U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

EERE & Buildings to Grid Integration

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DOE Building Technologies Office

July 22, 2015

EERE: Office of Energy Efficiency and Renewable Energy

BTO: Building Technologies Office (Portfolio – RD&D, Deployment, Regulatory)

Opportunity to Control Building Loads is Key to Integrating EE & RE effectively with the GRID!

Buildings consume 74% electricity produced in the US (CBECS 2009)

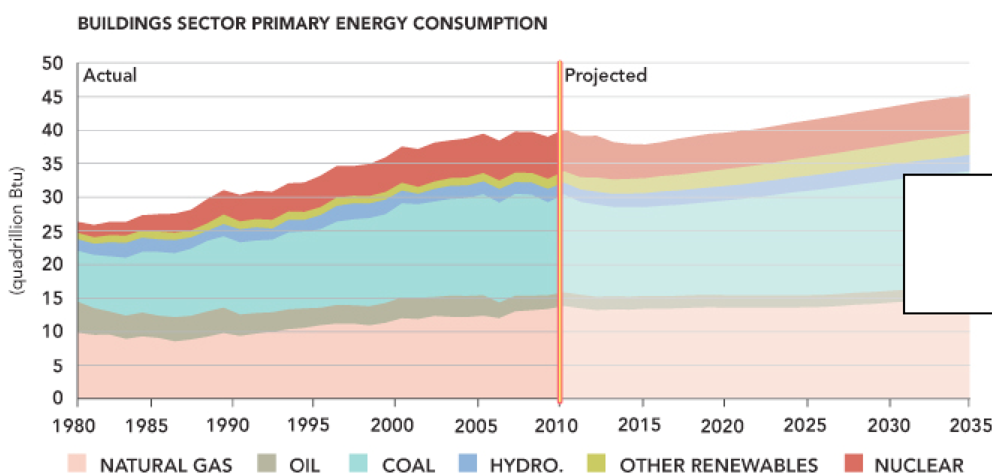
Buildings have the potential to reduce their consumption by 20%-30% (18 quads or 2,500 million tons of oil) through advanced sensors and controls

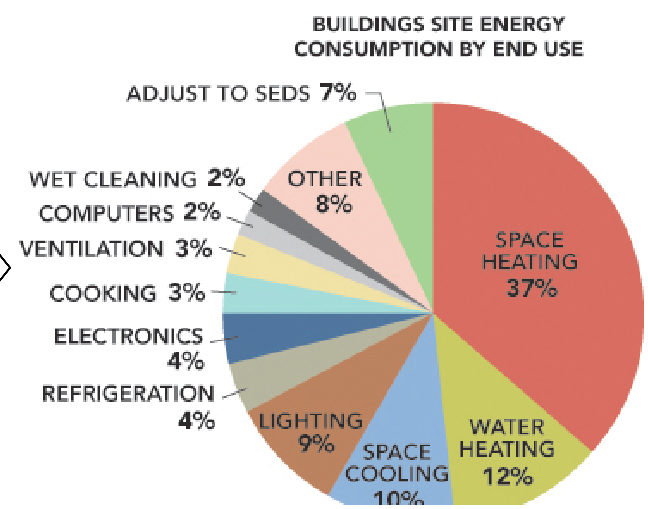
Potential nationwide value of demand dispatch could be several billion dollars **yearly** in reduced energy costs with 10% participation

(NETL, Demand Dispatch – Intelligent Demand for a More Efficient Grid, August 2011)

90% of the commercial buildings are < 50,000 ft^2 and need aggregation

Commercial buildings are an integral part to EE, RE, and Grid Integration at SCALE!!!





5.5 million commercial, 117 million residential,

projected to be 80% of load growth through 2040

Scaling Transaction Based Controls

Vision

- Buildings operating at optimum energy efficiency over their lifetimes, interoperating effectively with the electric power grid.
- Buildings that are self-configuring, self-commissioning, self-learning, self-diagnosing, self-healing, and self-transacting to enable continuous optimal performance.
- Lower overall building operating costs and higher asset valuation.

http://energy.gov/eere/buildings/downloads/buildings-grid-technical-opportunities-introduction-and-vision

Mission

- - Work with the market to develop and deploy cost effective solutions to building owners/operators, service providers, and manufacturers to manage energy consuming assets more easily and efficiently (38 quads of primary energy).
- - Utilizing these solutions, enable optimum building energy efficiency and performance, renewable generation with reduced utility investments, and standardized financial transactions for across the meter opportunities

Research, Development and Deployment

Develop and commercialize advanced diagnostics and controls to create self-aware buildings that optimize performance.	**Define, test, quantify and validate the value proposition, response and related services provided by Building Technologies**	**Enable buildings to interact (e.g. with the grid) to support transactive energy opportunities and deliver the value proposition**

Scaling Transaction Based Controls

Research, Development and Deployment

Data and Information –consistent and comparable data on equipment capabilities and performance requires a common test procedure, and easily accessible data based *upon characterizing ("testing") the equipment.* Our initial work on the framework is done and we have received comments from GWAC members!

Interoperability – along with a common data taxonomy we need common communications protocols, or at least a bridge between different protocols – otherwise every interconnection requires a patchwork of different systems.

DOE is supporting open communication protocols that can transact with both proprietary and non proprietary systems to increase overall applicability and reduce costs.

Cost – because each piece of equipment needs additional work to interoperate, there is added cost to the end user, manufacturers and utilities. *We provide our solutions (transaction platform, initial apps, data) to the market for free, the market actors have an initial platform at no cost, and can then create new value streams for added success.*

How do we enable Transaction Based Energy[1] Ecosystem?

USG should focus on Core, Foundational Areas of connected devices and buildings…

1. Reference Guide For a Transaction Based Building Controls Framework

Core Sensors, Controls Program, & B2G RD Program
(VOLTTRON & Applications)

- VOLTTRON v1.0 to v3.0
- Emerson Refrigerated Cases – Demand Defrost & Networked Control
- Emerson Small Footprint Supermarkets Control
- PV-Buildings Responsive Loads
- PV-Buildings Load Flexibility

Interoperability

Interoperability is defined in BTO's QER document, "The National Opportunity for Interoperability and Its Benefits for a Reliable, Robust, and Future Grid Realized Through Buildings."

Cyber-Security

BTO-FEMP working to define and convene what this means to buildings.

Characterization

The measurement and evaluation of physical or informational responses that are possible for connected equipment.

*These core, foundational areas allow for scalable, market based solutions to develop in the form of **applications** – reducing the time, burden and cost for the public.*

Feature Article

Want to get started on transactive energy and nanogrids? Steal this government software

Jul 30, 2014 Talk Back Free Alerts More On This Topic SHARE

Quick Take: *We've been talking for years about the need to move sensing, intelligence and control to the edges of the grid. A centralized approach simply can't achieve the visibility and response time needed in a world where everything is connected.*

More recently, we've been talking about ***transactive energy as a solution****. Essentially, transactive energy lets devices publish their power needs and prioritization. Fine in theory, but how do you put that into practice?*

LATEST STORIES

Want to get started on transactive energy and nanogrids? Steal this government software
A grid management solution for today's grid >>

How to keep your smart meters safe from attack (and not just cyber-attacks)
Thwarting the dangers >>

Smart grid technology roundup: What's new in metering, analytics and more
New developments in smart grid tech >>

HOT TOPICS

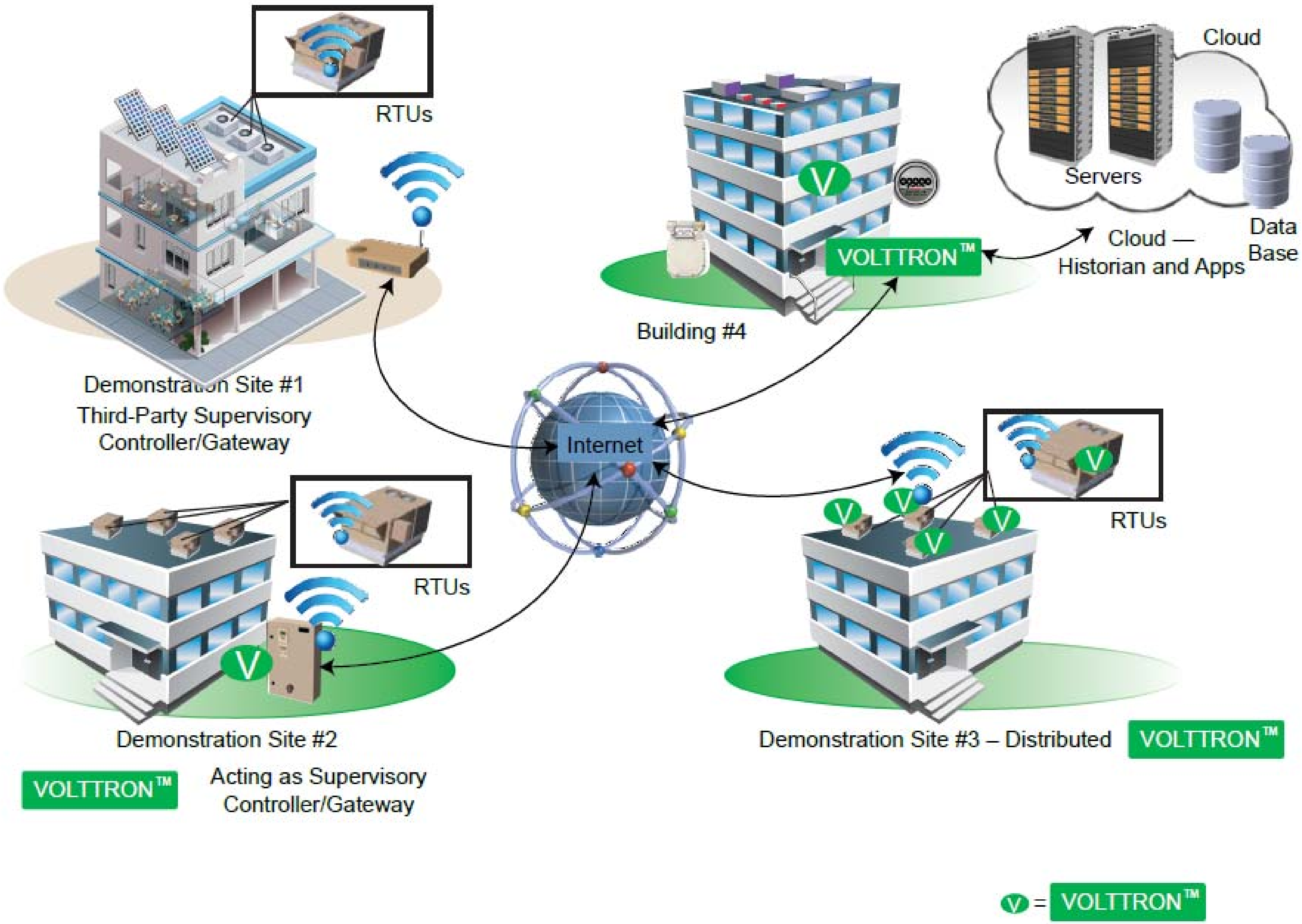
Now utilities can tell customers how much energy each appliance uses (just from the smart meter data)
The next step for smart meters? >>

Utilities: If you think solar rooftops are a pain, wait until solar streets get here
Now in second prototype stage >>

What the race to control the home means

http://www.smartgridnews.com/artman/publish/Delivery_Grid_Optimization/Want-to-get-started-on-transactive-energy-and-nanogrids-Steal-this-government-software-6665.html#.U9lgCGRdXRc

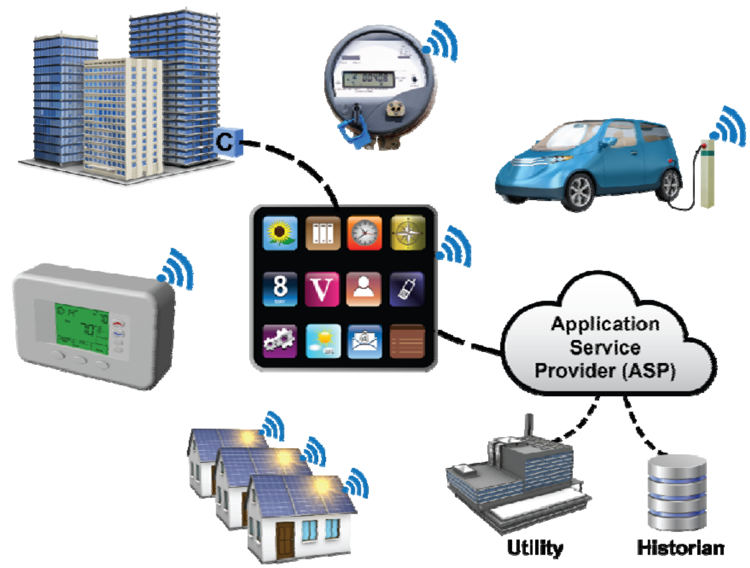
Transactional Platform - VOLTTRON



From VOLTTRON 1.0 to 3.0

USG should focus on Core, Foundational Areas of connected devices and buildings…allowing for scalable, market based solutions to develop in the form of applications – reducing the time, burden and cost for the public.

- FY14 - PAST
  - v1.0 **Focused on building up the controls platform/framework**
    - Agent execution environment
    - Basic platform services
    - Modbus driver
  - v1.2 **Expanded capabilities of platform**
    - BACnet support
    - Multi-node communication
- FY15 - PRESENT
  - v2.0 **Incorporated PNNL IP from the original research**
    - Agent signing and verification
    - Resource monitoring
    - Agent mobility
- FY16 - FUTURE
  - v3.0 **Hardening Security/Manageability**
    - Focus on improving security, manageability and resilience – preparing for large scale deployment and commercialization
    - Beta release planned for end of July and full release in September
    - Initiate scalability testing



<u>Existing Features in VOLTTRON:</u>

Platform Services
- Historian of choice (sMAP, Postgres, SQLite, MySQL, etc.)
- Weather, logging, OpenADR, etc.
- Modbus, BACnet – DNP3 to come

Energy Efficiency Agents
- Automated fault detection and diagnostics for a number of building systems
- Automated measurement and verification

Grid Service Agents
- Intelligent load controls – prioritizing loads to control
- Demand response (real-time pricing, critical peak pricing, etc.)
- Mitigating short-term variation of renewable generation

VOLTTRON Transitioning to Market

- LABs working with Transformative Wave Technologies (TWT) to deploy a commercially viable VOLTTRON-based RTU solution
  - Small- and medium-sized commercial buildings
  - Energy efficiency and grid services
- LABs working with Emerson Climate Technologies to develop a VOLTTRON-based solution for convenience stores and supermarkets

VOLTTRON Transition to Community

- 1st VOLTTRON technical meeting hosted by Case Western Reserve University last July
  - Over 50 people attended in person and 50 more participated via webinar – diverse group, university, industry, national laboratory
- 2nd technical meeting is July 23-24 hosted by Virginia Tech in Arlington, VA
  - Expecting 60 people to attend and a number of others will join online
    - University, industry, utilities, national laboratory

VOLTTRON Gaining Research Acceptance & Increasing Commercial Interest

A National User Community

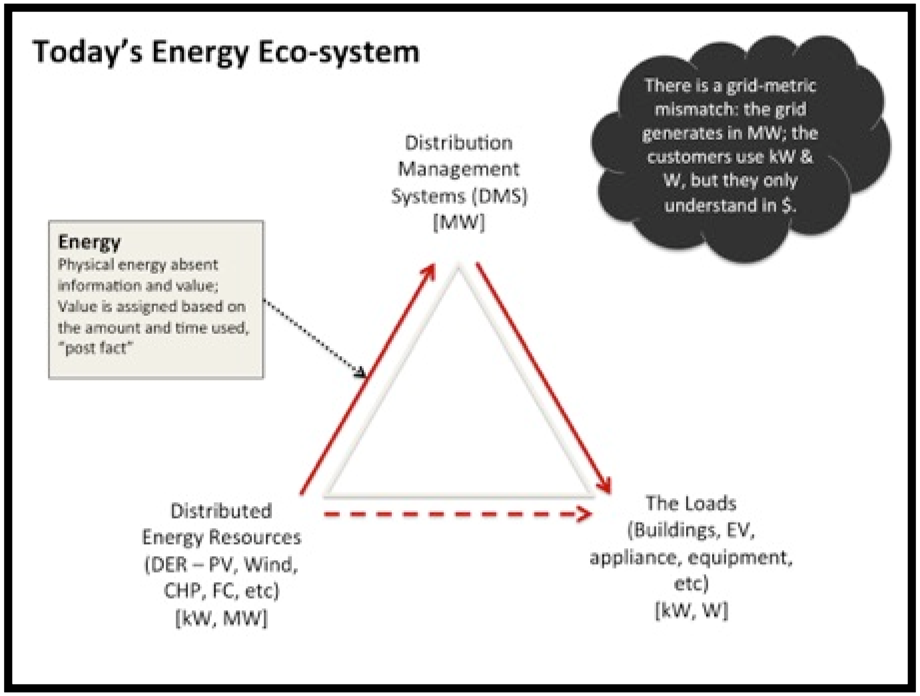
- Oak Ridge National Laboratory
- NREL
- Berkeley Lab
- Virginia Tech
- Drexel University
- Case Western Reserve University
- UTSA University of Texas at San Antonio
- Montana State
- Fresno State
- University of Victoria
- State University of New York at Binghamton

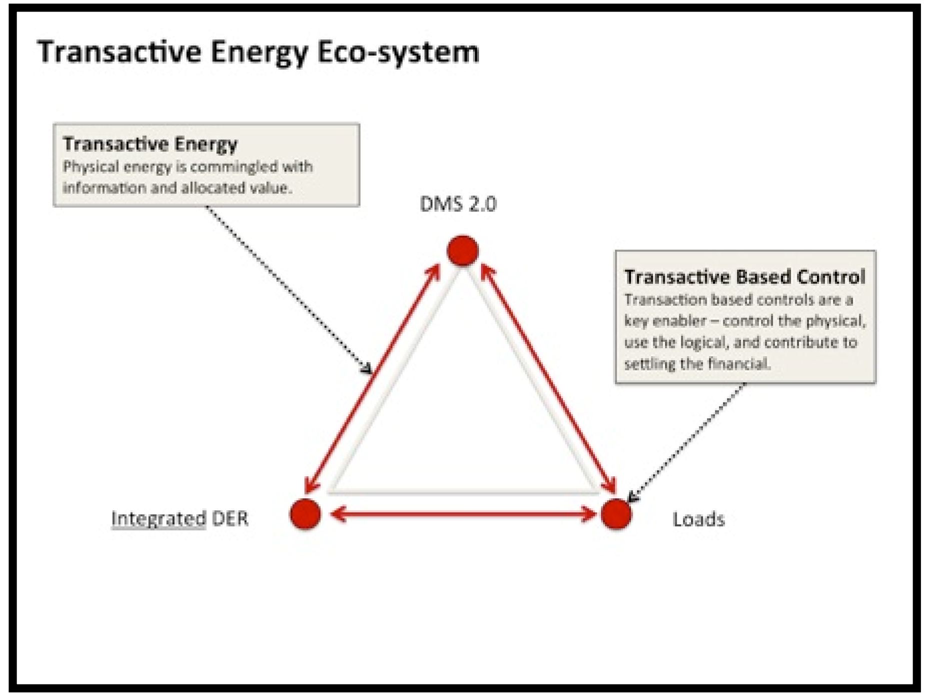
Commercial Users

- transformativewave
- Siemens
- Energy Analytics
- Emerson Climate Technologies
- Johnson Controls
- MelRok
- Bosch

What is the future? A Transaction Based Energy Eco-system*

*** There are many forms of "transaction based energy systems" that go by other names: Transactive Energy, Prosumers, etc. Transactive Energy was chosen for the FY15 budget because it is a proven open source solution, originally funded by DOE (OE), and already in use by the utilities.**





- Transactive Energy = Physical energy is commingled with information and assigned value.
  - That "value" is allocated and can be based on a non-energy criteria expressed as price (i.e. "green-ness" of the power, asset valuation, comfort, etc).
  - Transactive Energy is inherently..
    - Physical (Transactive Energy is Energy + Information)
    - Logical (Transactive Controls are control systems that act on information)
    - Financial (Transactive Settlements use price to determine value to users)

Scalable Transaction Based Controls – Market Uptake

Research, Development and Deployment

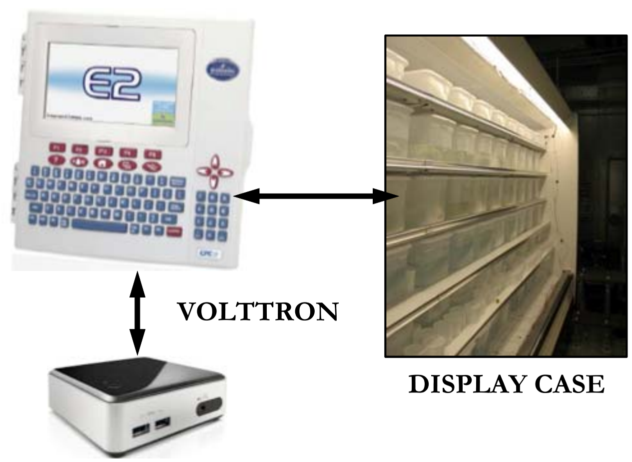
- **Apps, apps, and more apps!!!**
  - Applications using the VOLTTRON platform help both large and small companies to develop new solutions, or improve existing ones, and drive them into the market.
    - We need clear value proposition for consumers, manufacturers, utilities and service providers.
  - Current applications include…
    - ✓ Buildings as "virtual batteries" - balance 50kW PV with building loads (FY14-15)
    - ✓ M&V apps for utility programs also provides M&O support to building owners (FY14, FY15)
    - ✓ Electric Vehicle application to stage charging, deliver grid services, and push non-energy services to consumers (FY15)
  - We supportive of VOLTTRON application for home appliances (FY15-16)

On-demand Defrost Application (FY14)

EMERSON
Climate Technologies

- Problem:
  - Frost formation on the evaporator coils decreases system operational efficiency
  - Typically **defrost cycles are timed** and based on 75°F dry bulb temperature and 55% relative humidity.
  - Low temp cases: **~720kWh/month/case defrost energy**

- Solution:
  - Utilize existing temperature measurements (discharge air temp) and develop algorithms to perform defrost on-demand.
  - **Retrofit VOLTTRON platform and control app to Emerson E2 controller to perform on-demand defrosting**



- Results
  - Testing data collected at ORNL demonstrated savings potential
  - Application developed and field testing at Emerson Labs, Sydney, OH – **testing data showed up to 75% reduction in defrost energy (39,650 – 57,900 kWh/store/year)**
  - Emerson interested in applying nationwide

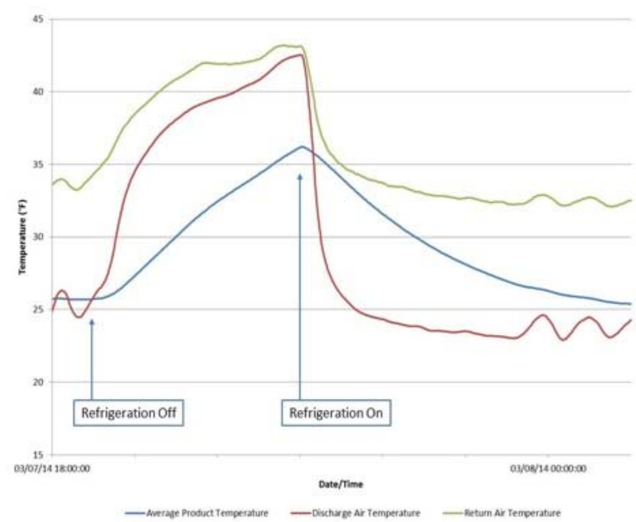
Unified Control - Small Footprint Supermarkets (FY15)

EMERSON
Climate Technologies

- Retrofit system for coordinating HVAC and refrigeration systems in small footprint supermarkets for
  - **reducing peak demand**
  - **reducing energy consumption, and**
  - **enabling transactive energy services**

ecoSYS Site Supervisor

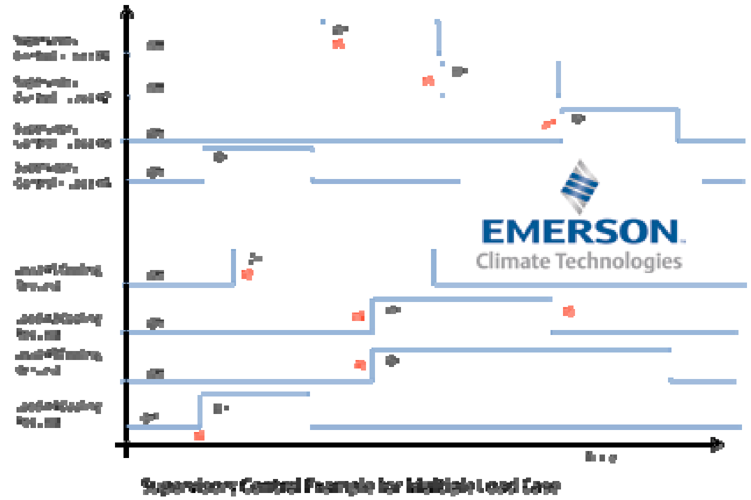
- **Integration of VOLTTRON platform with Emerson ecoSYS Site Supervisor to enable whole store control**
  - Access to all equipment endpoints to VOLTTRON application through JSON-RPC
  - Ability to get sensors data and set control setpoints



- Control application under development
  - Operate building equipment, such as HVAC and refrigeration systems, as installed
  - **Supervisory management layer over existing control systems to enable optimal scheduling**

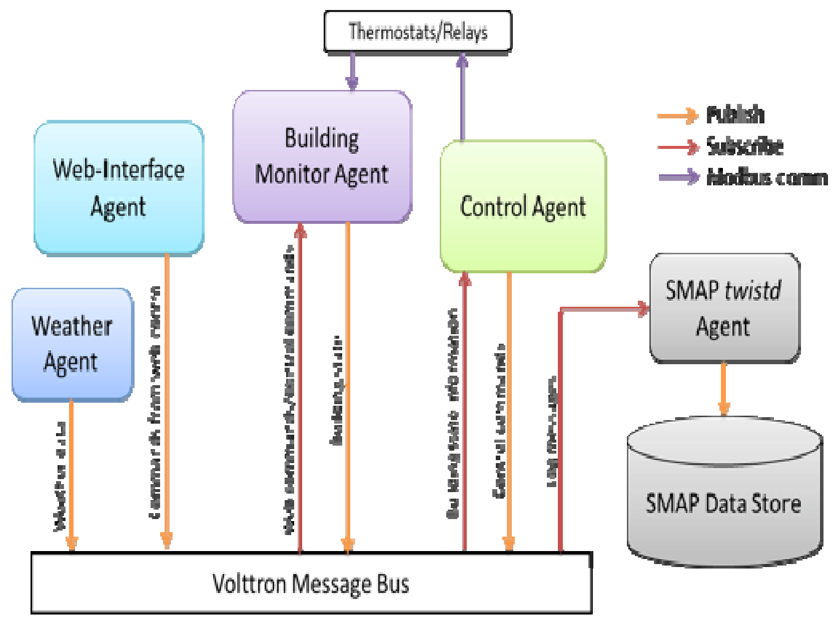
Unified Control - Small Footprint Supermarkets (FY15)

- Supervisory load management application
  - **Enable flattened load profile as baseline**
  - **Enable load control to adapt to a demand profile**
  - **Operate loads within operational constraints**



- Deployment focused
  - **Retrofit deployment to existing stores**
  - Scalable optimal scheduling strategy
  - Utilize thermal storage for demand relief
  - Enable transactive applications (revenue generating for building owner)

- VOLTTRON applications integrated to operational strategy
  - Embedded devices realizing control functionality
  - Scalable retrofit deployment focused



Responsive Loads

- **Transactive energy provided by building loads require high-speed wide area control of loosely coupled loads**
  - Control response can be generated in a centralized or decentralized fashion
    - Utility level information
    - Building-level loads

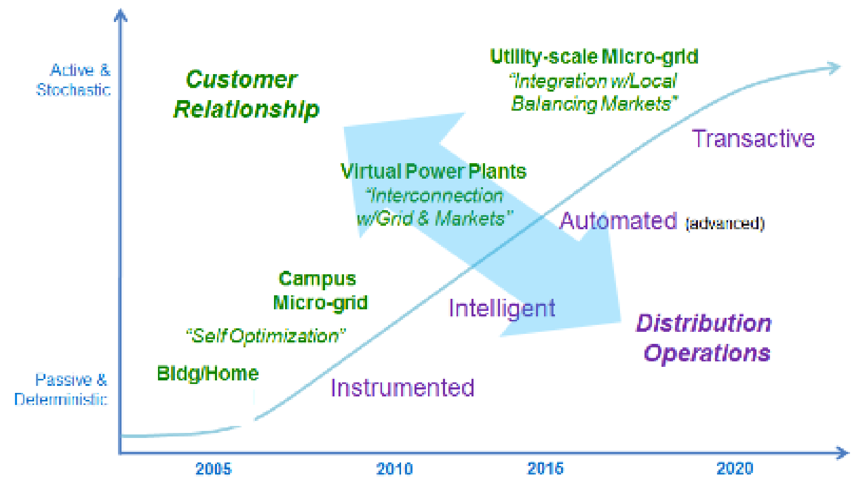


Figure 4: Stages of adoption of transactive operations for industry
Source: Paul De Martini, 1st International Conference and Workshop on Transactive Energy[9]

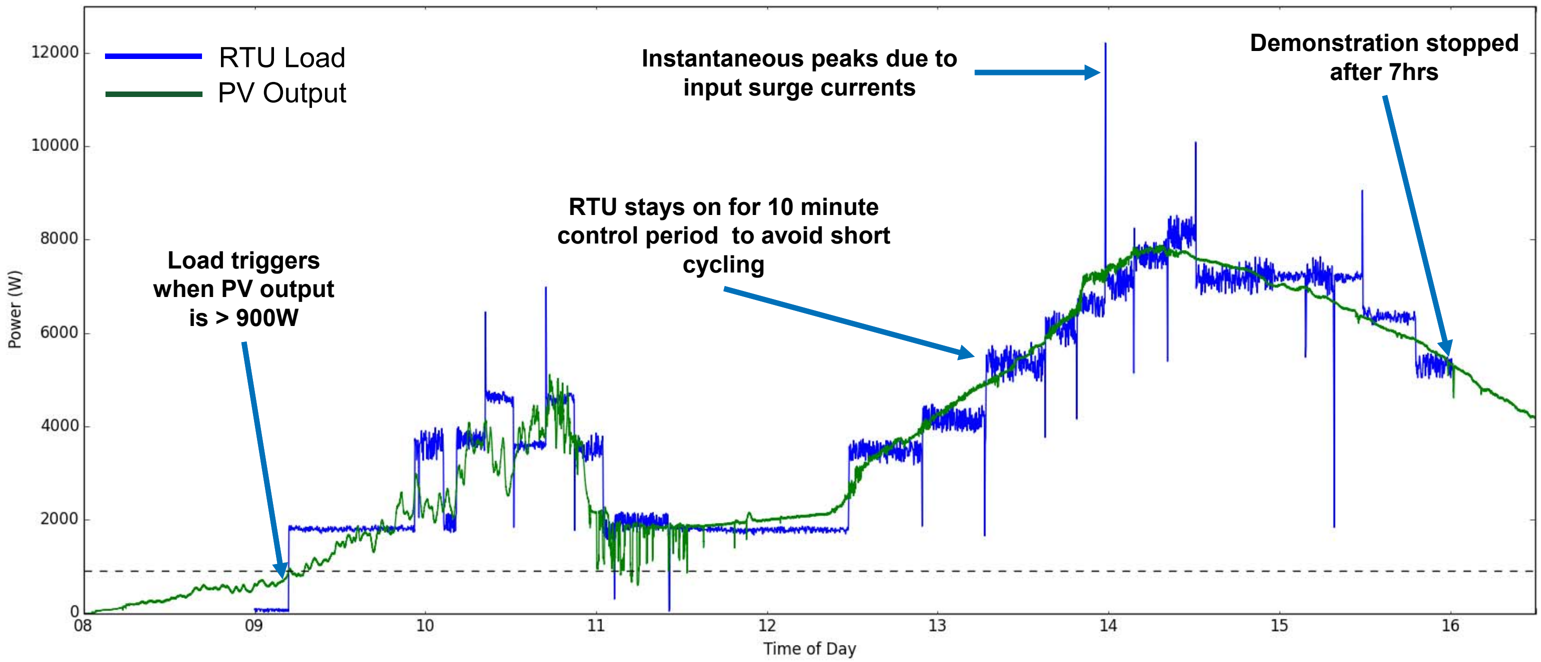
- Develop embedded transactive devices that can control building systems over wide-area heterogeneous networks

- **Demonstration of Load Flexibility**
  - Load tracks PV within safety constraints while reducing number of cycles
  - Load is ~3X the maximum capacity of the PV generation capacity
  - Resolution of load controllability is carefully chosen
  - 4 Packaged RTUs controlled to provide renewable support

Four HVAC units removing heat at rates c_1, c_2, c_3, c_4 or adding heat at rates h_1, h_2, h_3, h_4

Four thermostats reading indoor air temperatures T_1, T_2, T_3, T_4

PV output v.s. load consumption



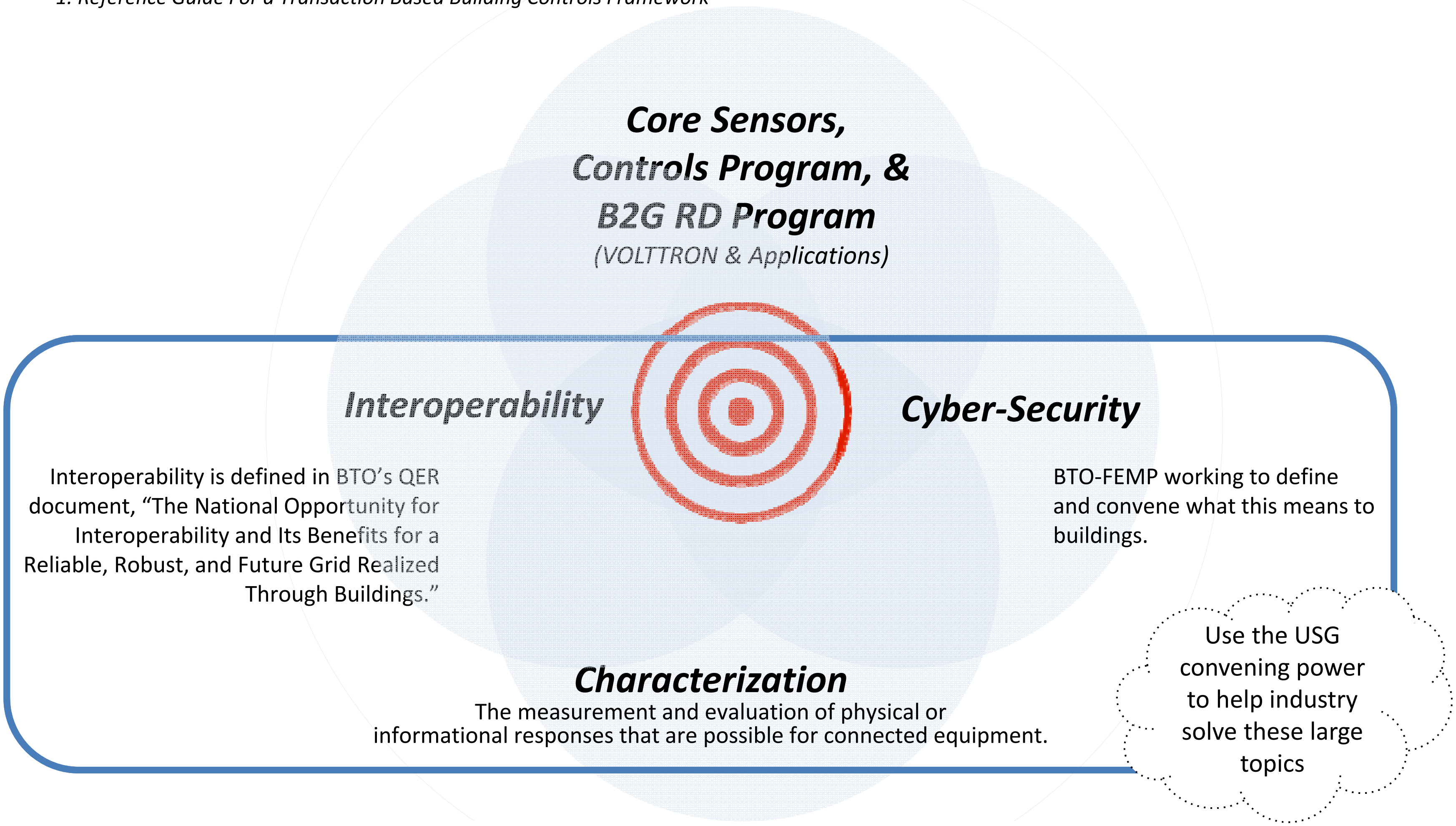
- Load tracks PV with in safety constraints while reducing number of cycles
- Load is ~3X the maximum capacity of the PV generation capacity
- Resolution of load controllability is carefully chosen
- 4 Packaged RTUs controlled to provide renewable support

Significant possibility exists for load to provide "renewability regulation" – load as a resource. Control response can be generated in a centralized or decentralized fashion.

How do we enable Transaction Based Energy[1] Ecosystem?

USG should focus on Core, Foundational Areas of connected devices and buildings…

1. Reference Guide For a Transaction Based Building Controls Framework



These core, foundational areas allow for scalable, market based solutions to develop in the form of ***applications*** *– reducing the time, burden and cost for the public.*

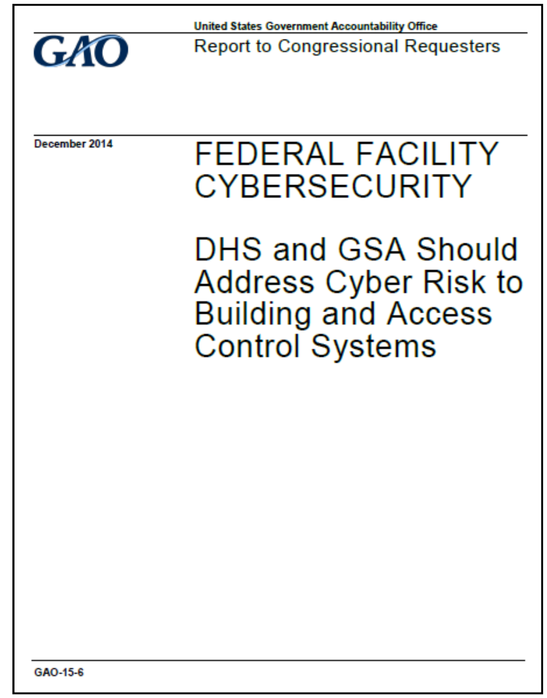
How do we enable Transaction Based Energy Ecosystem?

Cyber Security

FEMP-BTO C2M2 Project Overview

- FY15 Objectives:
  - **Assess whether the Energy Sector Cybersecurity Capability Maturity Model (ES-C2M2) developed for utilities is relevant to building owners/operators and the vendor supply chain**
  - Define steps to adapt the ES-C2M2 to create a Buildings-C2M2
  - Vet the C2M2 approach through advisors, workshops, tests at PNNL

- FY16 plans include:
  - Pilot testing with select federal landlords
  - Modification of survey, scoring and comparison tools
  - Development of a launch campaign
  - Assess supply chain implications


GAO

United States Government Accountability Office

Report to Congressional Requesters

December 2014

FEDERAL FACILITY CYBERSECURITY

DHS and GSA Should Address Cyber Risk to Building and Access Control Systems

GAO-15-6

ES-C2M2 History

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The Electric Sector Cybersecurity Risk Management Maturity Initiative

- White House initiative led by DOE, in partnership with DHS and the electric sector under the Critical Infrastructure Partnership Advisory Council
- Common model that evaluates cybersecurity capabilities within the sector and how those capabilities mature over time

Initiative objectives

- Enable the evaluation of cybersecurity capabilities in a consistent manner across electric utilities
- Enable utilities to communicate cybersecurity capabilities in meaningful terms
- Enable utilities to prioritize actions and investments to improve cybersecurity

Pilot objectives

- Evaluate the draft model and questionnaire and identify needed improvements and clarifications
- Evaluate the value of the model, questionnaire, and evaluation process to utilities

Additional information

- www.whitehouse.gov/blog/2012/01/09/protecting-nation-s-electric-grid-cyber-threats

ES-C2M2 Model Domains

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RISK	Risk Management
ASSET	Asset, Change, and Configuration Management
ACCESS	Identity and Access Management
THREAT	Threat and Vulnerability Management
SITUATION	Situational Awareness
SHARING	Information Sharing and Communications
RESPONSE	Event and Incident Response, Continuity of Operations
DEPENDENCIES	Supply Chain and External Dependencies Management
WORKFORCE	Workforce Management
CYBER	Cybersecurity Program Management

- Domains defined by an industry Advisory Group
- Significantly informed by subject matter experts

The ES-C2M2 Model At A Glance

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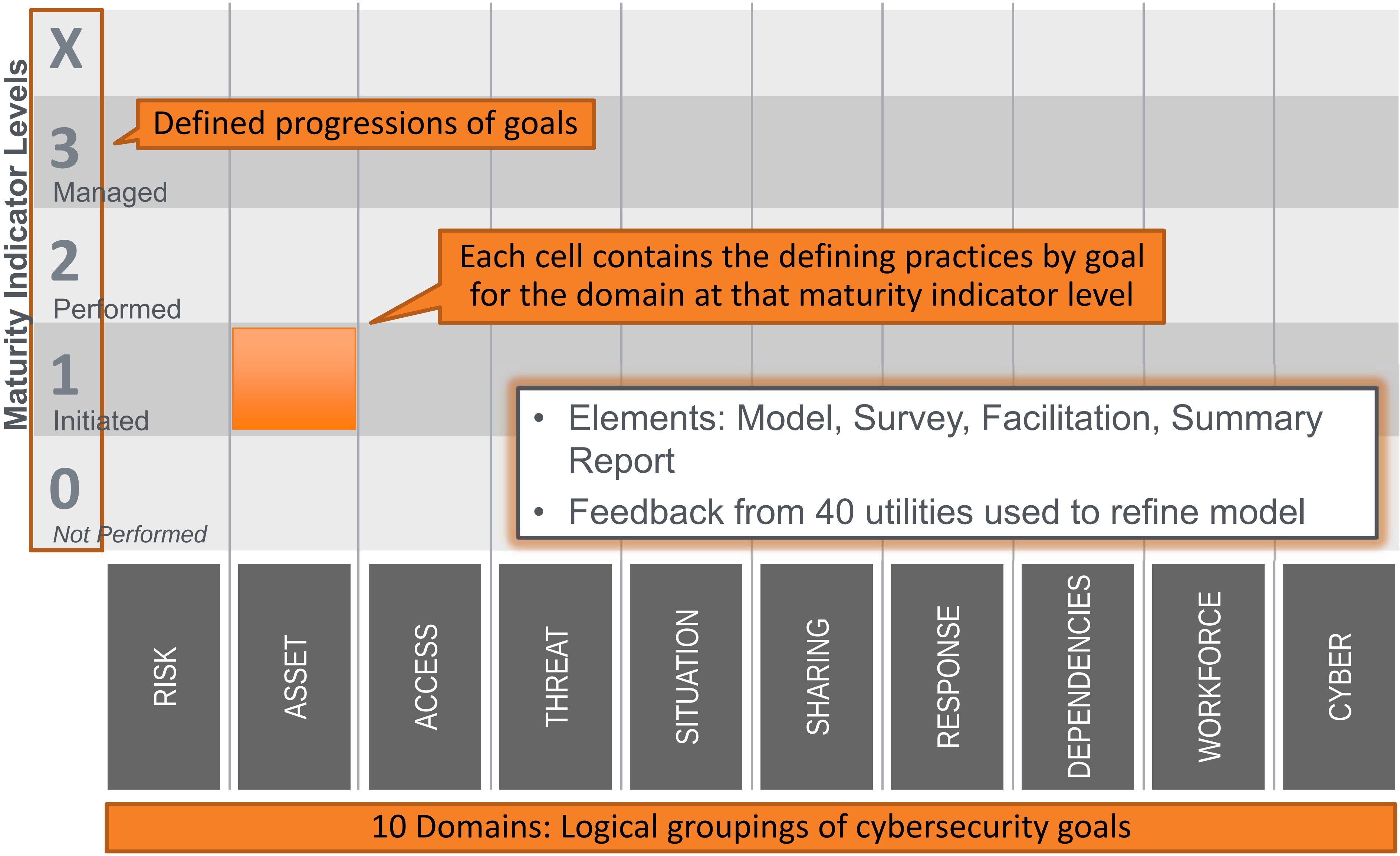


- Elements: Model, Survey, Facilitation, Summary Report
- Feedback from 40 utilities used to refine model

How do we enable Transaction Based Energy Ecosystem?

Characterization Activities

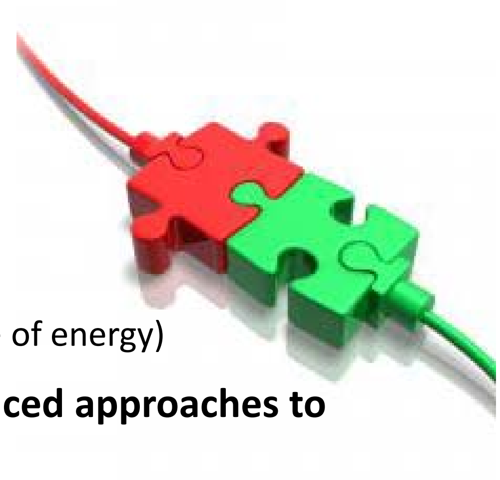
- **Published “A Framework for Characterizing Connected Equipment”**
  - Characterization is not annual efficiency testing, a label, test procedure development, or any part of the Energy Star program.
  - Characterization is a first step toward mapping equipment responses to services and helping industry to evaluate value and benefit to stakeholders.
  - Being adopted by industry… EPRI, ASHRAE, CEE

- **Characterization of Connected Equipment**
  - Characterize what equipment is capable of in order to determine services that can be delivered
  - Focus on **characterizing grid and end-user services**
  - Selected RTU based on FR comments on Framework and input from industry at three technical meetings

- **Connected Equipment Maturity Model**
  - Benchmark and track maturity of connected features
  - Identify trends, gaps, and opportunities
  - Partner with industry to develop the model through a DOE led technical working group
  - Leverage structure of DOE SGMM & ES-C2M2 models

How do we enable Transaction Based Energy Ecosystem?

Interoperability: Why We Need Connected Buildings (1)



- Today's stock of **buildings are noticeably "un-connected"**
  - **Limited by existing control and coordination technology**
  - Advanced automation deployments constrained to large buildings due to automation equipment, installation, and maintenance costs
  - Value streams are often hidden and untapped (e.g., time dependent value of energy)
- **Large-scale deployment of clean energy technologies requires advanced approaches to building equipment integration and electric grid coordination**
- Improved integration approaches for deploying technology can **enable new services**
  - Examples include advanced power electronics, operations diagnostics, grid-responsive building technologies, vehicle charging coordination
- **Greater energy and business efficiencies can be mined through co-optimization approaches that reach across the meter**
  - Allow intelligent trade-offs between comfort/quality of service and consumption

Interoperability is essential for buildings information exchange (within buildings and with external parties)

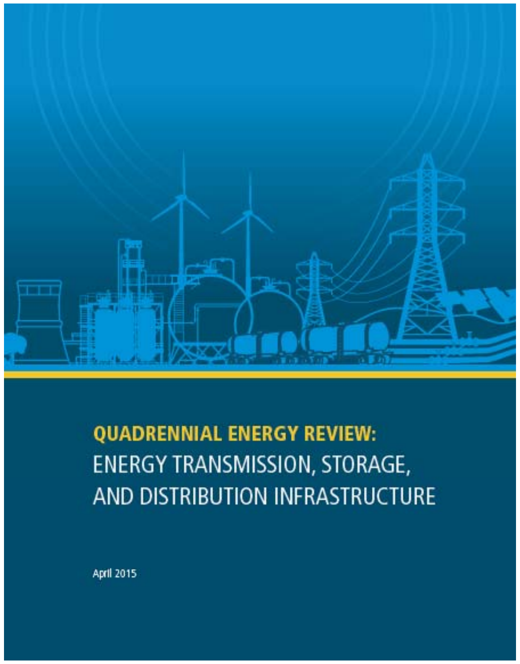
How do we enable Transaction Based Energy Ecosystem?

Interoperability: Why We Need Connected Buildings (2)

- **BTO Approach works with Industry**
  - Draft a buildings interoperability vision document with industry input
  - Develop a roadmap – engage stakeholder community
  - Consider initial value propositions – is there a "killer app"?

- **BTO Process is open and transparent**
  - Vision meeting March 2015 to discuss current landscape of buildings interoperability and hear from technology leaders about Internet of Things (IoT) and next gen. buildings automation concepts and challenges
  - EERE Webinar May 2015 (127 participants)

- *All meeting materials including industry PPTs available at http://energy.gov/eere/buildings/buildings-grid-integration*



Key Finding from **QER**:

> *"Enhancing the communication to customer devices that control demand or generate power will improve the efficiency and reliability of the electric grid. For example, open interoperability standards for customer devices and modified standards for inverters will improve the operation of the grid. (Page S-15)"*

BTO & OE Funded the project in FY15, but ***no kick off or announcements have been made.***

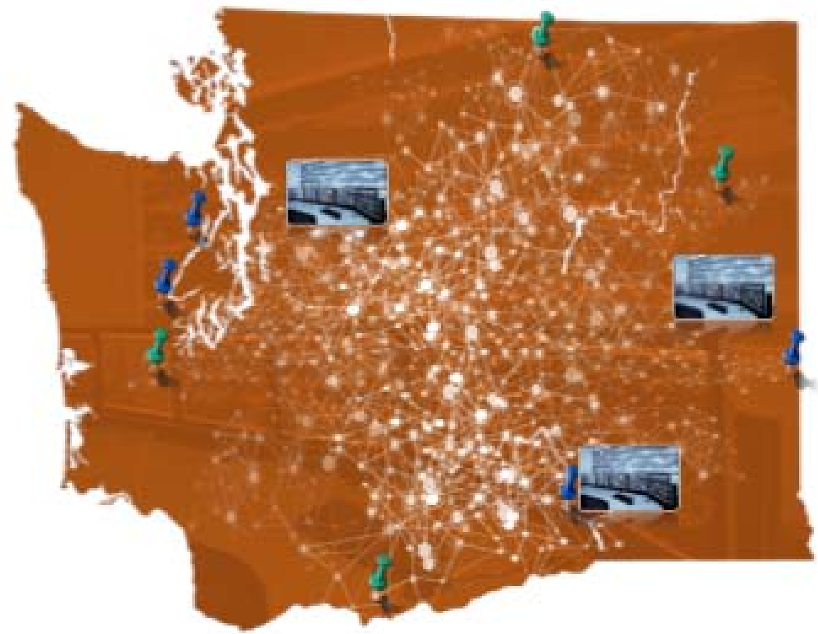
The Clean Energy & Transactive Campus

DOE (OE & EERE) & WA State (UW, WSU)

FY15 - ~$2M DOE, $2M WA Legislature (match)

The Clean Energy & Transactive Campus

Increasing and expanding the hosting capacity of EE and RE technologies by empowering buildings



- **Builds Upon Prior DOE & WA Investments**
  - ARRA Northwest demonstration project
  - BTO transactive network R&D
  - OE microgrid investments
  - WA Clean Energy Fund storage investments

- **The CETC is the first campus and fleet experiment**, R&D, and demonstration in the nation in which these ideas will be deployed, measured and test as well as exposing these ideas to needed researchers, faculty, staff, and students.

- **Transactive Campus Encompassing Three Locations, Multiple Assets**
  - PNNL: transactive buildings and transactive campus responsive to signal from municipal utility
  - WSU: thermal and electrochemical storage, PV, and microgrid integrated with smart & resilient city via Avista Power
  - UW: smart building and transactive campus

The project's outcome is to create a "recipe" for replication of transactive control and coordination for 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.

The Clean Energy & Transactive Campus

Increasing and expanding the hosting capacity of EE and RE technologies by empowering buildings

- The goals of the CETC span EERE programs, yet the common dominator is the buildings' role as outlined in the *Transaction Based Controls Reference Guide (Volume 1)*:
  - **BEYOND DEMAND RESPONSE** – enable buildings, fleets of equipment, and other "behind the meter" assets to deliver services to the grid while optimizing EE for the owners.

    "How can we coordinate distributed equipment that is not directly controlled by the utility to deliver valuable services to the owners and operators of buildings and the grid simultaneously?"

  - **GRID SCALE, RIGHT-SIZED STORAGE** – enable buildings to function as "virtual" storage devices thereby reducing the total capacity of grid storage needed to meet the needs of a utility.

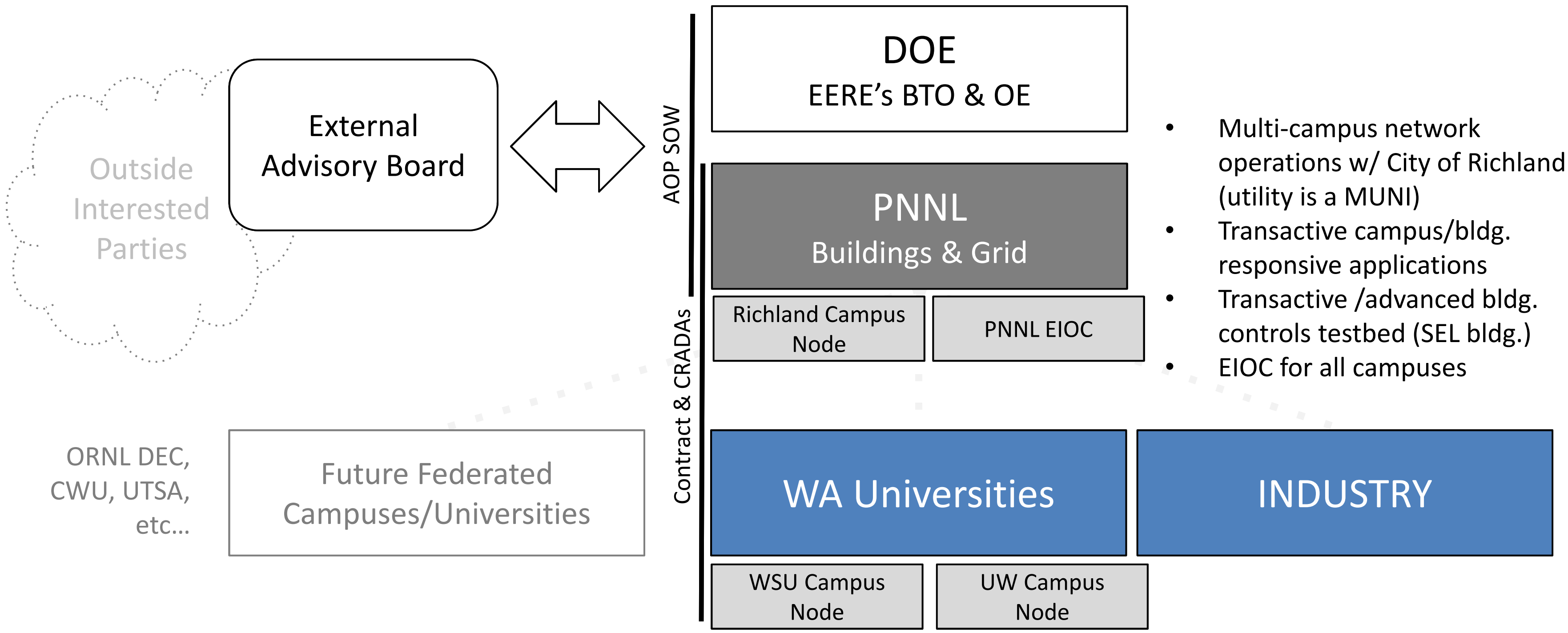
    "How can we utilize building loads and control of assets to optimize storage requirements for the grid?"

  - **BEHIND THE METER RESPONSE TO PV** – lessen, dampen, and otherwise minimize the effects of building and site sighted PV as seen by the utility.

    "How can we utilize groups of building loads, integrated with on-site storage, to minimize variability impacts of installed PV for utilities?"

The Clean Energy & Transactive Campus

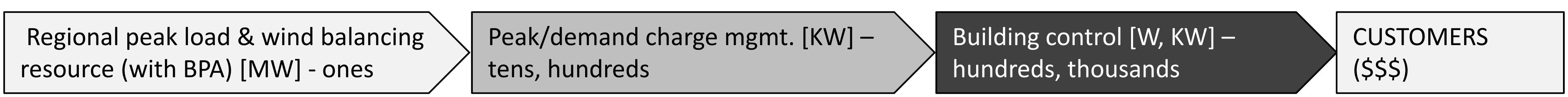
Roles and Responsibilities



- Microgrids as a resilience resource/smart city **w/ Avista Power**
- Solar PV & CEF battery in WSU microgrid ops
- Curricula development

- Energy efficiency applications, leveraging transactive network
- Smart inverter integration **w/ Seattle City Light's distribution**
- Curricula development

The CETC is the first campus and fleet experiment *in the nation spanning control across the "inherent grid scale mismatch"*

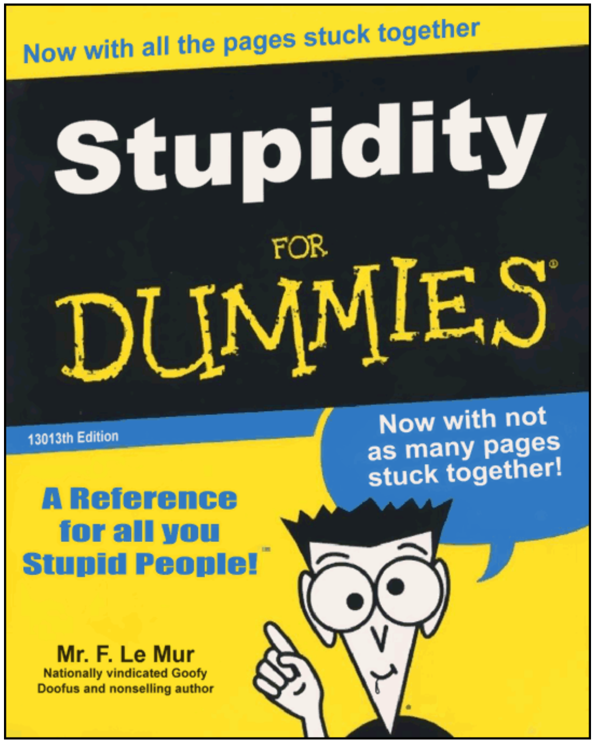


Backup Slides

Smart buildings today are not too smart…

Examples:

- Existing sensor/control systems do not self-configure , self-setup, or self optimize driving cost up to “get it right”
- Thermostats are typically deployed across too large a space to properly condition the building for comfort
- Advanced sensor/control systems are too expensive thereby “taxing” optimization
- Existing sensor/control systems are not capable of adequate diagnostics offering no automatic fault detection or response
- Lighting control is typically independent of thermal control yet the effects are dependent
- Occupancy sensors are expensive to deploy yet rarely operate effectively
- Building devices/equipment typically cannot communicate with each other
    - Building management systems provide minimal control and are only cost effective for larger buildings.

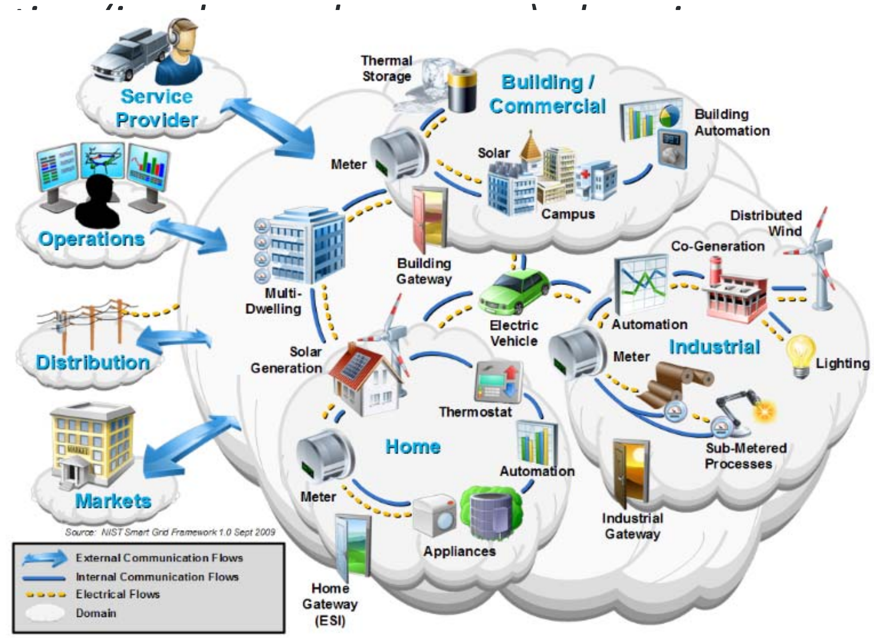


Smart buildings start with smart sensors and controls.

Smart buildings lead to better utilization of energy at all scales

- Buildings need to be smart to participate in transactions within the building, with other buildings, and with grid entities.

- Sensors and controls at the whole building level and at the component level are fundamental to optimize DER and the grid.
  - Hypothesis: *The financial viability of building efficiency may be sub optimized since margins are thin. Grid integr*
    financially viable in many instances, BUT… a model with multiple transactions within an energy ecosystem enhances the value proposition.



- All BTO Sensors and Controls projects are designed to improv building performance and incorporate the broader transaction capability.

Advanced controls are transaction based controls

The Transaction Based Control's Vision enables Distributed Energy Resources (DER)

Buildings will be self-configuring, self-commissioning, and self-learning such that they optimize operation, maximize all cost effective energy savings and are enabled to participate in transactions within the building, between buildings, and with the grid

Understanding the Problem

The lack of ability to transact energy related services with other buildings or entities (other than the ISO/Utility) impedes financial motivation to engage robustly with distributed Renewable Energy and Storage.

- Currently, facilities are forced to use, store, or (if generating RE) directly sellback to the utility – this model has financial and physical limitations.
- There is currently limited ability or market to share performance information or transact load/energy services with other surrounding buildings or surrounding loads (i.e chillers, EV charging stations, etc.).
- Therefore, the owners/operators aren't financially or operationally motivated to act outside of simply taking advantage of Utility sponsored incentive programs.

What we believe in… the Opportunity for Buildings

- Buildings have a large role in helping to enhance grid reliability and enabling the rapid integration of Renewable Energy and Storage.

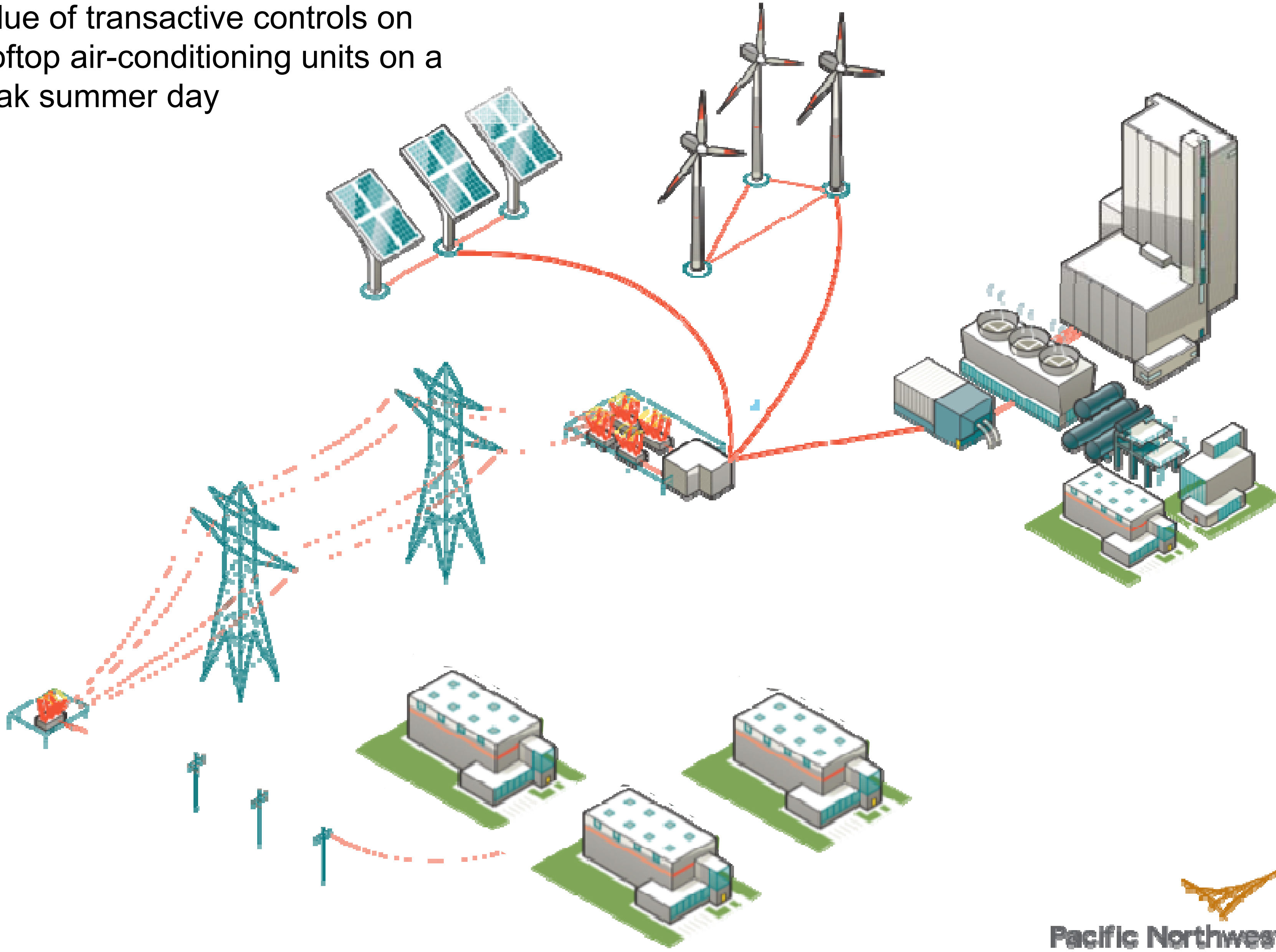
BUT

- Buildings today are limited by existing controls systems that can't easily transact at the speed or scale that is required by the grid
  - High cost to "get it right" with existing technology and economics
  - Currently only implemented in large buildings
  - Components are emerging with greater capabilities of control

- Building solutions must "think across the meter"
  - Energy Efficiency is at the core, but there are additional value streams to/from third party entrepreneurs
  - Better control of loads have other benefits
- Thinking Differently will unlock new value streams…

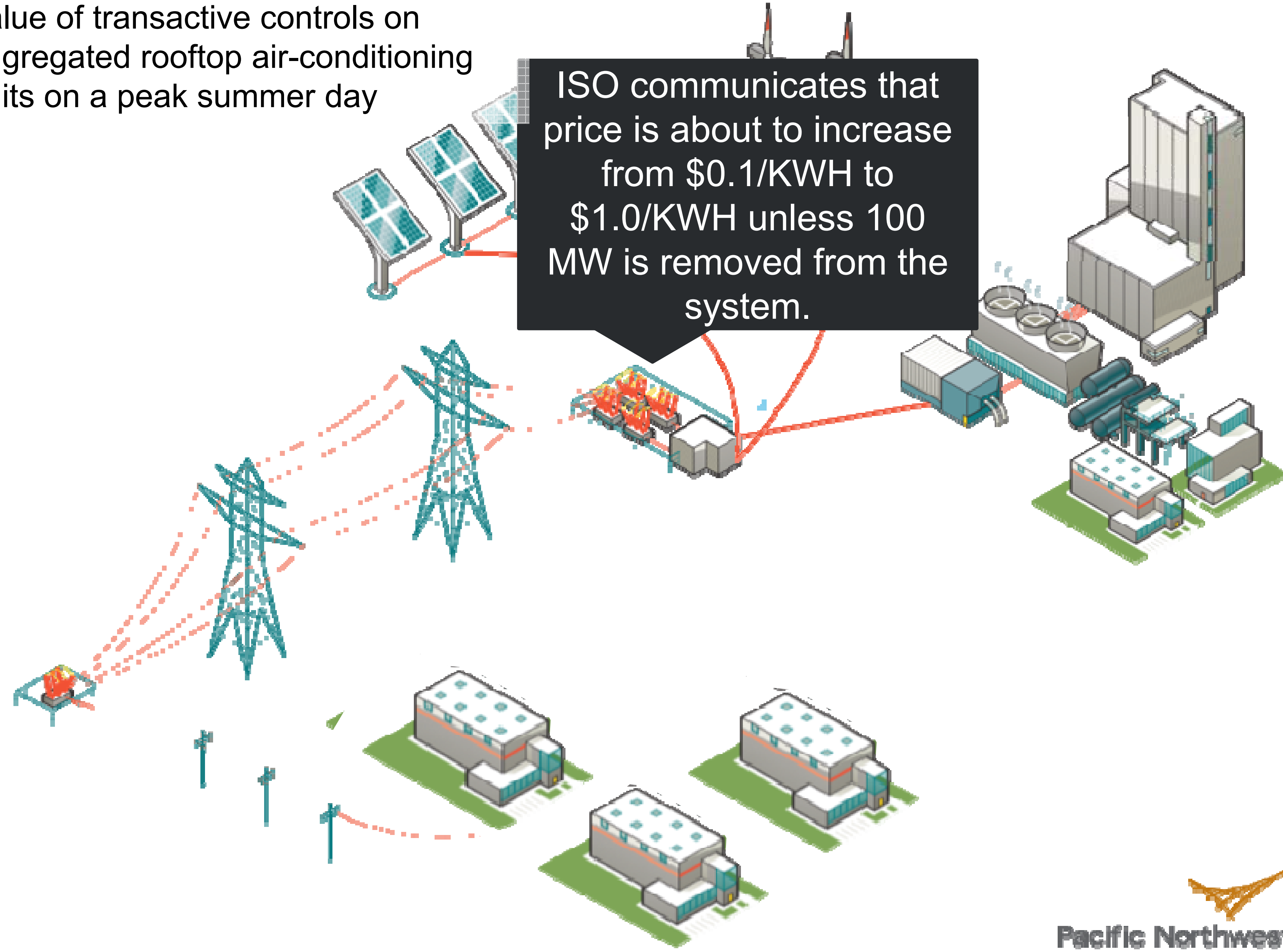
Example Opportunity:

- Value of transactive controls on rooftop air-conditioning units on a peak summer day



Example Opportunity:

- Value of transactive controls on aggregated rooftop air-conditioning units on a peak summer day



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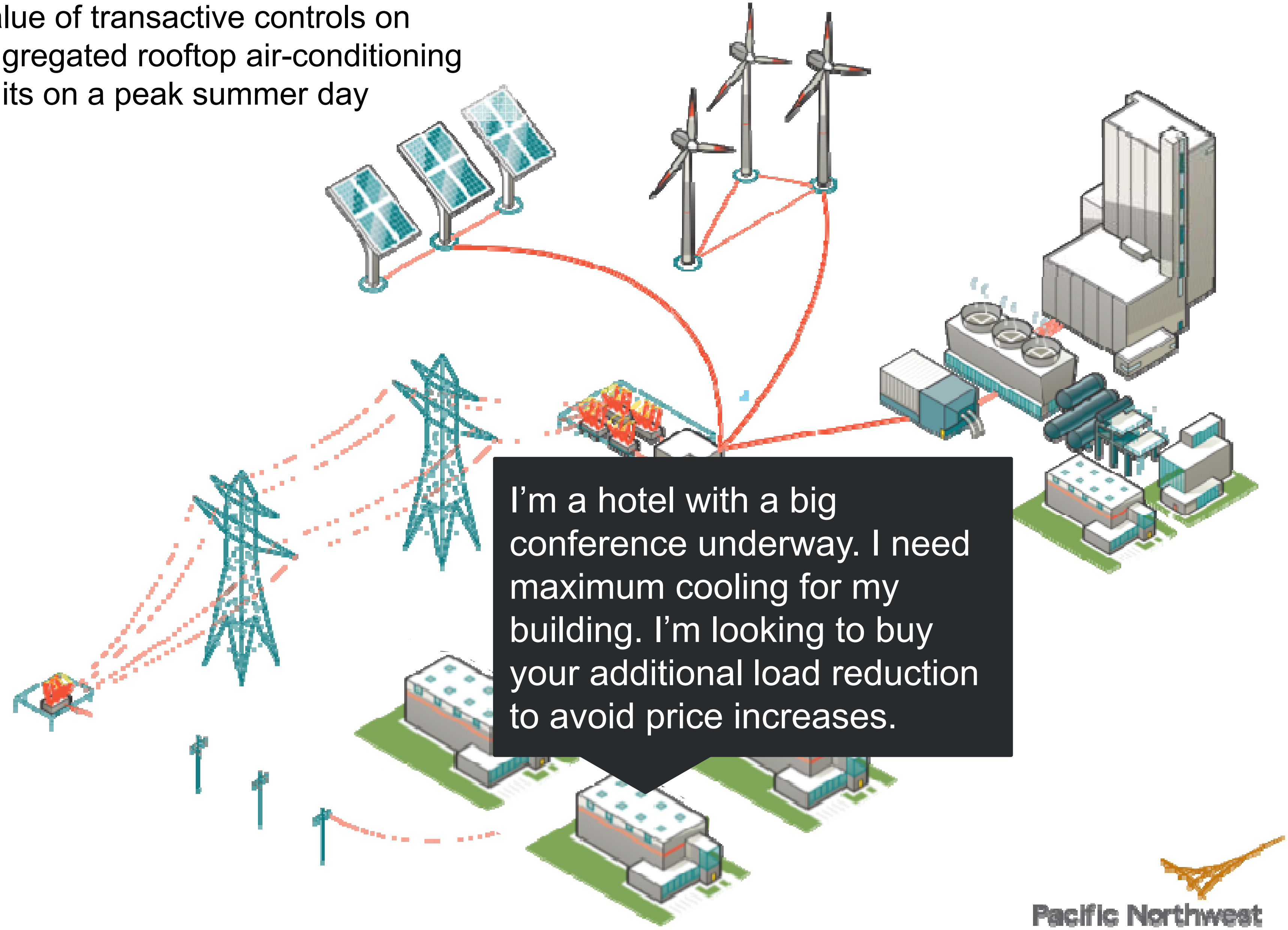

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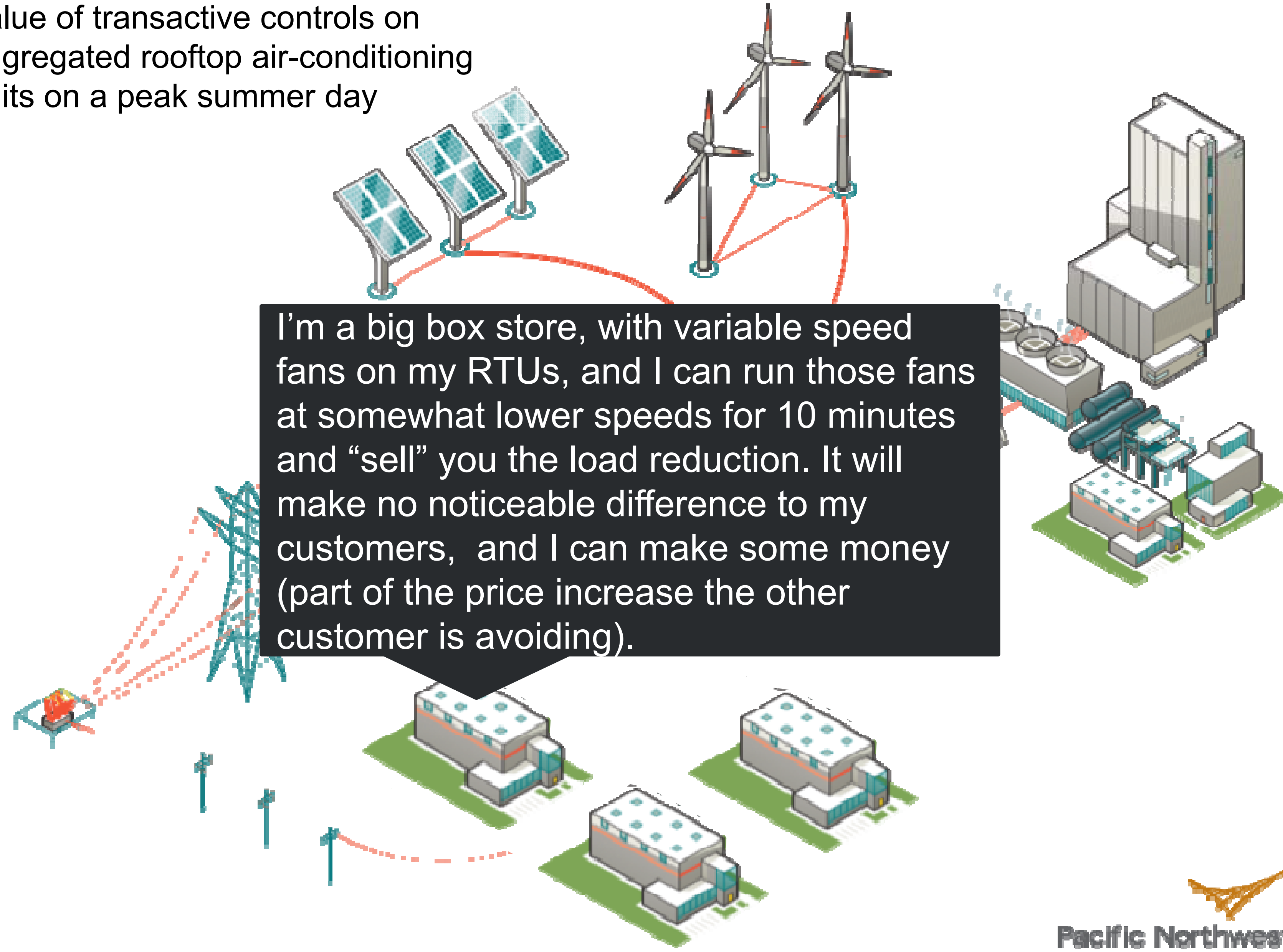

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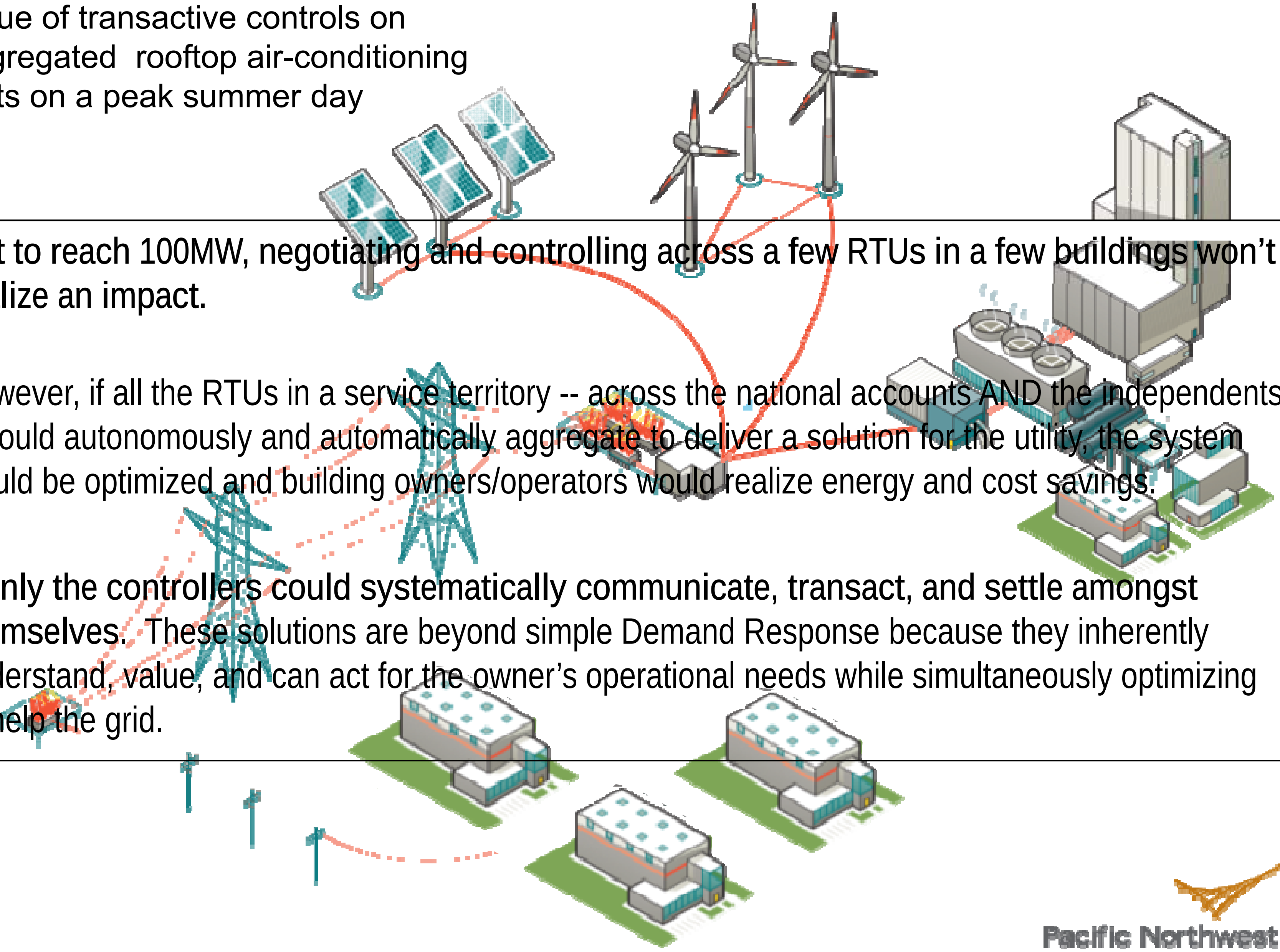

But to reach 100MW, negotiating and controlling across a few RTUs in a few buildings won't realize an impact.

However, if all the RTUs in a service territory -- across the national accounts AND the independents -- could autonomously and automatically aggregate to deliver a solution for the utility, the system would be optimized and building owners/operators would realize energy and cost savings.

If only the controllers could systematically communicate, transact, and settle amongst themselves. These solutions are beyond simple Demand Response because they inherently understand, value, and can act for the owner's operational needs while simultaneously optimizing to help the grid.

Scaling Transaction Based Controls

Research, Development and Deployment

Develop and commercialize advanced diagnostics and controls to create self-aware buildings that optimize performance.

Define, test, quantify and validate the value proposition, response and related services provided by Building Technologies

Enable buildings to interact (e.g. with the grid) to support transactive energy opportunities and deliver the value proposition

- Fundamentals needed to enable buildings that are self-configuring, self-commissioning, self-learning, self-diagnosing, self-healing, and self-transacting to enable continuous optimal performance.

- **Reference Guide to Transaction Based Building Controls** (FY14-FY15)
  - Fundamental work to define building related services (FY14) and the Minimum Requirements (FY15) to deliver those services.

- **Framework for Characterization of Connected Devices** (FY14-FY15)
  - Defined measurement process to characterize the response that "connected devices" can provide, including grid, operational and other services.

- **National Strategy for the Interoperability** (FY15)
  - Interoperability is the biggest requirement for a low cost and scalable smart grid, smart cities and smart buildings.

The Reference Guide

A Vision for Services (Volume 1)

- **End User Services**
  - Operations, Maintenance, and Energy Efficiency of behind the meter assets (example: EE, Continuous Commissioning)
    - EERE technologies have historically focused on these services. How can we best consolidate these value streams?
- **Energy Market Services**
  - New services where energy production and "use" can be ex-changed between parties (potentially outside of regulated markets) Example: Provision of energy storage to avoid capacity charges
    - How do we explain and then help the market capture these values? We must identify potential energy market services that can be provided by technologies.
- **Grid Services**
  - Traditional services the Grid needs -from DR to Ancillary Services
    - How can EERE technologies deliver these services at the lowest cost?
    - McKinsey report quantifies the value of these services but it does not match solutions to EERE technologies
- **Societal Services**
  - Services that "society" needs or values (example: Staging of recovery)

VOLUME 2 is entitled, "Transaction-Based Building Controls Framework (Volume 2): Platform Descriptive Model and Requirements"

Transaction-Based Building Controls Framework, Volume 2: Platform Descriptive Model and Requirements

- Describes the requirements of a Transaction-Based Control Reference Platform
- Using an example instantiation (VOLTTRON) defines those requirements
  - Provides component descriptions and diagrams explaining role in the platform
  - Using actual applications demonstrates usage of platform services
  - Highlights the security features
- Includes a more general discussion of Transaction Based Control beyond current implementation
- Encourages multiple, interoperable Transaction Based Control platform implementations in order to build up an ecosystem of platforms working together to achieve the goals of Transactional Energy


U.S. DEPARTMENT OF ENERGY

PNNL-XXXXX

Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830

Transaction-Based Building Controls Framework, Volume 2: Platform Descriptive Model and Requirements

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Jereme Haack
Brandon Carpenter
Srinivas Katipamula
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George Hernandez

June 2015

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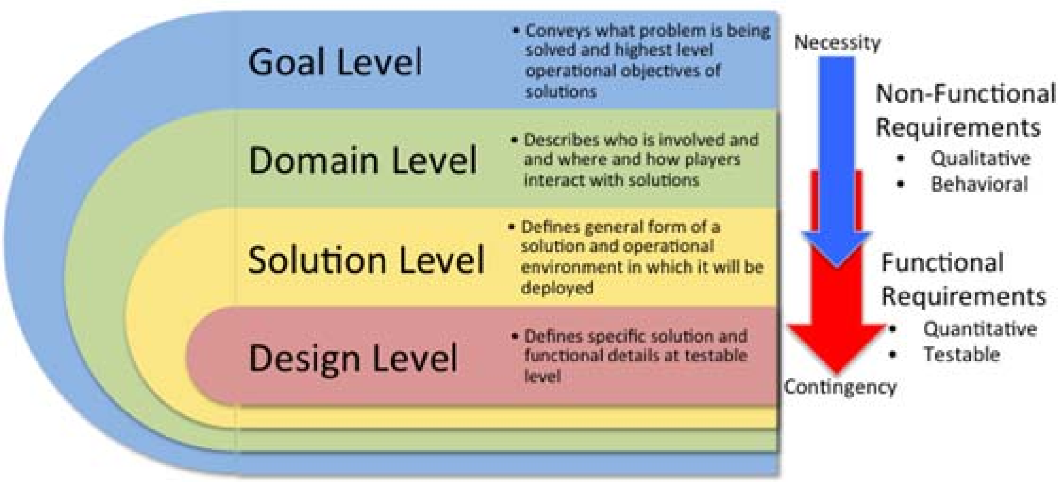
Transaction-Based Building Controls Framework, Volume 2: Platform Descriptive Model and Requirements

- Describes high level goals
  - Using an exemplary transaction-based controls reference platform, VOLTTRON, orients the user by providing Transaction Based Control reference platform requirements
  - Provides an overview of the various Transaction Based Control components

- Describes the solution and design level requirements in detail
  - Describes in detail an exemplary platform that can be used to meet these requirements
  - Presents use cases that describe how a particular instantiation of a Transaction Based Control platform can be used to implement building heating ventilation and air conditioning system diagnostics and grid services
  - Presents the security features of the exemplary platform

- Describes additional features beyond the features in the current reference platform



Scaling Transaction Based Controls-Interoperability

Research, Development and Deployment

Develop and commercialize advanced diagnostics and controls to create self-aware buildings that optimize performance.

Define, test, quantify and validate value proposition, response and related services provided by Building Technologies

Enable buildings to interact (e.g. with the grid) to support transactive energy opportunities and deliver the value proposition

Vision is enabled by the development of a **Transactional Network** (TN), Open Source Solution. This project is the first step in developing, demonstrating and deploying scalable, cost-effective and open solutions

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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BERKELEY LAB
LAWRENCE BERKELEY NATIONAL LABORATORY

OAK RIDGE
National Laboratory

Multi-Lab Coordinated and Cooperative Initiative

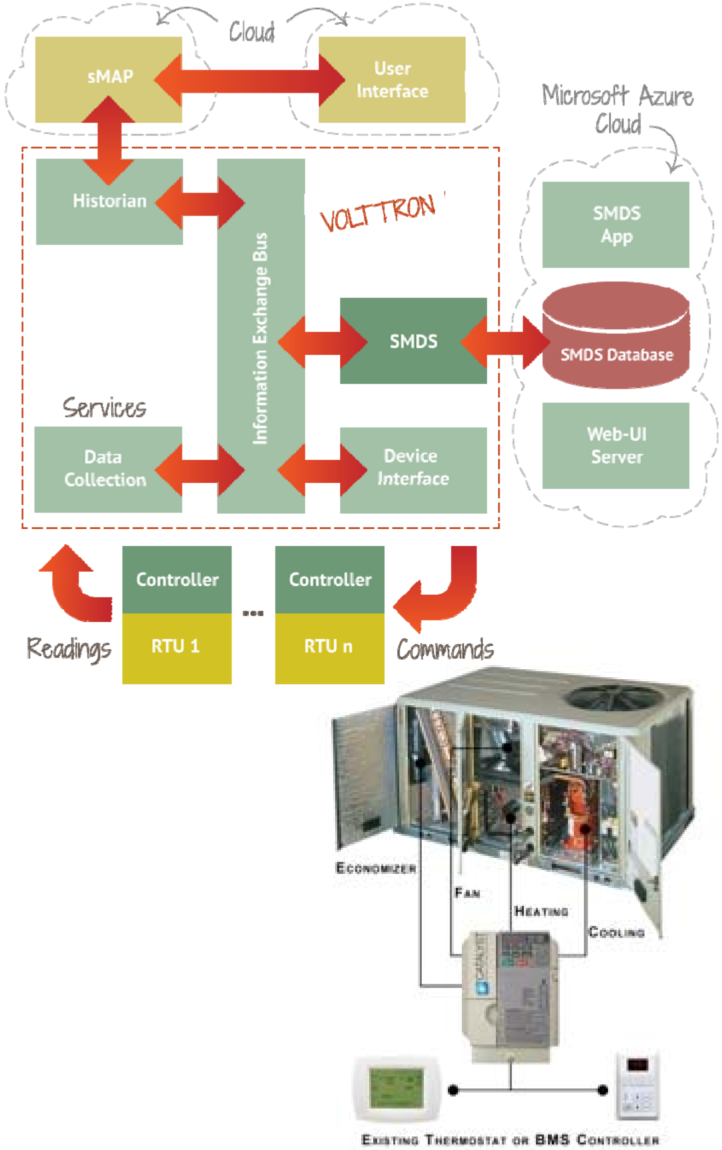
PNNL -Transactional Network Applications (2014)

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

Demand Response Agent: Make RTUs more grid responsive - leading to a more reliable electric power grid and to mitigate impacts of intermittent renewable generation

Automated Fault Detection and Diagnostics:

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



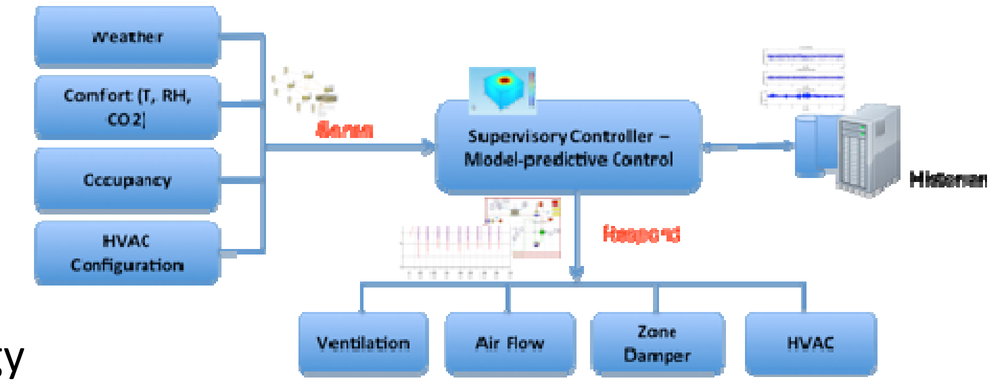
ORNL- Transactional Network Applications (2014)

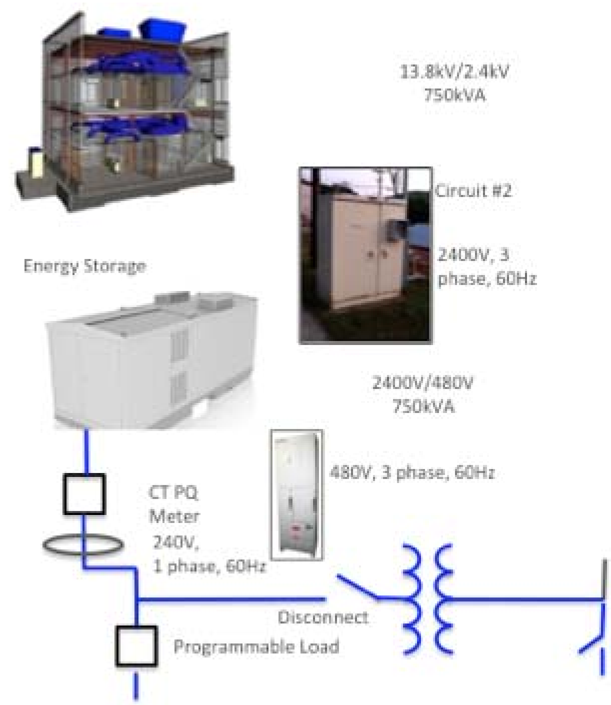
Wireless Interoperability Seamless integration of wireless sensors into the transaction network platform

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

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

Super-Market Refrigeration Develop refrigeration system applications (with Emerson) to improve their performance and to provide energy services to the grid.





U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Lab Concentrations going into FY15 and Beyond

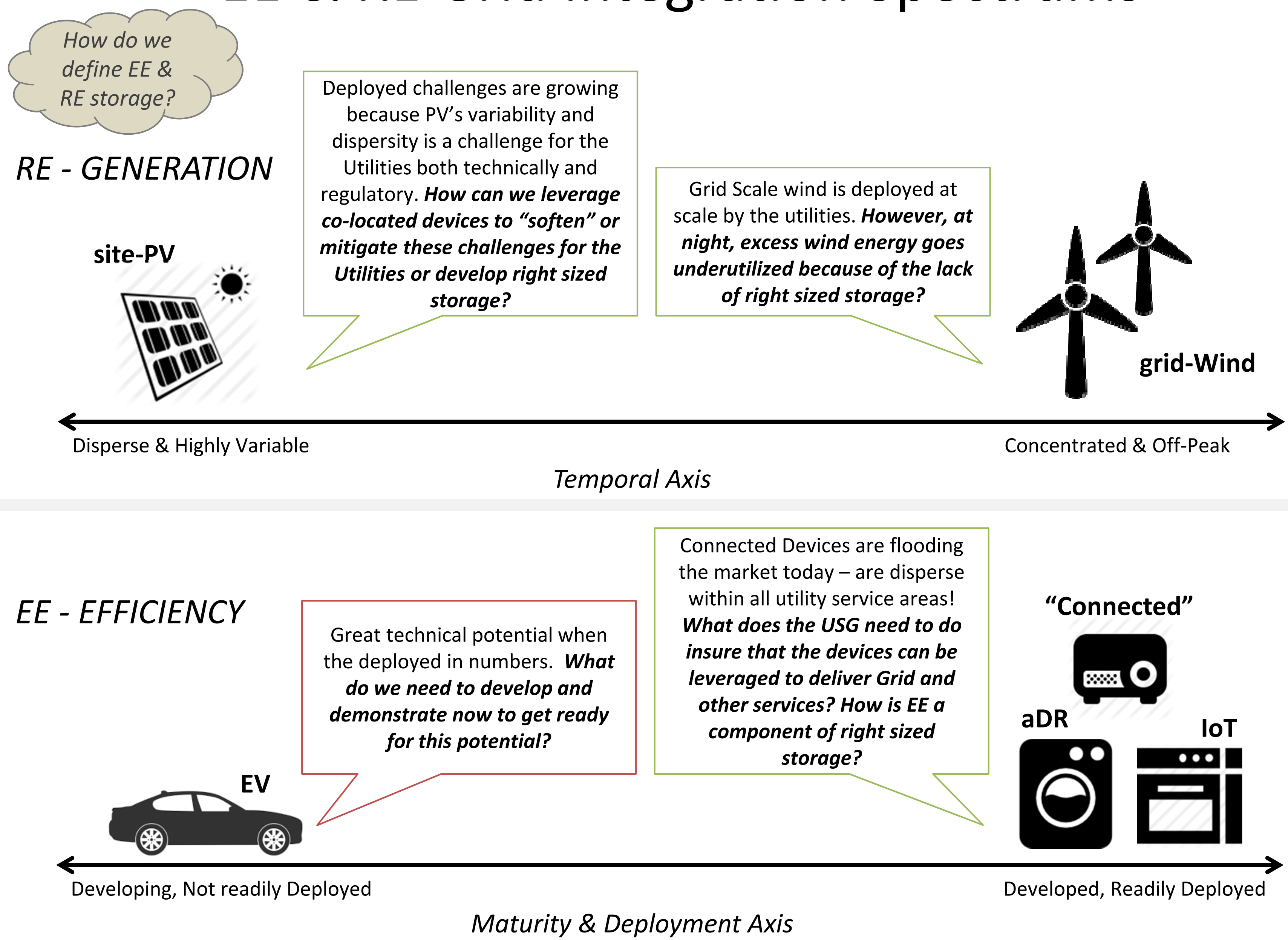
PNNL – core controls lab for BTO, manager of VOLTTRON Code with the OE Cyber Team at PNNL, manages all "regulatory" procedures due to the Stds program at PNNL, develops operational agents.

ORNL – core sensor lab, develops RE-OE related system agents, desire to connect BTO's assets with OE's assets to provide DOE clear opportunities and resources.

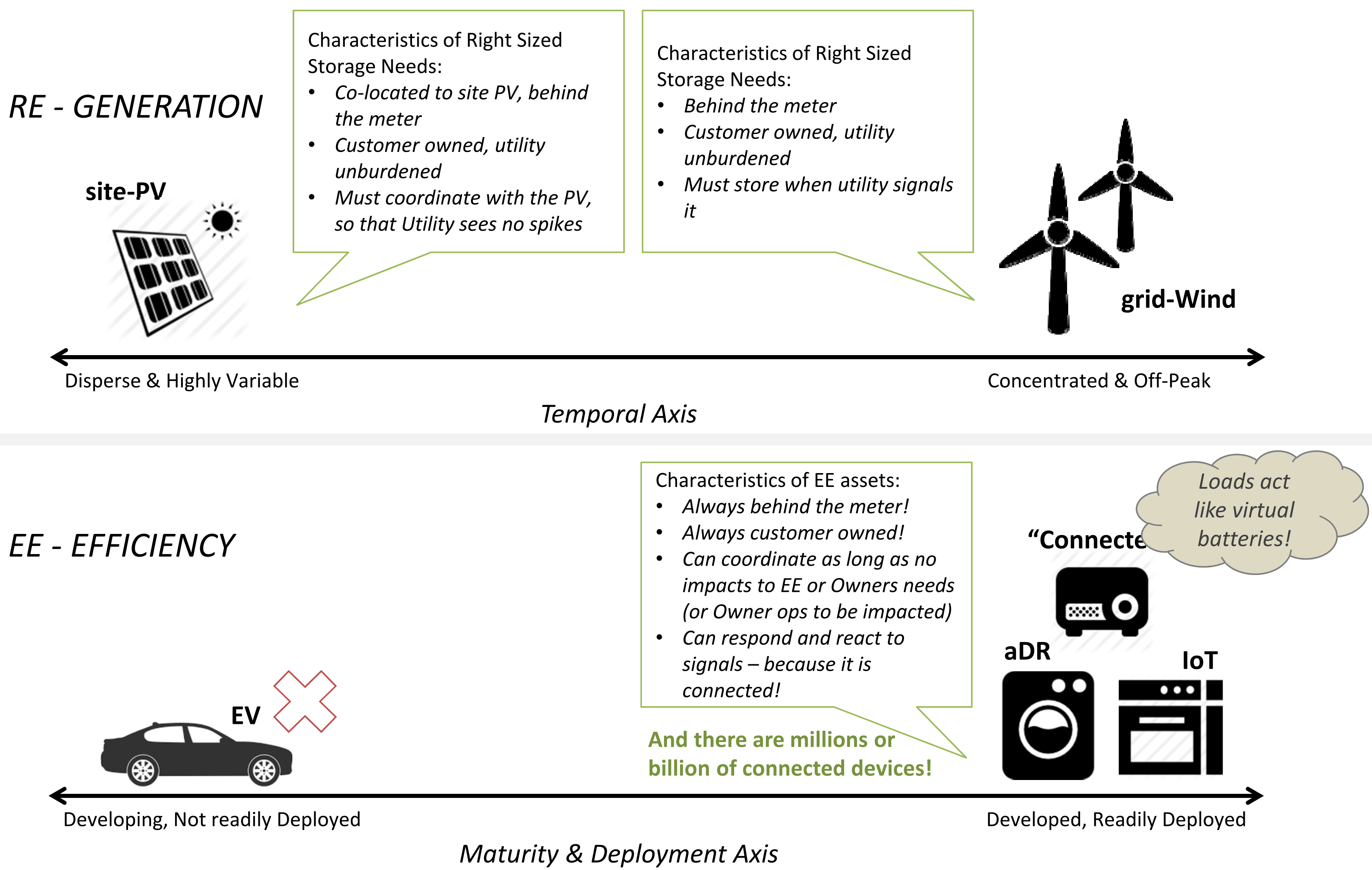
LBNL – developing M&V agents, work with DOD on resource constraint situations.

NREL – developing model rigs (through a public process), installing VOLTTRON capabilities in ESIF for all EERE programs, developing agents specific to EVs and Municipal storage.

EE & RE Grid Integration Spectrums



Integration Spectrums Define Storage Needs



Defining Right Sized Storage

- Connected loads can't serve 100% of the RE's storage needs – some electric storage will be needed.

- Therefore, how do we define this "right sized storage"?
  - Do we first reduce the total load – system EE first?
  - Can we measure the loads at various states to understand the extent by which they can be leverage?

- Examples include…
  - ORNL's coordination of RTU controls against PV
  - ORNL's work with Emerson to control refrigeration cases

- However, at scale, this will take…
  - Voltage Regulation Using Responsive Loads
  - Grid-responsive Control
  - In-Network Intelligence

<u>Requirements Analysis:</u>

- The PV generation signal can be analyzed as three signal components
  - High frequency second level variations
  - Medium frequency components at hour level
  - Low frequency components that correlate with the solar activity.

- High frequency signal will require fast responsive loads like variable frequency drives, electric/thermal storage, and resistive element (water heaters).

- The medium frequency components and low frequency can be served using a combination of the HVAC systems and other building loads.

- Load forecasting and short term PV forecasting approaches can refine the control response.

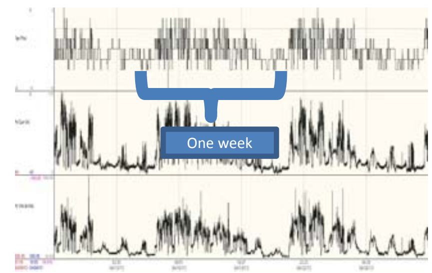
Voltage Regulation Using Responsive Loads

- Variability in solar photovoltaic (PV) power production introduces
  - Two-way power flow on the distribution circuit
  - Voltage variations temporally and spatially on feeder and substation

- Typically loads act autonomously without any coordination with the grid or PV

- Traditional electric grid is load following (temporally)

- Responsive loads that can be controlled temporally and spatially to minimize difference between demand and PV production

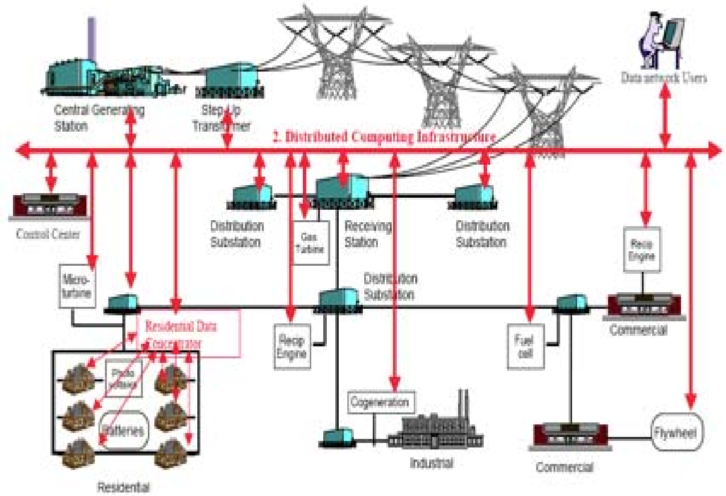


Courtesy Portland Gas & Electric

Increased tap changes over an order of magnitude due to renewable integration cause accelerated failures & additional maintenance

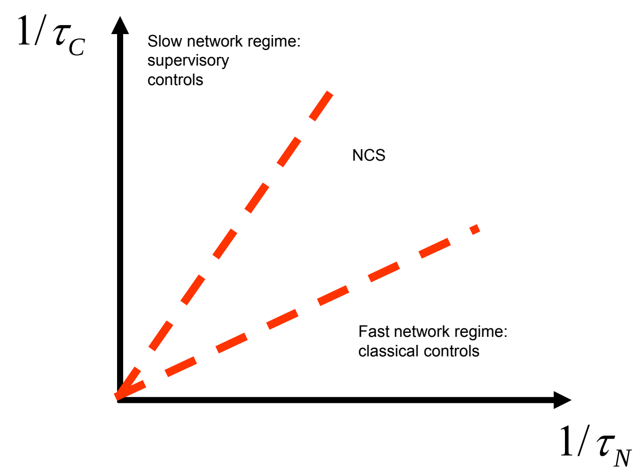
Grid-responsive Control

- Identify requirements for sensors or information sources including frequency, price, voltage



- Develop control framework attributes
  - Decision making
  - Self-organization and aggregation
  - Information and communication technology
  - Dynamic configuration

- Transaction-based control including constrained optimization of building load operation to provide services required for the grid
  - Non-ideal communication attributes
  - Stochastic energy usage patterns
  - Operational constraints

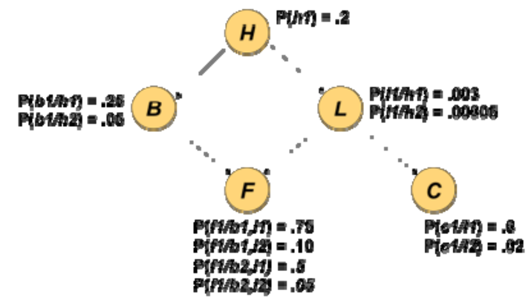


In-Network Intelligence

- **Decentralized agents** with defined dynamics

$$\dot{x}^i = f^i(x^i, u^i) \quad x^i \in \mathbb{R}^n, u^i \in \mathbb{R}^m$$
$$y^i = h^i(x^i) \quad y^i \in \mathbb{R}^q$$

- Establish **communication graph of the network** of nodes



- Understand **Communications channel constraints**

$$y^i_j[k] = \gamma y^i(t_k - \tau_j) \quad t_{k+1} - t_k > T_r$$

- **Develop strategy** that needs to be executed – Peak Reduction etc.

$$J = \int_0^T L(x, \alpha, \mathcal{E}(t), u)\, dt + V(x(T), \alpha(T)),$$

- **Decentralized control execution**
  - slow time constant systems
  - fail-safe controls
  - low-commissioning costs