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Energy information systems (EIS): Technology costs, benefit, and best practice uses

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Executive Summary

Energy information systems are the web-based software, data acquisition hardware, and communication systems used to store, analyze, and display building energy data. They often include analysis methods such as baselining, benchmarking, load profiling, and energy anomaly detection.

This report documents a large-scale assessment of energy information system (EIS) uses, costs, and energy benefits, based on a series of focused case study investigations that are synthesized into generalizable findings. The overall objective is to provide organizational decision makers with the information they need to make informed choices as to whether or not to invest in an EIS—a promising technology that can enable up to 20 percent site energy savings, quick payback, and persistent low-energy performance when implemented as part of best-practice energy management programs.

Decisionmakers today lack the critical information needed to answer the following three questions about energy information systems:

1. What are the technology costs of an EIS?

2. What are the energy- and cost-savings benefits of an EIS?
Quantifying the energy and cost-savings benefits associated with EIS use is a complex issue, for several interrelated reasons:

- An EIS is a process tool that includes a human-in-the loop; an information technology, as opposed to a widget, component, or device.
- An EIS *enables* savings, rather than directly generating savings
- An EIS is almost always implemented as part of a multi-faceted approach to energy management that includes organizational action such as capital upgrades, continuous performance tracking, occupant and operator engagement, and retuning and commissioning.

Energy information systems enable building energy and cost savings in three primary ways:

Operational Efficiency: An EIS provides visibility into energy performance, and insight into instances of energy waste that can be eliminated through low- or no-cost measures such as scheduling, commissioning, and occupant or operator practices.

Measure Identification: An EIS may be used to identify and justify opportunities to improve efficiency by implementing capital improvements.

Persistence of Savings: An EIS can be used to ensure that energy performance improvements and efficiency gains are maintained over time.

3. How should the technology be used so that maximum benefits are achieved?
Factors that can influence the benefits derived from the use of EIS technology include:

- The building's energy performance or level of efficiency before the EIS was installed.
- The depth of metering and monitoring integrated within the EIS—the extent of submetering and/or integration of system-level or controls information.
- The engagement and expertise of the EIS user.
- The user's ability to act on insights gained from EIS use and to effect changes in building equipment or operations.
- More specific best practices associated with specific uses of the tool and its features.

Methodology

This study includes 26 case investigations of organizations that have implemented energy information systems. This cohort represents a diversity of climates and commercial EIS technologies, as well as commercial subsectors, including retail, health care, office, and education. Each case investigation was conducted according to a common template so that findings could be synthesized and analyzed for general conclusions. The study design included both qualitative and quantitative information, and the information-gathering strategy was to *ask for* high-granularity responses, while *accepting* the level of resolution the participant was actually able to provide. From the 26 participating organizations, year-over-year energy consumption and utility cost data were acquired for 9 portfolios and 28 individual sites; detailed technology uses were collected from 23 organizations; and technology cost data were collected from 25 organizations.

Energy information system pricing models and distributions of purchase costs were quantified using procurement records and costs reported by participants. Multi-year trends of portfolio building-level energy use were combined with information on depth of metering and efficiency projects (retrofits, commissioning, and controls upgrades), as well as user-specific interview responses to identify key factors that are associated with deeper energy savings. Interview responses were also used to identify specific technology benefits and best practice uses. Key findings are summarized and discussed below.

Key Findings

Technology Cost Models and Procurement Costs

- The most common cost models comprised annual or monthly billing, with costs assessed per building or according to a single lumped rate for the entire portfolio.
- The five-year cost of ownership, based on up-front and extrapolated ongoing costs were $150,000, or $1,800/pt, or $.06/sf.
- Costs spanned several orders of magnitude, indicating some economies of scale, and significant variation across offerings, and across the market.

Figure 1 details the number and type of pricing models for ongoing EIS software costs that were reported study participants. Tables 1 shows the range in up-front, ongoing and 5-year total costs that were reported across the entire cohort, and Table 2 summarizes costs according to the cohort median.

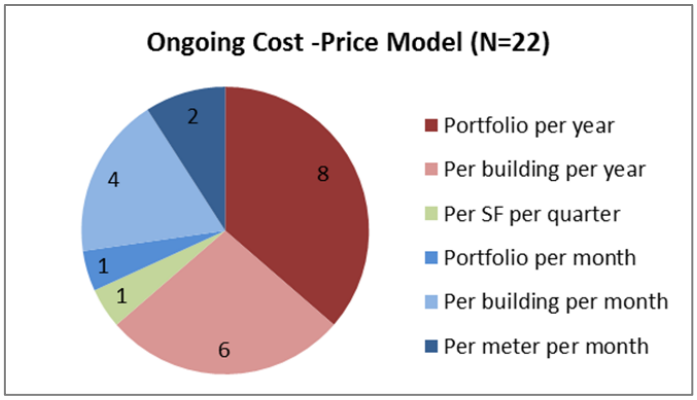

Figure 1. Pricing models for ongoing EIS (energy information system) software costs, reported by study participants

Table 1. Ranges in EIS software costs: up-front, ongoing, and 5-yr total costs of ownership

Type of Costs	Range			
	[$]	[$/pt]	[$/building]	[$/sf]
Up-front (N=18)	0 to 1,700-300,000	0 to 10-3,400	0 to 15-120,000	0 to 0.0008-0.77
Ongoing (N=17)	1,000-140,000	5-3,100	12-25,000	0.0004-0.15
5 yr ownership (N=14)	31,000-790,000	140-16,000	300-130,000	0.02-1.1

Table 2. Median EIS software costs: up-front, ongoing, and 5-yr total costs ownership

Type of Costs	Median			
	[$]	[$/pt]	[$/building]	[$/sf]
Up-front (N=18)	23,000	230	1,400	0.01
Ongoing (N=17)	16,000	200	400	0.01
5 yr ownership (N=14)	150,000	1,800	3,600	0.06

Most of the cases in this study comprised enterprises and campus implementations, with a large number of buildings, and it is unknown whether they are equally applicable to smaller implementations. These results do not include metering or other hardware costs, nor do they include instances where trend logs from building automation systems (BAS) were integrated into the EIS.

Factors Associated with Greater Energy Savings

- The extent of efficiency projects and site EUI before EIS installation were the two factors found to be the most strongly associated with greater savings.
- Depth of metering and total years since EIS installation were the next strongest factors associated with greater savings
- Higher user engagement and user empowerment were not associated with greater energy savings, however this finding should not be interpreted as definitive evidence that these factors are not important.

By definition, the extent of efficiency projects should have a direct causal impact on the depth of achieved energy savings. The fact that this element was found to be the most significant serves as a validation point for the study methodology and findings. Similarly, EUI is intuitively recognized as a strong indicator of the amount of energy that can be saved using commonly available solutions and practices.

In contrast to efficiency projects, metering alone does not result in energy savings. However it does make sense that implementations with more granular levels of monitoring information have the potential to provide deeper performance insights and greater savings over time. Total years of EIS installation may have resulted in a strong associated because most cases had installed their EIS within the last one to two years. Over time, operational inefficiencies can be resolved, and the building can reach a point of persistent efficient operation, where further savings require more aggressive retrofits and other improvement measures.

EIS Benefits and Best Practices

- Energy information systems were cited as a critical component in achieving 17 percent median site savings, and 8 percent median portfolio savings; these energy savings were calculated to represent approximately $56,000 and $1.3 million in utility cost savings.
- Key benefits of EIS use fall into three categories: operational efficiency, utility billing validation and payment, and data or information for custom analyses.
- Best practices associated with greater energy savings included metering beyond the whole-building level; benchmarking to prioritize operational improvement efforts; regular load profiling and continuous anomaly detection; peak demand monitoring; and establishing strong communications between operations and analysis teams.
- In three of four cases for which sufficient information was available, payback was less than two years.

The range and median of achieved energy savings and utility cost savings are summarized in Table 3.

Table 3. Current energy performance and changes in energy use since the EIS was installed, and estimated changes in energy costs, for 28 individual buildings and 9 portfolios across 21 cases

Energy Metric	Individual Sites (N=28)		Portfolios (N=9)	
	Range	Median	Range	Median
Current Annual EUI	28–320 kBtu/sf/yr	78 kBtu/sf/yr	44–330 kBtu/sf/yr	97 kBtu/sf/yr
Change in EUI since EIS installed	-2–87 kBtu/sf/yr	17 kBtu/sf/yr	0–48 kBtu/sf/yr	14 kBtu/sf/yr
Percent change in EUI since EIS installed	-3–47%	17%	0%–33%	8%
Estimated change in annual energy cost since EIS installed	$2,000–$1,100,000	$56,000	-$70,000–17,000,000	$1,300,000
Estimated change in energy cost intensity since EIS installed	0.02–1.5 $/sf	0.4 $/sf	-0.003–0.9 $/sf	0.4 $/sf

Efficiency projects and other energy management activities were conducted in parallel with EIS use over multi-year time periods. Therefore the relative impacts of each cannot be decoupled, and direct attribution of the total savings exclusively attributable to the EIS technology is not possible. Even so, all but 2 of 23 cases reported that the EIS was an essential technology in achieving savings, and efficient operations. In four cases, participants either provided their own estimates of payback on the EIS installation or were able to provide project costs and savings information that was granular enough to calculate payback. In three of these cases, payback was less than two years, commensurate with other case studies in the public domain.

Conclusions

This work provides important insights as to the value proposition for implementing and using energy information systems. Prior to this study one could determine from the literature and public domain case studies that EIS can enable savings up to 20 percent, depending on a number of potential factors. Information on technology costs was especially difficult to find, and limited to a small number of older or more narrowly scoped studies. The results from this work indicate that in several dozen mostly enterprise or campus-level deployments, site and portfolio savings of 17 and 8 percent, and utility cost savings of $56,000 and $1.3 million, respectively, could not have been achieved without the use of the energy information system. Across this cohort, greater savings were associated with deeper metering. Median five-year costs of ownership (excluding hardware) for these large implementations were $150,000, or approximately $1,800 per monitoring point and $.06/sf. Some economies of scale were observed, with per-point costs decreasing as the number of points hosted in the EIS increased.

1. Introduction

Energy information systems are the web-based software, data acquisition hardware, and communication systems used to store, analyze, and display building energy data [Granderson 2009; Motegi 2003]. They often include analysis methods such as baselining, benchmarking, load profiling, and energy anomaly detection [Granderson 2011b; Kramer 2013].

This report documents a large-scale assessment of energy information system (EIS) uses, costs, and energy benefits, based on a series of focused case study investigations that are synthesized into generalizable findings. These findings will provide the foundation of a business case for EIS technology adoption. The overall objective is to provide organizational decision makers with the information they need to make informed choices as to whether or not to invest in an EIS—a promising technology that can enable up to 20 percent site energy savings, quick payback, and persistent low-energy performance when implemented as part of best-practice energy management programs [Capehart and Middelkoop 2011; Granderson 2011a; Motegi 2003; Smith 2011].

Decisionmakers today lack the critical information needed to answer the following three questions about energy information systems:

1. What are the technology costs of an EIS?

While not generally publicly available, technology costs can be quantified using purchasing information such as technology procurement invoices or similar business records. This data, provided by recent customers of EIS can provide a better understanding of current costs than can be gained from the literature. For example, a 2009 study that characterized EIS costs was limited to six offerings, that appear to offer more basic functionality than today's more advanced enterprise-grade software tools [NBI 2009]. A much earlier study, also addressed EIS technology costs, however, may not reflect today's market [CEC 2002].

2. What are the energy- and cost-savings benefits of an EIS?

Quantifying the energy and cost-savings benefits associated with EIS use is a complex issue, for several interrelated reasons:

- An EIS is a process tool that includes a human-in-the loop; an information technology, as opposed to a widget, component, or device.
- An EIS *enables* savings, rather than directly generating savings
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The following sections discuss elements of the study design that are most directly related to identifying technology costs, energy and cost-saving benefits, and best practices that can be used to achieve the maximum benefit. Appendix B contains key excerpts from the full set of information requested from each participant.

2.1 Technology Costs

Each study participant was asked to provide as detailed an accounting of technology costs as possible, based on the records their organization had maintained since the EIS was procured. EIS pricing models vary, therefore the study design accommodated many options; for example, up-front as well as ongoing costs, itemized as well as bundled costs, and hardware as well as software costs. Figure B-1 in Appendix B shows the questions that were included in the study to accommodate diverse pricing models. Implementation details, such as the number of points integrated into the EIS and whether the EIS was an on-premise or a

cloud-based system, were used to understand pricing differences, and to synthesize case-specific findings into common terms for comparison.

2.2 Energy and Cost-Saving Benefits

To understand energy and cost-savings benefits associated with use of the EIS, participants were interviewed and asked to provide year-over-year trends of energy consumption and utility costs, with a record of major capital projects, retrofits, or other efficiency measures. Figure B-2 in Appendix B contains some of the interview questions related to technology benefits; Figure 1, below provides an example of year-over-year trends for a portfolio, and for a site within that portfolio.

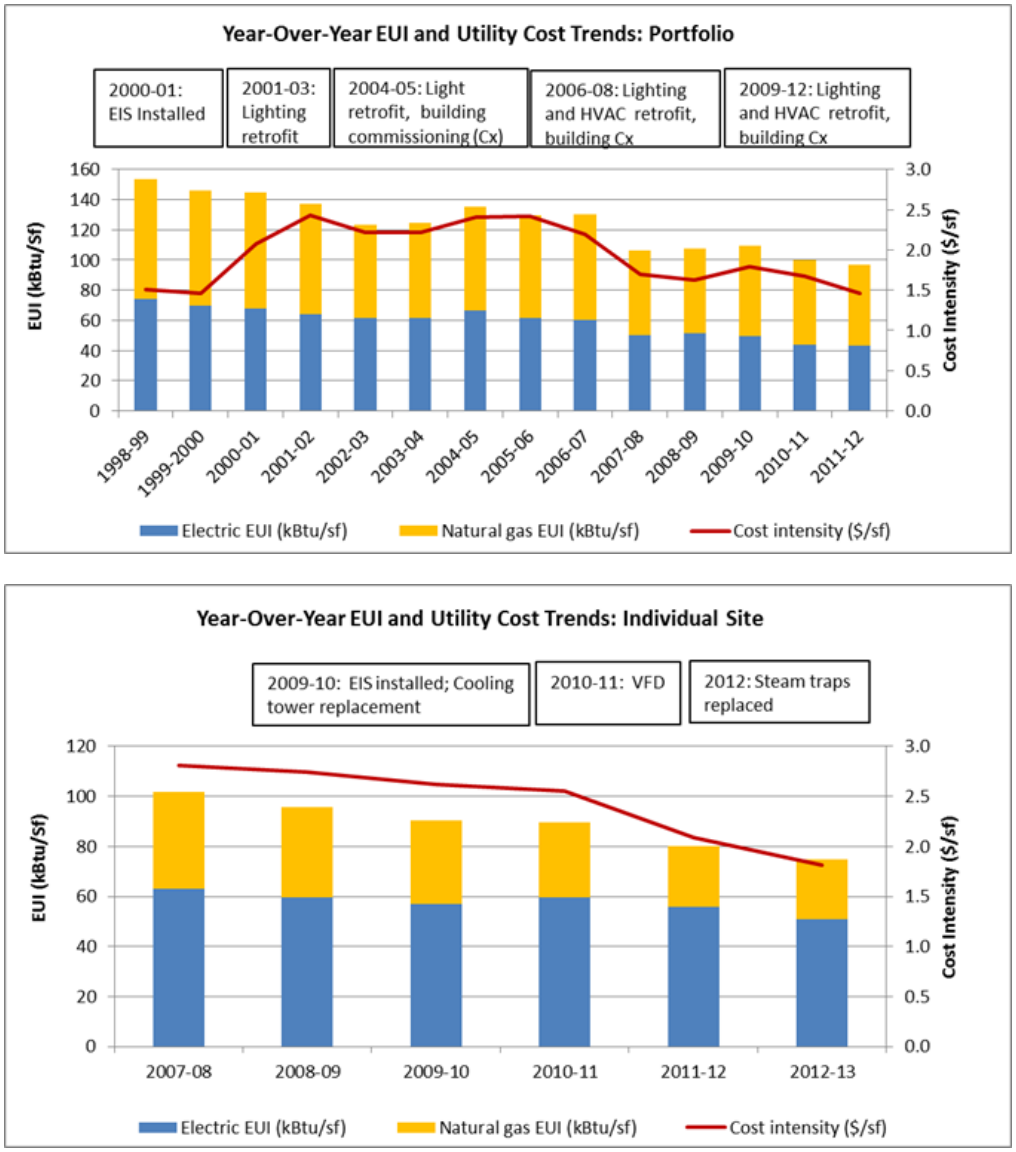

Figure 1. Year-over-year energy use and utility cost trends for a portfolio (top) and single building (bottom), with annotations to indicate major projects and year of EIS installation

Energy data from each site was converted to a common unit—annual, total combined fuels energy use per square feet [kBtu/sf/yr]—which is often referred to as *annual energy use intensity* (EUI). Several metrics were explored to characterize changes in organizational energy use relative to the time that the EIS was installed, including the difference in average EUI before and after EIS installation, the difference in EUI between the most recent year and the year before EIS installation, and the percent difference in EUI between the most recent year and the year before EIS installation. Ultimately, the difference in EUI between the most recent year and the year before EIS installation was determined to be the most suitable metric for the questions being asked in this study, and was well matched to the information that participants were able to provide. Energy consumption for individual buildings was not normalized for weather because aggregate annual totals were the unit of analysis. Prior work has shown that for annual data, degree-day normalization can introduce more error than improvement [Eto 1985]. Although occupancy rates can be a key driver of building energy consumption, occupancy data were not available for collection in the study.

2.3 Factors Associated with Technology Benefits

Five factors that may be associated with the benefit derived from the use of EIS technology are: (1) the building energy performance before the EIS was installed, (2) the depth of metering and monitoring, (3) user engagement, (4) user empowerment to take action based on the information provided, and 5) total years of EIS installation, i.e. time of possession. Building performance prior to EIS installation was characterized using the year-over-year energy use information shown in Figure 1, and the other factors were characterized based on responses to interview questions.

2.3.1 Building Energy Performance Prior to EIS Installation

In general, there are deeper energy savings to be attained in buildings that have high EUIs than in buildings that already operate at a low EUI. For this study, the energy performance of portfolios and buildings were characterized as *high* or *low* based on national average EUIs for the given commercial subsector. Specifically, if the EUI was higher than the national subsector average [EIA 2003] the energy performance was characterized as *high*, and if it was lower than the national average, the performance was characterized as *low*.

2.3.2 Depth of Metering and Monitoring

The questions that were asked to determine depth of metering are shown in Figure B-3 in Appendix B. Depth of metering for each case was characterized as *high* or *low,* according to the following process:

- Three members of the research team independently applied their expert judgment to evaluate each case as high or low, without attempting to apply a specific rule.
- Individual assessments were combined to determine a consensus-based high/low assignment for each case.
- The research team then defined a rule that could be used to objectively represent their collective expert judgment.
    - *low* = campus-level or whole-building metering only
    - *high* = presence of submetering and/or integration of trend logs from the building automation system
- The resulting rule was applied all cases in the study data set.

2.3.3 User Engagement

User engagement with the EIS was determined based on the number of person-hours per month that each organization dedicated to use of the technology. If the reported person-hours were higher than the median for the cohort of cases, user engagement was characterized as *high*; if it was below the median, it was characterized as *low*.

2.3.4 User Empowerment

User empowerment to take action based on the information gained using the EIS was assessed based on a single question that asked on a scale of 1 to 3, how quickly the user is able to act to resolve energy problems that have been identified. Cases that responded "2" or "3" were characterized as *low* empowerment, while those that responded "1" were characterized as *high*.

2.3.5 Years of EIS Installation

If the total years of installation was higher than the median for the cohort of cases, this factor was characterized as *high*; if it was below the median, it was characterized as *low*.

2.4. Extent of Efficiency Improvement Measures

Energy information systems are rarely implemented in isolation, most often being implemented as a critical element of a multi-faceted approach to energy management that also includes capital upgrades, retrofits, and commissioning. All of the cases in this study implemented a series of efficiency improvements over time, and participants were asked to provide a detailed accounting of these improvements and their energy impacts. The level of detail in this accounting ranged from case to case, depending on the records that were maintained. The extent of improvement measures over time is, of course, a crucial aspect of contextualizing the year-over-year energy consumption information, as reflected in the annotations in Figure 1.

Similar to the process described above to identify the depth of metering and monitoring, the extent of efficiency improvements was characterized as *high* or *low* based on the combined judgment of three members of the research team. The rule that was applied was based on knowledge of the types of activities that yield deeper energy savings:

- *high* = cases that conducted commissioning of HVAC systems *or* that implemented projects that included both lighting and HVAC end uses
- *low* = all other cases

3. Results

This section presents findings for the synthesized collection of case investigations, focusing on observed trends in technology costs and benefits, and on key factors that were found to influence those benefits.

3.1 Energy Information System Technology Costs

Public domain information regarding EIS technology costs is not widely available. The technology procurement pricing information that was collected in this study was used to investigate common pricing models, as well as actual ranges of prices and total costs.

3.1.1 Energy Information System Delivery and Pricing Models

Energy information systems are most commonly delivered as software-as-a-service offerings; however, on-premise implementations are possible, and were used in 5 of the 23 cases in this study. Software costs are most often broken into a single up-front cost and a recurring ongoing cost that is usually assessed annually. Up-front costs may include an itemized charge for configuration labor or may be bundled into other up-front vendor services.

Ongoing software costs are assessed with diverse frequency (e.g., monthly, quarterly, or annually), and according to diverse measures (e.g., per building or a single annual fee). The distribution that was reported by the cases in this study is shown in Figure 2. For the cases included in this study, annual fees were about twice as common as monthly fees. Fees were typically assessed at the building or portfolio level, with per-meter or per-square foot charges much less common.

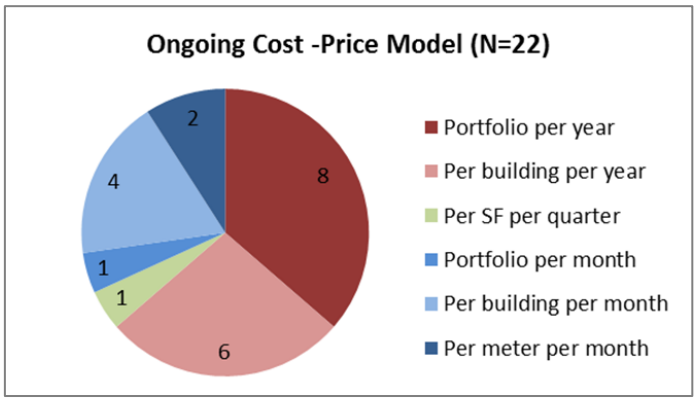

Figure 2. Pricing models for ongoing EIS (energy information system) software costs, reported by study participants

3.1.2 Energy Information Systems Software Costs

Table 1 summarizes up-front and ongoing software costs across 18 total cases, in both total dollars and dollars per point. Across all cases, the number of points hosted within the EIS ranged from 6 to 1,000, and the median was 200 points. In this study a "point" is defined as a single datum that is trended and stored in the EIS. In the majority of cases, "points" corresponded to whole-building and submetered gas and electricity data. Number of points was used as a common denominator, or normalization factor, across cases for several reasons. First, for software, it was reasoned that the number of points hosted, analyzed, and maintained is the actual service or product being purchased. Second, up-front costs were found to scale linearly with the number of points, as opposed to other parameters

such as the number of buildings. Appendix C contains a summary of technology costs according to dollars per building and dollars per square feet, in addition to dollars per point.

Reported technology costs include software costs only, for example configuration, installation, hosting, data acquisition and maintenance, and ongoing access fees. Metering costs are readily available, and therefore not a focus of this work.

Total up-front software costs ranged from $0 to $1,700–$300,000. Per point costs ranged from $0/pt to $10–$3,400/pt, with most cases falling in the $100–$500/pt range. Costs per point did not trend significantly downward with an increase in the number of points, indicating an absence of strong economies of scale in up-front software costs.

In some cases, up-front costs included an itemized charge for configuration labor. These configuration costs ranged from $5,000–$66,000. Per-point configuration costs varied widely overall, from $20–$700/pt, but did stabilize at $20–$100/pt for implementations that exceeded ~300 points.

Ongoing software costs ranged from $1,000–$135,000, with per-point costs of $5–$3,100/pt. In contrast to up-front costs, some economies of scale were observed; software costs per point decreased as the number of points increased. Above ~300 pts, ongoing costs were $5–$50/pt. The highest ongoing cost—$3,000/pt—corresponds to a case in which the actual vendor pricing model was assessed on a $/sf basis.

Table 1. Up-front and ongoing software costs for 18 total cases

Type of Cost		Range [$]	Range [$/pt]	Median [$/pt]
Up-front	Total up-front costs	0 to 1,700–300,000	0 to 10–3,400	230
	Configuration costs	5,000–66,000	20–700	110
Ongoing		1,000–135,000	5–3,100	200

It is interesting to contrast these costs to those reported over ten years ago in [CEC 2002]. In the current study, when expressed in terms of dollars per building, up-front costs ranged from 15-120,000. This both includes, and is larger than the 3,000-50,000 dollars per site that was reported in the study rom the early 2000s. Similarly, this study found ongoing annual costs of 12-25,000 dollars per building, which includes, and is larger than the 300-12,000 reported in the previous study. However, since this study comprised mostly largely portfolios and campuses, and the earlier work focused on site-level costs, it is not clear that the results from the two reports can be directly compared.

Figure 3 provides a graphical representation of some of the information provided in Table 1, showing the distribution and median up-front and ongoing software costs [$/pt]. In Figure 4, ongoing costs are extrapolated and added to up-front costs, to determine a calculated five-

year ownership cost. The median five-year total cost calculated for the cases in this study was approximately $1,800/pt.

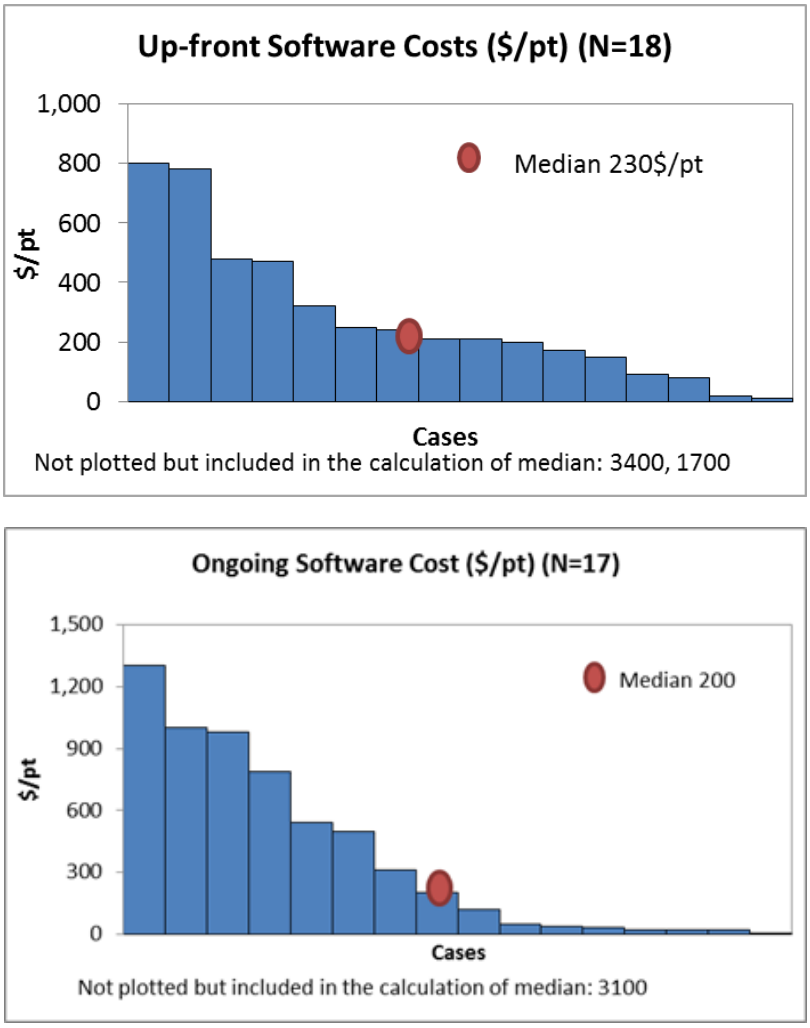

Figure 3. Distribution and median of up-front (top) and ongoing (bottom) software costs of energy information systems, as reported by study participants

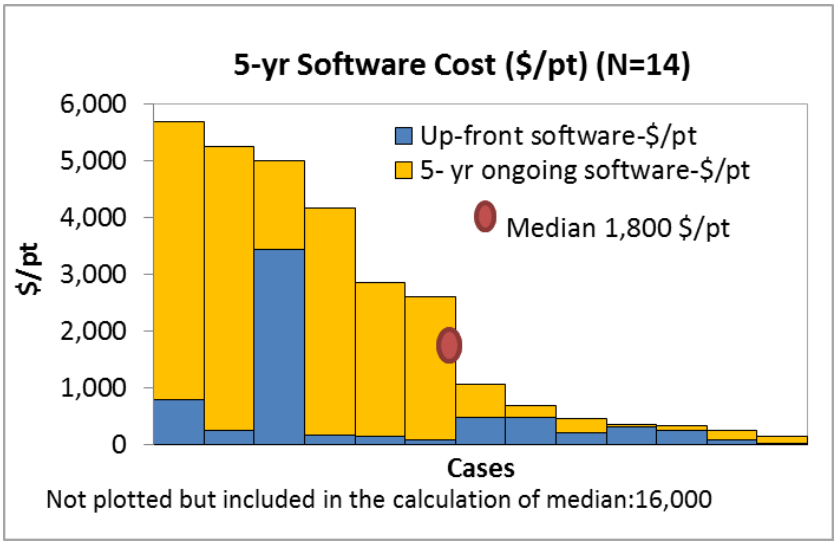

Figure 4. Distribution and median of total cost of EIS ownership, calculated over a five-year period

Overall, these findings indicate that for the cases in this study, the total costs of EIS software ranged over two to three orders of magnitude. These large ranges are driven in part by the size of the implementation; up-front configuration costs and ongoing costs [$/pt] did decrease significantly as the number of points exceeded approximately 300. However, there remains significant diversity in costs. For example, for the five cases that maintained approximately 10 total points, the ongoing costs still ranged over two orders of magnitude. This variation is believed to be due to differences in vendor pricing and technology offerings, as well as to the overall maturity of this rapidly evolving market.

3.2 Technology Benefits

3.2.1 Achieved Energy and Cost Savings

The cases that comprise this study exhibit impressive year-over-year reductions in portfolio and site energy use. Table 2 summarizes current performance levels, as well as absolute and percent changes in EUI since the EIS was installed. The changes in annual energy costs are also provided in Table 2. These data comprise 21 cases, which provided information for 28 individual building sites, and 9 full portfolios.

Figure 5 and Figure 6 show the *distribution* of absolute and percent energy savings, as well as energy cost savings across the same 28 buildings and 9 portfolios. The median energy savings was 17% for individual buildings and 8% for portfolios; the median energy cost savings was 0.4$/sf for both individual sites and portfolios. Study participants were not generally able to provide year-over-year utility costs, *and* associated tariff changes. Therefore, utility cost savings were estimated using national average energy prices, as described in Appendix D.

Table 2. Current energy performance and changes in energy use since the EIS was installed, and estimated changes in energy costs, for 28 individual buildings and 9 portfolios across 21 cases

Energy Metric	Individual Sites (N=28)		Portfolios (N=9)	
	Range	**Median**	**Range**	**Median**
Current Annual EUI	28–320 kBtu/sf/yr	78 kBtu/sf/yr	44–330 kBtu/sf/yr	97 kBtu/sf/yr
Change in EUI since EIS installed	-2–87 kBtu/sf/yr	17 kBtu/sf/yr	0–48 kBtu/sf/yr	14 kBtu/sf/yr
Percent change in EUI since EIS installed	-3–47%	17%	0%–33%	8%
Estimated change in annual energy cost since EIS installed	$2,000–$1,100,000	$56,000	-$70,000–17,000,000	$1,300,000
Estimated change in energy cost intensity since EIS installed	0.02–1.5 $/sf	0.4 $/sf	-0.003–0.9 $/sf	0.4 $/sf

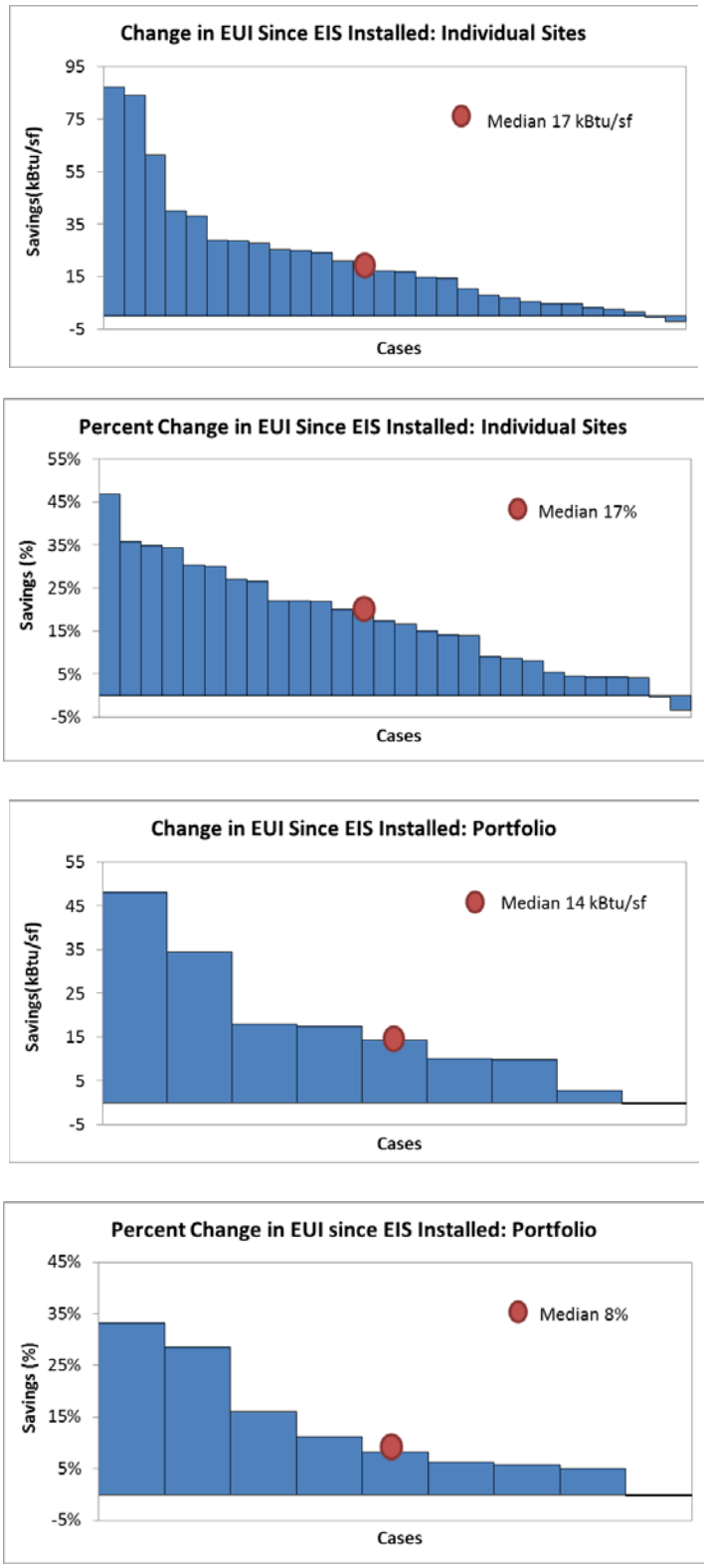

Figure 5. Distribution of total and percentage energy savings that were achieved in 28 buildings (top 2 plots) and in 9 portfolios (bottom two plots)

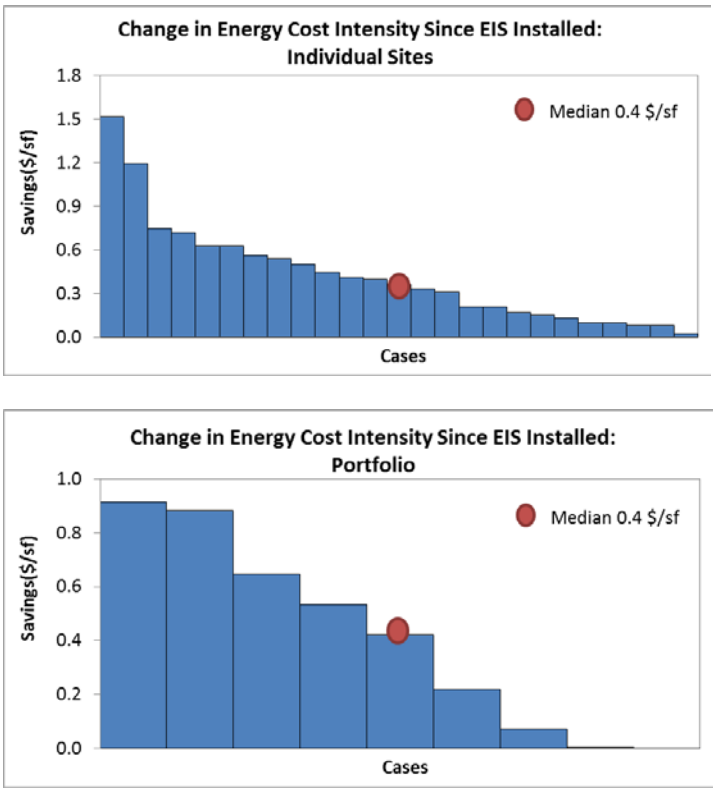

Figure 6. Distribution of estimated energy cost savings [$/sf] in 28 buildings (top) and in 9 portfolios (bottom)

In addition to total savings, the savings for each year can be plotted, as in Figure 7. Here, each line represents a building, and the y-axis represents percent savings relative to the year before the EIS installation; the "base year." The x-axis represents savings relative to the base year, for each year that the EIS was in place. The red line indicates the median for the cohort. This plot shows that in most cases, savings increased over time.

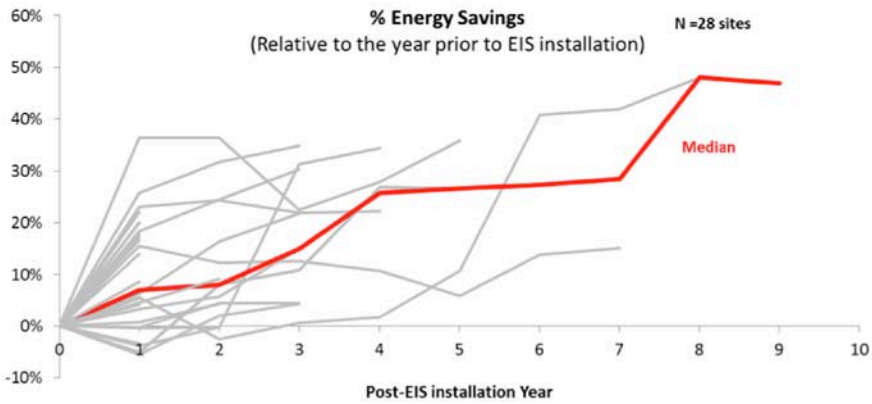

Figure 7. Percent change in EUI, relative to year of an EIS installation; the gray lines indicate savings for each of 28 individual buildings, and the red line represents median savings across the cohort.

These achieved energy savings and performance levels are attributable to a number of interdependent activities, including efficiency improvement projects, use of the EIS technology, and other energy management practices.

Figure 8 shows total site energy savings [kBtu/sf/yr] versus the extent of efficiency improvement projects, for 28 individual buildings. As expected, greater energy savings are associated with the cases that have a greater extent of efficiency projects.

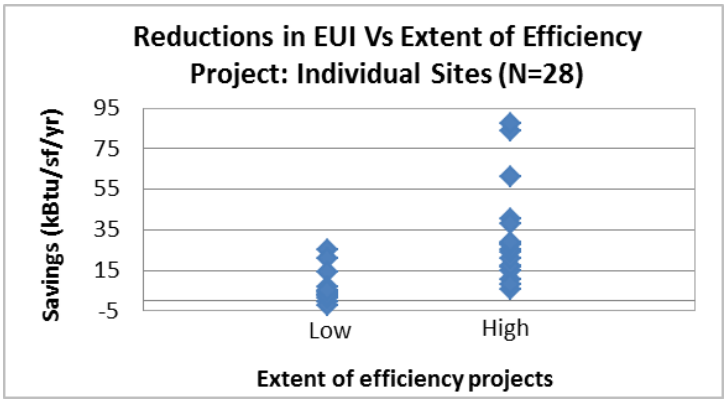

Figure 8. Reductions in EUI versus extent of efficiency project activity for 28 buildings

3.2.2 Benefits of EIS Use

While the extent of efficiency projects was one factor in achieving energy reductions over time, use of the EIS was another—a full 21 of 23 respondents stated that they could not achieve these performance levels *without* the use of the EIS. The benefits of EIS use that were most commonly cited are categorized into the three categories: operations, utility costs and billing, and data and information access. These benefits are summarized below.

Operations

- Identification of operational efficiency opportunities associated with scheduling, the presence of faults and energy anomalies, and changes typical or expected load profiles
- Ability to track energy performance over time and compare energy use within and between buildings

Utility Costs and Billing

- Verification of utility bills
- Monitoring of peak loads and management of utility demand charges

Data and Information Access

- Availability of data to inform organization-specific custom analyses, e.g., utility recharges and project-specific energy savings and payback
- Information to ground and set organizational or site energy goals

Each study participant was asked whether they had attempted to quantify the payback or return on investment from their EIS. Although these capital budgeting metrics are commonly used to justify the investment in efficient building components, equipment, or systems, they were not often tracked for the EIS implementations in this study. This could be due to the previously mentioned difficulties in attribution of savings exclusively to the EIS versus other concurrent activities. It might also be because these users are confident in the technology's efficacy and are satisfied with their experience, and therefore not compelled to quantify its value. For example, when asked if he had calculated the return on investment or payback of the EIS installation, on participant countered "does a mechanic quantify the value of *their* tools?"

Two cases reported a simple payback for their EIS implementation, and for two cases the research team was able to calculate a payback from the data that the organization provided. These four instances are not directly comparable because they do not necessarily use the same assumptions, or equivalent accounting of total technology investment costs, and total utility cost savings. Nevertheless, in three of these four instances, the payback was less than two years.

3.3 Best Practices and Factors Associated with Greater Energy Savings

The benefits of EIS use and technology payback examples that were presented in the previous section were directly reported by study participants. As noted in the Introduction and Methodology sections, the factors that may be related to achieved energy savings include EIS-specific factors such as depth of metering, user engagement, user empowerment, and total years since the technology was installed. In addition, building- or organization-specific factors such as the energy use intensity before the EIS was installed, and extent of efficiency projects, can also have an impact. This section presents an analysis of the extent to which each of these factors is associated with greater achieved energy savings.

Figure 9 contains plots that show the absolute energy savings (kBtu/sf) that were achieved relative to each potential factor of influence. In these plots, energy savings are shown on the y-axis, and box-and-whisker plots represent the distribution of achieved EUI reductions for cases in which the factor of influence was characterized as *low*, and for cases in which it was characterized as *high*. The horizontal bars, or 'whiskers', indicate the minimum and maximum savings; the bottom and top of each box indicate the 25th and 75th percentiles; and the transition from green to blue indicates the 50th percentile, or the median savings.

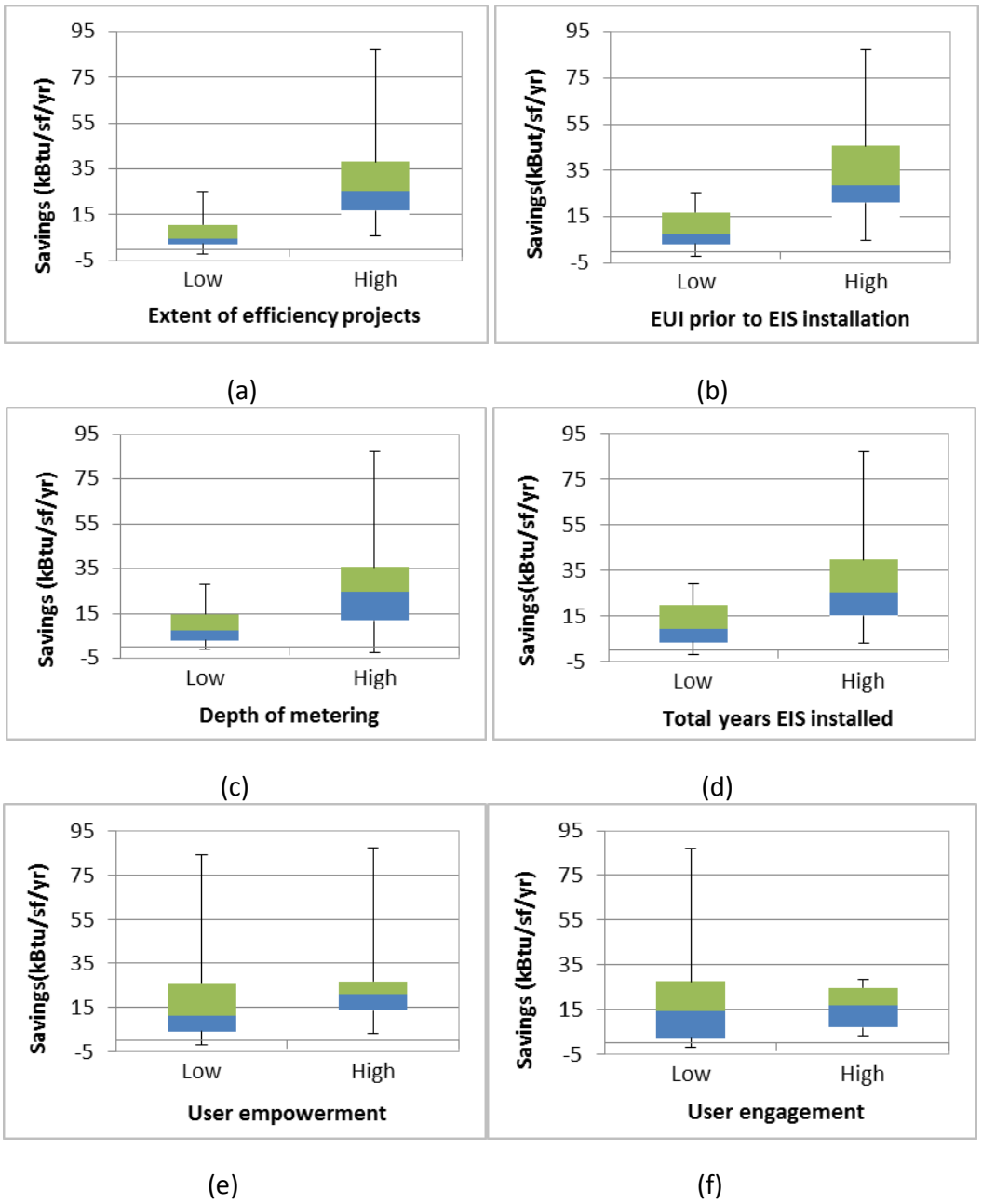

Figure 9. Reductions in EUI for each factor considered, for 28 individual buildings: (a) Extent of efficiency projects; (b) EUI prior to EIS installation; (c) Depth of metering; (d) Total years EIS installed; (e) User empowerment; (f) User engagement

The plots in Figure 9 provide a visual summary of the each potential factor of influence that was considered in the study. Instances in which the savings for the *low* group are obviously offset from, or different from the *high* group, indicate factors that appear to have a significant effect on achieved savings. For example, extent of efficiency projects and EUI prior to EIS installation, located in the top row of plots, stand out as having a greater potential effect on achieved savings. Conversely, instances in which the distributions for the

low and the *high* group show extensive overlap indicate a less clear relationship with achieved energy savings. For example, there is little difference in the energy savings achieved in cases with *low* versus *high* user engagement (see plot on bottom right).

In addition to visual inspection of the data, a statistical analysis was conducted to determine the size and significance of the relationship between each factor and achieved site energy savings. For each factor, the difference in median energy savings from the *low* and *high* group was evaluated using the Wilcoxon-Mann Whitney (WMW) test [Mann 1947]. This test is a non-parametric equivalent of the independent means t-test, and applicable to cases in which the dependent variable (in this study, achieved energy savings) does not follow a normal distribution. The effect size for each factor was calculated based on the z-score obtained from the results of the WMW test and the sample size, according to Field [2009].

For those unfamiliar with statistical hypothesis testing, the effect size can be interpreted as a normalized representation of the magnitude of the different savings achieved in the low group versus the high group. For the effect sizes reported in this study, any value between .1 and .3 is considered "small," while .3-.5 is "medium," and greater than .5 is "large" following the conventions established in [Cohen 1988]. The p value provides insight into the association between the factor considered and achieved energy savings. It shows whether the difference in achieved energy savings between the *low* group and the *high* group was statistically significant – that is, whether the difference is truly distinguishable, or a simple artifact of the sampling of study participants. Table 3 summarizes the results of this statistical analysis.

Table 3. Wilcoxon-Mann Whitney assessment factors potentially associated with greater energy savings

Factor	Difference in median savings between *low* and *high* groups [kBtu/sf]	Effect size	Wilcoxon-Mann Whitney p value
Extent of efficiency projects	21	0.67	0.0004
EUI prior to EIS installation	21	0.65	0.001
Depth of metering	17	0.44	0.02
Total years EIS installed	16	0.43	0.02
User empowerment	10	0.24	0.21
Use engagement	2	0.11	0.58

These results show that extent of efficiency projects and EUI prior to EIS installation are most strongly associated with high energy savings, with large significant differences between cases in the *low* and *high* groups. Depth of metering and total time that the EIS

was in place were the next factors strongly associated with increased energy savings. For these factors, the effect size was medium, and the significance of the result was high, with p-values less than .05. User engagement and user empowerment were not strongly associated with greater energy savings, and there was little difference in the savings achieved in the *high* and *low* groups.

3.3.1 Best Practice EIS Uses

The statistical analysis of potential factors of influence showed that depth of metering was associated with greater savings. Although the presence of metering does not directly *cause* savings, the association was strong, and the difference in savings achieved was large. Based on these findings, implementation of metering beyond the whole-building or whole-campus level is a recommended best practice. In addition to more granular information for issues of operational efficiency, submetering can enable meter-based recovery of utility costs for campus recharges or tenant billing.

Additional data from the case studies supplemented the results from the statistical analysis. Those organizations that achieved the largest energy savings were qualitatively assessed as a subgroup, and the following additional best practice technology uses were identified:

Operational Efficiency

- *Load profiling on a regular basis*: Inspection of time series plots of interval energy consumption data, at least weekly, and at a minimum at the whole-building level. Inspection of submetered building- or equipment-level load profiles can generate further performance insights.

- *Use of automated energy anomaly detection features*: As opposed to simple threshold-based alarming, use of a mathematical baseline consumption model to automate identification of atypical energy use. Baseline models account for key drivers of energy use such as outside air temperature, time of day, and day of week. Automation and interval metering enable continuous performance assessment and timely identification of energy waste.

- *Use of x-y scatter plots of load versus outside air temperature* to assess efficacy of the control and operation of temperature dependent loads, such as whole-building energy, or chiller power.

- *Benchmarking portfolio and site performance:* "Triage" of the worst performing buildings, and referral for deeper investigation to resolve problems. This is a particularly effective strategy in managing the efficiency of a large portfolio of buildings.

- *Tight integration between the energy analyst and building operations:* Regular communication and information-sharing to close the loop between problem identification and resolution.

- *Conversion of energy consumption information into monetary information:* Use of utility tariffs or cost estimates to explicitly represent the cost of energy used. This was noted as an important motivational technique that can communicate the tangible dollar value of energy savings or waste.

Utility Billing Validation and Payment

- *Continuous monitoring of peak load to manage demand charges:* Use of whole-building and sometimes submetered data to control the magnitude of peak loads. Especially in larger buildings, electric demand charges can comprise a significant portion of total utility costs, so that peak load management is an effective means of reducing total costs of operation.

- *Use of software features to streamline utility-related processes:* Minimization of personnel resources required for bill payment and cost reporting, particularly for portfolios with a large number of utility accounts.

- *Identification of billing and metering errors:* Energy use totals and peak loads that are monitored and tracked in the EIS can be used to mistakes in utility charges.

Use of Data for Additional Analyses

- *Verification of project savings:* Historic records of whole-building or submetered data can be exported to quantify achieved energy savings (some advanced EIS automate this capability). This can serve two purposes: (1) validation that efficiency measures are indeed generating the expected level of savings, and (2) hard evidence for financial groups, to confirm the utility cost savings from completed projects.

- *Sustainability reporting:* Energy use records are increasingly used by enterprises to streamline the aggregation of data into quantities required for corporate or organizational reports. In some cases the EIS reporting features were used directly, and in other cases the data were exported for further manipulation.

4. Discussion and Conclusions

This study represents the first large-scale assessment of EIS technology costs and benefits, based on over two dozen implementation cases. Energy information system pricing models and distributions of purchase costs were quantified using procurement records and costs reported by participants. Multi-year trends of portfolio building-level energy use were combined with information on depth of metering and efficiency projects (retrofits, commissioning, and controls upgrades), as well as user-specific interview responses to identify key factors that are associated with deeper energy savings. Interview responses were also used to identify specific technology benefits and best practice uses. Key findings are summarized and discussed below.

4.1 Key Findings

Technology Cost Models and Procurement Costs

- The most common cost models comprised annual or monthly billing, with costs assessed per building or according to a single lumped rate for the entire portfolio.
- The five-year cost of ownership, based on up-front and extrapolated ongoing costs were $150,000, or $1,800/pt, or $.06/sf.
- Costs spanned several orders of magnitude, indicating some economies of scale, and significant variation across offerings, and across the market.

Most of the cases in this study comprised enterprises and campus implementations, with a large number of buildings, and it is unknown whether they are equally applicable to smaller implementations. These results do not include metering or other hardware costs, nor do they include instances where trend logs from building automation systems (BAS) were integrated into the EIS.

Factors Associated with Greater Energy Savings

- The extent of efficiency projects and site EUI before EIS installation were the two factors found to be the most strongly associated with greater savings.
- Depth of metering and total years since EIS installation were the next strongest factors associated with greater savings
- Higher user engagement and user empowerment were not associated with greater energy savings.

By definition, the extent of efficiency projects should have a direct causal impact on the depth of achieved energy savings. The fact that this element was found to be the most significant serves as a validation point for the study methodology and findings. Similarly, EUI is intuitively recognized as a strong indicator of the amount of energy that can be saved using commonly available solutions and practices.

In contrast to efficiency projects, metering alone does not result in energy savings. However it does make sense that implementations with more granular levels of monitoring information have the potential to provide deeper performance insights and greater savings over time. While the study findings show that deeper metering was associated with deeper savings, they do not reveal the *ideal maximum* depth or level of submetering; that is, the point at which the value of additional information begins to fall off or plateau.

Total years of EIS installation may have resulted in a strong associated because most cases had installed their EIS within the last one to two years. Over time, operational inefficiencies can be resolved, and the building can reach a point of persistent efficient operation, where further savings require more aggressive retrofits and other improvement measures.

Considered individually, user-specific engagement and empowerment were not associated with deeper energy savings. This should not be interpreted as definitive evidence that these factors are not important. It is possible that while there were *relative* differences in engagement within this cohort, the cohort may represent high engagement in an absolute

sense. In addition, there could have been bias in self-reported levels of empowerment that obscured this factor's true importance. It is also possible that these factors become more important when considered *in combination* with other factor such as depth of metering. This is a topic for further exploration in future work.

EIS Benefits and Best Practices

- Energy information systems were cited as a critical component in achieving 17 percent median site savings, and 8 percent median portfolio savings; these energy savings were calculated to represent approximately $56,000 and $1.3 million in utility cost savings.
- Key benefits of EIS use fall into three categories: operational efficiency, utility billing validation and payment, and data or information for custom analyses.
- Best practices associated with greater energy savings included metering beyond the whole-building level; benchmarking to prioritize operational improvement efforts; regular load profiling and continuous anomaly detection; peak demand monitoring; and establishing strong communications between operations and analysis teams.
- In three of four cases for which sufficient information was available, payback was less than two years.

Efficiency projects and other energy management activities were conducted in parallel with EIS use over multi-year time periods. Therefore the relative impacts of each cannot be decoupled, and direct attribution of the total savings exclusively attributable to the EIS technology is not possible. Even so, all but 2 of 23 cases reported that the EIS was an essential technology in achieving savings, and efficient operations. In four cases, participants either provided their own estimates of payback on the EIS installation or were able to provide project costs and savings information that was granular enough to calculate payback. In three of these cases, payback was less than two years, commensurate with other case studies in the public domain.

This work has provided core insights as to the value proposition for implementing and using energy information systems. Prior to this study one could determine from the literature and public domain case studies that EIS can enable savings up to 20 percent, depending on a number of potential factors. Information on technology costs was especially difficult to find, and limited to a small number of older or more narrowly scoped studies. The results from this work indicate that in several dozen mostly enterprise or campus-level deployments, site and portfolio savings of 17 and 8 percent, and utility cost savings of $56,000 and $1.3 million, respectively, could not have been achieved without the use of the energy information system. Across this cohort, greater savings were associated with deeper metering. Median five-year costs of ownership (excluding hardware) for these large implementations were $150,000, or approximately $1,800 per monitoring point. Some economies of scale were observed, with per-point costs decreasing as the number of points hosted in the EIS increased.

5. Future Work

Future work should continue to explore the relationship between energy savings and the use of EIS. This work should consider additional tracking of the analyses that are most valuable to motivate actions that result in greater energy savings. The work presented in this study focused on large enterprise-wide EIS implementations; solutions to reduce the costs of EIS, are needed so that the technology can be deployed to small and medium sized buildings, are also needed. Finally, understanding new and emerging business models, particularly those that include analytical services, will be important in increasing the adoption of these tools.

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Appendices

Appendix A: Characterization of Cases

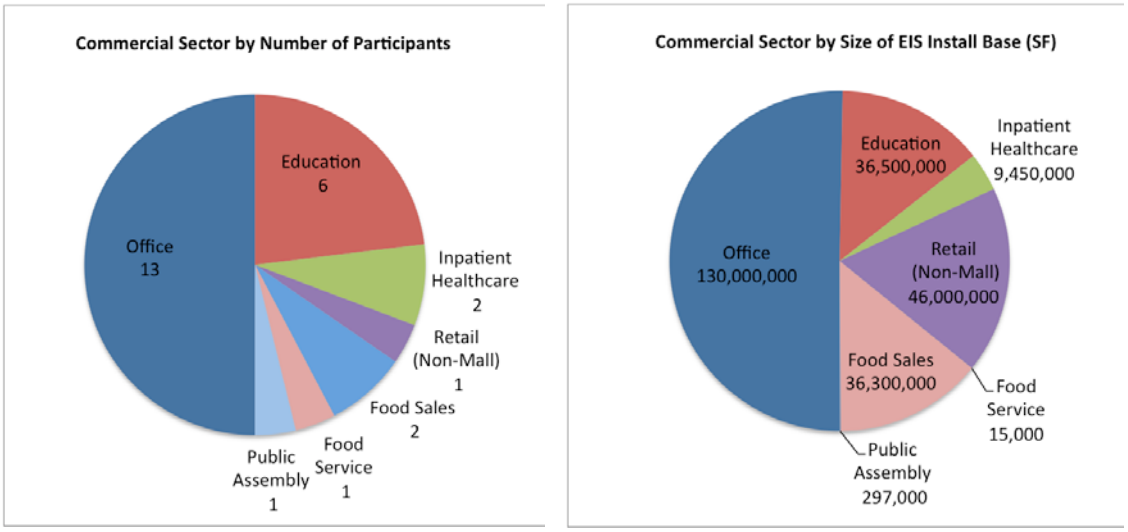


Figure A-1: Number of participants in each commercial sector, 26 participants total (left) and size of EIS install base in each commercial sector, with approximately 259 million square feet of EIS install base in total (right).

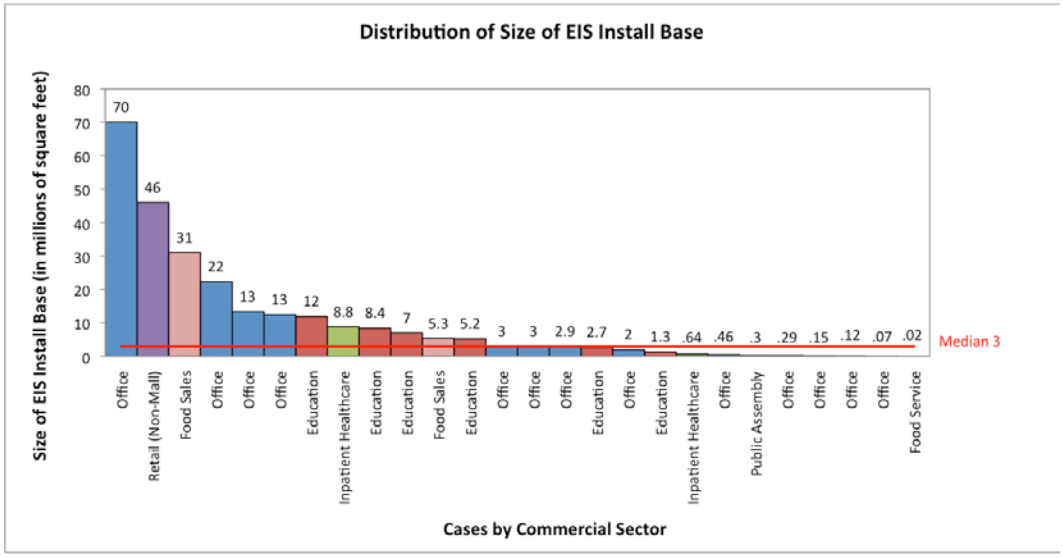


Figure A-2: Distribution of size of EIS install base in millions of square feet. Each case is labeled by commercial sector.

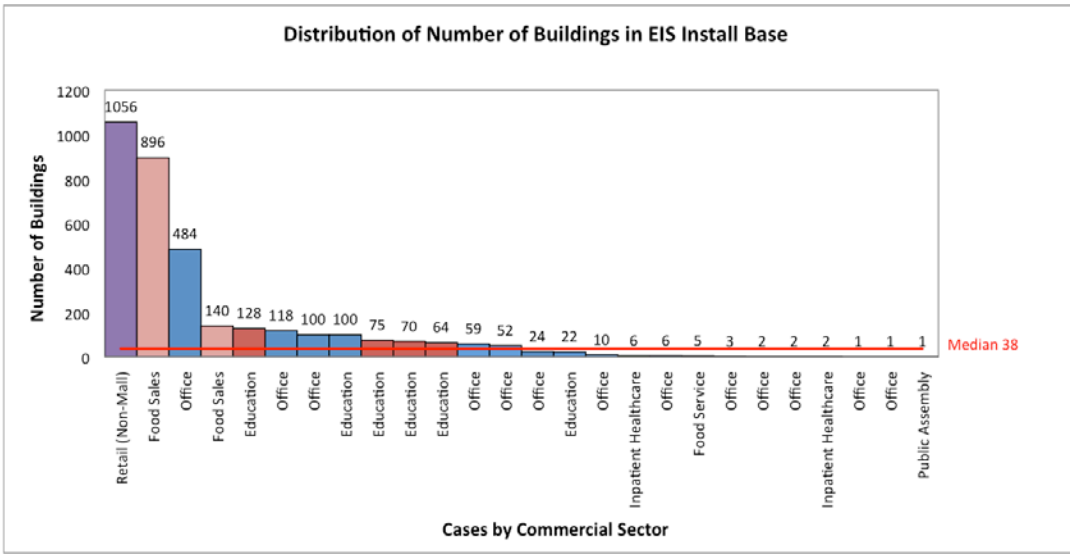


Figure A-3: Distribution of number of buildings in EIS install base. Each case is labeled by commercial sector.

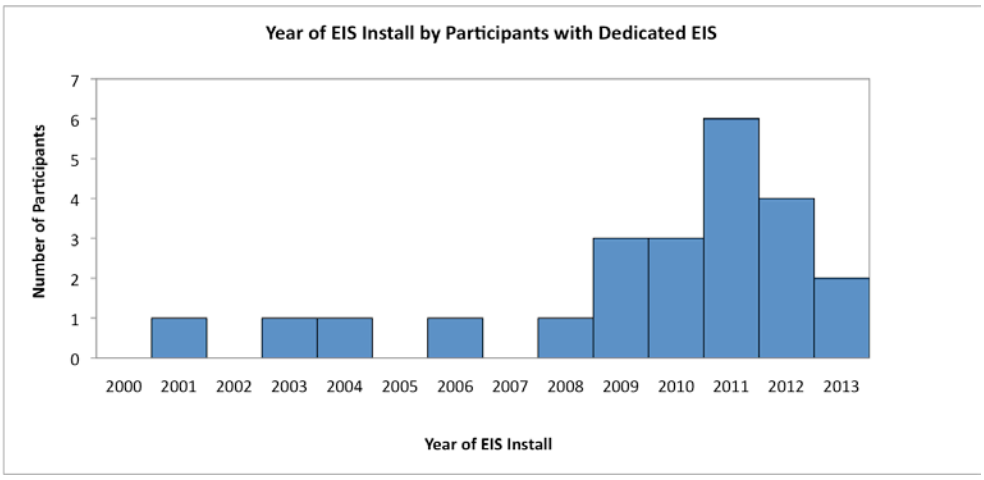


Figure A-4: Year of EIS install by participants with a dedicated EIS, 23 participants in total, not including those using a building automation system (BAS) to collect, visualize, and analyze metered and submetered energy use.

Figure A-5: Locations of the 28 individual buildings included in the year-over-year data analysis.

Appendix B: Detailed Description of Questions Addressed in Case Investigations

Technology Costs
Up-front Costs: Hardware
Meter Costs ($)
Sensor Costs ($)
Installation Labor Costs ($)
Other Hardware Costs (specify type and $)
Up-front Costs: Software
Per-Point Cost ($)
Per-User Cost ($)
Feature or Module Specific cost ($)
Configuration Labor ($)
Integration Labor Costs ($)
Other Software Costs (specify type and $)
Ongoing Costs: Software and Operations
Software Recurring Costs ($)
Other Ongoing Costs (specify type and $)

Figure B-1: Questions that were included in the study to address technology costs

EIS Energy and Cost Benefits
Operational Benefits
Metrics used to track building, campus, or portfolio energy use [e.g., kBTU/sf/yr, BTU/yr, total kWh and therms, E* score, kWh/employee …]
How quickly can you act to resolve identified issues? [1 = immediately, 2 = within acceptable delay, 3 = very slowly]
Would you be able to achieve your current levels of performance without this tool?
Sustainability Reporting Benefits
What year did your organization begin tracking energy consumption?
Do you use the EIS to streamline sustainability reporting? (yes or no)
Energy- and Cost-Saving Benefits
Have you estimated the energy savings impact of the EIS? - How? YOY reductions in use? Improved ENERGY STAR scores? ROI? Reductions in utility costs?
Has the tool enabled you to identify ECMs more easily or more frequently?
If yes, what are examples of some of the types of ECMs?
Has EIS installation enabled you to manage (reduce) demand charges?
Has the EIS enabled your organization to set more energy goals or more advanced energy goals?

Figure B-2: Questions that were included in the study to address energy and cost savings benefits

EIS Meters and Sensors
Whole-Building Fuel Meters
Whole-building electric:
Whole-building gas:
Whole-building other:
System-Level Meters
System-level electric:
System-level gas:
System-level other:
Equipment-Level Meters
Equipment-level electric:
Equipment-level gas:
Equipment-level other:
Other
Other Sensors Used in the EIS [Type, Vendor - temp, flow, occupant]
End Use Load disaggregation
Integration
Is the EIS integrated with any points from the BAS?
Scale of Monitoring
What is the approximate total number of points monitored in the EIS?

Figure B-3: Questions that were included in the study to address depth of metering and monitoring

Appendix C: EIS Technology Costs

This appendix contains a summary of EIS technology costs according to dollars, dollar per point, dollars per building, and dollars per square feet.

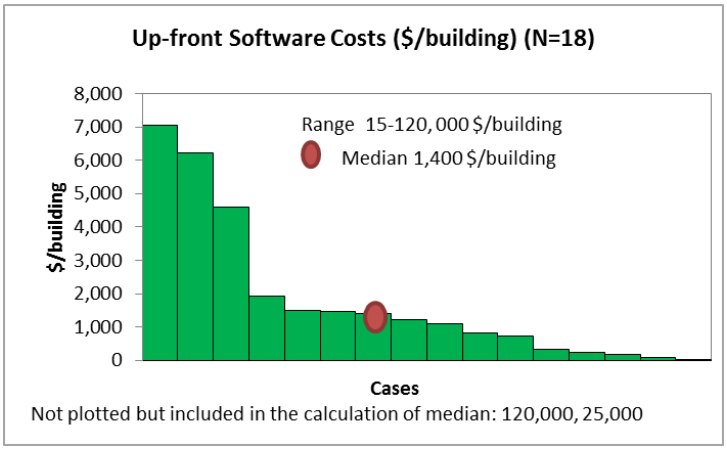
Across all cases, the number of buildings in EIS install base ranged from 1 to 560, and the median was 17 buildings; the size of EIS install base ranged from 0.2 to 22 million square feet, and the median was 3 million square feet.

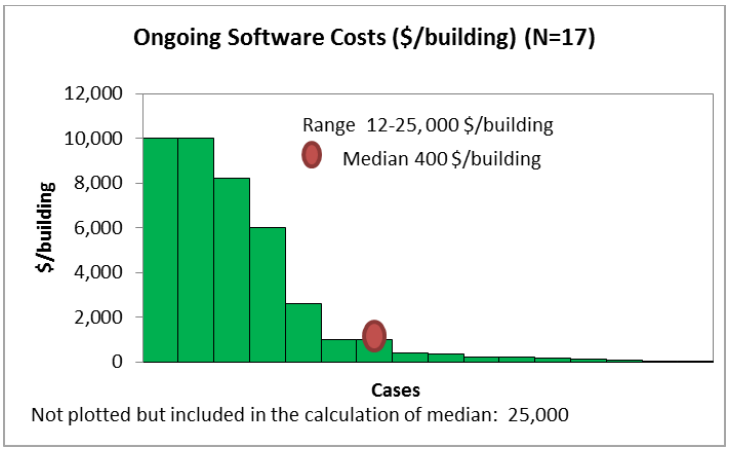
Table C-1. Ranges in EIS software costs: up-front, ongoing, and 5-yr total costs of ownership

Type of Costs	Range			
	[$]	[$/pt]	[$/building]	[$/sf]
Up-front (N=18)	0 to 1,700-300,000	0 to 10-3,400	0 to 15-120,000	0 to 0.0008-0.77
Ongoing (N=17)	1,000-140,000	5-3,100	12-25,000	0.0004-0.15
5 yr ownership (N=14)	31,000-790,000	140-16,000	300-130,000	0.02-1.1

Table C-2 .Median EIS software costs: up-front, ongoing, and 5-yr total costs ownership

Type of Costs	Median			
	[$]	[$/pt]	[$/building]	[$/sf]
Up-front (N=18)	23,000	230	1,400	0.01
Ongoing (N=17)	16,000	200	400	0.01
5 yr ownership (N=14)	150,000	1,800	3,600	0.06





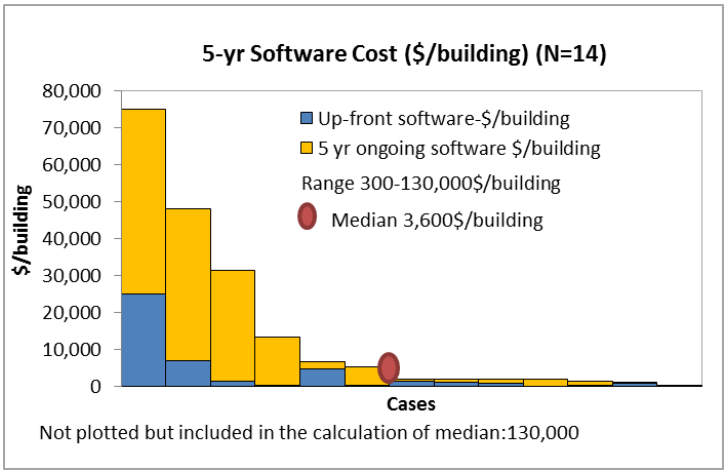


Figure C-1: Distribution, range, and median of up-front software costs (top), ongoing software costs (middle), and total cost of five-year EIS ownership, expressed according to dollars per building

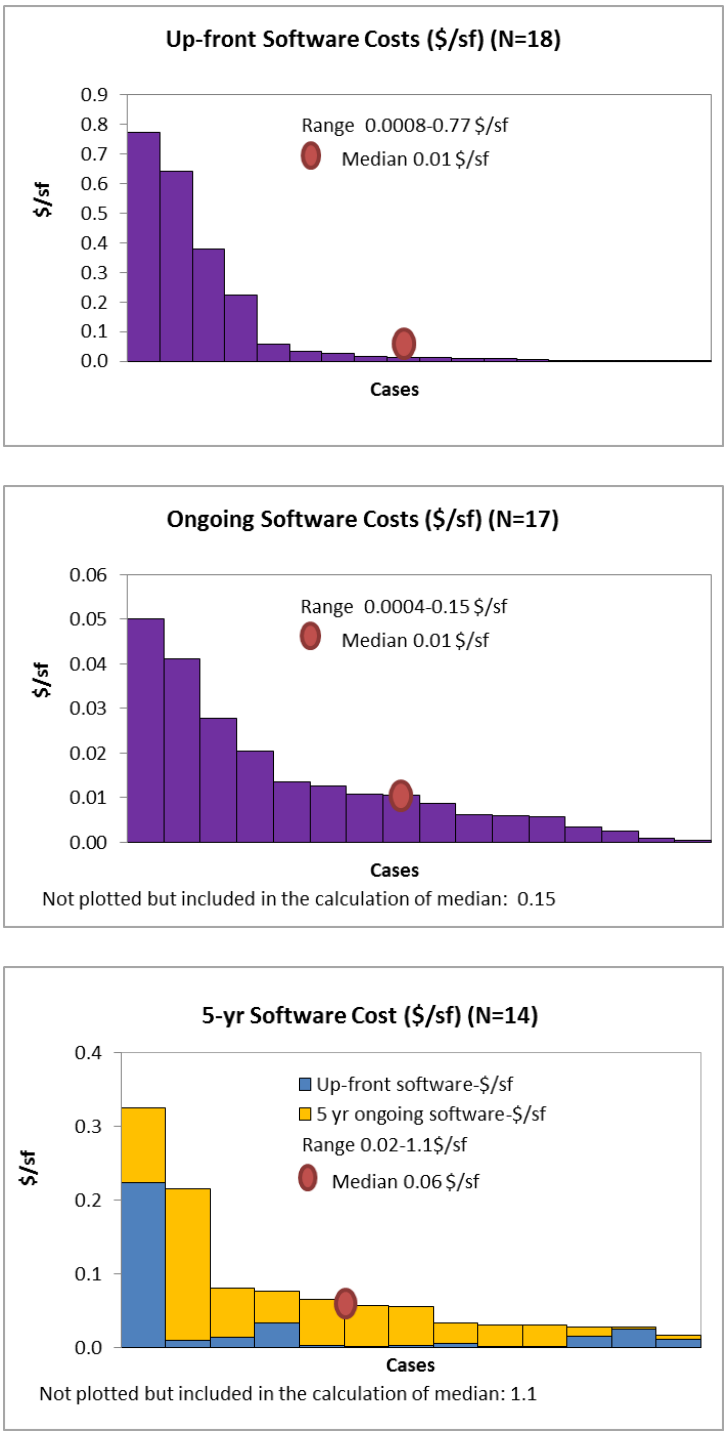


Figure C-2: Distribution, range, and median of up-front software costs (top), ongoing software costs (middle), and total cost of five-year EIS ownership, expressed according to dollars per square feet

Appendix D: Estimated Energy Cost Savings

This appendix summarizes the process used to calculate energy cost savings for each site or portfolio in the study.

1. Calculate electrical and natural gas energy savings:

   Electrical energy savings (kBtu/sf) =Electrical EUI of the year before EIS installation (kBtu/sf) – Electrical EUI of the most recent year (kBtu/sf)

   Natural gas energy savings (kBtu/sf) = Natural gas EUI_of the year before EIS installation (kBtu/sf) – Natural gas EUI_of the most recent year (kBtu/sf)

2. Calculate electrical and natural gas energy cost savings:

   Electrical energy cost savings ($/sf) = Electrical energy savings (kBtu/sf) × National average electricity price ($/kBtu)

   Natural gas energy cost savings ($/sf) = Natural gas energy savings (kBtu/sf) × National average natural gas price ($/kBtu)

   where national average electricity price is 0.3$/kBtu and national average natural gas price is 0.008$/kBtu, according to 2012 national average energy price in commercial sector reported by U.S. Energy Information Administration (EIA).

3. Calculate energy cost savings:

   Energy cost savings ($/sf) = Electrical energy cost savings ($/sf) + Natural gas energy cost savings ($/sf)

   Energy cost savings ($) = Energy cost savings ($/sf) × Area (sf)

National average electricity and natural gas prices were based on reported values from the US Energy Information Administration, accessed on November 15, 2013, and available from:

http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_3

http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_a.htm