U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Energy Management Information Systems Technical Resources Report

July 2021

FEMP Federal Energy Management Program

(This page intentionally left blank)

Contacts

Jefferey B. Murrell, P.E.
U.S. Department of Energy, Energy Efficiency Renewable Energy Office, Federal Energy Management Program
Metering Program Manager
955 L'Enfant Plaza, Room 8034
Washington, D.C. 20585
Phone: (202) 586-3874
E-mail: jefferey.murrell@ee.doe.gov

Jay Wrobel
U.S. Department of Energy, Energy Efficiency Renewable Energy Office, Federal Energy Management Program
Facility and Fleet Optimization Team Leader
955 L'Enfant Plaza, Room 8025
Washington, D.C. 20585
Phone: (202) 586-4927
E-mail: jay.wrobel@ee.doe.gov

Jesse Dean, CEM
National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
Phone: (303) 384-7539
E-mail: jesse.dean@nrel.gov

Acknowledgments

This document summarizes and contributes to a considerable body of work at the Federal Energy Management Program and U.S. Department of Energy's Building Technologies Office, Better Buildings Alliance, and Smart Energy Analytics Campaign to explore the energy reduction potential of Energy Management Information Systems, along with related research and development, demonstration and deployment activities, policies, and associated impacts to the future evolution and operation of federal facilities across the United States.

This report was authored by Jesse Dean and James Dice of the National Renewable Energy Laboratory. The authors would like to acknowledge the contributions and valuable assistance provided by various staff members of the Federal Energy Management Program, the Building Technologies Office, the national laboratories, and the Navy Smart Grid program.

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy under Contract No. DE-AC36-08GO28308. Funding was provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Federal Energy Management Program.

All reported findings are based on vendor-supplied information at the time of the study. Current capabilities are subject to change, and readers are encouraged to confirm information based on their specific needs. Moreover, the Energy Management Information Systems that were selected as examples are representative of the market, but not comprehensive, and inclusion in the study does not imply endorsement.

Glossary

Advanced meter	An advanced meter records energy or water consumption data hourly or more frequently and provides for daily or more frequent transmittal of measurements over a communication network to a central data collection point. Advanced meters usually have the ability to record other physical quantities in addition to consumption. Related to an advanced meter, an advanced metering device is an electronic meter with built-in metering and communication capabilities, or a separate electronic device coupled to a standard meter that enables communication to the onsite advanced metering infrastructure.
Advanced metering infrastructure (AMI)	An integrated network of advanced meters, communications networks, and data management systems. Advanced metering infrastructure can refer broadly to an agency's entire portfolio of advanced meters and related assets (referred to in this document as the agency's "AMI system"), or more narrowly to the assets at a particular site or building.
Agency	An executive agency as defined in 5 U.S.C. § 551(1), including sub-agencies of the agency, and excluding the Government Accountability Office.
Authorization to operate	The official management decision given by a senior federal official or officials to authorize operation of an information system and to explicitly accept the risk to agency operations (including mission, functions, image, or reputation), agency assets, individuals, other organizations, and the Nation based on the implementation of an agreed-upon set of security and privacy controls. Authorization also applies to common controls inherited by agency information systems (Office of Management and Budget [OMB] 2016).
Authorizing official	A senior agency official or executive within an agency with the authority to formally assume responsibility for operating an information system at an acceptable level of risk to agency operations and assets, individuals, other organizations, and the Nation. The authorizing official is responsible for granting the authorization to operate an information system.
Building function	The classification of a federal building by its predominant use categories (e.g., office, warehouse, education) as defined by the Federal Real Property Profile (Federal Real Property Council 2019).
Covered facility	A facility that an agency has designated as subject to the requirements of section 432 of the Energy Independence and Security Act of 2007 (EISA), codified at 42 U.S.C. § 8253(f), which requires agencies to designate covered facilities comprising at least 75% of their total facility energy use. A covered facility may be defined as a group of facilities at a single location or multiple locations managed as an integrated operation. A covered facility may also be a single building, if so identified by the agency.
Energy Management Information System (EMIS)	A broad family of tools and services used to manage commercial building energy use. These technologies include energy efficient and energy saving information technologies, energy management systems, fault detection and diagnostic systems, benchmarking and utility bill tracking tools, automated system optimization tools, and building automation systems.

Federal Risk and Authorization Management Program (FedRAMP)	A government-wide program that provides a standardized approach to security assessment, authorization, and continuous monitoring for cloud products and services.
Facility	Any building, installation, structure, or property (including any applicable fixtures) owned or operated by, or constructed or manufactured and leased to, the federal government, including a group of facilities at a single location or multiple locations managed as an integrated operation, and contractor-operated facilities owned by the federal government. This document uses the term "facility" when referring to multiple buildings or sites and the term "building" to refer to individual structures.
High performance and sustainable buildings	Federal buildings documented in the Federal Real Property Database as qualifying as a sustainable federal building as outlined in the Implementing Instructions for Executive Order 13834, "Efficient Federal Operations."
Information system	As defined in OMB Circular A-130, an information system is a discrete set of information resources organized for the collection, processing, maintenance, use, sharing, dissemination, or disposition of information (OMB 2000).
Life-cycle cost-effective	Life-cycle cost-effective means, with respect to an advanced meter, the estimated savings gained by installation of the advanced meter exceed the estimated costs over the lifespan of the advanced meter, as determined in accordance with 10 CFR Part 436, Subpart A.
Risk management framework	A process developed by the National Institute of Standards and Technology by which agencies can assure the security of information and information systems and authorize the operation of those systems at an acceptable level of risk to agency operations and assets, individuals, other organizations, and the Nation.
Service entrance	The point of demarcation between a utility's service equipment and the customer's property. For electricity services, the service entrance would typically be the utility's meter; from there, electric current would flow to the customer's main breaker. A building could have multiple service entrances depending on its size.
Standard meter	An electromechanical or solid-state meter or phase controller that cumulatively measures and records aggregated usage data that are periodically retrieved for use in customer billing or energy management. A meter that is not an advanced meter is considered to be a standard meter under this guidance.
Subagency	A bureau, service, or other component within an agency that manages its buildings and facilities separately from its parent agency.
Submeter	A meter that is subordinate to the main advanced meter on a building. Submeters record a portion of the total energy or water consumed by a building and may be used to isolate the consumption of a large energy- or water-consuming system or a building tenant.
Supply line	A main source of a utility's commodity. Examples could include a natural gas line supplying a building, or the main set of conductors supplying electricity. A building could have multiple supply lines of the same commodity depending on the building's size.

Acronyms and Abbreviations

AFDD	automated fault detection and diagnostics
AHU	air handling unit
AMI	advanced metering infrastructure
API	application programming interface
ASO	Automated System Optimization
BAS	building automation system
BCA	Building Commissioning Association
CBM	condition-based maintenance
CLASP	circuit-level analytics and submetering platform
CMMS	computerized maintenance management system
CSF	Cybersecurity Framework
CT	current transformer
DDC	direct digital control
DER	distributed energy resource
DERCF	Distributed Energy Resources Cybersecurity Framework
DOE	U.S. Department of Energy
ECI	energy cost index
ECM	energy conservation measure
EIS	Energy Information Systems
EISA	Energy Independence and Security Act of 2007
EMIS	Energy Management Information System
EnMS	Energy Management System as defined in ISO 50001/50001 Ready
ES-C2M2	Electric Sector Cybersecurity Capability Maturity Model
ESPC	energy savings performance contract
E.O.	Executive Order
EPAct	Energy Policy Act of 2005
EUI	energy use intensity
EV	electric vehicle
FCF	Facilities Cybersecurity Framework
FEMP	Federal Energy Management Program
FDD	Fault Detection and Diagnostics

FY	Fiscal Year
GEB	grid-interactive efficient building
GIS	geographical information system
GSA	U.S. General Services Administration
HVAC	heating, ventilation, and air conditioning
IPMVP	International Performance Measurement & Verification Protocol
IoT	internet of things
ISO	International Organization for Standardization
IT	information technology
KPI	key performance indicator
LBNL	Lawrence Berkeley National Laboratory
MAP	Monitoring Action Plan
MBCx	monitoring-based commissioning
MDMS	meter data management system
M&V	measurement and verification
NIST	National Institute of Standards and Technology
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
OT	operational technology
PG&E	Pacific Gas and Electric
PNNL	Pacific Northwest National Laboratory
RFI	Request for Information
RFP	Request for Proposals
RMF	Resource Management Framework
SaaS	Software as a Service
SCADA	Supervisory Control and Data Acquisition
SEAC	Smart Energy Analytics Campaign
UCS	utility control system
UESC	utility energy service contract
WBE	Whole Building Energy Module

Executive Summary

This technical resources report provides information and best practices for understanding, designing, and implementing Energy Management Information Systems (EMIS). An EMIS can help agencies improve energy performance, reduce operational cost, and for federal staff, can serve as a valuable component of an agency's portfolio-level energy and water metering strategy.

An EMIS is a general label for a software tool, information technology, or system that monitors, analyzes, and controls building energy use and system performance. EMIS can support and improve site energy management by providing building owners and operators with well-organized building performance and energy consumption data, enabling a host of analytic capabilities. These capabilities include portfolio-wide energy benchmarking, data visualization, and key performance indicator tracking; automated fault detection and diagnostics; automated measurement and verification of energy conservation measures; and supervisory control enabling automated system optimization and demand management. To maximize the effectiveness of the EMIS system, the site or agency should implement a companion energy management system (EnMS), an organizational process that codifies the energy goals and policies, empowers staff by leadership commitment, and executes on the EMIS outcomes to improve energy performance. This EnMS process includes proper staffing and training, developing energy improvement lists, and coordinating with energy and operations staff and management to implement operational and project-based improvements and should comply with the new International Organization for Standardization (ISO) 50001 requirements in the Energy Act of 2020.

The purpose of this report is to illustrate how EMIS can enable federal agencies to improve energy performance, reduce costs, and meet energy goals. Additionally, this report illustrates how to determine what EMIS functions and capabilities may be applicable to a given federal agency. This report includes EMIS functions and capabilities, their applicability and benefits to given federal agencies, and information that can be used throughout the EMIS life cycle for federal agencies ranging from system design to implementation and ongoing maintenance. Information is intended to be used by the EnMS team to execute improvements and provide information and action recommendations to a site's energy managers, facility managers, procurement and contracting staff, building automation systems operators, and facilities maintenance staff of federal buildings. Federal agencies are encouraged to incorporate an EMIS into their five-year metering plan,[1] and use the EMIS to track the performance of the program, as specified in Energy Act of 2020.[2]

This report is intended to be used as a resource to drive increased adoption of EMIS systems in the federal sector. Key report content to help with increased adoption in the federal sector includes a framework for understanding EMIS, direct and indirect benefits of EMIS to federal agencies, EMIS capabilities and their relevance to agencies, systems and sources of data that can be connected to an EMIS, components of an EMIS technology stack, and steps and considerations in planning an EMIS deployment. For agencies ready to implement an EMIS, the report includes links to an EMIS Request for Proposal template and guidance on EMIS deployment and operation—important additional resources to help guide a federal EMIS project further into its life cycle.

[1] This guidance document and additional FEMP resources for metering in Federal buildings are available at: https://www.energy.gov/eere/femp/metering-federal-buildings

[2] Public Law 116–260, Energy Act of 2020 (Dec. 27, 2020).

Table of Contents

List of Figures

List of Tables

Introduction

Energy Management Information Systems (EMIS) are a broad and rapidly evolving family of tools that monitor, analyze, and control building energy use and building/metering system performance (U.S. Department of Energy [DOE] 2015a). Leveraging commercially available EMIS tools represents a significant opportunity for energy savings and improved operational performance for the federal sector. EMIS are at the forefront of transforming energy management best practices by providing building owners and operators with well-organized building performance and metered energy consumption data enabling a host of analytic capabilities, such as:

- Enhanced metering system capabilities and application of metered data
- Portfolio-wide energy benchmarking, data visualization, and key performance indicator (KPI) tracking
- Detailed automated fault detection and diagnostics (AFDD) to track performance 24 hours per day/7 days per week
- Automated measurement and verification (M&V) of energy conservation measures (ECMs)
- Integration with smart building systems
- Supervisory control that enables automated system optimization and demand management.

The EMIS landscape is evolving quickly, enabled by a convergence of low-cost data storage and computing, advancements in data analytics, and embedded internet connectivity of a variety of end-use systems, such as lighting, plug loads, and more. While these advancements are enabling cutting-edge capabilities and innovation, it is important to understand that EMIS is a proven technology that is ready to be deployed today. In fact, many federal agencies already employ EMIS, are expanding EMIS programs across their portfolios, and are using EMIS to integrate commercial off-the-shelf products like building automation systems (BAS) and advanced metering infrastructure (AMI) that are widely deployed throughout the federal facility stock.

The Federal Energy Management Program's (FEMP's) mission is to provide technical and financial expertise to help federal agencies meet energy-related goals and provide energy leadership for the United States (FEMP 2021). This effort is directly related to achieving federal energy reduction requirements and promoting metering best practices, which are directly supported and enabled by EMIS. FEMP, in coordination with DOE's Building Technology Office, is uniquely positioned to help facilitate the successful adoption of EMIS throughout the federal sector and help drive further innovation and private-sector investment in state-of-the-art EMIS systems.

The purpose of this report is to describe how EMIS can enable federal agencies to improve energy performance, reduce costs, and meet energy goals through the proactive utilization of energy data to optimize energy performance. Additionally, this report illustrates how to determine what EMIS functions and capabilities are possibly applicable to a given federal agency. Section summaries are provided below to help orient the reader and introduce how this information can be used throughout the EMIS life cycle for federal agencies.

- *What Are Energy Management Information Systems?* Introduces a framework (Capabilities, Scope, Stack, and Operations) to describe what an EMIS is. The framework lays the foundation for understanding how data is collected, stored, and used to create value for the agency.
- *Benefits of EMIS to Federal Agencies*: Outlines the direct, indirect, and societal value of EMIS to federal agencies. Direct benefits include energy savings, automated M&V, and avoidance of performance drift. Indirect benefits begin with enabling visibility into facility, campus, and portfolio-level energy usage and performance. This section also explains how EMIS meets many other

objectives for agencies, including analyzing and applying metered data, mitigating challenges encountered in the federal sector with standard BAS and AMI installations, coordinating with a site's energy management system (like DOE's 50001 Ready program), enabling compliance with newer ASHRAE standard 90.1 requirements, and supporting various federal laws and requirements.

- *EMIS Capabilities*: Outlines the core capabilities and how they can be used within the federal facility portfolio to improve performance and to analyze/apply metered data. Some common capabilities in the EMIS marketplace include centralization, normalization, and visualization of metered data; utility bill management; interval meter analytics; and M&V support. EMIS also support AFDD, supervisory control, and operations and maintenance (O&M) optimization. Within each core capability, various subcapabilities are outlined as they relate to the core capabilities. Similar to EMIS scope items, federal agencies are encouraged to use this section to identify which capabilities are most relevant for their procurement and deployment purposes when developing and implementing their five-year energy and water metering plans.

- *EMIS Scope*: Outlines the various systems and sources of metered data that can be connected to an EMIS, including utility bills, weather, AMI, BAS, utility control systems (UCS), distributed energy resources (DERs), grid-interactive buildings (GEBs), energy-efficient and energy savings information technologies, the electric grid, electric vehicle (EV) charging stations, data centers, and computerized maintenance management systems (CMMS). While EMIS scope items for a typical federal facility only comprise a subset of the various scope items listed, a comprehensive list is provided to allow the federal agency to prioritize which scope items are most important to them.

- *EMIS Stack*: Details the four components that comprise an EMIS technology stack. The stack is all devices, data services, and applications that meet the needs of the user.

- *EMIS Planning*: Discusses the steps and considerations involved in planning an EMIS deployment. This section covers setting goals, defining roles and responsibilities, selecting EMIS capabilities/scope, establishing feasibility, preparing documentation, and also outlines challenges and cybersecurity considerations. This section is intended to be used as a step-by-step resource to help federal agencies plan out their EMIS procurement process.

- *EMIS Procurement*: Introduces purchasing considerations and a recently updated EMIS specification document that is intended to streamline the process of procuring EMIS for federal agencies.

- *EMIS Deployment*: Walks through the steps associated with installing an EMIS, such as preparing for systems integration, installation, data modeling, customization, quality checking, and training. This section is intended to walk the federal agency through an approach to successfully installing advanced meters and EMIS.

- *EMIS Operation*: Intended for use by the organization's metering or EMIS team—those who will be using the EMIS on an ongoing basis—this section recommends standard processes and regular action to reap the benefits provided by EMIS. It outlines how the EMIS should be used to identify and prioritize opportunities; and validate, diagnose, triage, and implement corrective actions. In addition, this section covers how the EMIS should be kept updated and maintained.

- *Conclusions*: Concludes the document and introduces the FEMP EMIS website, deployed in Spring 2021, which serves as a landing page for federal agencies looking to explore EMIS further.

This technical report is intended to be used by a wide range of federal facilities staff, including energy managers, facility managers, procurement and contracting staff, BAS operators, and facilities maintenance staff. Readers are encouraged to use the summaries above to determine which chapters are most relevant to their specific job function.

What Are Energy Management Information Systems?

EMIS are the broad and rapidly evolving family of software tools that monitor, analyze, and control building energy use and system performance. The term EMIS has been in use since at least 2012, when the Lawrence Berkeley National Laboratory (LBNL), the Consortium of Energy Efficiency, and Pacific Gas and Electric's (PG&E) Emerging Technologies program, among other stakeholders, developed an EMIS framework with six product classifications to differentiate features and capabilities of different EMIS products, such as Energy Information Systems (EIS) and Fault Detection and Diagnostics (FDD) (Guild, Koeppel, and Hilger 2012).

Given the significant EMIS advancements since 2012, it is necessary to update this framework to better evaluate evolving EMIS product offerings. Advances in technology and a subsequent surge in venture capital investments in EMIS software companies have fueled an outpouring of new products and service offerings, many of which have overlapping capabilities and feature sets. The resulting software market is too complicated to divide into six distinct categories. Additionally, emerging capabilities, such as artificial intelligence and the growing influence of analytics software beyond energy management, extend beyond the original 2012 framework. For example, EMIS is now used for predictive maintenance, which stretches beyond energy management into O&M and capital planning, which is further described in the O&M Optimization section. A new framework for understanding EMIS is provided below that accommodates the rapid pace of change.

Framework for Understanding EMIS

All EMIS deployments can be broken down into three functional elements (Capabilities, Scope, and Stack), which are summarized below and in Figure 1. The elements form a system of devices, data services, and software applications that aggregate facility data and aid in the optimization of energy use at the building, campus, or agency level. A fourth element, Operations, represents the people, organizational processes, and actions recommended to successfully use an EMIS, which is described below as the EnMS process.

EMIS Functions and Benefits

EMIS provide a wide range of benefits for building-level or campus-wide energy management capabilities and operational improvements. These can include predictive maintenance, automated supervisory controls, FDD, energy reporting, underlying data for energy management systems processes, aggregation and analysis of meter data, support for building re-tuning and retro-commissioning, and renewable energy and DER performance tracking.

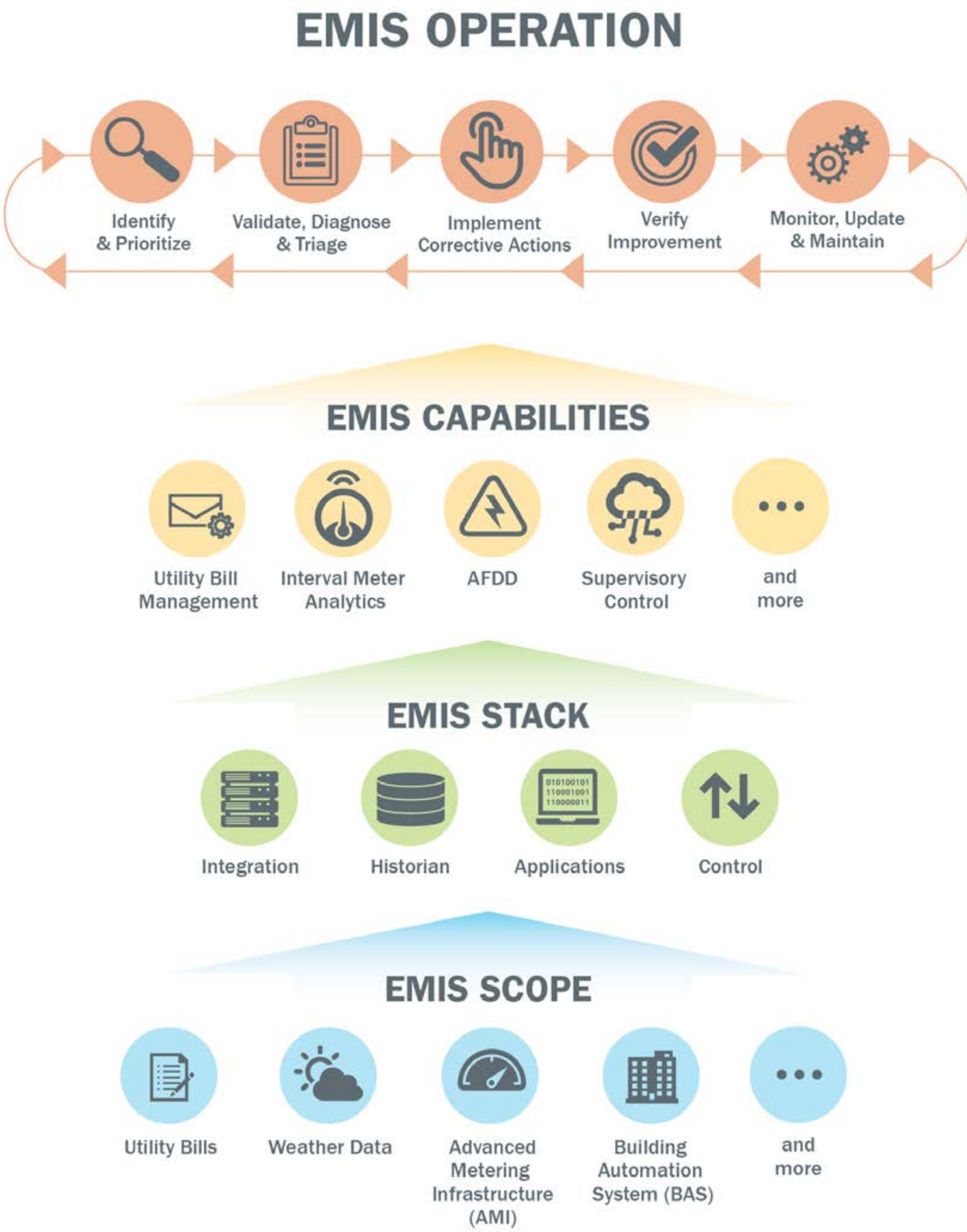

Figure 1. EMIS framework developed in 2019

Image Credit: NREL, James Dice, and Fred Zietz

To define and procure an effective EMIS, an agency or organization must consider all four elements of an EMIS (Scope, Stack, Capabilities, and Operations), with a special focus on the desired capabilities and available scope. The capabilities and scope will drive the internal components of the EMIS stack and the actions needed out of EMIS operations. These four elements are described in more detail below.

- **EMIS Capabilities**: The outputs of the EMIS that provide value to users. Core capabilities are as follows:
    - **Centralize, Normalize, Visualize Data**—Automatically bring data streams together from different sources into a common database to allow for visualization
    - **Utility Bill Management—**Tracking, understanding, and processing data from utility bills
    - **Interval Meter Analytics**—Tools specifically designed to analyze meter data at intervals of one hour or less
    - **M&V—**Quantify and verify the energy savings performance of individual ECMs or efficiency projects
    - **AFDD—**Automatically detect equipment-level or system-level faults and diagnose their causes
    - **Supervisory Control**—Perform automated changes to underlying building systems for optimization
    - **O&M Optimization—**Tools to integrate the above capabilities with O&M processes to increase efficiency
- **EMIS Scope**: Building systems and data sources that are integrated with the EMIS. Common data or data sources include utility bills, weather data, facility-related data, AMI, BAS, UCS, DERs, internet of things (IoT) devices, EV charging infrastructure, and geographical information systems (GIS).
- **EMIS Stack**: All of the devices, data services, and applications that meet the needs of the user. The stack has many different components depending on the EMIS implementation (Cutler et al. 2016):
    - **Integration** components are responsible for managing communication between the scope and the historian. It could include hardware and software, including drivers for protocol translation.
    - The **historian** stores time series data and associated metadata in one or more databases, providing those data on request to applications.
    - **Applications** consist of all high-level analysis tools that rely on collected data.
    - **Supervisory control** supports applications that have a need to affect the operation of building devices in an automated or semiautomated manner.
- **Operations**: The actions enabled or improved by the EMIS capabilities that are taken by facilities staff, operators, energy managers, and occupants to optimize the building, campus, or agency.

Benefits of EMIS to Federal Agencies

For operators of federal facilities, deploying an EMIS has the potential to produce substantial value and to enhance its existing metering system program. This includes direct energy and cost savings as well as indirect benefits realized through data-driven operational improvements. Additionally, EMIS provides an unmatched toolset for supporting compliance with federal laws and regulations concerning energy efficiency and performance reporting. Because EMIS can provide value in many ways to a given agency, these benefits often impact a broad set of stakeholders. This section highlights some of the top benefits, which are summarized in Figure 2.

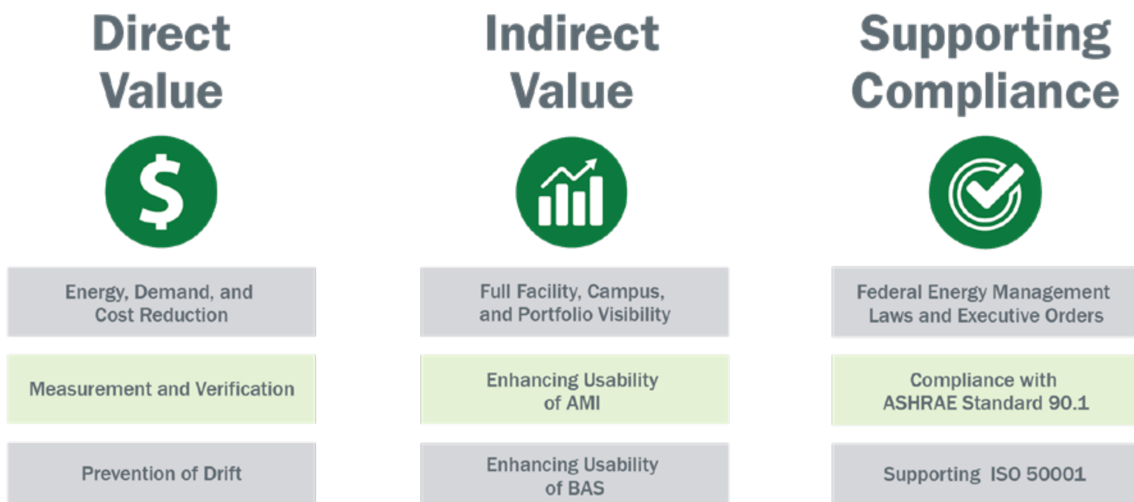

Figure 2. Benefits of EMIS to federal agencies

Image Credit: NREL, James Dice and Fred Zietz

Direct Value

EMIS drives direct value to agencies through reducing energy and demand costs and preventing building performance from drifting over time. These savings have been cited as the highest motivators for installing EMIS (Kramer et al. 2019a), and there is great potential across all federal agencies, where total utility expenditures topped $16.5 billion in Fiscal Year (FY) 2018 (DOE 2021a). If all agencies adopted EMIS and realized the median savings of 9% reported by the Smart Energy Analytics Campaign (SEAC, a public-private partnership encouraging the use of EMIS technologies monitoring practices), the annual energy cost savings would be approximately $1.5 billion (Kramer et al.).[3]

While many agencies already utilize various free software tools (such as the U.S. Environmental Protection Agency's ENERGY STAR® Portfolio Manager for benchmarking), commercially available EMIS tools offer agencies enhanced benefits that justify the investment required to achieve these savings. Further, SEAC results show high returns on EMIS investment (Lin, Kramer, and Granderson 2020). In 2020, for campaign participants who implemented AFDD, median annual savings were $0.27 per square foot, compared to deployment and recurring costs of $0.05 and $0.07 per square foot, respectively (Lin, Kramer, and

[3] For more information on the SEAC, see: https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Smart%20Energy%20Analytics%20Campaign%20Year%203%20Report_LBNL.pdf

Granderson). Prior campaign analyses of other EMIS capabilities, such as Interval Meter Analytics, showed similar or higher rates of return (Kramer et al. 2019b).

Energy, Demand, and Cost Savings

The federal sector has decreased energy intensity (as measured by energy use divided by square feet) by 50% since 1975 (DOE 2021a). Facilities that have already made substantial improvements with traditional ECMs now experience diminishing returns from further investment. To meet additional reduction goals, EMIS can be a source of untapped opportunities for ECMs such as failed heating, ventilation, and air conditioning (HVAC) components, air handling unit (AHU) scheduling problems, and control sequences that need to be optimized. EMIS can also help operators analyze and understand energy demand profiles, create demand reduction strategies, quantify and verify demand changes, and allow the automation of those strategies through supervisory control. Utility rebates and incentives for installing EMIS can further shorten the payback period for deploying an EMIS.

Measurement & Verification

A variety of external factors typically affect a federal agency's monthly energy usage and associated cost, such as variable energy prices, changes in building operation or space utilization, and changes in weather patterns from year to year. These factors can make the M&V of energy savings nontrivial and time-consuming. As energy conservation and demand reduction measures are implemented, EMIS can support M&V via either whole building weather normalized regression analysis, automated processing and weather normalization of 15-minute interval AMI data, or EMIS support can be isolated to individual ECMs.

Prevention of Performance Drift

Operators of commercial buildings strive for ever-increasing levels of energy efficiency and operational performance. To help meet these goals, design engineers are specifying increasingly complex and sophisticated HVAC and BAS, while integrating automated metering, smart lighting controls, IoT devices, EV charging stations, on-site distributed generation systems, and electrical or thermal energy storage. Over time, this increased complexity also has the tendency to broaden the gap between design intent and the in-situ performance of commercial buildings as facilities operation staff have difficulty keeping up with the O&M requirements of each facility.

As facility operational performance declines over time, energy use increases, and interior thermal comfort can start to degrade or drift (Mills 2011). Historically, the traditional approach to addressing these ongoing operational efficiency issues has been to commission the facility when it is first constructed and to retro-commission or retune the facility every four to five years. EMIS allow facility operators to address this problem continuously by collecting and using data to ensure building systems operate correctly, often in support of a monitoring-based commissioning program (MBCx), enhanced O&M programs, and 15-minute interval data anomaly detection. A graphical representation of the additional savings over time from an MBCx EMIS system are graphically illustrated in Figure 3 (Mills 2009).

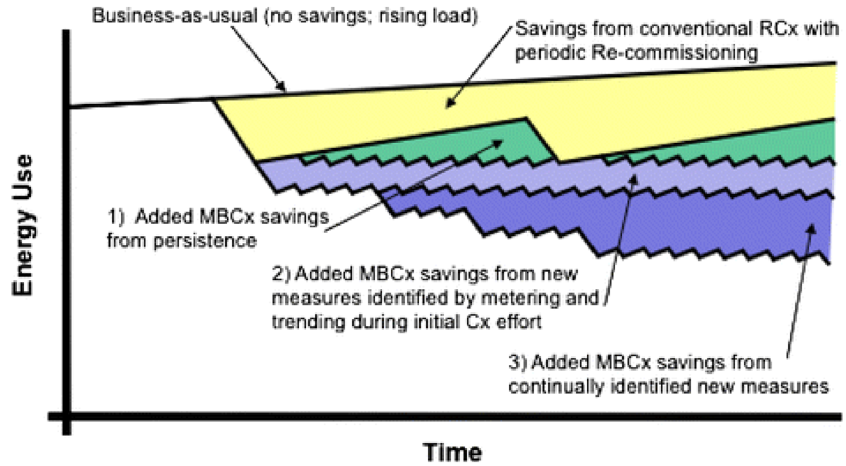

Figure 3. MBCx ongoing savings

Image Credit: Lawrence Berkeley National Laboratory

Indirect Value

The data visualization and analytics capabilities of EMIS can be used to create added value for an agency's core mission and stakeholders. This added value can often outweigh the direct impact of EMIS. The indirect benefits are separated into four subsections: (1) full facility, campus, and portfolio visibility; (2) mitigating challenges with AMI and BAS; (3) compliance with applicable federal laws and regulations; and (4) supporting DOE's 50001 Ready program in the proceeding sections.

Full Facility, Campus, and Portfolio Visibility

Federal energy management presents a number of challenges in centralizing the data in one place to provide situational awareness of O&M and energy management. In the federal sector, 94% of all federal buildings are located on federal campuses, and 90% of the federal real property portfolio is located on campuses with eight or more buildings per campus (U.S. General Services Administration [GSA] 2012). In many cases, a relatively small energy management and facilities staff manages one or more campuses of buildings, with tens up to thousands of buildings (Table 1).

Table 1. Characterization of Federal Buildings

	Stand-Alone Buildings	Campus Buildings	Total	Percentage of Federal Buildings on Campuses
Number of Buildings	19,168	275,846	295,014	94%
Square Footage (in millions)	472.9	2,389.9	2,862.8	83%

Source: GSA 2012. Data for the Federal Bureau of Investigation unavailable at this time.

For many federal buildings located on campuses, energy is purchased, reported, and managed on a total installation basis rather than an individual building basis. In many instances, electricity, natural gas, and water are tracked by utility-owned revenue meters at the campus level, typically with some additional deployment of individual building meters. In some instances, electricity is billed at the campus level with natural gas metered by the utility at the building level. Federal campuses typically have central chilled water and steam or hot water plants that serve multiple buildings. Further, a significant portion of the electricity consumed on a federal campus is typically consumed by lighting and equipment external to buildings. An additional portion of campus electricity is consumed by buildings of less than the minimum threshold for individual energy and water building metering specified in the *Revised Federal Metering Guidance* (DOE 2021b).

Pursuant to the Energy Policy Act of 2005 (EPAct), agencies have installed dedicated advanced energy and water meters that provide data at least daily and measure at least hourly consumption of electricity. As of FY 2019, federal agencies reported 37,632 advanced electricity meters in 115,316 buildings meeting the requirement of "appropriate for advanced electrical meter" (DOE 2021c). As of FY 2018, federal agencies reported installing 6,314 advanced natural gas meters out of 35,113 buildings meeting the requirement of "appropriate for advanced natural gas meter" (DOE 2021d). As of FY 2018, federal agencies reported installing 1,908 advanced steam meters out of 5,120 buildings with interval steam meters capable of providing steam readings on an hourly basis (DOE 2021e). These advanced meters represent only a portion of the approximately 300,000 buildings in the federal portfolio, and thus do not provide comprehensive coverage of federal building interval energy usage. Consequently, utility invoices remain the most effective method for tracking campus energy consumption. Section 1002 of the Energy Act of 2020 provides updates to guidance concerning water efficiency, facility evaluations/auditing, metering and ECM/water conservation measure implementation.[4] Due to the way federal campuses are billed for utilities and constructed, EMIS presents a significant opportunity for federal agencies to integrate data from utility invoices, 15-minute AMI data, and other relevant data sources into one common platform and enable a host of advanced energy management capabilities outlined in proceeding sections.

Enhancing Usability of AMI and BAS

In addition to the aforementioned challenges of measuring energy usage and managing energy at the campus level, in some cases, historic implementations of AMI have utilized meter data systems (such as the Army's Meter Data Management System [MDMS]) that were designed to be used by utilities rather than facility managers. These meter data systems and BAS may not have imbedded capabilities and functionality to fully utilize meter data to model predicted building load profiles, benchmark building energy usage, compare usage across facility types, and automatically track weather normalized energy savings.

Some implementations of AMI also have issues with data dropouts and network connectivity issues that result in frequent loss of meter data. Many meter data systems use simple 15-minute load profile graphs that have no built-in automated features that allow for useful, automated analysis of tens to hundreds of buildings on a single site. A typical AMI data graph from a meter data system used by an unspecified federal facility is provided in Figure 4, which shows the 15-minute load profile for a building over a 15-day period in blue, the cumulative energy consumption for the period in red, and associated kW-hr on the right-hand side of graph. In this current state, there is limited useful information and diagnostic information that can be pulled from these types of charts without the need for significant manual processing, regression analysis, and manual processing of 15-minute interval electrical data for further benchmarking analysis.

[4] Energy Act of 2020. https://www.energy.senate.gov/services/files/32B4E9F4-F13A-44F6-A0CA-E10B3392D47A

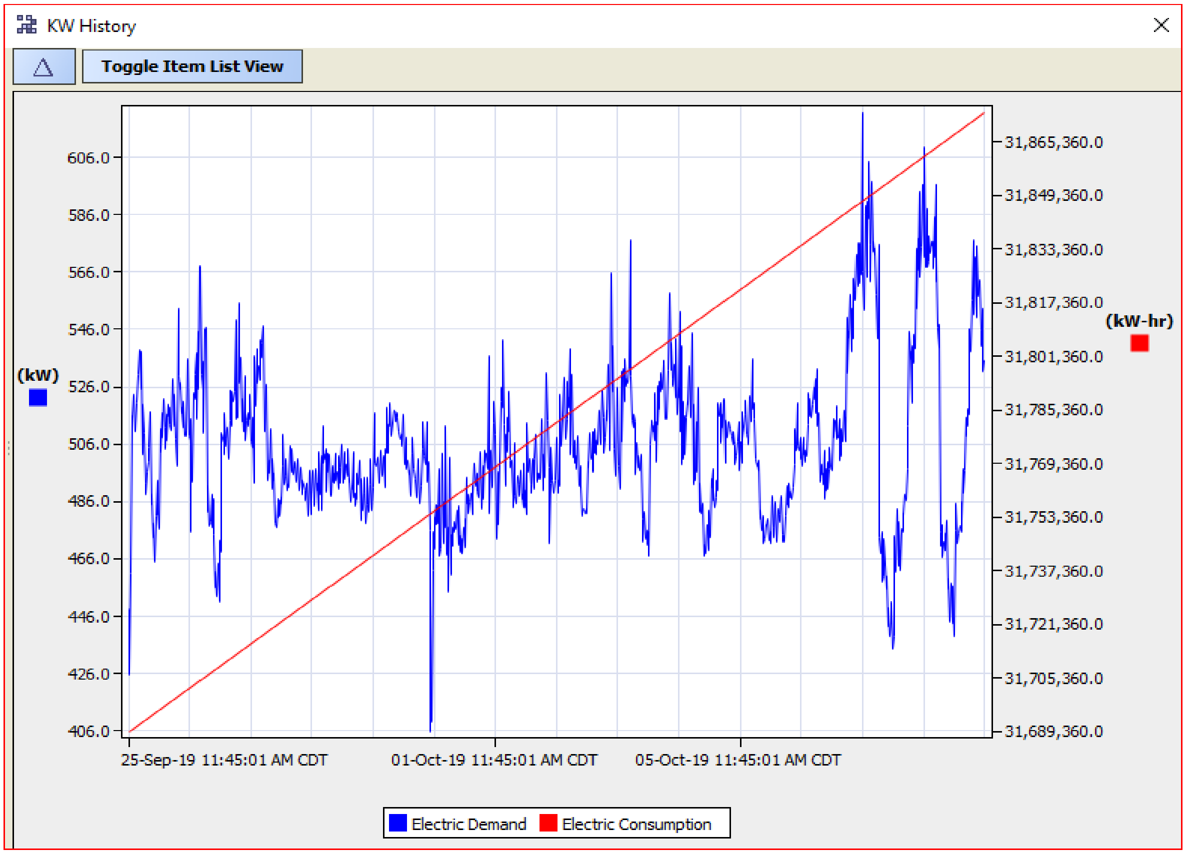

Figure 4. Example AMI meter data

Image Credit: NREL, Jesse Dean

BAS deployment challenges can also exist within the federal sector. Although some federal agencies have been able to standardize on a specific BAS vendor for a given campus, many federal campuses have multiple BAS vendors on each campus. In addition to various BAS vendors, there are often numerous equipment-level controllers not fully integrated into the BAS that can be integrated into an EMIS, numerous vintages of BAS operating systems, and varying levels of functionality. Due to this complexity across the federal government, there is a significant need for EMIS to centralize BAS functionality to a single user interface (or common operating picture), store data from disparate BAS systems into a common database, perform analytics across disparate BAS systems, and implement supervisory control actions across the portfolio from a single EMIS.

EMIS deployment and operation have the potential to significantly reduce federal sector energy usage by addressing the issues of both campus and individual building-level energy usage and reporting, AMI analytics, and BAS centralization and analysis.

Supporting Compliance with Federal Laws and Regulations

Since the passage of EPAct of 2005, a series of federal facility energy management laws and executive orders have been issued that affect federal agency portfolios regarding how federal energy usage is measured, managed, and reported (U.S. Environmental Protection Agency 2020). Federal agencies are required by these laws and executive orders to meet various Energy Independence and Security Act of 2007 (EISA) and Energy Act of 2020 requirements for the following: (1) Acquisitions and Electronics Stewardship, (2) Facility Energy Efficiency, (3) Fleet Management, (4) Greenhouse Gases, (5) High Performance Sustainable Buildings, (6) Performance Contracting, (7) Performance Tracking and Reporting, (8) Renewable Energy and Electricity, (9) Waste Management, and (10) Energy and Water Metering. A comprehensive, agency-wide EMIS directly and indirectly supports a number of these requirements. The direct requirements supported by an agency-wide EMIS are outlined in Appendix A.

A vertical mapping between federal requirements and EMIS capabilities is provided in Figure 5. As shown, federal EMIS can serve as a critical asset in meeting federal mandates and executive orders. A total of 101 instances where EMIS can support these mandates and executive orders were identified.

EMIS Capabilities

Category From EPAct, EISA 2007, & EO	Centralize, Normalize, Visualize Data	Utility Bill Management	Interval Meter Analytics	Measurement & Verification (M&V)	Automated Fault Detection and Diagnostics (AFDD)	Supervisory Control	O&M Optimization
Energy Reduction	✔	✔	✔	✔	✔	✔	✔
Data Center Management	✔	✔	✔	✔	✔	✔	✔
Benchmarking of Federal Facilities	✔	✔	✔	✔			
Energy and Water Evaluations	✔	✔	✔	✔	✔		✔
Follow Up on Implemented Measures	✔		✔	✔	✔	✔	✔
Recommissioning and Retro-Commisioning	✔		✔	✔	✔	✔	✔
Web Based Certification	✔	✔	✔	✔			
Metering Requirements	✔	✔	✔	✔			
Annual Energy Report	✔	✔	✔	✔			
Renewable Energy Report	✔		✔				
Waste Management	✔	✔					✔
Water Management	✔	✔	✔	✔	✔		✔

Figure 5. Vertical mapping of federal mandates to EMIS capabilities

Image Credit: NREL, James Dice and Fred Zietz

The EMIS capabilities that support federal mandates are further supported by the Energy Act of 2020, which expands on previous AMI metering requirements by requiring water metering, and redefines ongoing metering as a *"process of commissioning using monitored data, the primary goal of which is to ensure continuous optimum performance of a facility, in accordance with design or operating needs, over the useful life of the facility, while meeting facility occupancy requirements."*[5] An EMIS that integrates AMI infrastructure fulfills this new ongoing metering objective. In addition, retro-commissioning of energy consuming systems in commercial, federal, and other facilities is cost effective, and for federal facilities is also statutorily required—the Energy Act of 2020 stipulates that each "covered facility"[6] must complete a comprehensive energy and

[5] Public Law 116–260, Energy Act of 2020 (Dec. 27, 2020).

[6] For information on the statutory term "covered facilities," see "Facility Energy Management Guidelines and Criteria for Energy and Water Evaluations in Covered Facilities (42 U.S.C. 8253 Subsection (f), Use of Energy and Water Efficiency Measures in Federal Buildings), section III, "Criteria for Covered Facilities," at https://www.energy.gov/sites/prod/files/2013/10/f3/eisa_s432_guidelines.pdf.

water evaluation and recommissioning or retro-commissioning for approximately 25% of the covered facilities once every four years. The Energy Act of 2020 also includes an exemption that states that recommissioning or retro-commissioning shall not be required if the facility is "under ongoing commissioning, recommissioning, or retro-commissioning."[7] If the EMIS includes AFDD as described below, it would automate the ongoing commissioning process and would meet the requirements of the exemption. Implementation of an EMIS that includes AFDD would significantly reduce the costs of manually recommissioning a facility every four years.

Supporting Compliance with ASHRAE 90.1

ASHRAE 90.1-2019 – Energy Standard for Buildings Except Low-Rise Residential Buildings, which will be codified by jurisdictions across the United States in the coming years, applies only to newly constructed commercial buildings (ASHRAE 2019a). The standard requires building owners and facility managers to deploy submetering to track and analyze the effectiveness of code compliance efforts and identify how energy is used (ASHRAE 2019a). Specifically, Standard 90.1-2019 requires submetering of total electricity use; HVAC systems; interior lighting; exterior lighting; and receptacle circuits (ASHRAE 2019a). As local code jurisdictions work to adopt the latest version of ASHRAE 90.1, it will become standard practice to construct and design new buildings with individually submetered end-use loads. Required submeters could be tied into the EMIS for interval meter analytics to process this large quantity of submetered data. Additionally, the *ASHRAE Smart Grid Application Guide for Building Professionals* includes many features and required capabilities available through advanced EMIS (ASHRAE 2019b).

Supporting Energy Management Systems Standards Such as International Organization for Standardization (ISO) 50001

While EMIS provides a process for data-informed decisions and operations, a site can also benefit from coupling an EMIS to an EnMS as defined in ISO 50001. The EnMS codifies administrative and operational practices around the understanding and management of energy. This practice includes proper staffing and training, developing energy improvement lists, and coordinating with energy and operations staff and management to implement operational and project-based improvements. DOE data has shown an annual energy performance improvement of approximately 5% with a properly structured EnMS in place, such as ISO 50001 (Howard 2019). ISO 50001:2018 is a voluntary international standard that serves as a best practice for establishing, implementing, maintaining, and improving an EnMS. DOE has developed the 50001 Ready program as a self-attesting, self-certification path to implementing ISO 50001. DOE will provide recognition to U.S. sites that meet the 50001 Ready requirements and provide no-cost tools and resources for its implementation. For more information, see https://www.energy.gov/50001Ready.

Section 1002 of the Energy Act of 2020 adds responsibility for facility energy managers to consider the use of an EnMS and pursuing ISO Standard 50001 certification. Moreover, Executive Order 14008: Tackling the Climate Crisis at Home and Abroad tasks heads of agencies with taking "steps to ensure that, to the extent consistent with applicable law, Federal funding is used to spur innovation, commercialization, and deployment of clean energy technologies and infrastructure" (Executive Order No. 14008, 2021).

[7] Public Law 116–260, Energy Act of 2020 (Dec. 27, 2020).

Key requirements of the 50001 Ready program include:

- Develop a policy for more efficient use of energy
- Create targets and objectives to meet the policy
- Use data to better understand and make decisions concerning energy use and consumption
- Measure the results
- Review the effectiveness of the policy within all levels of the organization
- Continually improve energy management (based on the *plan-do-check-act* process)
- Respond to issues that arise while implementing ECMs or addressing nonconformities.

The 50001 Ready framework requires agencies to continually improve their energy management based on the *plan-do-check-act* process. This process can be supported by a functioning EMIS, which can be used to help identify and prioritize energy efficiency measures during planning. In addition, as ECMs are implemented, the EMIS can be used to verify savings through the *check* part of the process. Finally, EMIS can be used to act on additional energy efficiency opportunities.

One of the primary components of the 50001 Ready program is outlining the elements of the site's EnMS process. EnMS, as defined per ISO 50001, combines elements of site energy policy, energy management action plans, energy data collection and benchmarking, and reporting to help federal agencies comply with federal energy reduction goals. EMIS software products outlined in this technical report are not required per ISO 50001, but can serve as a critical element to complement an EnMS and help an agency both achieve ISO 50001 and track progress over time. While the EnMS brings the cultural and organizational aspects that will lead to proven energy performance improvements (mostly through no- and low-cost actions), a companion EMIS can bring improved data and operational controls to offer even greater energy improvements.

While this section has detailed some of the top benefits for deploying EMIS in federal agencies, the list of potential motivators can go far beyond this and is beyond the scope of this technical report. EMIS deployment can also support initiatives such as sustainability, resilience, retuning, DERs, cybersecurity, occupant engagement, operational technology (OT), O&M, and supply chain management. Finally, EMIS deployments can provide value to almost all types of federal facilities, including high energy users like laboratories and data centers.

EMIS Capabilities

Figure 6. The stack component of the EMIS framework

Image Credit: NREL, James Dice and Fred Zietz

An EMIS collects and analyzes raw data from connected systems and meters into actionable outcomes that provide value to users. This section provides an overview of these actionable outcomes—it is not intended to be a comprehensive list of all available features, as new functionality is being released continuously by new and existing EMIS vendors. Subsections below are organized around four primary and three secondary outcomes. For more information on EMIS capabilities, see https://betterbuildingssolutioncenter.energy.gov/alliance/technology-solution/energy-management-information-systems.

Primary Capabilities

Primary capabilities or features represent the most common EMIS use cases. The solutions, vendors, and products focusing on these use cases are more developed and have a strong track record of results. Several case studies exist for federal agencies and private sector building owners that have deployed and are operating EMIS programs with these capabilities:

1. *Utility Bill Management*—Tracking, understanding, and processing data from utility bills
2. *Interval Meter Analytics*—Tools specifically designed to analyze meter data at intervals of one hour or less
3. *AFDD*—Automatically detect equipment-level or system-level faults and diagnose their causes
4. *Supervisory Control*—Perform automated changes to underlying building systems for optimization.

Secondary Capabilities

Secondary capabilities are emerging in the marketplace and becoming more mature. In general, they represent untapped opportunities to expand the value of the above primary list of capabilities. As the EMIS marketplace is evolving faster and faster, these secondary capabilities should be considered in both short- and long-term EMIS planning:

1. *Centralize, Normalize, Visualize Data*—Automatically bring data streams together from different sources into a common database to allow for visualization
2. *M&V*—Quantify and verify the energy savings performance of individual ECMs or efficiency projects
3. *O&M Optimization*—Tools to integrate the above capabilities with O&M processes to increase efficiency.

Examples are provided for educational purposes only and do not represent an endorsement of any specific vendor, product, or feature. The reader is advised to use this section to begin to understand what is possible before moving into the EMIS planning and procurement stages.

Utility Bill Management

This section outlines EMIS capabilities dedicated to tracking, understanding, and processing data from utility bills. These tools help users calculate and visualize whole-building energy consumption over time and compare buildings to each other using monthly utility bill data. Some tools take this further into the management of the bills themselves, offering suites of tools for validation, payment processing, and storage.

Usage and Cost Tracking

A core EMIS function is to graph energy consumption over time and calculate energy related key performance indicators (KPIs). Utility bill data provides valuable high-level insights, such as how much energy the building uses per year or per month, how much that energy costs, and how it is changing over time, as shown in Figure 7.

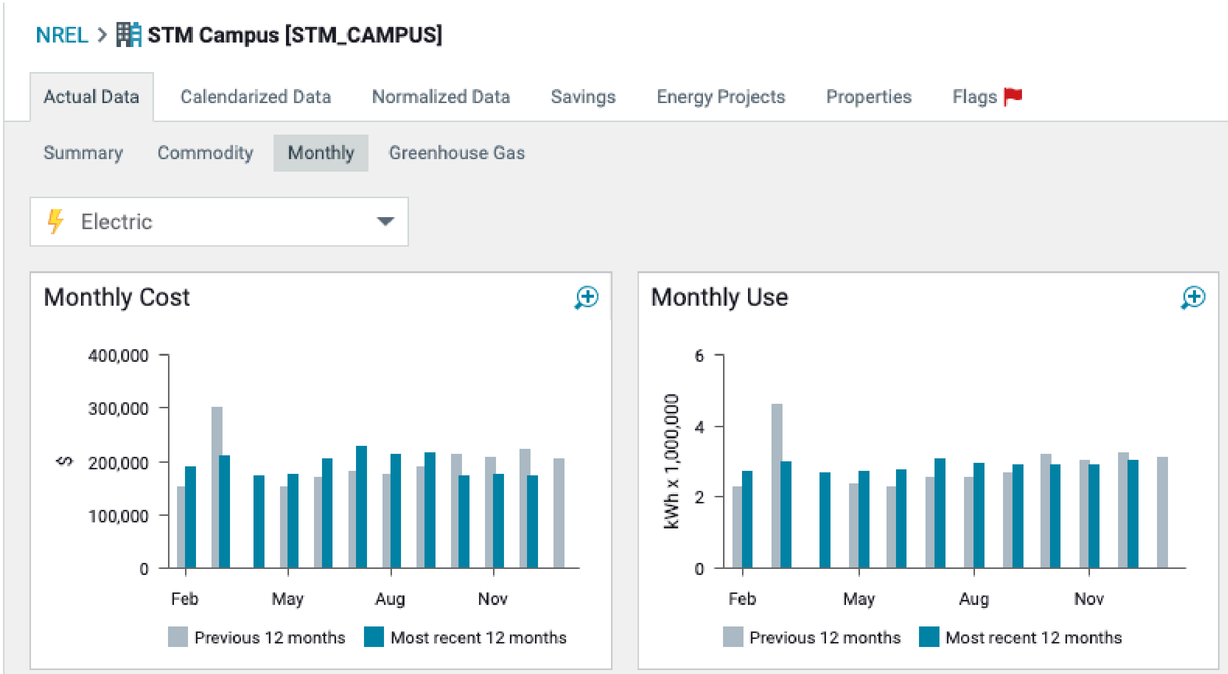

Figure 7. Example of EMIS usage and cost tracking

Image Credit: NREL, EnergyCAP

Benchmarking

Energy benchmarking is the practice of comparing a building's current energy performance with its historical performance or with the energy performance of similar types of buildings. Typically, this is done by converting energy usage from utility bills into common benchmarking KPIs, such as energy use intensity (EUI) or energy cost index (ECI), as noted above and detailed for agencies in the Federal Building Energy Use Benchmarking Guidance document (DOE 2014a). This section outlines four ways users can make use of EMIS benchmarking capabilities.

Cross-sectional benchmarking allows the user to visually compare a building to a set of peer buildings, which helps determine whether a building has potential to improve its energy efficiency (DOE 2017). Among a portfolio of buildings, it helps energy managers determine which building should be the highest priority for efficiency efforts. Figure 8 illustrates how cross-sectional benchmarking can be used across a large portfolio (71 buildings in this case) to compare each building's total building annual electricity usage (kWh/ft^2/yr.) to quickly identify which buildings have the highest energy use per square foot as compared to a group of representative peer buildings.

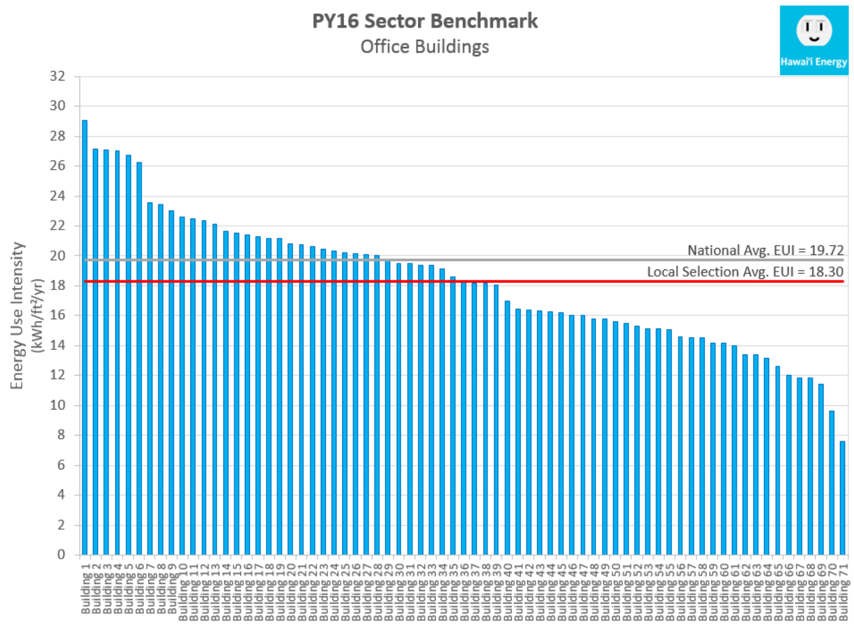

Figure 8. An example of cross-sectional benchmarking to compare buildings

Image Credit: Hawai'i Energy

Longitudinal benchmarking allows the user to visually compare a single building's performance to its historical performance to track energy savings over time (DOE 2015b). Given that a large number of federal facilities consist of a campus of buildings whose energy usage is rolled up to a single electric and natural gas utility meter, longitudinal benchmarking is often used in the federal sector to track EUI reductions for individual campuses, or at the agency level to track an agency's progress in meeting federal energy use reduction goals.

A *glidepath* is a combination of cross-sectional and longitudinal benchmarking that allows the user to visualize both scenarios at once (Figure 9). This can be useful in assessing the agency's progress toward its energy reduction goals and highlight any poor performing departments, regions, installations, or facilities (Granderson et al. 2011).

Figure 9. An example of a portfolio benchmarking glidepath

Image Credit: LBNL (Granderson et al. 2011)

Finally, two-way integration between the EMIS and ENERGY STAR Portfolio Manager allows EMIS users to automatically comply with the federal building benchmarking requirements and also use the 1–100 score provided by Portfolio Manager in EMIS benchmarking charts.

Bill Processing

Some organizations use an EMIS to perform a variety of accounting-related tasks to process utility bills. Bill validation features allow users to audit utility bills for errors such as incorrect meter readings or charges. As shown in Figure 10, the EMIS may provide simple visualizations to help the user spot issues, or automated error checking to spot utility bill errors automatically. The screenshot features the software detecting a duplicated invoice number.

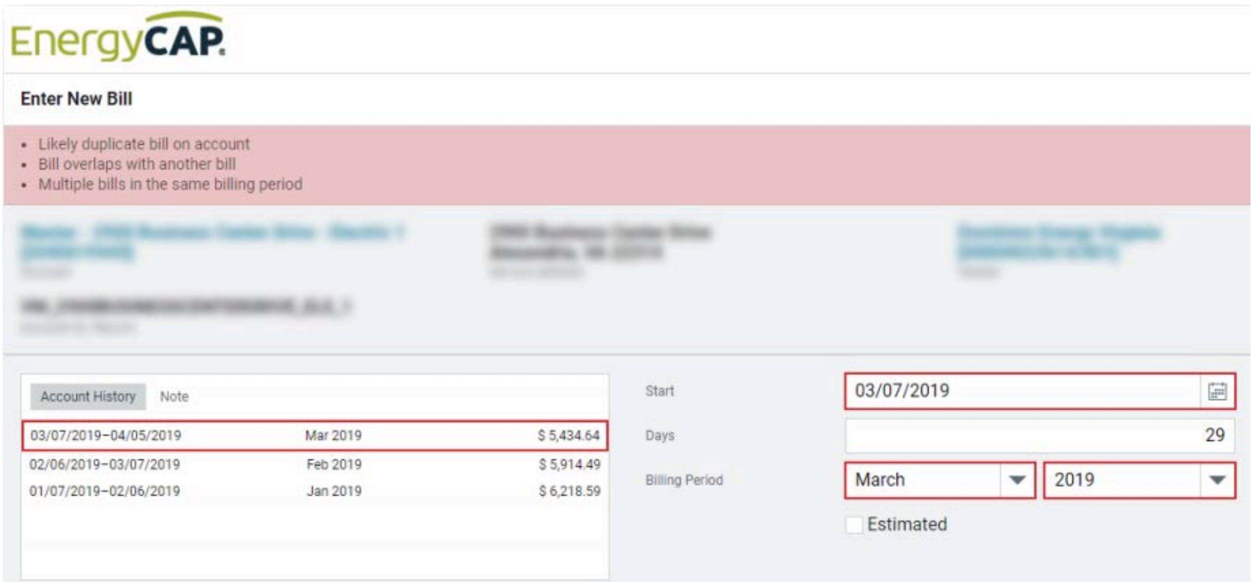

Figure 10. Example of a billing error discovered using bill validation

Image Credit: EnergyCAP 2020

Payment processing features allow users to streamline accounting processes, such as bill payments and cost reporting, and may include integration with accounts payable software. Budgeting allows users to use historical data to set predictions and budgets for upcoming time periods such as quarters or fiscal years. Internal or tenant billing tools allow users to allocate utility costs among different user groups and produce chargebacks or rebills. In the absence of submeters that show actual usage allocations, bills are typically divided up proportionally by tenant floor area, tenant nominal occupancy, or a similar known proxy metric.

Interval Meter Analytics

EMIS offer a variety of tools specifically designed to analyze meter data at intervals of one hour or less. These "interval data" offer far more granularity than monthly utility bills, and these tools excel at processing all that extra data in ways that help users find opportunities for performance improvements.

Advanced Bill Processing

Interval data allow users to enhance the utility bill processing capabilities discussed above. Advanced utility bill validation features allow the user to compare totalized data from federal AMI meters to the data reported on the utility bill. Advanced internal or tenant billing tools allow the user to allocate utility costs according to the actual usage of buildings, departments, or tenants.

Visualization

Interval meter visualizations are a well-documented and powerful EMIS feature for helping users analyze energy demand profiles over time. Daily and weekly profiling visualizations are used to understand how energy use changes based on the time of day or day of the week. A 24-hour period is often referred to as a daily profile. LBNL's Energy Information Handbook provides a detailed primer on how load profiles can be used to uncover three types of performance improvement opportunities (Granderson et al. 2011):

- Improving equipment scheduling controls and tailoring them to actual building occupancy (Granderson et al. 2011)
- Reducing base loads in offices and similarly operated buildings where the difference in energy demand between the base and peak loads can indicate whether unnecessary loads are running when not in use (Lin, Singla, and Granderson 2017)
- Reducing peak demand usage or utility demand charges (Granderson et al. 2011).

Heat maps are similar to profiles and are typically used to analyze longer time periods, such as a full year. The advantage of a heat map is the ability to leverage color as a third dimension to present a lot of data in a very compact space. They can also be easily combined with heating and cooling degree day data to compare demand data to weather patterns, such as in the example shown in Figure 11.

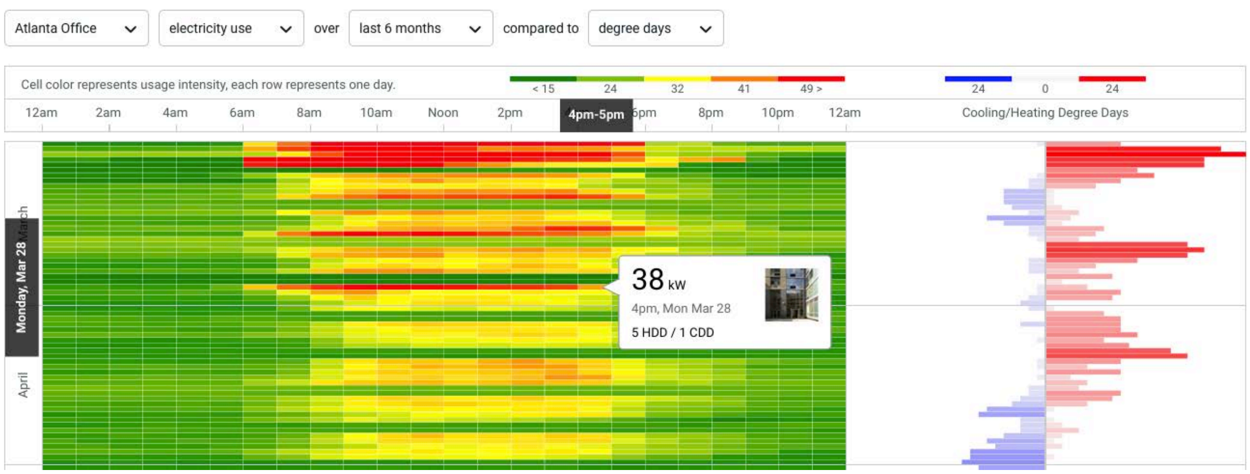

Figure 11. An example heat map matched with weather patterns

Image Credit: Lucid Design Group 2020

Some EMIS vendors also offer tools that match daily or weekly profiles to trends from underlying systems, allowing the user to determine the equipment loads that are most significantly impacting usage at the meter.

Applied Modeling

Another valuable type of interval meter analytics is based on the creation of a mathematical model of expected usage for each meter. The model is then compared to actual usage on a regular basis (e.g., hourly or daily) to uncover various opportunities.

Models are typically formulated using linear regression modeling tools in the EMIS, where the "dependent variable" (i.e., a meter usage at a given time), is defined based on the value of the "independent" variables, such as weather or occupancy conditions. Figure 12 provides an example of a single variable linear regression of electrical demand (kW) as a function of outside air temperature (°F).

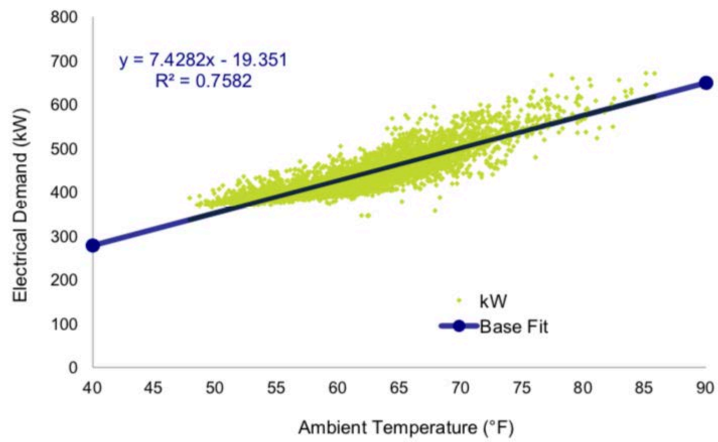

Figure 12. Applied modeling using linear regression

Image Credit: Bonneville Power Administration 2012

Single-variable change point models, such as those that use a balance point of 65°F, have historically been used to determine when either heating or cooling systems are enabled in commercial buildings. These models have been enhanced into three-to-four-point change models to more accurately predict building energy usage. One example of this type of model is the Whole Building Energy Module (WBE), a component of the Whole Building Diagnostician, developed by Pacific Northwest National Lab (PNNL), which tracks end use of the total building electrical energy via AMI interval data, sub metered end-use loads, or equipment-level submetering.[8] It provides a graphical record of building- or system-level performance and usage on a daily basis. The history determines constant variables or fluctuations for different times of the year. Over time, the daily performance history allows the user to identify major changes in energy consumption. WBE uses the following variables to predict and diagnose energy consumption: time of day, day of year, day of week, outdoor air temperature, relative humidity, and occupancy (PNNL 2020a). The WBE has been licensed by a number of EMIS providers. Others are using similar multivariable/point change point models.

Some emerging EMIS features provide automated modeling supported by machine learning or similar statistical packages. These models use recent energy use (generally the last 6–12 months) to keep the model continually updated without intervention from the user. Figure 13 provides an example of a machine learning program that is used to predict building load profiles for the day (shown in light grey), with the actual building load profile shown in light blue, and additional submetered data shown in yellow. These types of visualizations and models are helpful in identifying anomalies and for M&V as discussed below, and are used to automatically track energy savings over time (PNNL 2020a).

[8] See https://availabletechnologies.pnnl.gov/technology.asp?id=60

Figure 13. Machine learning model used to predict building load profile over the next 24 hours

Image credit: Prescriptive Data

Applied interval meter data models are typically not used independently, but instead can be used to aid the user in the following capacities:

- *Anomaly detection* compares metered usage to that predicted by the model. If metered usage surpasses the prediction by a certain threshold value, the EMIS notifies the user of an anomaly (Figure 14). Other types of anomaly detection include water leaks, gas leaks, and power outages.
- *Gap backfilling* features allow the EMIS to fill in missing data from the past, which is a common issue with AMI meters. The model determines the expected usage based on the building conditions during the outage and writes the modeled usage to the EMIS database. Note that gap backfilling can also be accomplished without models (e.g., with interpolation). The backfilled data is typically tagged to show the user that it is not metered data.
- *Forecasting* features use the model, along with a forecast of the independent variables (e.g., weather forecast) to predict the usage over the next 24 hours or several days.
- *M&V*, which is detailed in the M&V section below.

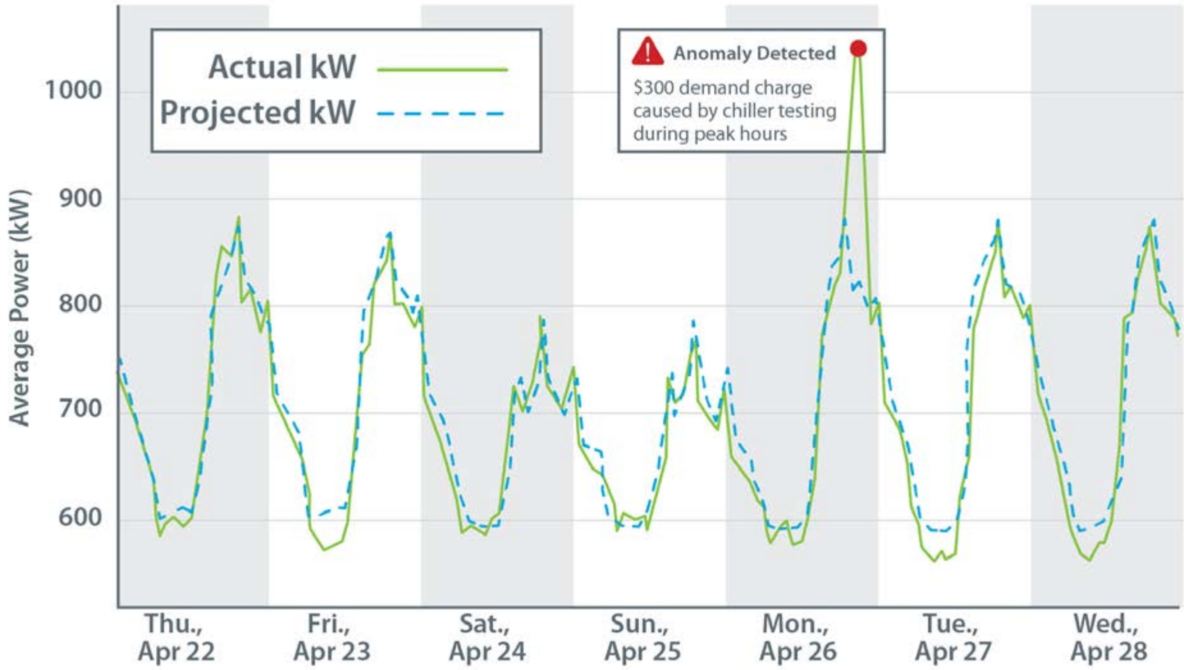

Figure 14. An anomaly detection algorithm identifies a spike in electric demand.

Image Credit: LBNL (Granderson et al. 2011)

Distributed Energy Resources Monitoring

EMIS can be used to monitor DERs, such as photovoltaics (Figure 15), and produce valuable KPIs such as energy production, displaced conventional electricity, and net energy use. Additionally, DER systems can be analyzed to evaluate the overall performance compared to expectations. For example, the performance of a solar array can be evaluated by comparing array output to local solar irradiance data (Granderson et al. 2011).

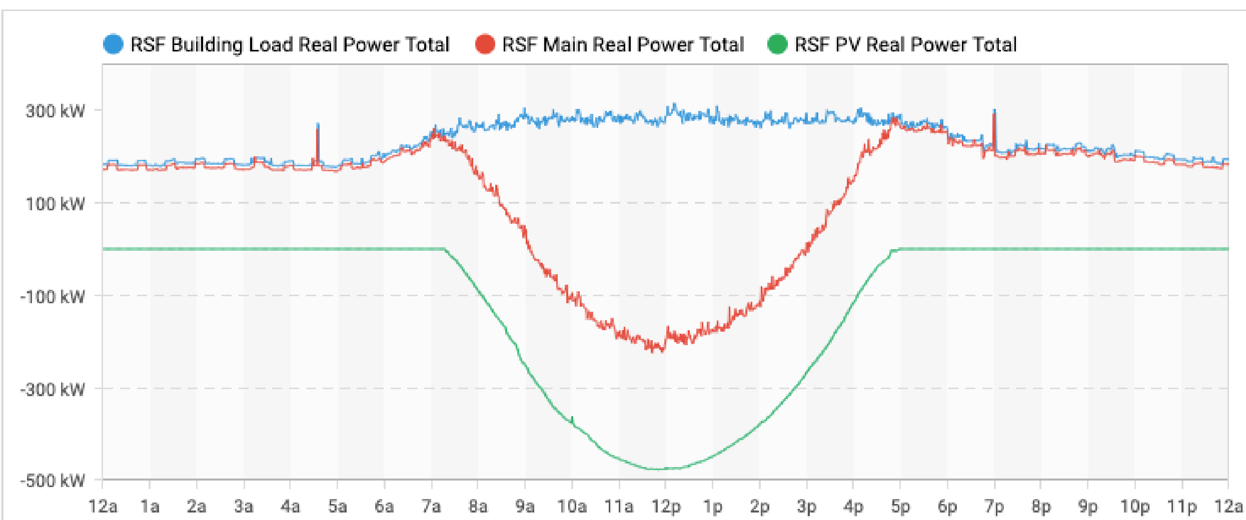

Figure 15. DER photovoltaic performance monitoring

Image Credit: NREL, SkySpark

Virtual Metering

EMIS users can leverage the computational power of an EMIS to create virtual points, including virtual meters. Virtual meters calculate an energy consumption value for end uses such as HVAC or lighting using static equipment data, engineering calculations, and live data from the equipment. Once individual pieces of equipment have been virtually metered, all similar end uses can be rolled up to determine the estimated total for that end use.

Automated Fault Detection and Diagnostics

AFDD is the process of identifying (detecting) deviations from normal or expected operation (faults) and resolving (diagnosing) the type of problem or its location (Lin, Kramer, and Granderson 2020). AFDD is an advanced EMIS capability that uses algorithms to detect equipment-level or system-level faults and diagnose their causes. It vastly reduces the time required to find these faults by standard methods, such as trend visualization and analysis (Building Commissioning Association [BCA] 2017). By continuously collecting data and analyzing it using rule-based algorithms, the analysis is automated and can be applied to very large data sets on a real-time basis. Several federal agencies such as National Aeronautics and Space Administration and U.S. Army Corps of Engineers also refer to AFDD as condition-based maintenance (CBM).

AFDD has been successful for many years in other industries; however, in the buildings industry, while popularity is growing, AFDD adoption has been relatively slow (Granderson et al. 2017). AFDD is most commonly conducted for HVAC or critical mechanical systems but is applicable to all systems in buildings. These tools are used to identify equipment and component failures, performance degradation, system design issues, controllability issues, operator overrides, and incorrect sequences of operation (BCA 2017). Incorporating AFDD tools can add value to agencies' operations and EMIS implementations in many ways, including:

- *Finding hidden issues*: Many building performance problems are masked and compensated for by other parts of the system, resulting in no detectable occupant discomfort (Granderson et al. 2011). AFDD tools can detect these and prevent them from increasing energy consumption or leading to larger operational problems or unexpected failures (Lin, Granderson, and Kramer 2020).

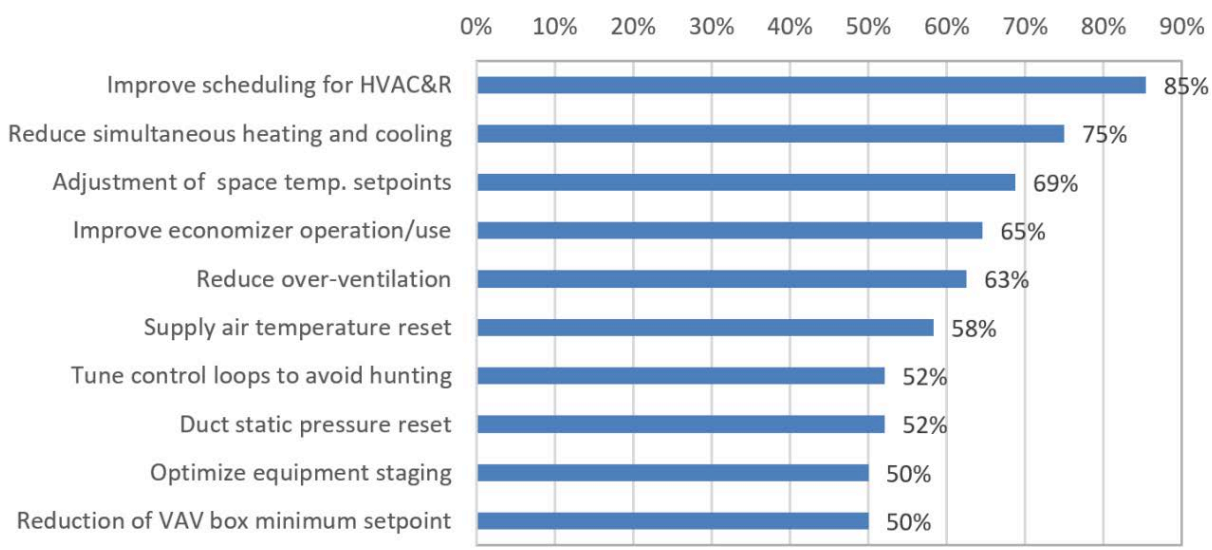

Figure 16. Common measures identified and implemented through use of AFDD technology

Image Credit: LBNL (Granderson et al. 2011)

- *Improving comfort with zone-level diagnostics*: Due to the sheer number of zones and terminal devices in large buildings, operators often do not have time to monitor performance at this level. AFDD transfers all this work to the software, which identifies for operators which terminal devices are malfunctioning, as shown in Figure 17. Each color represents a different fault, including variable air volume box reheat valves leaking, variable air volume airflow not achieving set point air flow, and variable air volume box airflow=0 when the variable air volume box should have been providing airflow to the zone.

Figure 17. Zone-level fault detection and diagnostics

Image Credit: NREL, SkySpark

- *Identifying root causes*: Many of the capabilities discussed above are valuable in the discovery of issues, but often the underlying cause of an issue is unknown (BCA 2017). AFDD can be paired with these other capabilities to indicate more specifically what can be done to improve operations. For example, a heat map may be used to determine that HVAC systems are running during unoccupied hours. AFDD tools would go further, indicating exactly which systems are the culprits and what the cause might be.

The software tools offering AFDD typically also offer additional capabilities, including many of those discussed in previous sections. Beyond those previously discussed, some important advanced capabilities are fault prioritization and hierarchical rule sets.

When AFDD software tools are applied to large buildings or a campus of facilities, the sheer number of identified faults can be overwhelming for facilities staff. Further, some faults are drastically more important to operators than others. Fault prioritization (Figure 18) is deployed in many AFDD products and is typically based on the estimated energy cost savings of correcting a given fault. There is a wide range of capabilities when it comes to AFDD’s ability to calculate accurate energy cost savings. Many tools are programmed with simplified rule-of-thumb calculations while others run in-depth equipment-level engineering analysis to calculate cost savings. The ability to accurately calculate energy savings and energy cost savings helps to prioritize faults for the building operator and is especially useful when deploying AFDD at scale across a large number of HVAC systems and buildings. The nonenergy benefits of correcting faults can also be used for prioritization, including equipment criticality, the size of the equipment, or the impact on occupant comfort.

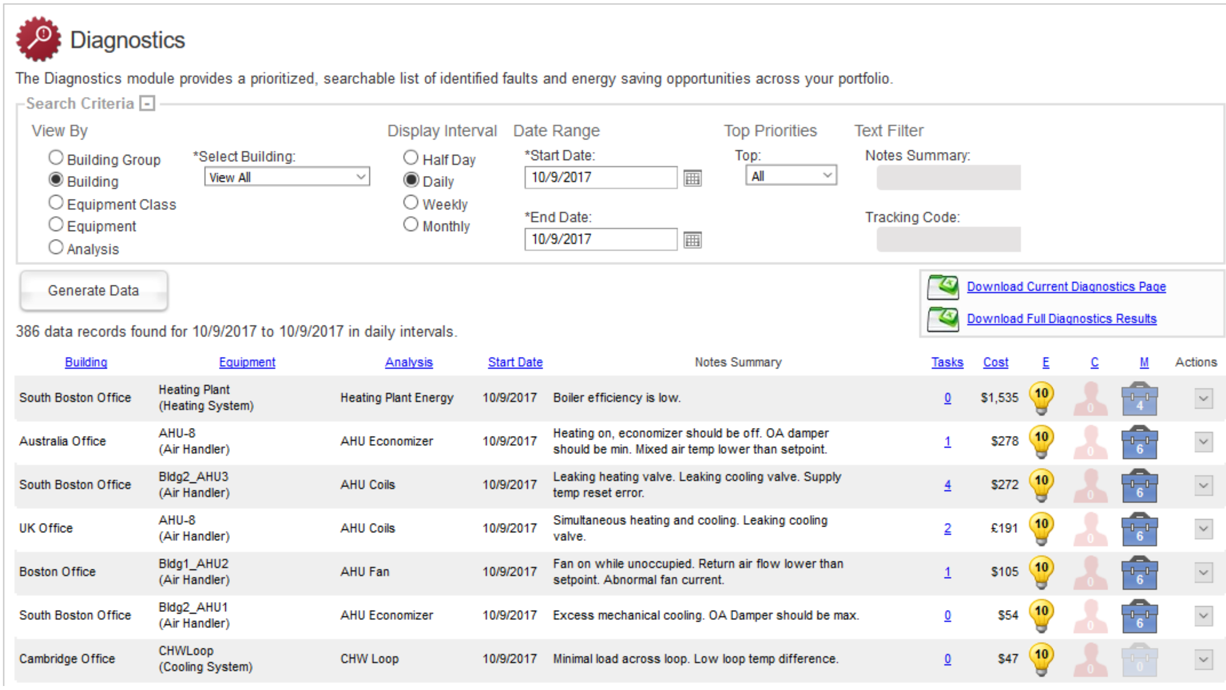

Figure 18. A prioritized list of faults detected

Image Source: KGS Buildings Clockworks 2020

Other programs let the facility operations staff deactivate rules for subsystems and focus on faults on chillers, boilers, and air handlers (for example). Identifying and correcting faults in these larger systems should always take precedence over correcting lower-level faults in terminal units and thermal zones. The National Institute of Standards and Technology (NIST) has also developed hierarchical AFDD schemas that essentially deactivate rules for subsystems until the faults in the larger systems have been addressed. In the NIST hierarchical rule schemas, it is recommended that all faults in central plants be addressed as a first step, followed by AHUs, and then terminal units (Schein and Bushby 2005).

Automated Fault Detection and Diagnostics Approaches

There are many different approaches to deploying AFDD and integrating it into a given building's operation. While the varying approaches can be a challenge for agencies trying to understand what is available in the vendor marketplace, the following considerations can help filter and substantially narrow the field. The three primary approaches to identifying faults are rule-based diagnostics, physical model-based diagnostics, and black box methods that include statistically driven models such as regression models, artificial neural networks, and other pattern recognition techniques (Katimapula and Brambley 2005).

Rule-Based Diagnostics

Rule-based diagnostics are the most common approach today. They use simple engineering equations and relationships to identify suboptimal operation of individual pieces of equipment and systems.

Physical Model-Based Diagnostics

Physical model-based AFDD is typically categorized as either a detailed or simplified physical model. Physical models are based on mathematical models of the monitored plant, process, or entire building. At the system level, a model is constructed of a given piece of equipment (such as a large centrifugal chiller) based on the nameplate performance ratings, operational schedules, performance maps, and the targeted control sequence for the given piece of equipment (Katimapula and Brambley 2005). In a physical model, the behavior of the system is modeled based on a given set of measured inputs (e.g., outside air temperature, time of day) and the given model parameters (e.g., performance specifications, control sequence), and the modeled output variables are compared to measured performance to diagnose suboptimal performance. Detailed whole building energy models offer the potential advantages of providing real-time diagnostics to systems that are not tied into a centralized control system, such as plug loads and lighting systems. Whole building energy models can also help determine how well more sophisticated energy conservation measures are performing, such as an optimal start/stop control sequence for a given AHU versus using a more simplified mass/capacity factor for the building.

Black Box Models

Black box models differ from physical models in that there is often no need for prior knowledge of the physical systems and characteristics and are purely based on qualitative relationships. Qualitative relationships are based on measured process histories and mathematical pattern identification models. For example, a black box model of a chiller plant would consist of measuring electrical energy use over time and correlating it to time of day, outside air temperature, and outside air humidity.

Once the system operation is determined to be optimal by on-site facilities staff, an acceptable standard deviation can be defined and used to detect suboptimal operation. Model-based and black box methods are growing in popularity with increases in computing and machine learning/artificial intelligence capabilities. These methods provide some advantages over rule-based approaches, including the reduced time and effort required to set them up and therefore increased scalability over large portfolios.

Some AFDD software platforms are flexible enough to utilize all three types of FDD, while others provide only one type.

Customization

Some EMIS vendors provide an open platform and let on-site users and/or third-party engineering firms write and deploy custom AFDD algorithms, while other vendors have developed a library of proprietary algorithms that they apply to specific systems in a one-size-fits-all manner. For example, a vendor might have a predefined set of chillers, AHU, and variable air volume box terminal unit rules. When evaluating vendors, agencies should consider the level of customization needed for their desired EMIS scope and capabilities.

Automated Fault Detection and Diagnostics via Monitoring Based Commissioning

MBCx is the continuous application of the commissioning process to a building or energy system and is an effective method to keep energy costs low and minimize system problems that may be caused over time by building performance deterioration and changes to building operations (Swegon Air Academy 2017). The term MBCx includes (1) MBCx software tools that collect data from BAS and AMI and perform analytics to identify performance improvements, and (2) MBCx processes for implementing and verifying improvements made based on the analytics. AFDD of BAS data is one of the primary capabilities in MBCx, and MBCx is typically considered a level 3 EMIS, as defined in Figure 39 in the EMIS Planning section below.

Supervisory Control

Typically, the capabilities described above share a common attribute: improvements in building operation are achieved if operators act upon the information provided by the EMIS (California Energy Commission 2011). In other words, each opportunity identified by EMIS is an open loop that human operators need to close to create value. In addition, for the above capabilities, there is typically a one-way communication of data from the underlying system to the EMIS. Supervisory control capabilities are an emerging set of features that close the loop automatically, allowing the EMIS to make automated changes to underlying building systems, much like an airplane or self-driving car’s autopilot function.

The following sections outline emerging types of supervisory control offered by EMIS vendors. Agencies should note that executing supervisory sequences can be challenging because one needs to ensure the commands provide the proper level of authority over, and do not conflict with, underlying control sequences.

Setpoint Enforcement

Simple supervisory control sequences are being deployed in solutions such as the Navy Smart Grid to ensure space temperature setpoint compliance across all Navy buildings on a given base. This strategy is also used to ensure AHU start and stop time schedules match building schedules. This type of simple supervisory control can be very beneficial for federal energy managers in ensuring buildings are operated to federal standards. Note that this type of supervisory control need not occur automatically. An example is shown in Figure 19, which features the ability to turn lights on and off and change the temperature setpoint.

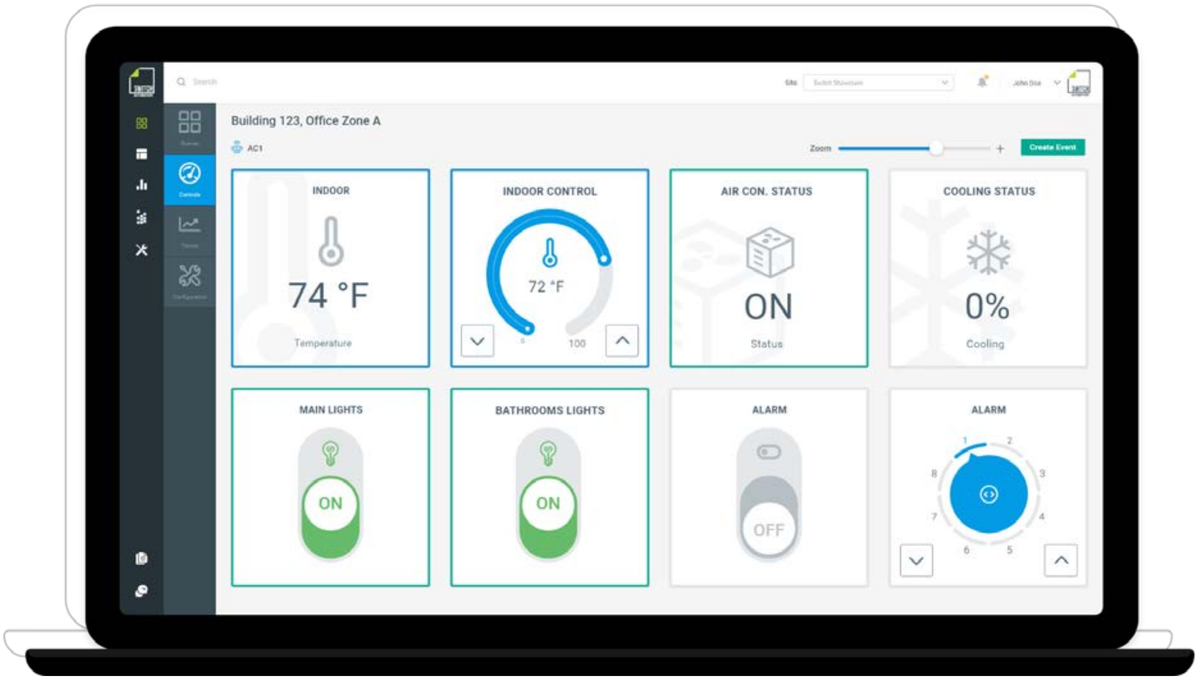

Figure 19. Simple supervisory control capabilities

Image Source: Switch Automation

Automated System Optimization

Automated System Optimization (ASO) is a type of supervisory control that uses a parameter optimization algorithm (Guild, Koeppel, and Hilger 2012). Typically proprietary and focused on HVAC systems, it performs analyses on multiple variables and sends commands to the BAS to optimize both comfort and energy savings. The software continuously adjusts setpoints to satisfy changing building loads in a more efficient way (California Energy Commission 2011).

While the list of vendors and systems targeted is evolving, ASO tools are predominantly focused on variable flow central plant and primary air distribution equipment. Further, some vendor solutions are targeting only one type of system, such as chilled water plants, whereas others provide options and flexibility in system type.

An example of an ASO algorithm is chilled water plant optimization, which is designed to reset the chilled water supply temperature and condenser water supply temperature setpoints based on real-time conditions at downstream AHUs (Figure 20).

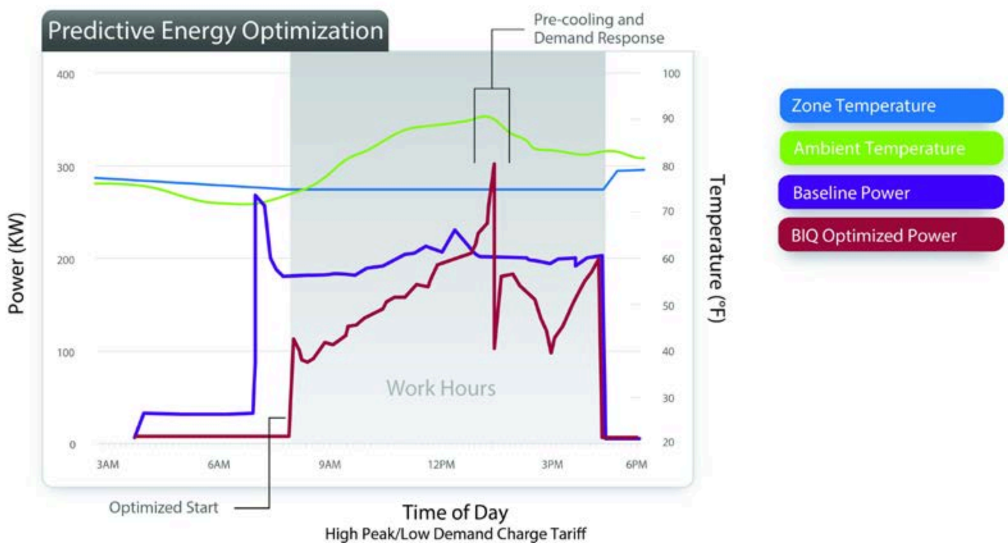

Figure 20. An example of automated system optimization

Image Source: Clean Technica and BuildingIQ (2014)

One consideration for agencies is whether the building is already equipped with the necessary hardware, such as variable frequency drives and sensors, to accomplish the optimization sequences provided by ASO. If not, the first cost of this solution can be very expensive.

Demand Management

EMIS can help support agencies' demand management initiatives to reduce utility costs in two ways: utility-initiated and building-initiated reduction. Utility-initiated reduction occurs when the electric utility sends control signals or requests to the building to reduce demand. This can be accomplished through dedicated protocols, such as OpenADR, that communicate directly with the EMIS or directly to the BAS. Building-initiated reduction is when the facility operates equipment assets to deliberately achieve demand reductions and reduce utility costs. Because building-initiated demand management depends on integrated, organized, and accessible data to perform reliably, an EMIS can be a powerful tool for implementing these strategies (Cutler et al. 2016).

Grid-Interactive Efficient Buildings

GEBs are an emerging interest area for DOE and will continue to grow in significance for federal agencies (Neukomm, Nubb, and Fares 2019). Growing peak electricity demand, infrastructure constraints, and an increasing share of variable renewable electricity generation are stressing the electrical grid. Flexible and dispatchable electricity loads, like those inherent to buildings, can be used to reduce grid stress. EMIS can interact with the utility grid, sending and receiving signals and initiating supervisory control over end-use systems connected to the EMIS.

GEB can manipulate energy assets, such as traditional power-consuming assets like lighting and HVAC, along with on-site resources like rooftop photovoltaics, EV charging, and battery storage. Depending on the availability of grid data (and associated revenue streams), GEBs can respond to grid needs while providing economic benefits to the agency. Additional benefits from pursuing a GEB strategy can include better system integration and control, increased resilience, and reduced utility costs.

As detailed throughout this technical report, EMIS can be the backbone of the energy efficiency improvements required to set the stage for GEB. Beyond efficiency, advanced EMIS analytical solutions can play a significant role in load-changing functionalities (commonly referred to as shed, shift, and modulate) required for GEB in the following ways:

- Two-way communication of signals between buildings and the grid
- Monitoring, predicting, and learning from building-level conditions (occupant needs and preferences) and outdoor conditions (weather and grid needs)
- Coordinating and executing complex control strategies that adapt based on changing conditions over multiple time scales
- Estimating and verifying the energy and demand savings of different strategies and impacts from stochastic building conditions (e.g., occupancy behavior)
- Deciding among multiple strategies to optimize efficiency with flexibility and occupancy comfort (Neukomm, Nubb, and Fares 2019).

Automated Performance Testing

Another emerging supervisory control capability is the ability for EMIS to automate equipment and system performance tests. Normally part of the commissioning process, performance tests involve executing commands to simulate the system's full sequence of operations and determine compliance.

Using an EMIS, the execution of these tests can be transformed from a manually executed, time-intensive process to an automated process with many benefits beyond time savings, including the ability to test 100% of equipment instead of the industry standard sampling approach that leaves up to 90% of equipment untested. The results of the tests can then be captured and documented using AFDD functionality (Rohloff and Meacham 2016).

Centralize, Normalize, Visualize Data

Beyond the more traditional and specific capabilities listed above, an emerging EMIS function is to centralize data streams together from different sources to allow for visualization and comparison. This drastically reduces the time required to analyze data and create reports for stakeholders. Advanced visualizations allow users to spot patterns in the data that would be difficult without the help of the software tool.

Centralization, normalization, and visualization of facility data through well-designed user interfaces can boost situational awareness, enable portfolio management via a single interface, and promote energy awareness among building occupants (Cutler et al. 2016). All of these are enabled by and depend on the well-curated data that an EMIS provides. The following sections provide more detail on important components of centralizing, normalizing, and visualizing data: the user interface, KPIs, reporting, and advanced visualizations.

User Interface

The user interface is designed to allow the user to efficiently navigate, analyze, and interact with EMIS data and represents the core functionality associated with centralizing, normalizing and visualizing data. User interface designs can vary based on many factors, and some are even configurable by the user. Some organizations prefer the EMIS to look the same for all users, and some vary the look based on the user's role. For example, an energy manager may care about energy-related metrics, whereas a facility manager prioritizes comfort or O&M related metrics.

A primary feature of EMIS user interfaces is the visualization of data using charts—either stand-alone or grouped into dashboards. As shown in Figure 21, a dashboard can be customized and arranged according to the needs of the EMIS user (MACH Energy 2020). Some vendors even allow users to create their own dashboard design. This example shows yesterday's electric usage compared to expectations and today's electric usage, allowing the user to act on any deviations from expectations.

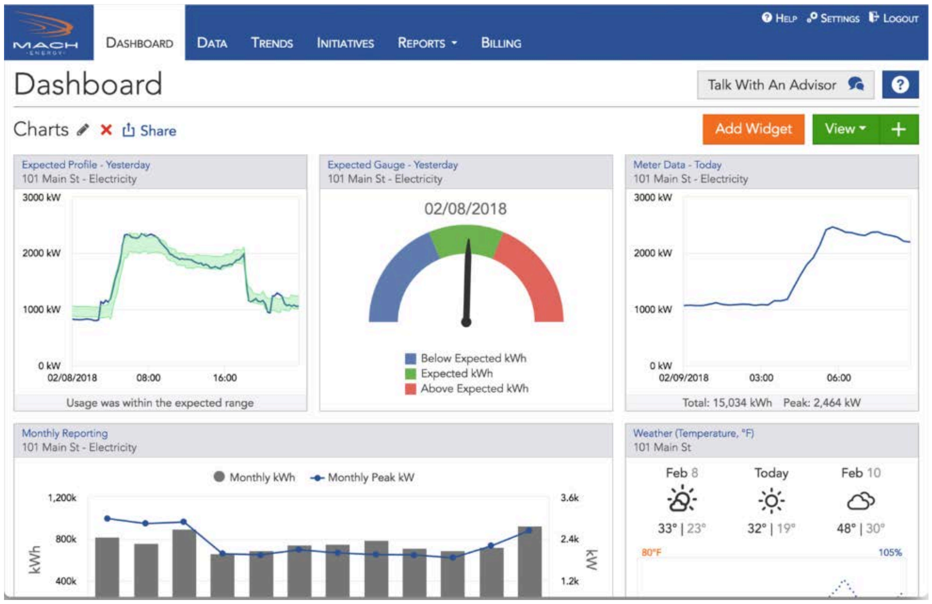

Figure 21. An example of EMIS charts grouped into a dashboard

Image Credit: MACH Energy 2020

Key Performance Indicators

A KPI is a metric (California Energy Commission 2011) that can be tracked and compared to historical or expected values to describe building performance, allowing the identification of when systems deviate from expectations to prompt corrective action (BCA 2017). While underlying systems, such as BAS, can track thousands of points within a building, a KPI combines data from multiple points to provide deeper meaning. For example, Figure 22 provides summary KPIs for AHU fan runtime per building, a daily range of building electric demand in kW, daily building energy usage, and so on. KPI views like this are helpful for quickly scanning the portfolio or building to determine areas of focus and find outliers.

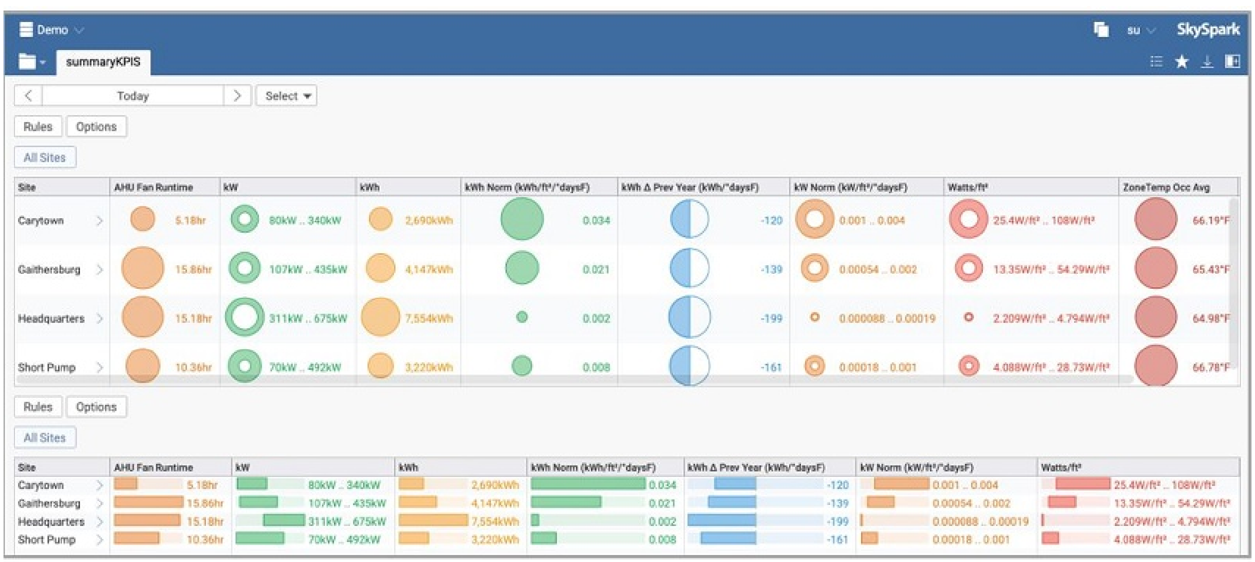

Figure 22. Example of EMIS KPIs displayed as bubble and bar charts

Image Credit: SkySpark

KPIs can be designed based on the agency's goals and performance targets. They can vary in type (e.g., energy, operations, comfort, emissions, project performance) and scope (e.g., portfolio, utility, building, system, equipment, and zone). Several example KPIs are provided below:

- Normalizing energy use or costs by building area to compare buildings: EUI (kBtu/square foot/year) and ECI ($/square foot/year)
- Tracking the chilled water plant kW per ton of cooling delivered to measure how efficiently the plant is operating
- Tracking the percentage of time when zones are within their temperature setpoints to assess performance at a glance and check for improvement or degradation over time (California Energy Commission 2011).

Once KPIs are calculated, EMIS software also allows users to overlay them into dashboards and other visualizations to further aid in discovering opportunities. For example, chilled water system and equipment graphics can be supplemented with the kW/ton KPI discussed above. Or, as shown in Figure 23, portfolio-level KPIs, such as EUI (in kBtu/ft^2/yr) or ECI, can be overlaid onto maps of the portfolio providing a bird's eye view of EUI for all facilities, with the largest circles representing the buildings with the highest energy usage per square foot.

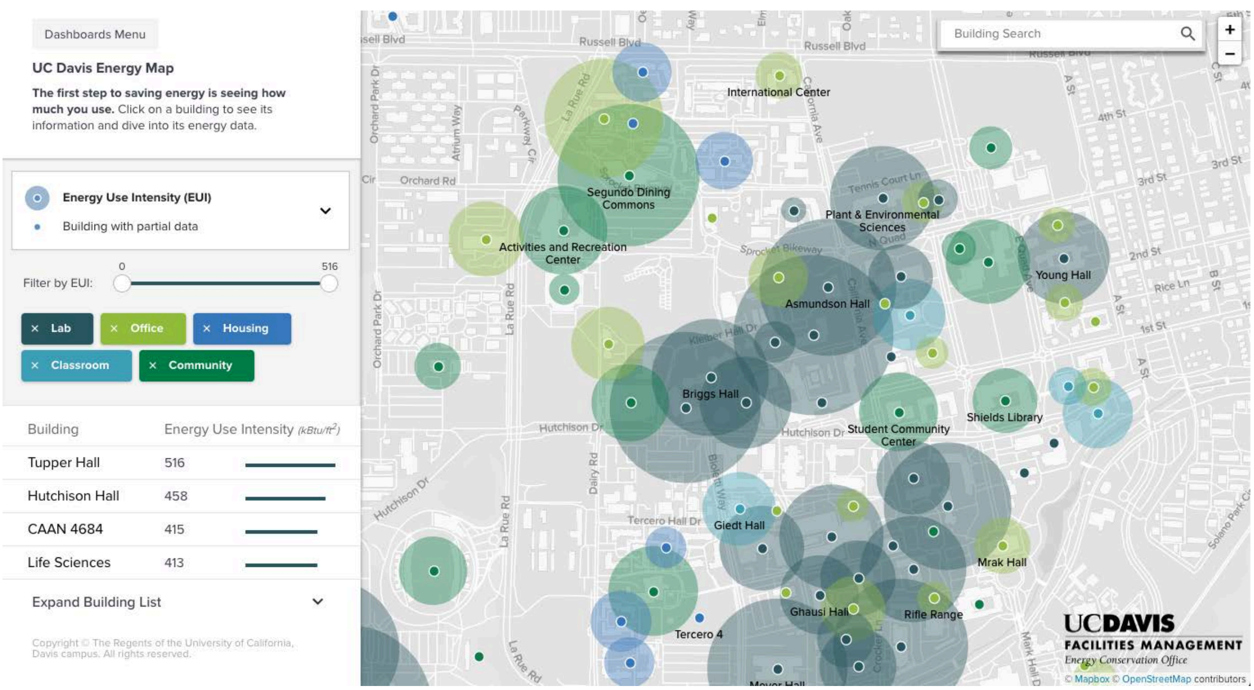

Figure 23. An example of an EMIS map with overlaid KPI data

Image Credit: University of California Davis 2020

Reporting

Another core function of centralizing, normalizing, and visualizing data is the ability to create reports. Similar to dashboards, reports provide sets of charts or tables in different configurations to meet the user's needs. Some reporting tools provide the ability to automate the export of reports to external recipients at regular intervals, and many advanced users are using this functionality to replace time-consuming manual reporting requirements.

In addition to customized internal reporting, a specific and increasingly important EMIS reporting function is to process energy data into formats required for corporate or organizational sustainability or greenhouse gas reporting. As discussed above in Supporting Compliance with Federal Laws and Regulations, EMIS reporting can be helpful for fulfilling obligations to stakeholders external to each agency.

Advanced Visualization

Advanced visualizations are tools for centralizing, normalizing, and visualizing data that provide additional insights compared to the typical bar, pie, or line charts. Primary use cases are in drilling down into system operation to determine root causes of faults or to verify whether system changes had the desired outcome. EMIS enables the user to view data from disparate sources (e.g., electrical demand, weather, and building operations) simultaneously to better understand root cause of unexpected or energy intensive operations.

Advanced time series plots allow the user to combine various data sources together (Figure 24). Notice how this visual provides a clean view of four different types of BAS points: temperature sensors, a damper output, a fan speed, and a fan's on/off status. This allows EMIS users to easily look for patterns and opportunities for improvement.

Figure 24. Example of a time series plot combining different data types

Image Credit: NREL, SkySpark

Similarly, scatter plots are valuable for analyzing relationships between system performance and outside air temperature to assess the efficacy of the control of temperature dependent loads (Granderson, Lin, and Piette 2013). Further, scatter plots are used to plot system heating or cooling output (load) compared to the energy required to produce that load, such as with a chilled water plant kW versus the tonnage it is producing (Granderson et al. 2011).

Box and whisker plots show the user how the values in the data are spread out and are useful when comparing many similar pieces of data. For example, they can be used to view the chilled water valve output for every AHU over the previous week to look for outliers, as shown in Figure 25.

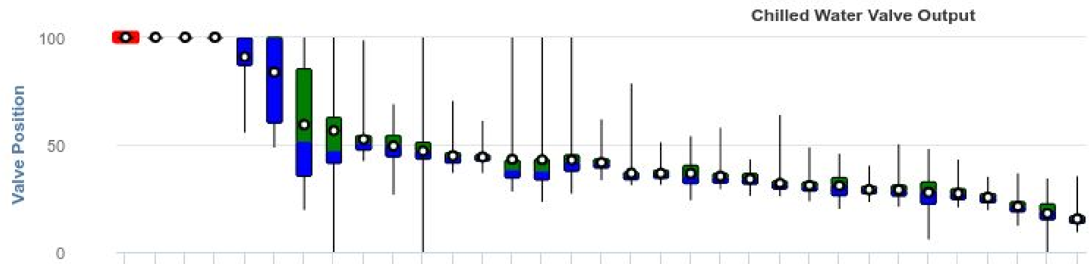

Figure 25. Visualization of AHU chilled water valve position using box and whisker chart

Image Credit: Talisen Technologies 2020

Measurement & Verification

M&V capabilities allow EMIS users to quantify and verify the energy savings performance of individual ECMs or efficiency projects. These tools use data from monthly utility bills, interval meters, and BAS, and typically include some sort of reporting functionality.

The International Protocol for Measurement and Verification (IPMVP) (Efficiency Valuation Organization 2015) was created to encourage consistency in how savings calculations are made (Efficiency Valuation Organization 2020). It details the principles, methodology, options, and M&V plan requirements for compliance. EMIS tools are designed to facilitate and automate the statistical and mathematical calculations inherent to each of the options. While all options are technically possible to execute using EMIS, Option C: Whole Facility is the approach most commonly provided by EMIS vendors.

IPMVP Option C

IPMVP Option C requires the creation of a mathematical model of "baseline" usage, which describes how the building operated in the past. Models are typically formulated using linear regression modeling tools in the EMIS, where the "dependent variable" (i.e., meter usage at a given time), is defined based on the value of the "independent" variables, such as weather or occupancy conditions. See LBNL's Energy Information Handbook for a primer on creating baseline models using this method (Granderson et al. 2011). Some EMIS vendors provide automated baseline modeling features supported by machine learning or similar statistical packages, which can save time for EMIS users responsible for a large portfolio of buildings.

The projected usage produced by the baseline model is then compared to actual usage and the difference is the avoided usage, or savings (Figure 26). For example, a baseline period might be the year preceding a retro-commissioning or retuning project. Once the project is complete, the historical baseline model uses current weather conditions to calculate what the energy use would have been if the improvements had not been made, typically referred to as the "projected" usage. When the current energy usage is less than the projected usage, this is an indication of the amount of energy the project is saving (Sitton Energy Solutions 2020).

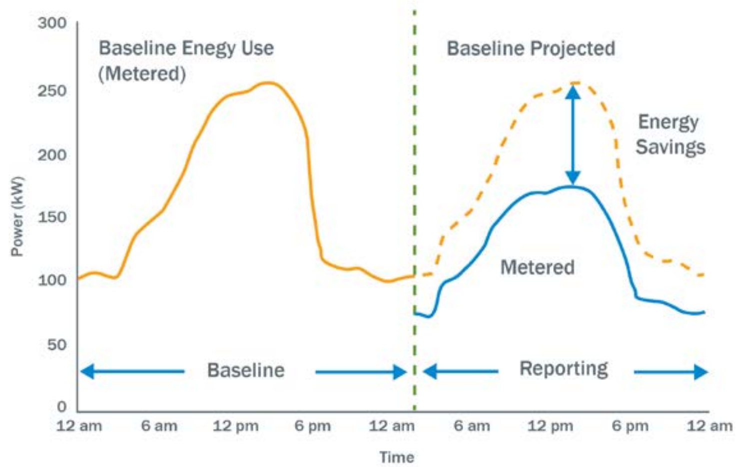

Figure 26. Annotated example of comparing projected to actual usage

Image Credit: LBNL (Granderson et al. 2011)

Typically, EMIS vendors provide tools to further visualize and convey energy savings. One example is a cumulative sum chart, which quantifies total accrued savings over time (Granderson et al. 2011). This can be valuable for helping federal energy managers to automatically track savings over time, especially the results of energy savings performance contracts (ESPCs) and utility energy service contracts (UESCs). It can also aid in federal reporting through FEMP's Compliance Tracking System and ISO 50001 Ready requirements.

M&V with Interval Data

As AMI meters have increased in prevalence, some EMIS vendors have added advanced M&V capabilities taking advantage of the increasing granularity of available meter data. These enhancements can benefit EMIS users in many ways, including providing early warning signs of savings degradation and providing more actionable insights (KW Engineering 2020). Figure 27 shows an hourly estimate of the baseline usage (red) overlaid with the actual hourly usage (blue), indicating significant electric savings.

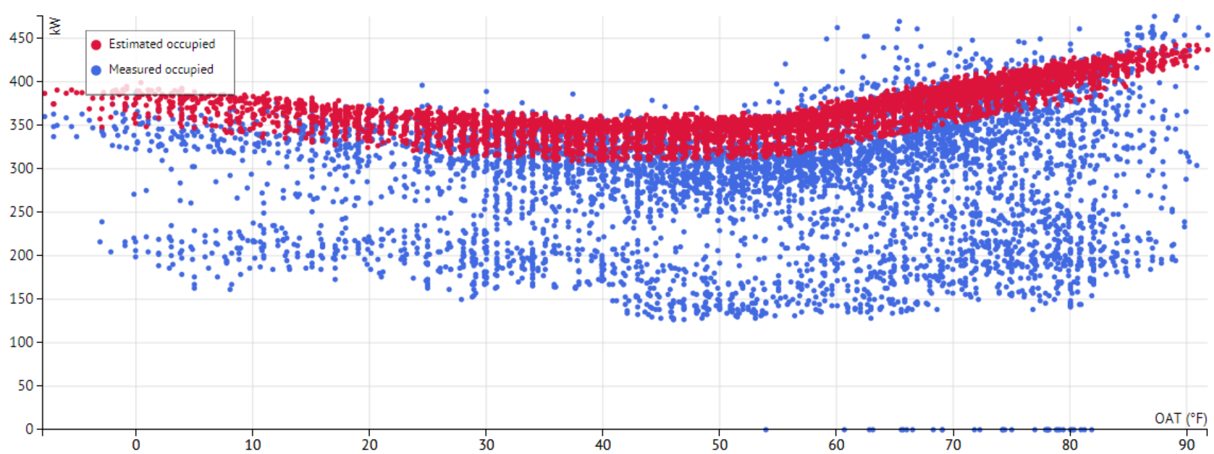

Figure 27. M&V with interval data

Image Source: KW Engineering 2020

Operational Verification

Another key M&V activity detailed in the IPVMP is operational verification, which entails making sure implemented ECMs are installed, commissioned, and performing as intended (KW Engineering 2020). In addition to field verification of the installation, EMIS users can utilize visualization and analytics tools to review system operational data and verify performance across all modes of operation.

O&M Optimization

As detailed in the EMIS Operation section below, EMIS software is most effective when heavily integrated with an effective EnMS like DOE's 50001 Ready and other O&M processes. Many EMIS vendors offer tools or assistance to help support this integration. These tools increase O&M efficiency in three primary ways:

- Simple issue tracking
- Connecting to a CMMS to communicate work order information
- Generating predictive or condition-based maintenance recommendations.

Issue Tracking

As opportunities for performance improvement are identified using EMIS, the EnMS team can make sure the people side of the action is completed and can be managed through to resolution using built-in issue tracking capabilities. An example is shown in Figure 28. Users can assign the issues to an owner, such as O&M staff or external service providers. Typically, once assigned, all stakeholders can interact and discuss the issue through comments until the issue is closed. Other options include mobile support, email subscriptions for updates to issues, and the ability to filter the list of issues by metadata such as assignee, equipment, or issue type.

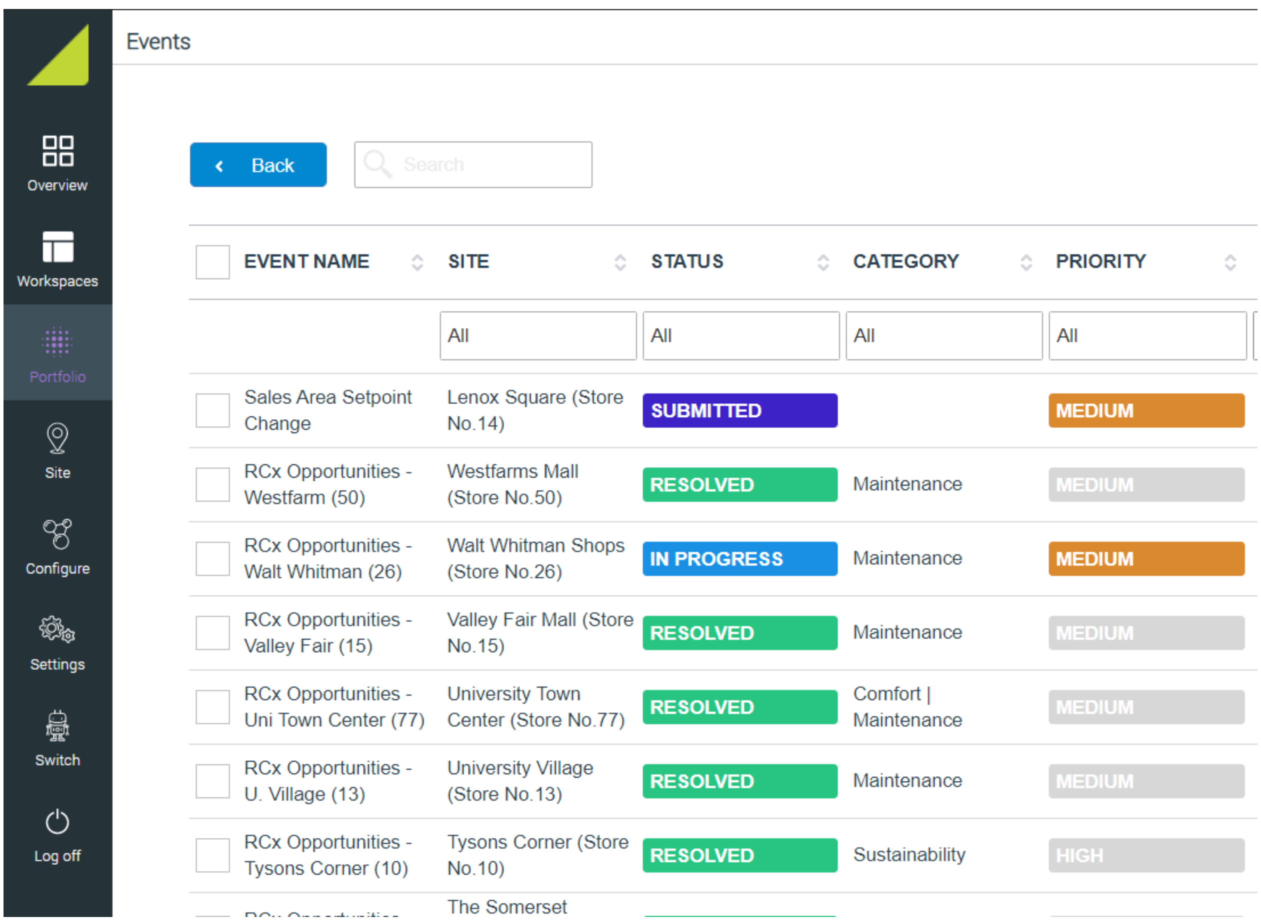

Figure 28. Built-in issue or opportunity tracking capabilities

Image Source: Switch Automation 2020

Work Order Generation and Management

In addition to simple issue tracking, an additional capability of EMIS is the integration with the agency's CMMS software. Users have the ability to set up automated or manual work orders from within the EMIS, which are pushed into or pulled from the CMMS software for resolution. Further, if two-way communication between the two systems is established, EMIS users can receive feedback on the work order completion to help streamline the tracking of issues.

Additionally, data visualization and KPI capabilities inherent to EMIS can be used to provide summaries of O&M data, such as tracking and time estimates for maintenance (mean time to repair), time between failures (mean time between failures), time for replacement, and downtime of active devices. A benchmarking analysis by device, building/utility, or region can be used to draw comparisons to standards or other buildings within the agency.

Condition-Based and Predictive Maintenance

Traditionally, O&M staff have practiced either calendar-based maintenance, where there is a fixed schedule, or reactive maintenance, where equipment is repaired or replaced only after failure. CBM and predictive maintenance practices enable more proactive, informed decisions by detecting the onset of performance degradation and allowing the user to correct the issue prior to failure or detection by building occupants. An emerging EMIS capability uses equipment data collected from underlying systems and integrated CMMS to generate these recommendations. Common examples include:

- Analyzing the differential pressure across a filter in an AHU can alert O&M staff when filter replacement is required, rather than changing the filter out at some predefined interval, as is standard with preventive maintenance.
- Detection of a reduction in heat transfer across a heat exchanger, calculated using the difference between temperature sensors, can assist in the scheduling of tube cleaning or a modification to chemical control measures.
- Detection of system parameters operating outside of their normal operating ranges using Advanced Pattern Recognition and machine learning technology enable the application to learn the unique operating profile for each asset during all loading, ambient, and operational process conditions. For example, CBM vibration sensors can detect anomalies of motors and turbines at hydroelectric dams, facilities, and non-covered structures and can alert O&M staff when equipment replacement is required.

Due to increased digitization of facilities, much of the equipment installed is already provided with instrumentation that can be used to provide the data required for the above analyses. Where the instruments are not present, sensors can be installed and integrated with EMIS (Sullivan et al. 2010).

The insight into real-time performance of building equipment enables maintenance programs to be conducted based on the current or predicted performance of that equipment, benefiting the agency by reducing equipment failure rates, avoiding the labor costs required to check on equipment status, and performing unnecessary maintenance.

EMIS Scope

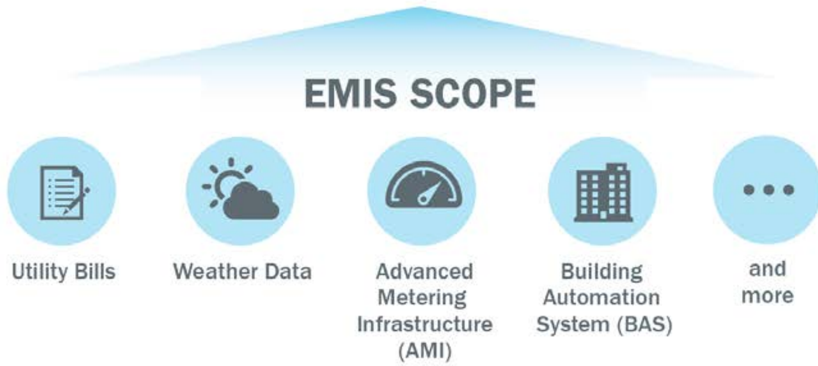

Figure 29. The Scope component of the EMIS framework

Image Credit: NREL, James Dice and Fred Zietz

While the potential capabilities of EMIS can be vast and powerful, they depend heavily on the underlying systems with which they connect and their associated data. The scope of the EMIS includes the systems with which it is integrated. Potential scope systems, as detailed in this section, are shown below in Figure 30. Although EMIS can provide value when it includes just a few types of data, the ability to generate new insights and organizational value grows as the scope expands. For more information on scope, see https://www.energy.gov/eere/buildings/grid-interactive-efficient-buildings.

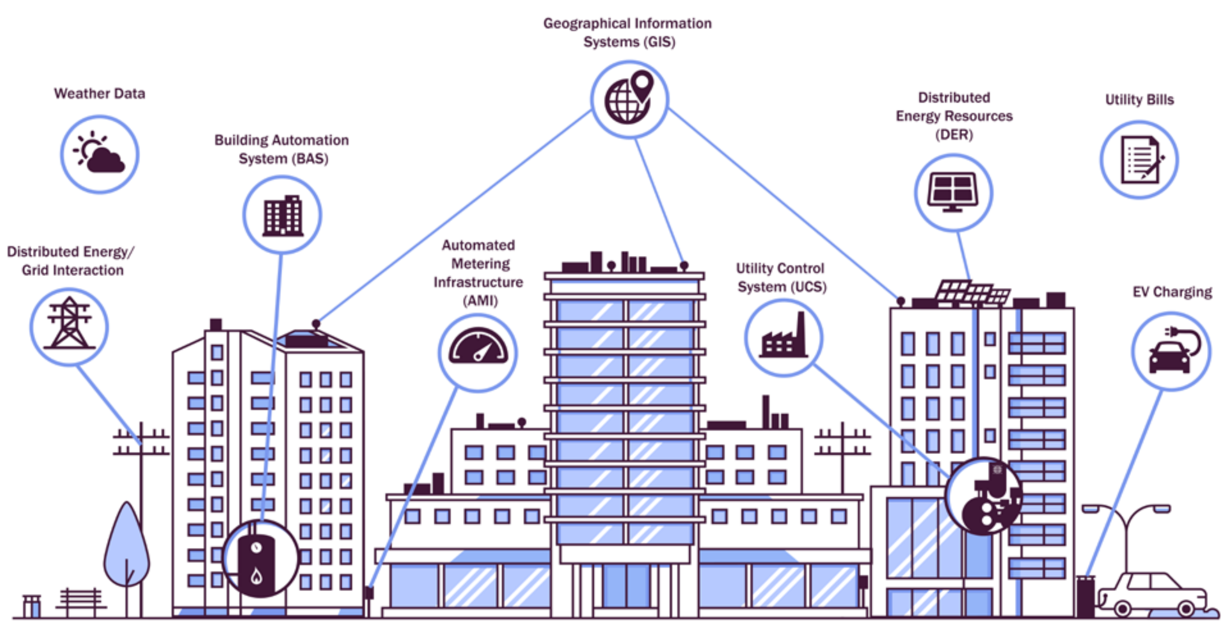

Figure 30. Potential EMIS scope systems and data sources

Image Credit: NREL, James Dice and Fred Zietz

Communication between an EMIS and any underlying system involves integration of data via common communication standards called protocols. For example, BAS communication protocols include BACnet, LonWorks, and a vast number of proprietary protocols offered by control systems manufacturers. Additional protocols—such as Modbus—are widespread in the electric utility industry, AMI installations, and are commonly used in a variety of other building and utility control systems (Cutler et al. 2016). Data integration converts all of these time series data into a single format and database. Depending on the integration method, this process can be time consuming and expensive if the scope system was not installed with communication in mind. This is a key consideration in the planning process, as outlined later in this document.

Once integration is complete, many EMIS applications need to be supplemented with static and dynamic data, often called metadata that describes the facility itself and provides context. When combined with flowing time series data, metadata provides context for the execution of analytics capabilities. For example, a turnstile occupancy counter can provide the EMIS information on the number of occupants at a given time and space. The number of occupants over time is dynamic data, whereas the location of the sensor in the building is static data. Further examples of both types of metadata are as follows:

- **Static facility data**: Metadata that describes the facility itself. Examples include building location, O&M manuals, installation manuals, equipment design data, equipment location, system types, sequences of operation, system relationships, and so on. An advanced form of static facility data is GIS. Data from GIS can be used in EMIS for geospatial analysis, including network analysis and association of objects based on their position in space. Ideally the EMIS would pull static facility data from federal asset databases, such as the U.S. Department of Defense's BUILDER platform.

- **Dynamic facility data:** Metadata that describes what is happening in the facility at any given time. Examples include occupancy data, process or production data, calendar of facility events, occupant-provided data through mobile apps, and so on.

The remainder of this section outlines typical systems included in the EMIS scope, including what type of data is included and how it is integrated into EMIS. Communication can be one way or two way between EMIS and each scope system, depending on the capabilities of the EMIS.

Utility Bills

Working with utility bill data provides the foundation for tracking energy consumption and costs over time, comparing buildings against peers, calculating energy savings, and much more. Each federal agency uses different utility bill processing systems, with some federal agencies still manually transcribing usage data from utility bills into their utility bill management system. In addition, there are a number of federal agencies that have not included utility bill data into an EMIS, and this data scope represents an appropriate starting point for implementing an EMIS (Table 2).

Table 2. Utility Bill Data and Integration into EMIS

Common Points	Scope	Data Interval	Important Metadata	Integration Methods
• Consumption • Power/demand • Cost	Whole building or campus level	Monthly (though underlying timeseries data may be available from utility, see AMI section below)	Building attributes like: • Use type (office, data center, etc.) and square footage • Tariff information including fixed monthly charge $/month, demand charge $/kW, energy charge $/kWh, time of use schedule, etc.	• Manual data entry • Integration with the EPA's ENERGY STAR Portfolio Manager • The Green Button XML standard • Integration with an automated utility data acquisition service

Weather Data

Local weather data provides important information about nearby ambient conditions. When combined with other types of data, weather data is used to normalize energy or system usage data based on fluctuations in weather, predict future energy use, and control HVAC or storage systems based on weather forecasts (Table 3).

Table 3. Weather Data and Integration into EMIS

Common Points	Scope	Data Interval	Important Metadata	Integration Methods
• Outside air temperature • Wet bulb temperature • Relative humidity • Wind speed and direction • Solar irradiance	Whole building or campus level	Monthly, hourly, or 15 minute or less	Location of weather station, collection method (local meteorological station data, web-based, or local sensor data)	• Third party sources, accessed through web services or application programming interface (API) • Local measurement, typically accessed through BAS or UCS, is more applicable where shorter sampling intervals (<15 min) or near real-time data is required (Guild, Koeppel, and Hilger 2012). • The Green Button XML standard

Advanced Metering Infrastructure

Federal laws pertaining to automated meter installations have resulted in a large increase in the number of interval meters installed and available to support agencies' energy management initiatives. With the increasing number of energy and water meters comes an explosion in the amount of data; an EMIS can help agency energy managers make sense of all that data. The Army's MDMS and the GSA's metering ION EE system are current examples of successful metering EMIS in the federal government. Typical federal AMI programs also have a long list of functionality and integration issues that are further addressed in the planning section of this technical report.

Whole building AMI meters may either be those provided by the utility company or dedicated meters designed to disaggregate energy use for a building that is on a shared utility meter. System-level energy and water meters are used to measure energy within a single or multisystem boundary. Emerging submetering technologies now allow the cost-effective measurement of even smaller electrical loads and water consumption. These can be panel- or tenant-level, or as small as individual circuit-level submetering or plug load metering.

Regardless of the load measured, AMI data provides the EMIS user with increased granularity and therefore enhanced capabilities compared to monthly data, including the verification of utility bills, proper allocation of costs to tenants, demand response or load shedding, M&V of energy project performance, and AFDD (Table 4).

Table 4. AMI Data and Integration into EMIS

Common Points	Scope	Data Interval	Important Metadata	Integration Methods
• Electricity (Amp, V, PF, kW, kWh) • Natural gas (therms) • Chilled water (ton-hr.) • Heating hot water (Btu) • Steam (pounds) • Water (gpm)	• Whole building • Sub-system or floor level • Equipment level • Branch-circuit sub metering	Hourly or 15-minute	• Downstream equipment/loads • Tariff/time of use information • Direction of energy flow (import vs. export) • Average or instantaneous readings	• EMIS gateway can be integrated directly with meters via communication protocols such as Modbus or BACnet • EMIS gateway can be integrated with the BAS (see below) if the meters are already tied into the BAS • Some meters are provided with a web gateway, accessed through web services or API • Utility or third party provided, accessed through web services or API

In the federal sector there are baseline functionality and cybersecurity requirements that must be met before an AMI system is integrated into an EMIS. The *Revised Federal Building Metering Guidance* outlines the requirements for AMI in the federal sector, including how they are used in annual reporting requirements, the cybersecurity accreditation requirements for AMI systems, and a framework for implementing a five-year metering plan (DOE 2021b). The framework includes ongoing commissioning to ensure an agency's AMI is meeting baseline functionality requirements. Table 5 below outlines the baseline AMI functionality levels required for AMI system to be integrated into an EMIS—ideally the system would be at Level 4 prior to EMIS integration.

Table 5. Baseline AMI Functionality Levels for EMIS Integration

Level	Description	Goals	Implications	Troubleshooting
1	Working (stand-alone)	Energy and water meters are recording valid data into onboard memory	Metering functions as designed, current transformers (CTs) installed correctly, configuration correct	Confirm proper bootup (firmware, power connections), compare with third party meter, reconfigure
2	Connected	Can ping server from laptop at meter connection point and can ping meter from server	Confirms IP address, subnetwork, virtual local area network, radio/switch/router access control lists	Meter network configuration, radio/switch/router configuration, server network configuration
3	Remotely communicating	Remote meter management available. From server can connect to real-time data, download logs, upload firmware, upload device profile, time sync	Transport is satisfactory for all remote management tasks to complete within reasonable time and without error	Assess communications bandwidth, throughput, errors, latency, uptime for all network equipment
4	Reporting to native data acquisition server/MDMS	Central server is automatically collecting programmed data and data is accepted as valid	AMI is fully operational with sustained network communication	Configuration of MDMS
5	Reporting to EMIS	Enterprise EMIS has been deployed and is successfully collecting, analyzing, and reporting a standard set of 12–16 points per meter, with less than 4 hours of latency	AMI is fully operational at enterprise level	Server, EMIS software, proxy configurations

Submetering

Circuit-level analytics and submetering platform (CLASP) technologies provide the ability to monitor individual circuits within an electrical panel in a building, cost-effectively providing detailed power and energy consumption data at a much more granular level than was previously achievable. While the fundamental hardware components of CLASP—split core CTs and power monitoring meters—have existed for some time, the new offerings on the market have integrated these components and have streamlined data organization, transport, and access via software solutions accessible through web and application programming interfaces (GSA 2019).

Newer CLASP solutions can be installed on multiple electrical panels in a single day, and CLASP provides the ability to monitor power at each electrical circuit in the building, providing insight into different end-use consumption (e.g., plug loads, lighting loads, or HVAC), specific device-level consumption, or the floor- or panel-level consumption within a building. CLASP allows for various innovative use cases such as tenant billing, tenant engagement, M&V, AFDD, identification of ECMs, time of use management, and demand response and should be considered for integration into larger EMIS programs.

Building Automation Systems

Modern buildings are typically equipped with a BAS control system that is responsible for operating the building's HVAC systems. These systems consist of a network of sensors, actuators, transducers, and relays.

Sensors and actuators connect to controllers and represent inputs and outputs, respectively. Transducers convert a signal in one form of energy to a signal in another, such as determining whether a fan motor is on or not. Conversely, relays switch electrical equipment on and off (GSA 2019).

The BAS provides data to an EMIS either by interfacing directly with the device itself or indirectly through data collected in an existing database (Table 6). The EMIS may send commands to controllers in the BAS to execute supervisory control sequences. Specific details regarding challenges and best practices for implementing supervisory control sequences via an EMIS are outlined in the capabilities section above.

Table 6. BAS Data and Integration into EMIS

Common Points	Scope	Data Interval	Important Metadata	Integration Methods
Inputs such as: • Temperature (°F • Pressure (psi or in. H_2O) • Humidity (% RH) sensors Outputs such as: • On/off commands • Setpoints • Speed outputs • Actuator outputs	• System • Equipment Note: EMIS capabilities are enhanced when full systems are included.	15 minute or less	• Units • Measurement • Point and equipment relationships	• EMIS gateway can be integrated directly with BAS via common protocol such as BACnet • Some BAS vendors provide with a web gateway, accessed through web services or API • EMIS gateway can perform automated queries of the BAS historian database, if applicable

As BAS implementation has matured across the federal sector over the last few decades, there are three primary best practices that agencies are working to implement, that collectively help to improve the functionality of the BAS, reduce ongoing cybersecurity costs, and help with more seamless integration with third-party EMIS:

1. **Deploy a Standardized BAS Point Naming/Data Model—**Similar to TCP/IP used for the modern internet and business networks, a BAS network requires extensive planning and maintenance. Developing a standard for device identification, network naming, trunk size, etc. are important and will greatly save the agency in the long run. For example, in 2017 GSA issued *GSA Data Normalization for Building Automation Systems* (GSA 2020a). This document established standardized requirements for BAS point naming, implemented Project Haystack tagging requirements, and clarified the necessary fields required for matching assets to BAS equipment across the entire GSA portfolio (GSA). As federal agencies develop similar standards, they should include human and machine-readable point names, standard equipment types, system types, sequences of operations, required points, and semantic modeling.

2. **Standardize on a Limited Number of BAS Providers for New Construction and Renovation—** BAS systems need to be continually maintained for effective, safe, and efficient operation. This requires a controls technician who can proficiently operate the controller and the software or servers that interface with the BAS controllers. In order to improve operational efficiency, reducing the number of control manufacturers across a federal agency reduces the number of programming languages that the technicians need to be able to support and reduces the number of software systems—and associated licenses—that must be maintained by an installation, which reduces ongoing

cybersecurity and operational costs. This standardization also gives operators the ability to operate BAS systems across a federal portfolio from a centralized workstation.

In order to implement standardized BAS systems, federal agencies such as the Navy are working to standardize on a single BAS provider for the HMI, and use BACnet communication such that the inputs/outputs from one manufacturer's controller can be passed effectively to another manufacturer's controller, allowing the HMI interfaces to integrate controllers from multiple manufacturers for those non-native devices.

3. **Standardize on a Single Open Protocol—**As a general best practice, agencies are encouraged to select a BAS protocol that is used agency wide and standardize on that protocol. Only 'open protocols' (such as BACnet or LonWorks) should be considered for the agency's BAS network and most agencies have found the widest interoperability by standardizing on the BACnet protocol.

Utility Control Systems

UCS, also called Supervisory Control and Data Acquisition (SCADA) systems, manage and monitor electrical and mechanical utility production and distribution on campuses. These systems monitor and control individual utility plants such as electrical substations, steam plants, and wastewater treatment plants.

Similar to BAS, UCS provides data to an EMIS either by interfacing directly with the device itself or indirectly through data collected in an existing database. The EMIS may send commands to controllers in the UCS to execute supervisory control sequences, such as opening/closing switch gear in electrical substations (Table 7).

Table 7. UCS Data and Integration into EMIS

Common Points	Scope	Data Interval	Important Metadata	Integration Methods
• Capacitor bank voltage and current • Substation transformer power • Voltage, current, frequency, power factor • High voltage switching station power • Circuit breaker control commands	• Campus • Building • System • Equipment	15 minute or less	• Units • Measurement • Point and equipment relationships	• Direct integration via Programmable Logic Controllers • Remote Terminal Unit • Open Platform Communications drivers

Distributed Energy Resources

DERs are connected to the distribution system close to the load, such as solar photovoltaics, small-scale wind turbines, combined heat and power, microgrids, energy storage, microturbines, and diesel generators. Deployment of DERs, in particular distributed photovoltaics, has increased in recent years and is anticipated to continue increasing in the future.

Integrating DERs with EMIS can help DERs meet expected performance criteria, prevent system failures that lead to disruptions and energy production losses, and provide detailed analysis on metrics such as energy produced and offset. Additionally, if a demand management supervisory control capability is expected to be delivered by the EMIS, then the appropriate systems must be integrated and accounted for. DER-specific control sequences must also be considered when designing a supervisory control approach for the EMIS (Table 8).

Table 8. DER Data and Integration into EMIS

Common Points	Scope	Data Interval	Important Metadata	Integration Methods
• Real and reactive power • Voltage • Current • State of charge (for energy storage systems) • Total energy throughput • System status	• System • Equipment	15 minute or less	• Downstream equipment/loads • Tariff/time of use information • Design/peak power capacity • Utility interconnection agreement	• EMIS gateway can be integrated directly with DER meters via communication protocols, such as BACnet, SunSpec, Modbus, DNP3, or SEP2 standards via IEEE Std 1547 (2018) • Some DER meters are provided with a web gateway, accessed through web services or API • Utility or third-party provided, accessed through web services or API

Grid Interaction

Standards such as OpenADR 2.0 offer a common language to connect producers and consumers of energy for GEB implementation, and utilities or wholesale electricity markets may provide relevant data streams that must be integrated to deliver on desired GEB capabilities. EMIS providers are starting to offer OpenADR 2.0 capabilities and incorporate the ability flex building loads in response to grid signals (Table 9).

Table 9. Grid Interaction Data and Integration into EMIS

Common Points	Scope	Data Interval	Important Metadata	Integration Methods
• Dynamic prices • Load flexibility metrics • Load shed priority levels • Carbon intensity metrics such as marginal emissions	• Campus • Building • Meter-level	Hourly and less	Tariff/time of use information	• Open communication model such as OpenADR • Utility provided proprietary communication model • OASIS databases

Electric Vehicle Charging Stations

As the number of EVs used to commute to federal facilities increases, EMIS can help agencies support this growth in an optimized way, minimizing overall electrical demand and electric costs (Fathy and Carmichael 2019). Charging station data can be integrated with EMIS to manage building coincident peak demand of all connected systems and further support GEB strategies (Table 10). For more information, see https://www.energy.gov/eere/femp/federal-fleet-management.

Table 10. Electric Vehicle Charging Stations Data and Integration into EMIS

Common Points	Scope	Data Interval	Important Metadata	Integration Methods
• Charging station demand (kW) • Connection state • Charge current • Energy delivered • Current vehicle charge (% or kWh)	Equipment level	15 minute and less	• Maximum charge rate • Location in distribution network • Breaker/transformer ratings	• EMIS gateway can be integrated directly with EV charging station meters via communication protocols such as Modbus or BACnet • EV charging stations can be integrated into the BAS • Some charging stations are provided with a web gateway, accessed through web services or API

Data Centers

Similar to the way a building's EUI can be used for energy benchmarking, tracking the power usage effectiveness, energy reuse effectiveness, and water usage effectiveness allows a data center to determine the efficiency of its operation in terms of energy and water usage. Section 1003 of the Energy Act of 2020 requires DOE and EPA to assess the adequacy of current metrics, benchmarks, and best practices under the National Data Center Energy Efficiency Information Program for use by FEMP and others.[9] EMIS can integrate with data center meters or data center information management systems to determine the power consumed by IT infrastructure in order to calculate these important KPIs. The data center industry typically uses data center infrastructure management systems that often include EMIS. Further, integration with data center cooling systems allows EMIS users to monitor cooling performance (Table 11). For more information, see https://www.energy.gov/eere/femp/energy-efficiency-data-centers.

[9] Public Law 116–260, Energy Act of 2020 (Dec. 27, 2020).

Table 11. Data Centers Data and Integration into EMIS

Common Points	Scope	Data Interval	Important Metadata	Integration Methods
• PDU, UPS, and RPP power (kW) • Cooling tower make up water flow (gpm) • Cooling system power and energy	• System • Equipment level	15 minute and less	System and equipment relationships	• EMIS gateway can be integrated directly with data center meters via communication protocols such as Modbus or BACnet • Data center equipment can be integrated into the BAS • Some data center information management systems provide a web gateway, accessed through web services or API

Computerized Maintenance Management Systems

A CMMS is a type of management software that performs functions, such as generation and tracking of work orders, in support of the maintenance of equipment (Sullivan et al. 2010). EMIS can connect to an agency's CMMS to push work orders when issues are discovered and/or pull information on equipment to be used in analytics such as mean time to repair or mean time to replacement. Additionally, the CMMS can be a source of the facility-related static metadata discussed above (Table 12).

Table 12. CMMS Data and Integration into EMIS

Common Points	Scope	Data Interval	Important Metadata	Integration Methods
N/A	Equipment level	N/A	• Equipment naming • Equipment location • Equipment relationships (e.g., variable air volume to AHU, and so on) • Manufacturers • Models • Ratings • Maintenance intervals	EMIS gateway can be integrated directly with the CMMS through a web gateway, accessed through web services or API

EMIS Stack

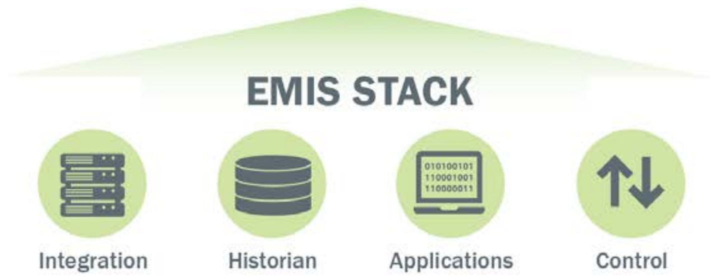

Figure 31. The Stack component of the EMIS framework

Image Credit: NREL, James Dice and Fred Zietz

An EMIS stack is comprised of multiple interconnected components, starting with integration drivers that transfer data to and from the EMIS scope. The historian stores time series data in a database. Applications subscribe to those data to perform a variety of capabilities for the user. Finally, working in concert with applications, the controls provide feedback or control signals to execute supervisory control actions.

Integration

The integration components manage communication between the EMIS scope systems and the historian, including translation between protocols. Communication is dependent on the responsiveness of the systems and the quality of the building's communication networks. Many BAS networks are not designed for heavy data acquisition, meaning large or frequent data requests can compromise local BAS controllers' ability to perform basic control functions. Therefore, integration should include a load-balancing capability that restricts network traffic as needed to preserve performance across the EMIS scope (AMI, BAS, and so on).

Historian

The historian stores time series data and associated metadata in one or more databases and provides those data on request to applications. The value of accurate, well-organized metadata cannot be overstated. Incorrect metadata can directly affect accuracy in the interpretation of measured values, cascade into incorrect operation of upstream EMIS applications, or create confusion in identifying the correct system or equipment for calibration or repair. See the EMIS Planning section for more on metadata management.

Applications

EMIS applications consist of all high-level analysis tools that rely on collected building performance data in the historian. Examples include dashboards, benchmarking and reporting software, and FDD tools. Applications query historical data from the historian and may also read real-time data directly from the integration components. Many examples of applications are shown in the Capabilities section of this document.

Supervisory Control

EMIS controls represent supervisory control algorithms that affect the operation of building devices in an automated or semi-automated manner. See the EMIS Capabilities section for more on this capability. Supervisory control requires a communication path from applications to building systems, either by allowing bidirectional communication through integration drivers or via a separate path. This two-way communication introduces a host of integration and security challenges that data-consuming applications with one-way data transfer do not experience.

The EMIS stack works together to provide capabilities and benefits to the end user of the EMIS. A graphical representation of the EMIS stack configuration (Cutler et al. 2016) used for the NREL Intelligent Campus program is provided in Figure 32.

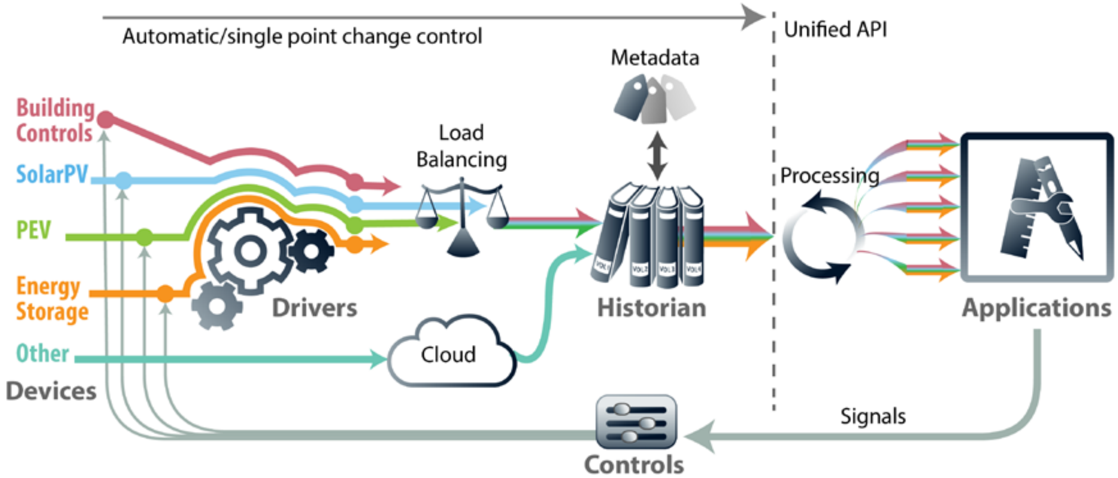

Figure 32. NREL's conceptual EMIS architecture, including functional components

Image Credit: Marjorie Schott, NREL, and iStockphoto.com

Figure 32 graphically displays the four EMIS stack components—integration, historian, applications, and control—as they were implemented for NREL's Intelligent Campus program. The dissection of the EMIS into functional components provides a clearer understanding of the requirements for each component and creates opportunities for integrating different products to create a system that meets site-specific requirements. The NREL Intelligent campus stack includes an open-source historian feature that allow various third-party applications to pull data from the historian and use the data to enable various EMIS capabilities in proceeding sections.

EMIS Supporting Operations

Figure 33. The Operation component of the EMIS framework

Image Credit: NREL, James Dice and Fred Zietz

While EMIS are extremely powerful tools, they should not be considered stand-alone energy efficiency equipment capable of producing results. Generally, with the exception of automated supervisory controls, EMIS are human-in-the-loop tools. They require regular use by a well-resourced team to fully convert data to information to insights to action to verified results.

Effective EMIS use requires integrating ongoing EMIS activities into the organization's standard operating procedures, and preferably a companion EnMS—the codification of strategic energy management processes. An EnMS establishes and manages the human side of energy performance improvement and can utilize the EMIS information to enact further energy improvements. A prime role of an EnMS is for management to create and empower an energy team and to prioritize energy improvements as a part of site operations. Creation of operational processes requires thinking through how the team will review the EMIS for improvement opportunities, take action to implement the improvements, and identify what coordination or authorizations are needed (DOE 2015a). Operational processes to be delineated should also include verification that the improvements were successful and communication of results to key stakeholders. Finally, the EMIS itself requires regular maintenance and improvements to remain effective, just like the underlying systems it is monitoring. The EnMS should manage and operate the EMIS and synergize human and data flows to optimize energy performance. DOE has a no-cost program, with DOE recognition, called 50001 Ready to support implementation of an EnMS (LBNL 2020).

The EnMS and EMIS processes work well as the basis for EMIS operational processes. If the organization already has active processes in these areas, they should be modified to integrate the use of EMIS. This section will provide an overview of the components of effective processes and best practices, which are shown in Figure 34. While these processes are beyond the scope of this technical report, the reader is recommended to review the *Building Commissioning Handbook*, 3rd edition (BCA 2017), LBNL's MBCx Plan Template (Granderson, Kramer, and Curtin 2018), and the 50001 Ready Navigator (LBNL 2020) for detailed information.

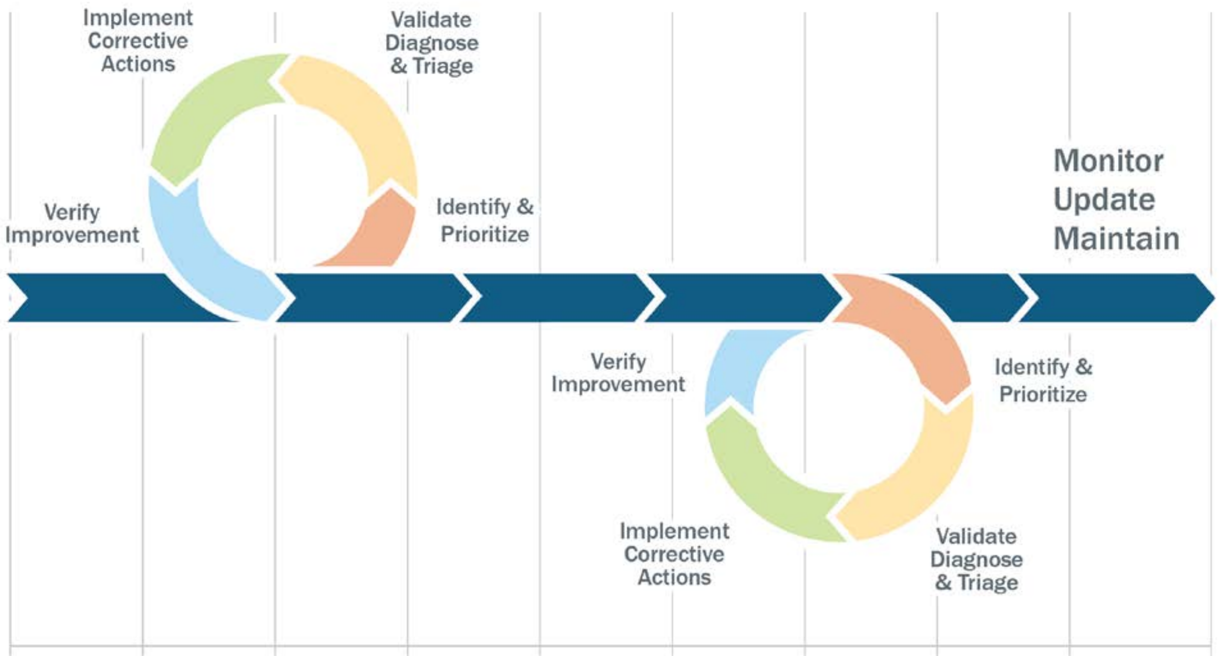

Figure 34. Overview of recommended steps in EMIS operational process

Image Credit: NREL, James Dice and Fred Zietz

As noted in previous sections, the EMIS software landscape is very broad. Software support for operational processes is no exception. Some vendors offer more comprehensive operational tools than others, while many are focused on simply displaying data or lists of issues. Agencies should consider these capabilities when establishing software selection criteria.

Identify and Prioritize

In the Identify and Prioritize step, the EnMS team can utilize the EMIS to identify improvement opportunities, which are prioritized based on qualitative or quantitative metrics such as calculated energy savings and criticality. After issues are prioritized, EnMS teams can use the EMIS tracking system such as an issues log. The California Commissioning Collaborative has a sample Issues Log template (California Commissioning Collaborative 2012). As shown in Figure 35, the issues log can also be built into the EMIS software itself, allowing the EnMS team to track improvement opportunities through the implementation cycle.

It is most efficient for the EnMS team to use automated prioritization tools, if the EMIS software provides them, as the first phase of prioritizing opportunities that the EMIS uncovers. The team should perform any manual prioritization only if needed. LBNL's MBCx Plan Template provides an example Monitoring Action Plan (MAP) that can aid in this step (Kramer, Crowe, and Granderson 2017). The MAP is a document that defines the metrics, views, and analytics that will be tracked to identify opportunities for performance improvement. It is recommended to ensure the MAP includes identifying and prioritizing issues with the EMIS itself. See the Quality Checking section above for common EMIS quality issues that should be automatically or manually checked for.

Validate, Diagnose, and Triage

The EnMS team then uses the EMIS and underlying systems to confirm the validity of improvement opportunities, determine root causes, and triage into implementation categories. The data analysis and visualization tools within the EMIS can help validate issues and determine root causes. A survey of the underlying systems may be required as a second step.

Once the root cause is diagnosed, the complexity and effort involved in implementation will vary for different opportunities. Triaging the opportunities into predefined categories helps to streamline the implementation process. When creating implementation categories, consider:

- How will the criticality of opportunities be addressed? (e.g., is the improvement an emergency?)
- Who will implement the improvement? (e.g., in-house controls technician, contractor, and so on)
- Can the agency establish pre-approved investment criteria to determine which performance improvement opportunities will be invested in? (e.g., pre-approval for all measures with less than a one-year simple payback)
- How much will the improvement cost? (e.g., low- or no-cost, investment requiring pre-approved budget, investment requiring budget that has not been approved, and so on)
- Can common measures and/or groups of similar measures be deployed across many sites in bulk to take advantage of economies of scale? (DOE 2015a)
- How will improvements be transferred to or integrated with the agency's work order system?

Finally, the EnMS team will likely uncover opportunities to improve the EMIS itself. These types of improvements should be included in the implementation process.

Implement Corrective Actions

The EnMS team then implements the prioritized improvement opportunities in each implementation category. If the improvement can be made from the EMIS or underlying control system workstation (e.g., changing a schedule), the EMIS operator can implement it right away without involving the rest of the team. For other measures, the team should develop clear recommendations for the steps to complete implementation (BCA 2017).

Successful EnMS teams establish a regular EnMS meeting cadence to track the energy management system implementation, the site's performance, and the findings from the EMIS' functionality. For example, teams can meet weekly for low- or no-cost implementation, monthly for implementing ECM bundles, and quarterly for improvements to the EnMS, and EMIS itself.

Verify Improvement

Once measures are implemented, the EnMS team can use the EMIS to ensure proper implementation. Ideally, the root cause of each issue can be reported back to the EMIS operator to improve the EMIS analytics, prioritization, and diagnosis processes. After the opportunity is verified, M&V capabilities can be used to automatically or manually quantify energy and cost savings and create savings reports. Figure 35 shows an example of an HVAC scheduling measure that was implemented incorrectly. After several days of troubleshooting, the team was able to verify proper operation and energy savings.

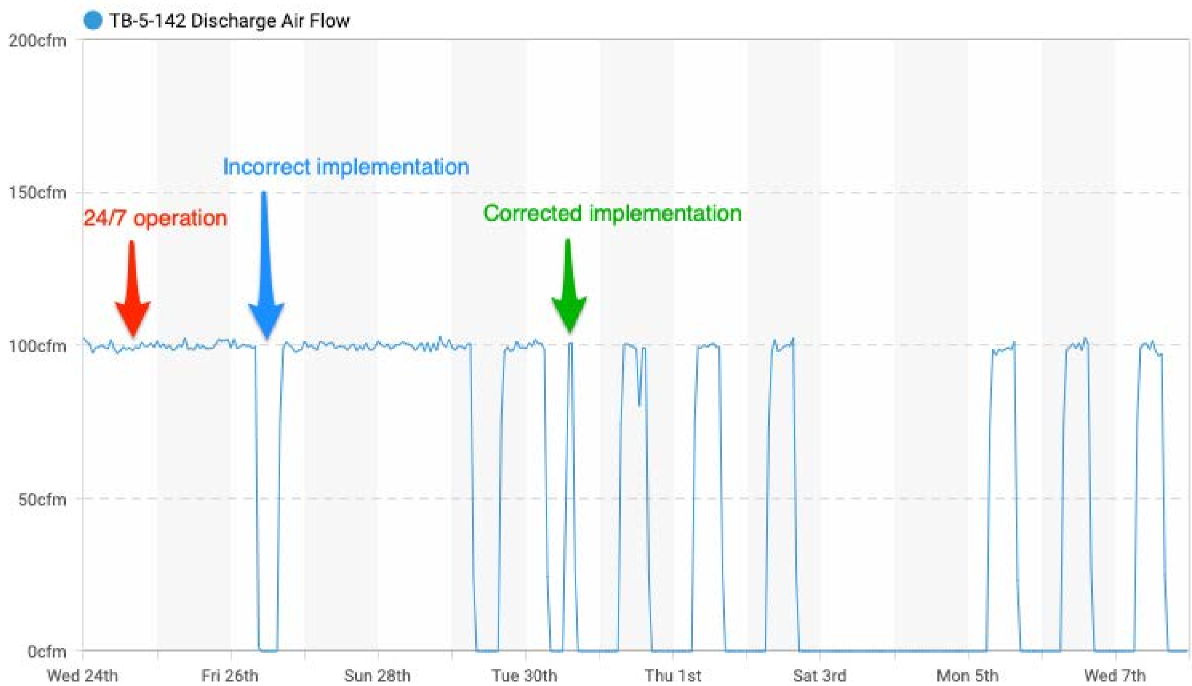

Figure 35. Example of operational verification of HVAC schedule implementation

Image Credit: NEXUS Labs, SkySpark

Monitor, Update, and Maintain

While the process steps above are typically executed in weekly, monthly, or quarterly intervals, this section captures the ongoing tasks required to support the overall process. The organization should keep team members trained on the EMIS itself. As improvements are made to building systems, building operators should be notified and trained on all changes or modifications. As the building itself changes, the building documentation (e.g., sequences of operations), standard operating procedures, cybersecurity protocols, and the EMIS itself should be updated to reflect the changes.

EMIS Planning

The following EMIS planning process supports federal agencies in procuring and deploying a successful EMIS program.

Challenges

Before commencing EMIS planning and deployment, agencies should be aware of challenges and potential solutions to support the implementation of successful projects. Once these obstacles are identified, solutions to relevant challenges can be included in the agency's strategy and planning efforts, which are covered in the following sections.

1. Market Complexity

The breadth and rapid change of the EMIS marketplace makes it difficult to understand current product offerings due to product rebranding, company acquisitions, and vague value propositions. This makes it difficult to identify exactly what capabilities potential tools offer, what infrastructure requirements are needed for deployment, and what factors differentiate each solution (Guild, Koeppel, and Hilger 2012). To further complicate the issue, EMIS users often find that multiple vendors are needed to fulfill the full subset of capabilities needed to meet their goals. As a result, determining total cost of ownership, including labor, and comparing that across vendors is a major challenge.

Potential Solution: It is important to understand the scope of the data sources available, and to define the exact goals/capabilities that the agency is pursuing with an EMIS implementation (as described in the following section of this technical report). This can help map requirements to specific product offerings and weed out ones that do not apply.

2. Difficulty Making the Business Case

Participants in the Smart Energy Analytics Campaign have expressed the difficulty in assembling the business case for EMIS (Kramer et al. 2019).

Potential Solution: See further discussion below in the Establish Feasibility section.

3. Viability for Small Buildings

Deploying EMIS has a minimum cost for a building of any size, which can make the return on the EMIS investment less attractive for small buildings or projects. In addition, the *Revised Federal Building Metering Guidance* does not recommend interval meters/AMI for federal sector buildings of less than the minimum threshold for individual building metering (DOE, 2020b). Smaller facilities typically have packaged HVAC systems that are not connected to the agency's BAS

Potential Solution: Smaller buildings that do not have utility meters, AMI meters, or BAS systems should not be included in a federal agency's EMIS. If the building has utility meters and/or AMI, a scaled-down version of the EMIS that just focuses on benchmarking and AMI analytics should be targeted in the procurement. See discussion below on designing EMIS levels.

4. Lack of Information

The success of EMIS software deployment depends on the accuracy of data being communicated. Many facilities lack the documentation needed to achieve quality data and provide the context for how the building and systems are put together.

Potential Solution: At first, federal agencies should focus their efforts on buildings that have adequate documentation or have facility data that is uploaded into the agency's asset management system. Also, agencies should put in place requirements for collecting this information as new equipment is installed.

5. Operational Technology/Information Technology Integration

Building systems typically reside on OT networks that are physically or virtually isolated from IT networks. OT and IT staff are often similarly siloed. Since EMIS implementations often require the use of both networks, there can be significant coordination to allow proper communication while maintaining cybersecurity.

Potential Solution: As outlined below, OT/IT staff should be engaged early in the EMIS planning and deployment processes so that agency cybersecurity requirements can be incorporated into the planning and design phases.

6. System Integration

Federal agencies often have a large number of different building automation systems, equipment-level controllers, and vintages of BAS, which use a wide variety of protocols for communication and require software drivers to translate data into standardized formats. Many systems were not installed with integration in mind and may need to be upgraded to allow communication at all. Once the connection is established, full functionality of the legacy systems needs to be maintained, which could necessitate further upgrades. In addition, many federal agencies still have a number of buildings with pneumatic controls that need to be upgraded to direct digital control before the building could be connected to an EMIS.

Once data is flowing between systems, the challenge of interpreting it remains. Modern building systems do not provide sufficient context, or metadata, to enable the analytical applications of EMIS as discussed previously. Context on each data point is often limited to what is contained in the point name itself, which rarely contains sufficient information. Even if point names are descriptive, issues with naming consistency make it difficult for software to automatically add metadata, resulting in costly and laborious integration efforts.

Potential Solution: As outlined below, the EMIS team should include system integrators and technicians who are involved in the planning process. EMIS vendors and service providers offer these services, as well as software and hardware tools that aid in mitigating this challenge.

7. Data and Analytical Quality

Over time, meters and sensors fall out of calibration, reducing the accuracy of measurements and increasing the possibility of system issues. An EMIS system relies on functioning and calibrated meters and sensors to support analytical quality. Related data-quality and coherency issues include misaligned timestamps, dropped data, and mismatched precision as the data are transferred from each connected system into the EMIS platform (Cutler et al. 2016).

Potential Solution: For federal AMI, before the baseline functionality requirements outlined in Table 5, the AMI system needs to be commissioned and working properly before it is integrated into the EMIS. If only a subset of the AMI infrastructure is commissioned and working correctly, the interval meters on that system should be integrated into the EMIS first, and all additional interval meters needing commissioning should be integrated at a later date once the commissioning issues are resolved.

8. Team Commitment and Staffing

In a 2011 report, Accenture profiled an EMIS pilot at Microsoft's headquarters and cited a major challenge in securing the "full commitment and close collaboration between all stakeholders" including executives, building engineers, IT staff, and external service providers (Accenture 2011). EMIS implementation requires an engaged team, processes for working together across department lines, and funding to fully support the effort. Similarly, the staff assigned to the EMIS team must have adequate time to take on a new system.

Potential Solution: EMIS should be coupled with an energy management system (such as DOE's 50001 Ready) to bring together all stakeholders to identify roles and responsibilities in overall energy management and get buy-in from each team member. An EnMS reflects the human element of energy optimization—the use and maintenance of the EMIS for the system's data and operational benefits. The level of effort and interaction with the EMIS need to be identified as a priority and appropriate training should be provided to ensure EMIS operators know how to use the EMIS platform. As EMIS designs become more sophisticated, EnMS team members need to have technical skills in controls, HVAC, and electrical systems in order to make use of analytical insights.

9. Change Management

EMIS processes can represent a change in the status quo for many building operations professionals. Facility staff members can be skeptical of adding more to their workload, as they are busy reacting to a full schedule of existing priorities.

Potential Solution: The implementation of an EMIS should be integrated in the EnMS, including personnel of the energy team, as well as operations and management. Expectations of the level of effort and interaction with the EMIS need to be identified as a priority and appropriate training needs to be provided to ensure EMIS operators know how to use the EMIS platform. In general, the benefits of the EMIS will be linked to the prioritization and empowerment from leadership, and an EnMS helps to maximize the leadership-energy team link to empower change.

Cybersecurity

Cybersecurity is a critical part of planning an EMIS implementation. Critical systems are often integrated with or operate on the same networks as EMIS scope systems, necessitating stable, continuous, and secure communication. When connecting EMIS to building automation and utility control systems, there are also a large number of physical assets that could cause harm to the building and its occupants if a malicious act or human error were introduced (Cutler et al. 2016). This technical report does not address the cybersecurity considerations associated with EMIS scope systems. Relevant to this technical report is concern for the cybersecurity of the installation and ongoing communication of an EMIS.

It is imperative to ensure all EMIS scope systems are connected securely to the EMIS and do not open vulnerable pathways to other facility networks and operations. This section provides a brief overview of the Risk Management Framework (RMF), the process by which federal agencies authorize the operation of their information systems, the Framework for Improving Critical Infrastructure Cybersecurity, the Federal Risk and Authorization Management Program, the Facilities Cybersecurity Framework developed by PNNL, and the Distributed Energy Resources Cybersecurity Framework (DERCF). In the EMIS planning process, each agency should include a description of how these frameworks will be applied to secure the EMIS.

Risk Management Framework

The Federal Information Security Modernization Act (FISMA) of 2014 requires federal agencies to implement a security program to manage organizational risk and assure the agency-wide security of information and information systems, including agency-owned assets as well as those provided or managed by another agency or contractor. It is important to note that this only applies to federal facilities with pre-existing equipment that are applicable EMIS scope items, such as AMI, BAS, etc. To agencies that fall under this requirement, agency EMIS scope systems that may be integrated into the EMIS and related assets that collect, process, store, maintain, use, share, disseminate, and dispose of information should demonstrate compliance with information security requirements.

As directed by the Federal Information Security Modernization Act, the National Institute of Standards and Technology (NIST) created the RMF, a framework to help organizations assess and manage risks to their information and systems. NIST Special Publication 800-53 Revision 4 contains an extensive list of controls relevant to securing Federal Information Systems and are organized by related families (NIST 2013). The

RMF provides a process that integrates security and risk management activities into the system development life cycle. The risk-based approach to security control selection and specification considers effectiveness, efficiency, and constraints due to applicable laws, directives, Executive Orders, policies, standards, or regulations. The RMF is a six-step process to guide individuals responsible for mission processes in the development of an enterprise cybersecurity program. Further detail is provided in NIST Special Publication 800-37 Rev. 2, *Risk Management Framework for Information Systems and Organizations: A System Life Cycle Approach for Security and Privacy*, and associated publications.

Framework for Improving Critical Infrastructure Cybersecurity

Executive Order 13800, Presidential Executive Order on Strengthening the Cybersecurity of Federal Networks and Critical Infrastructure, signed May 11, 2017, requires all federal owners and operators of critical infrastructure to use NIST's Framework for Improving Critical Infrastructure Cybersecurity, commonly referred to as The Cybersecurity Framework (CSF) to manage cybersecurity risk. The Executive Order recognizes the increasing interconnectedness of federal information and operational systems and requires agency heads to ensure appropriate risk management for the agency's enterprise, and for the Executive Branch as a whole.

In addition, the CSF provides a common language to address cybersecurity risk inside and across organizations, which can improve communications, awareness, and understanding. There are many resources available to assist with mapping the CSF to RMF, as well as other external frameworks. Challenges inevitably arise due to the unique configurations and environments that exist from site to site. To combat this, NIST provides a reference tool that allows the user to interact with the CSF dynamically, as well as other informative references (NIST 2020). Per Executive Order 13800, federal agencies are required to use the Framework for Improving Critical Infrastructure Cybersecurity developed by NIST, or any successor document, to manage the agency's cybersecurity risk to critical systems, including AMI. Additionally, it holds agency heads accountable by the President for ensuring that cybersecurity risk management processes are aligned with strategic, operational, and budgetary planning processes. Results of the evaluation can be incorporated into the agency's EMIS planning process by reference. Further detail is provided in the NIST white paper, *Framework for Improving Critical Infrastructure Cybersecurity*, version 1.1.

Federal Risk and Authorization Management Program (FedRAMP)

Software as a Service (SaaS), where software applications are hosted in a cloud-based environment and associated with a license, is becoming increasingly more common in the space of EMIS and beyond. FedRAMP provides standardized low, medium, and high classifications that certify systems that use SaaS based on their security implications and potential impact. These classification levels are based three security objectives:

- Confidentiality: Information access and disclosure includes means for protecting personal privacy and proprietary information.
- Integrity: Stored information is sufficiently guarded against modification or destruction.
- Availability: Ensuring timely and reliable access to information (GSA 2020b).

Systems categorized in the "low" classification have fewer controls associated with them, and typically lower cost and quicker approval process whereas "high" classification has the opposite effect. More information about FedRAMP can be found at https://www.fedramp.gov/understanding-baselines-and-impact-levels/.

Facilities Cybersecurity Framework

The Facilities Cybersecurity Framework (FCF) is a publicly available web application that provides a self-assessment module optimized around cybersecurity needs for facility-related control systems. Adapted from the CSF, FCF provides a common taxonomy and mechanism for building stakeholders to:

- Describe their current security posture
- Target state for cybersecurity
- Identify and prioritize opportunities for improvement
- Assess progress toward a target state
- Communicate cybersecurity risk among stakeholders (PNNL 2020b).

The FCF tool has a unique feature that includes scenario-based training exercises based on alerts and events specifically created for the training game. Events can include specific vulnerabilities or attacks that an adversary is using, while alerts present specific information via video. Each event is mitigated by selecting an appropriate control to implement. This allows for a user or team to gain experience making decisions based on information available to them, while also understanding the financial trends associated with their decisions.

In addition to generating a wholistic report, the FCF assessment provides a Qualitative Risk Assessment, allowing stakeholders take an inventory of critical assets and organize them visually, as shown in Figure 36.

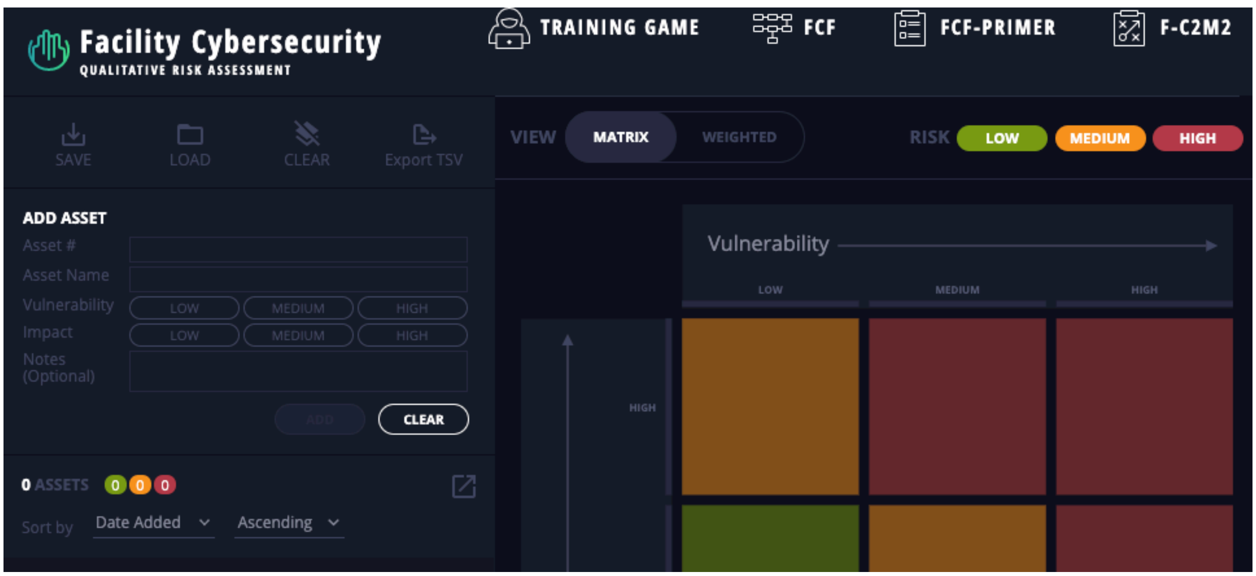

Figure 36. Qualitative Risk Assessment provided by the FCF

Image Credit: PNNL 2020c

Users of FCF can upload the results from previous assessments to measure improvements over time to the Comparative Evaluation section of the tool. The FCF also has a module that is aligned with the RMF. This hybrid tool provides an overlay of the RMF, organized by the five steps outlined in the CSF.

Distributed Energy Resources Cybersecurity Framework

In 2019, NREL developed the DERCF and accompanying web application to address the lack of guidance for securing DERs (Powell et al. 2019). The web-based tool assists a federal facility's management team by bringing guidance and structure to the extensive array of cybersecurity controls applicable to DERs and walking the user through a three-pillar assessment framework. The DERCF utilizes existing work encapsulated in the Department of Energy's Electric Sector Cybersecurity Capability Maturity Model (ES-C2M2) into a pillar focused on cybersecurity risk management, called Cybersecurity Governance (DOE 2014b). To extend that content, NREL has developed two additional pillars, technical management and physical security, that focus on controls related system-level settings, and site security as it relates to DERs.

Upon completion of an assessment, users are provided with a set of results that identify and assess their cyber and physical assets, as well a customized, prioritized list of action items to help address potential vulnerabilities. Figure 37 presents a screenshot of the DERCF tool's dashboard page, containing an at-a-glance view of progress, scores, action items, and more.

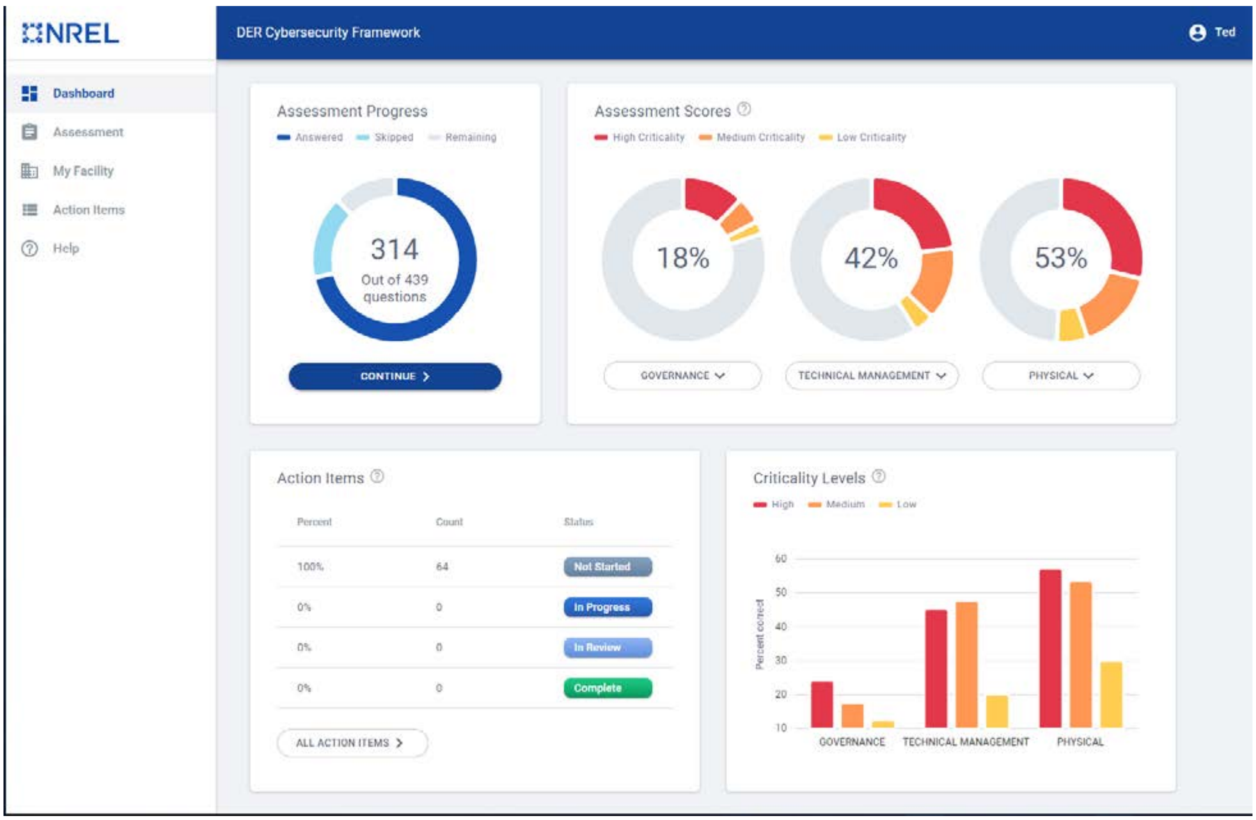

Figure 37. Screenshot of the DERCF tool's cybersecurity dashboard

Image Credit: NREL

Current DERCF work includes close alignment with the chronological steps in the RMF, as well as the overarching "Prepare" step designed to make the RMF process simpler.

Planning

Given the above obstacles and cybersecurity challenges, a strategic plan for EMIS deployment is imperative. The EMIS plan establishes the goals of the EMIS along with its scope and capabilities, such that the team members, service providers, and tools required for the project are well understood, including the activities that will be performed on an ongoing basis. The EMIS plan should be part of the site's overall EnMS process as the EnMS includes and empowers all energy-related staff and brings leadership into the continuous improvement process around energy which the EMIS will inform.

A key consideration for EnMS and EMIS deployment is the commitment by leadership. Given the resources needed to execute, staff must be empowered and a deployment plan must be executed and managed. Often this execution can be part of the energy policy and action plans of the site or agency's EnMS process. One common strategy to consider at the outset of EMIS planning is to deploy a smaller-scale EMIS pilot before implementing throughout the entire agency. This approach allows the team to encounter and handle the above challenges, as well as those that cannot be foreseen. Likewise, a pilot provides the ability to test out the selected EMIS vendors and tools in a low-risk manner before making a large investment. A pilot project may narrow the EMIS deployment by the number of buildings, the scope included, or the capabilities required.

Another strategy undertaken by federal agencies is to develop a five and/or ten-year building technology roadmap for their facilities and portfolio. In addition to identifying gaps in required capabilities and framing budgets for technology acquisition, a roadmap will be critical for the creation of technical standards that will supplement organizational policy and acquisition documentation that concerns building technology implementations and provide guidance to the vendors doing the implementation. EMIS planning can make up a part of the overall technology roadmap. As discussed in the EMIS Scope section of this report, BAS planning should be included as well.

This section outlines the components of an EMIS plan, shown in Figure 38, which will support the procurement, deployment, and operational processes in subsequent sections.

Figure 38. Recommended steps in the EMIS planning phase

Image Credit: NREL, James Dice and Fred Zietz

1. Set Goals

Due to the number of stakeholders involved each agency's EMIS deployment, it is critical to understand, document, and communicate the goals of an EMIS program. When setting goals, these questions are valuable to consider:

- How does EMIS fit in with the site's energy management system? How does it support the EnMS team's energy management and facility management goals?
- In what ways will EMIS create value (direct and indirect) for the agency?
- How will the investment in EMIS be justified? (i.e., what is the business case?)
- How will EMIS support the agency's compliance with federal laws and regulations?
- How will the EMIS support the energy data reporting and analysis of the EnMS, including benchmarking, KPIs and operational controls?

2. Roles and Responsibilities

The implementation and operation of EMIS requires expertise in building operations, metering technology, building controls, system integration, networking, network security, and the EMIS software selected. Therefore, federal agencies should, as described earlier, develop an EnMS to use the EMIS that includes a broad representation of expertise and define the roles and responsibilities of each team member to ensure success.

EnMS teams are often made up of a combination of internal staff and external service providers. For example, it is common practice to hire a consulting engineering firm for ongoing monitoring, analysis, and measure identification and prioritization, allowing the internal operations and energy management team to take actions based on the service provider's recommendations (DOE 2015a). Agencies should assess internal capabilities to determine the need for hiring new staff and the scope for external service providers.

The remainder of this section outlines the main areas of responsibility that should be covered by an EnMS team.

Site EnMS Energy Manager/EMIS Program Manager

An individual within the site's EnMS with overall jurisdiction and responsibility for EMIS program execution.

Authorizing Official

A senior agency official or executive within the site's EnMS with the authority to formally assume responsibility for operating an information system at an acceptable level of risk to agency operations and assets, individuals, other organizations, and the nation. The authorizing official is responsible for granting the authorization to operate an information system.

OT/IT Representatives

Most EMIS implementations involve extensive IT infrastructure and technical support to enable their functionality. Coordination is required to set up hardware or virtual servers, certify cybersecurity, pass data across the network, and, potentially, communicate with an external cloud or SaaS. This introduces gaps in skillsets and capabilities that if not addressed organizationally will negatively impact the effectiveness of the building technology and increase the implementation and long-term maintenance costs. The system architecture should be designed and set up with involvement from the server, network, and firewall administrators. Involving them early in the process will help mitigate potential roadblocks as EMIS is implemented.

Sites should determine if their internal IT organizations are suited to taking a significant role in provisioning services and support for EMIS, or if they need to look to a third-party service provider for this expertise and support. While there are some notable differences in building technologies relative to the types of hardware and software that a traditional IT organization is used to supporting, nevertheless, there are potentially significant risk avoidance and cost savings to be acquired in the areas of network architecture, systems administration, and IT security policy administration. It is important to note that while most EMIS solution providers will install the basic required IT infrastructure to support their solution, it is typically done in a way that does not scale for future requirements, and almost certainly does not adequately address cybersecurity concerns. These IT personnel should be added to the site's EnMS energy team.

System Integrator and/or BAS Technician

A system integrator or controls technician will be expected to understand the intricacies of the systems comprising the EMIS scope, including the system architecture and how each system can communicate with the EMIS (BCA 2017). The system integrator will set up hardware and configure pathways and protocols for systems to communicate and transfer data.

EMIS Analyst

This EnMS team member is responsible for using the EMIS on a regular basis and ensuring it is configured properly for the organization. This typically includes the technical aspects of setting up the EMIS according to the EMIS plan (as defined below) and making sure the EMIS is actively used beyond initial setup, including hardware and software maintenance and upkeep.

EMIS analysts should have the ability to perform initial troubleshooting of performance issues that an EMIS helps identify. This helps resolve issues faster, reduces dependence on external service providers, and can help avoid the unnecessary dispatch of field labor.

Energy Manager and/or Monitoring-Based Commissioning Agent

This EnMS team member is responsible for leading and organizing the team through the EMIS operational process, ensuring that issues identified through the EMIS are tracked, validated, prioritized, implemented, and verified. This person also typically designs new analytics such as AFDD rules and KPIs.

Facility Managers and O&M Staff

The EnMS team needs to include a member or members from the facility engineering and operations and maintenance staff. These team members are responsible for executing and managing the implementation of opportunities identified through the EMIS program.

Program Managers

Staff who are responsible for the overall management of the EMIS program and will coordinate within their areas and estimate budgetary needs.

Project Managers

Staff who track installation and commissioning efforts, draft statements of work, coordinate with contracting offices, direct field personnel, and track budgets.

Procurement Specialists

Staff who understand the agency's procurement protocols and who will coordinate procurement procedures such as RFPs.

Contracting Officers/Representatives

Staff who are authorized to perform contract administration functions and who ensure contractors meet federal performance requirements.

Program Support Personnel

Staff who handle general logistics and supply chain management.

3. Design EMIS Capabilities and Scope

The next step in the planning process is to define how the EMIS capabilities fit into the site's EnMS and support the site's energy goals. When defining capabilities, it is recommended to consider different sets of capabilities for different facilities in the portfolio. For example, small facilities with no complex building systems will benefit from utility bill management and interval data analytics capabilities but will see diminishing returns from adding more sophisticated system-level capabilities such as AFDD and supervisory control. In larger facilities with complex building systems, sophisticated EMIS capabilities may be vital to meeting goals. Each agency's EMIS plan will differ in how it applies EMIS capabilities to its EnMS goals and policies. Once the capabilities are defined, the next step is to determine which building systems need to be integrated with the EMIS to fulfill them.

Further, an agency may apply the EMIS to just one site or across several sites in the agency, depending on energy use, established EnMS or other factors. To illustrate this design approach, consider an agency with a broad mixture of different building sizes and sophistication. The first step would be to define the level of EMIS capabilities and scope to apply to all buildings. Then, for each subset of larger and more sophisticated buildings, defines additional levels of capabilities and scope needed to meet agency goals. Eventually, for certain buildings the solution could include AFDD for utility control systems, supervisory control of building and utility controls, and applicable local grid services. The outcome for the agency may look similar to Figure 39 and could be applied to individual buildings or across an entire portfolio.

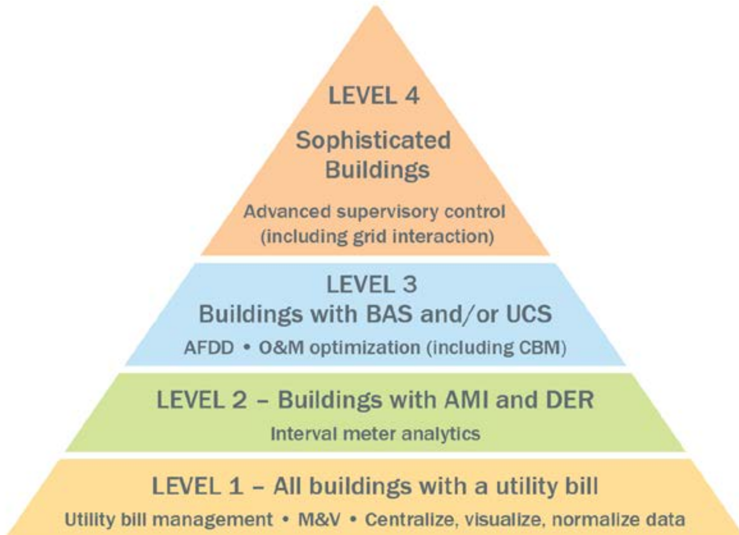

Figure 39. Example of how an agency might design an EMIS for the portfolio

Image Credit: NREL, James Dice and Fred Zietz

The capabilities and scope for Level 1 (all sites) are shown in Figure 40 as an example.

Figure 40. Example of EMIS scope and capabilities to apply to all buildings

Image Credit: NREL, James Dice and Fred Zietz

Finally, the EMIS design process should include considerations of the typical packages of capabilities available in the EMIS marketplace. For example, an EMIS vendor that focuses on Utility Bill Management capabilities will not typically provide more sophisticated capabilities, such as AFDD. Conversely, an EMIS vendor that focuses on AFDD will not typically provide standard Utility Bill Management capabilities; however, there are and will continue to be exceptions to these general trends as the marketplace evolves. Agencies can consider an EMIS stack that includes multiple vendors and products that meet the design intent rather than attempting to check all boxes with one vendor or product.

4. Establish Feasibility

Once the capabilities and scope are defined, confirm the initial EMIS concept by establishing feasibility. The feasibility of the EMIS plan starts with a survey of systems in the scope to provide a more detailed vetting and inform the detailed planning of EMIS implementation. In this step, the goal is to determine what data exists, the data resolution, and how the data can be accessed and communicated with the EMIS. The understanding and investigation of existing data sources is a key input to subsequent steps. After the survey, the initial hardware and software architecture of the EMIS can be designed and used to create a budget, business case, and obtain necessary approvals. When the budget is assembled it should include all costs inherent to an EMIS solution, including:

- EMIS Scope Upgrades: Costs associated with upgrades to enable the desired EMIS functionality. Examples are energy metering hardware and communications, adding points to the BAS, or retrofits
- Base EMIS Cost: Software license, deployment labor
- Annual Recurring Costs: Software license renewals or SaaS fees, O&M labor
- Implementation Costs: In-house and contracted labor, materials, and equipment associated with implementing opportunities identified through the EMIS operations process.

The business case can be completed by estimating the utility cost savings expected as a result of EMIS deployment and operations. Several publications by LBNL can help agencies in constructing budget savings estimates for different types of EMIS capabilities (Lin, Kramer, and Granderson 2020; Kramer et al. 2019b).

Next, the team should investigate the availability of financial incentives from the local utility. At the time of this writing, EMIS-related incentives are available from electric utilities in New York, Colorado, Chicago, and several other service territories. In general, incentive payments offset a portion of the base EMIS costs and the annual recurring costs. Implementation costs are often offset based on how much energy and/or demand savings are expected from the implementation of each measure identified using EMIS. The Smart Energy Analytics Campaign website provides a spreadsheet with a list of available incentives for each state (DOE 2021f).

Finally, many building owners choose to conclude their feasibility assessment by performing a pilot project. For example, some decide to pilot the top one or two EMIS platforms (or combination of platforms) on a small number of buildings over a three-to-six-month period to ensure the EMIS platform meets their needs. Piloting ensures an EMIS platform is selected that meets the needs of the federal agency and is free of operational problems before deploying it at scale across the entire portfolio. During this piloting process it is also important to ensure that the EMIS platform is delivering value and would result in a life cycle cost effective deployment when considering SaaS costs, labor costs, and so on.

5. Define Data Management Standards

A common strategy to overcome some of the challenges noted above and to ensure the full usability of an agency's building data is to create standard data management practices. The creation of a procedure to standardize point naming and metadata assignment ensures consistent data across the campus. The standardized naming ensures consistency between the EMIS historian and the point names in the connected systems, enabling efficient correction of problems that are identified by EMIS capabilities. This allows for greater consistency across sites and greater headquarters- or enterprise-level deployment and functionality of EMIS, just as headquarters- or enterprise-level implementation of an EnMS process allows for greater, and streamlined, energy performance improvement.

Incorporation of open standard protocols and data modeling provides flexibility and interoperability. Conversely, the use of proprietary standards leads to vendor lock-in and limits scalability, adaptability, and the ability to readily incorporate future technologies. Movements to define open standards, such as Project Haystack and the Brick Schema, provide structured and standardized deployments and accelerate new application development. By constructing the EMIS with open standard components, owners can retain flexibility and data ownership.

6. Prepare Documentation

The final step in EMIS planning brings together the detailed information needed for procurement and deployment of the EMIS. Depending on the scope of implementation, the following documentation may be needed for deployment:

- **EMIS Program Goals**: Outline goals of the project, recommended capabilities, EMIS data sources/scope, and so on
- **Role and Responsibilities**: The above roles assigned to internal and external team members
- **Facility Documentation**: Current facility requirements (California Commissioning Collaborative 2012), utility account and meter information, meter and equipment lists, drawings, system architectures, sequences of operations, recent energy audits or commissioning reports
- **EMIS Architecture**: Network diagram, hardware and software required, IT integration method, EMIS scope integration method
- **EMIS Scope**: Equipment list for each system, points list to/from each system
- **EMIS Capabilities**: Analysis methods to be performed, user interface requirements, analytics (such as FDD rules and KPIs) requirements, modeling requirements, customization required
- **Data Management Standards**: Point naming standard, data modeling standard, and data ownership policy.

EMIS Procurement

Once the site or agency establishes an EMIS plan, the next step is to procure software and services to execute the plan. This section builds on the planning process above by introducing by discussing an EMIS specification document that can assist with EMIS procurement, in addition to EMIS purchasing considerations Agency-specific procurement processes are outside of the scope of this technical report.

Request for Information/Request for Proposals Specification

An updated EMIS Specification was released in 2020 and is intended to guide the user through the specification, procurement, and selection of an EMIS or related building performance monitoring and diagnostic technologies. This package of materials It includes a Request for Information (RFI)/Request for Proposal (RFP) Template, an EMIS Technology Specification, an ongoing EMIS Services Specification, and additional sections to define the proposal format, eligibility, and evaluation approach. This package is available to download[10] and allows the end user to create a customized draft RFP to match the model EMIS plan resources.

This dual federal and commercial EMIS RFP tool builds on the specification tool provided by the Department of Energy's Building Technologies Office (DOE 2015c). As the previous specification document was focused on EIS the new version includes a detailed specification for fault detection and diagnostics tools, automated system optimization, and ongoing services to support the use of the EMIS. The EMIS RFP tool can also be tailored to the federal sector to include key cybersecurity requirements and specified EMIS technologies.

Purchasing Considerations

Federal agency EMIS teams should be aware of several key decision factors and considerations when purchasing EMIS technology and services. This section provides an introduction and outline to these best practices.

Narrow the Field

The breadth of the EMIS software market can be overwhelming for EMIS teams. Before releasing the RFP, consider defining requirements carefully such that it narrows the field of qualified respondents using the EMIS planning process outlined above.

Consider Selecting Multiple EMIS Providers

Due to the breadth of the EMIS software market, software vendors vary in how well they fulfill individual capabilities. Depending on the agency's EMIS plan, it may be most beneficial to select multiple vendors to ensure the entire spectrum of capabilities desired is provided.

Define the Scope and Pricing Structure

A point of confusion for prospective EMIS buyers is what the vendors have included in their proposal. This makes it difficult to perform an apples-to-apples comparison of vendor proposals. Some vendors provide only software, while others provide only services and resell software provided by others. Others still provide software and services as a bundled package. Software vendors may provide their product under a SaaS agreement or other types of agreements.

Each vendor's proposal should explain the pricing structure for all software, hardware, integration, data commissioning, other services, and costs required for the project. The scope and pricing should be broken out in the following categories at a minimum:

- Hardware
- Software licenses

[10] EMIS Specification_LBNL_Dec2020.docx

- Annual software license maintenance fees
- Software and hardware set-up labor
- Annual maintenance labor.

When defining the scope, consider creating a dedicated scope for third-party service providers. If this scope is a significant portion of the EMIS project, consider selecting a software vendor with an active network of third-party service partners to minimize future dependence on one service vendor.

Consider an Open Data Layer

Similarly, one emerging best practice is installing a separate driver and historian layer allowing the trial and testing of multiple EMIS applications without needing to restart the integration from scratch. If the agency operates a large campus or portfolio, it could be beneficial in the long term to trial two or three EMIS applications to get a direct apples-to-apples comparison. Once the vendor or vendors are selected, the EMIS can be rolled out to the rest of the campus/portfolio at lower risk.

Define IT Requirements

Critical to implementing an EMIS that meets the agency's expectations and technical requirements is superior contract documentation. Agencies need to pay close attention not only to the details of the scope and the technical requirements of the EMIS technology itself, but also to requirements related to information technology. The RFP and contract need to specify the requirements of the agency's OT/IT representatives, including network administration, storage, backup, application hosting (local and/or cloud), security, permissions, and access control. Energy Act of 2020 requires each federal agency develop an implementation strategy for energy efficient and energy-saving IT. The implementation strategy for 'Information Technology' as specified in Section 11101 of United States Code Title 40, shall consider: (A) advanced metering infrastructure; (B) energy efficient data center strategies and methods of increasing asset and infrastructure utilization; (C) advanced power management tools; (D) building information modeling, including building energy management; (E) secure telework and travel substitution tools; and (F) mechanisms to ensure that the agency realizes the energy cost savings of increased efficiency and utilization. Sub-categories (A) and (D) are directly related to EMIS, and in addition to ensuring the EMIS complies with any IT requirements, the IT group should be consulted to see if EMIS applications can be installed to help meet Energy Act of 2020 requirements that the agency's IT group is responsible for. While developing a robust IT security policy and related contract specifications around building technologies is a daunting challenge, there are existing and widely accepted standards that should be utilized; these are partially addressed in the Cybersecurity section above.

Integration into ESPCs or Utility Energy Service Contracts

Many federal agencies rely heavily on alternative financing, through either ESPCs or UESCs to finance energy projects at federal sites. There is a great opportunity to integrate EMIS into federal ESPCs or UESCs, resulting in process enhancements at each stage of the project, including the preliminary assessment, investment grade audit, commissioning during the construction phase and M&V during the performance period. These enhancements would enable automated M&V, better ongoing AFDD and condition-based maintenance and allow the agency to implement more advanced smart building technologies, including more complex solutions like grid interactive efficient buildings (Dean et al. 2021).

Based on the EMIS process outlined above, the agency should work with their alternative finance team to build EMIS requirements into the Notice of Intent to Award and outline the buildings EMIS should be considered for, the scope items requesting to be integrated into the EMIS, and how the agency is requesting the EMIS be used in each phase of the project.

EMIS Deployment

During EMIS deployment, the team will execute the installation, programming, and setup activities scoped during the planning and procurement phases. Most of the deployment activities will be done by vendors, but it is important for the agencies to participate to get the most out of the EMIS deployment. Agencies are the authority on their buildings; deployment will go best when they engage and take responsibility for the execution of their EMIS plan and the robustness of the system. This process extends beyond simply installing hardware and software—the EMIS must be commissioned, and the team must be trained for operation as required by their roles and responsibilities.

Installing EMIS

Preparing Systems for Integration

Many modern building systems were not designed or installed with the intention to facilitate smooth communication with EMIS software. To allow better communication with the EMIS, some systems should be prepared for integration. System integrators may need to modify naming conventions, modify data points from a closed to an open protocol, or set up historian trends to support this effort. System technicians should ensure all sensors and meters are calibrated and communicating before their data is pulled into the EMIS platform. For reference, the California Commissioning Collaborative provides a template and sample document to follow for facility sensor calibration (California Commissioning Collaborative 2012).

System Integration

Creating the connections between EMIS and systems in the EMIS scope is often called systems integration. The systems need to be integrated in order to establish a common communication language, or protocol, and convert all of the time series data into a single format. A communication gateway or API connection will be established between EMIS and each system to allow the exchange of data.

Data Modeling

A vital part of integration is adding context that describes the data. This is typically accomplished through semantic modeling, which attaches metadata to the data to describe relationships between sensors or equipment and describe attributes such as units and type of measurement. According to the agency's standard developed during EMIS planning, the integrated systems, equipment, and points will be named and modeled to add context to each connected data point. Figure 41 shows an example of the Project Haystack data modeling standard applied to NREL's Intelligent Campus program.

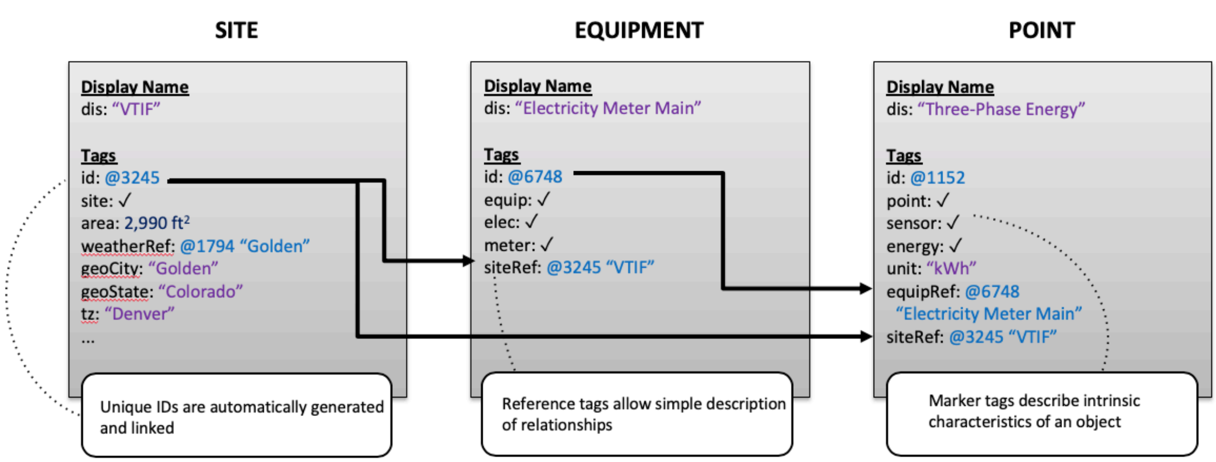

Figure 41. NREL's data modeling schema based on Project Haystack

Image Credit: NREL, Steve Frank

Customization

Many EMIS vendors provide capabilities that are not fully operable out of the box, so the next step is to customize and tune the EMIS. Typical customized visualization features include graphical user interfaces, dashboards, graphics, and reports that may differ based on the stakeholder that is logged into the system. Analytics such as KPIs, AFDD rules, prediction models, M&V baselines, and fault prioritization capabilities should also be customized based on the agency's EMIS plan.

Quality Checking

Once the EMIS is set up, the data, visualization, and analytics need to be quality-checked for common issues. Issues should be tracked in an issues log with follow-up actions assigned to the appropriate team member. A common issue is missing data or gaps in data. Figure 42 shows can example of how this looks in the EMIS.

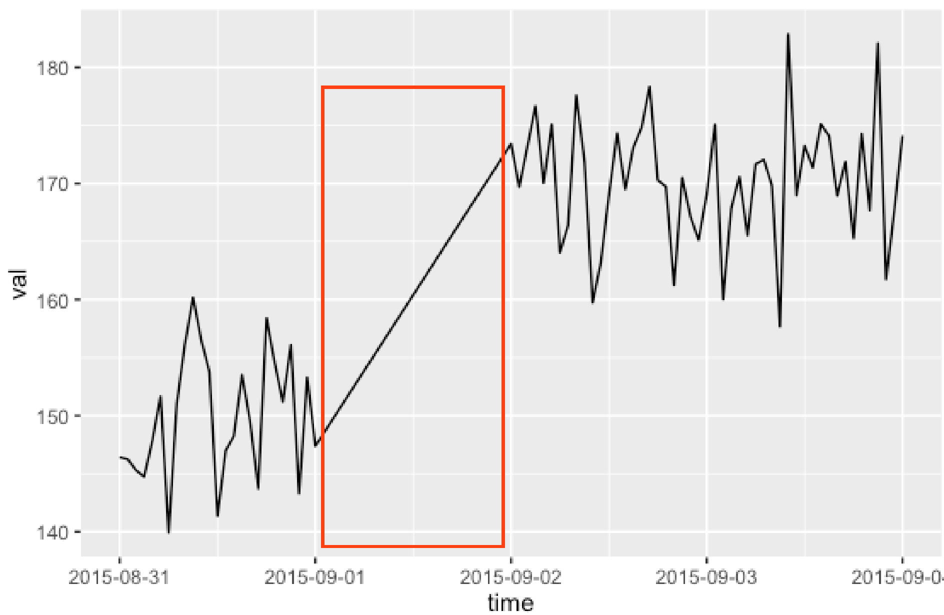

Figure 42. Example of a gap in time series data

Image Credit: Rashid 2016

Other typical issues include inaccurate sensor or meter data, erroneous data naming or modeling, insufficient data interval, software bugs, erroneous analytics (e.g., false negative and false positive faults), and dropped communication between devices.

Training

The final step of EMIS deployment is to train all team members to perform their roles and ensure those staff are part of the EnMS energy team. The vendor and/or service provider should fulfill the specified training requirements and document the materials needed for training. As necessary, training should be repeated on a regular schedule to make sure all operators are up to speed. For advanced users, software vendors' training classes offer the opportunity to deepen expertise and reduce dependence on external service providers. Starting in 2022, FEMP will begin offering general in-person and online EMIS training.

FEMP Tools & Resources

An agency's five-year metering plan should include or reference relevant tools and resources that utilize metering data to support federal data requirements or programs that advance the agency's mission. Meters are important sources of data to ensure the mission of sites as well as the quantification and reporting of energy and water use. FEMP has many programs and resources that can utilize the data from meters to support energy and water management and optimization and to develop, procure, and operate optimal EMIS. FEMP resources to consider include:

- **Metering**. FEMP provides many resources to support agencies with energy and water meters, including best practices and implementation plans.[11]
- **Benchmarking**. DOE provides guidance and resources to assist federal sites in complying with statutory building benchmarking requirements, including:
  - **Energy Independence and Security Act, Section 432: Federal Facility Management and Benchmarking Requirements Overview**[12]
  - **Federal Building Energy Use Benchmarking Guidance**: Offers guidance about EISA 432 benchmarking of federal facilities.[13]
  - **Benchmarking Starter Kit:** The Benchmarking Starter Kit provides step-by-step guidance on how to benchmark a building using Portfolio Manager. The Benchmarking Starter Kit can be found on the ENERGY STAR website at www.energystar.gov.
- **Federal Comprehensive Annual Energy Reporting Requirements:** Guidance on comprehensive fiscal year reporting to meet the energy management requirements of the National Energy Conservation Policy Act, as amended (42 U.S.C. 8253-8258); the Energy Policy Act of 2005 (42 U.S.C. 15852); and associated executive orders[14]:
  - **Annual Energy Management Data Report Workbook for Fiscal Year Reporting**: Top-tier federal departments and agencies must use FEMP's Annual Energy Management Data Report workbook for comprehensive reporting of fiscal year energy, costs, square footage, and associated operational data.
  - **Reporting Guidance for Federal Agency Annual Report on Energy Management:** for submitting the required narrative information for their annual energy reports. The Reporting Guidance includes three attachments:
    - Guidance for Receiving Credit on Energy Performance Goal for Projects that Save Source Energy but Increase Site-Delivered Energy
    - Guidance to Receive Credit on Energy Performance Goal to Normalize for Weather in Benchmarked Buildings
    - Guidance to Receive Credit on Energy Performance Goal for Energy Intensity Improvements in Goal-Excluded Buildings.

---

[11] https://www.energy.gov/eere/femp/metering-federal-buildings
[12] http://energy.gov/eere/femp/eisa-section-432-federal-facility-management-and-benchmarking-requirements
[13] http://energy.gov/eere/femp/eisa-section-432-federal-facility-management-and-benchmarking-requirements
[14] https://www.energy.gov/eere/femp/federal-facility-consolidated-annual-reporting-requirements

- **Guidelines Establishing Criteria for Excluding Buildings from the Energy Performance Requirements of Section 543 of NECPA**
- **Federal Comprehensive Annual Energy Performance Data**: Government performance toward efficiency goals, data sets for the most recently reported fiscal year, greenhouse gas emissions inventories, and historical energy data going back to FY 1975.[15]

- **50001 Ready**. Through 50001 Ready,[16] DOE provides guidance and resources to allow federal sites to institute an EnMS that conforms to the ISO 50001 standard and allows for self-certification of compliance. In addition, 50001 Ready can be used across multiple sites in a standardized fashion at the regional, bureau or agency level to streamline the responsibilities of individual sites and allow for greater continuity of operations. Meter data can be leveraged to support many of the 50001 Ready tasks, particularly in the areas of energy systems measurement and monitoring, assessing opportunities, and benchmarking and reporting.

- **Technical Resilience Navigator**. The Technical Resilience Navigator[17] helps organizations manage the risk to critical missions from disruptions in energy and water services through a comprehensive, risk-informed resilience planning process. Its systematic approach to identifying energy and water resilience gaps and developing and prioritizing solutions that reduce risk enables organizations to address vulnerabilities to their critical energy and water systems, reduce outage impacts, and support continuous mission operations.

- **Auditing**. DOE provides audit guidance and tools available to all federal agencies.[18] These resources arm federal agencies in saving energy and water by identifying needed ECMs to assist them in meeting the evaluation requirement set by EISA Section 232. Some of the resources include workforce development (training), energy/water analysis tools, decision tree to identify the appropriate audit approach, and statement of work templates to assist agencies in procuring audit services.

- **Retro-commissioning**. DOE provides several resources for federal agencies. Re-tuning is a form of retro-commissioning, which is required by EISA Section 232.[19] DOE has been very active in engaging agencies on the re-tuning concept. Some resources offered include training (workforce development), re-tuning assistance, and regional workshops. Early reports show re-tuning accomplished at federal sites resulted in annual energy savings greater than 18%.

- **Water Tool**. FEMP provides agencies with guides and resources on how to increase water efficiency and reduce water use in federal buildings and campuses.[20] For example, the resource Prioritizing Building Water Meter Applications[21] offers technical information to assist agencies in developing a prioritization for water metering of buildings using a comprehensive water use approach.

[15] https://www.energy.gov/eere/femp/federal-facility-annual-energy-reports-and-performance
[16] More information on the DOE 50001 Ready program is available at: https://energy.gov/50001Ready/
[17] https://trn.pnnl.gov/
[18] https://www.energy.gov/eere/femp/energy-and-water-audits-federal-buildings
[19] https://www.energy.gov/eere/femp/re-tuning-federal-buildings
[20] https://www.energy.gov/eere/femp/water-efficiency-federal-buildings-and-campuses
[21] https://www.energy.gov/eere/femp/prioritizing-building-water-meter-applications

Conclusions

This report provided an updated framework to characterize EMIS systems, and explored the EMIS scope, stack, capabilities and operations. EMIS tools offer significant opportunities for energy savings and improved operational performance for a range of federal facilities. The tools have the potential to transform energy management best practices by providing well-organized building performance and energy consumption data to building owners and operators, enabling a host of analytic capabilities. Proper deployment of EMIS should include the establishment of an EnMS which codifies the people and cultural side of energy performance improvement and uses the EMIS to execute energy and operational improvements.

Key to successful implementation is a thorough understanding of the EMIS stack, thoughtful prioritization of the elements of the EMIS scope for each facility or portfolio, and careful procurement planning for an effective competitive solicitation. Once a technology is selected, effective EMIS deployment and operation depend on clearly defined goals, roles, and thorough documentation.

The FEMP EMIS website (www.energy.gov/eere/femp/energy-management-information-systems-federal-facilities), was deployed in Spring 2021 and serves as a landing page for federal agencies looking to explore EMIS further. It provides hyperlinks to the large body of work that informs many of the themes and topics in this document. The website will also feature several case studies of EMIS deployments in federal portfolios, including GSA, U.S. Army, U.S. Navy, U.S. Army National Guard, and at NREL.

Federal agencies are encouraged to incorporate an EMIS into their five-year metering plan,[22] and use the EMIS to track the performance of the program, as specified in Energy Act of 2020.[23] In a rapidly evolving landscape, EMIS is a proven technology that has been successfully deployed by many federal agencies. These EMIS technologies have significant potential for both new adoption and expanded future deployment in the federal sector, providing value in many ways and often impacting a broad set of stakeholders.

[22] This guidance document and additional FEMP resources for metering in Federal buildings are available at: https://www.energy.gov/eere/femp/metering-federal-buildings
[23] Public Law 116–260, Energy Act of 2020 (Dec. 27, 2020).

References

Accenture (2011). "Energy-Smart Buildings: Demonstrating How Information Technology Can Cut Energy Use and Costs of Real Estate Portfolios." Accessed June 26, 2020. https://www.cacx.org/meetings/meetings/2012-04-12/Microsoft-energy_smart_buildings_whitepaper.pdf.

ASHRAE (2019a). ANSI/ASHRAE/IES Standard 90.1-2019 -- Energy Standard for Buildings except Low-Rise Residential Buildings. Accessed October 8, 2020. https://www.ies.org/product/ansi-ashrae-ies-standard-90-1-2019-energy-efficiency-standard-for-buildings-except-low-rise-residential-buildings/.

ASHRAE (2019b). *Smart Grid Application Guide: Integrating Facilities with The Electric Grid*. Atlanta, GA: ASHRAE. https://www.techstreet.com/ashrae/standards/smart-grid-application-guide-integrating-facilities-with-the-electric-grid?product_id=2097813.

Bonneville Power Administration (2012). *Regression for M&V: Reference Guide.* Portland, OR: Bonneville Power Administration. https://www.bpa.gov/EE/Policy/IManual/Documents/July%20documents/3_BPA_MV_Regression_Reference_Guide_May2012_FINAL.pdf.

Building Commissioning Association (2017). *2017 Building Commissioning Handbook, 3rd edition.* Hillsboro, OR: Building Commissioning Association. https://www.bcxa.org/knowledge-center/building-commissioning-handbook/.

California Commissioning Collaborative (2012). "Commissioning Tools and Templates." Accessed June 26, 2020. https://cacx.org/resources/cxtools/index.html.

California Energy Commission (2011). *The Building Performance Tracking Handbook.* https://www.cacx.org/PIER/documents/bpt-handbook.pdf.

Cutler, Dylan, Stephen Frank, Michelle Slovensky, Michael Sheppy, and Anya Petersen (2016). "Creating an Energy Intelligent Campus: Data Integration Challenges and Solutions at a Large Research Campus." ACEEE Summer Study on Energy Efficiency in Buildings. https://aceee.org/files/proceedings/2016/data/papers/12_1016.pdf.

Dean, Jesse, Harris, Tom, Voss, Phil, and James Dice (2021). *Enhancing Performance Contracts with Monitoring-Based Commissioning*. Washington, DC: Federal Energy Management Program.

EnergyCAP (2020). "Energy Management Software." Accessed June 26, 2021. https://www.energycap.com/software.

Efficiency Valuation Organization (2015). "A Fresh Look for the 2016 IPMVP Core Concepts." Accessed June 26, 2021. https://evo-world.org/en/recent-news-home/1025-a-fresh-look-2016-ipmvp-core.

Efficiency Valuation Organization (2020). "International Performance Measurement and Verification Protocol (IPMVP)." Accessed June 26, 2021. https://evo-world.org/en/products-services-mainmenu-en/protocols/ipmvp.

Executive Order No. 14008 (2021). Tackling the Climate Crisis at Home and Abroad, 86 C.F.R. 7619 (7619-7633).

Fathy, Angelique, and Cara Carmichael (2019). "Why Building Owners Should Care About Increasing EV Adoption." *Rocky Mountain Institute.* Accessed June 26, 2020. https://rmi.org/why-building-owners-should-care-about-increasing-ev-adoption/.

Federal Energy Management Program (2021). "About the Federal Energy Management Program." Accessed June 26, 2021. https://www.energy.gov/eere/femp/about-federal-energy-management-program.

Federal Real Property Council (2019). *Guidance for Real Property Inventory Reporting*. Washington, D.C.: U.S. General Services Administration. https://www.gsa.gov/cdnstatic/FY%202019%20FRPP%20DATA%20DICTIONARY.pdf.

Fonts, Alberto (2014). "Predictive Energy Optimization: Smart Buildings, Smart Grids, Smart Cities." Cleantechnica.com. Accessed June 26, 2020. https://cleantechnica.com/2014/02/12/predictive-energy-optimization-smart-buildings-smart-grids-smart-cities/.

Granderson, Jessica, Mary Ann Piette, Ben Rosenblum, R. Lily Hu, Daniel Harris, Paul A Mathew, Phillip N Price, Geoffrey C Bell, Srinivas Katipamula, and Michael Brambley (2011). *Energy Information Handbook: Applications for Energy-Efficient Buildings Operations.* Berkeley, CA: Lawrence Berkeley National Laboratory. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/energy-information-handbook.pdf.

Granderson, Jessica, Guanjing Lin, and Mary Ann Piette (2013). *Energy information systems (EIS): Technology costs, benefit, and best practice uses.* Berkeley, CA: Lawrence Berkeley National Laboratory. https://buildings.lbl.gov/publications/energy-information-systems-eis.

Granderson, Jessica, Rupam Singla, Ebony Mayhorn, Paul Ehrlich, Draguna Vrabie, and Stephen Frank (2017). *Characterization and Survey of Automated Fault Detection and Diagnostic Tools*. Berkeley, CA: Lawrence Berkeley National Laboratory. https://eta-publications.lbl.gov/sites/default/files/lbnl-2001075.pdf.

Granderson, Jessica, Hannah Kramer, and Claire Curtin (September 10, 2018). "How to Implement Monitoring-Based Commissioning." *FacilitiesNet*. Accessed June 26, 2020. https://www.facilitiesnet.com/buildingautomation/article/How-To-Implement-Monitoring-Based-Commissioning--17961.

Guild, Jeff, Eric Koeppel, and Curtis Hilger (2012). "Energy Management & Information Systems." San Francisco, CA: PG&E Emerging Technologies Program. https://www.etcc-ca.com/sites/default/files/OLD/images/stories/enovity_emis_pge_et_report_final.pdf.

Howard, Ann (2019). "Mission Assurance through Energy Assurance DoD Installations and the Use of ISO 50001." *Defense Standardization Program Journal* (January–April 2019); pp. 33–38. https://www.dsp.dla.mil/Portals/26/Documents/Publications/Journal/190417-DSPJ-03.pdf.

Katimapula, Srinivas and Michael Brambley (2005). "Methods for Fault Detection, Diagnostics, and Prognostics for Building Systems—A Review, Part 1." *HVAC&R Research (*11:1); pp. 3–25. https://www.tandfonline.com/doi/abs/10.1080/10789669.2005.10391123.

KGS Buildings (2020). "KGS Buildings." Accessed June 26, 2020. https://www.kgsbuildings.com/.

Kramer, Hannah, Eliot Crowe, and Jessica Granderson (2017). *Monitoring-Based Commissioning Plan Template.* Berkeley, CA: Lawrence Berkeley National Laboratory. https://drive.google.com/file/d/0BzgPTwDtt6KdYkNYRDR3ZGMtUVU/view.

Kramer, Hannah, Guanjing Lin, Jessica Granderson, Claire Curtin, Eliot Crowe, and Rui Tang (2019a). *Synthesis of Year Three Outcomes in the Smart Energy Analytics Campaign.* Berkeley, CA: Lawrence Berkeley National Laboratory.

Kramer, Hannah, Guanjing Lin, Jessica Granderson, Claire Curtin, and Eliot Crowe (2019b). *Buildings analytics and monitoring-based commissioning: industry practice, costs, and savings.* Berkeley, CA: Lawrence Berkeley National Laboratory. https://eta-publications.lbl.gov/sites/default/files/building_analytics_-_kramer.pdf.

KW Engineering (2020). “Why NMEC Is Simply Sublime.” Accessed June 26, 2020. https://www.kw-engineering.com/nmec-normalized-metered-energy-consumption/.

Lawrence Berkeley National Laboratory (2020). “50001 Ready Navigator.” Accessed July 8, 2020. https://navigator.lbl.gov/.

Lin, Guanjing, Rupam Singla, and Jessica Granderson (2017). *Using EMIS to Identify Top Opportunities for Commercial Building Efficiency.* Berkeley, CA: Lawrence Berkeley National Laboratory. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/EMIS_Top_Opportunities-May_2017.pdf.

Lin, Guanjing, Hannah Kramer, and Jessica Granderson (2020). “Building Fault Detection and Diagnostics: Achieved Savings, and Methods to Evaluate Algorithm Performance.” *Building and Environment* 168, 106505. https://doi.org/10.1016/j.buildenv.2019.106505.

Lucid Design Group (2020). “Optimize Energy & Resource Usage.” Accessed June 26, 2020. https://lucidconnects.com/solutions/building-data-analysis.

Mach Energy (2020). “Customizable Dashboard.” Accessed June 26, 2020. https://www.machenergy.com/customizable-dashboard.

Mills, Evan (2009). *Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions.* Berkeley, CA: Lawrence Berkeley National Laboratory. http://cx.lbl.gov/documents/2009-assessment/lbnl-cx-cost-benefit-pres.pdf.

Mills, Evan (2011). “Building commissioning: a golden opportunity for reducing energy costs and greenhouse gas emissions in the United States.” *Energy Efficiency* (4); pp. 145–173. https://doi.org/10.1007/s12053-011-9116-8.

Neukomm, Monica, Valerie Nubb, and Robert Fares (2019). *Grid-Interactive Efficient Buildings: An Overview.* Washington, D.C.: Office of Energy Efficiency and Renewable Energy. https://www.energy.gov/sites/prod/files/2019/04/f61/bto-geb_overview-4.15.19.pdf.

National Institute of Standards and Technology (2013). *Security and Privacy Controls for Federal Information Systems and Organizations*. Washington, D.C.: U.S. Department of Commerce. https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-53r4.pdf.

National Institute of Standards and Technology (2020). “Cybersecurity Framework (CSF) Reference Tool.” Accessed June 26, 2020. https://www.nist.gov/cyberframework/nist-cybersecurity-framework-csf-reference-tool.

Office of Management and Budget (2000). *Transmittal Memorandum No. 4 (Revised): Management of Federal Information Resources*. Washington, D.C.: Office of Management and Budget. https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/circulars/A130/a130trans4.pdf.

Office of Management and Budget (2016). *Circular No. A-130: Managing Information as a Strategic Resource*. Washington, D.C.: Office of Management and Budget. https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/circulars/A130/a130revised.pdf.

Pacific Northwest National Laboratory (2020a). “Whole Building Diagnostician.” Accessed June 26, 2020. https://availabletechnologies.pnnl.gov/technology.asp?id=60.

Pacific Northwest National Laboratory (2020b). “Facility Cybersecurity Framework.” Accessed June 26, 2020. https://facilitycyber.labworks.org/.

Pacific Northwest National Laboratory (2020c). "About the Facility Cybersecurity Framework." Accessed June 26, 2020. https://facilitycyber.labworks.org/fcf/about.

Powell, Charisa, Konrad Hauck, Anuj Sanghvi, Adarsh Hasandka, Joshua Van Natta, and Tami Reynolds (2019). Guide to the Distributed Energy Resources Cybersecurity Framework. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5R00-75044. https://www.nrel.gov/docs/fy20osti/75044.pdf.

Rashid, Haroon (October 17, 2016). *Re: Differentiate missing values from main data in a plot using R* [Discussion Post]. Stack Overflow. https://stackoverflow.com/questions/40087340/differentiate-missing-values-from-main-data-in-a-plot-using-r.

Rohloff, Adam, and Jim Meacham (2016). "Data Analytics from Cradle to Grave." *ASHRAE Journal* (58:2); pp. 34-48. https://www.techstreet.com/standards/data-analytics-from-cradle-to-grave?product_id=1910144#jumps.

Schein, Jeffrey and Steven Bushby (2005). *A Simulation Study of a Hierarchical, Rule-Based Method for System-Level Fault Detection and Diagnostics in HVAC Systems*. Washington, D.C.: National Institute of Standards and Technology. https://nvlpubs.nist.gov/nistpubs/Legacy/IR/nistir7216.pdf.

Sitton Energy Solutions (2020). "Sitton Energy Solutions." Accessed June 26, 2020. https://sittoncg.com/.

SkyFoundry (2020). "SkySpark." Accessed June 26, 2020. https://www.skyfoundry.com/.

Swegon Air Academy (2017). "HVAC Commissioning: Definition, qualified personnel and tips." Accessed November 17, 2020. https://www.swegonairacademy.com/2017/10/26/hvac-commissioning-definition-qualified-personnel-and-tips/.

Sullivan, G. P., R. Pugh, A. P. Melendez, and W. D. Hunt (2010). *Operations & Maintenance Best Practices*. Richland, WA: Pacific Northwest National Laboratory. https://www.energy.gov/sites/prod/files/2013/10/f3/omguide_complete.pdf.

Switch Automation (2020). "Switch Automation." Accessed June 26, 2020. https://www.switchautomation.com/.

Talisen Technologies (2020). "Talisen Technologies." Accessed June 26, 2020. https://www.talisentech.com/.

United States Department of Energy (2014a). *Federal Building Energy Use Benchmarking Guidance.* Washington, D.C.: United States Department of Energy. https://www.energy.gov/sites/prod/files/2014/09/f18/benchmarking_guidance08-2014.pdf.

United States Department of Energy (2014b). "Electric Sector Cybersecurity Capability Maturity Model (ES-C2M2)." Washington, D.C.: United States Department of Energy. https://www.energy.gov/sites/prod/files/2014/02/f7/ES-C2M2-v1-1-Feb2014.pdf.

United States Department of Energy (2015a). *A Primer on Organizational Use of Energy Management and Information Systems (EMIS).* Berkeley, CA: Lawrence Berkeley National Laboratory.

United States Department of Energy (2015b). *Metering Best Practices: A Guide to Achieving Utility Resource Efficiency, Release 3.0*. Richland, WA: Pacific Northwest National Laboratory. https://www.wbdg.org/ffc/doe/national-laboratory-criteria/metering-best-practices.

United States Department of Energy (2015c). *Energy Management Information Systems (EMIS) Specification and Procurement Support Materials*. Berkeley, CA: Lawrence Berkeley National Laboratory. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/emis_proc_spec_BBA_FINAL_021815_508.pdf.

United States Department of Energy (2017). "Using EMIS to Identify Top Opportunities for Commercial Building Efficiency." Accessed June 26, 2020. https://betterbuildingssolutioncenter.energy.gov/resources/using-emis-identify-top-opportunities-commercial-building-efficiency.

United States Department of Energy (2021a). "Comprehensive Annual Energy Data and Sustainability Performance." Accessed March 30, 2021. https://ctsedwweb.ee.doe.gov/Annual/Default.aspx?ReturnUrl=%2fAnnual%2fReport%2fGovernmentWideSiteDeliveredEnergyUseAndCostsInAllEndUseSectorsConstantDollarsCurrentYear.aspx.

United States Department of Energy (2021b). *Federal Metering Guidance 2020 Update.* Washington, D.C.: United States Department of Energy.

United States Department of Energy (2021c). "FY 2018 Agency Progress towards Electricity Metering Goals." Accessed March 30, 2021. https://ctsedwweb.ee.doe.gov/Annual/2018/Report/AgencyProgressTowardsElectricityMeteringGoals.aspx.

United States Department of Energy (2021d). "FY 2018 Agency Progress towards Natural Gas Metering Goals." Accessed March 30, 2021. https://ctsedwweb.ee.doe.gov/Annual/2018/Report/AgencyProgressTowardsNaturalGasMeteringGoals.aspx.

United States Department of Energy (2021e). "FY 2018 Agency Progress towards Steam Metering Goals." Accessed March 30, 2021. https://ctsedwweb.ee.doe.gov/Annual/2018/Report/AgencyProgressTowardsSteamMeteringGoals.aspx.

United States Department of Energy (2021f). "Utility Incentives." Accessed March 30, 2021. https://smart-energy-analytics.org/utility-incentives.

United States Environmental Protection Agency (2020). "Summary of the Energy Policy Act." Accessed June 26, 2020. https://www.epa.gov/laws-regulations/summary-energy-policy-act.

United States General Services Administration (2012). "Federal Real Property Public Data Set."

United States General Services Administration (2019). "Submeters and Analytics: Full Panel." Accessed June 26, 2020. https://www.gsa.gov/governmentwide-initiatives/sustainability/emerging-building-technologies/published-findings/energy-management/submeters-and-analytics-full-panel.

United States General Services Administration (2020a). "GSA Data Normalization for Building Automation Systems." Accessed June 26, 2020. https://imlive.s3.amazonaws.com/Federal%20Government/ID225042502317072408508488262343172231156/Exhibit_B.pdf.

United States General Services Administration (2020b). "Understanding Baselines and Impact Levels in FedRAMP." Accessed June 26, 2020. https://www.fedramp.gov/understanding-baselines-and-impact-levels/.

University of California Davis (2020). "Campus Energy Education Dashboard." Accessed June 26, 2020. https://ceed.ucdavis.edu/.

Appendix A: Federal Requirements Related to EMIS

Laws & Requirements	EMIS Capabilities: Centralize, Normalize, Visualize Data	Utility Bill Management	Interval Meter Analytics	Measurement & Verification (M&V)	Automated Fault Detection & Diagnostics	Supervisory Control	Operations & Maintenance Optimization
Facility Energy Efficiency							
Building Energy Intensity Reduction • Subject to certain exclusions, each federal agency must reduce the energy consumption per gross square foot of its federal buildings relative to a fiscal year (FY) 2003 baseline by 27% by 2014 and by 30% by FY 2015 per EISA 2007 § 431, subject to the exclusions of EPAct 102(c). • Per Executive Order 13834 § 2(a) federal agencies are directed to achieve and maintain annual reductions in building energy use and implement energy efficiency measures that reduce costs.	✓	✓	✓	✓	✓	✓	✓
Data Center Management • Per Section 1004 of EA of 2020, DOE and EPA will assess the adequacy of current metrics, benchmarks, and best practices under the National Data Center Energy Efficiency Information Program for use by FEMP and others.	✓	✓	✓	✓	✓	✓	✓
Benchmarking of Federal Facilities • Per EISA 2007 § 432 (42 U.S.C. § 8253(f)(8)), agencies are required to enter energy use data for each metered covered facility into a building energy use benchmarking system.	✓	✓	✓	✓			
Energy and Water Evaluations • Per EISA 2007 § 432, agency energy managers are required to complete an annual comprehensive energy and water evaluation for approximately 25% of agency covered facilities in a manner that ensures that an evaluation of such facility is completed at least once every four years. • Executive Order 14008 tasks heads of agencies with taking steps to ensure federal funding is used to spur innovation, commercialization, and deployment of clean energy technologies and infrastructure.	✓	✓	✓	✓	✓		
Follow Up on Implemented Measures • Per EISA 2007 § 432, for each measure implemented under 42 U.S.C. § 8253(f)(4), agencies are required to ensure that equipment is fully commissioned at acceptance to be operating at design specifications; a plan for appropriate operations, maintenance, and repair of the equipment is in place at acceptance and is followed; equipment and system performance is measured during its entire life to ensure proper operations, maintenance, and repair; and energy and water savings are measured and verified.	✓		✓	✓	✓	✓	✓
Recommissioning and Retro-Commissioning • Per EISA 2007 § 432, as part of the evaluation under 42 U.S.C. § 8253(f)(3)(A), energy managers are required to identify and assess recommissioning measures (or if the facility has never been commissioned, retro-commissioning measures) for the facility.	✓		✓	✓	✓	✓	✓
Web-Based Certification • Per EISA 2007 § 432, for each covered facility, an agency is required to use a web-based tracking system to certify compliance with the requirements for energy and water evaluations under 42 U.S.C. § 8253(f)(3), implementation of identified energy and water measures under 42 U.S.C. § 8253(f)(4), and follow-up on implemented measures under 42 U.S.C. § 8253(f)(5).	✓	✓	✓	✓			

Laws & Requirements	Centralize, Normalize, Visualize Data	Utility Bill Management	Interval Meter Analytics	Measurement & Verification (M&V)	Automated Fault Detection & Diagnostics	Supervisory Control	Operations & Maintenance Optimization
Greenhouse Gas Management and Reporting							
Reporting • Pursuant to Executive Order 13834 Section 2(h) and 42 U.S.C. § 17143, agencies are instructed to track and report on greenhouse gas emissions and reductions.	✓	✓	✓	✓			
High Performance Sustainable Buildings							
Metering Requirements • Per EISA 2007 § 434; EPAct 2005 § 103, agencies are required to install metering and advanced metering devices in federal buildings in accordance with U.S. Department of Energy metering guidelines.	✓	✓	✓	✓			
Performance Tracking and Reporting							
Annual Energy Report • Per EISA 2007 § 527, federal agencies must submit to the Office of Management and Budget an annual government efficiency status report on compliance with each of the requirements of 42 U.S.C 17143: status of the implementation by the agency of initiatives to improve energy efficiency, reduce energy costs, and lower greenhouse gas emissions and savings to U.S. taxpayers resulting from mandated improvements.	✓	✓	✓	✓			
Renewable Energy Report							
Biannual Reporting • Per EPACT 2005 § 203, not later than April 15, 2007, and every two years thereafter, the U.S. Department of Energy is to provide a report to Congress on the progress of the Federal government in meeting the goals established under 42 U.S.C. § 15852.	✓		✓				

Table column group header: EMIS Capabilities

(This page intentionally left blank)

FEMP
Federal Energy Management Program

U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

For more information, visit:
energy.gov/eere/femp

DOE/GO-102021-5424 ▪ July 2021