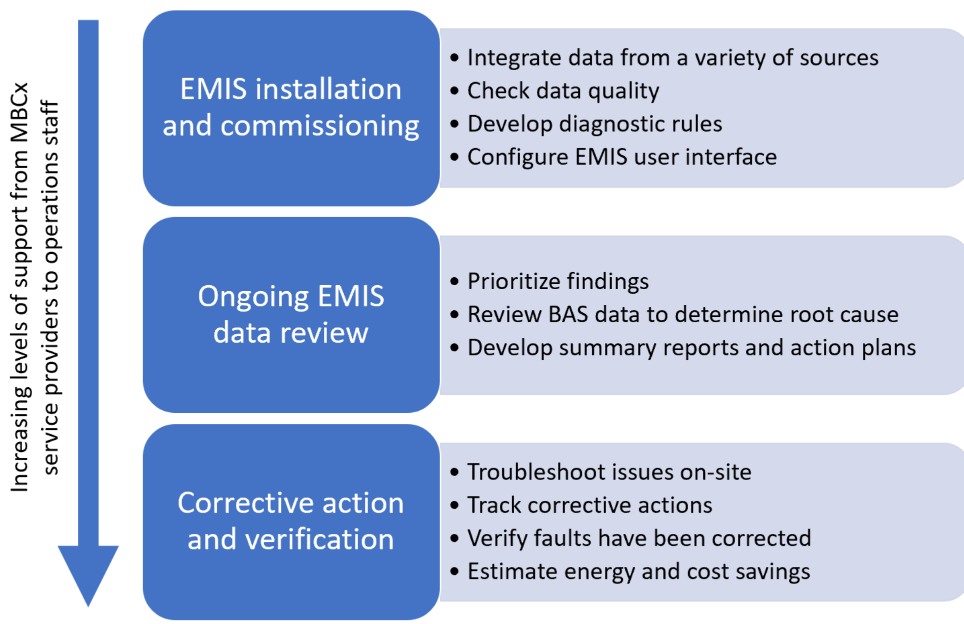

Figure 16. Support Options for the Ongoing Use of EMIS

This expansion in services offers potential to increase access to the technology and its associated benefits for a new class of owners who otherwise may not be using it due to the lack of in-house staff time or expertise to implement an MBCx process.

4.6. Industry Needs

Through an understanding of what has enabled successful analytics implementation and the barriers that hindered participants, the industry would benefit from improvements in the following key areas:

Data quality and data management: Accurately and efficiently gathering, communicating, and storing data from various systems, devices, and multiple formats is a common challenge to owners implementing EMIS, and it often results in long implementation time frames. The sensor data points in each building are generally created with names that describe different perspectives of the data points, like the data type, content, unit, location, and relationships to other equipment. These names are usually inconsistent among commercial vendors, buildings, and even subsystems in the same building. Thus, interpreting the names of data points to a united format that is readable for FDD tools involves labor-intensive efforts. The process of installing FDD software is streamlined when data points are named and tagged in a standardized way. Creating a united metadata schema to understand the relationships between points—as well as establishing standard, consistent naming conventions—are key steps toward streamlining the implementation of FDD tools. Project Haystack and Brick are two such schema currently under development.

Meeting diverse user needs: Finding a single EMIS that serves data management, benchmarking, utility bill management, analytics, and project tracking needs is a challenge. There is potential for tool partnerships to meet this need, or the industry may expand tool capability or consolidate tools to provide more comprehensive solutions. MBCx service providers may also serve this integration role as they analyze data streams potentially using multiple tools and supply integrated analysis to owners.

Methods for making the business case: Owners have trouble determining the return on investment for specific EMIS installations since it may not be clear prior to MBCx what the savings will be. Further, it can be difficult to attribute savings to EMIS as an enabling tool that requires actions based on the analysis. Utility incentives programs spur the MBCx market, however there are few such programs currently available to owners. Possibly, over time, EMIS will become a standard accepted operational cost rather than a capital expense investment.

Organizations implementing EMIS need guidance to reduce the time and cost it takes to implement these technologies. The following three areas need continued owner support:

EIS/meter data analytics: Organizations need more guidance on how to use meter data to gain diagnostic value. Owners have shared that it is difficult to create energy dashboards that meet needs of varying user groups because they are not sure what to put on the dashboards or how set up the analytics to direct user groups to savings opportunities.

EMIS review and selection: Determining which EMIS products and services will meet organizational needs and what functionality exists within the vendors' products has been difficult for owners. There is a hesitancy to broadly distribute EMIS RFPs to many vendors since reviewing responses is time consuming, so organizations tend to select a few vendors and send the RFP to them. With such a large field of products available, it is difficult to identify this "short list."

Best practices and peer connections: Campaign participants often note that they do not know how others are implementing EMIS tools and MBCx processes. They have shared a need for support in making the business case for MBCx, developing RFPs for EMIS and/or MBCx, configuring their EMIS, and verifying energy savings.

MBCx is currently in the early adopter phase, with the most significant growth supported by campus EMIS installations in the higher education and commercial office market sectors, and a few MBCx-focused utility programs. Addressing the industry needs outlined above will help move ongoing MBCx processes into the mainstream to help achieve lasting operational benefits for owners.

5. Conclusions

There is a growing national trend in the use of analytics in commercial buildings. EIS are becoming common for portfolio owners that want to track energy use centrally and prioritize energy efficiency efforts, and FDD is gaining traction as it helps facility teams track the performance of systems. These research conclusions were drawn from a dataset of 96 participants updated in July 2019, covering more than 500 million sq ft of commercial floor area and more than 5,900 buildings. This is the largest dataset nationally on EMIS technology use, and it will grow over the next year as the partnership continues.

FDD users achieved 9 percent median savings compared to 4 percent median savings for EIS users (both savings after two years of implementation). While these savings are not attributable to specific measures, the EMIS users shared their top measures implemented, including improvements to HVAC scheduling, adjustment of setpoints, reducing simultaneous heating and cooling, and improving airside economizer operation.

At $0.05/sq ft, the base cost for FDD software implementation was five times higher than the EIS base cost, and FDD ongoing costs ($0.02/sq ft) were double that of EIS. In-house staff utilized their EIS a median of one hour per month per building, and their FDD a median of nine hours per month per building. FDD implementations have more data streams and complexity than EIS; therefore, higher costs than those associated with EIS are expected.

Many of the organizations in the partnership have made the business case to install analytics. There is a growing dataset and group of case studies demonstrating successful EMIS implementation; however, some organizations still find it difficult to make a compelling business case. To date, 24 success stories[7] are available that summarize best practices, savings, and costs of leading owners in their use of EMIS technologies and implementation of MBCx processes. Calculations of cost-effectiveness for a subset of participants for which cost and savings data were both available show that implementing EIS or FDD resulted in a 1–2 year simple payback period.

The need to use both EIS and FDD technologies is clear. Some participants implement FDD and do not know how much energy they are using or saving. Conversely, those that implement only EIS may miss the more nuanced operational opportunities identified through FDD. EIS and FDD can work together to provide both a top-down and bottom-up analysis of a building's energy use and systems.

There are a variety of successful approaches (i.e., using an in-house team or a third party) for utilizing an EMIS to find and fix operational measures. However, there is a need to improve data integration and management, navigate the many EMIS vendor options, and improve prioritization of fault findings. Owners that dedicate adequate staff time to review the analytics and address the opportunities identified reap the benefits. In successfully utilizing EMIS tools, owners can move from reactive to proactive building operations that are continuously informed by data analytics.

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[7] Success stories are short case studies on those Campaign participants that received recognition by DOE. The success stories are available for download at https://smart-energy-analytics.org/success-stories.

6. Future Research and Next Steps

The Smart Energy Analytics Campaign expects to enroll more than 100 organizations over the course of the Campaign. Each year the Campaign is in operation, this research report will be updated to reflect the most complete dataset and findings. The Campaign is on track to generate the most complete dataset on EMIS tools and MBCx processes available nationally, with detailed reporting on costs and savings. This research will help build awareness of MBCx, a relatively new process in the commercial buildings industry.

The Campaign is set to finish in spring 2020 with the final round of owner awards. Campaign partners (participants and industry partners) will be invited to continue their collaboration with the U.S. Department of Energy through the Better Building Alliance's EMIS Technical Team. This group will continue to share EMIS and MBCx best practices, as well as explore newer areas as EMIS expands beyond HVAC applications, such as how to use EMIS to support integration and operation of their distributed energy resources, stand-alone lighting control systems, and other IoT devices.

Additional research and resources in the following areas will advance the state of the art and promote implementation of EMIS tools and MBCx processes.

- **Technical approaches:** Develop automated fault correction techniques, predictive diagnostics, and methods for improving the accuracy of using whole building interval meter data to measure real-time savings.
- **Integration procedures:** As owners begin to integrate distributed energy resources (DER) (solar photovoltaics, battery storage, fuel cells), advanced lighting controls, and other IoT devices into their portfolios, methods for leveraging these new data streams into EMIS analytics will be needed.
- **Protocols:** Develop a standardized protocol for EMIS assessment, to consistently quantify benefits of the technologies.

The use of EMIS tools in MBCx processes has expanded significantly over the last 20 years, yet there is still the challenge of moving these processes beyond the early adopters. While EMIS technology advances will help reduce the time necessary to implement EMIS and the value gained from the analytics, the market also needs a growing infrastructure of service providers and a trained building operations workforce to make the promise of these technologies a reality. And moving into the future, these advancements will help transform the use of EMIS into a standard cost of operation for commercial buildings.

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