The Department of Energy
Office of Energy Efficiency and Renewable Energy
BUILDING TECHNOLOGIES OFFICE

Meeting on the Software Framework for Transactive Energy

Case Western Reserve University, Room 202, Dively Conference Center
11240 Bellflower Road, Cleveland, Ohio 44106

Welcome

The Department of Energy Building Technologies Program and Case Western Reserve University would like to welcome you to the inaugural meeting on a "Software Framework for Transactive Energy." I would like to thank you for attending and for your active participation and also thank Case Western Reserve University for graciously hosting these meetings and discussions. We look forward to and value your perspective on building a community around software solutions enabling transactive energy in buildings!

At DOE, we envision a transactive energy ecosystem capable of meeting all clean energy demands and capacity requirements from generation to buildings end-use. This vision would allow the millions of sensors, meters, smart appliances, loads, and distributed generation assets to seamlessly communicate and coordinate, to the benefit of both building owners and the grid. In support of that vision, DOE/BTO has convened stakeholders in public and technical meetings, and conducted R&D to further the understanding of transactive energy as a means to improve building energy performance and the reliability and resilience of our power grid. At this meeting we are now looking for specifics of the various solutions that can turn this vision into reality. We believe this includes VOLTTRON™, a transaction based software platform and an open source software environment for developing and deploying a variety of market driven applications.

Over the next two days, we will discuss current and future applications that utilize the VOLTTRON platform to demonstrate transactive energy principles in buildings, outline use cases of the technology, and showcase several building/grid applications to improve, such as building energy efficiency, electric vehicle charging, or integration of renewable energy.

It is my hope that this meeting will inspire stakeholders - including industry members, university and other researchers, software developers and practitioners – to engage in the crafting of a shared vision for realizing transactive energy. And I hope everyone understands our demonstration of transactive energy through VOLTTRON demonstrates how buildings can act as dynamic, self-optimizing participants in the power system.

The community we are forming will be at the forefront of a complex technological challenge that has the potential to bring economic and energy benefits to all Americans.

Thanks again for your time. We look forward to a productive and stimulating meeting.

Joe Hagerman

Senior Policy Advisor,
DOE/Building Technologies Office

Logistics Information

The meeting will be held in Room 213 of the Dively Building at Case Western Reserve University, in Cleveland, Ohio (as indicated on the attached map). Parking is available across the street from the conference center.

Meeting Location
Dively Conference Center
Room 202
George S. Dively Building
11240 Bellflower Road
Cleveland, Ohio 44106
Campus Map (http://weatherhead.case.edu/about/facilities/CampusMap.pdf)
Conference Facility (http://weatherhead.case.edu/about/facilities/dively/second-floor)

Parking
Ford Road Parking Garage
1980 Ford Drive
Cleveland, Ohio, 44106
***The maximum rate for parking is $10/day and the garage is located across the street from the Dively Conference Center.

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Meeting Purpose

The purpose of this in-person workshop is to give an overview of the VOLTTRON™ platform as well as the Transactional Network concept and build and expand the community around this technology. The U.S. Department of Energy's Building Technologies Office (DOE-BTO) is supporting research on transactive energy for buildings aiming to greatly improve energy efficiency and the integration of renewable energy. DOE-BTO aspires to increase the awareness of VOLTTRON and the Transactional Network concept by convening stakeholders from the buildings sector- including industry members, researchers, software developers and practitioners- to build a community of early adopters. While the workshop will include technical discussions about the capabilities, supported devices, and hardware/software requirements of VOLTTRON, the workshop is intended to attract a wide audience to socialize the concept and potential of the platform among interested parties.

The workshop will present current and future applications of VOLTTRON, outline use cases of the technology, and showcase VOLTTRON's potential to address several buildings-related optimizations, such as buildings' energy efficiency, electric vehicle charging, or integration of renewable energy, among others.

Summary

VOLTTRON™ is a DOE-BTO funded platform for transactive energy applications that allows sensing and control actions to take place as close to devices as possible. Designed to support modern control strategies, including use of agent-based and transaction-based controls, VOLTTRON enables mobile and stationary software agents to perform both information gathering, processing, and control actions. VOLTTRON has been used in the Transactional Network project; a multi-lab effort between Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory and Pacific Northwest National Laboratory examining the role transactive networks could play in optimizing commercial building.

VOLTTRON is equipped to communicate with building systems (e.g. MODBUS or BACnet devices) and external services, has a built-in data historian and weather service, supports OpenADR 1.2., has a flexible messaging system (publish/subscribe), as well as utility and supporting classes to simplify application development, and logging service for saving application results and logging information. More broadly, it is a highly interoperable reference platform for transactive energy applications, enabling the integration of buildings and the grid.

A technology community is a voluntary association of skilled professionals looking to develop or advance a specific technology or an aspect of it. Technology communities could be as small as a handful of members, or include millions, as in the case of the Oracle Technology Network Community. There are several benefits to forming a technology community. The main advantage of technology communities is their inherent capability to access a wide range of knowledge, pool intellectual assets and skill sets and, as a

community, solve intricate problems that individuals by themselves might not be able to solve.

DOE-BTO aims to broaden the applications of transactive energy (TE) and foster a community of VOLTTRON users, leading to several outcomes, such as:

- A catalog of real-world TE applications related to buildings.
- A reference TE platform supported by the community participants.
- TE applications developed on the reference TE platform for demonstration purposes.
- An interoperability testing and certification suite to ensure multi-vendor interoperability
- Multiple demonstration facilities to help evangelize TE applications for buildings.
- A software repository to store TE applications, the reference platform and test suites, and an associated bug tracking and enhancement request.
- A peer to peer technical support forum for fostering discussions and answering questions.
- How-to documents to help build various TE applications on commonly encountered and readily available hardware.
- A forum to track and discuss bugs, enhancements of the TE platform and the various applications.

The community would also contribute to the wider application of TE in buildings by addressing research gaps in the area of sensors, control technology, data mining and modelling standardization.

AGENDA July 23

Time	Topic	Presenter
7:30 a.m.	Continental Breakfast, Coffee/Tea	
8:00	Agenda Review, Ground Rules and Introductions	Facilitator
8:15	DOE/BTO Purpose and Context	G. Hernandez, PNNL
8:30	Motivation for the Transaction-Based Reference Platform	G. Hernandez, PNNL
9:00	Discussion	Facilitator
9:30	VOLTTRON Introduction and History	J. Haack, PNNL
10:00	Break	
10:15	VOLTTRON Technical Overview and Features	B. Carpenter, PNNL
11:15	Discussion	Facilitator
11:45	Lunch	
Developing Applications of VOLTTRON: Experience and Lessons Learned		
1:00 pm	LBNL	R. Brown, LBNL
1:20	Discussion	Facilitator
1:40	ORNL	T. Kuruganti, ORNL
2:00	Discussion	Facilitator
2:20	Break	
2:35	PNNL	S. Katipamula, PNNL
2:55	Discussion	
3:15	Virginia Tech	S. Rahman, VT
3:35	Discussion	Facilitator
4:00	Adjourn Day 1	

AGENDA July 24

Time	Topic	Presenter
7:30 a.m.	Continental Breakfast, Coffee/Tea	
8:00	Summary from first day	(Sean McDonald, Facilitator)
8:15	VOLTTRON Development Primer: How to create an application, how to use services	J. Haack, B. Carpenter, PNNL; M. Pipattanasomporn, VT
9:45	Break	
10:00	A Community of VOLTTRON Users: An Introduction	G. Hernandez, PNNL
10:30	A Community of VOLTTRON Users: Suggestions for Development	S. Katipamula, PNNL
11:00	Open Discussion	Facilitator
11:45	Lunch	
1:00 pm	Suggestions for DOE/BTO Proposed Future Development and Commercialization of VOLTTRON Platform	G. Hernandez, Facilitator
3:00	Adjourn	

DAY 1

DOE/BTO Purpose and Context

George Hernandez, PNNL

The US Department of Energy's EERE Building Technologies Office (BTO) is dedicated to developing and promoting efficient, environmentally friendly and affordable technologies, that will lower energy use and greenhouse gas emissions, spur economic growth and continue America's role as a global innovator. The overarching long-term goal of BTO is to reduce building-related energy use 50% by supporting the development and deployment of energy- efficient technologies and systems.

BTO's long-term vision for buildings is that they will actively support the integration of renewable and other variable, distributed generation resources while simultaneously providing building owners with enhanced comfort, amenity and economic and other opportunities. Buildings will furthermore provide cost-effective resiliency and robustness to the grid, offset expensive new generation and transmission investments, and enable several ancillary benefits, such as supporting the deployment of EVs.

Over the last two years, BTO has supported research on using transactive energy applications to lower buildings' energy use, raise building's efficiency, and provide wider, ancillary benefits to the power system. Transactive energy in buildings will rely on robust control software that enables automatic, market-based intra-building efficiency optimizations. BTO believes that the best way to further the development of such software lies in the formation of a broad community of stakeholders that provides technical expertise, develops applications, and a deployment platform supporting transactive energy for buildings.

Motivation for the Transaction-Based Reference Platform

George Hernandez, PNNL

A transactional energy platform defines the basic structure of the future energy integrated ecosystem. It will lay out the transition from today's static, one directional, and often times "manual" energy system ("current state") to a new "future state" of energy, characterized by highly automated, two way (or even n-way) exchanges of information, data and energy between entities in the energy system, leading to a flexible, resilient and automatically adjusting system. The future ecosystem will be characterized by a more distributed power

system, blurring currently clear lines between producers and users of power. Utilizing distributed generation, responsive loads and automation at the distribution system, the future ecosystem will see an abundance of software and application-based sensors that work autonomously to optimize energy generation and energy use starting at the smallest application all the way towards the largest entity. This is made possible by the addition of smart, intelligent meters and sensors to all stages of the energy system, able to interconnect, exchange information, and act upon it.

The framework enables transactions of products, rights and other services that support various micro and macro energy objectives. On the micro scale, these objectives include more efficient buildings. On the macro level, more efficient buildings will lead to reduced greenhouse gas emissions, increased grid reliability, an increased share of clean energy sources, and the creation of clean energy jobs.

This new model needs to seamlessly integrate new, distributed generation as well as smart assets while adding value to the building owner/customer and other third parties. It needs to be able to control and connect assets and loads, within buildings, between buildings and, at a possible future state, between buildings, the grid and third-party providers, and enable participants to transact in ways that lead to economic and environmental benefits. The idea is to derive benefits for the customer (e.g., better managing their bills) for participating in new markets and interacting with the grid and third-party providers.

VOLTTRON Introduction and History

Jereme Haack, PNNL

The VOLTTRON platform was originally developed as part of an internal PNNL initiative to address the challenges of the SmartGrid. This work was demonstrated in a hardware testbed and deployed in the PNNL instrumented homes.
As part of its Transactional Network initiative, BTO funded Pacific Northwest National Laboratory to develop an open source version of the platform to enable a variety of site/equipment specific applications to transact in a cost effective and scalable way.
This session will give an overview of the motivations behind the development of VOLTTRON and its history from the internally funded PNNL project to the open source BTO funded platform.

VOLTTRON Technical Overview and Features

Brandon Carpenter, PNNL

VOLTTRON provides an environment for agent execution and serves as a single point of contact for interfacing with devices (RTUs, building systems; meters, etc.), external resources, and platform services such as data archival and retrieval. VOLTTRON provides a collection of utility and helper classes, which simplifies agent development. VOLTTRON connects devices to applications implemented in the platform and in the Cloud, a data historian, and signals from the power grid. VOLTTRON incorporates a number of open source projects to build a flexible and powerful platform.

With the introductory session as a starting point, this session will go over these features in more detail and discuss future plans including the VOLTTRON 2.0 release.

Using the VOLTTRON Platform for Measuring Savings and Fault Detection in Lighting Systems

Rich Brown, LBNL

This talk describes work done at Lawrence Berkeley National Laboratory to use the VOLTTRON platform to measure savings from control of HVAC and lighting systems, as well as fault detection and diagnostics (FDD) of lighting control systems. The savings measurement agent uses a statistical model of historical time series from the building to automatically construct a baseline load shape to estimate energy, load, and bill savings.

This agent can be used to measure the savings impact of other control agents deployed within the VOLTTRON platform. The lighting FDD agent detects faults in lighting control systems and suggests improvements to better match lighting to occupant needs. We will summarize our experience working with the VOLTTRON platform and offer suggestions for future improvements.

Applications developed by LBNL:

- Baseline Load Shape Agent – Using historical data, determine the counterfactual load in the absence of a demand response event (i.e., what would the load have been had the building equipment not acted to reduce energy consumption).

- Measurement and Verification (M&V) Agent – Compare the actual energy use against the anticipated load given historical trends and current weather, to calculate long-term savings from energy efficiency improvements, as well as short-term load reductions.
- Economic Valuation Agent – Calculate the anticipated economic consequences (savings or costs) associated with changes in building equipment operations, such as responding to DR signals or responding to electricity tariffs - time of use and demand charges.
- Lighting Fault Detection and Diagnostics (FDD) – Detects faults in lighting control systems where manual or scheduled control is wasting energy (e.g., lights left on at night). Also suggests improvements to lighting schedules to better match lighting to occupant needs. The FDD models operate on usage data like relay state, override times, programmed lighting schedule and lighting power load, in order to identify faults and suggestions.
- Supervisory agents – Schedule and coordinate operation of FDD and M&V agents. The agents described above have been designed in a modular way, in that they provide a basic utility function for FDD and M&V available across the VOLTTRON platform. The supervisory agents control when the FDD and M&V agents are run, what data to provide them, and how to use the results.
- Demand Response Scheduler Agent – Accurately provide or convey published DR signals into the VOLTTRON platform using an OpenADR2.0 certified client or VEN.

Use of VOLTTRON Platform for Advanced Control of Building Equipment

Teja Kuruganti, ORNL

This talk will describe the work done at Oak Ridge National Laboratory to use the VOLTTRON platform for three different applications including control of multiple roof top units, photovoltaic forecast-driven model predictive control, and supermarket refrigeration control. The aim is to cost-effectively deploy advanced control solutions to optimally control building equipment. The presentation will describe our experience in using VOLTTRON for control applications along with some preliminary thoughts on using event-driven architectures, such as VOLTTRON, to perform closed-loop control and future applications in transactive energy.

Experience in Developing Applications/Agents for the VOLTTRON Platform, PNNL

Srinivas Katipamula, PNNL

This talk will describe PNNL developed applications/agents for the VOLTTRON platform to highlight the transactional network concept using rooftop units as a basis: automated fault detection diagnostics, demand response, smart monitoring and diagnostics and intelligent duty cycling applications. The talk will also discuss the experience in developing the applications, the details of how the applications were deployed on VOLTTRON, the VOLTTRON services that these applications uses and the lessons learned for the development effort. A list of applications that are scheduled for development in FY15 will be highlighted. The talk will conclude with a brief summary of results from the field.

VOLTTRON as a Platform for Building Energy Management Open Source (BEMOSS) Application, Virginia Tech University

Manisa Pipattanasomporn, Saifur Rahman, Murat Kuzlu, VT

BEMOSS is an open-source software package that is designed to improve sensing and control of equipment/appliances in small- and medium-sized commercial buildings, reduce energy consumption and help implement demand response. It aims to offer: scalability, robustness, plug and play, open protocol, interoperability, cost-effectiveness, as well as local and remote monitoring. VOLTTRON, developed by Pacific Northwest National Laboratory, is chosen as the software platform to support the BEMOSS operating system. This presentation describes underlying reasons for choosing VOLTTRON, our experience with VOLTTRON, as well as software enhancements made to VOLTTRON so that it has a broader appeal to help control selected HVAC, lighting and plug loads in commercial buildings.

DAY 2

VOLTRRON Development Primer: How to create an application, how to use services

Jereme Haack, Brandon Carpenter, PNNL

This session will get into the technical details of deploying the VOLTTRON platform and of developing agents to execute in the environment. The goal is to give newcomers a head start and to go over capabilities experienced developers may not be aware of.

We will walk through VOLTTRON agents to serve as working examples for other developers. Through this, we will examine the agent base class, topic and message handling, how to utilize platform services, etc.

A Community of VOLTTRON Users: An Introduction

George Hernandez, PNNL

The U.S. Department of Energy's Building Technologies Office (BTO) has funded several research projects furthering transactive energy for buildings. One of the BTO funded projects is the Transactional Network project that used the PNNL-developed VOLTTRON™ platform. While the work on the VOLTTRON platform is continuing, the BTO set a goal to form a technical community around the concept of transactive energy in buildings.

The community would contribute to the wider application of transactive energy in buildings by addressing research gaps in the area of sensors, control technology, data and modelling standardization. Since transactive energy for buildings is in the early stages of development, it can benefit immensely from support by DOE in order to build and nurture a successful community. A technology community built around transactive energy can help grow acceptance by providing a reference application deployment platform, a set of proven applications with known benefits, and an active, grassroots support eco-system. An active and diverse community also broadens the capabilities and motivates interoperability. This activity can be maintained and enhanced by holding workshops and technology "bake-offs" which give members a chance to both highlight their research and familiarize them with the platform**.**

A Community of VOLTTRON Users: Suggestions for Development

Srinivas Katipamula, PNNL

DOE/BTO has been funding research on transactive energy (TE) for buildings. One of the projects funded by BTO is the Transactional Network project that used the PNNL-developed VOLTTRON™ platform for integrating control, sensing, analysis and diagnostic applications in buildings. While the work on the VOLTTRON platform is continuing, the BTO set a goal to form a technical community around the concept of TE in buildings.

A technology community is a voluntary association of skilled professionals looking to develop or advance a specific technology or an aspect of it. There are several benefits to forming a technology community. The main advantage of technology communities is their inherent capability to access a wide range of knowledge, pool intellectual assets and skill sets and, as a community, solve intricate problems that individuals by themselves might not be able to solve. Because technology communities are often voluntary based, they also can provide free access to resources that otherwise would have to be purchased or hired on the free market.

There are number of desired outcomes for the TE community. This talk will highlight some of the desired outcomes and also present a concept of how the community should be formed, what it should do and how it should be managed.

Suggestions for DOE/BTO Proposed Future Development and Commercialization of the VOLTTRON Platform

George Hernandez, Jereme Haack, Brandon Carpenter, PNNL

There will be an open discussion of the potential future services and features that might be supported for development by DOE. In particular, DOE is interested in what is required to broaden the usage of VOLTTRON in a variety of commercial applications. Questions include:

- What are some characteristics the software platform must include?
- What other transactive energy applications should be developed on the reference platform for demonstration purposes?
- Where could VOLTTRON be further tested?
- How can DOE help to foster interaction and further the community?