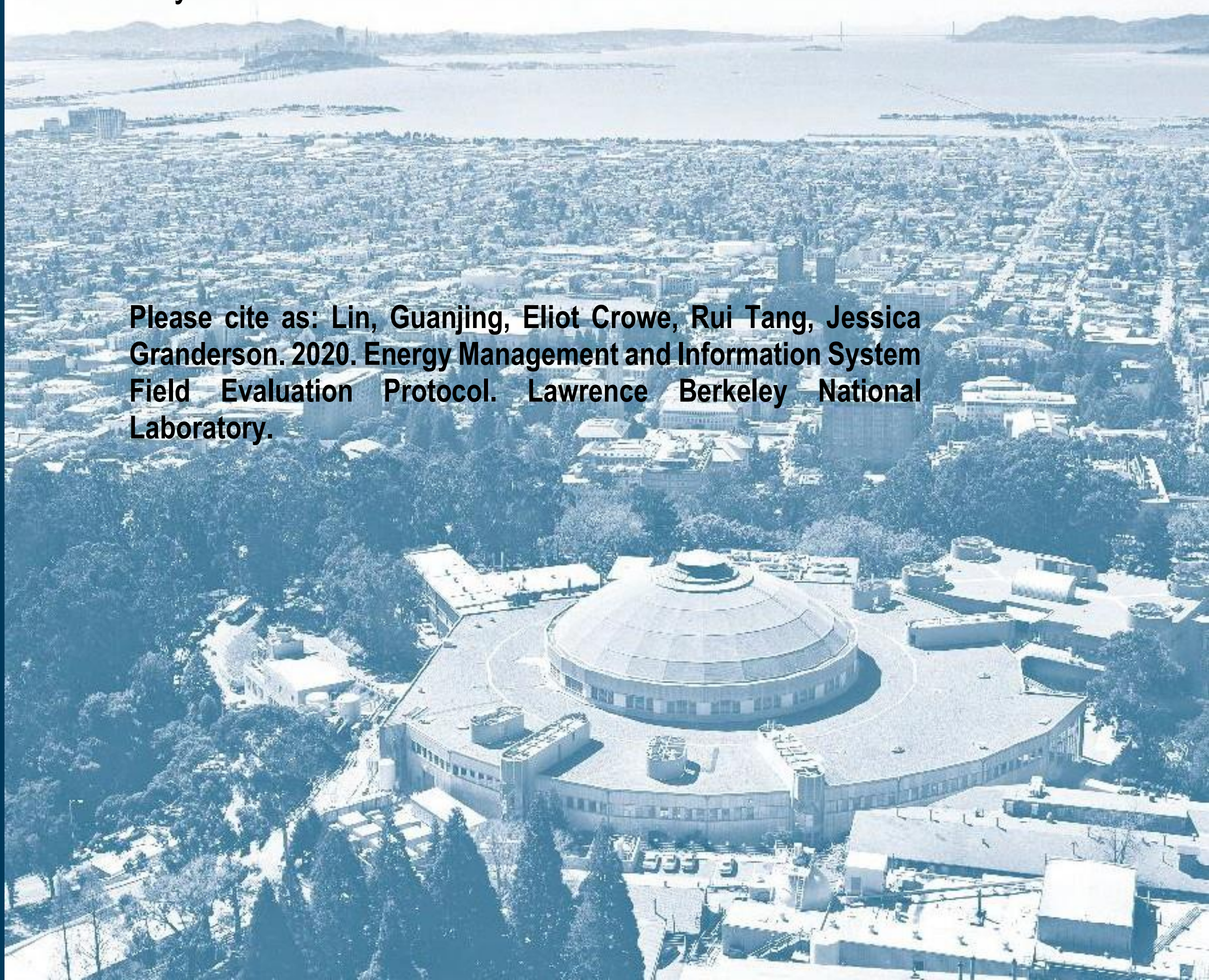
Lawrence Berkeley National Laboratory

Energy Management and Information System Field Evaluation Protocol

Guanjing Lin, Eliot Crowe, Rui Tang, Jessica Granderson

Building Technology and Urban Systems Division
Lawrence Berkeley National Laboratory

Energy Technologies Area
May 2022



Please cite as: Lin, Guanjing, Eliot Crowe, Rui Tang, Jessica Granderson. 2020. Energy Management and Information System Field Evaluation Protocol. Lawrence Berkeley National Laboratory.

Acknowledgements

This work is supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Building Technologies Program, of the U.S. Department of Energy under Contract no. DE-AC02- 05CH11231. The authors wish to acknowledge Harry Bergmann and Hannah Debelius for their guidance and support of the research, as well as the suggestions from our technical advisory group members. We are also grateful to the Consortium for Energy Efficiency for their support in the planning, review, and outreach phases of the development.

Table of Contents

1. Introduction

This document presents a field evaluation protocol for Energy Management and Information Systems (EMIS). It was developed to provide a standardized approach to assessing the energy and non-energy benefits of EMIS. The primary target audience for this work comprises evaluators and researchers on:

- Federal or state-sponsored emerging technology programs
- Utility industry emerging technology programs
- Large building portfolio pilot studies

Market actors, including researchers, utility program administrators, energy standards developers, and building owners have a strong desire to better understand the costs and benefits of EMIS as they push for deeper, more comprehensive approaches to energy efficiency. However, they have faced challenges with: (1) finding robust data in a form that matches their needs and was gathered in a consistent manner, and (2) conducting (or engaging third parties to conduct) studies in a clear and consistent manner. This protocol provides a more consistent approach to evaluate EMIS performance, thereby addressing a critical market barrier that has limited EMIS adoption to date. With better data, these market actors can help drive greater market supply, demand, and incentives for adoption of EMIS solutions.

As shown in Figure 1, EMIS are combined hardware and software products that comprise a broad range of analytics functionality and services to manage commercial building energy use, covering three main types of functionality:

- **Energy information systems (EIS):** EIS analytics focus on meter-level monitoring, analysis, and charting, and may incorporate automated opportunity analysis.
- **Fault detection and diagnostics (FDD):** FDD analytics automate the process of detecting faults and suboptimal performance of building systems and help to diagnose potential causes. FDD focuses on system-level monitoring, analysis, and charting.
- **Automated system optimization (ASO):** ASO analytics continuously analyze and modify building automation system (BAS) control settings to optimize heating, ventilation and air conditioning (HVAC) system energy use while maintaining occupant comfort. Some EMIS technologies have the capability to implement demand flexibility control strategies which can adjust a building's load profile across different timescales for grid benefits.

EMIS supports the identification and implementation of operational improvements in commercial buildings. A recent major study showed median whole building savings of 3 percent for EIS and 9 percent for FDD analytics.[1] Despite their potential and a fast-growing range of options, EMIS remain under-adopted technologies throughout the commercial building stock. There is a growing body of EMIS

[1] Kramer, H., G. Lin., C. Curtin, E. Crowe, and J. Granderson. 2020. *Proving the Business Case for Building Analytics.* Lawrence Berkeley National Laboratory.

field validation projects[2,3,4]; however, EMIS are "human-in-the-loop" process tools that present unique validation challenges (e.g., approaches to system-level measurement and verification [M&V], quantification of non-energy benefits, and the linkage between information analysis and savings).

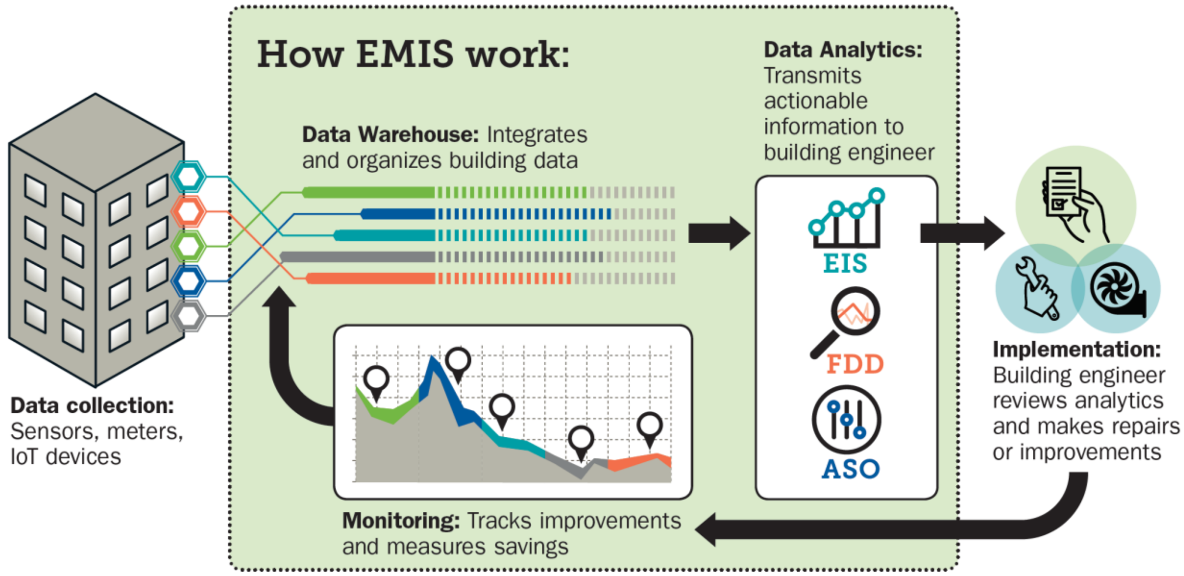


Figure 1. Energy Management and Information System (EMIS)

Previously there has not been a standardized state-of-the-art protocol for EMIS assessment. As a result, market actors often recognize the benefits of EMIS but struggle to find the data necessary to support the promotion, adoption, and further advancement of these technologies.

To address these EMIS validation challenges, we've worked with industry stakeholders to develop a standardized common protocol that has minimum recommended elements and optional elements. Development of the protocol drew upon many past EMIS evaluation projects led by Berkeley Lab, a literature review on a wide range of EMIS assessments (Appendix A lists the EMIS field study publications that were reviewed), and interviews with key stakeholders.

This protocol includes a template to describe EMIS technology features and capabilities, provides an easy-to-follow EMIS field evaluation plan, and identifies minimum and optional evaluation parameters and approaches for determining costs and benefits from EMIS. It is intended to set the bar for developing a minimum set of standardized metrics, supplemented with a broader set of optional

[2] Fernandes, S., J. Granderson, R. Singla, and S. Touzani. 2018. "Corporate Delivery of a Global Smart Buildings Program." *Energy Engineering* 115(1): 7–25.

[3] Abdul-Aziz, H., B. Lasternas, L. Feuster, and V. Loftness. 2017. *Building Performance Optimization while Empowering Occupants toward Environmentally Sustainable Behavior through Continuous Monitoring and Diagnostics.* U.S. Department of Defense Environmental Security Technology Certification Program. EW-201406.

[4] Lane, K., and L. Epperson. 2014. *Enterprise Plug-and-Play Diagnostics and Optimization for Smart Buildings.* California Energy Commission. CEC-500-2015-084.

metrics, rather than defining a comprehensive set of best practices for EMIS validation. For example, documenting EMIS cybersecurity compliance capabilities is a strongly recommended best practice but is not a required metric under this protocol. A project sponsor may also include any number of custom assessment metrics tailored to their specific needs (e.g., reduction in central plant average kilowatt [kW]/ton), in addition to the minimum required criteria defined in this protocol.

The remaining sections of this document are:

- **Section 2: Overview of EMIS field evaluation,** which contains a brief summary of the key steps in the EMIS evaluation process.
- **Section 3: EMIS field evaluation plan,** which provides detailed guidance for the key areas covered in an evaluation plan.
- **Section 4: Field evaluation parameters and approaches,** which describes all the required/optional performance parameters, along with standardized methods for developing/calculating the metrics.
- **Appendices**
    - Appendix A: EMIS Evaluation Resources
    - Appendix B: Site Selection Criteria
    - Appendix C: Sample Evaluation Report Outline and Standard Metrics Reporting Table
    - Appendix D: Common Capabilities of EMIS
    - Appendix E: Common O&M Tasks
    - Appendix F: Common Efficiency Measures
    - Appendix G: Glossary

2. Overview of EMIS Field Evaluation

The goal of conducting a field evaluation of EMIS is to assess the performance of a specific EMIS technology in a real building. Evaluating an EMIS can take considerable time and effort, so it is important to take a methodical approach to maximize the value of the eventual results. Table 1 illustrates the key steps in the EMIS evaluation process, which are designed to ensure that roles are clearly understood, data and risks are managed effectively, and that final results are accurate and meet the project sponsor's ultimate objectives.

Table 1. Key steps in the EMIS evaluation process

Step	Description	Resources
1: Select the EMIS test site.	An information-gathering screening form is developed based on technology requirements and evaluation performance objectives. The form lists the required and preferred site characteristics, such as building size, type and accessibility of BAS, HVAC system and configurations, control baseline, and metering conditions. The key screening considerations include the satisfaction of the required site and system characteristics, the availability of baseline data, the changes in occupancy, and if any major energy efficiency project happened in the baseline period or will happen in the post-installation period.	Appendix B provides an example of an information-gathering form used to select multiple test buildings for the evaluation of an EMIS with ASO functionality.
2: Develop an evaluation plan.	The EMIS field evaluation plan defines how the performance of the EMIS will be evaluated and specifies the evaluation activities before and after EMIS installation. It presents the technology and site information and also defines the performance objectives, metrics, analysis approaches, and schedule.	The key elements of the evaluation plan are discussed in Section 3. The performance parameters, metrics, and approaches are discussed in Section 4.
3: Collect baseline data and information.	Baseline data and information are collected at the beginning of the evaluation and the defined baseline period. Depending on the selected performance objectives, the baseline data may include the energy use, weather data, utility tariffs, space conditions, existing operation and maintenance process, and more.	Field evaluation baseline data requirements are covered in Section 4.
4: Track the technology installation / commissioning.	To evaluate the effort needed for EMIS installation and commissioning, information is gathered to document the items like the activities implemented during the process, the responsibilities of different stakeholders for each activity, the lead time of this stage, process challenges, and best practices.	The installation/commissioning plan will be covered in the Evaluation Plan (Section 3), and the assessment approach is covered in Section 4.5.1.
5: Collect and analyze post-installation data and information.	For each EMIS performance parameter being evaluated, data will be gathered after the EMIS has been operational for the required amount of time. Performance data may be a combination of quantitative and qualitative data. In the case of quantitative data, it is recommended to review the data shortly after EMIS installation to ensure that data will be of sufficient quality.	Field evaluation post-installation data requirements are covered in Section 4.

6: Produce an evaluation report.	An evaluation report is the final deliverable in the field evaluation.	Appendix C provides an example outline structure for a field evaluation report and a standard evaluation reporting template.

3. EMIS Field Evaluation Plan

Once an EMIS has been chosen for evaluation and a test site has been selected, the next step in the EMIS assessment process is to develop an EMIS field evaluation plan. A sample evaluation plan is provided in many general M&V guidelines, such as the U.S. Department of Energy's (DOE) Federal Energy Management Program (FEMP) Measurement and Verification guidelines[5] and the Energy Valuation Organization's (EVO) IPMVP-Compliant LEED M&V plan.[6] The project sponsors may also have an evaluation plan template they would like you to use. Therefore, this section focuses on the discussion of key areas that should be emphasized in the EMIS field evaluation plan, including:

- Description of the technology and field evaluation sites.
- Evaluation objectives and approaches.
- Evaluation activities.

Each of these areas is described in more detail below.

3.1. Description of the technology and field evaluation sites

This section of the evaluation plan documents the technology and field evaluation site descriptions, which are critical to interpreting the EMIS assessment results and providing context. For example, certain EMIS may excel when applied to some building/system types; hence, documenting those aspects in the Field Evaluation Plan (and reproducing them when documenting assessment results) helps any reader understand that context. Table 2 summarizes documentation requirements for the EMIS technology being evaluated, and Table 3 summarizes the documentation requirements for field evaluation sites.

[5] U.S. DOE Federal Energy Management Program (FEMP). 2015. *M&V Guidelines: Measurement and Verification for Performance-Based Contracts Version 4.0.*

[6] Energy Valuation Organization (EVO). 2008. *Sample IPMVP-Compliant LEED Measurement and Verification Plan*.

Table 2. Documentation requirements for the EMIS technology being evaluated

Item	Documentation Requirements
EMIS analytics	Select: EIS, FDD, or ASO (can indicate multiple if applicable)
EMIS name	Software name
EMIS vendor	Software vendor name
Data points integrated into EMIS	Describe: BAS data (can specify if limited to certain systems or system types), meter data (specify whole building and/or submeter data), weather data, and other pertinent data.
EMIS technology capabilities	Describe: For example, energy consumption visualization, M&V, indication of faults showing equipment operating out of range or outside the parameters defined by fault rules, key performance indicator tracking, or automated control setpoints optimization. For ASO functionality, the optimized control setpoints (e.g., supply air temperature setpoint, static pressure setpoint) should be stated. Please see Appendix D for the common capabilities of EIS, FDD, and ASO analytics.
IT cybersecurity (optional)[7]	Describe: Security certifications, compliance with industry-accepted standards, etc., if applicable.

[7] This is not suggesting that IT cybersecurity considerations should be optional when installing EMIS, only that documenting them is not a requirement under this evaluation protocol.

Table 3. Documentation requirements for EMIS field evaluation sites

Item	Documentation Requirements
Building type	For example, office, hospital, or K-12 school. (Follow the Commercial [CBECS][8] classification where possible.)
Building area	Floor space, in square feet
Building location	Climate zone, city, and state
Occupancy schedule	For example, Monday–Friday, 8:00 am–5:00 pm
HVAC system configuration	If the FDD or ASO is being evaluated, describe the configuration and major components of the HVAC system/subsystem the FDD or ASO covers.
Building automation system	Describe the system's model and make. If the ASO is evaluated, the existing control sequence of the optimized control setpoints should be described, e.g., "The chilled water setpoint is reset between 42°F and 48°F based on the maximum chilled water valve position from each air handling unit."
Will the building have any major energy improvement projects or occupancy changes in the next one to two years?	Yes, No, or unknown
Has the building had any major energy improvement projects or occupancy changes in the past one year?	Yes, No, or unknown
Has the building been retrocommissioned within the past five years? (optional)	Yes, No, or unknown
What is the energy use intensity (EUI)? (optional)	Energy use intensity (in thousand Btu per square foot per year [kBtu/ft^2/yr])

[8] Commercial Building Energy Consumption Survey (CBECS). Building Type Definitions. https://www.eia.gov/consumption/commercial/building-type-definitions.php.

3.2. Evaluation objectives and approaches

The EMIS field evaluation plan should document the objectives of the evaluation and reference the key stakeholders targeted by the EMIS implementation (those people driving the objectives and/or expected to be affected by the EMIS). Example objectives may include:

- Energy savings, perhaps in line with organizational sustainability targets or a strategic plan.
- Load reduction during peak periods, when electricity costs are highest.
- Improvements to occupant comfort satisfaction (e.g., reducing hot/cold calls from occupants).
- Improvements in operations and maintenance (O&M) practices.

Defining evaluation objectives helps when selecting the key metrics that will be included in the evaluation design. Analysis approaches for the selected metrics also need to be presented in the evaluation plan. The following required or optional metrics and their analysis approaches are discussed in detail in Section 4.

- Annual energy savings (Required).
- Annual energy cost savings (Required).
- Monthly peak demand reduction.
- Demand decrease intensity, demand increase intensity.
- Occupant comfort satisfaction.
- Operations and maintenance.
- EMIS cost (Required).
- Simple payback (Required).
- Net present value (NPV).
- Savings-to-investment ratio (SIR).
- Efforts of the installation and commissioning process.
- Capability to enable energy efficiency (Required).
- Accuracy of issues/opportunities identified by the FDD.

3.3. Evaluation activities

A comprehensive EMIS field evaluation requires careful planning and an extended period of data collection after installation, meaning the whole process can take two to three years. In contrast to the evaluation of traditional “widget” technologies, EMIS evaluation may include both quantitative objectives (e.g., energy savings, cost-effectiveness) and qualitative objectives (e.g., ease of installation, occupant comfort satisfaction). Multiple types of data and information may be required for measurement and verification, such as the system operational data to verify control optimization, hot and cold trouble calls to track comfort satisfaction, and feedback from the building operator to understand the improvement of O&M practices. Therefore, to ensure success, the evaluation plan should state the M&V activities carefully in the pre-installation, technology installation and commissioning, and post-installation period. This information enables key stakeholders to review and provide input on the planned activities upfront. Potential M&V activities are described briefly in Table 4.

Table 4. M&V activities in the EMIS field evaluation

Evaluation stages	**M&V activities**
Pre-installation	● Collect the building and technology information as described in tables 2 and 3. ● Install submeters to isolate the energy consumption at the system or equipment level if needed. ● Work with the site operator and technology vendor to establish the mechanism to collect data and information, i.e., download/transmission of meter data and/or BAS data, hot/cold trouble call records, and interval labor hours to support the technology installation and use. ● Collect the baseline data and information, and confirm the data quality.
Technology installation and commissioning	● Conduct an interview at the end of the installation and commissioning process to understand the efforts, challenges, and best practices. ● Collect technology costs and internal labor costs spent at this stage.
Post-installation	● Collect the post-installation data and information. ● Review the data shortly after the reporting period starts to ensure that data will be of sufficient quality. ● Check data regularly to ensure continued data collection and quality. ● Hold regular check-in calls with site operators to gather feedback on technology use. ● Perform analysis and conduct additional tests, if needed. ● Conduct an interview at the end of the evaluation to obtain overall feedback on the technology.

4. Field Evaluation Parameters and Approaches

At the core of the EMIS validation protocol is a set of evaluation parameters that will allow for a consistent comparison between EMIS tools (see Table 5), along with associated methods for determining those parameters. The assessment approaches taken may be based on quantitative data, surveys, or a combination of both. These evaluation parameters were chosen based on literature review and stakeholder interviews to determine the highest value core metrics, along with those that may apply in some, but not all, circumstances. At a minimum, energy savings, energy cost savings, EMIS cost, simple payback, and capability to enable energy efficiency are required for a basic EMIS assessment. Additional optional parameters fall under the following four categories:

- **Energy and utility cost:** In addition to annual energy savings and cost savings, stakeholders may want to assess peak demand reductions, particularly in regions where utilities apply high demand charges. Where utilities offer demand response (DR) programs, stakeholders may also want to assess the ability of EMIS to support deployment of demand flexibility strategies.
- **Non-energy benefits:** Non-energy benefits can provide significant value to building owners. An occupant comfort metric allows for quantification of improvements in indoor environmental quality, and an O&M metric can verify EMIS impact on internal operational practices.
- **Cost-effectiveness:** While simple payback is relatively easy to calculate and understand, some organizations employ more sophisticated methods to calculate long term return on investment. Net present value (NPV) and savings-to-investment ratio (SIR) are two common examples included as optional metrics under this protocol.
- **Operational capabilities:** Capturing the overall impact of an EMIS is critical to most stakeholders, but for many it is also important to validate specific performance claims. It is essential to understand how effective an EMIS is at enabling energy efficient operational practices, and how the tools contribute to the energy savings. It also is necessary to provide instructions for integrating the tools into the energy management process with a "standard operating procedure." The protocol offers another two optional metrics, to address how easy an EMIS is to install and commission, and how accurately an EMIS can identify operational faults and make appropriate recommendations.

Among the optional parameters listed in Table 5, 'Occupant comfort satisfaction' is highly recommended for the evaluation of ASO, as optimizing existing controls should not adversely affect comfort. Also 'Accuracy of issues/opportunities identified by the FDD' applies only for the evaluation of FDD. As noted earlier, this EMIS validation protocol is not intended to address every possible evaluation parameter that could be applied to any situation. The key objective is to define a clear set of core parameters that will align with most stakeholders' objectives.

Table 5. EMIS field evaluation parameters summary

Evaluation Parameter	Required or Optional	Approach
Energy and utility cost (Section 4.1)		
Annual energy savings (kBtu per ft^2, percent reduction)	Required	Data analysis
Annual energy cost savings ($)	Required	Data analysis
Annual greenhouse gas emission reduction (pounds of carbon dioxide equivalent, $lbCO_2e$)	Optional	Data analysis
Monthly peak demand reduction (kW)	Optional	Data analysis
Demand flexibility (W/ft^2, kW, percent)	Optional	Data analysis
Non-energy benefits (Section 4.2)		
Occupant comfort satisfaction	Optional (recommended for ASO)	Data analysis and/or survey
Operations and maintenance	Optional	Data analysis and/or survey
EMIS cost (Section 4.3)		
EMIS cost ($, $ per ft^2)	Required	Survey
Cost-effectiveness (Section 4.4)		
Simple payback (years)	Required	Data analysis
Net present value ($)	Optional	Data analysis
Savings-to-investment ratio	Optional	Data analysis
Operational capabilities (Section 4.5)		
Effort of the installation and commissioning process	Optional	Survey
Capability to enable energy efficiency	Required	Survey
Accuracy of issues/opportunities identified by the FDD	Optional (applicable to FDD only)	Data analysis

4.1. Energy and utility cost metrics

4.1.1. Annual energy savings (Required)

Defining EMIS energy savings is one of the most challenging aspects of EMIS validation, and it faces three major challenges:

- EMIS is not a widget technology. The use of EMIS leads to multiple energy efficiency measures. The energy savings should capture the impacts of all the measures.
- The building energy consumption is affected by various factors. The savings estimation needs to consider the changes in these variables, such as weather conditions and building occupancy.
- From a practical standpoint, an EMIS validation project may have time and/or budget constraints that affect the level of M&V rigor that can be applied to an EMIS validation project.

Given these challenges and constraints, there is some allowable flexibility in how to determine annual energy savings for an EMIS validation project.

EMIS annual energy savings constitute the energy savings arising from the use of the EMIS. This will typically result from O&M improvements and/or behavior changes. These improvements are required to be documented in the evaluation (Section 4.5.2). Annual energy savings[9] are required, and are expressed in three ways:

- Annual energy savings: kBtu (Also report kilowatt-hour [kWh], therm, steam, hot/chilled water, or other savings separately if multiple energy sources are affected by the EMIS installation.)
- Percent reduction of annual energy consumption
- Annual energy savings per conditioned square foot (kBtu/ft^2)

Below are different periods of an EMIS field validation study. Under this protocol, annual energy savings are calculated using the energy data from the baseline and reporting periods:

- Baseline period: A stable[10] state of building operation period that existed prior to EMIS installation
- EMIS installation and commissioning period
- Reporting period: A data collection period for determining annual energy savings, which typically includes:
    - Identification of initial set of operational deficiencies.[11]
    - Root cause analysis for some or all of the identified deficiencies.
    - Development of a list of recommended improvement measures.

[9] Energy savings calculations are based on gross energy consumption; any on-site generation should be ignored, e.g., if expressing percent energy savings, it should be based on gross consumption, not the net consumption after on-site generation is taken into account.

[10] “Stable” implies a period with no major changes in the building, such as major retrofits, changes in occupancy, or schedule. Energy consumption stability may be assessed using baseline model fitness metrics.

[11] Resolution of identified measures may not apply to ASO tools, which are intended to continuously optimize system settings.

- Assessment of cost and technical feasibility of recommended measures (which may not be necessary for simple measures being resolved in-house).
- Installation of some or all of the improvements.
- Continuous operation with the improvements.

The International Performance Measurement and Verification Protocol (IPMVP)[12] defines four generic M&V approaches for determining energy savings: Option A - Retrofit Isolation with Key Parameter Measurement, Option B - Retrofit Isolation with All Parameter Measurement, Option C - Whole Building Utility Data Analysis, and Option D - Calibrated Computer Simulation. Under this protocol, the recommended savings estimation method for determining annual energy savings is to follow Option C or Option B, which determines savings impacts based on actual metered data. The savings analysis based on the metered data provides an accurate means of verifying the impact of the multiple energy efficiency measures enabled by the EMIS. The engineering calculation in IPMVP Option A is usually used for estimating savings of an individual efficiency measure, and therefore is only acceptable as a backup if options B or C are not possible (e.g., due to insurmountable issues with obtaining meter data or project delays resulting in lack of time to gather reporting period meter data). IPMVP Option D uses simulation software (e.g., EnergyPlus, OpenStudio) to model energy performance of a whole building. Models must be calibrated with actual hourly or monthly billing data from the facility.[13] After the model has been calibrated, savings are determined by comparing a simulation of the baseline with either a simulation of the performance period or actual utility data. Option D is acceptable as a backup where a baseline does not exist (e.g., new construction or major building modification in the baseline period).

In addition to the IPMVP, several other guidelines (ASHRAE Guideline 14,[14] BPA Verification by Energy Modeling Protocol,[15] BPA Regression for M&V reference guide[16]) provide additional detailed guidance on the application of meter-based Option B and Option C approaches; for example, regression energy model types, development of the energy model, and software tools to assist with energy modeling. Critical success factors include the following:

- **Measurement boundary identification.** The measurement boundary to encompass the building or system within which the savings will be verified should be defined first. The boundary can be a whole building (Option C), which captures all the interactive effects of the efficiency improvements across a whole building. The boundary can also be a subsystem (Option B) that captures savings at an equipment/subsystem level that may not be discernable at the whole building meter. Option B is preferred when the implemented efficiency improvements are all related to a single building subsystem (e.g., HVAC system, chilled water system, chiller plant) and the system-level submeter historical data are available.

---

[12] Efficiency Valuation Organization. 2012. *International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings Volume I.* EVO-10000-1.

[13] U.S. Department of Energy Federal Energy Management Program. 2015. *M&V Guidelines: Measurement and Verification for Performance-Based Contracts Version 4.0.*

[14] ASHRAE. ASHRAE Guideline 14-2014: Measurement of Energy, Demand and Water Savings. 2014.

[15] Bonneville Power Administration. 2012. *Verification by Energy Modeling Protocol.*

[16] Bonneville Power Administration. 2012. *Regression for M&V Reference Guide.*

- **Baseline period and reporting period considerations.** Select the baseline and reporting periods to reflect building operations prior to and after EMIS installation, respectively. Since many of the energy efficiency measures enabled by EMIS are weather sensitive, baseline and reporting period data should both cover the full range of the building's typical operating conditions. When only monthly energy data are available, the baseline period should include at least 12 months of energy bill data. When daily or more frequent interval energy data are available, a shorter time period may be used if it is demonstrated to cover peak cooling season, peak heating season, and a season in between (e.g., summer, winter, and either spring or fall).[17] When evaluating an ASO tool, if there are not enough baseline data available, an alternate on/off ASO strategy (e.g., one week ASO on, one week ASO off; one day ASO on, one day ASO off) can be used to cover all the operating conditions in the shorter time period. All ASO-off periods are used as the baseline, and all ASO-on periods are used as the reporting period. Before creating the regression energy model, the collected energy data in the baseline period need to be examined to remove the true abnormal outliers. Anomalies in these data can significantly affect the energy savings outcome. If the reporting period is less than a year, the savings in the reporting period need to be extrapolated to annual savings, and the extrapolation approach must be documented.
- **Regression energy model selection.** Linear, change-point linear, and polynomial regression models are often used to create a baseline model for IPMVP Option C applications. The primary independent variables used for the model include weather conditions (usually outside air temperature), building operation schedule, and building occupancy. For the regression energy model of a chiller plant or chilled water system, the cooling load is the key independent variable. If there is no Btu meter installed for measuring the cooling load, the cooling load can be estimated using outside air temperature, outside air relative humidity (or outside air wet-bulb temperature), and day of the week. The day of the week is often best included as a categorical value (e.g., Sunday, Monday, Tuesday) and not as a numerical value.
- **Baseline model fit.** The quality of a specific baseline model can be assessed through application of model fitness criteria. Three statistical goodness of fit metrics are recommended to assess the accuracy of the baseline models: (1) the coefficient of determination (R^2), (2) the normalized mean bias error (NMBE), and (3) the coefficient of variation of the root mean squared error (CV(RMSE)).
- **Meter data resolution.** As a general rule of thumb, IPMVP Option C using monthly data requires expected savings > 10 percent of the whole building energy savings, and > 5 percent if using hourly data.

The M&V approaches defined in this protocol assume that the changes in metered energy consumption fully capture the impacts of improvements arising from the use of the EMIS.

[17] Using a full year of baseline data is an industry best practice for M&V. When using less than a year it is possible to assess the "coverage factor" (per ASHRAE Guideline 14) as a way to determine if your data are spanning a reasonable range of operating conditions.

4.1.2. Annual energy cost savings (Required)

Annual energy cost savings can be affected by many factors, including time-of-use utility cost schedules, monthly peak demand costs, presence of on-site generation, and the balance of consumption between electric, natural gas, and other resources. A full accounting of all these factors is not necessary under these protocols, though the project sponsor may want to develop cost metrics that go into more detail than this protocol's requirements.

Annual energy cost savings should be expressed in U.S. dollars and include the applicable year (by default this will be the year of the reporting period end date). Annual energy savings should be multiplied by the average cost per unit energy for each energy source included in the annual energy savings calculation. The average cost can be based on:

- Total site energy billing[18] for the baseline period divided by the total consumption during the baseline period (e.g., kWh, therm).
- Average unit cost of energy based on data sources such as the U.S. Energy Information Administration.

The approach taken to determine average cost per unit energy shall be documented (including specifying whether national or regional average costs are used, in the case of citing published resources).

4.1.3. Annual greenhouse gas emission reduction (Optional)

Under this protocol a project's annual greenhouse gas (GHG) reductions are expressed in pounds of carbon dioxide equivalent (lbCO_2e) non-baseload emissions. Emission reductions are calculated separately for electricity and natural gas savings, as described below.

Emission reductions from electricity savings

CO_2e reduction associated with electricity savings shall be calculated using conversion factors reported by eGRID[19]. The applicable emission rate may be obtained through the eGRID Data Explorer or by downloading the full eGRID dataset, using the following criteria:

- **Rate:** Non-baseload output emission rate (lb/MWh)
- **Metric:** CO_2 equivalent
- **Geographical resolution:** State or eGRID Subregion
- **Year:** Select most recent

[18] Total billing may include energy consumption costs and monthly peak demand charges. For the purpose of establishing an average cost per unit, the total costs may be used without disaggregating the different billing elements.

[19] https://www.epa.gov/egrid

Using the annual electricity savings calculated under section 4.1.1, convert to MWh and multiply by the appropriate emission rate to determine a given project's total lbsCO_2e reduction attributable to electricity savings.

Emission reductions from natural gas savings

In contrast to electricity savings, the emissions from natural gas do not vary by region. The CO_2 emission factor applicable to natural gas savings is 0.0053 metric tons CO_2/therm[20] (the result may be multiplied by 2204.62 to convert metric tons to pounds).

4.1.4. Monthly peak demand reduction (Optional)

There are two types of monthly peak demand: monthly non-coincident peak demand and monthly coincident peak demand. *Monthly non-coincident peak demand* is the highest kilowatt demand peak in any 15-minute interval in the billing month that is used for the calculation of demand charge in utility bills. *Monthly coincident peak demand* is the maximum demand during a utility's defined peak period (e.g., the utility's peak time-of-use period for a given billing period). For building owners, monthly non-coincident peak demand results in high utility bill charges. For utilities, monthly coincident peak demand leads to high costs of the power system's equipment. When evaluating the EMIS's impact on the monthly peak demand, it should clearly identify which monthly peak demand it means. The methods to evaluate EMIS impact on the monthly non-coincident peak demand and monthly coincident peak demand are presented below.

Monthly non-coincident peak demand reduction

ASHRAE Guideline 14 (2014)[21] describes the method to calculate monthly non-coincident peak demand reduction. It is expressed as the difference between the predicted non-coincident peak demand (kW) and the actual non-coincident peak demand (kW) during the EMIS evaluation reporting period, as shown in Equation 1. The predicted non-coincident peak demand is calculated using a baseline model that is developed based on the monthly non-coincident peak demand during the baseline time period.

$$\Delta kW_{non-coincident\ peak} = kW_{baseline} - kW_{reporting} \quad (1)$$

Where, $kW_{baseline}$ = the predicted non-coincident peak demand of the building in the reporting period
$kW_{reporting}$ = the actual non-coincident peak demand of the building in the reporting period

Monthly coincident peak demand reduction

Bonneville Power Administration's (BPA) *Estimating Peak Demand Impacts Application Guide*[22] provides guidance on the determination of monthly coincident peak demand reduction, including methods and examples. The guide defines the monthly coincident peak demand reduction as the average demand

---

[20] https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

[21] ASHRAE. ASHRAE Guideline 14-2014: Measurement of Energy, Demand and Water Savings. 2014.

[22] Bonneville Power Administration (BPA). 2019. *Estimating Peak Demand Impacts Application Guide.*

reduction during peak periods, as shown in Equation 2 (Note: This is different from quantifying the demand flexibility capability of an EMIS, which is covered in Section 4.1.5). It is expressed as the difference between the predicted coincident peak demand (kW) and the actual coincident peak demand (kW) during the EMIS evaluation reporting period. The aggregation of intervals should include the entirety of the peak demand period. Similar to the energy savings analysis, the predicted peak demand is calculated using a baseline model that is developed based on the peak demand during the baseline time period. This baseline peak demand model is different from the baseline model used in an energy savings analysis. It needs to be proven accurate to predict the demand during the defined peak period.

$$\Delta kW_{coincident\ peak} = \frac{\sum_{i=1}^{n} \left(kW_{baseline}^{i} - kW_{reporting}^{i}\right)}{n} \quad (2)$$

Where, $kW_{baseline}^{i}$ = the predicted demand of the building at interval *i* in the reporting period

$kW_{reporting}^{i}$ = the actual demand of the building at interval *i* in the reporting period

n = the number of data intervals in the peak demand period definition.

Utilities use a wide range of definitions for *peak period.* The methods used by utilities to quantify peak demand impacts are also different, e.g., some only count for the single highest hour during the defined peak period, and others calculate the average reduction across all hours in the peak period. Therefore, when reporting the results of an EMIS evaluation, the definition of peak period should be clearly documented, whether it is annual or seasonal, or a specific period of time, such as a summer weekday afternoon or winter peak billing hours.

4.1.5. Demand flexibility evaluation (Optional)

Electricity demand from buildings results from a variety of electrical loads that are operated to serve the needs of occupants. However, many of these loads are flexible to some degree; with proper communications and controls, loads can be managed to vary demand at specific times and at different levels, while still meeting occupant productivity and comfort requirements. On-site distributed energy resources (DERs) such as rooftop photovoltaics (PV), electric vehicle charging, and batteries can be co-optimized with building loads to expand demand flexibility options. Some EMIS technologies have the capability to support demand flexibility control strategies. Demand flexibility is the capability to adjust a building’s load profile across different timescales [23]. Load shed (also known as demand response) and load shift are the two main demand flexibility strategies enabled by EMIS technologies. Figure 2 shows the changes in building load profiles as a result of load shed and load shift strategies:

- **Load shed**: the ability to reduce electricity use for a short time period (e.g., one to four hours) and typically on short notice. Shedding is typically dispatched during electric system peak demand periods and during grid-related emergencies.

[23] Neukomm, M., Nubbe, V., Fares, R., 2019. Grid-Interactive Efficient Buildings Technical Report Series: Overview of Research Challenges and Gaps (No. NREL/TP-5500-75470; DOE/GO-102019-5227). National Renewable Energy Lab. (NREL), Golden, CO (United States). https://doi.org/10.2172/1577966

- **Load shift**: the ability to change the timing of electricity use for reasons such as minimizing demand during peak periods, taking advantage of the cheapest electricity prices, and/or reducing the need for renewable curtailment.

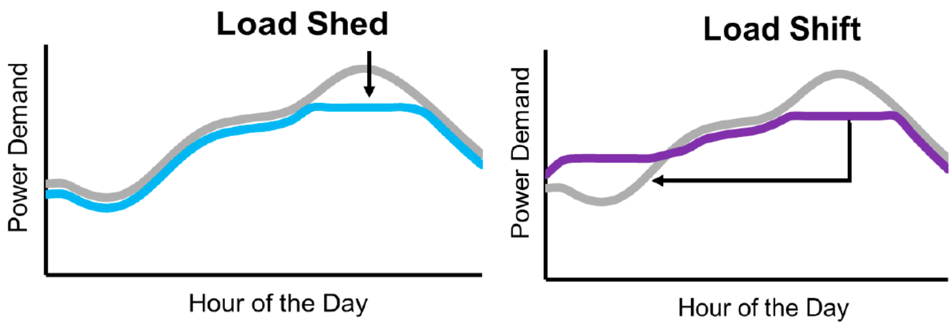


Figure 2. Building flexibility load curves[23]

This section describes several key metrics to quantify demand flexibility associated with a single load shed or load shift event implemented through the use of an EMIS technology[24].

Load shed (Shed) reduces electricity demand for a short period of time. In the traditional definition, demand response (DR) also refers to shedding loads when the customer receives a price or dispatch signal from their utilities or the grid during a specific time period on a specific day. Three metrics (D1, D2 and D3) are defined to measure the average demand decrease during a Shed event: "demand decrease (kW)", "demand decrease intensity (W/ft^2)" (a.k.a. "demand shed intensity [DSI]") and "demand decrease percentage (%)" as shown in Table 6. D2 is an intermediate step in calculating D1 and D3 and is useful in measuring the load shed results for performance based compensation. D1 is a useful metric because normalizing by building floor area allows comparison across buildings and benchmarking. D3 describes the load shed relative to the baseline total building load during the same period, which can also be used as a benchmarking metric. The calculation of these three metrics all require a baseline which represents a building's counterfactual load profile on an event day if no demand flexibility strategy was deployed.

The load data of actual use during a load shed event can be measured directly. The quantification of baseline has two steps: baseline load determination and baseline load adjustment. Different utilities' DR programs have different definitions of the load data of the baseline and the required adjustment. "N-day average baseline" is a typical baseline load calculation method, which averages the hourly power demand of the *N* selected baseline days of the same type as the event day, across the applicable hours of the day for the event. For example, Southern California Edison uses a 10-day average baseline and a "day-of" adjustment[25] (e.g., using the prior 10 weekdays if the event occurred on a weekday). When determining the load reduction, the evaluation should clearly document the baseline load formulation

[24] Lawrence Berkeley National Laboratory, 2022, Defining & Testing an Electricity Demand Flexibility Benchmarking Metrics Framework for Grid-interactive Efficient Commercial Buildings.

[25] Southern California Edison. 2018.10-Day Average Baseline and "Day-Of" Adjustment.

used, the adjustment made, the selected baseline load, and the load during the event. The Federal Energy Regulatory Commission's report provides guidance on methods for M&V of DR[26].The EMIS M&V report from the San Diego Gas & Electric emerging technologies program[27] describes an example of how the DR potential of an EMIS is evaluated in a field study.

Load shift consists of a two-part load change: demand increase ("load take" or Take) and demand decrease (Shed). Therefore, all of the above metrics defined for load shed also apply to the Shed part of load shift. In addition, an additional set of three metrics - I1, I2 and I3 - were defined for "load take" (in Table 6), which are similar to D1, D1 and D3 for Shed. They are also calculated using the same baseline load profile. In the above metrics definitions, demand decrease is defined as positive values so as to be consistent with the conventions in traditional DR programs, and therefore, demand increase are negative values.

In order to understand how a load shed or shift strategy impacts energy consumption, another metric E1 is defined, which measures the building's net energy consumption reduction from baseline energy consumption as a percentage in a 24-hour window around the shed or shift event. It assumes that typical load shed or shift events are completed within 24 hours but can be modified for different needs.

Table 6: Single-event Metrics for Demand Decrease and Increase

Metrics	Formula / Definition	Unit
D1: Demand Decrease Intensity (DDI, or "*Shed Intensity*")	= D2 / Floor Area	W/ft^2
D2: Demand Decrease	= Average demand decrease during a single "shed" period	kW
D3: Demand Decrease Percentage (DDP)	= D2 / Baseline average demand during "shed" period	%
I1: Demand Increase Intensity (DII)	= I2 / Floor area	W/ft^2
I2: Demand Increase	Average demand increase during a single "take" period	kW
I3: Demand Increase Percentage (DIP)	= I2 / Baseline average demand during "take" period	%

[26] Goldberg et.al. 2013. *Measurement and Verification for Demand Response.* https://www.ferc.gov/industries/electric/indus-act/demand-response/dr-potential/napdr-mv.pdf.

[27] San Diego Gas & Electric. 2015. *Model-based Predictive HVAC Control Enhancement Software.* (M&V report)

E1: Net Building Consumption Reduction Percentage (24 hours)	= Net daily kWh reduction from the baseline / Baseline daily kWh consumption x 100%	%

A set of "Single-event Metric Attributes (Attributes)" is recommended to be presented with the metric results, because electricity use is dynamic, varying by day of week, hour of day, season, and weather. For example, a Demand Decrease Intensity (D1) metric value of 0.5 W/ft^2 may be associated with the following Attributes values.

- *DF strategy*[28]: turning off 50% lights and implementing +3°F Global Temperature Adjustment
- *Event duration*[29]: 2 hours
- *Time of day*[30]: 12:00pm - 6:00pm
- *Day of week*[31]: Tuesday
- *Year*: Measured in 2021
- *Baseline method*[32]: 10-day average, with pre-adjustment
- *Weather condition*[33]: Peak outside air temperature = 82°F

4.2. Non-energy impacts metrics

4.2.1 Occupant comfort satisfaction (Optional)

Thermal comfort impact is especially important for the evaluation of ASO, as it should not adversely affect the comfort condition when optimizing the existing controls. The impact of comfort can be determined with the following three metrics.

4.2.1.1 Changes in space conditions (space temperature and humidity) relative to the ASHRAE thermal comfort zone before and after the EMIS deployment

The approach for this metric is to conduct the data analysis using a simplified model of the ASHRAE thermal comfort zone[34] (Figure 3) to determine if the space conditions in the selected zones change significantly after the implementation of an EMIS. In this model, regions of comfort for winter and summer are defined by boundaries on a plot of relative humidity versus air temperature, as measured in

[28] A building may support multiple control strategies to shed or shift load such as adjusting thermostat setpoint to reduce HVAC load, dimming lights, curtailing plug loads, or discharge thermal or electrical storage. Not all of the available strategies may be used in all Shed/Shift events as they can be prioritized based on the building's utility tariff, utility program rules, and the impact on building services. For example, a building may choose to deploy a single strategy for an economic program vs. several strategies in an emergency DR program event.

[29] Electrical load shed from some building loads are easier to sustain than the others. For example, it is easier to dim lights for a few hours than cycling off HVAC for hours because the space may get uncomfortable for the occupants.

[30] Building loads (e.g. lighting, plug load, HVAC, etc.) and their ability to shed or shift vary throughout the day and week as occupancy and operation mode change (e.g. HVAC set-back during unoccupied periods). Time-of-day can be a category rather than a value, e.g. 0:00-8:00, 8:00-12:00,12:00-18:00, 18:00-0:00.

[31] The same building's DF performance from the same DF strategy can change significantly over time due to operational changes, equipment conditions and other factors.

[32] DF metric value can vary significantly depending on the chosen baseline method.

[33] Some building loads such as HVAC are often dependent on weather conditions, and therefore, can influence load shed or shift from these loads.

[34] ANSI/ASHRAE Standard 55-2013. 2013. *Thermal Environmental Conditions for Human Occupancy.* American Society of Heating Refrigeration and Air Conditioning Engineers. ISSN 1041-2336.

the interior space. To analyze the impact of the technology on comfort conditions, the fraction of points outside of the comfort zone after the EMIS implementation is compared to that before the EMIS implementation. The space's air temperature is acquired from the BAS trend logs for the variable air volume (VAV) terminal units. If measurements of relative humidity are not available at the zone level, the relative humidity of the space's air is estimated in a two-step calculation based on the space's air temperature, the return air temperature, and the relative humidity of the air handling unit/rooftop unit (AHU/RTU) that serves the space. The detailed description of this two-step calculation can be found in LBNL (2017).[35]

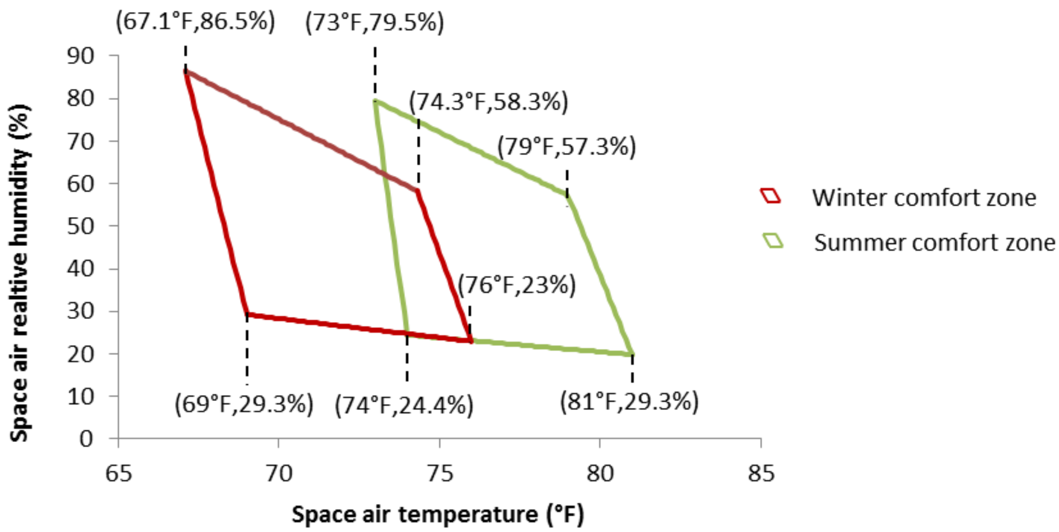


Figure 3. A simplified representation of the ASHRAE thermal comfort model, with comfort as a function of relative humidity and air temperature

4.2.1.2 Changes in hot/cold trouble calls before and after the EMIS deployment

The evaluation team can work with the site building operations staff to track hot/cold trouble calls reported from maintenance software or other resources. The number of trouble calls from the time periods when the EMIS is not installed is compared to those from the same time periods in the year after the EMIS is deployed.

4.2.1.3 Changes in subjective comfort survey results before and after the EMIS deployment

The impact of occupant comfort also can be evaluated with a subjective survey indicating the occupants' satisfaction with comfort. Using a point scale, the occupants can indicate if they are dissatisfied, neutral, or satisfied with the overall temperature, airflow movement, and air quality. The changes in the percent satisfied, neutral, and dissatisfied capture the comfort level changed as a result of the EMIS technology. To provide meaningful statistics results, the survey requires answers from a large number of the occupants. The selection of the surveyed occupants needs to consider factors such as occupant background, gender, and workspace location, to ensure their feedback is representative. Loftness et al.

[35] Granderson, Jessica et al. 2017. *Building IQ Technology Field Validation.* Lawrence Berkeley National Laboratory.

(2016)[36] provides an example of the survey questionnaire. Compared with the other two metrics listed in Sections 4.2.1.1 and 4.2.1.2, this metric requires more involvement with the occupants and more resources from the evaluation team. Given that this performance parameter involves subjective judgment, it can be expected that results will be open to interpretation, partly dependent on external/contextual conditions, and may present challenges when generalizing across many assessments. This should be borne in mind by those reviewing EMIS evaluation results.

4.2.1.4 Whether there is a violation of specialized space requirements after the ASO deployment
In addition to thermal comfort (i.e., hot/cold), the changes in control setpoints with the deployment of ASO may influence other areas of the space conditions. For example, the reduction of AHU static pressure setpoint decreases the outside air intake, which risks not meeting the ventilation requirement defined in ASHRAE Standard 62.1[37] (e.g., the minimum zone outside air flow rate for office space is 0.15 cubic feet per minute per square foot [cfm/ft^2]). It also decreases the space pressure, which has the potential to not meet the pressure control requirements in clean supply rooms of hospitals. The measurement from the existing sensors or temporary data loggers can be used to compare with the requirements to see if there is a violation.

4.2.2 Operations and maintenance (Optional)

Operations and maintenance (O&M) refers to the decisions and actions regarding the control and upkeep of property and equipment. The use of EMIS may improve O&M efficiency. Reporting and data export functionality can improve facility management and human resource efficiency. FDD analytics can identify issues before they grow into occupant complaints or equipment failure. For example, operators generally do not have time to perform preventative maintenance on all terminal units due to the large number; operations are typically assessed when there are comfort complaints. Using FDD analytics, 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. EMIS also can be used to inform retrofit strategies at the facilities, such as identifying retrofit options, sizing equipment, and verifying savings. Therefore, documenting the benefits of O&M in the evaluation can help provide a full picture of EMIS benefits and also assist in garnering facility staff support for future EMIS use.

The evaluation of O&M benefits is conducted through the interview of building operators and other related EMIS users. Items to be documented include:

- Whether the EMIS impacts the O&M process in a positive way, a negative way, or is neutral.
- The O&M tasks for which the EMIS has been used. The common O&M activities are summarized in Appendix E.
- The process of completing the O&M tasks without and with the EMIS.
- When possible, an estimate of O&M labor hours saved through the use of the EMIS.

[36] Loftness et al. 2016. *Building Performance Optimization While Empowering Occupants Toward Environmentally Sustainable Behavior Through Continuous Monitoring and Diagnostics.* ESTCP project EW-201406.

[37] ASHRAE. ASHRAE standard 62.1-2019. 2019. *Ventilation for Acceptance Indoor Air Quality.*

As with an occupant comfort survey, quantifying this performance parameter involves subjective judgment, and reviewers of evaluation results should exercise caution when interpreting and generalizing based on results.

4.3. EMIS cost metric

4.3.1. EMIS cost (Required)

Consistently documenting EMIS costs is essential for establishing cost-effectiveness metrics. Given the wide range of implementation methods (e.g., the extent of installation performed internally versus one performed by a third party) and varying building baseline conditions (e.g., availability of metering hardware), EMIS costs can vary considerably. Further, getting an EMIS fully operational can take time; for example, once a software interface is active, it may take many months to ensure that data are accurate, analytics are fully configured, and dashboards meet user requirements. Accordingly, the cost metric in this section defines a standardized approach to defining costs for comparative purposes.

EMIS cost can be expressed in three ways:

- U.S. dollars (Required)
- U.S. dollars per square foot (total conditioned square footage of the building[s] being monitored) (Required)
- U.S. dollars per point monitored (total number of points uploaded to the EMIS, irrespective of whether all points are actively used in analytics) (Optional). Defining the cost per point monitored is less common, but may be of interest if the EMIS software is priced on a per-point basis.

EMIS technology is most commonly delivered as a software-as-a-service (SaaS) offering. Table 7 shows the breakdown and details of the items covered in EMIS costs. As shown in Table 7, the EMIS costs can be broken into two parts: (item A) EMIS implementation costs and (item B) ongoing annual EMIS operating costs. EMIS implementation costs are the one-time costs for implementing EMIS at the field validation site. Ongoing annual EMIS operating costs are the recurring costs for using EMIS. This cost information can be obtained through a survey of building operators and review of applicable invoices.

EMIS implementation costs

As shown in Table 7, EMIS implementation costs include the base costs for EMIS technology (item A) and the in-house labor costs for EMIS implementation (item B). The base costs for EMIS technology (item A) cover hardware costs (item A.1) for hardware installation and upgrade (if applicable), as well as the software costs (item A.2) for software installation and configuration. In-house staff time is necessary to support EMIS installation and commissioning; therefore, in-house labor costs should be considered as part of the EMIS implementation costs.

Ongoing annual EMIS operating costs

Also shown in Table 7, ongoing annual EMIS operating costs consist of ongoing annual costs for EMIS technology (item C) and ongoing annual in-house labor costs for EMIS use (item D). Ongoing annual costs for EMIS technology (item C) are further broken into annual EMIS costs (item C.1) that are charged for EMIS licensing or hardware, and annual third-party consulting costs (item C.2) for support in analyzing and implementing EMIS findings (as applicable). In-house labor costs for EMIS use is considered to be part of the ongoing annual EMIS operating costs, as in-house staff time may need to be spent on using the EMIS to identify and follow up on operational issues.

Table 7. Key elements of EMIS costs

Cost Items			Description
EMIS Implementation Costs	A: Base costs for EMIS technology	A.1: Hardware costs	Costs for hardware installation and upgrade (e.g., adding meters and sensors during the project for EMIS monitoring purposes, installing gateways for communication, getting data servers for data storage)
		A.2: Software costs	Costs for the EMIS software installation and configuration to bring in all the data points, alteration of the existing BAS to expose legacy data points, and training to site staff, including EMIS vendor and service provider costs
	B: In-house labor costs for EMIS installation and commissioning		Approximate total labor costs spent by in-house staff to support installation and configuration of the EMIS
Ongoing Annual EM	C: Ongoing annual costs for EMIS technology	C.1: Annual EMIS costs	The recurring annual cost for a software license, software-as-a-service fees, or hardware (e.g. occupancy counters)
		C.2: Annual third-party consultant costs	The average annual cost paid to a third-party consultant for support in analyzing and implementing EMIS findings
	D: Ongoing annual in-house labor costs for EMIS use		Approximate labor costs spent by in-house staff reviewing EMIS reports, identifying opportunities for improvement, and implementing measures (may be based on average hours spent per month)

IS O p er at in g C o st s		

Considerations when gathering the cost data summarized in Table 7 include the following:

- Reported costs shall be gross costs, i.e., disregard whether a portion of costs is paid through utility incentives, grants, or other means.
- In situations where the EMIS is provided free of charge or on a reduced cost “trial” basis, the EMIS vendor should provide the full market pricing to establish costs under this validation protocol (in such cases, note that the pricing is theoretical, not actual).
- EMIS hardware costs should not include upgrades to building controls or existing building commissioning, even if they are performed concurrently with EMIS installation.
- The internal labor cost may be embedded in the existing staff workload (and thus may not require additional funding). A survey can be conducted to ask for the estimated internal labor hours. The labor cost estimate is determined using the reported hours and a fixed labor rate. Estimating the internal labor cost is helpful, since some building owners’ EMIS installation/operation is heavily supported by third-party service providers, whereas others rely more heavily on internal staff. Estimating EMIS internal labor costs mean that full EMIS cost impacts are not underreported in the latter case.

4.4. Cost-effectiveness metrics

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 the technology provides (i.e., the improvement opportunities that are identified). The only functionality of EMIS that achieves direct savings is ASO, since the optimization is performed directly by the ASO functionality. The technology cost-effectiveness is measured by various financial metrics. The next section discusses two types of financial metrics: (1) a simple payback period metric and (2) two life-cycle financial metrics: net present value (NPV) and savings to investment ratio (SIR).

4.4.1. Simple payback period (Required)

Simple payback period (SPP) is the most widely used financial metric for energy efficiency projects. It is the number of years required to recover the initial investment through project savings. It is established using Equation 3:

$$Simple\ payback\ period = \frac{EMIS\ Implementation\ Costs + ECM\ Costs}{Annual\ Energy\ Cost\ Savings - Annual\ EMIS\ Operating\ Costs} \quad (3)$$

Where *ECM Costs* are the costs incurred for implementing the energy conservation measures (ECMs) found by the EMIS (e.g., adjusting system schedules, fixing leaking valves).[38] EMIS implementation costs and annual EMIS operating costs are explained in Section 4.3.

As shown in Equation 2, SPP captures not only EMIS implementation costs, but also the costs for implementing ECMs discovered through the use of the EMIS. The time period over which those ECM costs are incurred may vary, but the principle is that ECM cost calculations should correspond with the ECMs for which annual energy savings have been calculated under this protocol. For example, if an ECM is implemented at the end of the savings measurement period, its savings impact will not be captured, hence its cost need not be captured.

The denominator in Equation 2 may be considered the net annual cost savings, based on subtracting annual EMIS operating costs (EMIS software subscription, third party support, internal labor) from the annual energy cost savings (described in Section 4.1.2).

4.4.2. Net present value and savings-to-investment ratio (Optional)

Net present value is the total net cash flow that a project generates over its lifetime, including first costs, with discounting applied to cash flows that occur in the future. It indicates what a project's lifetime cash flow is worth today. The formula of NPV can be found in the ENERGY STAR Building Manual.[39] Savings-to-investment ratios are numerical ratios whose sizes indicate the economic performance of an investment. The SIR is found by dividing savings by investment costs. A practical SIR formula for building related projects is recommended by the National Institute of Standards and Technology (NIST).[40]

4.5. Operational capability metrics

To fully assess the EMIS technology scale-up and broad-scale applicability, the effort of technology installation and commissioning, capability to enable energy efficiency, and accuracy of issues/opportunities identified by the EMIS all should be considered in the evaluation.

---

[38] This cost category is not applicable for ASO, as it directly makes the efficiency changes in its system. Costs for internal staff to implement ECMs does not need to be accounted for.

[39] U.S. Department of Energy. *ENERGY STAR Building Manual*. https://www.energystar.gov/sites/default/files/buildings/tools/EPA_BUM_CH3_InvestAnalysis.pdf.

[40] Adetola, Veronica et al. 2014. *Energy Performance Monitoring and Optimization System for DoD Campuses.* ESTCP Project EW-201142.

4.5.1. Effort of the installation and commissioning process (Optional)

The EMIS installation and commissioning process is a comprehensive process involving multiple stakeholders, such as site's facility team, IT security team, BAS contractor, and EMIS vendor. It may take weeks to months for the total calendar time to complete the process. The possible activities during the EMIS installation process include getting IT approval for security clearance, installing or upgrading hardware (e.g., meters, sensors, building automation systems, gateways) for data acquisition, collecting and integrating data into the EMIS, selecting and implementing FDD rules and thresholds, and customizing the EMIS user interface to support visualization and reporting needs.

The possible activities during the commissioning process include performing data quality and accuracy checks, adjusting the parameters to reduce false alarms (FDD only) and meet comfort requirements (ASO only), and ensuring the user interface and reports are configured as desired. Documenting this process would provide guidance and save effort for potential users replicating the implementation. The assessment of the installation and commissioning process can be accomplished based on interviews with site operation staff and activity tracking throughout the course of the evaluation.

The following items can be documented during the installation and commissioning process:

- **Document the activities during the process and the lead time for completing the installation and the lead time for commissioning.**
- **Specify what kinds of support are needed from the on-site engineers and other staff, and estimate the labor hours.** For example, schedule a site walk-through, provide control specs and sequence and other system/equipment information, set up a network connection and wire for communication, provide feedback on parameter settings and the interface configuration, troubleshoot connectivity, and monitor the space condition and equipment operation during the commissioning.
- **Summarize the best practices and lessons learned.** Get feedback from installer and on-site staff, record the issues raised and the resolutions, and if possible provide recommendations for future procurement specification and standardization.

4.5.2. Capability to enable energy efficiency (Required)

In this protocol, the capability to enable energy efficiency has different meanings for ASO and EIS/FDD analytics. For ASO, it means the targeted control setpoints can be successfully changed by the ASO. For EIS/FDD, it means the ability to generate actionable information that leads to the actual efficiency measures. EMIS with EIS and FDD analytics are enabling tools—installation of the tool does not create savings directly. Rather, savings are achieved by acting upon the information that the technology provides (i.e., the improvement opportunities that are identified). Evaluating the capabilities for identifying efficiency opportunities and supporting the implementation of the efficiency measures will help potential adopters understand how the tools contribute to the energy savings. It can also provide support for successful integration of an EMIS into a building's energy management process (e.g., EMIS evaluation may show the benefits of a weekly operations review meeting to identify efficiency opportunities using the EMIS reports).

To evaluate the capability to enable energy efficiency of ASO, the data trends of the targeted control setpoints and measurements should be compared in the baseline and optimizer (reporting) periods. An assessment can validate if the setpoints change and if the measurements follow the optimized setpoints via BAS data trend analysis. For example, Figure 4 shows the ASO successfully reduces the AHU static pressure setpoint (SP) by 0.5 pounds per square inch (psi) compared with the baseline. The static pressure SP and static pressure in the optimizer period are shown in blue lines, and the static pressure SP and static pressure in the baseline period are shown in red lines.

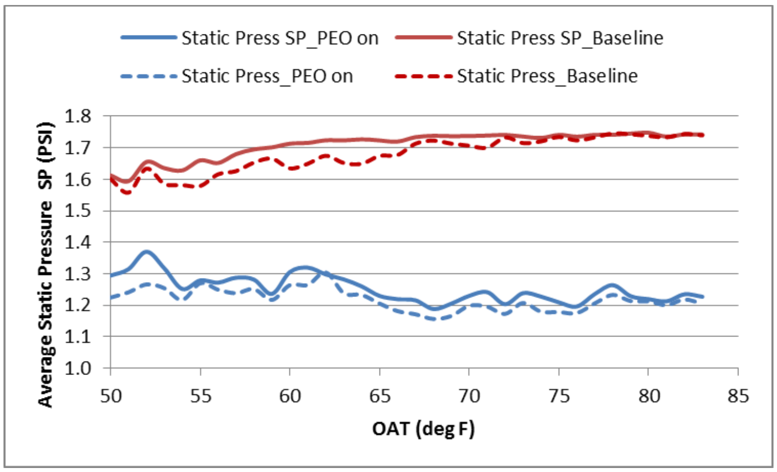


Figure 4. Example of comparison of control setpoints during the baseline and optimizer (post-installation) periods

To evaluate the capability to enable energy efficiency of EMIS with EIS and FDD analytics, the following items should be documented through building operator interviews and the results shown on the EMIS.

- **A record of the implemented efficiency measures based on EIS/FDD results and the analytics or visualization features that are used for identification.** An example summary is provided in Table 8. The common efficiency measures are summarized in Appendix F.
- **The workflow of identifying, prioritizing, and taking actions on the issues or opportunities identified by the EIS or FDD analytics.** Faults are prioritized using criteria like impact on energy, comfort, or existence of known issues. Determine which departments or business units are involved, and who is responsible for responding to the finding. Prioritize and assign a list of faults for inspection, inspect the faults, and implement the efficiency measures. Sometimes actions such as equipment scheduling can be addressed by site-level operational staff. In other cases, further investigation may be required, and control and mechanical subcontractors need to be involved. The documentation of workflow leads to a "standard operating procedure" which is easily repeated in the future application.

Table 8. Summary of the identified faults in an EMIS with FDD analytics and the implemented efficiency measures

System/Equipment	**Identified Faults**	**Implemented Efficiency Measures**
AHU 1-1 AHU 1-2	AHU on all the time	Enable calendar control
VAV 1-1, VAV 1-2, VAV 1-3, VAV 1-4	Zones are outside an acceptable comfort temperature range	Reset the automatic setpoint, tune VAV supply air flow
AHU 2-1	Incorrect economizer control	Reset the minimum outside air intake ratio
AHU 2-2	Valve cycling	Change control logic proportional–integral–derivative loop
Outdoor lighting	Outdoor lighting on a fixed schedule	Introduce daylight harvesting control

4.5.3. Confirm accuracy of issues/opportunities identified by the FDD (Optional)

Accuracy of the issues/opportunities identified is particularly important if the purpose of the evaluation is to know whether a given FDD's underlying algorithm is sound, or any better performing than another's or a previous version. One simple metric used for evaluating accuracy is true positive rate (Equation 4). *True positive* refers to the case in which the FDD analytics report the presence of the fault and field investigation confirms that fault.

The true positive rate, $TPR = \frac{\#\ of cases\ with\ true\ positive}{\#\ of\ faults\ identified\ by\ the\ FDD\ tool}$ (4)

More accuracy metrics are discussed in a research report.[41]

[41] Frank, Stephen et al. 2018. *Metrics and Methods to Assess Building Fault Detection and Diagnosis Tools.*

Appendix A: EMIS Evaluation Resources

EMIS Field Evaluation Plan

- U.S. DOE Federal Energy Management Program (FEMP). 2015. *M&V Guidelines: Measurement and Verification for Performance-Based Contracts Version 4.0.*
- Energy Valuation Organization (EVO). 2008. Sample IPMVP-Compliant LEED Measurement and Verification Plan.

Field Evaluation Guidelines

- Efficiency Valuation Organization. 2012. *International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings Volume I. 2012. EVO-10000-1.*
- ASHRAE. 2014. ASHRAE Guideline 14-2014: Measurement of Energy, Demand and Water Savings.

Field Performance Measurements Protocol

- ASHRAE. 2010. ASHRAE/CIBSE/USGBC Performance Measurement Protocols for Commercial Buildings. Atlanta: ASHRAE.
- ASHRAE. 2012. ASHRAE Performance Measurement Protocols for Commercial Buildings: Best Practices Guide. Atlanta: ASHRAE.

Field Evaluation Parameters and Approaches

Annual energy savings

- Bonneville Power Administration. 2012. *Verification by Energy Modeling Protocol.*
- Bonneville Power Administration. 2012. *Regression for M&V Reference Guide.*

Annual greenhouse gas emission savings

- ENERGY STAR. 2017. Portfolio Manager Technical Reference: Greenhouse Gas Emissions. Available online at https://portfoliomanager.energystar.gov/pdf/reference/Emissions.pdf?54a3-2b23.

Monthly average peak demand reduction

- ASHRAE. 2014. ASHRAE Guideline 14-2014: Measurement of Energy, Demand and Water Savings.
- Bonneville Power Administration (BPA). 2019. *Estimating Peak Demand Impacts Application Guide.*

Demand response load reduction

- Goldberg et.al. 2013. *Measurement and Verification for Demand Response.* https://www.ferc.gov/industries/electric/indus-act/demand-response/dr-potential/napdr-mv.pdf.
- San Diego Gas & Electric. 2015. *M&V report – Model-based Predictive HVAC control enhancement software.*
- Southern California EDISON. 2018. 10-Day Average Baseline and "Day-Of" Adjustment.

Occupant comfort satisfaction

- ANSI/ASHRAE Standard 55-2013. 2013. Thermal Environmental Conditions for Human Occupancy. American Society of Heating Refrigeration and Air Conditioning Engineers. ISSN 1041-2336.
- Granderson, Jessica et al. 2017. *BuildingIQ technology field validation.* Lawrence Berkeley National Laboratory.
- Loftness et al. 2016. *Building performance optimization while empowering occupants toward environmentally sustainable behavior through continuous monitoring and diagnostics.* ESTCP project EW-201406.
- ASHRAE standard 62.1-2019. Ventilation for Acceptance Indoor Air Quality. 2019. American Society of Heating, Refrigerating, and Air Conditioning Engineers.

Net present value (NPV) and savings-to-investment ratio (SIR)

- *ENERGY STAR Building Manual Chapter 3.* https://www.energystar.gov/sites/default/files/buildings/tools/EPA_BUM_CH3_InvestAnalysis.pdf.
- Adetola, Veronica et al. 2014. *Energy Performance Monitoring and Optimization System for DoD Campuses (final report).* ESTCP Project EW-201142.

Confirm accuracy of issues/opportunities identified by the FDD

- Frank, Stephen et al. 2018. *Metrics and Methods to Assess Building Fault Detection and Diagnosis Tools.*

EMIS Field Study Publications

- PG&E's Emerging Technologies Program. 2011. *Assessment of an Energy Information System for the Grocery Sector.* ET Project Number: ET10PGE1031.
- PG&E's Emerging Technologies Program. 2012. *Fault Detection and Diagnostic Software.* ET Project Number: ET11PGE3131.
- Howett, Dan et al. 2015. *Socially Driven HVAC Optimization Federal Building and US Courthouse Phoenix, Arizona.* Oak Ridge National Laboratory.
- Milesi Ferretti, Natascha, Michael A. Galler, and Steven T. Bushby. 2017. *Performance Monitoring of Chilled-Water Distribution Systems Using HVAC-Cx.* National Institute of Standards and Technology.

- Mercado, Andrea, and John Elliott. 2012. Energy Performance Platform: Revealing and Maintaining Efficiency With a Customized Energy Information System. *ACEEE Summer Study on Energy Efficiency in Buildings.*
- Gorbounov, Mikhail et al. 2016. *Field testing of diagnostics for state-of-the-art RTUs. Consortium for Building Energy Innovation.*
- Hail, J. C. et al. 2016. *Optimization of Variable Speed Chiller Plants: Frank M. Johnson Jr. Federal Building and U.S. Courthouse, Montgomery, Alabama.* Pacific Northwest National Laboratory.
- Wall, Josh, and Ying Guo. 2018. *Evaluation of Next-Generation Automated Fault Detection & Diagnostics (FDD) Tools for Commercial Building Energy Efficiency – Final Report Part I: FDD Case Studies in Australia.* RP1026. Low Carbon Living CRC. February 2018. Page 68.
- Frey, Donald and Vernon Smith. 2018. *Advanced Automated HVAC Fault Detection and Diagnostics Commercialization Program.* Energy Research and Development Division. Final Project Report.
- Owen, Tom et al. 2010. Employee Engagement and Energy Information Software Supporting Carbon Neutrality. *ACEEE Summer Study on Energy Efficiency in Buildings.*
- Rohloff, Adam et al. 2016. "Data Analytics From Cradle to Grave." *ASHRAE Journal* 58(2), 34.
- Lane, Kyle and Levi Epperson. 2015. *Enterprise Plug-and-Play Diagnostics and Optimization for Smart Buildings. Energy Research and Development Division.* Final Project Report.
- Loftness, Vivian et al. 2016. *Building Performance Optimization while Empowering Occupants Toward Environmentally Sustainable Behavior through Continuous Monitoring and Diagnostics.* ESTCP Project EW-201406.
- Parthasarathy, Girija. 2016. *Central Plant Optimization for Waste Energy Reduction (CPOWER).* ESTCP Project EW-201349.
- Daly, Allan. 2017. *Rapid Deployment of Optimal Control for Building HVAC Systems Using Innovative Software Tools and a Hybrid Heuristic/Model-Based Control Approach.* ESTCP Project EW-201409.
- Adetola, Veronica et al. 2014. *Energy Performance Monitoring and Optimization System for DoD Campuses.* ESTCP Project EW-201142.
- Adetola, Veronica et al. 2013. *Scalable Deployment of Advanced Building Energy Management Systems.* ESTCP Project EW-201015.
- Granderson, Jessica, et al. 2011. "Building energy information systems: User case studies." *Energy Efficiency* 4:17–30.
- Cook, Jonathan et al. 2012. Coordinating Fault Detection, Alarm Management, and Energy Efficiency in a Large Corporate Campus. *ACEEE Summer Study on Energy Efficiency in Buildings.*
- Katipamula, S. 2003. *Demonstration of the Whole-Building Diagnostician in a Single-Building Operator Environment.* Pacific Northwest National Laboratory.
- Kircher, Kevin et al. 2010. Toward the Holy Grail of Perfect Information: Lessons Learned Implementing an Energy Information System in a Commercial Building. ACEEE Summer Study on Energy Efficiency in Buildings.
- Henderson, Philip, and Meg Waltner. 2013. *Real-Time Energy Management: A Case Study of Three Large Commercial Buildings in Washington, D.C.*

- SDG&E's Emerging Technologies Program. 2015. *M&V Report - Model-Based Predictive HVAC Control Enhancement Software.* DR13SDGE0006 Report.

Appendix B: Site Selection Criteria

This appendix contains the information-gathering form and site selection criteria that is used to identify demonstration sites. As an example, the following is the site selection criteria of an Automated System Optimization (ASO) EMIS field evaluation project.

Step 1: Site personnel identify initial candidates using the checklist below. Exclude buildings that lack any of the "required" characteristics.

Priority Level	Characteristic	Check Here if the Building Has this Characteristic
Required	Floor area is > 100,000 ft^2	¨
Required	Presence of a remotely accessible building automation system (BAS) addressable with BACnet/other protocol	¨
Required	Mechanical systems with a central plant (chillers and boilers) or large package rooftop unit (> 60-ton cooling capacity) with variable frequency drives (VFDs) and modulating chilled water valves/multiple compressors (cooling stages)	¨
Required	Variable air volume (VAV) system	¨
Required	Direct digital control built out to the air handling unit (AHU) level (pneumatic thermostats and actuators ok)	¨
Required	Whole-building-level metering	¨
Required	Building- or regional-level point of contact with willingness and knowledge to provide evaluation information regarding occupant/tenant and energy management impacts, and utility tariff information	¨
Required	Good documentation of as-built drawings and design document, especially the electrical and mechanical riser diagrams	¨
Required	Good documentation of control systems, e.g., control drawings, control sequences	¨

Required	Interval whole-building metering and submetering for HVAC equipment	¨
Preferred	Space temperature and relative humidity (RH) measurements through the BAS	¨
Preferred	Stable occupancy, operations, and internal loads during the demonstration period	¨
Preferred	On-site weather station that measures outdoor dry bulb, outdoor relative humidity, outdoor wind speed and direction, and global horizontal irradiance	¨
Preferred	Submetering of plug loads, lighting, and other non-HVAC building loads	¨

Step 2: For each initial candidate building, personnel familiar with the building would provide the following information to the demonstration point of contact, who will relay the information with the down-selection team.

General Information	Response
Address	
Vintage	
History (year and scope) of major renovations/retrofits	
History of building commissioning/retrocommissioning	
Major space use types present in building	
Square footage	
On-site staff or not	
Occupancy variation, historic and future	
Annual electricity and gas usage	
Available metering level (whole-building or submetering), type (interval or monthly), historic data range (e.g., 1 year)	

HVAC Information	Response
History of major HVAC system upgrades	
Is the HVAC system a central chiller/boiler with AHU? If yes:	
Chiller capacity and type (vapor-compression vs. absorption)	
Boiler capacity	
Single duct or dual duct AHU?	
Is the HVAC system a package rooftop DX unit? If yes:	
Cooling capacity	
Heating capacity	
Number of cooling stages	
BAS and Internet Connectivity	**Response**
BAS make and model	
Are the whole-building metering and submetering in the BAS?	
Can a PC be located at the site with network access to both the BAS network and the Internet?	
Does the building have its own virtual private network (VPN)?	

Appendix C: Sample Evaluation Report Outline and Standard Evaluation Reporting Template

Report outline

1. Introduction
2. Description of technology and demonstration sites
   2.1 Technology description
   2.2 Demonstration site description
3. Evaluation metrics and approaches
4. Evaluation results
5. Discussion
6. Conclusion

Standard Evaluation Reporting Template

An Excel spreadsheet has been created that captures the results identified in the EMIS protocols for field evaluations. The Excel template can be downloaded here. Below are screenshots from the template.

EMIS Field Evaluation Reporting Summary:
Building Information

Building Description

Building Name:	
Building Location - City:	
Building Location - State:	
Building Size (square feet):	
Building Location (zip code):	
Building Type:	
For Other Building Type (describe):	

Occupancy Schedule

Monday	☐	from	0:00	to	0:00
Tuesday	☐	from	0:00	to	0:00
Wednesday	☐	from	0:00	to	0:00
Thursday	☐	from	0:00	to	0:00
Friday	☐	from	0:00	to	0:00
Saturday	☐	from	0:00	to	0:00
Sunday	☐	from	0:00	to	0:00

Building Automation System

Make:	
Model:	

Building Systems & Equipment Covered by EMIS

HVAC	☐	**Metering**	☐
Central cooling plant	☐	**Lighting**	☐
Central heating plant	☐	**Plug Loads**	☐
Air handling unit	☐		
Rooftop unit	☐		
Terminal units	☐		
Chiller	☐		
Boiler	☐		
Cooling tower	☐		
Pump	☐		
Fan	☐		

Other systems (describe):	

Figure C-1. Building description in the evaluation reporting template

EMIS Field Evaluation Reporting Summary:
Technology Information - Data Points

EMIS System Description

System Name: ☐

Vendor Name: ☐

Data Points Integrated into EMIS (mark all those that apply):

Interval energy & power meter data ☐

Whole building electricity meter	☐	Electric submeter - for end uses	☐
Whole building gas meter	☐	Chilled water BTU meter	☐
Whole building water meter	☐	Hot water BTU meter	☐
Electric submeter - for tenants	☐	Steammass flow meter	☐

Other interval & power meter data (describe):

HVAC system trend data ☐

Central cooling plant trend data	☐	Rooftop unit trend data	☐
Central heating plant trend data	☐	Terminal units & thermostat trend data	☐
Air handling unit trend data	☐		

Other HVAC system trend data (describe):

IoT sensor data ☐

Temperature IoT sensor data	☐	Occupancy IoT sensor data	☐
Humidity IoT sensor data	☐	Carbon dioxide IoT sensor data	☐

Other IoT sensor data (describe):

Lighting control system trend data ☐ **Plug load control system trend data** ☐

Other system trend data (describe):

Figure C-2. Technology description (part 1) in the evaluation reporting template

EMIS Field Evaluation Reporting Summary:
Technology Information - Functionality

EMIS Functionality & Capabilities (mark all those that apply):

Energy Information System ☐
Energy consumption (costs) visualization ☐
EIS performance indicator (KPI) tracking ☐
Energy performance analysis ☐
Demand management ☐
Measurement and verification ☐
Energy reporting and data export ☐

Other EIS capabilities (describe):

Fault detection and diagnostics ☐
Operational data visualization ☐
FDD key performance indicator (KPI) tracking ☐
Fault prioritization ☐
Fault reporting and data export ☐

Other FDD capabilities (describe):

Automated system optimization ☐
System/equipment on/off schedule ☐
Central cooling plant chilled water leaving temperature setpoint ☐
Central cooling plant cooling tower leaving temperature setpoint ☐
Central cooling plant hydronic differential pressure setpoint ☐
Central cooling plant chiller/pump/cooling tower staging ☐
Central heating plant chilled water leaving temperature setpoint ☐
Central heating plant hydronic differential pressure setpoint ☐
Central heating plant boiler/pump staging ☐
AHU/RTU supply air temperature setpoint ☐
AHU/RTU supply air static pressure setpoint ☐
Space heating and cooling setpoints ☐

Other ASO capabilities (describe):

Figure C-3. Technology description (part 2) in the evaluation reporting template

EMIS Field Evaluation Reporting Summary:
Energy and Utility Savings & Costs

Time Periods				
Baseline Period	Start Date		End Date	
Reporting Period	Start Date		End Date	

Savings Calculation Approach

IPMVP Options (select)	[IPMVP Option]
Other (describe)	

Energy and Utility Cost Savings	Value (enter)	Units
Annual energy savings (kBtu)		kBtu
Annual energy savings (%)		%
Annual energy intensity savings (kBtu/ft²)		kBtu/ft²
Annual energy cost savings		$/year
Monthly non-coincident peak demand reduction		kW
Monthly coincident peak demand reduction		kW

Demand Flexibility		
Demand Decrease Intensity (D1)		W/ft²
Demand Decrease (D2)		kW
Demand Decrease Percentage (D3)		%
Demand Increase Intensity (I1)		W/ft²
Demand Increase (I2)		kW
Demand Increase Percentage (I3)		%
Net Consumption Reduction Percentage (E1)		%

EMIS Technology Costs

Enter Costs in Dollars	Base Cost (install & commission)		Recurring Cost (annual)	
EMIS technology software costs		$		$ per year
EMIS technology hardware costs		$		$ per year
EMIS 3rd party services costs		$		$ per year
In-house labor cost estimate		$		$ per year

Enter Costs in Dollars per Square Foot	Base Cost (install & commission)		Recurring Cost (annual)	
EMIS technology software costs		$/ft²		$/ft² per year
EMIS technology hardware costs		$/ft²		$/ft² per year
EMIS 3rd party services costs		$/ft²		$/ft² per year
In-house labor cost estimate		$/ft²		$/ft² per year

Cost Effectiveness		
Simple Payback		years
Net present value		$
Savings-to-investment ratio		

Figure C-4. Evaluation results (part 1) in the evaluation reporting template

EMIS Field Evaluation Reporting Summary: Capability to Enable Energy Efficiency

Measures enabled or resolved through EMIS (mark all those that apply):

Category	Operational Improvement Measures	Select all measures that apply (Required)	Enter number of actions (Optional)
Scheduling Equipment Loads	Improve scheduling for HVAC	☐	
	Improve scheduling for lighting	☐	
	Improve scheduling for plug loads	☐	
Economizer /Outside Air Loads	Improve economizer operation/use	☐	
	Reduce over-ventilation	☐	
Control Problems	Reduce simultaneous heating and cooling	☐	
	Tune control loops to avoid hunting	☐	
	Optimize equipment staging	☐	
	Zone rebalancing	☐	
Controls: Setpoint Changes	Adjustment of heating/cooling and occupied/unoccupied space temperature setpoints	☐	
	Reduction of VAV box minimum setpoint	☐	
	Duct static pressure setpoint change	☐	
	Hydronic differential pressure setpoint change	☐	
	Preheat temperature setpoint change	☐	
Controls: Reset Schedule Addition or Modification	Supply air temperature reset	☐	
	Duct static pressure reset	☐	
	Chilled water supply temperature reset	☐	
	Hot water supply temperature reset or hot water plant lockout	☐	
	Condenser water supply temperature reset	☐	
Equipment Efficiency Improvements	Add or optimize variable frequency drives (VFDs)	☐	
	Pump discharge throttled or over-pumping and low delta T	☐	
Occupant Behavior Modification	Routinely share energy information or guidance on proper use of equipment with occupants through EMIS	☐	
	Hold an energy savings challenge using EMIS data	☐	
Retrofits	Lighting upgrade or improve lighting controls: replace lighting fixtures with more efficient fixtures, add lighting control system	☐	
	High efficiency HVAC equipment: airside: replace airside HVAC equipment with more efficient equipment	☐	
	High efficiency HVAC equipment: waterside: replace waterside HVAC equipment with more efficient equipment	☐	

Other operational improvement measures (describe additional measures)		

Figure C-5. Evaluation results (part 2) in the evaluation reporting template

EMIS Field Evaluation Reporting Summary: Operational capabilities (optional reporting)

Installation & Commissioning Process Effort

Elapsed time to complete installation	[enter #]	weeks
Elapsed time to complete commissioning	[enter #]	weeks

Activities during installation phase (describe)

Activities during commissioning phase (describe)

Support needed from on-site staff during installation phase (describe)

Support needed from on-site staff during commissioning phase (describe)

Best Practices (describe)

Lessons Learned (describe)

Accuracy of issues/opportunities identified by FDD (describe)

Occupant comfort (describe)

Operation and maintenance (describe)

Figure C-6. Evaluation results (part 3) in the evaluation reporting template

Appendix D: Common Capabilities of EMIS

This appendix lists the common capabilities under the categories of EIS, FDD, and ASO analytics.

Category	Capabilities	Description
EIS	Energy consumption (costs) visualization	Track and provide views of the meter points on a subhourly (e.g., 15-minute) basis; provide visualizations of real-time and historic energy costs.
	Key performance indicator (KPI) tracking	Track KPI for energy related metrics, such as equipment, system, or building level energy use intensity, greenhouse gas emissions.
	Energy performance analysis	Analyze interval energy data and provide actionable information. Common analysis includes time series load profiling, heat map visualization, benchmarking, baseline energy consumption modeling, and energy anomaly detection. Please see the *Energy Information Handbook* (2011) for the description of analytics.[42]
	Demand management	Provide peak demand monitoring; provide notification when the demand for critical metered loads passes a threshold.
	Measurement and verification (M&V)	Provide M&V capabilities in accordance with the International Protocol for Measurement and Verification, establish an energy usage baseline prior to the efficiency project, and express savings as a total, for a given pre- and post-efficiency project period.
	Energy reporting and data export	Provide a default or customized energy report; allow users to export energy data.
FDD	Operational data visualization	Visualize and plot time series operational data and control setpoints (e.g., temperature, pressure, flow rate)
	Key performance indicator (KPI) tracking	Track KPI for equipment or system efficiency (e.g., chilled water plant [kW/ton] and heating plant efficiency) and comfort-related indoor environmental conditions (e.g., occupant comfort index showing the percent of operating hours within zone target temperature ranges for all spaces).
	Fault detection and diagnostics	Identify and diagnose faults within the building systems. Below is a partial list of faults in FDD analytics for the HVAC system.

[42] Granderson, Jessica et al. 2011. *Energy Information Handbook: Applications for Energy Efficiency Building Operations.* Lawrence Berkeley National Laboratory.

		General faults applicable to all HVAC equipment: • Sensor faults, including those outside of a feasible range, flat-lining, bias, drift, or failure • Stuck/leaking valves and dampers in water- and air-side systems • Scheduling, i.e., equipment is operating outside of intended hours • Hunting or cycling, i.e., poorly tuned control loops • Manual overrides in place Air handling units: • Under or over economizing • Excessive outdoor air intake • Unnecessary simultaneous heating and cooling • AHU discharge air temperature reset • AHU static pressure reset • Fouled or blocked coil and dirty filters Terminal units: • VAV minimum supply airflow too high (causing reheat) • VAV supply airflow constantly at maximum flow • Zones outside an acceptable space temperature range • Space heating and cooling setpoints: insufficient dead-band or night setback Chilled water plant: • Chilled water leaving temperature reset • Chilled water plant lockout • Hydronic differential pressure reset • Cooling tower condenser water leaving temperature reset • Chiller short cycling Boiler plant: • Hot water plant lockout • Hot water leaving temperature reset • Hydronic differential pressure reset • Boiler short cycling
	Fault prioritization	Prioritize fault based on an estimate of impact, and recommend actions

	Fault reporting and data export	Generate a default or customized report of the identified faults; allow users to export operational data
ASO	Automated control setpoints optimization	Define the optimized control setpoints and implement in the building automation system. The possible optimized control setpoints in HVAC system include: • System/equipment on/off schedule • Chiller plant chilled water leaving temperature setpoint • Chiller plant cooling tower leaving temperature setpoint • Boiler plant hot water leaving temperature setpoint • Hydronic differential pressure setpoint • AHU supply air temperature setpoint • AHU static pressure setpoint • Space heating and cooling setpoints

Appendix E: Common O&M Tasks

This appendix presents common operation and maintenance activities for different internal stakeholders, as shown below.

Executives

- Building performance dashboard review: Provide public energy dashboards to display performance for executive management. Dashboards also provide useful at-a-glance information to other stakeholders such as the public and energy or sustainability managers.
- ENERGY STAR interface: Automate data transmission and facilities' certification with the EPA ENERGY STAR Portfolio Manager.

Utility Bill Manager

- Utility bill allocation: Allocate utility costs to different tenants or occupant groups sharing a building according to actual energy usage.
- Utility bill validation: Detect potential billing errors.
- Utility budgeting: Forecast future energy use and utility costs.
- Automated bill payment or streamlined account processing

Sustainability Manager

- Renewable energy tracking: Monitor and track units of renewable energy consumed on site.
- Greenhouse gas (GHG) tracking: Calculate, monitor, and report site GHG emissions complying with any associated regulation requirement.

Energy Manager

- Cross-sectional benchmarking: Compare energy consumption with similar buildings, and prioritize buildings for efficiency improvements.
- Efficiency project management: Log and track the status of energy efficiency projects (e.g., start, ongoing, finish) and descriptions of measures and expected savings.
- Measurement and verification: Establish baseline energy use and post-project energy use to determine the efficiency project savings.
- Peak load tracking and analysis: Identify peak demand and hours at the site level.
- Regular energy performance review: Conduct a monthly meeting to review building energy performance.
- Energy tracking: Monitor and track the energy consumption and intensity at the site, system, or major energy-consuming equipment level.
- Load profiling: Inspection of 24-hour periods of interval meter data to understand the relationship between energy use and time of day, as well as contributions of large energy consuming equipment to total building load.
- Longitudinal benchmarking: Compare energy usage for a site, system, or equipment component against past performance.

- Energy anomaly detection: Identify and flag unexpectedly high or low energy use.
- Energy reporting: Provide regular energy or cost reports.
- Goal tracking: Track organization goals on reduction of energy consumption or costs.

Facility team or field engineers

- System/equipment fault identification: Detect operational faults in systems or equipment, with recommendations to guide investigation and resolution.
- Fault root cause analysis and investigation: Support field observation to pinpoint a specific fault resolution.
- System or equipment operational performance tracking: Track the system or equipment level key performance indexes (KPIs); for example, comfort index, cooling plant efficiency, fan system efficiency, or a measured variable such as supply air temperature, zone airflow rate, or zone temperature.
- Performance reporting: Provide regular equipment health or comfort KPI reports.
- Preventative maintenance: Support preventative maintenance activities that are actions performed on a time- or machine-run-based schedule that detect, preclude, or mitigate degradation of a component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level.
- Retrofit strategies determination: Inform retrofit strategies at the facilities, such as identifying retrofit options and sizing equipment.

Appendix F: Common Efficiency Measures

This appendix presents 26 common efficiency measures, as shown below.

Category	Efficiency Measure
Scheduling Equipment Loads	**Improve scheduling for HVAC and Refrigeration:** Shorten operating hours of HVAC and refrigeration systems to better reflect the actual building occupancy schedule and service needs.
	Improve scheduling for lighting: Minimize the lighting runtimes.
	Improve scheduling for plug loads: Minimize office equipment runtimes, e.g., installing advanced power strips that automatically cut power according to an occupant-defined schedule.
Economizer/Outside Air Loads	**Improve economizer operation/use:** Repair/optimize the mixed air economizer control in an AHU (e.g., fix dampers, replace damper actuators, modify economizer control sequence).
	Reduce over-ventilation: Adjust the minimum outdoor air ventilation setpoint to reduce heating and cooling loads.
Control Problems	**Reduce simultaneous heating and cooling:** Eliminate unintended simultaneous heating and cooling by repairing problems such as a stuck/leaking coil valve or sensor errors.
	Tune control loops to avoid hunting: Adjust equipment/actuator controls to reduce cycling (turning on and off).
	Optimize equipment staging: Add or optimize the equipment staging control (i.e., turning the equipment on to meet the load while maintaining optimum part-load performance).
	Zone rebalancing: Ensure proper airflow to be delivered to each zone.
Controls: Setpoint Changes	**Adjustment of heating/cooling and occupied/unoccupied space temperature setpoints:** Add or optimize controls of the zone terminal units to allow spaces' temperatures to drift more during occupied/unoccupied hours.
	Reduction of VAV box minimum setpoint: Reduce the VAV box minimum setpoint to reduce the heating and cooling load.
	Duct static pressure setpoint change: Reduce the duct static pressure setpoint to reduce fan energy consumption.
	Hydronic differential pressure setpoint change: Reduce the hydronic differential pressure setpoint to reduce pump energy consumption.
	Preheat temperature setpoint change: Reduce AHU preheating settings.
Controls: Reset Schedule Addition or Modification	**Supply air temperature reset:** Add or optimize control of the supply air temperature based on either outside air temperature or space loads.
	Duct static pressure reset: Add or optimize control of the duct static pressure based on either outside air temperature or space loads.

	Chilled water supply temperature reset: Add or optimize control of the chilled water supply temperature based on either outside air temperature or cooling load.
	Hot water supply temperature reset or hot water plant lockout: Add or optimize control of the hot water supply temperature based on either outside air temperature or heating load.
	Condenser water supply temperature reset: Add or optimize control of the condenser water supply temperature based on either outside air wet-bulb temperature or chiller load.
Equipment Efficiency Improvements	**Add or optimize variable frequency drives (VFDs):** Add a VFD to the fan or pump.
	Pump discharge throttled or over-pumping and low delta T: Fix pump issues to allow it provide the proper water flow.
Occupant Behavior Modification	**Routinely share energy information or guidance on proper use of equipment with occupants through EMIS technology.**
	Hold an energy savings challenge using EMIS data.
Retrofits	**Lighting upgrade or improve lighting controls:** Replace lighting fixtures with more efficient fixtures; add lighting control system.
	High efficiency HVAC equipment (Airside): Replace airside HVAC equipment with more efficient equipment.
	High efficiency HVAC equipment (Waterside): Replace waterside HVAC equipment with more efficient equipment.

Appendix G: Glossary

Terms	Definition
ASO (Automated System Optimization)	A functionality of EMIS focused on continuous controls optimization. ASO dynamically modifies building automation system control settings to optimize HVAC system energy usage while maintaining occupant comfort. Two-way communication with the BAS is the distinguishing feature of ASO solutions. These tools both read data from the BAS and write analytically based optimal setpoints back to the BAS, based on data such as measured indoor, outdoor, and energy price conditions.
BAS (Building Automation Systems)	Systems used to control building heating, ventilation, and air-conditioning (HVAC) systems, and in some cases, building lighting and security systems.
Baseline data	The measurements and facts describing facility operations and design during the baseline period. This will include energy use or demand and parameters of facility operation that govern energy use or demand.
Baseline model	The set of equations that describe the relationship between energy use or demand and other factors that affect energy use in the baseline period.
Baseline period	The period of time chosen to represent operation of the facility or system before implementation of an EMIS. This period is ideally one year, to reflect one full operating cycle of a system or facility with variable operations.
Commissioning	A process that provides documented confirmation that the technology as constructed functions in accordance with the intent of the design and satisfies the building's operational needs.
Demand response	Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.
EIS (Energy Information System)	Meter-level monitoring, analysis, and charting (hourly or more frequent consumption data, at whole building or submeter level). It may incorporate automated opportunity analysis that typically includes predictive energy models that identify energy use anomalies and measure project savings.
Energy consumption	The amount of energy consumed in the form in which it is acquired by the building.

Energy cost	The total cost for energy, including charges such as base charges, demand charges, customer charges, power factor charges, and miscellaneous charges.
Energy savings	A reduction in energy use, often quantified by accounting for key normalization factors such as weather or hours of operation.
EMIS (Energy Management and Information Systems)	A broad family of tools and services to manage commercial building energy use. These technologies offer a mix of capabilities to store, analyze, and display energy use and system data, and in some cases, provide control. EMIS is an umbrella term that covers both meter-level and system-level EMIS.
FDD (Fault Detection and Diagnostics)	FDD automates the process of detecting faults with physical systems and processes, and diagnoses their potential causes. FDD for HVAC generally use a database of “expert rules” that analyze BAS and meter data to determine fault conditions.
IPMVP (International Performance Measurement and Verification Protocol)	A protocol that provides an overview of the current best practice techniques available for verifying results of energy efficiency, water efficiency, and renewable energy projects in commercial and industrial facilities. It also may be used by facility operators to assess and improve facility performance. The IPMVP is the leading international standard in measurement and verification protocols. It has been translated into 10 languages and is used in more than 40 countries.
Monthly coincident peak demand	The maximum demand during utility’s defined peak period (e.g., the utility’s peak time-of-use period for a given billing period).
Monthly non-coincident peak demand	The highest kilowatt demand peak in any 15-minute interval in the billing month that is used for the calculation of demand charge in utility bills.
NPV (Net Present Value)	The difference between the present value of cash inflows and the present value of cash outflows over a period of time. NPV is used in capital budgeting and investment planning to analyze the profitability of a projected investment or project.
Peak demand savings	The reduction in the demand from the pre-retrofit baseline to the post-retrofit demand once independent variables (such as weather or occupancy) have been adjusted for.
Reporting period (Post-installation period)	The time following the EMIS installation and commissioning during which savings are to be determined.

Simple payback period	The number of years required to recover the investment through project savings.
SIR (Savings-to-investment ratio)	Numerical ratios whose sizes indicate the economic performance of an investment.
Submetering	A method of using multiple meters to collect real-time energy data from any source in a building (electricity, water, gas, or other uses such as district steam and chilled water). Submeters can measure consumption by space, equipment type, or source to capture information that is more granular than the information gathered at the whole-building level. Submetering also allows building management to bill tenants for their individually measured utility usage.