Building–Grid Integration for a Transformative Energy Future

Pacific Northwest National Laboratory (PNNL) continues to redefine the relationships between the electric power grid and the built environment, moving the nation toward an efficient, decarbonized energy future.

The challenge is clear. To help combat climate change and assure economic security, America must reimagine and create an energy future that realizes a transition to clean energy and reins in greenhouse gas emissions. There are many facets within this challenge, including today's growing presence of distributed energy resources (DERs)—wind and solar power, energy storage, electric vehicles, and more. Incorporation of DERs into the grid requires increased flexibility of electricity demand. The same is true for electrification, or the transition from fossil-fuel-powered devices and appliances to electric.

The built environment offers flexibility. Through building–grid integration strategies, it will be possible for homes, commercial buildings, and other structures to communicate with—and serve as shock absorbers for—the power grid by automatically and seamlessly adjusting their electricity consumption at times when the grid is juggling DERs and customer demand. Energy efficiency is also part of this scenario because buildings that consume less electricity help mitigate demand pressures.

A WINNING STRATEGY

PNNL's work in building–grid integration is guided by a set of strategic capabilities and objectives:

Understanding energy use – PNNL's unique "whole building" understanding of energy consumption, management, and control provides insights into how buildings use, generate, and store energy at any given time. This enables integrated, real-time control and coordination solutions between the grid and buildings.

Integrating building systems – Often, the control systems that manage a building's operation function separately. PNNL seeks solutions that integrate these systems toward efficiency and improved connectivity with the power grid.

Taking a cost-effective approach – PNNL focuses on developing low-cost methods and technologies that are flexible, scalable, automated, and turnkey for buildings of different ages and operational systems so that little or no customization is needed.

Using PNNL's campus as a test site – Networked campus buildings serve as a "buildings living laboratory" for implementing and testing PNNL's building–grid concepts and technologies.

Expanding technology application – As a next step, tested and approved technologies are deployed in other real-world buildings in the Northwest region and beyond for continuing evaluation and refinement.

Acknowledging realities of a transactive future – PNNL's research teams understand that a fully realized transactive energy vision that makes it possible for the grid and buildings to negotiate energy needs, costs, and delivery is aspirational. But in the interim, components of a transactive future can be delivered and implemented today for positive national energy, environmental, and consumer benefits.

PNNL RESOURCES AND CAPABILITIES FOR ADVANCING BUILDING–GRID INTEGRATION

Staff Expertise	Experts at PNNL possess decades of relevant building–grid experience, having pioneered transactive control concepts, building Re-tuning™, and other key advances. PNNL's capabilities are focused in areas including building simulation and design; building systems; distributed systems; economic, policy, and institutional support; electricity security; and optimization and control. Researchers also deliver cybersecurity solutions to meet today's needs.
Buildings Living Laboratory	Eleven buildings on the PNNL campus in Richland, WA, and one building on the Sequim, WA, campus are networked and enabled for evaluating buildings-related technologies in occupied settings. This real-world capability has supported testing of PNNL's passive and Re-tuning™ diagnostics, Intelligent Load Control (ILC), Transactive Control and Coordination (TCC), and integration of distributed renewable energy resources.
Systems Engineering Building (SEB)	The SEB, part of the Buildings Living Laboratory, is a research and office building on the Richland campus that also represents a singular, unique Department of Energy (DOE) resource. The building's ducting and operational infrastructure are fitted with sensors that allow testing of building control concepts and technologies. SEB, in addition to housing the Electricity Infrastructure Operations Center—a nationally recognized proving ground for new grid modernization technologies—is connected to a nearby solar array and also offers a state of Washington funded thermal energy storage system, electrical energy storage system, and side-by-side environmental chambers, representing a clean energy testbed.
Eclipse VOLTTRON™	A distributed sensing and control software platform developed at PNNL in 2012, Eclipse VOLTTRON™ provides a centerpiece capability for achieving PNNL's building–grid technology solutions. Eclipse VOLTTRON™ is flexible and inexpensive to deploy, launches applications that monitor building operational systems, and serves as a communications and decision-making bridge to the power grid.
Modeling and Simulation Tools	PNNL offers a multitude of modeling and simulation tools for buildings and the grid that can be used singularly or grouped together to inform approaches and technologies. These capabilities include commercial and residential prototype models, the Transactive Energy System Platform, Grid Project Impact Quantification, integrated grid co-simulation, and more.
Technology Development	PNNL's technology development skillset combines all capabilities and resources to produce effective methods and technologies. Technology advances have included ILC, which enables building systems to automatically reduce or increase electricity consumption based on grid needs, saving energy and reducing grid stress. ILC has been successfully applied and tested in buildings on the PNNL campus and has been deployed in buildings in Spokane, WA, Washington D.C., and other locations. TCC has also been successfully tested at PNNL and sets the stage for a transactive energy future in which the power grid and buildings (and even systems within buildings, such as heating/cooling units) automatically negotiate energy use, costs, and delivery.

LANDMARK PROJECTS

PNNL's work in building–grid integration and related fields has delivered new knowledge and technologies informing the development of an efficient and clean future energy system.

Distribution System Operation with Transactive (DSO+T) Study

The largest ever simulation of its kind, the PNNL-led DSO+T Study, launched in 2018, showed that if a transactive energy system were deployed on the Electric Reliability Council of Texas grid, peak loads would be reduced by 9 to 15 percent. That savings could translate to economic benefits of up to $5 billion annually in Texas alone, or up to $50 billion annually if deployed across the entire continental United States. The project produced a multi-volume report that was released in early 2022.

The study was designed to simulate and analyze a distribution system operator's use of transactive energy mechanisms to engage the large-scale deployment of flexible DERs, such as air conditioners, water heaters, batteries, and electric vehicles, in the operation of the electric power system.

Researchers at PNNL apply technologies such as Eclipse VOLTTRON™ to provide low-cost solutions for energy efficiency and grid services.

Clean Energy and Transactive Campus Project

The Clean Energy and Transactive Campus Project (CETC), an ongoing project launched in 2016, is creating a blueprint to replicate and scale up transactive control methodologies for application in buildings, campuses, and communities across the nation. The project also seeks to establish a clean energy and responsive building-load research and development infrastructure in Washington State.

CETC produced the ILC and TCC technologies, which continue in development and deployment, and explored the integration of distributed renewable energy resources and implementation of passive diagnostics and automated Re-tuning™ for building efficiency.

The Washington State Department of Commerce, the University of Washington, Washington State University, the University of Toledo, and Case Western Reserve University have partnered with PNNL in various stages of the CETC.

Connected Communities

PNNL's expertise that makes homes and commercial buildings more efficient and "connected" to the power grid is being deployed in two separate, multi-million-dollar projects as part of DOE's Connected Communities effort.

DOE in 2021 announced funding for 10 Connected Communities projects nationwide. The projects serve as models for future efforts, seeking to transform thousands of homes and workplaces into state-of-the-art, energy-efficient buildings that interact with the grid to coordinate their energy consumption.

Researchers at PNNL are partnering with Spokane Edo LLC and PacifiCorp on respective projects in Spokane, WA, and Salt Lake City, UT. PNNL is introducing ILC and the Eclipse VOLTTRON™ software platform to both projects while providing a range of technical expertise.

PNNL's Thermal Energy Storage System, battery energy storage systems, and other capabilities inform the development of transactive methods and technologies by demonstrating how electricity use can be coordinated and shifted to times of less demand.

DOE: THE KEY SUPPORTER OF PNNL'S BUILDING–GRID INTEGRATION RESEARCH

Funding for PNNL's efforts in building–grid integration and transactive control has been provided by DOE agencies that include the Building Technologies Office, Office of Electricity, and the Grid Modernization Initiative.

ABOUT PACIFIC NORTHWEST NATIONAL LABORATORY

PNNL is a Department of Energy Office of Science laboratory located in Richland, Washington, with an enduring mission to transform the world through courageous discovery and innovation. Our science and technology inspires and enables the world to live prosperously, safely, and securely.

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