Pacific Northwest
NATIONAL LABORATORY

PNNL RESEARCH FOR A TRANSACTIVE ENERGY FUTURE

CLEAN ENERGY AND TRANSACTIVE CAMPUS PROJECT

Pacific Northwest National Laboratory (PNNL), through its leadership in the Clean Energy and Transactive Campus Project (CETC), is helping the U.S. Department of Energy drive a new energy vision for the nation. In this vision, leading-edge control technologies seamlessly engage America's buildings, power system, and renewable energy resources, and then effectively coordinate the real-time buying, selling, and delivery of energy. This "transactive" control and coordination approach will improve energy management in buildings and power grid reliability, while bringing more clean energy online.

Since the initiation of CETC in 2016, PNNL-led experiments have explored responsive and flexible electricity load management strategies for buildings. The experiments, which have resulted in new concepts and technologies for meeting transactive energy objectives, are focused in:

- Intelligent Load Control
- Transactive Control and Coordination of Building Energy Loads
- Passive Diagnostics and Automated Re-tuning for Building Efficiency
- Integration of Distributed Renewable Energy Resources.

Experiment methods and outcomes are described in more detail in the following pages.

VOLTTRON™ Platform Enables CETC Experiments

The groundbreaking VOLTTRON™ distributed sensing and control software platform, developed at PNNL in 2012, has been central to the deployment and testing of CETC technologies. In addition to launching the project's specially-designed algorithms to carry out specific actions in building systems, VOLTTRON™ securely collects and analyzes system data and converts it to actionable information.

CETC: A SNAPSHOT

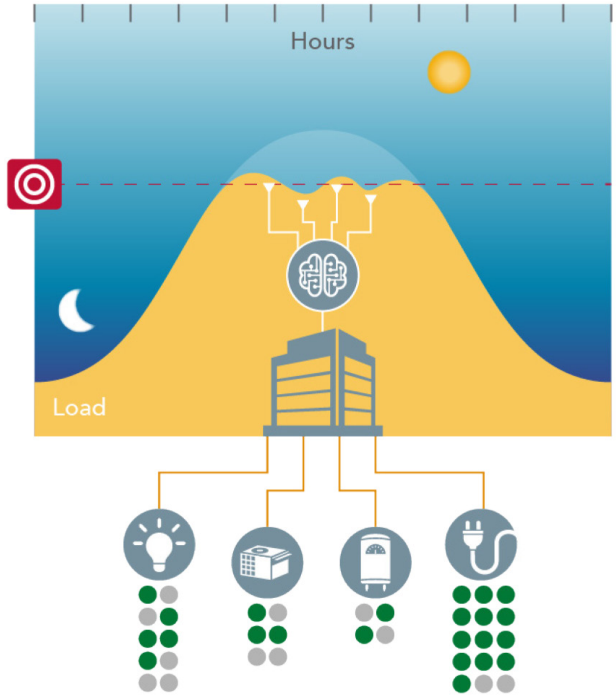
- **Key Objectives**: Create a blueprint to replicate and scale up transactive control methodologies for application in buildings, campuses and communities across the nation; establish a clean energy and responsive building load research and development infrastructure in Washington State.
- **Participants**: Pacific Northwest National Laboratory, Washington State University, the University of Toledo (joined in 2017), the University of Washington (2016-2017), and Case Western Reserve University (2017-2018). Each participant has pursued specific projects that integrate with overall CETC objectives. Utilities and industry also are supporting CETC activities.
- **Funding:** Funded by the U.S. Department of Energy and the Washington State Department of Commerce (2016-2018)
- **Timeline:** CETC launched in 2016 and concludes in 2021.

PNNL EXPERIMENTS

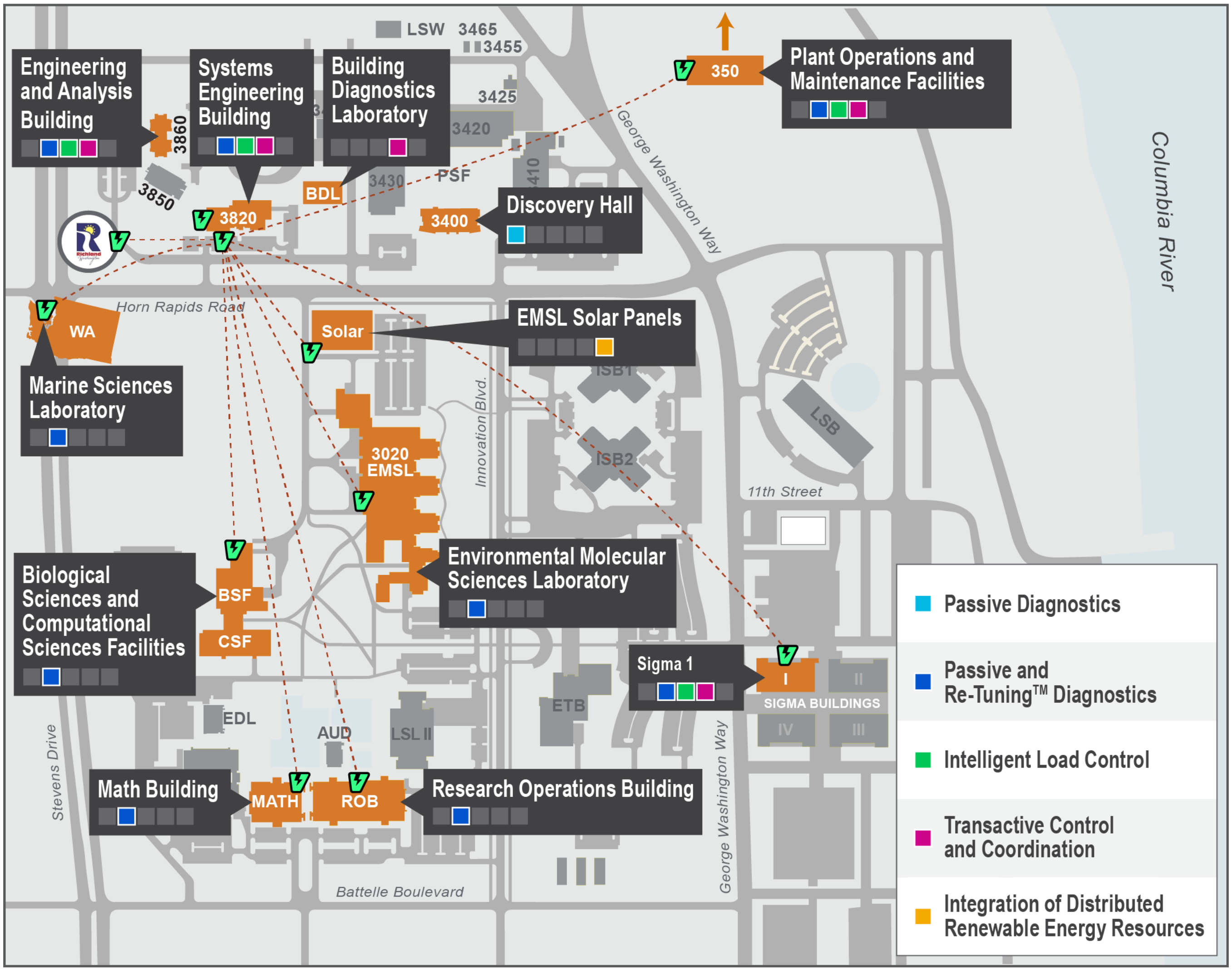
Intelligent Load Control (ILC)

ILC involves the use of the VOLTTRON™ platform with PNNL-developed algorithms to manage maximal, or "peak," electricity loads in buildings, while concurrently maintaining occupant comfort. To accomplish this, ILC draws upon a method known as the Analytic Hierarchy Process (AHP), which prioritizes control actions for optimal results, using both qualitative and quantitative rules. AHP can help determine, for example, whether shutting down or turning on heat pumps in a certain sequence will achieve a building's load management goals.

ILC was implemented in multiple PNNL buildings, controlling the operation of heat pumps and variable-air-volume (VAV) boxes serving offices and other work spaces. Test results demonstrate that when building energy consumption peaked at different times during the day—such as the first thing in the morning—ILC quickly prioritized heat pump and VAV operations, shutting down some units while running others. The approach successfully dropped demand to meet an established consumption limit while maintaining occupant comfort within an acceptable range.



Intelligent Load Control is the "brain" behind coordination of building functions, such as lighting, heating, and cooling, to adjust peak power loads and meet consumption targets. As illustrated in this graphic, ILC automatically prioritizes functions, turning them on (green dots) and off in a sequence that reduces power consumption, while concurrently making sure occupants remain comfortable.



On the PNNL campus in Richland, WA, and at the Marine Sciences Laboratory in Sequim, WA, CETC technologies have been deployed in multiple buildings. VOLTTRON™, represented by the green "v" icons, manages the deployments, gathers building data, and sends it to the Building Operations Control Center (BOCC) in the Systems Engineering Building, where campus building operations are monitored.

In addition to peak load management capabilities, two additional ILC applications have been developed and successfully tested: Capacity Bidding and Transactive Control. Essentially, Capacity Bidding involves the grid reaching agreement with a building to reduce electricity consumption during certain timeframes, in return for incentives. Under the Transactive Control application, buildings effectively negotiate with the grid to obtain a certain amount of electricity at a certain cost, and then manage building operations to that target.

The goal of ILC developers is to make these approaches easy to configure and scale to other buildings with different types of end uses and, ultimately, to enable management of large numbers of buildings using the methodologies.

Transactive Control and Coordination (TCC) of Building Energy Loads

While ILC theoretically could be implemented in the nation's current energy system, it also was designed to serve as a bridge toward the more futuristic and complex system represented in the TCC experiment.

TCC combines algorithms and the VOLTTRON™ platform to essentially create markets within different building zones and smart devices as part of an automated, real-time process. For example, an air handling unit (AHU) that provides air conditioning would obtain electricity at a certain cost directly from the energy market and then sell its product—cool air—to zones within the building. The zones electronically "bid" on the cooling capacity based on price and desired occupant comfort levels.

Under this approach, the AHU or other controllable loads respond to a price-temperature curve that essentially relates the current energy price to the predetermined comfort expectations of building occupants. The curve influences AHUs to either reduce power load to balance cost and comfort objectives, or in cases of abundant, economical electricity, perhaps increase consumption to perform tasks in advance, such as pre-cooling a building.

The TCC technology has been implemented in multiple PNNL buildings for evaluation, and results have confirmed the ability of this method to achieve experiment objectives.

Passive Diagnostics and Automated Re-tuning for Building Efficiency

This experiment, which involved testing in multiple PNNL buildings, successfully evaluated and validated the effectiveness of automated passive diagnostics and Re-tuning capabilities to identify equipment issues, correct problems, improve building operations and energy efficiency, and, ultimately, inform efforts to scale diagnostics for broader use. The experiment met its objectives and was concluded in 2018.

Integration of Distributed Renewable Energy Resources

Large-scale use of clean, renewable energy is highly desirable, but the intermittent nature of these distributed energy resources can have a disruptive impact on the power grid. PNNL's experiment applied an algorithm to successfully track signals from both a solar generation site on campus and the local power system, analyze resulting data, and quickly adjust a building's supply fan speed to reduce or increase power consumption.

CETC Future Steps

CETC will continue to make enhancements to ILC and TCC technologies and test the methods in buildings at the University of Toledo and in Washington, D.C. A broader field test, in a utility's service territory, is planned for 2021, the final year of the project.

For additional information about CETC, visit the project website at https://bgintegration.pnnl.gov/connectedcampus.asp.

About PNNL

Located in southeastern Washington State, PNNL addresses many of America's most pressing challenges in energy, the environment, and national security through advances in basic and applied science. The national laboratory was founded in 1965, employs more than 4,000 staff members, and has an annual budget of approximately $1 billion. Battelle operates PNNL for the U.S. Department of Energy's Office of Science—the single largest supporter of basic research in the physical sciences in the United States.

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U.S. DEPARTMENT OF ENERGY

January 2019 PNNL-SA-122777