Transactional Network Overview

2014 Building Technologies Office Peer Review

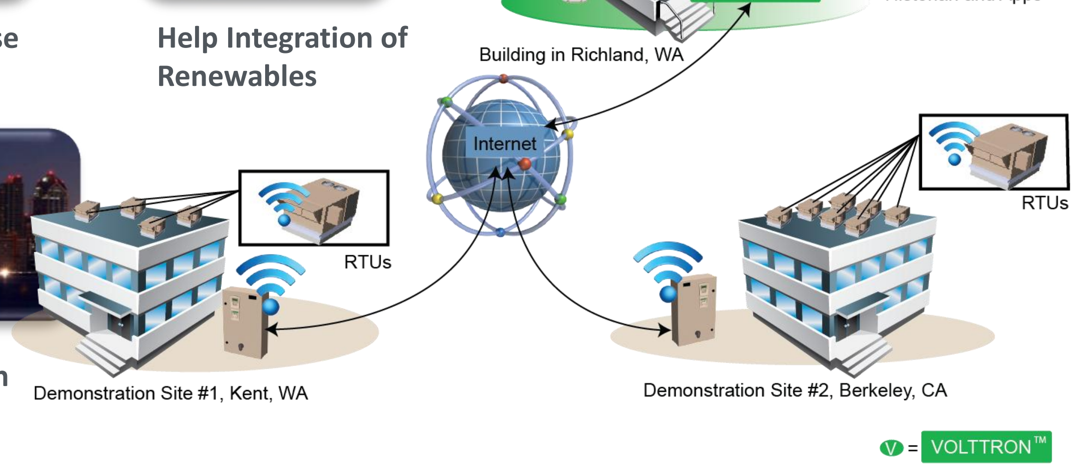
Improve Operational Efficiency of Building Systems

Manage End-Use Loads

Help Integration of Renewables

Accommodate Millions of Electric Vehicles

Help to Maintain Reliability

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Project Summary

Timeline:

Start date: January 2013

Planned end date: 2016

Key Milestones

1. Public release of VOLTTRON 2.0; 10/2014
2. Complete identification and implementation of demand side energy services provided by supermarket refrigeration systems; 09/2014
3. Complete demonstration of transactional lighting network; 09/2014

Key Partners:

Transformative Wave
Emerson
NorthWrite
EnerNoc

Budget:

Total DOE $ to date: 3,600K

Total future DOE $: TDB

Project Goal:

Develop and deploy transactional network platform to enable **energy efficiency** and building-grid integration through development, demonstration and propagation of an **open source, open architecture platform** that enables a variety of site/equipment specific applications to be applied in a **cost effective and scalable way**. Also, to lower the cost of entry for both existing and new service providers by making the data transport or information exchange typically required for operational and energy related products and services more ubiquitous and interoperable.

Target Market/Audience:

The market is all buildings (commercial and residential, potentially industrial); the audience is both existing and new energy service providers.

Purpose, Objectives and Target Market and Audience

Problem Statement: Operational efficiency of commercial buildings is significantly low; significant penetration of distributed renewable generation and integration of electric vehicles will create challenges; there are number of barriers for exchanging information both within the building and between building and the electric grid cost-effectively; lack of scalable solutions; lack of open and "standard" protocols; lack of near "real-time" measurement and verification process

- Leading to significant energy waste and increase in carbon emission
- Potentially disrupting secure and reliable energy delivery

- This project is the first step in developing, demonstrating and deploying scalable, cost-effective and open solutions

Objective: Develop and deploy transactional network (TN) platform to enable **energy efficiency** and building-grid integration through development, demonstration and propagation of an open source, open architecture platform that enables a variety of site/equipment specific applications to be applied in a cost effective and scalable way

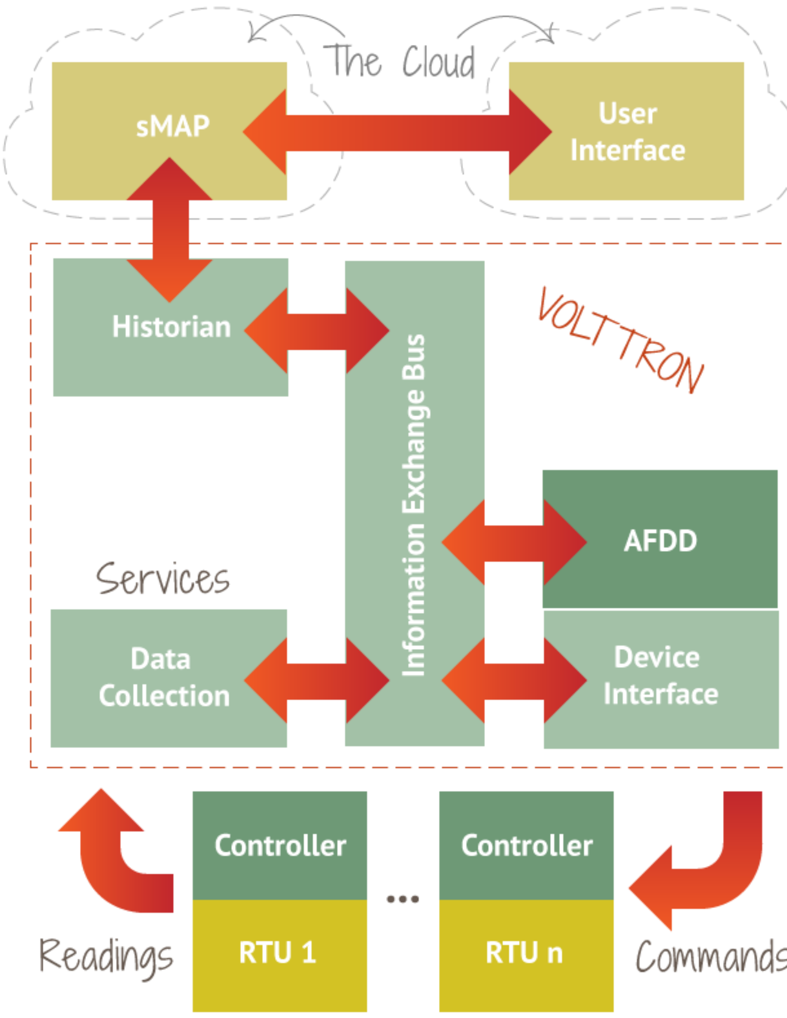
Target Market and Audience: All buildings (commercial and residential) that consume over 40 quads of primary energy. The solutions being developed in this project could also be applied to parts of the industrial sector as well. The audience includes both existing and new energy service providers

Impact of Project

- The goal of the project is to lower the barriers for technology solutions that would improve the operating efficiency of the building stock and enable buildings to interact with the grid for mutual benefit, at scale and cost-effectively
  - Through development, demonstration and deployment of an open source and open architecture platform, along with path towards widespread adoption
- Initially, the project team has released and will continue to update the TN platform along with a number of applications/agents as open source
- Before the end of the FY, the team will identify a community of early adopters and encourage them to use the platform and also develop additional applications for the platform
- The community will involve control vendors, energy service providers, universities and national laboratories
- Currently, in addition to the three laboratories, two universities and an energy service provider are already using or committed to using the TN platform
- Over the next 5 years, we anticipate growing the number of TN community members exponentially

What is the Transactional Network?

- **Transactional network** enables:
  - Interactions among networked systems (e.g., RTUs and other building systems) and the electric power grid
  - software applications on the platform or in the Cloud
- Embedded automated diagnostics and advanced controls on the transactional platform and building systems (e.g., RTU controller)
- Applications running in the Cloud in cases where the transactional platform and controller resources (i.e., processing and storage) are inadequate
- Applications that provide continuous monitoring and verification, automated energy management, etc.



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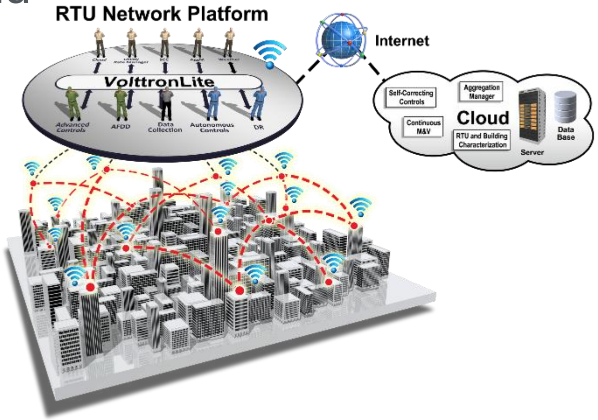
Project Scope and Team

- Enable **transactions** of energy saving solutions, operational improvement solutions AND the transactions between networked systems and the grid to mitigate variable distributed renewable energy sources
- Initially in FY13, the transactional concept was demonstrated using networked rooftop air conditioners and heat pump units (RTUs)
- In FY14, the concept is being extended to monitor and control of **lighting and refrigeration systems**; also extending support to monitor and control any building system connected to **BACnet** (building automation and control network) controllers and coordination on multiple TN nodes
- In the future, it can be extended to homes and network appliances in homes and electric vehicles
- Work is being done at the three national laboratories
  - Pacific Northwest
  - Oak Ridge
  - Lawrence Berkeley



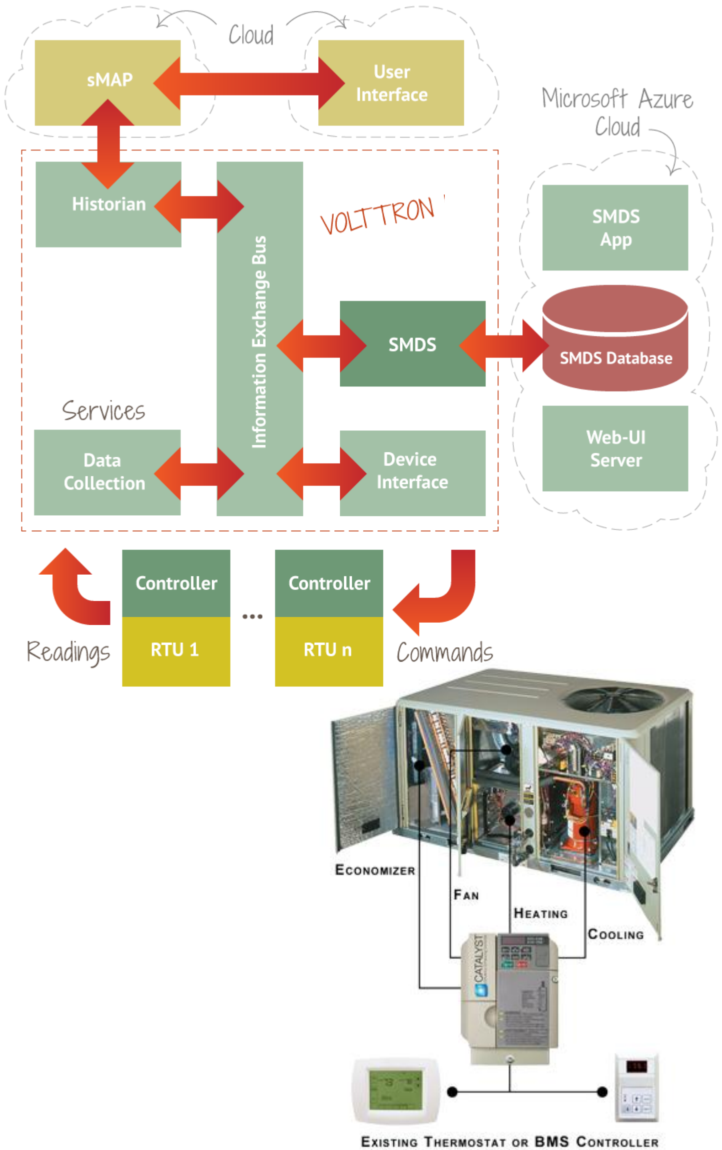
PNNL Transactional Network Applications

Embedded Advanced RTU Controls: Improve operational efficiency of RTUs through use of advanced RTU controls leading to energy and carbon emission reductions over 50%

Demand Response Agent: Make RTUs grid responsive, leading to a more reliable electric power grid and to mitigate variable distributed renewable generation

Automated Fault Detection and Diagnostics:

- Detect economizer and ventilation failures as they occur and notify building operator to correct them
- Refrigerant-side performance degradation (or improvement)
- Energy and cost impacts of the degradation (or improvement)
- Operation schedule changes
- Selected operation faults, such as compressor short cycling, 24/7 operation, system never on, and inadequate ventilation



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Approach: PNNL

Approach: The project team, in a collaborative way, is developing and testing the TN platform and a number of applications that are hosted on the platform; service agents that provide access to external data sources; and services to coordinate applications hosted in the Cloud

Key Issues: TN platform will allow multiple applications/strategies to be hosted at a lower transaction cost and is the first step in achieving the vision of integrating the buildings with the grid while ensuring that buildings are operated efficiently

- Because buildings consume over 70% of the electricity generated, integrating buildings with the grid will fulfill many of the Smart Grid goals as well, including increasing distributed renewable generation reliably and enabling participation in the ancillary services market

Distinctive Characteristics: TN platform and the associated applications/agents have been released as open source; as new applications/agents and components are developed they will be released as open source as well

- So others can enhance the platform, develop additional agents to control other equipment and appliances and develop commercial products and services

PNNL Progress and Accomplishments

Lessons Learned: The building owners are cautious in accepting automated controls from software products. They generally are not willing to accept a command and control type of approach. So, we have designed our applications such that the user has the ability to override participation both at the local level (RTU) or at the global level (building), if they so chose to. Empowering the building owners allows for broader participation

Accomplishments: The TN platform version 1.2 has been released as open source; this open source repository has the core VOLTTRON software and all the relevant service agents, applications, wiki pages and user guide. All the features including the applications have been fully tested and are still being demonstrated at three demonstration sites

Market Impact: The project is developing a TN platform and demonstrating its usefulness in lowering the cost of entry for both existing and new energy service providers into the market. Although more demonstrations that are larger in scale and size are needed, the current demonstrations have shown the TN platform is able to deliver the impact envisioned. We are working with project collaborators and partners to accelerate the user community

Awards/Recognition: None at this time

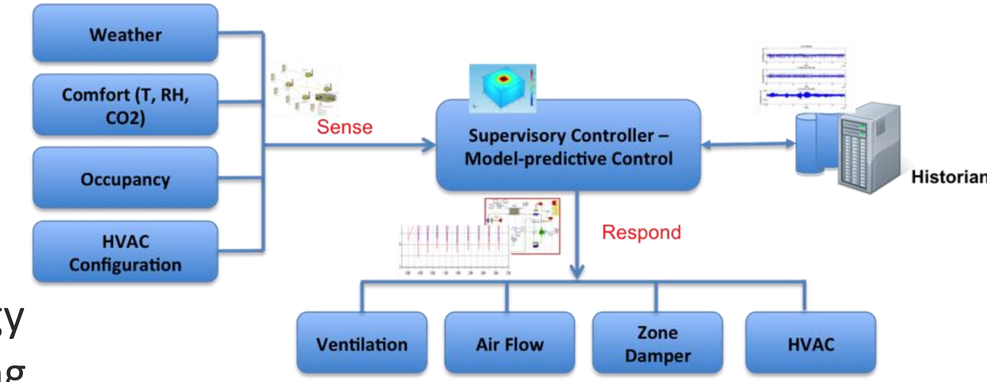
ORNL Transactional Network Applications

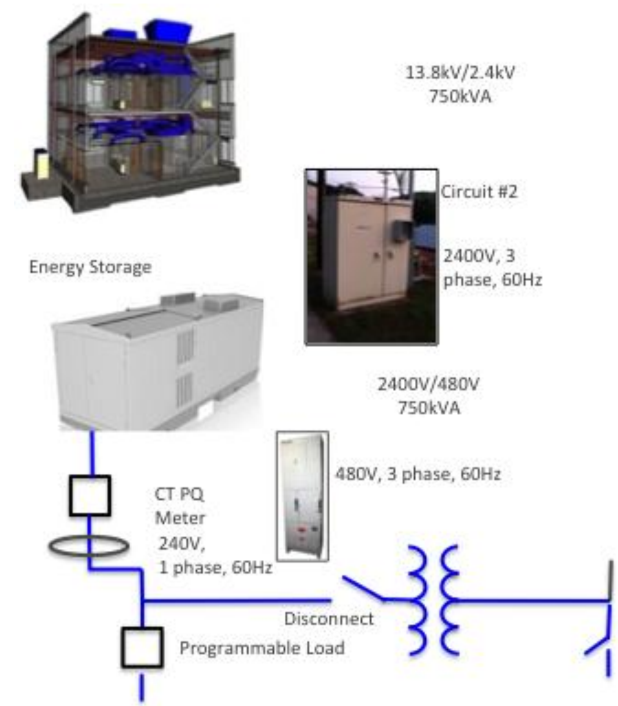
Wireless Interoperability Seamless integration of wireless sensors into transaction network platform

Renewable Integration Build autonomous controller to temporally match RTU energy consumption and peak PV generation using forecasting tools

Autonomous Control Build control formulation to orchestrate multiple RTUs with in a single building for a particular grid service (peak reduction, renewable integration) and energy efficiency applications (occupancy, weather forecast)

Super-Market Refrigeration Develop applications (in collaboration with Emerson) to utilize refrigeration systems to provide energy services to grid and improve the energy efficiency of these systems



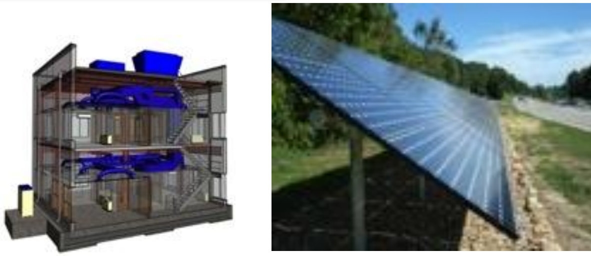


Approach: ORNL

Approach: Develop model-predictive control techniques for reducing peak demand and improve energy efficiency of rooftop units and supermarket refrigeration systems and integrate photovoltaic sources

Key Issues: Low-cost, “low-touch” retrofit of control technology into buildings and refrigeration systems to facilitate transactive opportunities for energy efficiency and with the electric grid

Distinctive Characteristics: Our approach allows for integration of control technologies into buildings to make them grid-ready for transactive energy with minimal retrofit cost



ORNL Progress and Accomplishments

Accomplishments: In FY13, demonstrated 50% peak reduction in a multi-RTU building and ~10% energy savings with an estimated return or investment of the system in less than 2 years. Forecasting model for PV output was developed that can be integrated into a model-predictive control to optimize on-site renewable integration into building energy use

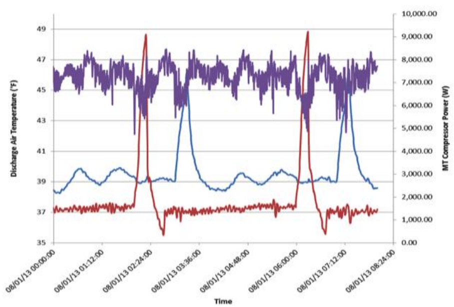
- In FY14, control formulation is being developed to perform on-demand defrost of refrigeration system with reduction in peak demand and overall energy consumption

centralbaptist fountain city

EMERSON. Climate Technologies

Market Impact: In FY13, demonstrated peak reduction of building HVAC energy use which constitutes roughly 30% of the total energy consumed in small and medium commercial buildings. This provides better flexibility on the load side to integrate grid requirements

- In FY14, refrigeration accounts for 50% of supermarket energy usage. On-demand defrost has the potential to reduce up to 720 kWh/case/month



LBNL Transactional Network Applications

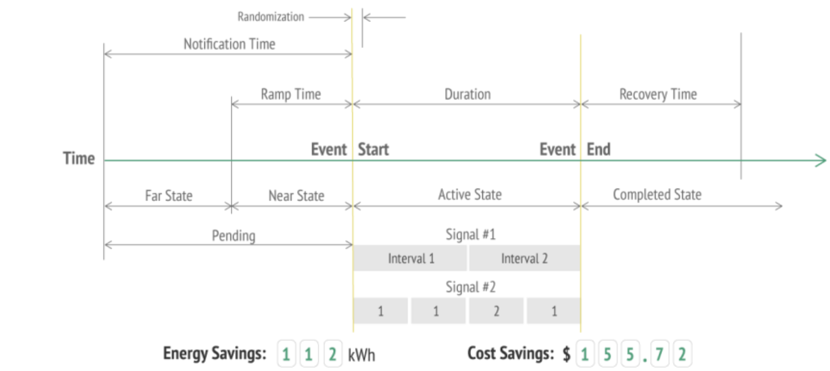
Demand Response Event Scheduler coordinates DR signals from outside server with available network resources

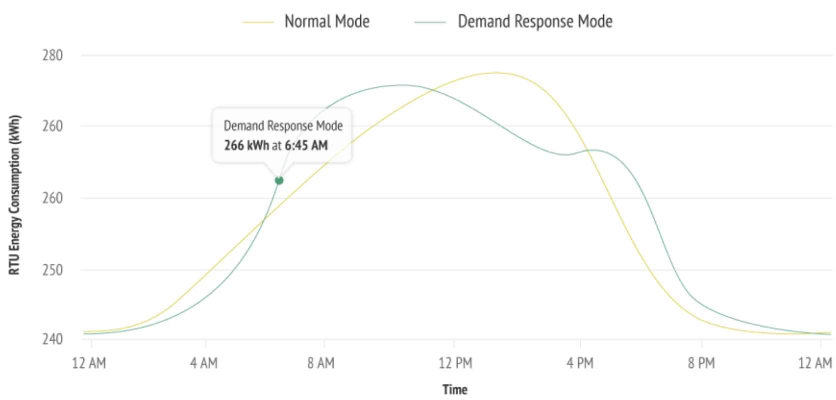
Baseline Load Shape provides basis for measuring change in peak demand and energy use

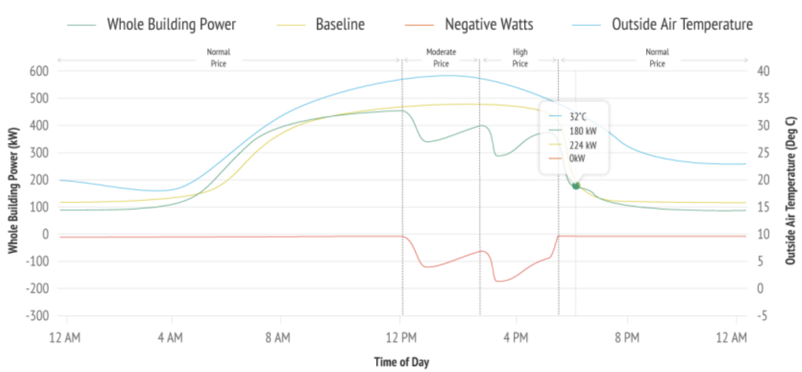
Demand Response Measurement quantifies change in load for each event

Energy Savings Measurement determines total energy savings benefit over time

Economic Savings Measurement translates results from measurement applications to financial savings ($)







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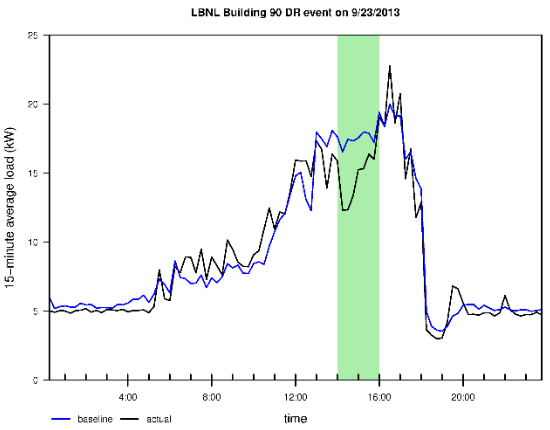
Approach: LBNL

Approach: LBNL has developed 2 capabilities for TN

- A standardized demand response communication agent using OpenADR
- An automated measurement and verification (M&V) agent for both short term demand response or long term energy efficiency measurement



Key Issues: First – the TN network can receive signals from a standards-based DR system that is the most common signal offered by utilities Second – the results from the automated M&V system are translated into financial savings for help in energy economics and good operations

Distinctive Characteristics: The automated M&V is part of a broader set of tools being piloted by utilities to reduce the cost for evaluations

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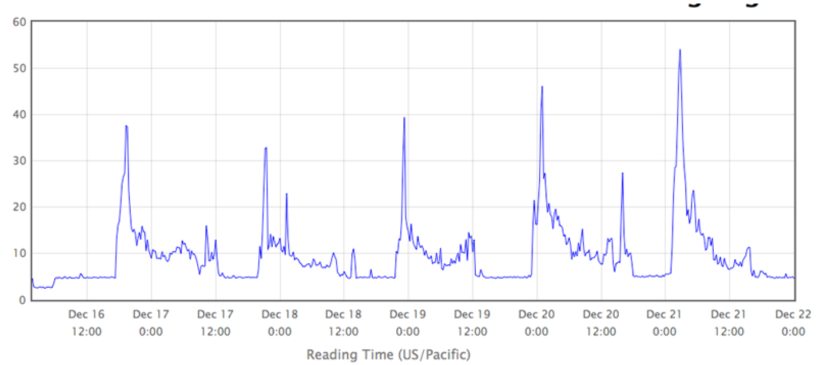
LBNL Progress and Accomplishments

Lessons Learned: The DR automation system was tested on a real building at LBNL along with the automated M&V systems. A recent finding showed large energy waste from the use of resistance heat rather than heat pump heating which will be fixed to cut energy use by 60% in early morning hours

Hourly electric load in winter showing high morning peaks



Accomplishments: The software provides a multi-purpose automated platform or broad interest to the evaluation community

Market Impact: This project is providing a foundational technique to reduce energy waste and improve efficient operation in buildings. We are developing plans for industry workshops to collaborate with partners and disseminate these results

Awards/Recognition: None

Project Integration and Collaboration

Project Integration: The project is led by PNNL with significant contributions from ORNL and LBNL staff. There is an active engagement of project staff with each other on weekly basis. All labs are also actively engaged with project partners and relevant stakeholders at every opportunity to accelerate the market impact

Partners, Subcontractors, and Collaborators: Transformative Wave, a small HVAC business from Washington state, supported the project by deploying their advanced controls product on RTUs and helping establish communication between the controller and TN platform. EnerNOC implemented an open source OpenADR client for the TN platform. Emerson is working with ORNL to develop innovative on-demand defrost

Communications: Technical and early adopter workshop is planned for later this year. A number technical papers have been written on VOLTTRON software. A number of reports are also publicly available. A user guide was also created to help early adopters. The TN concept has been presented to a number of potential user (universities, energy service providers, etc.)

Next Steps and Future Plans

Next Steps and Future Plans: The first step is to successfully complete the FY14 planned activities that are being conducted at all three labs

- Demonstration of coordination of multiple buildings or TN nodes and BACnet communications
- On-demand defrost cycle implementation on supermarket refrigeration system
- Lighting systems fault detection and diagnostics and controls
- Host a workshop for early adopters in summer
- Draft a plan to create a community with the following goals:
    - Construct and maintain a catalog of real-world transactive network applications related to buildings
    - A reference transactive network platform supported by the community participants
    - Transactive network applications that are developed on the reference transactive network platform for reference and demonstration purposes
    - An interoperability testing and "certification" suite for transactive network applications to ensure broad multi-vendor interoperability
    - Multiple demonstration facilities to help evangelize transactive network applications for buildings

REFERENCE SLIDES

PNNL Project Budget

Project Budget – RTU Network Project

Cost to Date: $1,573K, as of 3/21/2014

Additional Funding: $0K (Project is near completion)

Budget History					
FY2011– FY2013 (past)		FY2014 (current)		FY2015 – Q2 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$1,575K	$0K	$0K	$0K	$0K	$0K

Project Budget – VOLTTRON Nation Project (Task 5a)

Cost to Date: $16K, as of 3/21/2014

Additional Funding: $0K (Funding required to complete FY2015 scope will be carried over from FY2014)

Budget History					
FY2011– FY2013 (past)		FY2014 (current)		FY2015 – Q2 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$0K	$0K	$400K	$0K	$0K	$0K

PNNL Project Plan and Schedule

Describe the project plan including:

- Project original initiation date & Project planned completion date
  - Projects kicked off in FY2013.
  - Planned completion is Q2 of FY2014 for the RTU Network project initiated in FY2013. VOLTTRON Nation Project kicked off in Q2 of FY2014 with an anticipated completion of Q1 FY2015.
- Schedule and Milestones
  - All FY2013 and FY2014 deliverables and milestones for the RTU Network project have been completed.
  - Work is underway on the FY2014 VOLTTRON Nation Project.
- Explanation for slipped milestones and slips in schedule
  - Not applicable.
- Go/no-go decision points
  - Not applicable.
- Current and future work
  - XXXXX

PNNL Project Plan and Schedule

Project Schedule - FY2013 RTU Network Project													
Project Start: 10/1/2012		Completed Work											
Projected End: 3/31/2014		Active Task (in progress work)											
	◆	Milestone/Deliverable (Originally Planned)											
	◆	Milestone/Deliverable (Actual)											
	FY2013				FY2014				FY2015				
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	
Past Work													
Q1 Milestone: Selection of control manufacturer partner	◆												
Q1 Milestone: Selection of project partner complete	◆												
Q2 Deliverable: Slide presentation of RTU network concept		◆											
Q2 Deliverable: Document grid responsive control strategies for RTU (letter report)		◆											
Q2 Deliverable: Document embedded grid responsive controls to be tested on a RTU (report)		◆											
Q3 Deliverable: Document embedded airside Dx algorithms to be tested on a RTU (report)			◆										
Q3 Milestone: Complete implementation of the prototype RTU network			◆										
Q3 Deliverable: Slide presentation on RTU network design			◆										
Q3 Milestone: Implementation of embedded Dx and grid responsive controls in an advanced controller complete			◆										

PNNL Project Plan and Schedule

Project Schedule - FY2013 RTU Network Project		
Project Start: 10/1/2012		Completed Work
Projected End: 3/31/2014		Active Task (in progress work)
	◆ (red)	Milestone/Deliverable (Originally Planned)
	◆	Milestone/Deliverable (Actual)

	FY2013				FY2014				FY2015			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
Q3 Milestone: Complete development/implementation of the Cloud SMDS with multi-speed fan capability			◆									
Q3 Deliverable: Document sequence of operations for control strategies identified in Task 2.1 (report including the previous letter report from Task 2.1)			◆									
Q4 Milestone: Complete testing of the Cloud SMDS for RTUs outside the RTU Network				◆								
Q4 Deliverable: Design and implement the main page of the RTU Network Dashboard on the Cloud				◆								
Q4 Milestone: Complete testing of the prototype RTU network				◆								
Q4 Milestone: Testing and validation of embedded Dx and grid responsive controls in the field on RTUs complete				◆								
Q4 Deliverable: Final report documenting the design, implementation and initial test results for the RTU Network					◆							
Q4 Deliverable: Design and implement the application specific pages					◆							

PNNL Project Plan and Schedule

Project Schedule - FY2013 RTU Network Project												
Project Start: 10/1/2012		Completed Work										
Projected End: 3/31/2014		Active Task (in progress work)										
	◆	Milestone/Deliverable (Originally Planned)										
	◆	Milestone/Deliverable (Actual)										
	FY2013				FY2014				FY2015			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
Q4 Deliverable: SMDS module of the RTU Network Dashboard					◆							
Q4 Deliverable: Documentation on the SMDS methodology, the design of the Cloud SMDS and the results of testing					◆							
Current/Future Work												
Q1 Milestone: Complete the demonstration started in FY13					◆							
Q2 Milestone: BACnet device driver developed and tested						◆						
Q2 Milestone: Complete implementation of the multi-building coordination extensions						◆						
Q2 Milestone: Complete testing of the implementation of the multi-building coordination extensions						◆						

LBNL Project Budget

Project Budget: FY13 TN effort - $675k, with $250k in FY14 for a lighting agent and $750k related to occupancy sensing, data fusion and resource availability analysis
Variances: None
Cost to Date: The FY13 funds have been spent and we are on track with spending the FY14 funds with about
Additional Funding: LBNL is collaborating on testing the M&V agents with DOE's Commercial Building Integration Program as well as the Pacific Gas and Electric Company

Budget History					
FY2013 (past)		FY2014 (current)		FY2015 (planned)	
DOE	Cost-share*	DOE	Cost-share	DOE	Cost-share
$675k	$40k	$250k		TBD	

***Enernoc provided cost share in the DR agent, LBNL facilities cost share in 2014**
****$250k for Lighting Agent in FY14**

LBNL Project Plan and Schedule

Project Schedule												
Project Start: 12/1/2012		Completed Work										
Projected End: 09/30/2014		Active Task (in progress work)										
		Milestone/Deliverable (Originally Planned)										
		Milestone/Deliverable (Actual)										
	FY 2013				FY 2014				FY 2015			
Task	Q1 (Oct - Dec)	Q2 (Jan - Mar)	Q3 (Apr - Jun)	Q4 (Jul - Sep)	Q1 (Oct - Dec)	Q2 (Jan - Mar)	Q3 (Apr - Jun)	Q4 (Jul - Sep)	Q1 (Oct - Dec)	Q2 (Jan - Mar)	Q3 (Apr - Jun)	Q4 (Jul - Sep)
Past Work												
Working Prototype of Communication System												
Working Prototype: Analysis Tools measure RTU performance												
Working Prototype: Analysis to Quantify Performance												
Demo Aggregate analysis & control system												
Current /Future Work												
Lighting: Complete Phase One Demonstration (Final Report)												
Lighting: Develop software spec and test plan (12/01/13)												
Lighting: Program Lighting Control Agent (3/15/2014)												
Lighting: Integrate Control Agent to Occupied Space (go/no go)								on track for due date 5/1/2014				
Lighting: Demonstrate Transactional Lighting Network												

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ORNL Project Budget

Project Budget: In FY13 ORNL's TN effort is $300K to develop autonomous control and renewable integration applications. In FY14 ORNL's TN effort is $400K to develop refrigeration and occupancy-based RTU control applications

Variances: None

Cost to Date: $469K as of 3/15/14 between FY13 and FY14

Additional Funding: None

Budget History					
FY2013 (past)		FY2014 (current)		FY2015 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$300K	$0K	$400K	$0K	TBD	TBD

ORNL Project Plan and Schedule

Project Schedule												
Project Start: 10/1/2012	Completed Work											
Projected End: 9/30/2015	Active Task (in progress work)											
	Milestone/Deliverable (Originally Planned) use for missed milestones											
	Milestone/Deliverable (Actual) use when met on time											
	FY2013				FY2014				FY2015			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
Analysis of communication network requirements for integrating RTUs to provide energy services												
Design and development of autonomous control strategies for RTUs performing integrative grid services												
Demonstration at site for verification and validation of applications												
Identify demand-side energy services provided by supermarket refrigeration system in collaboration with commercial partner and data from equipment												
Design description (controller formulation) of a particular energy service identified in Q1												
Current/Future Work												
Deployment of Transactional Network platform – Volttronlite on supermarket refrigeration system to collect existing sensor data (to sMAP historian)												
Demonstrate TN platform integrated with supermarket refrigeration system and collect data and draft final report												