GRID MODERNIZATION INITIATIVE
PEER REVIEW

GMLC 1.3.99 Clean Energy and Transactive Campus Project

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Clean Energy and Transactive Campus Project (CETC)

**Project Description**

CETC will create a “recipe” to replicate and scale transactive control technologies for application in buildings, campuses, and communities across the nation. Transactive controls “recipes” will enable utilities and grid operators to actively engage buildings for mutual benefit. CETC will also establish a clean energy and responsive building load research and development infrastructure in Washington State.

**Value Proposition**

- **✓** Vast opportunities for improved reliability, consumer benefits, and energy efficiency exist at the buildings-to-grid nexus; this requires research, development, and the development and demonstration of transactive controls for energy management.
  - **✓** Why do we care?
    - **✓** Transactive controls can reduce energy cost, improve reliability of the electric grid, and potentially improve building efficiency and comfort.
    - **✓** Key step towards achieving a more modern, efficient, and reliable power grid.

**Project Objectives**

- **✓** Scalable transactive controls in buildings
  - **✓** BEYOND DEMAND RESPONSE – enable buildings, fleets of equipment, and other building assets to deliver services to the grid while maximizing energy efficiency.
  - **✓** GRID SCALE, RIGHT SIZED STORAGE – enable buildings to function as “virtual” storage devices to reduce the total capacity of grid storage needed to meet the needs of a utility.
  - **✓** BEHIND THE METER RESPONSE TO PV – lessen, dampen, and otherwise minimize the effects of building and distributed PV as seen by the utility.
  - **✓** Create a recipe for replication of transactive equipment, buildings, campuses, districts, and fleets in real-life as utilities, municipals, and building owners are facing larger deployments of clean energy technologies, aging infrastructure, and new regulations.
**Project Participants and Roles**

► **PNNL:**
  - Overall lead
  - Tests and validates transactive methodologies, develops technical documentation and user guides
  - Supports UW and WSU

► **UW:**
  - Develops smart grid testbed (battery energy storage system and adds inverters to solar arrays)
  - Develops methods for converting the project’s building data to actionable information

► **WSU:**
  - Develops a testbed to examine transactive control strategies for a campus-scale/city-scale micro-grid, incorporating new solar arrays and access to a utility’s grid-scale battery

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**PROJECT FUNDING***

<table>
<thead>
<tr>
<th></th>
<th>FY16 $K</th>
<th>FY17 $K</th>
<th>FY18 $K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>PNNL &amp; Partners</td>
<td>2,885</td>
<td>6,707</td>
<td>3,000</td>
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*50% cost-share from Washington State Department of Commerce

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Project partners are: PNNL, UW, and WSU; Case Western Reserve University and University of Toledo were added in Phase II
Primarily address three areas under System Operations, Power Flow, and Control focus area

- Task 4.1.3 – Validation of transactive control strategies to achieve defined control performance objectives through testing in real buildings
- Task 4.2.2 – Integration of buildings and grid using an innovative distributed sensing and controls platform – VOLTTRON™ and leveraging existing building management systems (BMS) for use cases involving high penetration of distributed energy resources or microgrids
- Task 4.2.3 – Development of open source solutions for coordinating and integrating BMS with other local energy network controllers, such as PV inverters, battery energy storage systems, microgrid controllers, etc.
Clean Energy and Transactive Campus Approach

► PNNL:
  - Tests and validates transactive methodologies via experiments on the PNNL campus in multiple buildings
  - Produces user guides for broader implementation

 ► UW:
  - Acquires battery energy storage system (BESS) and adds inverters to solar arrays to test the coordination of campus assets
  - Develops methods to optimize charge/discharge cycles of BESS using transactive signals
  - Develops methods for converting the project’s building data to actionable information

► WSU:
  - Develops a testbed to examine transactive control strategies for a campus-scale/city-scale micro-grid, incorporating new solar arrays and access to a utility’s grid-scale battery
  - Develops resiliency strategies
  - Develops bilateral energy trading concept using block-chain technology
Clean Energy and Transactive Campus Approach

► Develop and demonstrate transactive control technologies that improve building performance, management of building power loads, renewable energy integration, grid operations, cost, and efficiency

► Create methods that enable these approaches to be readily adopted and implemented in single buildings, sets of buildings, and communities at scale
Clean Energy and Transactive Campus Approach

► First behind-the-meter implementation of transactive energy at this scale, involving multiple buildings and devices

► Innovative DOE-supported, PNNL-developed VOLTTRON distributed control and sensing platform provides a foundational tool for supporting individual CETC experiments and connecting the partners’ research activities
  - VOLTTRON deploys “V-agents” (algorithms) in building and other systems to coordinate various actions

► Technology can be launched from inexpensive computing resources
Clean Energy and Transactive Campus Approach

System Operations, Power Flow, and Control

DATA COLLECTION AND CONTROLS

VOLTRON™

EVERYWHERE (Web)

EXTERNAL INTERFACE

EXTREMELY ACCESSIBLE (DMZ)

Traffic Scanner

HTTPS

VOLTRON Passthrough

PNNL Network

VOLTRON Management Central

VIP

Firewall

VIP

VIP

UW Facilities Network

WSU Facilities Network

DB

PNNL Network

PNNL Facilities Network

PNNL Buildings Managed by Others

Central Control

DATA STORAGE

VIP

DB Port

Internal Only Network
# Key Project Milestones

<table>
<thead>
<tr>
<th>Milestone (FY16-FY18)</th>
<th>Status</th>
<th>Due Date</th>
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<tbody>
<tr>
<td>Preliminary report of transactive controls on PNNL campus project</td>
<td>Complete</td>
<td>9/30/16</td>
</tr>
<tr>
<td>Development and testing of “max-tech” controls complete</td>
<td>On track</td>
<td>9/30/17</td>
</tr>
<tr>
<td>Testing and validation of multiple-campus experiment complete</td>
<td>On track</td>
<td>12/31/18</td>
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Intelligent Load Control (ILC)

► Automated management of building electricity peak, energy consumption, or energy budget

► Deployed in three PNNL buildings, primarily to control operation of multiple heat pumps serving offices and other work spaces

Test results demonstrate that when building energy consumption peaked at different times during the day, ILC quickly prioritized heat pump operations, maintaining building comfort at acceptable levels and reducing load to the desired target.

Establish the Target Peak

A. BEYOND DEMAND RESPONSE

B. GRID SCALE, RIGHT SIZED STORAGE
Clean Energy and Transactive Campus
Progress and Accomplishments

Transactive Control and Coordination of Building Energy Loads

► Creates markets within different building zones and devices as part of an automated, real-time process

► Deployed in a PNNL building’s air handling unit, results have confirmed the ability of this method to achieve experiment objectives
Facilities and operations (F&O) staff of buildings are concerned about cyber security of the controls infrastructure.

- Hesitant to introduce new hardware and software on to their networks

Grid services that do not require fast response (>5 minutes) can be deployed easily using existing building control sequences to provide short-term (<30 minutes) and long-term (>30 minutes) grid services.

Grid services that require fast responses (in order of minutes) are harder to implement with existing control sequences.

- Some modifications and enhancements essential for fast response grid service

F&O staff are willing to provide grid services, if there is a good business case.

Clean Energy and Transactive Campus
Lessons Learned
### Recommendation

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<tr>
<th>Recommendation</th>
<th>Response</th>
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<td>The campus project has achieved the experimental results that were planned for the first phase. Further, the project has exceeded expectations by undertaking some experiments in multiple buildings (rather than single buildings as planned) and completing the work in 9 months (rather than the planned 12 months).</td>
<td>The project teams agrees with this assessment.</td>
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<tr>
<td>The university participants have made progress according to plan and will have their physical assets in place to support the second phase of the project. Of note, the labs have been much quicker to deliver than the universities.</td>
<td>Much of the university funding was for setting up the testbed, which caused some procurement delays.</td>
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<td>The second phase of the project will provide the most important results for GMI, demonstrating how the methodologies developed by PNNL can scale. Furthermore, the teams will add enhancements related to battery management, PV integration, and incorporation into a micro-grid strategy.</td>
<td>The project teams agrees with this assessment and is looking forward to the challenge.</td>
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<td>The project team needs to fully engage DOE in defining the details of some elements of this work, particularly the PV integration scaling at UW and WSU (engage EERE) and the micro-grid R&amp;D at WSU (engage OE) to ensure that DOE needs are reflected in the work and are accomplished in this phase and that all DOE offices are engaged in the campus opportunity.</td>
<td>PNNL, WSU and UW held a webinar to update OE staff. PNNL also held a meeting with OE staff in February. Also, a number of OE and EERE staff attend the BTO Peer review meeting in March.</td>
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<td>In addition to scaling the methodologies developed to date the team is encouraged to identify additional experiments relevant to transactive control of building loads that can be explored in the second phase.</td>
<td>The Phase II project team is extending the transactive control experiments in buildings.</td>
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Communications:

Conferences:

► "Regional Transactive Campus Testbed – Design and Initial Results," 2016 Transactive Energy Systems Conference and Workshop, May 17, 2016, Portland, Ore. Presented by Chad Corbin

Publications to Date: Technical Reports and User Guides


► Hao H, G Liu, S Huang, S Katipamula. 2016. "Coordination and Control of Flexible Building Loads for Renewable Integration; Demonstrations using VOLTTRON" PNNL-26082, Richland, WA.


Brochures/Fliers:

► “Clean Energy and Transactive Campus Project” (4-page brochure developed by PNNL, December 2016)

► A Blueprint for the Nation’s Transactive Energy (2-page flier developed by PNNL, March 2016)

Publications to Date: Journal and Magazine Articles


► Create network to connect the project partners and facilitate broader testing

► Expand experiments at PNNL
  - Includes extension of the experiments to the other partners
  - Create transactive market simulator
  - Further extend experiments to multi-building and multi-campus scale for automated implementation of transactive buildings

► UW and WSU begin testing assets they have acquired and installed

► Case Western Reserve University and the University of Toledo join the project
  - Install BESS at both Case and Toledo
  - Enable building-grid integration on number of buildings on both campuses
  - Will replicate and extend PNNL-developed experiments in their facilities
These terms have been established in Building Technologies Office’s (BTO’s) public meetings and reference documents (through review and comment):

- **Transaction** – an exchange or interaction between entities, it can be:
  - Physical (in our case, Energy + Information)
  - Logical (in our case, controls or control systems that act on information)
  - Financial (in our case, a price to determine value to users)

- **Transactive Energy** – Gridwise Architecture Council definition - “techniques for managing the generation, consumption or flow of electric power within an electric power system through the use of economic or market-based constructs while considering grid reliability constraints”
  - The term “transactive” comes from considering that decisions are made based on a value to the parties involved. The decisions may be analogous to (or literally) economic transactions
Clean Energy and Transactive Campus

Transactive Controls Definitions (1)

► **Transactive Devices** or **Connected Equipment** – consumer products with information and communication technologies (ICT) that enable them to be exercised through transactions – without boundaries

- Many available technologies are typically proprietary (e.g. vendor specific ICT)

► **Transaction-Based Controls** – controls that exchange, negotiate, and respond to information through ICT

- Most common signal is economics based: “price” (others include, renewable imbalance, frequency, voltage, etc.)
- Needs advancements in fundamental sensors and controls – like plug-n-play, auto-mapping, etc.

► **Transactional Platform** – a software platform (e.g. ICT and related physical hardware) that allow applications to be programmed and negotiate/act on the exchange of information

- An example platform, VOLTTRON™ is fully supported throughout DOE (OE, EERE, others) and is open source
Clean Energy and Transactive Campus
Inside VOLTTRON™

VOLTTRON

Computerized Maintenance Management System Service

OpenADR Client

Information Exchange Bus

V-agents

Resource Monitor

Security Module

Command Module

Command Line

Data Collection Platform Management Platform Logging Process Control

Web User Interface

Management Console

Historian

Drivers

Actuator

Scheduler

Weather Service
Control building loads such as variable-frequency-drives (VFDs) on fans in AHUs and packaged rooftop units (RTUs) to absorb renewables generation losses and reduce grid fluctuations.