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Energy Management Information System Powers NREL's Intelligent Campus

As part of the U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP), the National Renewable Energy Laboratory (NREL) leverages its buildings and onsite distributed energy resources (DER) as research instruments within its Intelligent Campus program. Real, quantitative energy measurements from NREL's campus are used to study renewable energy, energy efficiency, energy storage, and systems integration.

At the heart of NREL's Intelligent Campus program is its Energy Management Information System (EMIS), a family of tools and services used to store, analyze, and display energy use and facility performance data for management of building and campus energy use. EMIS is an umbrella term that covers energy meter analytics, condition-based monitoring (CBM), meter data management systems, and fault detection and diagnostics (FDD). NREL's Intelligent Campus program develops innovative analytics and visualization to help operators improve energy performance. The EMIS serves as a demonstration environment for other federal facilities interested in learning about its design, features, and benefits.

Figure 1. Dashboards, such as this prototype energy performance view, offer live visualization of on-site energy loads and generation at NREL's Research Support Facility. The gauges inform operators whether energy consumption in each category is within, above, or below its expected range. *Illustration by Marjorie Schott, NREL*

A Lab-Wide Intelligent Campus Program for Clear, Consistent Energy Performance Data

When NREL constructed its net-zero Research Support Facility (RSF) in 2010, researchers were interested in monitoring, studying, and authenticating the building's actual energy performance. The lab needed a unified approach to gathering performance data within a single, well-defined architecture to avoid differences in naming conventions, organization, and data quality.

This need inspired NREL to launch its Intelligent Campus program, with objectives to:

- Organize, analyze, and present campus energy and water data to provide operational and research insights
- Demonstrate ongoing performance excellence in meeting federal requirements and goals
- Leverage data insights to optimize campus operations
- Enable hybrid operations and research initiatives.

The Intelligent Campus program enables implementation of leading-edge energy efficiency, analytics, and control strategies across NREL's campuses. NREL's Intelligent Campus program further positions NREL as a leader in defining facility operations best practices. To ensure the success of the program as a highly collaborative, integrated, campus-wide effort, it was housed within the lab's Site Operations team and allocated permanent funding, rather than project-based funding. The Intelligent Campus team includes NREL staff from directorates and centers across the laboratory, enabling collaboration between researchers and building operators. Tenets of the program include open standards for data organization and communication and the use of widely adopted, industry-built tools to reduce operating costs.

Figure 2. NREL's Intelligent Campus program implemented an EMIS that standardizes data, facilitates reporting, and enables new insights for 33 buildings across two campuses, including its South Table Mountain campus in Golden, Colorado (shown here).
Illustration by Josh Bauer, NREL

Designing an EMIS to Meet Organizational Goals

An EMIS software platform can be broken down into three functional elements—scope, stack, and capabilities. These elements comprise 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.

EMIS Scope

The EMIS scope includes data from utility bills, real-time weather, interval meters, building automation systems, DERs, electric vehicle charging infrastructure, and facility systems of record.

EMIS Stack

The EMIS stack includes several layers of devices, data services, and applications that meet facility and researcher needs:

- **The driver layer** includes the hardware and software responsible for communicating between the EMIS scope and the historian layer. It provides protocol translation and network load balancing.
- **The historian layer** stores time series data and associated metadata in one or more databases, providing this data to applications on request.
- **The applications layer** consists of all high-level analysis tools that rely on collected data.
- **The controls layer** is a separate, secure feedback loop that supports applications that affect the operation of building devices in an automated or semi-automated manner.

EMIS Capabilities

The NREL Intelligent Campus EMIS provides the following new and expanded energy management capabilities:

- **Centralization, normalization, and visualization** of facility data streamlines analysis and reporting, allows users to identify patterns in the data that would be difficult detect otherwise, enables portfolio management via a single interface, and promotes energy awareness among building occupants.
- **Interval meter analytics** capture meter data at subhourly intervals, providing far more granularity than monthly utility bills.
- **Automated FDD tools** allow 24/7 tracking of system performance for any control system monitored by the EMIS.
- **Supervisory control for electric vehicle supply equipment** enables adjustment of the amount of electricity drawn by charging equipment dynamically to limit campus peak demand.

EMIS for a "Living Laboratory"

NREL's campus operates as a living laboratory that integrates power from various sources (including solar panels and other on-campus energy generation technology) to address a range of energy needs such as electric vehicle charging for staff and visitors. Researchers and operations staff manage the system, determining how to balance the load to maximize renewable generation while minimizing energy consumption and peak demand.

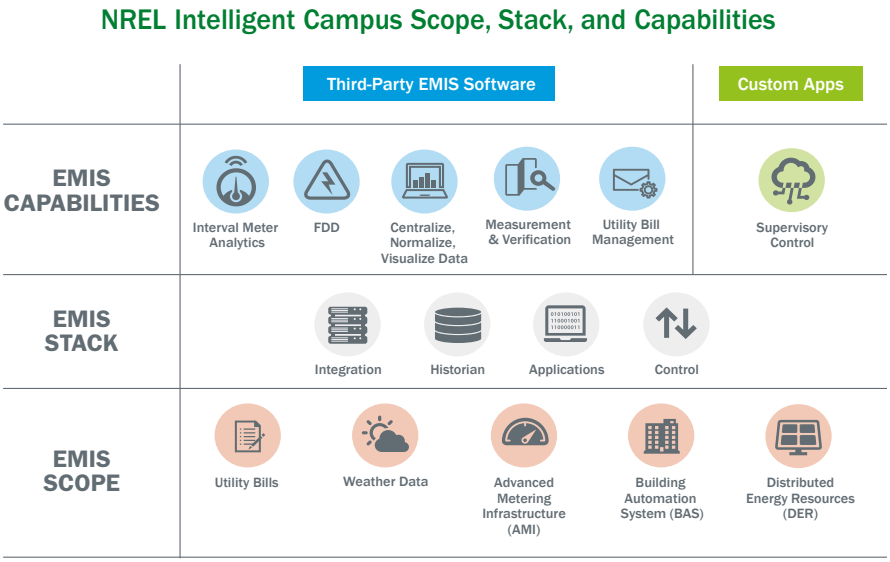

Figure 3. NREL's Intelligent Campus is powered by a range of EMIS capabilities, executed using several types of energy management software. The EMIS scope includes the building systems and integrated data sources. The EMIS stack includes several different layers of devices, data services, and applications that meet facility and researcher needs. *Illustration by Fred Zietz, NREL*

EMIS Benefits

NREL's Intelligent Campus Program EMIS includes improved reporting, real time analytics, and opportunities to better utilize building performance data.

Efficient Reporting and Identification of Energy Savings Opportunities

NREL's two campuses feature 33 buildings that are individually metered for electricity, natural gas, and hot and chilled water where appropriate. The Intelligent Campus EMIS enables NREL to meet federal reporting requirements by conducting performance assessments of individual buildings and across the entire organization. Whole building meters and submeters are used to identify energy efficiency opportunities, detect operational trends within the buildings, and set more ambitious organizational greenhouse gas emissions and sustainability goals. Additionally, monitoring and measurement capabilities of the EMIS were key in NREL's achievement of International Organization for Standardization (ISO) 50001 certification in energy management systems. Creating an EMIS allows for integration of both detailed interval data and high-level campus summary data for more clear and effective identification of energy opportunities across both campuses.

Better Data—And Storytelling Tools for Communicating Research

Anyone at NREL may access live data from the Intelligent Campus dashboards, encouraging individual accountability and empowering users to adjust their energy environment based on the information. For instance, if electric vehicle charging stations approach peak usage, an operational decision to reduce the available charging rates reduces unwanted peak demand costs. The dashboard system could also catch an aberration in usage—such as the lights automatically powering up on a holiday when the lab is closed—spurring a correction that saves energy and money. Researchers can display data to tell different stories to visitors and stakeholders about their work and secure funding for projects in the future. These novel visualizations allow experts and nonexperts alike to understand, appreciate, and emulate the exciting work taking place at NREL.

Advanced Analytics

NREL's EMIS features advanced visualization and automated FDD/CBM capabilities that allow the site operations team to identify opportunities for performance improvement. These tools vastly reduce the time required to find performance issues by standard methods, such as trend visualization and analysis. This capability is used to identify equipment and component failures, performance degradation, system design issues, controllability issues, operator overrides, and incorrect sequences of operation, and assists in preventative maintenance measures.

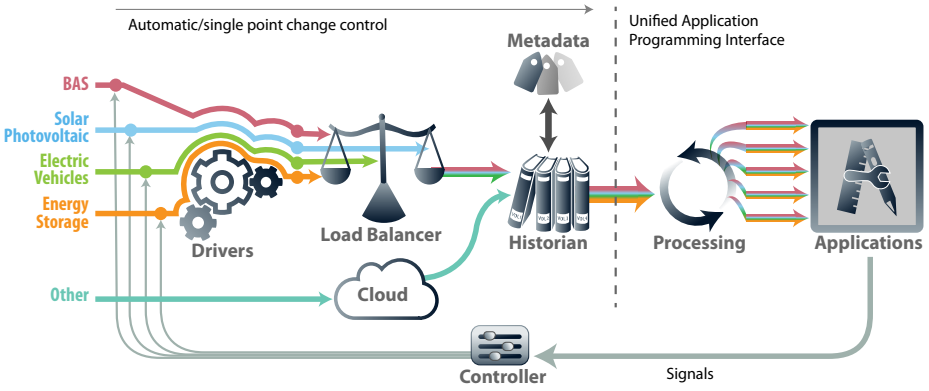

Figure 4. Multiple layers of the EMIS stack work together for enhanced analytics and building energy management. Drivers manage communication between the data sources in the Scope (left) and the historical data stored in the Historian layer (center) and provide collected data to the Applications layer (right). The system then communicates to the Controls layer, potentially modifying the operation of building devices. *Illustration by Marjorie Schott, NREL*

NREL's EMIS by the numbers

- **2** Colorado campuses
- **250** electrical meters
- **28,000** data points
- **1-minute to 15-minute** data logging intervals
- **123** integrated Level 2 electric vehicle charging stations

Lessons Learned from a Successful Campus-Wide EMIS Implementation

For facilities considering an EMIS, NREL's Intelligent Campus team offers several key learnings from its own implementation experience.

- **Start with a one-building pilot.** NREL successfully specified, procured, and deployed an EMIS as a one-building pilot and then deployed it to all facilities. Starting small allows the team to identify what works and what approaches need modification in future expansions.
- **Implement controls standards.** Translating a campus's worth of building automation system points into an EMIS depends on consistent and accurate naming, proper exposure of all data that need to be monitored, and programming that follows standard controls practices. Inconsistencies make point mapping extremely laborious and sometimes impossible. NREL's legacy control systems exhibit many of these problems. NREL is developing stringent controls standards so that future controls implementations will follow standard naming, point lists, and programming conventions. This will enable easy data collection and more robust analytics.
- **Effective EMIS requires engagement at all levels.** Planning an EMIS is a team project, from low-level building automation system programming to management-level strategy. The EMIS requires data, resources for analyzing the data, and a plan to use the findings. Building operator accountability to act on recommendations identified through FDD or CBM is essential to access the full benefit of the system.
- **An effective process is as important as the technology.** It is possible to build an effective data collection system and identify problems through FDD or CBM, but an actionable strategy is just as important to realize the value of the findings.
- **Consistent metadata semantics is critical.** A current challenge in building energy performance research is a lack of standardization and organization across the vast quantity of data generated by the smart devices in our homes, buildings, factories, and cities. NREL is using its EMIS as part of a new open-source effort to develop naming conventions and taxonomies for equipment and operational data, or "points," within building and energy systems to overcome these challenges and unlock value from the plethora of new data from these devices.

EMIS is a team project, from low-level building automation system programming to management-level strategy.

Learn More

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For more information about NREL's Intelligent Campus program, contact Michelle Slovensky at Michelle.Slovensky@nrel.gov. ■

Smart Energy Strategies for Federal Facilities

FEMP collects and promulgates best practices and information for federal agency staff to understand, design, procure, and implement EMIS as a valuable component of their portfolio-level energy and water planning, metering, and management strategies.

FEMP supports to federal facilities considering EMIS for improved site management to enhance energy performance, reduce costs, and meet energy goals.

Fort Carson's utility-scale lithium ion battery energy storage system. *Photo by Dennis Schroeder, NREL*

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