VOLTTRON™
Secure, Open, Interoperable, Flexible

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Outline

- Why do we need VOLTTRON™?
- Benefits of VOLTTRON™
- List of VOLTTRON™ Use Cases
- A Look at a Selected Use Cases

U.S. Building Energy Use in Context and Opportunities to Reduce it Through Transactive Controls

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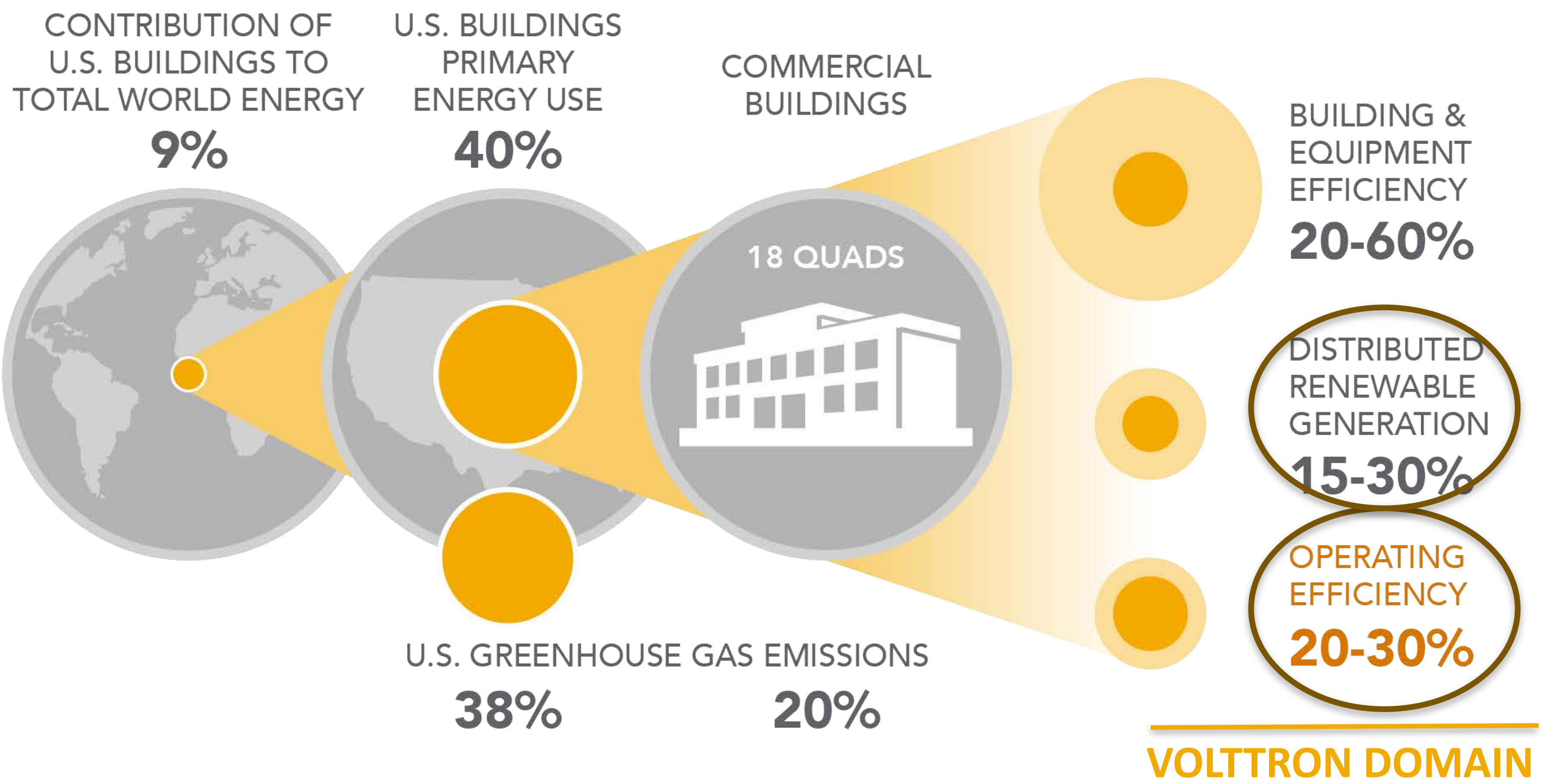
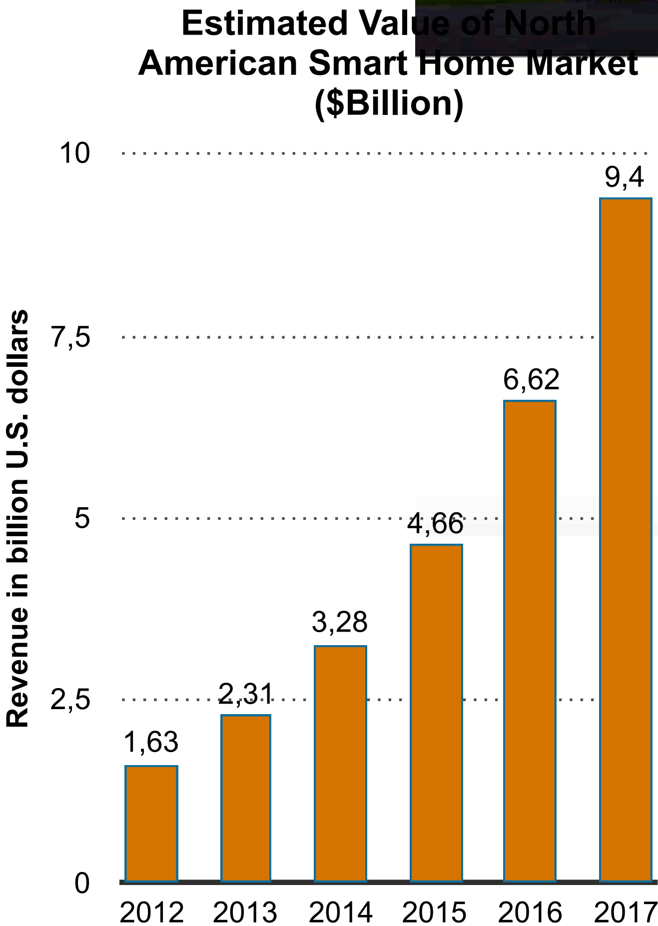


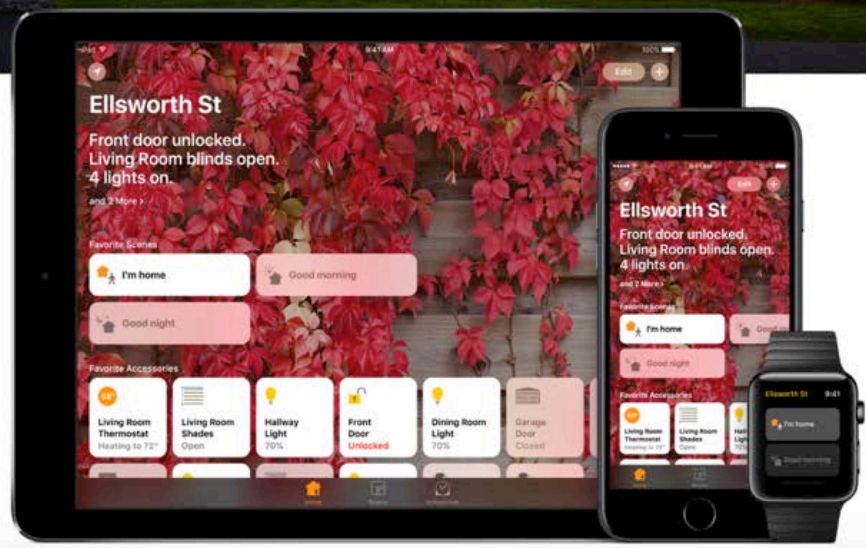
U.S. Buildings Consume Nearly 75% Electricity

Meanwhile At Home

Being able to control so many connected accessories at one place does NOT mean homes are SMART.



Source: Berg Insight, November 2013, Statista 2015 .



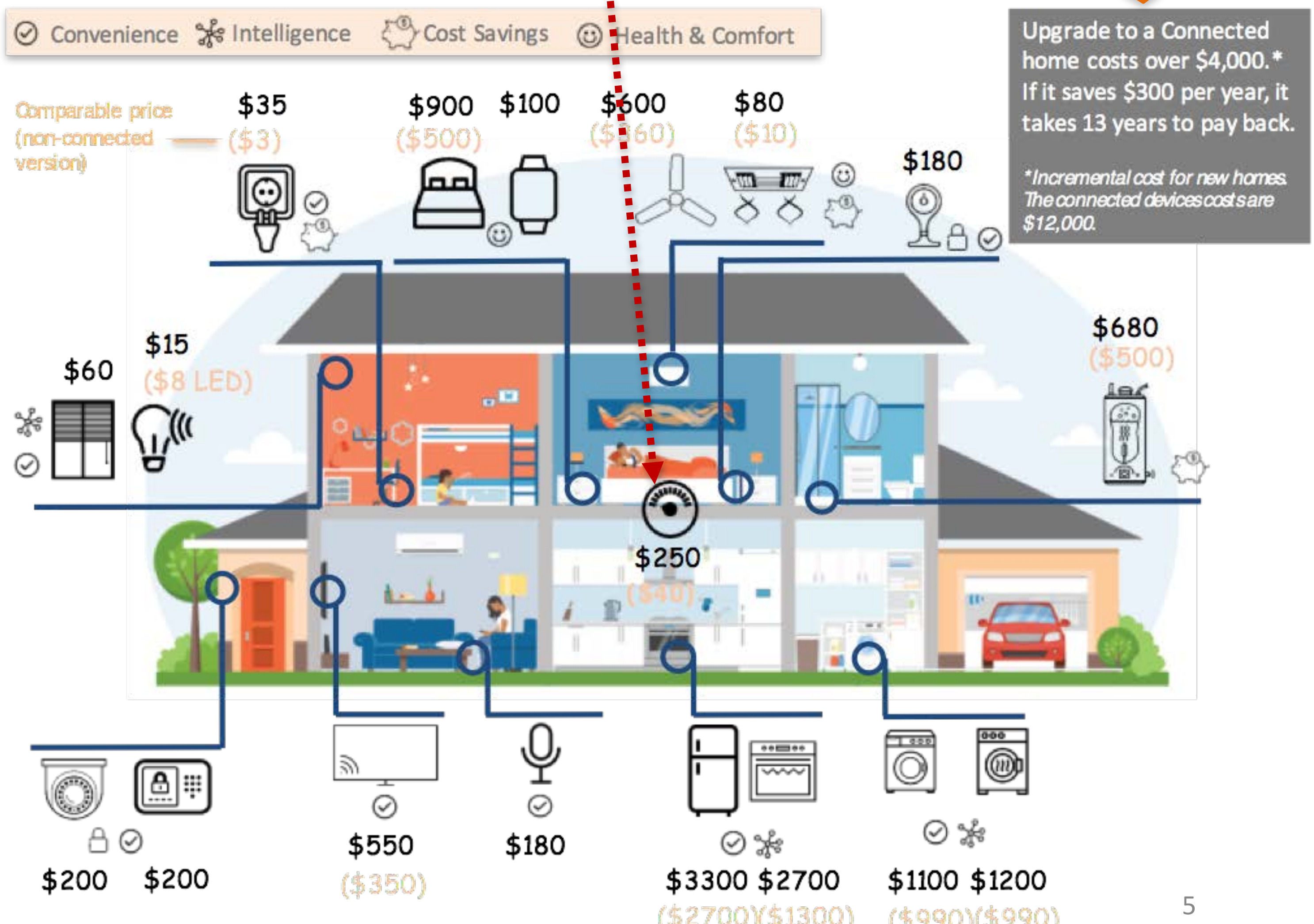
Despite the projection of tremendous market growth of connected devices in the near future, the current technologies (especially for residential and small commercial buildings) have not been valued in the mainstream market due to lack of connection with fundamental consumer benefits and demonstrated grid benefits.

System-level research strategies that enable a full integration of fragmentally developed connected devices is important to enable a truly transactive utility network for residential buildings (the attributes of which are also shared with small commercial buildings).

Many home apps function as internet-based digital remote controls of IoT devices.

One-way control signal from the Grid leads to unpleasant consume experience.

Are the connected products simply too expensive and thus inaccessible? OR do they lack a fundamental connection with consumer benefits?



VOLTTRON™: Key Benefits and Primary Use Areas

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- 3 Key Benefits:
  - Cost-effective – Open source software (free to users) and can be hosted on inexpensive computing resources
  - Scalable – Can be used in one building or a fleet of buildings
  - Interoperable – Enable interaction/connection with various systems/ subsystems, in and out of the energy sector
- 3 Primary Use Areas:
  - Building Efficiency – To help control building energy system performance
  - Building-Grid Integration – To support “beyond demand response” approach and integration of distributed energy resources into the grid
  - Transactive Control – To support a scalable, distributed control mechanism for transacting information about systems, loads and constraints to deliver user specified services.

What is VOLTTRON?

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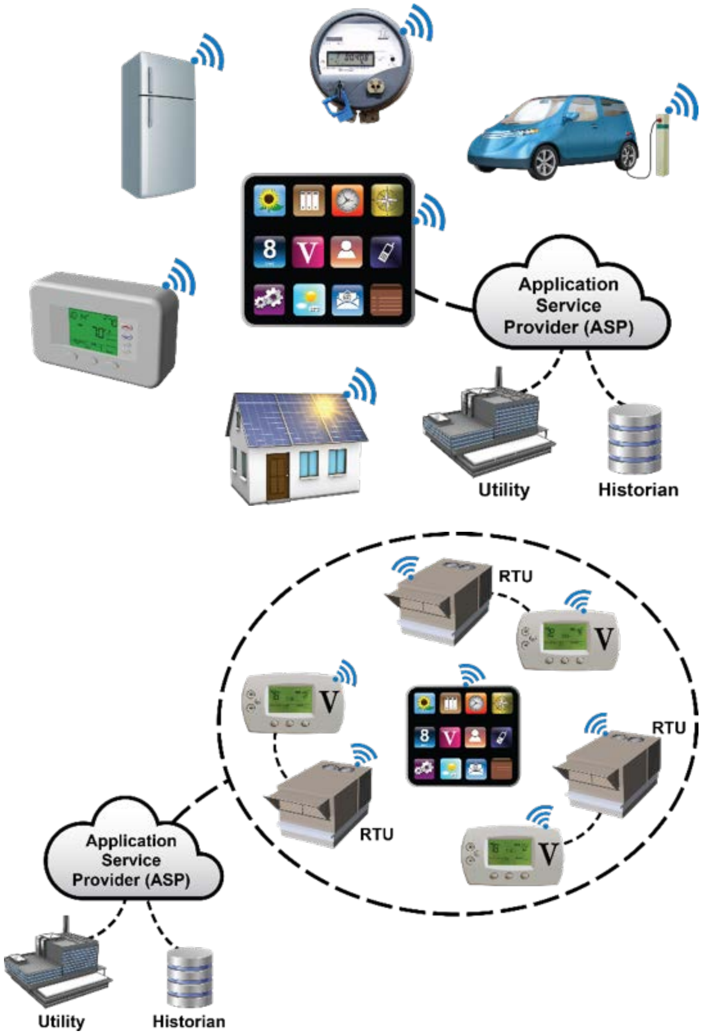
- VOLTTRON is an application platform (e.g. Android, iOS) for distributed sensing and control applications
- VOLTTRON is not a protocol
  - A protocol, such as SEP2.0. or OpenADR, are implemented as applications
  - VOLTTRON supports industry standard protocols
- VOLTTRON is not an application such as demand response
  - Demand response can be implemented as an application on top of VOLTTRON
- VOLTTRON is open, flexible and already benefits from community support and development



VOLTTRON Attributes

- Open, flexible and modular software platform
  - Easy application development
  - Interoperable across vendors and applications
  - Hides power and control system complexities from developers
  - Object oriented, modern software development environment
  - Language agnostic. Does not tie the applications to a specific language

VOLTTRON Attributes (cont.)

- Broad device and control systems protocols support built-in
  - ModBUS, BACNet, and others
  - Multiple types of controllers and sensors
  - Low CPU, memory and storage footprint requirements
  - Supports non-Intel CPUs
- Secure
  - Security libraries and cryptography built-in
  - Manage applications to prevent resource exhaustion (CPU, memory, storage)
  - Robust against denial-of-service (e.g. does not crash when scanned via NMAP)
  - Supports modern application development environments

VOLTTRON™ Timeline

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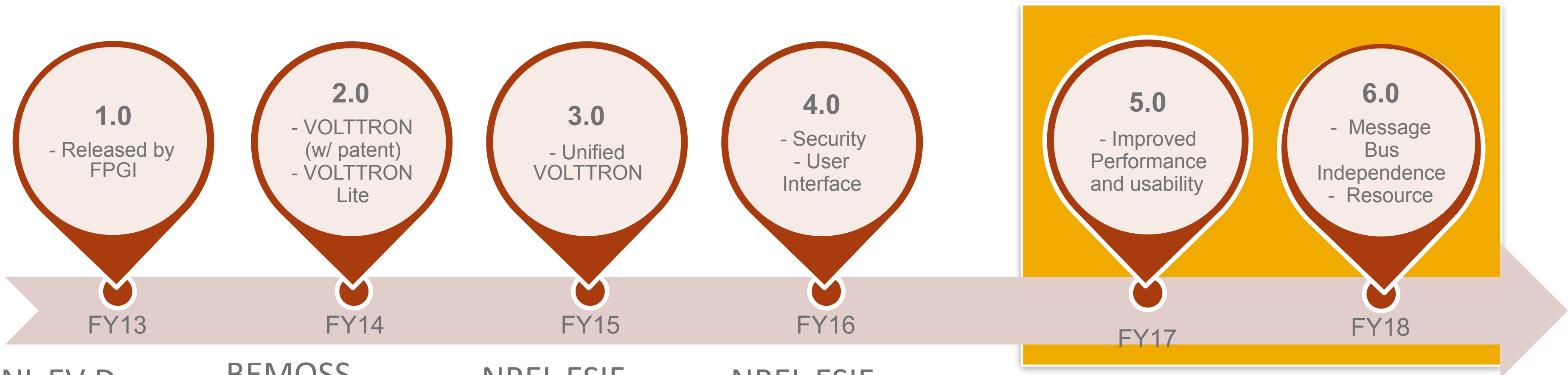
VOLTTRON™ Releases



FY13: PNNL EV Demo

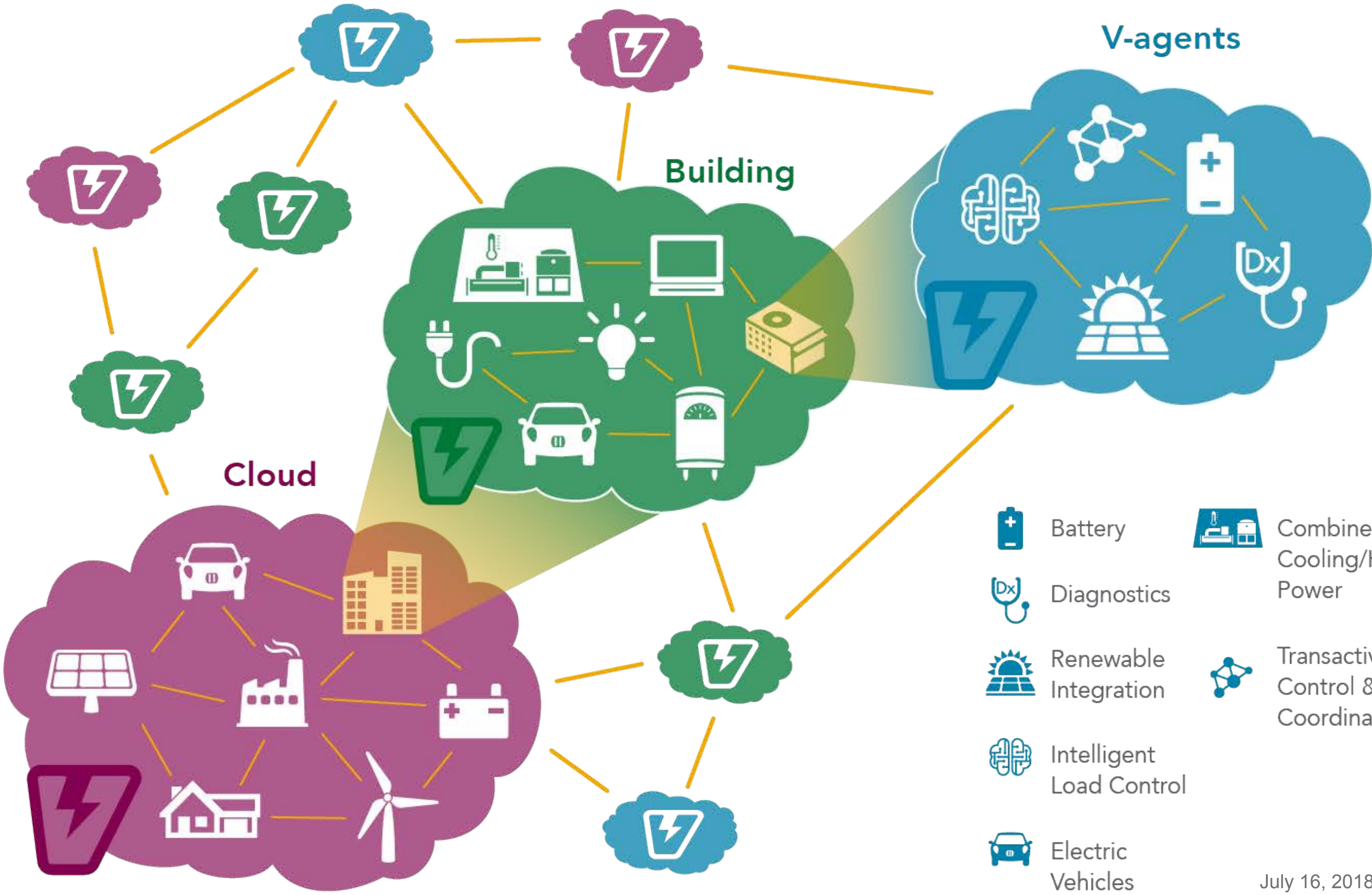
FY14:
BEMOSS
RTU Network
First User Forum

FY15:
NREL ESIF
2nd User Forum
Quality Logic Implements Transactive Node

FY16:
NREL ESIF
3rd User Forum
Transactive Campus
BIRD-IP
GMLC Usage
Buildings Challenge
TWT Deployment
Intellimation deploying 100 instances

FY17–FY18:
NW Tech Meeting
4th User Forum
VOLTTRON™ Foundation

VOLTTRON Eco-System



Battery

Diagnostics

Renewable Integration

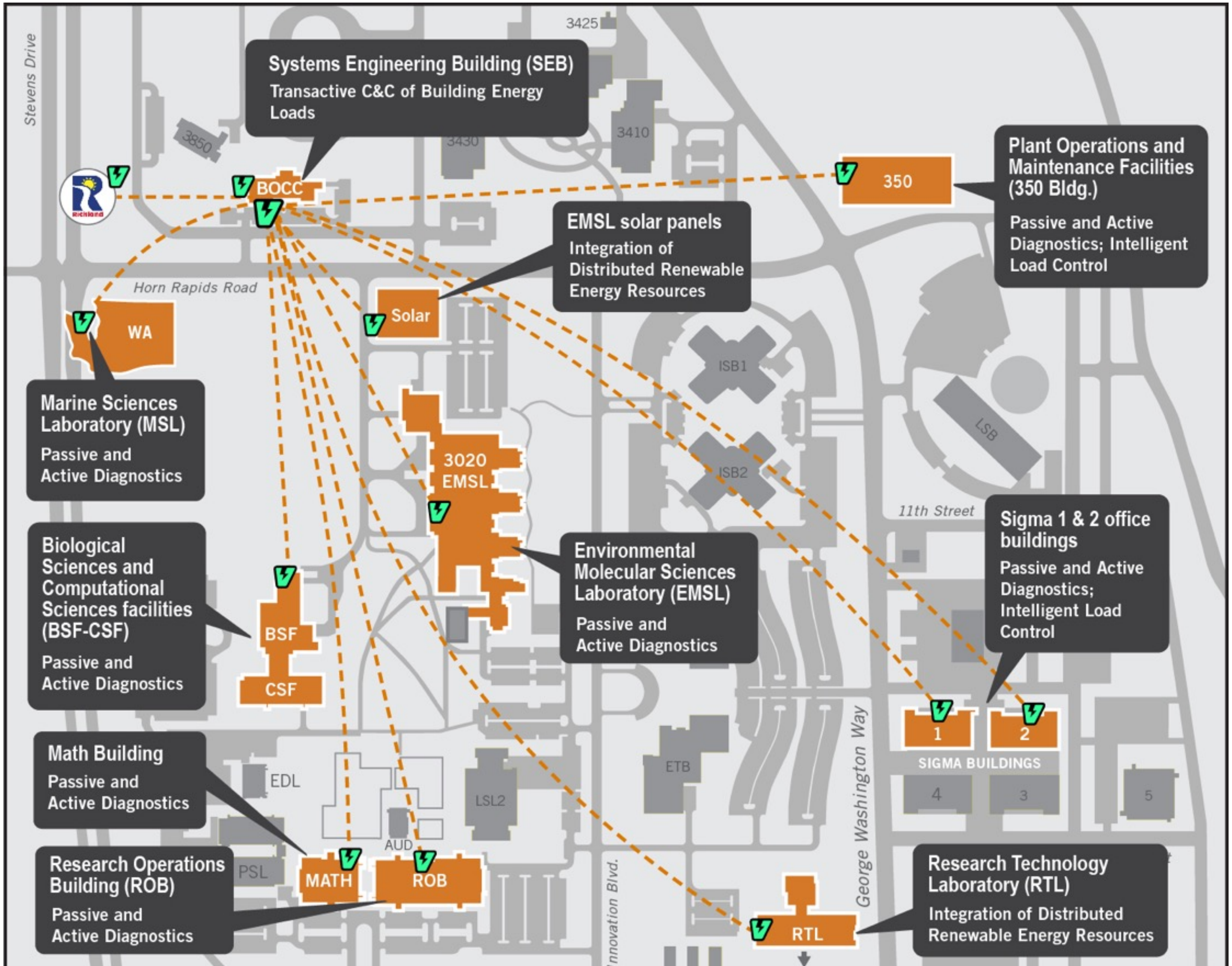
Intelligent Load Control

Electric Vehicles

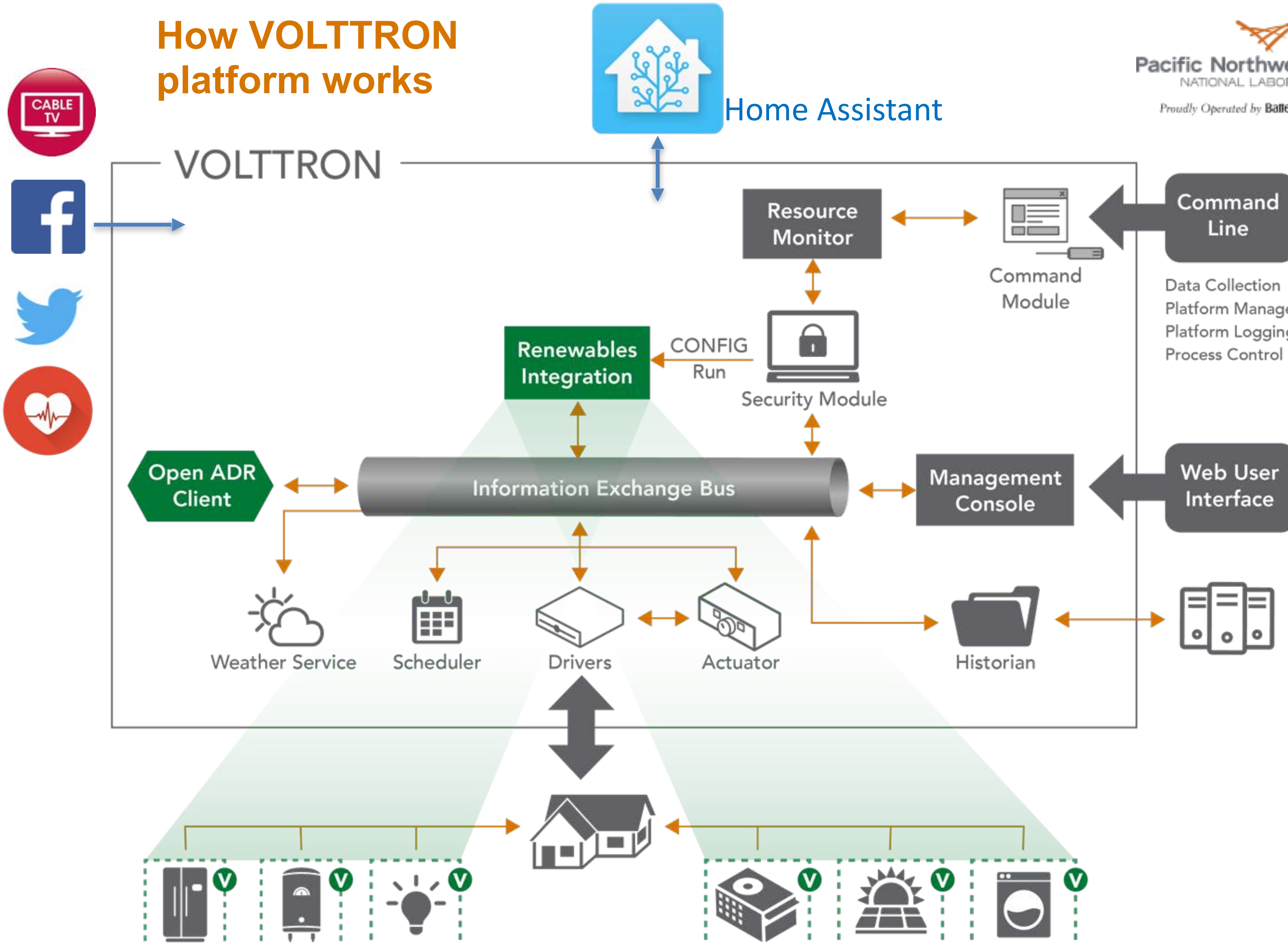
Combined Cooling/Heating Power

Transactive Control & Coordination

VOLTTRON Deployment on PNNL Campus



How VOLTTRON platform works



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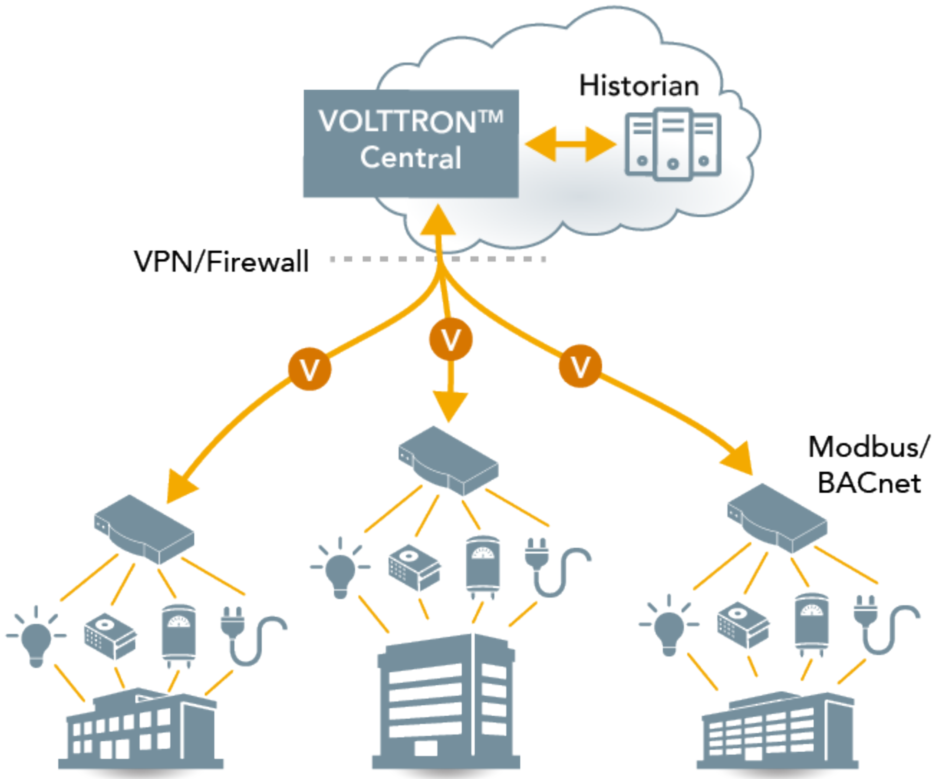
Scalable Deployment



Hardware Options

VOLTTRON™ Security

- Platform hardening guidelines for securing underlying Linux system
- Multi-platform Message Bus
  - Encrypted communication between VOLTTRON instances
  - Authorization required for agents to communicate with the VOLTTRON message bus
  - Pub/sub topics can be restricted to authorized agents
- Platform Security and Monitoring
  - Access to VOLTTRON instances restricted to approved hosts
  - System for forwarding crucial log files for analysis
  - Alerts can trigger emails to administrators
  - Monitor and alert on pub/sub topics for interruptions and unexpected values
- Agent Security
  - Role based access to agent capabilities
  - Agents execute in separate process from platform

Example VOLTTRON™ Use Cases

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- Interoperability Platform for Commercial Buildings and Homes
- VOLTTRON™-based Cloud Analytics
- Enabling "Smart" Building for "Smart" Cities
- Building Automation System (BAS) for Small/Medium Size Buildings (SMB)
- Deploying Energy Efficiency (EE) and Grid Services with SMB
- Secure Data Collection from BAS in Support of Third Party Cloud Analytics
- Deploying Energy Efficiency and Grid Services for Large Commercial Buildings
- "Re-tuning" Mandates (New York, Seattle, etc.)

Interoperability Platform for Commercial Buildings and Homes

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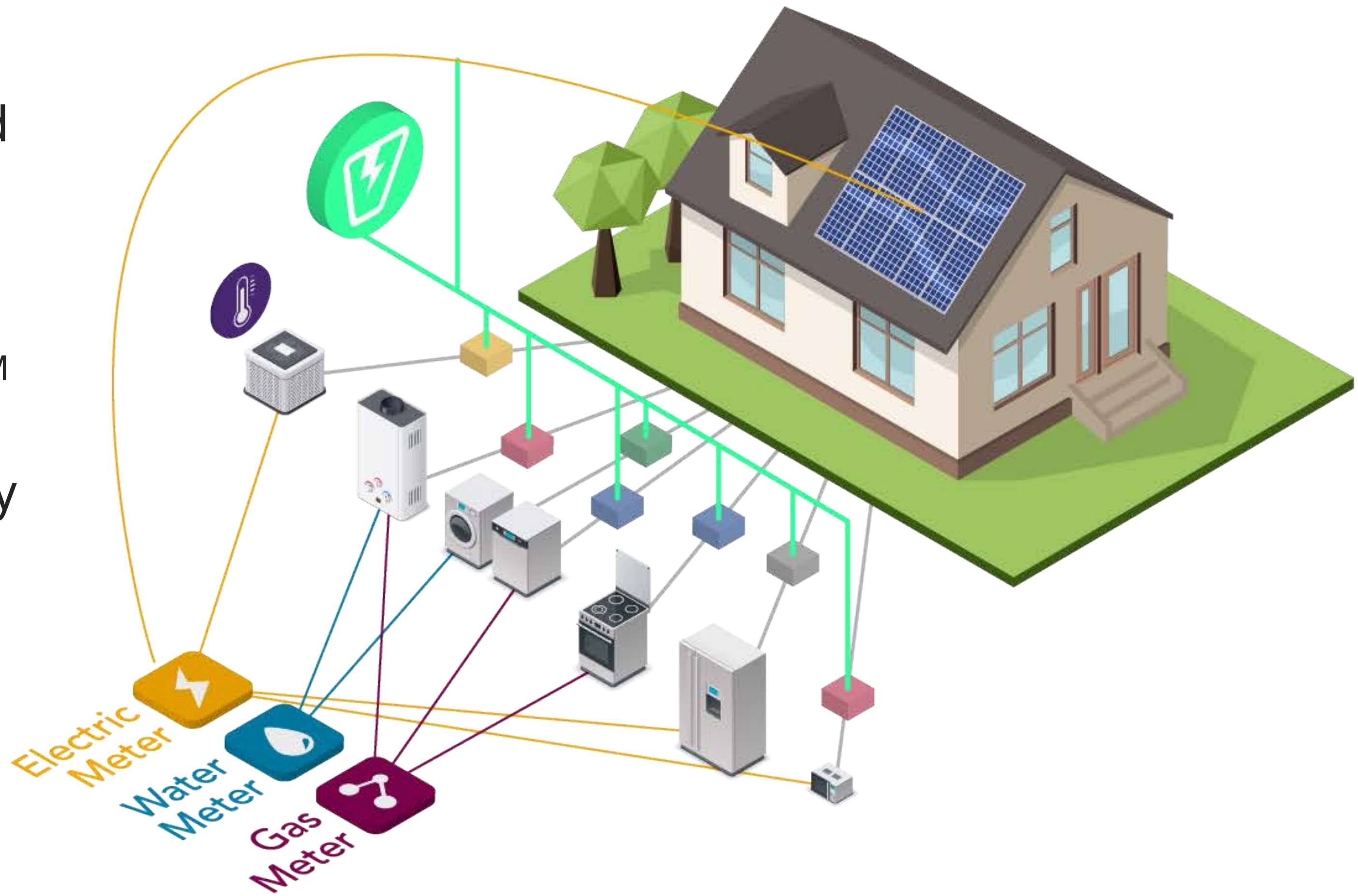
- On the home front lot of standards and alliances but none are dominant
- VOLTTRON™ can be an interoperability platform



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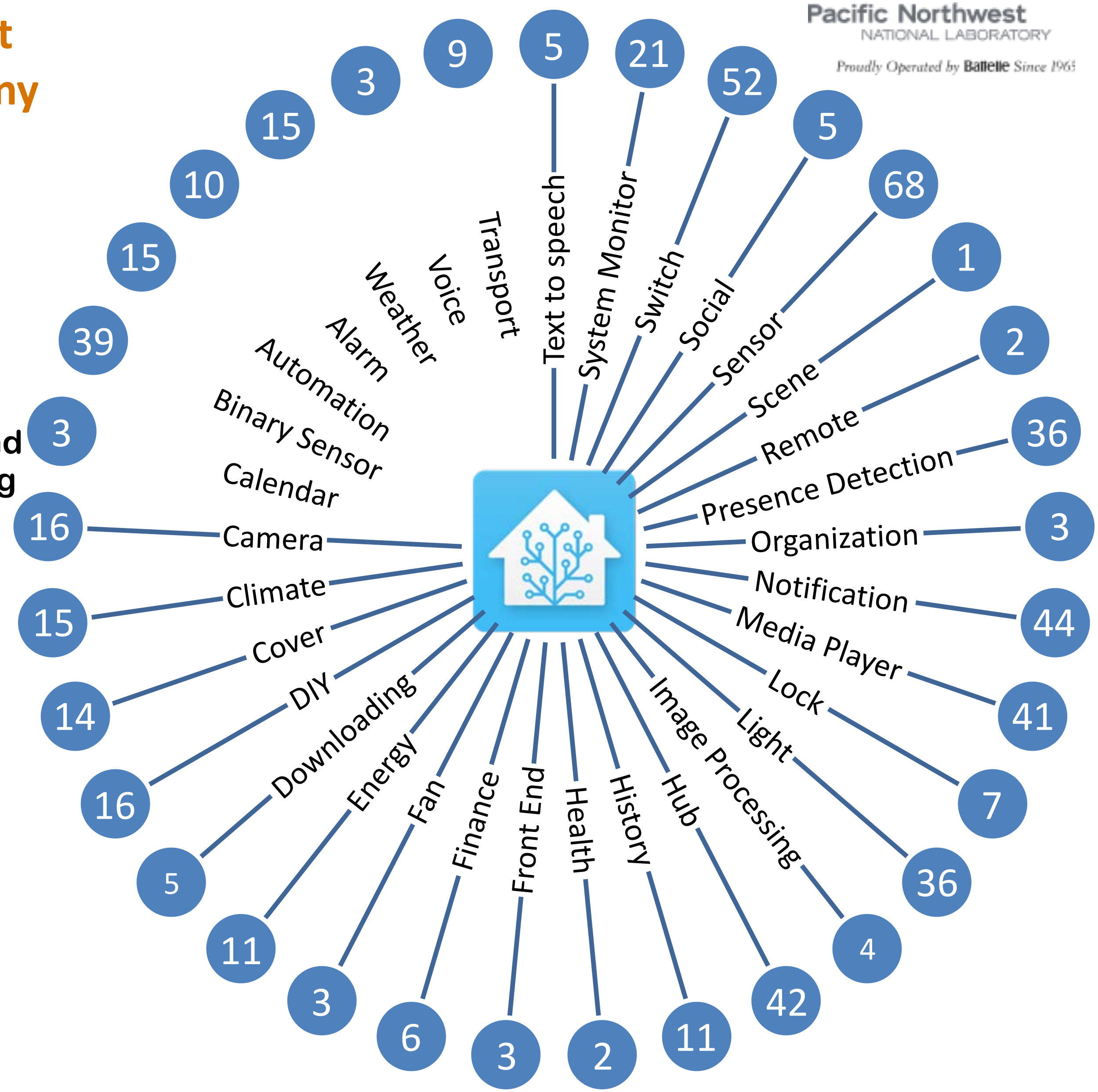
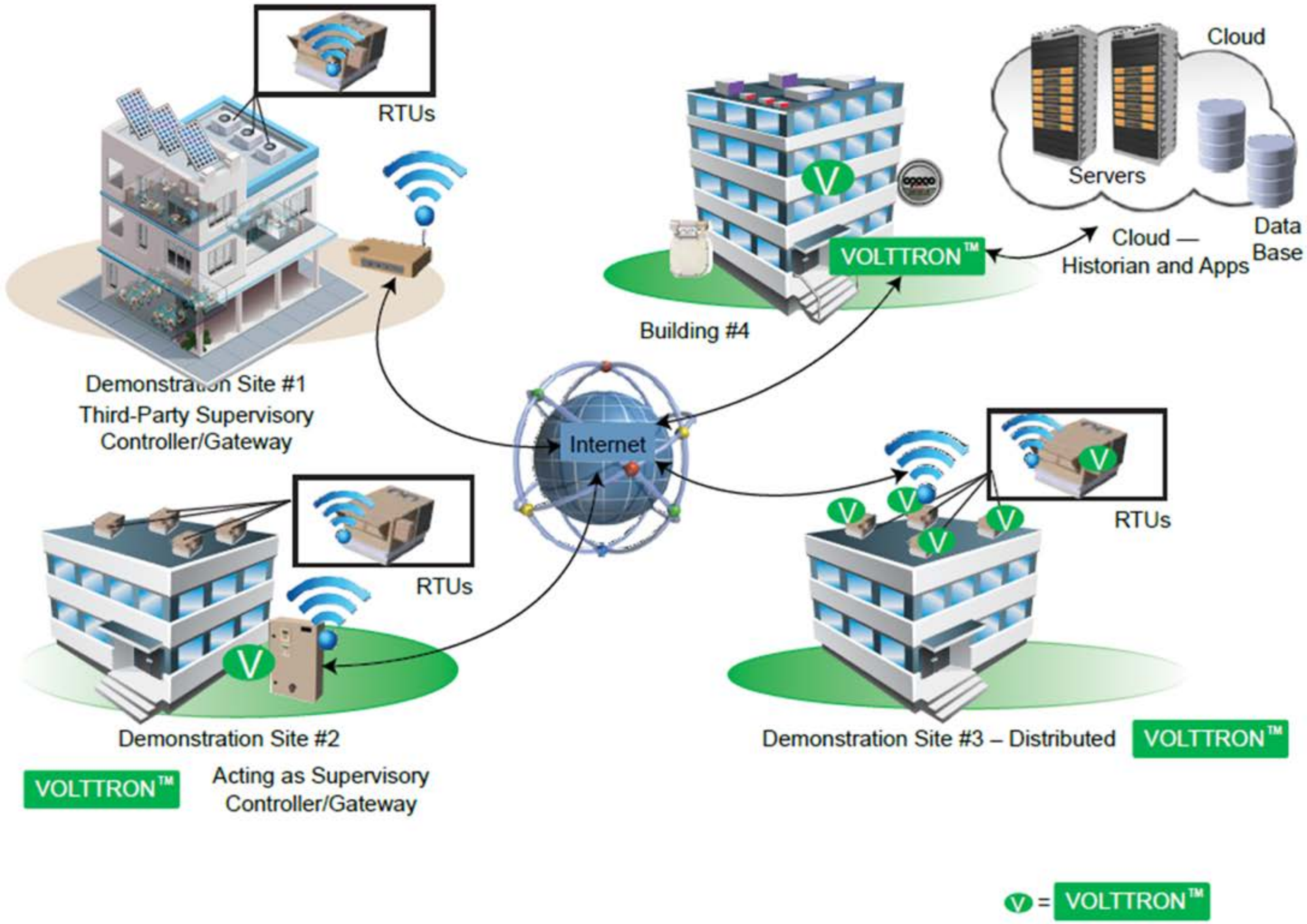
Open Source Platform such as Home Assistant can connect VOLTTRON platform to many components.

- Allow linking to IFTTT, weather information, or Amazon Echo device to controls from locks to lights to even a command line notifier.
- Pairs with both open sources and commercial offerings supporting over 600 components in 34 categories
- Easily to deploy on any machine runs Python
- Features easy-to-use user interfaces for all mobile devices
- Does not store all of the private information on the cloud ensuring data security
- Has a large community for technical support and trouble shooting



Number of devices/apps connected to Home Assistant by Category

Cloud Analytics



Secure Data Collection from BAS in Support of Third Party Cloud Analytics

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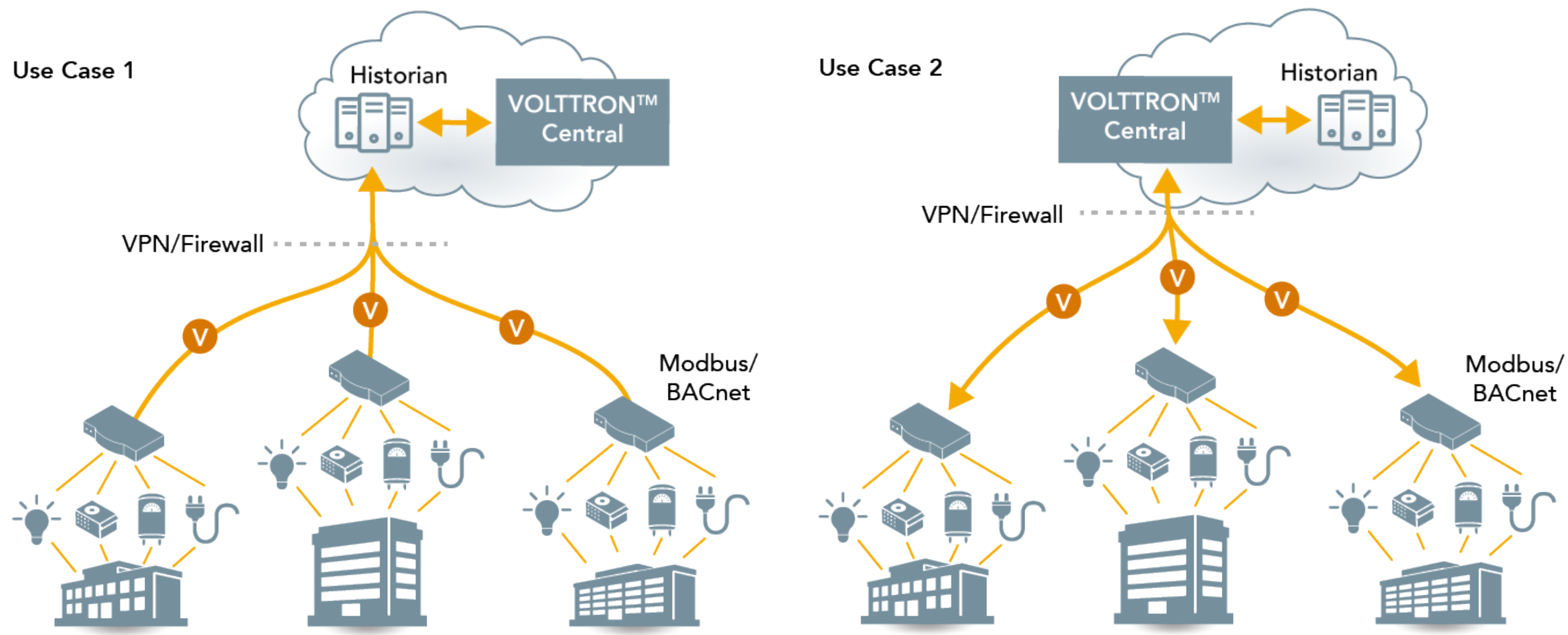
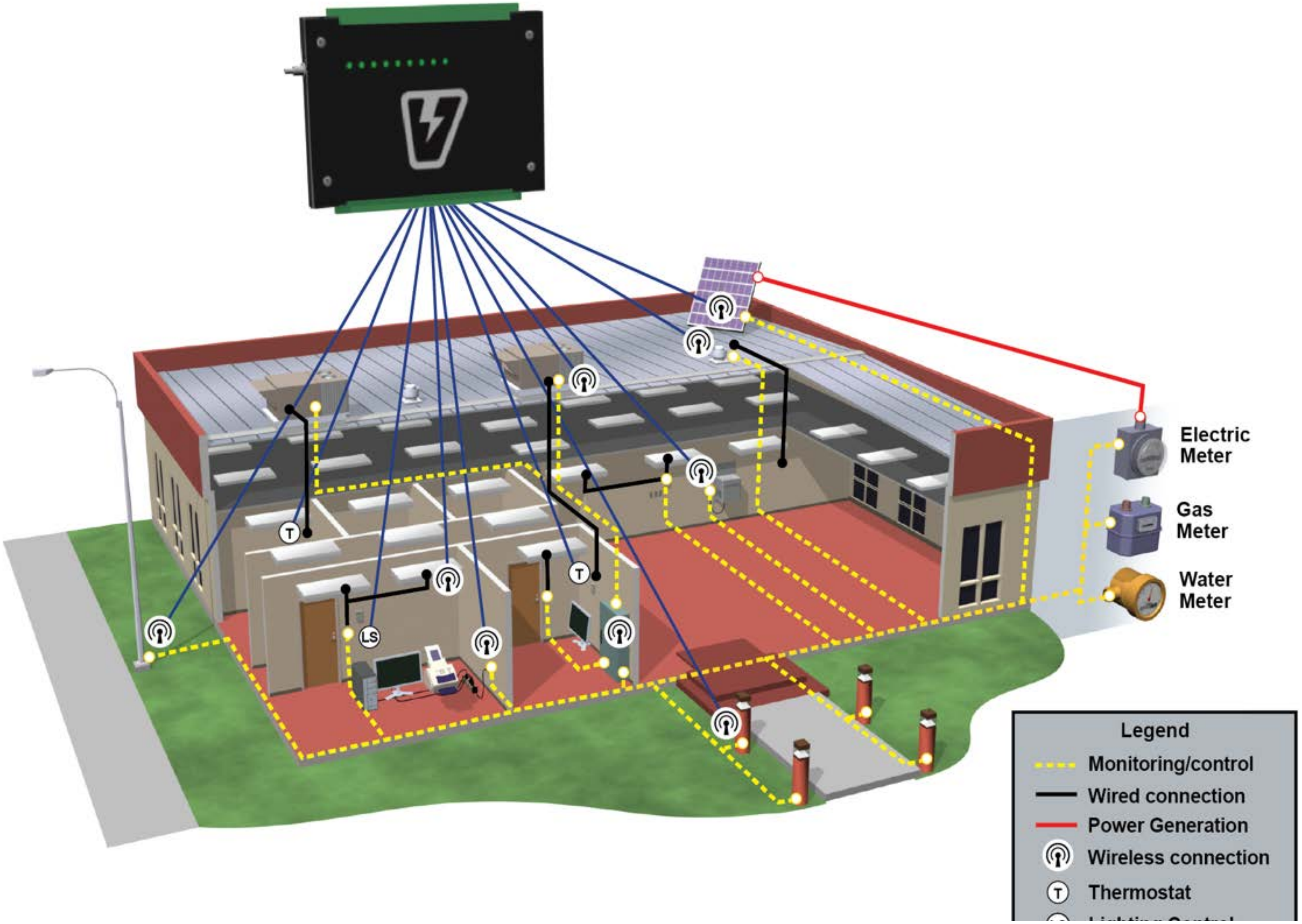


- Access to data from other devices
  - WiFi, Zigbee, proprietary devices thru API calls

BAS for Small/Medium Size Buildings

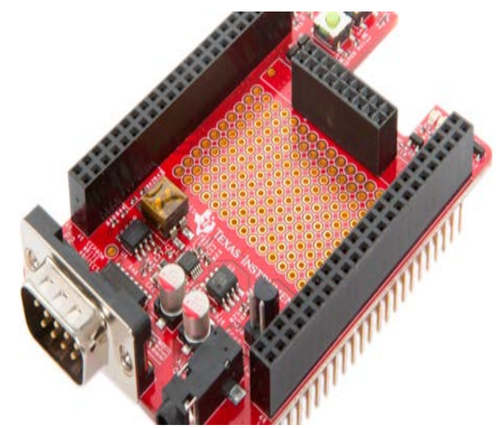


EE and Grid Services for SMB

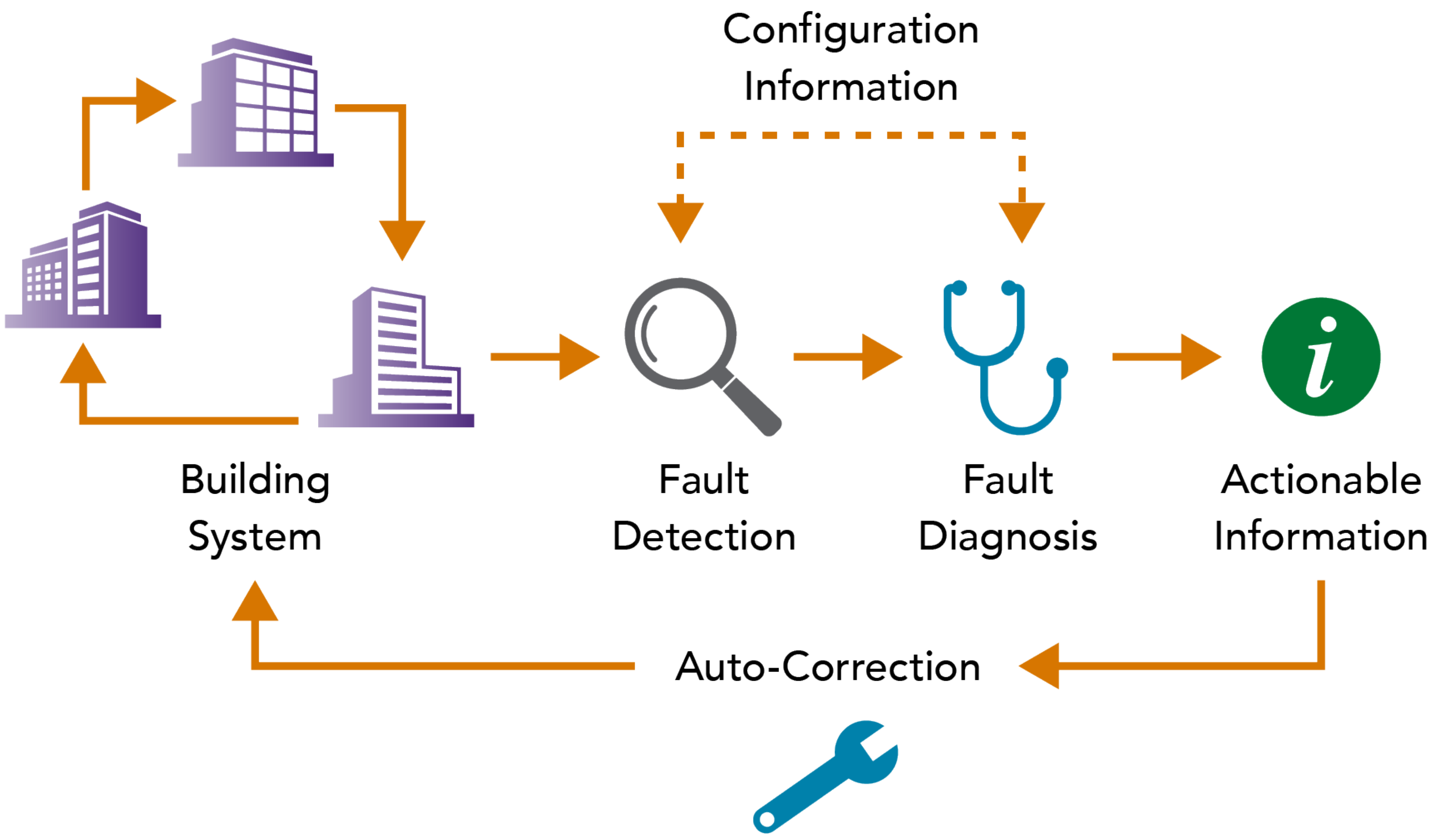
- Enforcing schedules and set point will result in energy and cost savings over 20%
- Beyond demand response
  - Intelligent load controls to support grid reliability
  - Supporting renewable generation technology integration

20% to 30%

Operating Efficiency



Energy Efficiency Services for Large Commercial Buildings: What



Energy Efficiency Services for Large Commercial Buildings: How

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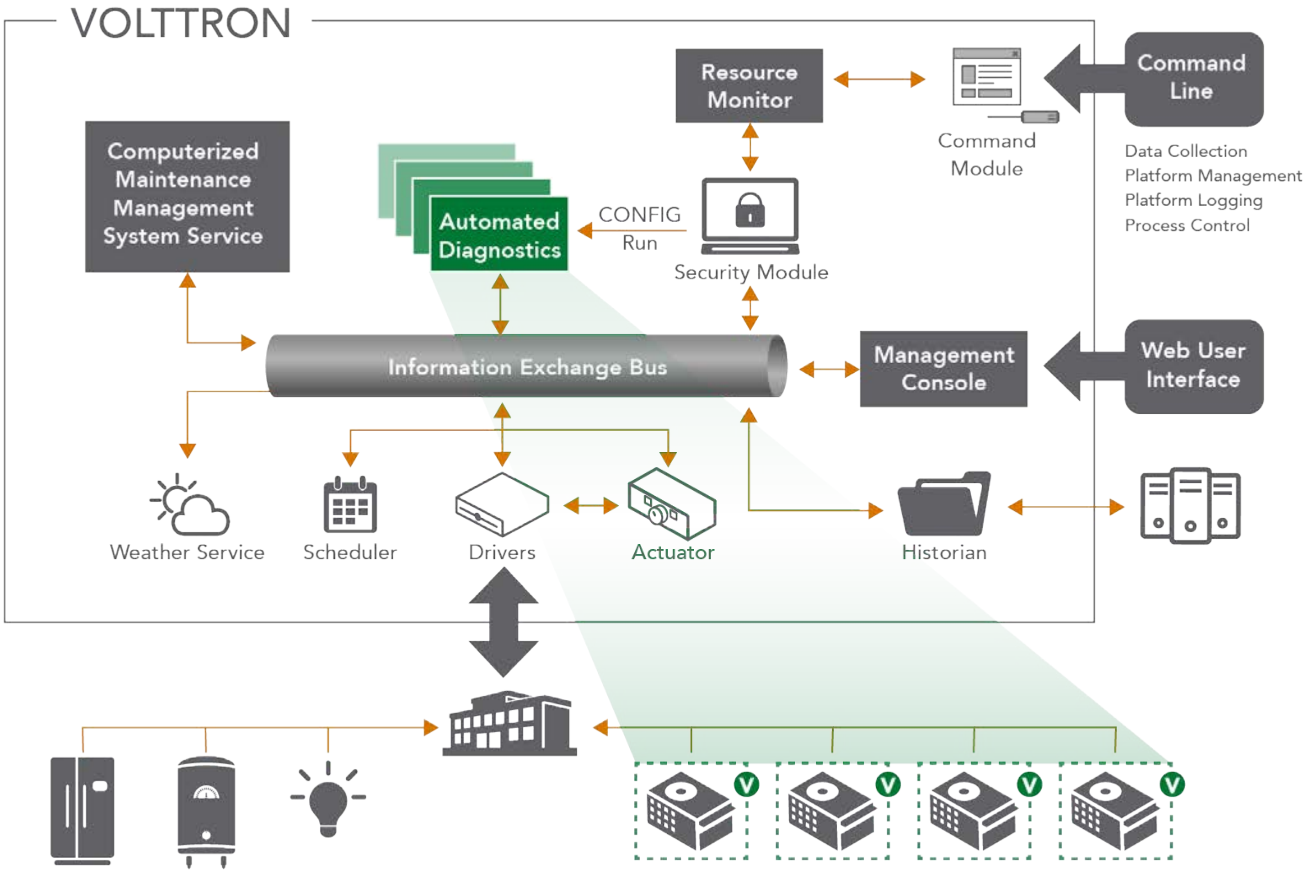
PNNL's VOLTTRON™ platform enables deployment of automated diagnostics and self-correcting controls in building devices



Energy Efficiency Services for Large Commercial Buildings: Result

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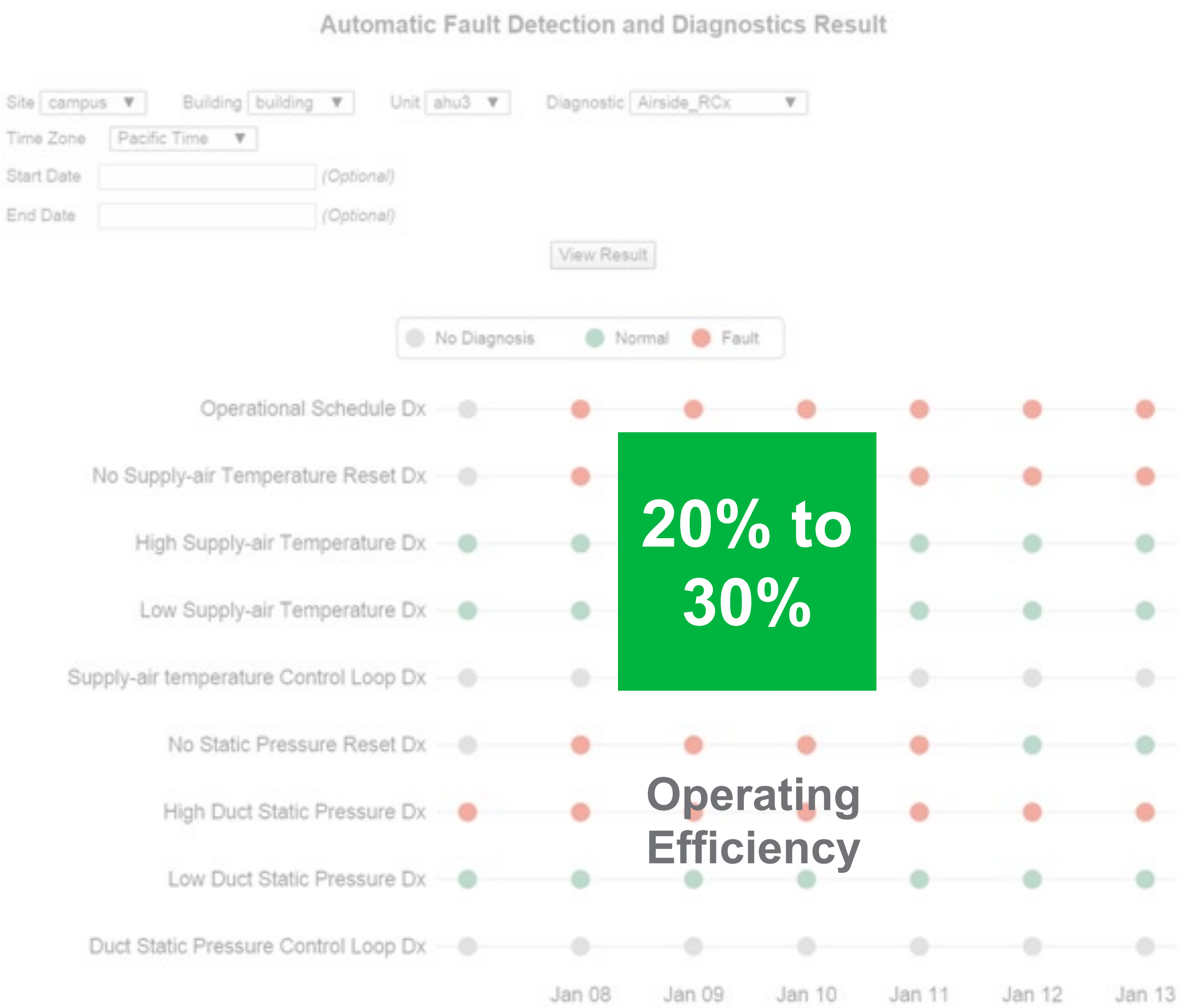

20% to 30%

Operating Efficiency

Katipamula S, RG Lutes, G Hernandez, JN Haack, and BA Akyol. 2016. "**Transactional Network: Improving Efficiency and Enabling Grid Services for Building**." Science and Technology for the Built Environment, 1-12 doi: 10.1080/23744731.2016.1171628

Katipamula S, K Gowri, and G Hernandez. 2016. "**An Open-source automated continuous condition-based maintenance platform for commercial buildings**. Science and Technology for the Built Environment (2016) 00, 1–10 doi: 10.1080/23744731.2016.1218236

VOLTTRON VISION

A open-source platform for future of energy

Energy Related Services (DOE’s main use cases)
Consumer Services (Building related services, such as equipment upgrades, repairs and maintenance; household product supplies and replacements, and social interactions).

The common storage and collection of building related information on a centralized platform allows for analysis, targeted data, advertisements, and opportunity/action.

Backup

Supporting “Re-tuning” Mandates

- Support Mandates/ Executive Order to periodically retro-commission building systems
- Support various city mandates to periodically retro-commission buildings
- More cost effective, systematic and also ensures persistence of energy savings on a continuous basis

Katipamula S, K Gowri, and G Hernandez. 2015. "**Automated Continuous Conditioned-Based Maintenance for Commercial Buildings**.” Accepted for publication in Science and Technology for the Built Environment

Focus: Grid Services
Transactive Coordination & Control

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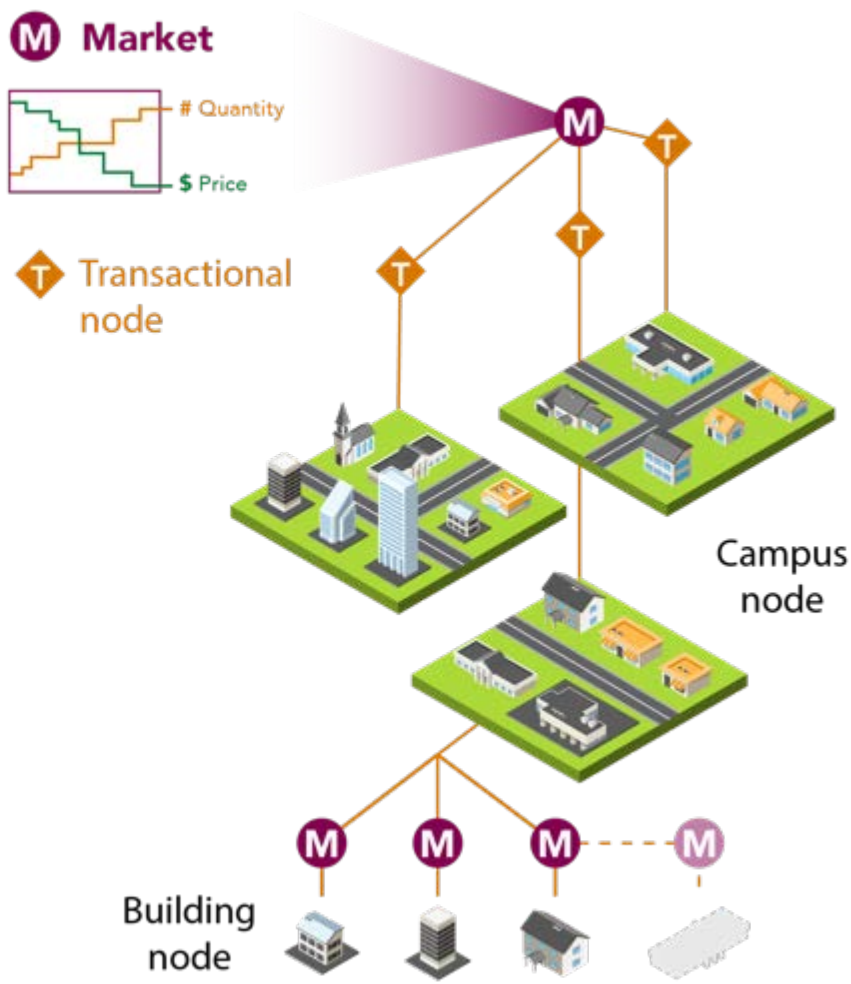

Use of signals from external markets to create markets at campus and individual building levels, resulting in better management of energy consumption.

Focus: Grid Services
Transactive Coordination & Control

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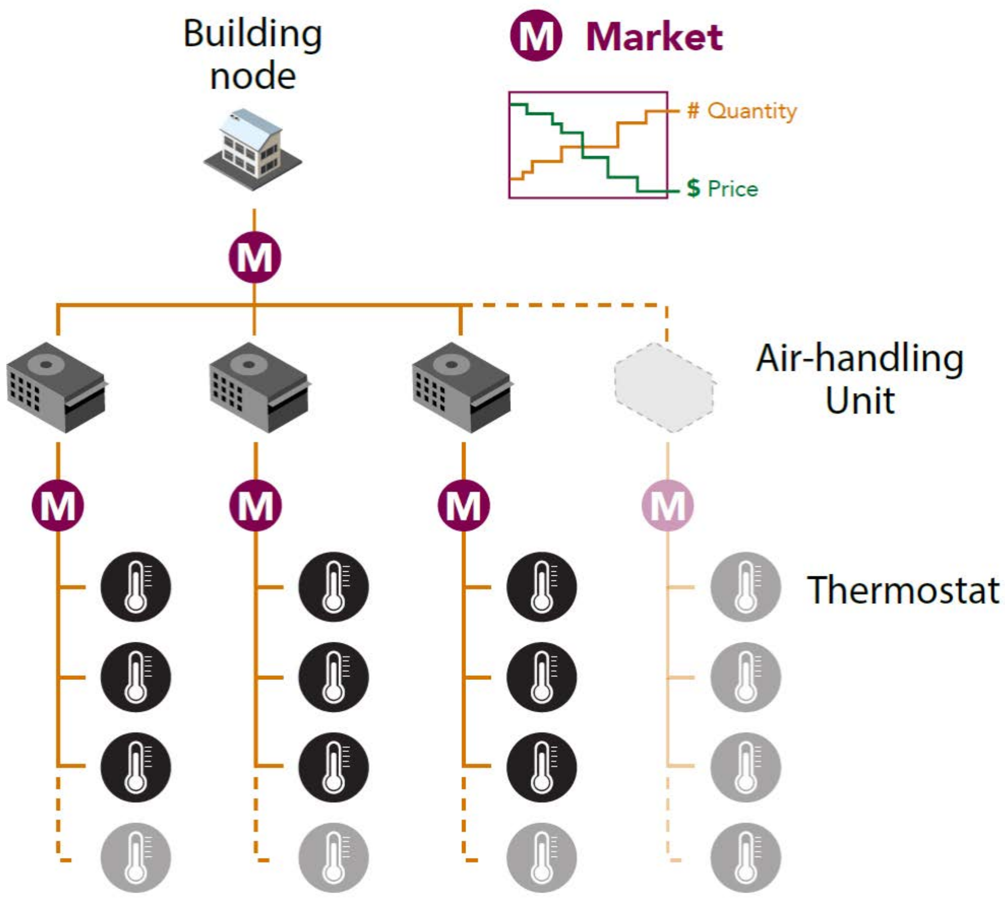

Building zones and devices become markets that "negotiate" prices and service levels

Transactive Coordination and Control: Deployment

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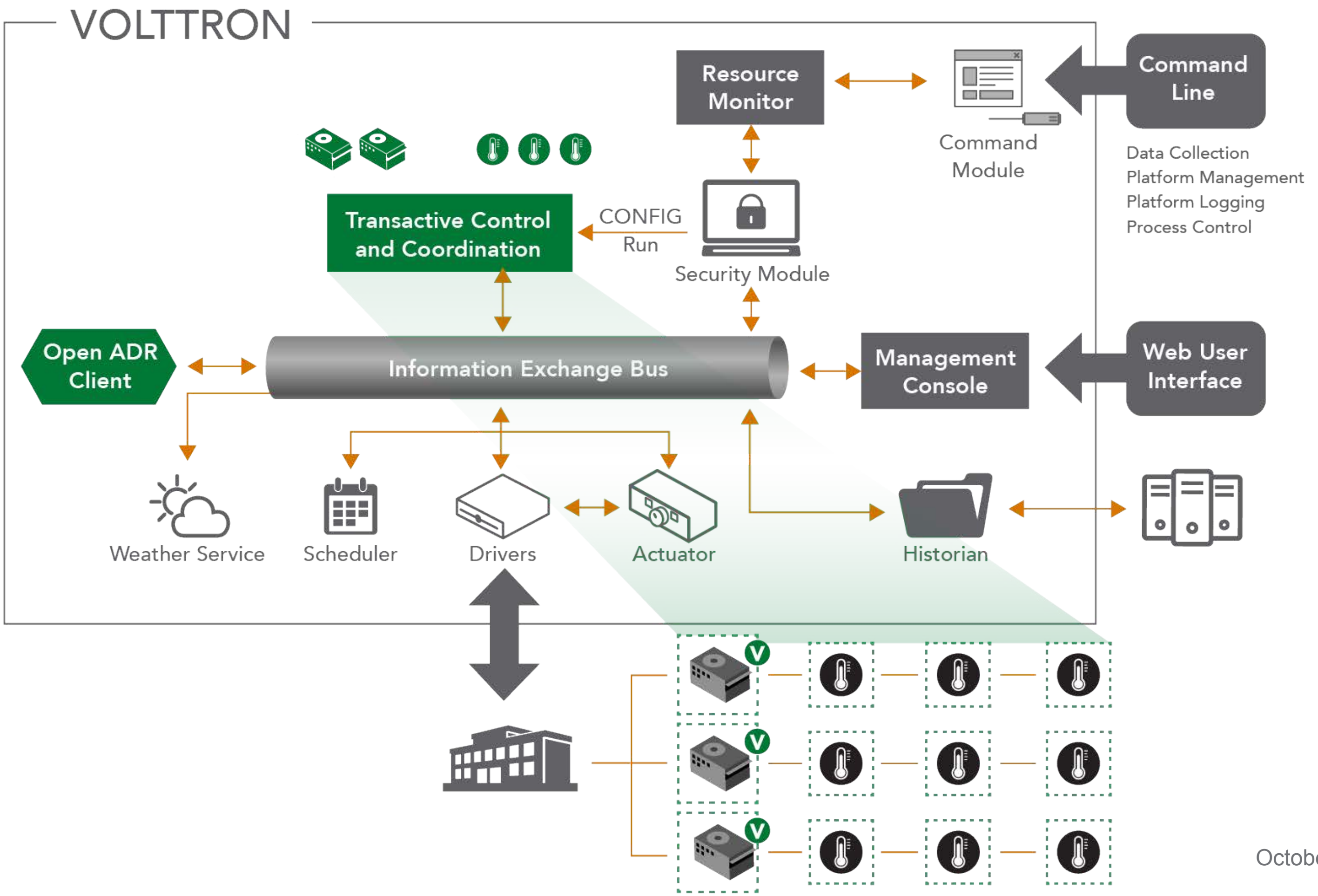
PNNL's VOLTTRON platform enables deployment of Transactive Coordination and Control in building devices

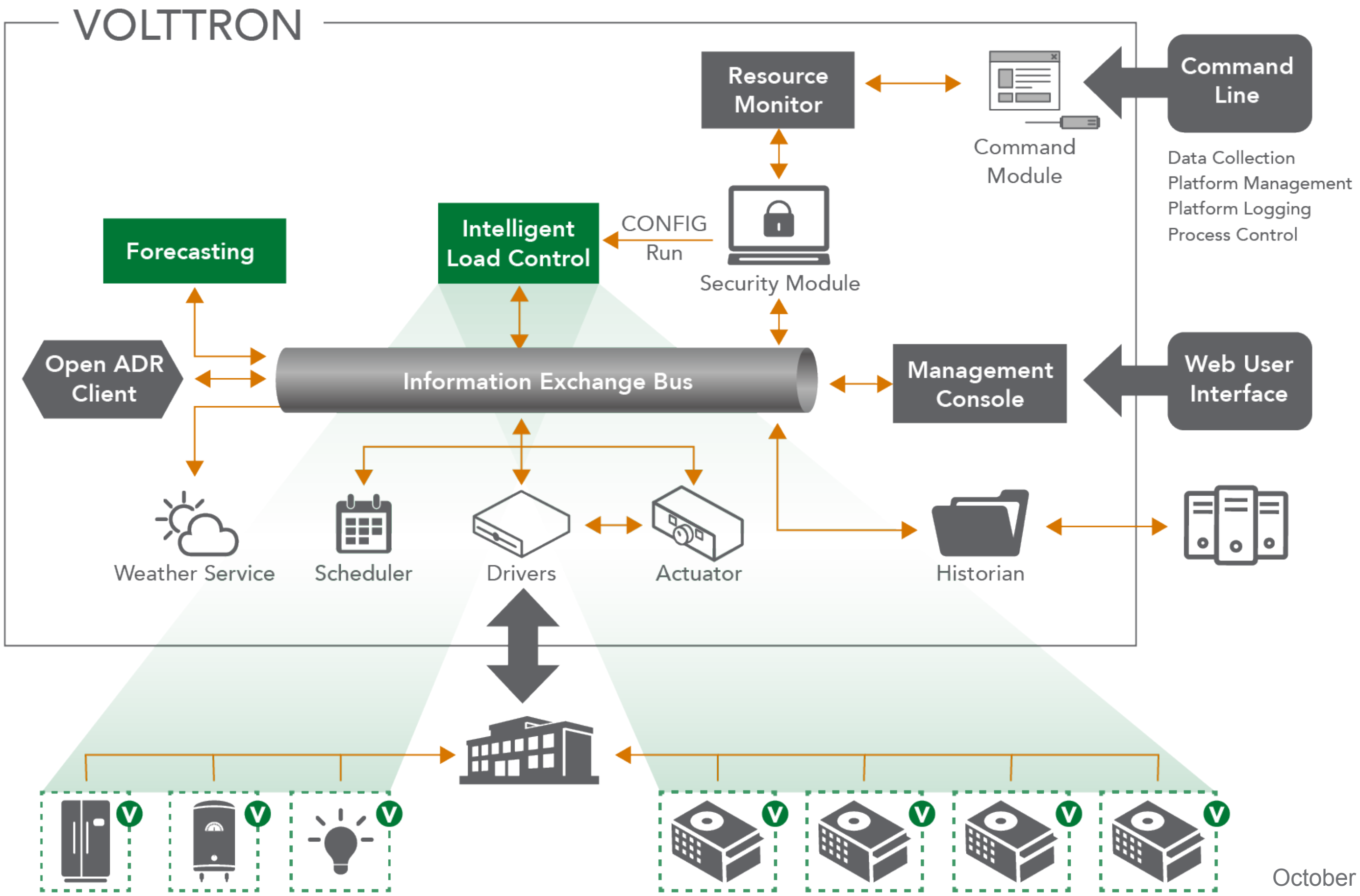


Grid Service: Intelligent Load Control

- Traditional Utility Rate Structure
  - Demand charge (15 min or 30 min average or rolling-average)
  - Typically based on a 30-day billing cycle
  - Traditional demand response programs
  - Time-of-use and critical peak pricing
- Transactive Energy
  - Dynamic rates (15 min or 60 min), real-time pricing as well as day ahead
- Either Case
  - Intelligent Load Control (ILC) can help manage peak or energy consumption target

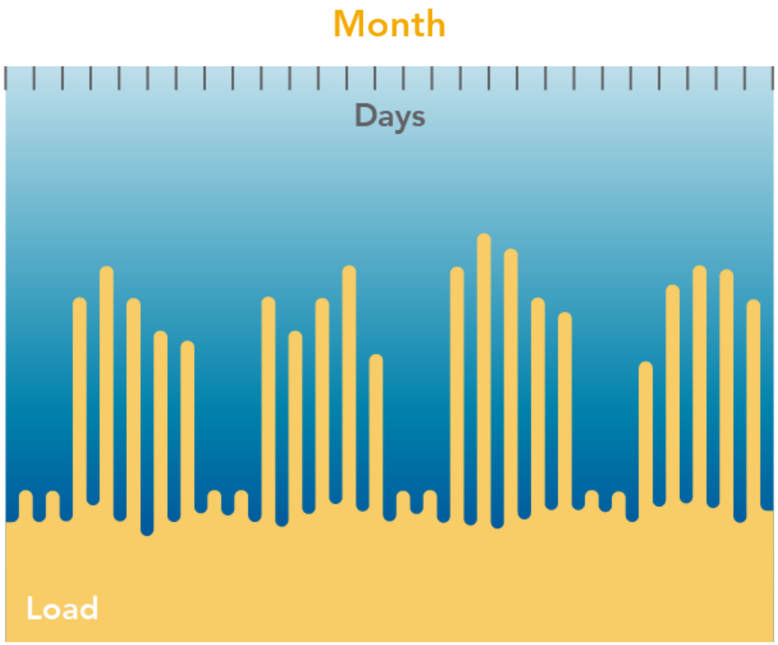
ILC: Deployment

PNNL's VOLTTRON platform enables deployment of Intelligent Load Control in building devices

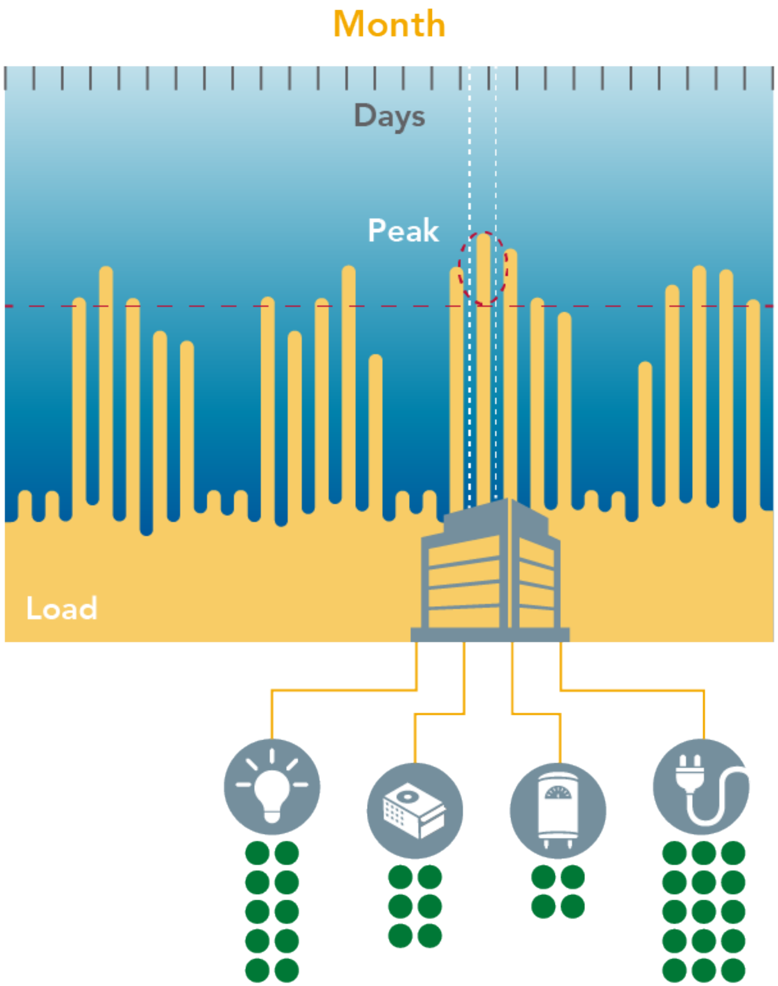


ILC: Traditional Utility Rate Structure

Forecast the Load for the Next Billing Cycle



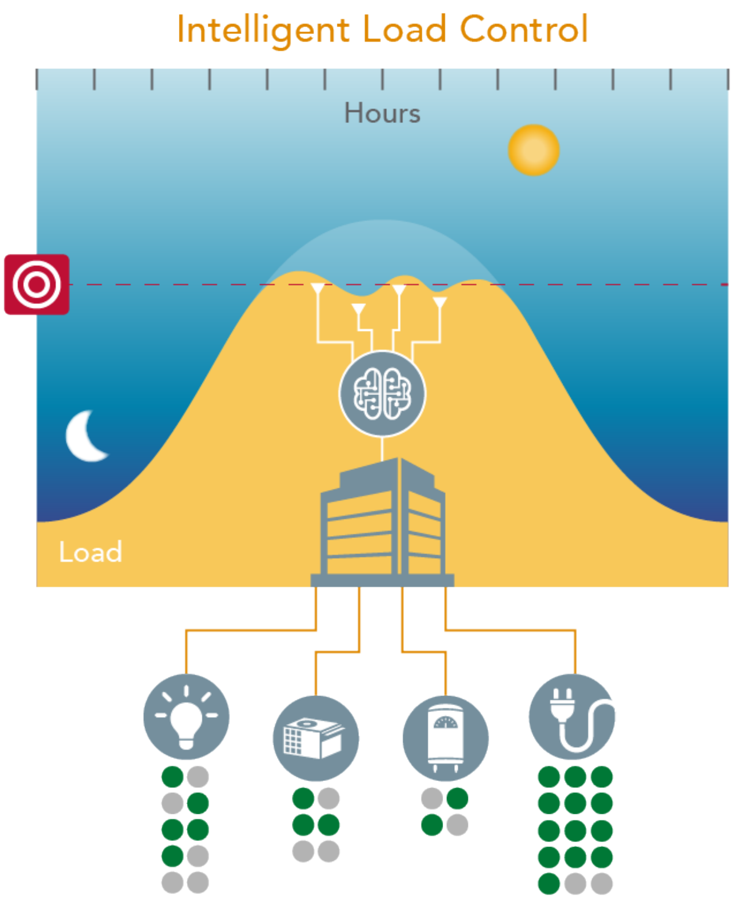
Establish the Target Peak



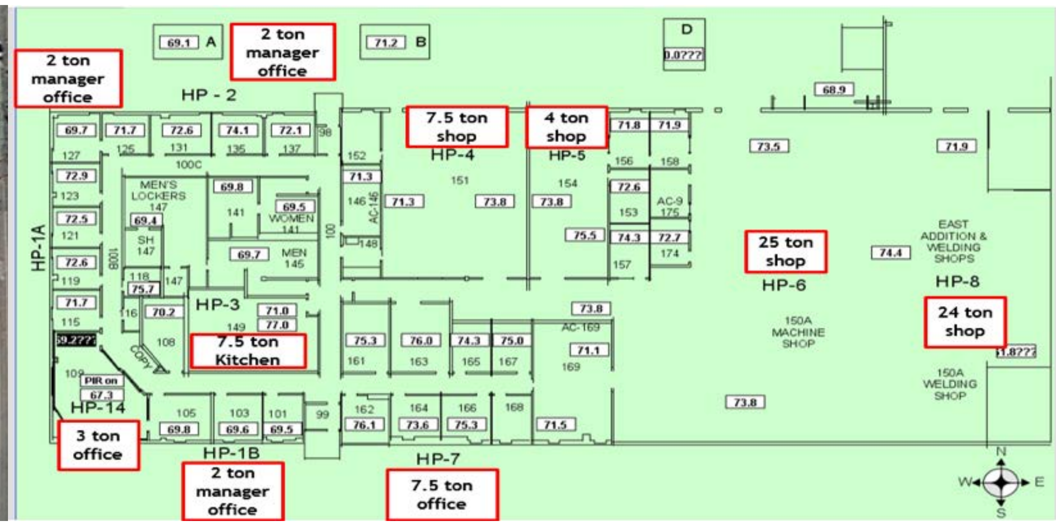
ILC: Manage Power use to a Target

- Deployment on PNNL campus building shows ILC can manage or reduce peak electricity demand by controlling heat pumps
- Without impacting occupant comfort

Kim W, and S Katipamula. 2016. "**Development and Validation of an Intelligent Load Control Algorithm**." Submitted for consideration for Energy and Buildings.

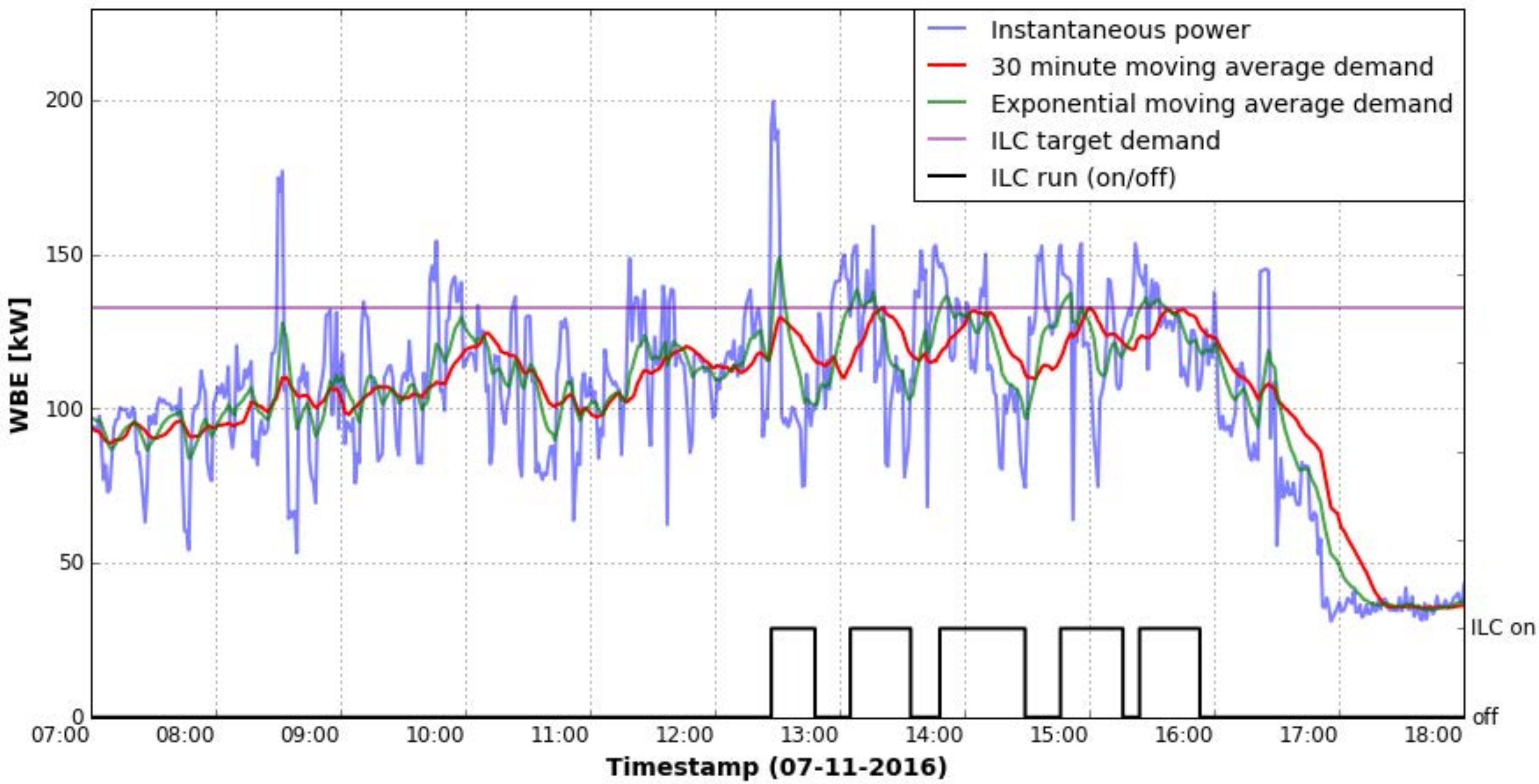


ILC Deployment in a Building



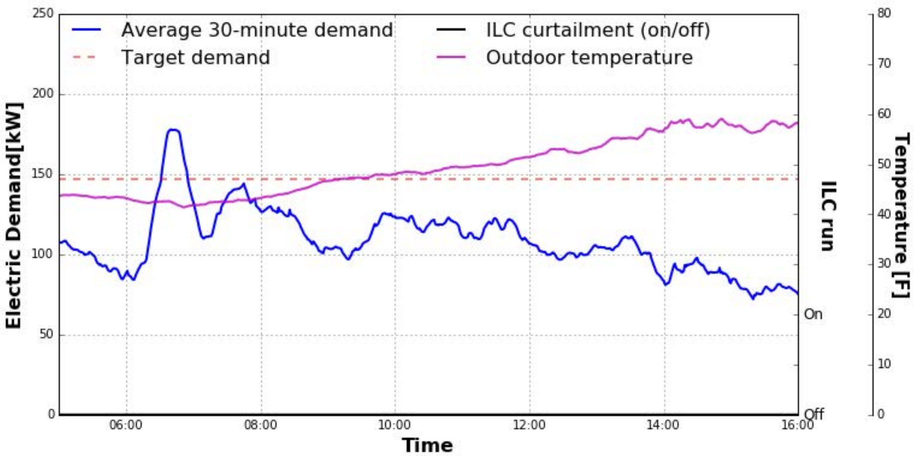
External view for the building on PNNL campus	Location of heat pumps in the building

ILC Implementation Details

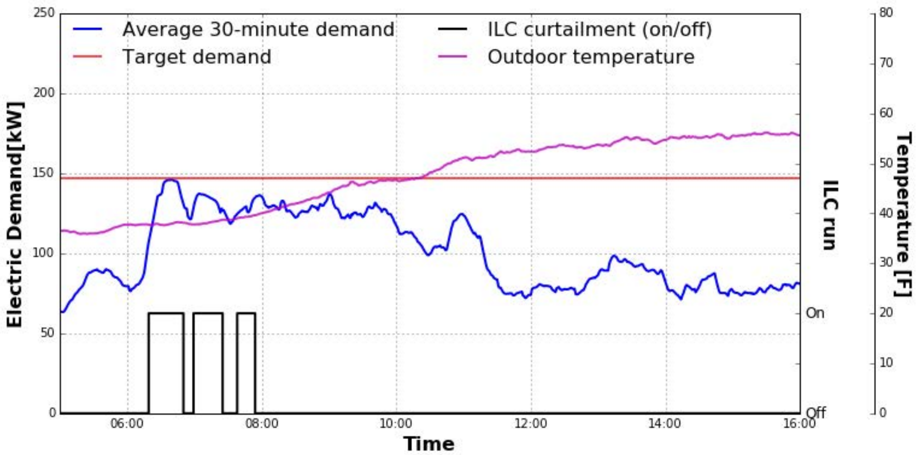


ILC Test During Heating Season

Example No ILC: March 14



Example with ILC: March 15



Temperature Profile and Heat Pump Status: Heating Season

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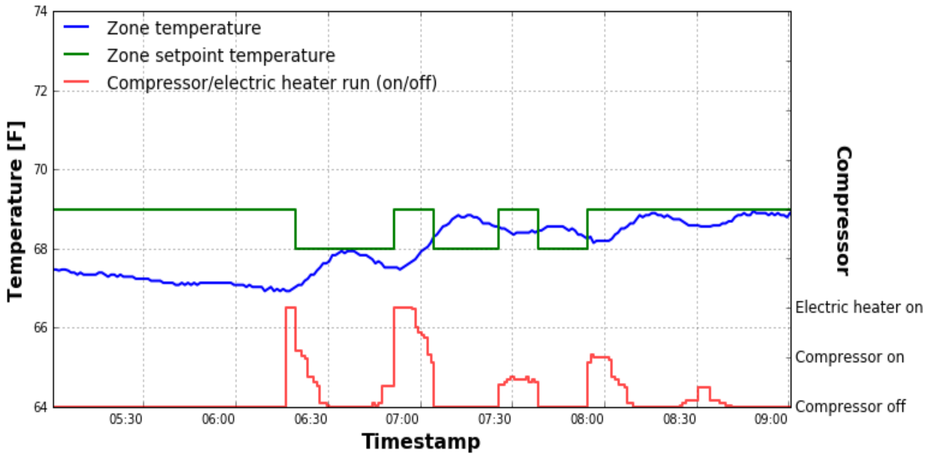
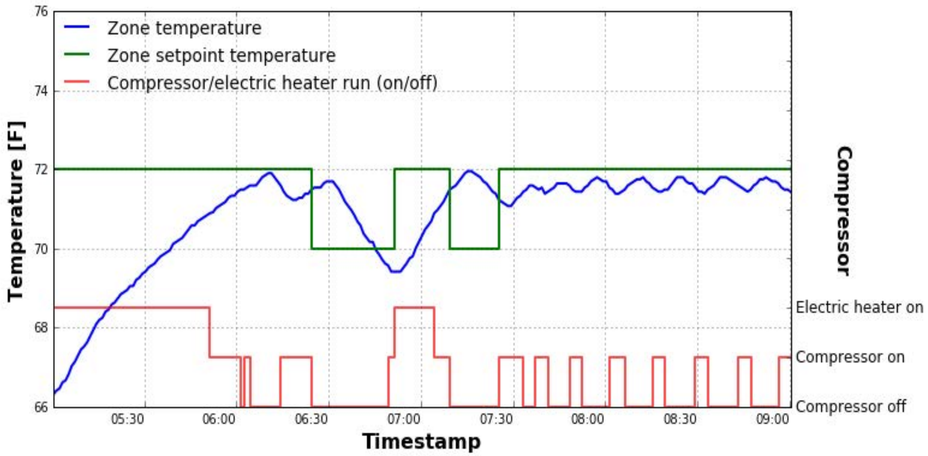
Heat Pump 4



Heat Pump 8

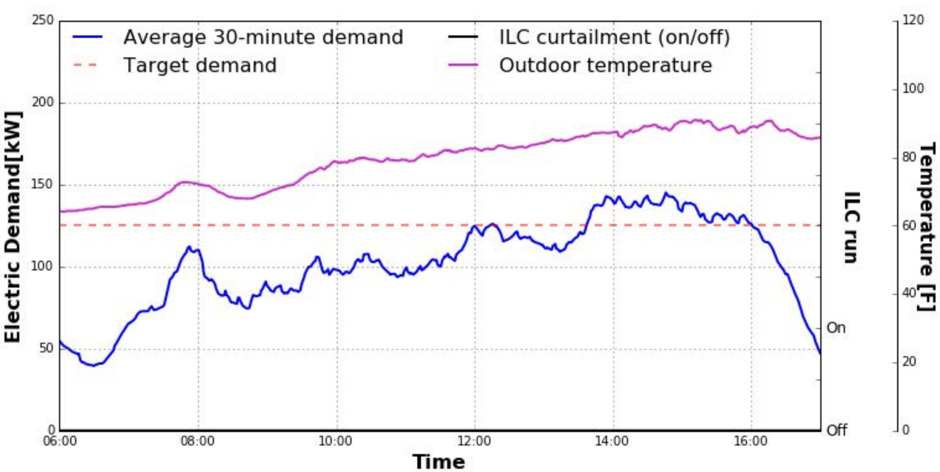


ILC Summary of Curtailment of a Single Test During Heating Season

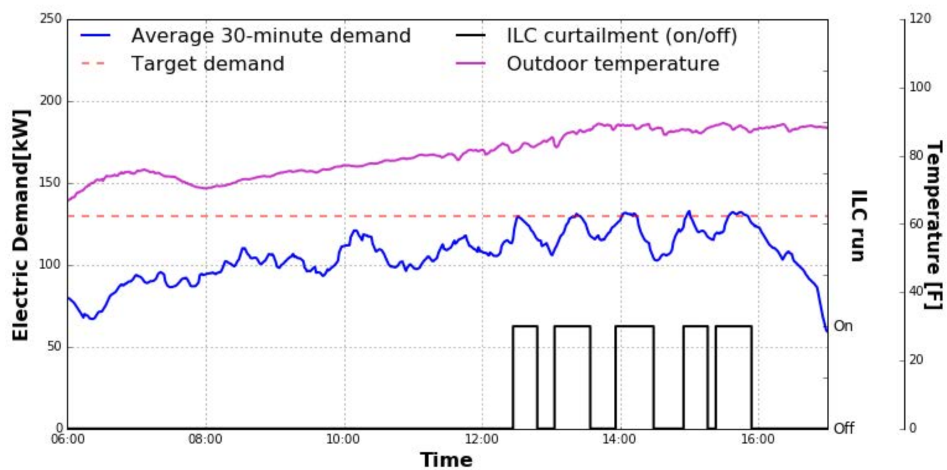
System model	Room type	Capacity [tons]	Electric Heater kW	1ST ILC	2nd ILC	3rd ILC	The number of Curtailment
HP1A	Manager office	2	7.5		X		1
HP1B	Office	2	7.5	X			1
HP2	Manager office	2	7.5				0
HP3	Kitchen	7.5	14				0
HP4	Shop	7.5	14	X	X		2
HP5	Shop	4	13	X			1
HP6	Shop	25	72				0
HP7	Office	7.5	14	X			1
HP8	Shop	20	54	X	X	X	3
HP350	Office	3	7.5				0
Sum				5	3	1	9

ILC Test During Cooling Season

Example No ILC: July 12



Example with ILC: July 11



Temperature Profile and Heat Pump Status: Cooling Season

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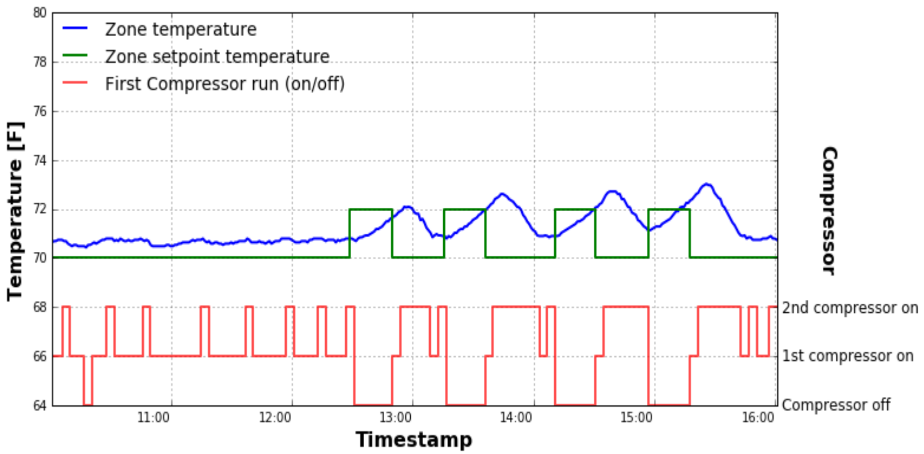
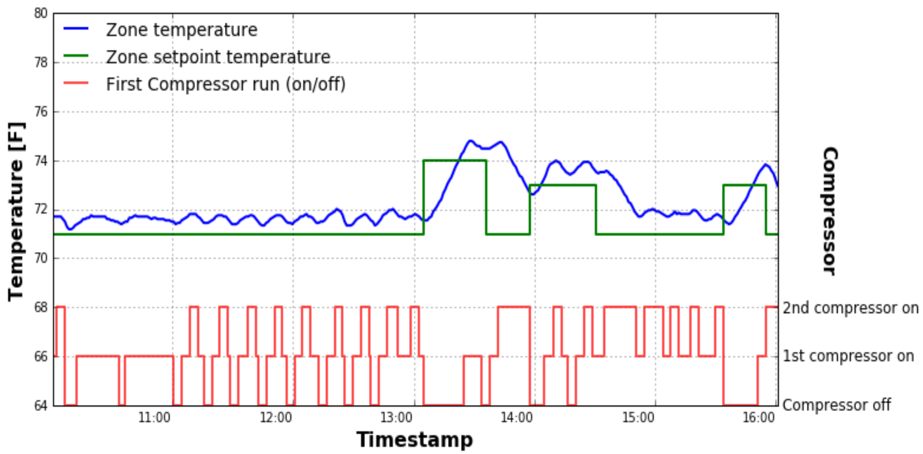
Heat Pump 4



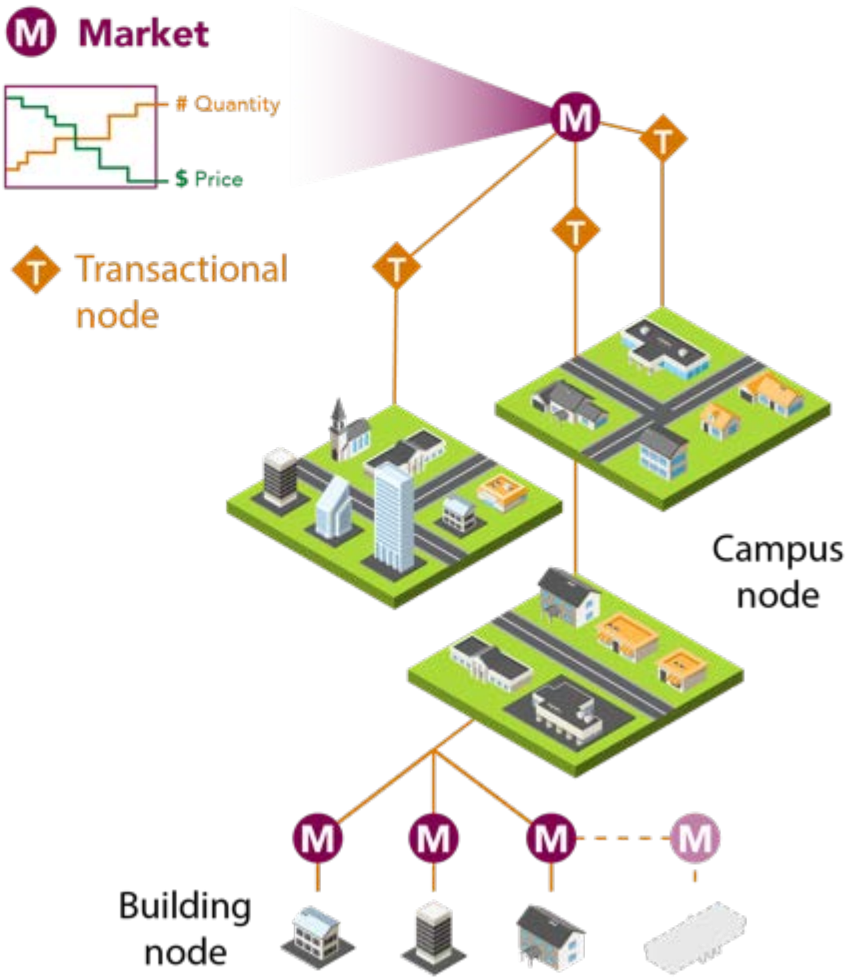
Heat Pump 8



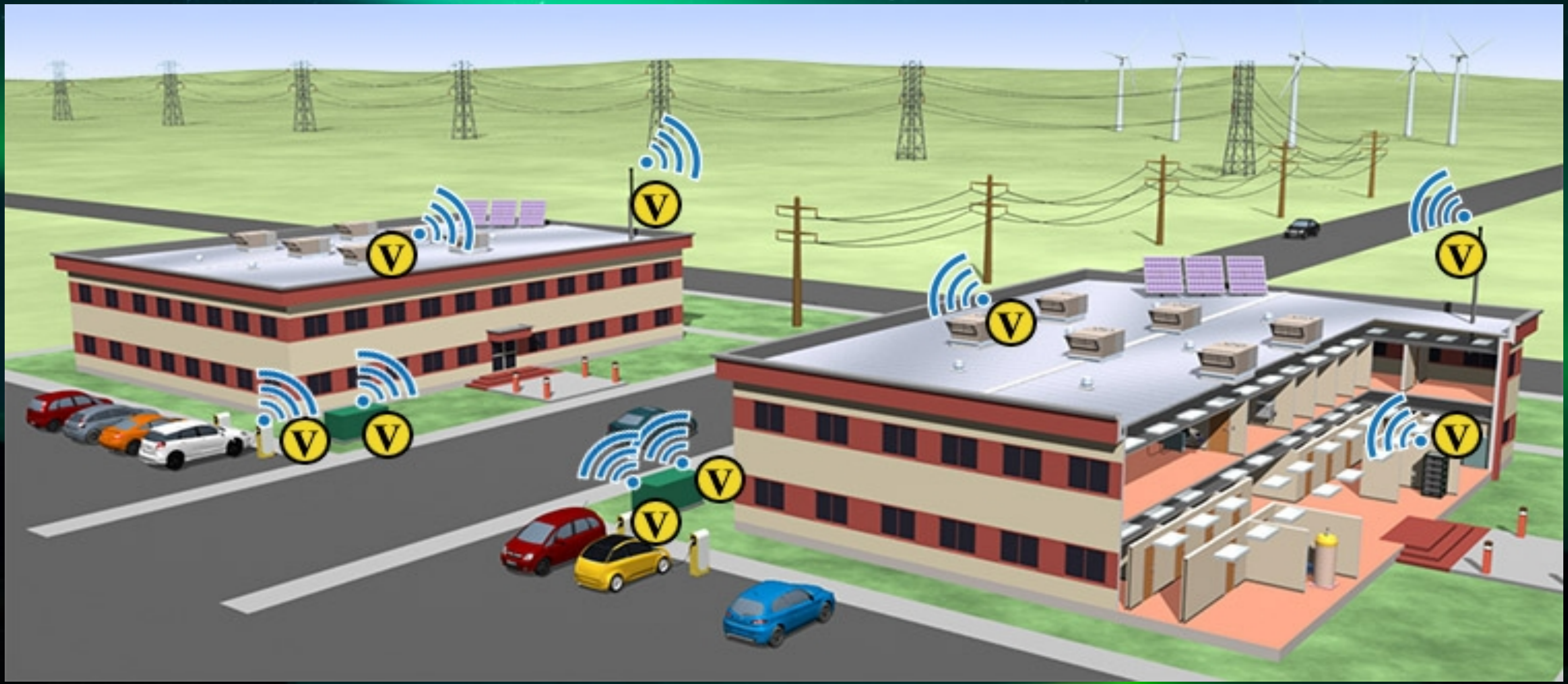
ILC Summary of Curtailment of a Single Test During Cooling Season

System Model	Room Type	Capacity [tons]	1st ILC	2nd ILC	3rd ILC	4th ILC	5th ILC	The number of Curtailment
HP1A	Manager office	2						0
HP1B	Office	2						0
HP2	Manager office	2						0
HP3	Kitchen	7.5	X				X	2
HP4	Shop	7.5		X	X		X	3
HP5	Shop	4						0
HP6	Shop	25	X	X	X	X		4
HP7	Office	7.5			X	X	X	3
HP8	Shop	20						0
HP350	Office	3						
Sum			2	2	3	2	3	12

Multiple Building ILC



Create a market at the campus level and use that to coordinate and manage peak across multiple buildings.



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