Transactive Controls in Buildings: Challenges and Opportunities

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Outline

- A Look at Building Energy Consumption
- Transactive Controls (TC)
  - Challenges
  - Opportunity
- Leveraging Multiple Value Streams
  - Increasing Energy Efficiency Services
  - Increasing Hosting Capacity of Renewables
  - Transactive Controls
- Closing Thoughts

Worldwide Building Resource Consumption

30%
Primary energy consumption

33%
Greenhouse gas emissions

25%
Total water consumption

60% Electricity consumption

US Building Resource Consumption

40%
Primary energy consumption

38%
Greenhouse gas emissions

9%
Total world consumption

Nearly 75% Electricity consumption

Opportunity to Reduce Building Energy Footprint and Grid Reliability

20% to 60%

Building and equipment efficiency

20% to 30%

Operating efficiency

15% to 30%

Distributed renewable energy generation

30% to 80% Reduction in building energy consumption is possible

TC Challenges: Hardware Infrastructure

- Less than 15% of commercial buildings have building automation systems (BASs)

- Small- and medium-sized commercial buildings lack the necessary infrastructure – over 60% of commercial floor space

- Residential market is fragmented with many “open” standards and lack of interoperability

TC Challenges: Software Infrastructure

- Deployment of transactive control in buildings requires models that can estimate the load and the consumption as modified transactive control sequences are deployed
- A physics based first principles model can provide the necessary information; however, they are difficult to create
  - Not a scalable solution
- Simplified empirical models that leverage adaptive learning techniques are needed for widespread deployment of transactive controls at scale
- Lack of interoperability both in commercial and residential building systems
- A need for a scalable reference platform to deploy transactive controls
  - VOLTTRON^{TM}, PowerMatcher, etc.

TC Challenges: Variation of End Uses in Large Commercial Buildings

- Large commercial buildings have complex and diverse heating, ventilation and air conditioning (HVAC) systems
- Heterogeneous end uses (HVAC, lighting, etc.)
  - Thermostatic vs. non-thermostatic
  - Discrete vs. continuous
- Multiple energy markets
  - Gas vs. electricity
  - Interdependent
- Multiple sub-markets within a market
  - Air vs. water
  - Interdependent
- Control response could take minutes
  - In many cases, the control is not direct
  - Direct controls possible, but would require significant changes
  - Not a major issue, if the markets cleared every 10 minutes or greater

TC Challenges: Variation of End Uses in Small Commercial Buildings

- Small commercial buildings have less complex HVAC systems
- End uses are heterogeneous
- Markets are simpler – either cooling or heating
- Mostly discrete loads – several minutes to respond
- Fewer loads that can be continuously modulated

TC Challenges: Market Structure

- Widespread use of Transactive Energy concepts and transactive controls require favorable markets structures
  - Dynamic rates
  - Market signals
- Market signals are going to be different in different regions, which makes interoperable interface standards to get at the value streams a challenge

TC Opportunity

- Over 75% of the electricity is consumed in buildings
- Large commercial buildings with BASs can be leveraged with little incremental cost to enable transactive controls
- Empirical end use models that can be adaptively “tuned” can be developed
- Open source scalable platforms, such as, VOLTTRON can
  - Be deployed to coordinate TC by integrating buildings with BASs with the electric grid
  - Can pave the way for inexpensive and “scalable” infrastructure for small- and medium-sized commercial buildings
- Buildings have “virtual” capacity and flexible loads
- Eventually there will be consolidation in home energy management offering or widespread adoption of open source interoperability platforms, such as, VOLTTRON

TC Opportunity: Multiple Value Streams

- To increase the return on investments, investments in hardware or software infrastructure must leverage multiple value streams by enabling deployment of
  - Energy efficiency services
  - Increased hosting capacity of renewable energy
  - Transactive control services

TC Opportunity: Energy Efficiency

20% to 30%

Lack of cost-effective, robust sensor and control solutions

+

Poor operation and maintenance practices and lack of automated technology

→

Results in up to 30% excessive building energy use

Excess energy use is caused by:

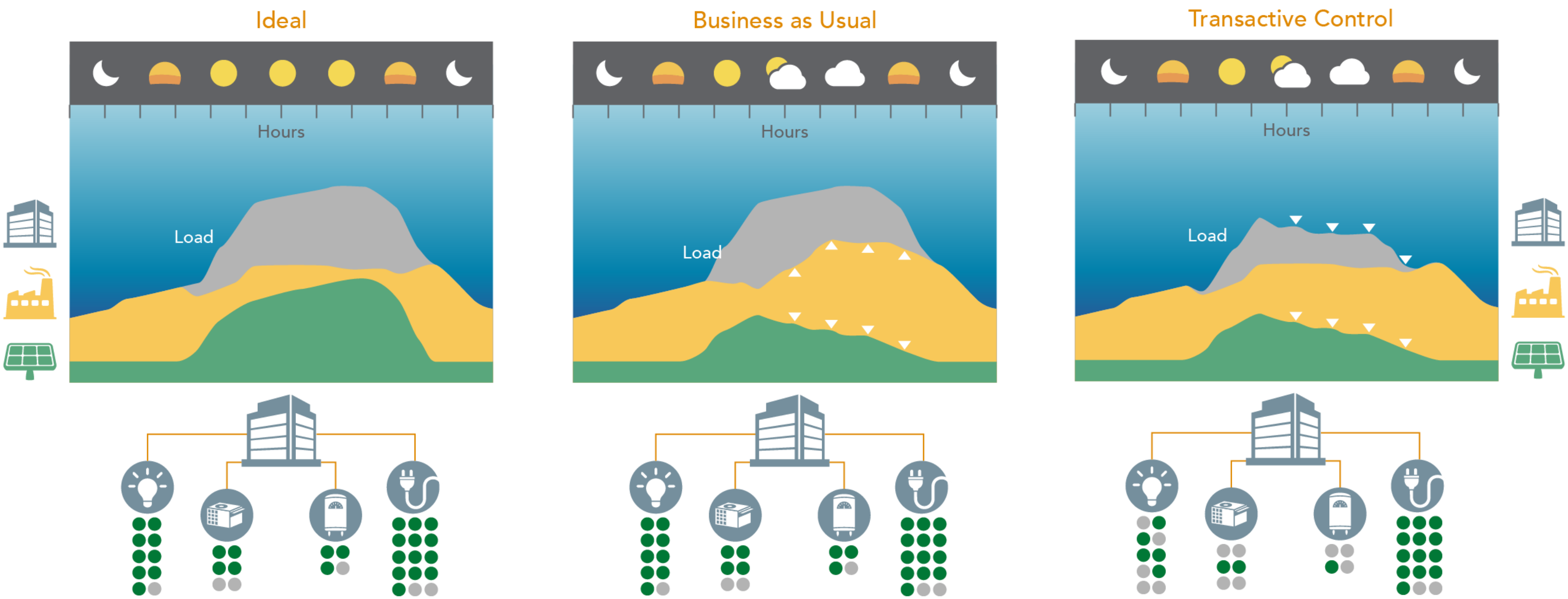
Lack of use of energy-savings control strategies

Override of automatic controls

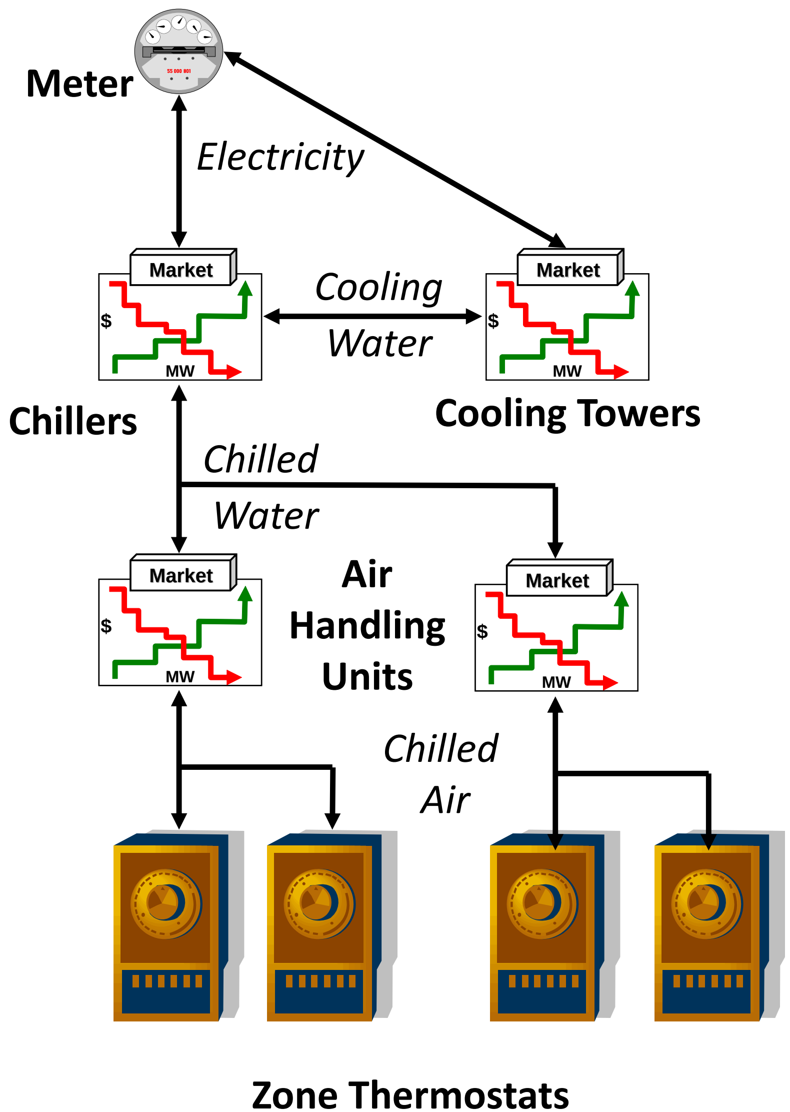
Improper actions

Incorrect original design or installation

TC Opportunity: Increase Hosting Capacity of Distributed Renewable Energy

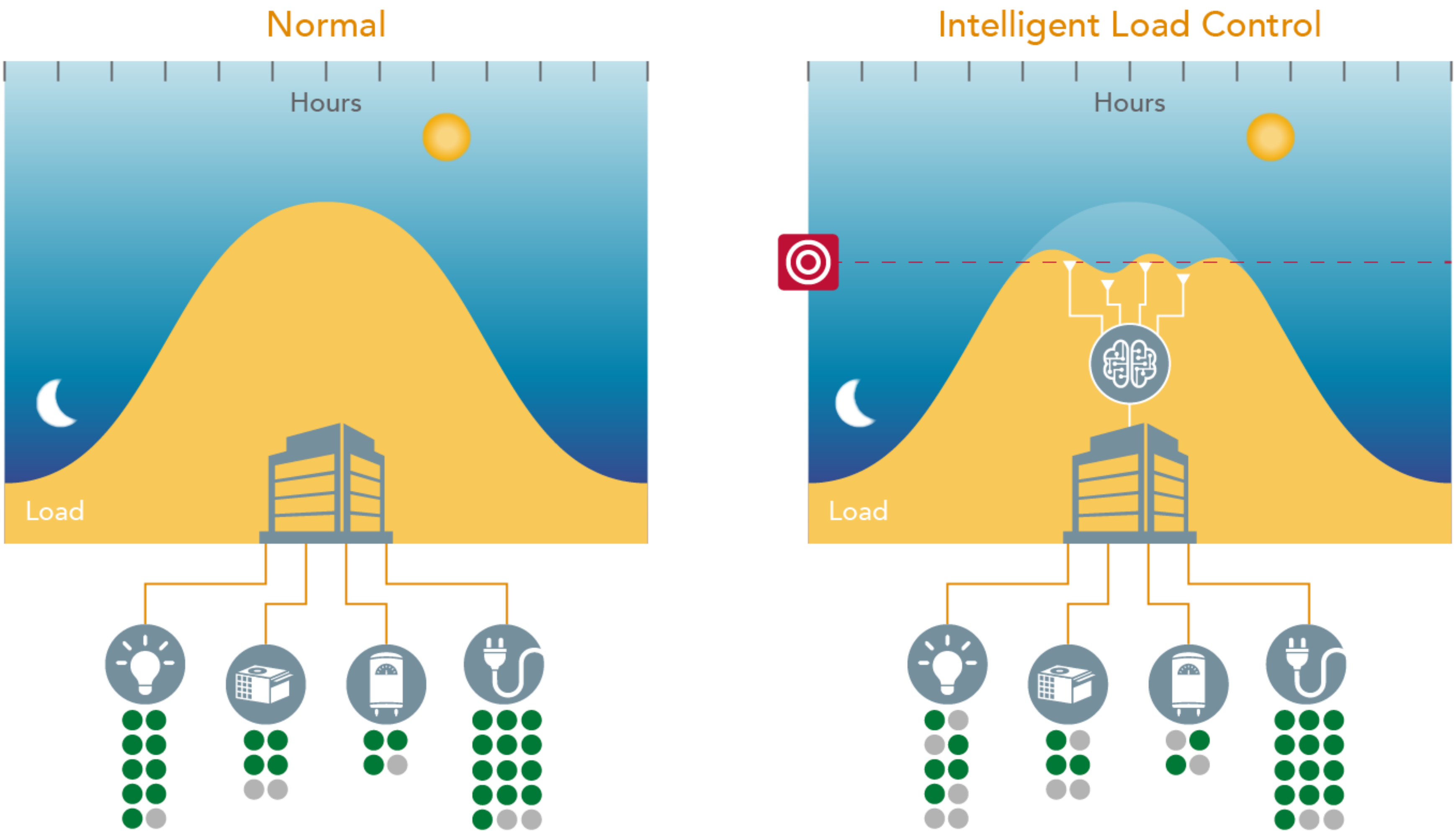


TC Opportunity: Market-Based Control



- Commercial building HVAC controls can be organized as a transactive network
- In principle, has similar self-organizing, self-optimizing properties
  - Chillers “buy” electricity, “sell” chilled water to AHUs, who “sell” chilled air to zone thermostats, etc.
- Incentive signal seamlessly penetrates, system readjusts automatically
- Efficiency potential from diagnostics and chiller/cooling tower optimizations

TC Opportunity: Managing Building Load



Closing Remarks

- There is tremendous opportunity for transactive controls in buildings
- Leveraging multiple value streams will make it cost-effective to deploy infrastructure
- Many of the challenges can be overcome, but a lot more pilots, demonstrations are needed
  - A number of these pilots are underway
- As part of the Northwest Pioneering Regional Demonstration project, we hope to create a number of “recipes” or “how-to guides”
- A number of applications are also being developed to improve building energy efficiency, increase hosting capacity of renewables and support grid reliability through building-grid integration
- The key to widespread adoption of Transactive Energy concepts is a favorable market structure

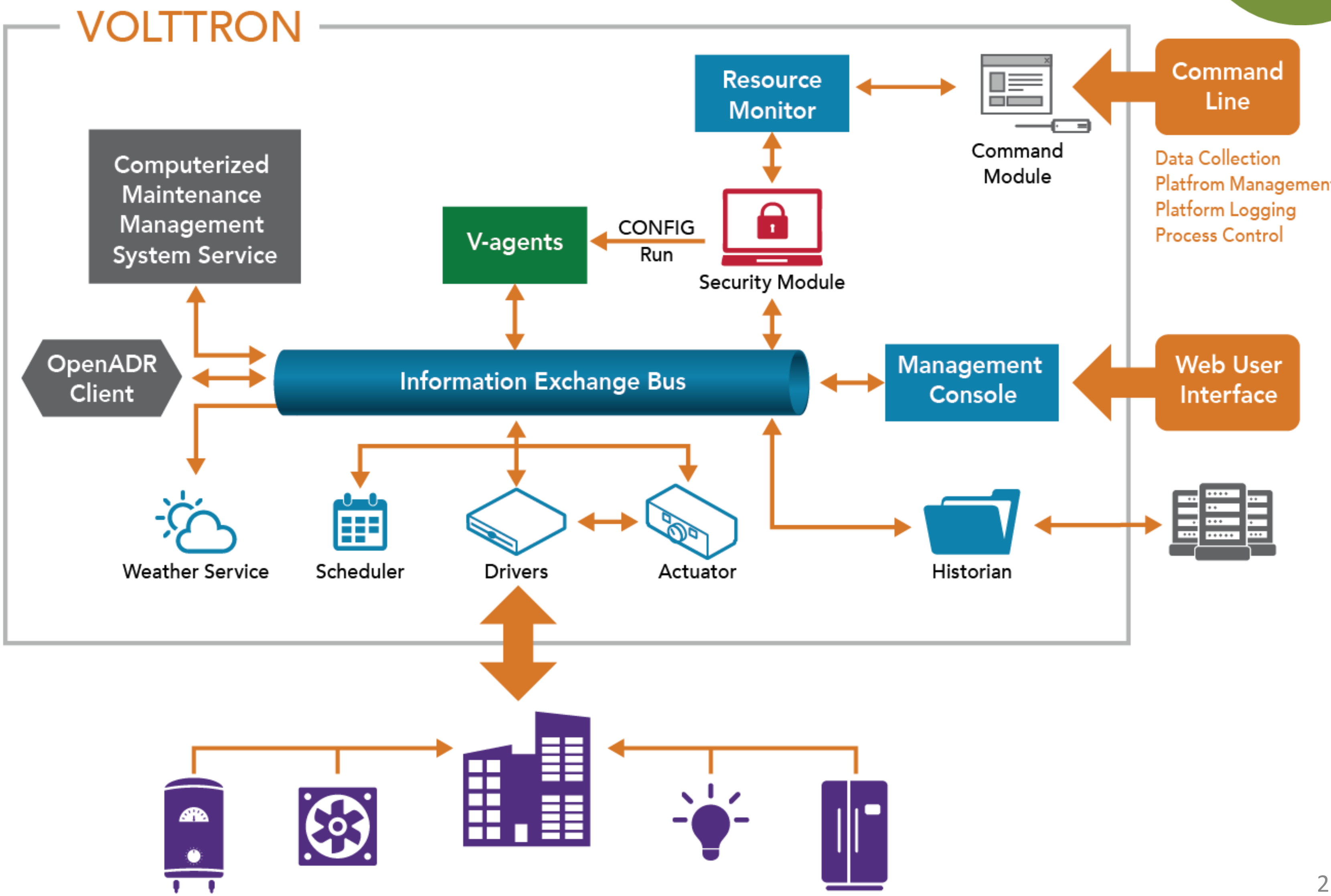
Backup Slides …..

What is VOLTTRON?

- VOLTTRON is an application **platform** (e.g., Android, iOS) for distributed sensing and control applications

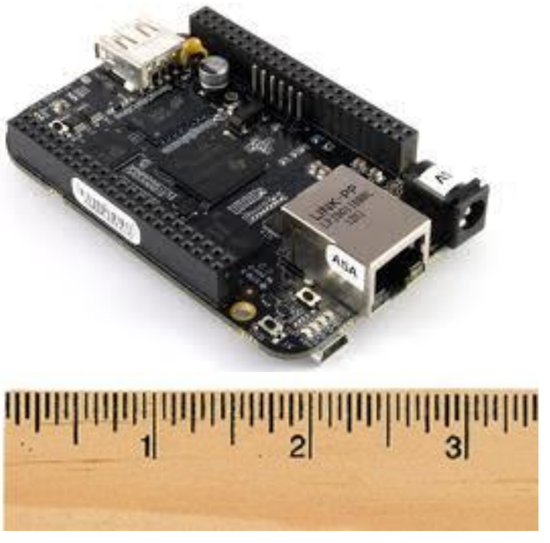
VOLTTRON Platform

20% to 30%



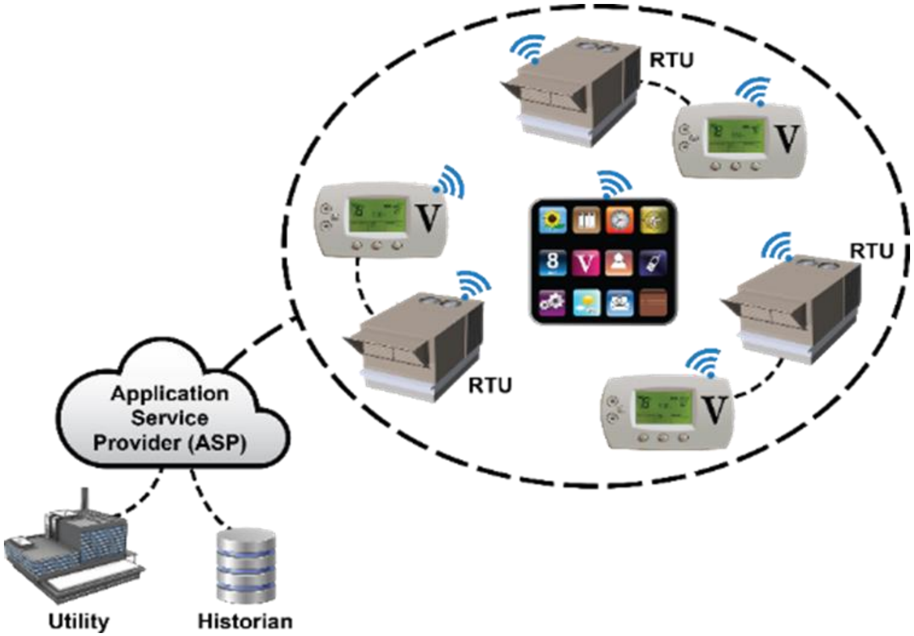
VOLTTRON Attributes

- Open, flexible, and modular
  - Object oriented, modern software development environment
  - Interoperable across vendors and applications
  - Language agnostic; does not tie applications to a specific programming language
    - Ruby, C, C#, C++, Python, Java, Perl
- Scalable
  - Single-board computers, desktop, and Cloud



VOLTTRON Attributes

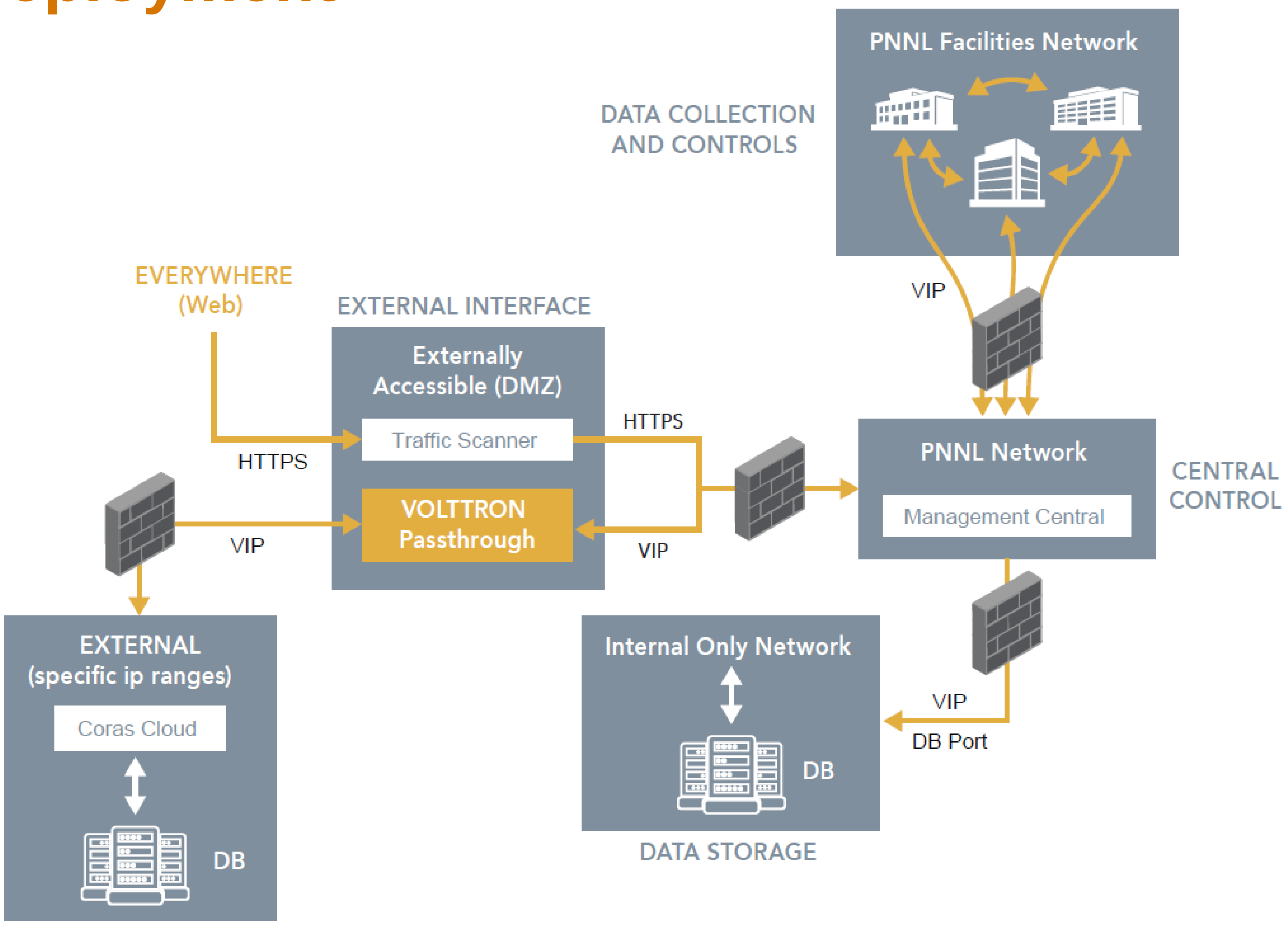
- Built in features to streamline application development
  - Language drivers for MODBUS and BACnet
  - Services for logging and storing data, accessing historical data, scheduling resources
  - Multiple types of controllers and sensors
  - Low CPU, memory and storage footprint requirements
  - Supports non-Intel CPUs

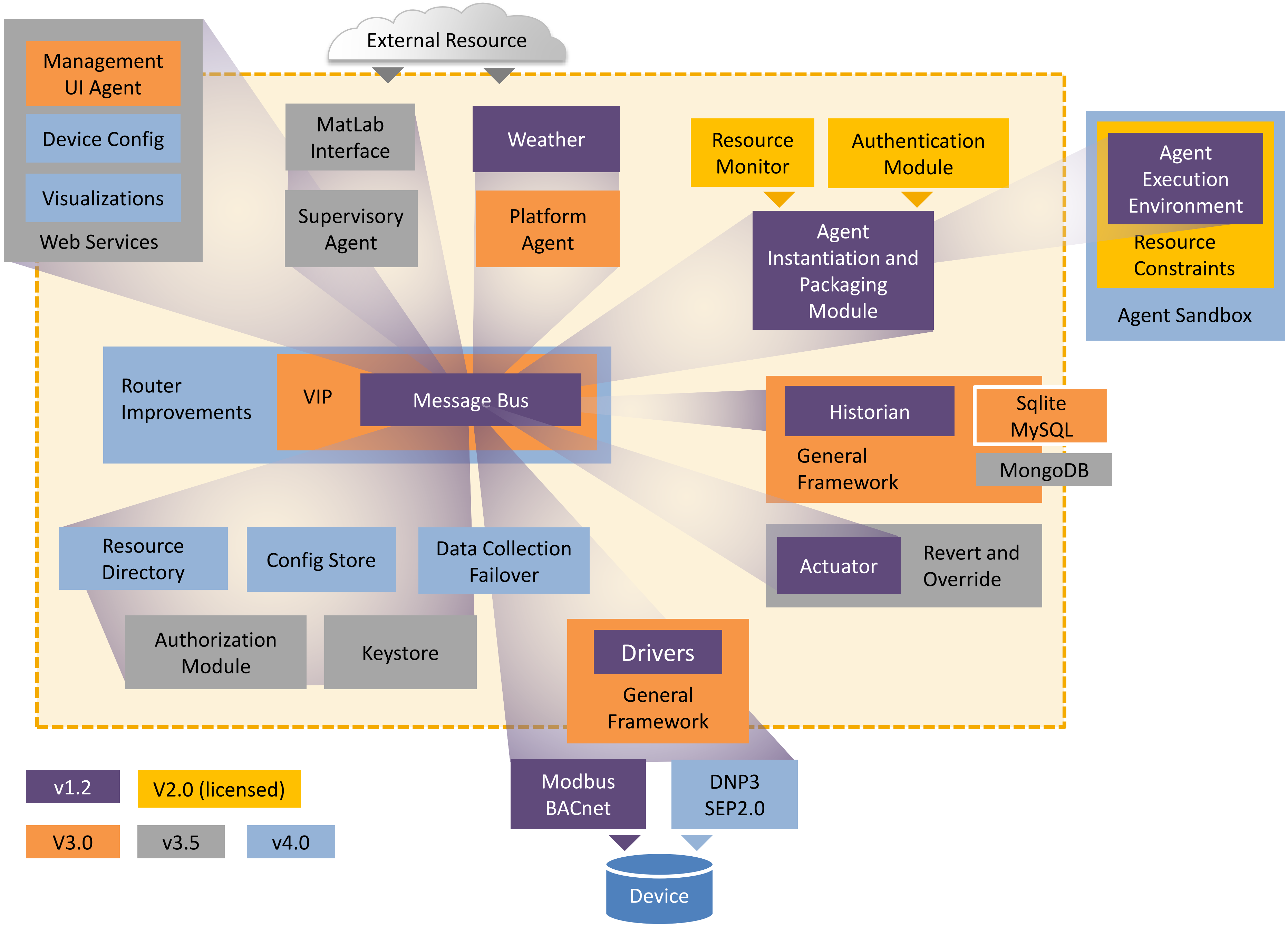


What VOLTTRON is Not

- VOLTTRON is NOT
  - A fully realized commercial grade product with a suite of applications already implemented to perform transactional actions
    - It enables application development, but in and of itself, it is not an energy efficiency solution
  - A protocol
    - Protocols, such as SEP2.0. or OpenADR, are implemented as applications
  - An application, such as demand response
    - Demand response can be implemented as an application on top of VOLTTRON

An Example Secure VOLTTRON Deployment




External Resource
Management UI Agent
Device Config
Visualizations
Web Services
MatLab Interface
Supervisory Agent
Weather
Platform Agent
Resource Monitor
Authentication Module
Agent Instantiation and Packaging Module
Agent Execution Environment
Resource Constraints
Agent Sandbox
Router Improvements
VIP
Message Bus
Historian
General Framework
Sqlite MySQL
MongoDB
Actuator
Revert and Override
Resource Directory
Config Store
Data Collection Failover
Authorization Module
Keystore
Drivers
General Framework
Modbus BACnet
DNP3 SEP2.0
Device
v1.2
V2.0 (licensed)
V3.0
v3.5
v4.0

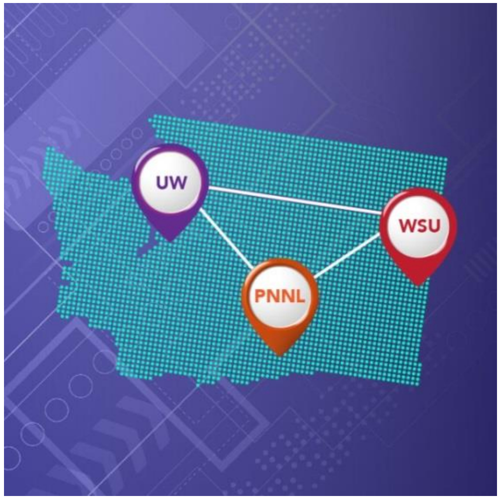
Clean Energy and Transactive Campus (CETC) Project

U.S. DEPARTMENT OF ENERGY

Department of Commerce
Innovation is in our nature.

Pacific Northwest NATIONAL LABORATORY

The Project



Partners:

- Pacific Northwest National Laboratory
- University of Washington
- Washington State University

Experiments:

- Started January 2016; project runs through 2017

Funding:

- $4.5 million, equally from U.S. DOE and Washington state's Clean Energy Fund

Unique:

- First implementation of transactive energy at this scale, involving multiple buildings and devices

Key project technology:

- PNNL's VOLTTRON™ distributed control and sensing software platform

Transactive Energy

What is it?

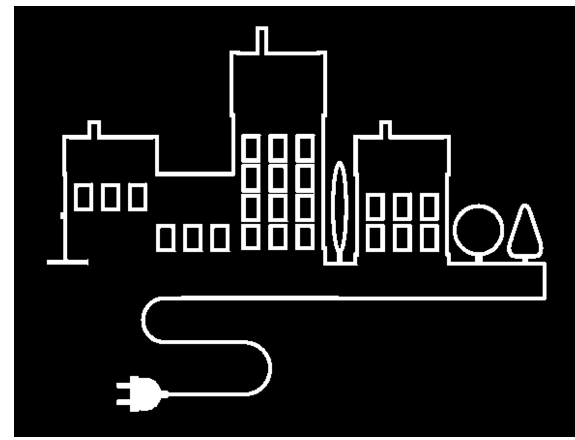
A seamless exchange of signals—representing electricity costs and needs—between power suppliers and users

- Results in:
  - More efficient use of electricity
  - Reduced energy costs for consumers
  - Increased grid flexibility to meet emerging needs
- A key "smart grid" component

Transactive energy offers novel efficiency opportunities for building systems *and* the power grid

Project Objectives

- **DOE**: Demonstrate that transaction-based controls can lead to a clean energy transformation and a reliable and stable electric grid
  - Create blueprint for broader deployment
- **State**: Establish a research and development testbed for renewable integration, efficiency and grid services
  - Position state as national leader in clean energy research and development



Partner Projects at a Glance

PNNL

- Overall project management
- Develop/implement transactive technologies in PNNL buildings and create network to connect the three campuses
- Measure/report on project performance

University of Washington

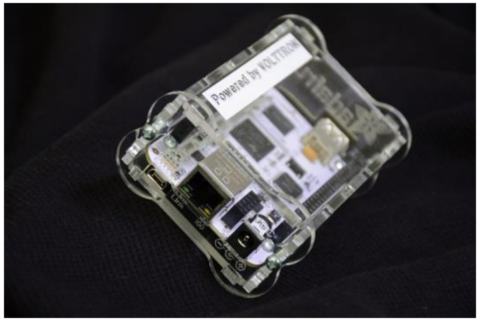
- Install battery energy storage system
- Add inverters to existing/new solar panels
- Translate project data into actionable info

Washington State University

- Establish solar energy modules and integrate in Smart City test bed and WSU microgrid
- Develop strategies for sharing energy between WSU's smart buildings and the solar modules

PNNL Experiments/Tasks

- Establish network infrastructure to connect campuses; create transactive signal
- Deploy intelligent load control in PNNL buildings to manage energy budgets and resource-constrained operations
- Validate/scale proactive controls to provide insights into building equipment problems; run diagnostics to correct
- Demonstrate market-based transactive control within buildings
- Control building loads to reduce grid power fluctuations from distributed renewable generation



CETC Progress: PNNL

Network Infrastructure:

Connect the three participating campuses to develop and test transactive energy concepts

- System requirements have been defined and the data collection process implemented; some VOLTTRON™ nodes are operational.

Intelligent Load Control (ILC):

Manage power use to an agreed-upon threshold

- Initial testing in PNNL building shows ILC can manage or reduce peak electricity demand by controlling heat pumps—without impacting occupant comfort. Deployment in second building proceeding.

PNNL

CETC Progress: PNNL, continued. . .

Automated Retro-Commissioning and Self-Correcting Controls:

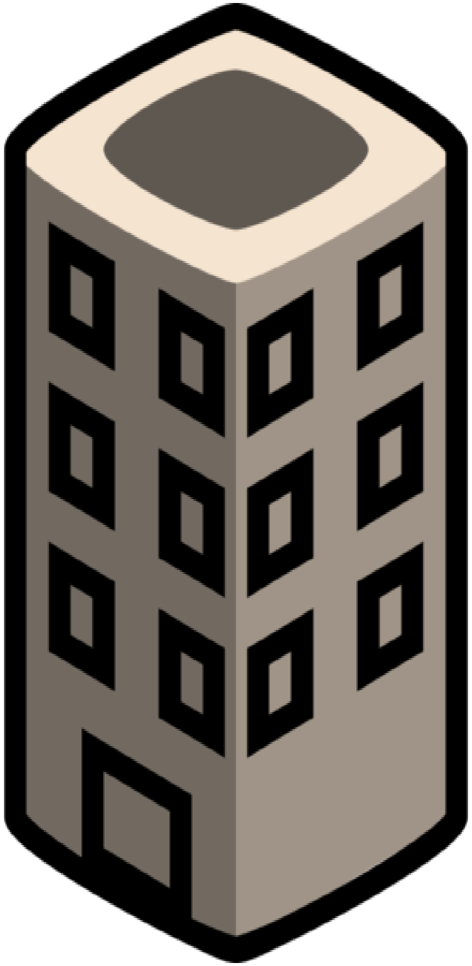
Validate/scale proactive controls to identify and correct building problems

- Diagnostic algorithms were implemented in economizers and air handling units in five PNNL buildings; validation continues. Early results indicate algorithms have been successful in identifying faults in building operations.

Transactive Control:

Develop apps to enable control of building systems and devices to save energy

- Apps created for building zones, air handling units/chillers, and transactive market approaches.



PNNL

CETC Progress: PNNL, continued. . .

Flexible Building Loads for Renewable Integration:

Control building loads to reduce grid power fluctuation from renewables, and from virtual and real energy storage

- PNNL building data (such as fan power and speed, air flow, etc.) and solar data (per intermittency) were collected and analyzed. Algorithms have been designed for—and early testing conducted on—fan tracking of a transactive signal.

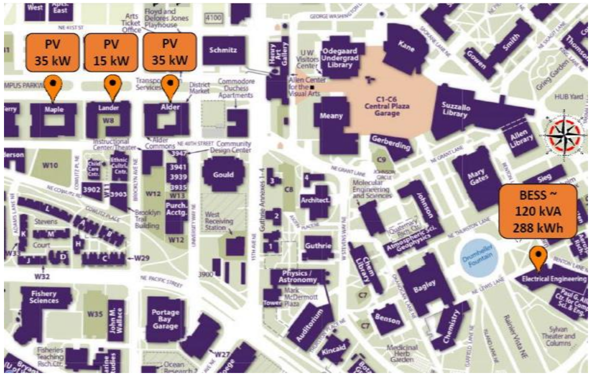
PNNL

University of Washington

- Install lithium-ion battery energy storage system
- Add smart inverters on existing and new photovoltaic arrays
- Establish a distributed energy resources operations center
- Develop/test tools that translate project data into actionable information
- Develop techniques, tools and strategies for the control of buildings, smart inverters and batteries.

CETC Progress: UW

- **Lithium-ion battery energy storage system (BESS)**: Increase flexibility of power consumption across campus
  - BESS Request for Proposals issued
  - Early simulations show the system can shave power peaks in a UW building, as well as respond to transactive signals.
- **Smart inverter installation on UW photovoltaic (PV) arrays:** Optimize generation and the ability to feed solar power into the grid
  - Architecture to control generation has been developed and implemented in VOLTTRON™.



Washington State University

- Establish test bed with emphasis on solar energy and grid integration
- Install solar panel system and grid integration software; bring both into the Smart City test bed and campus microgrid
- Integrate solar panels into distribution system feeders
- Develop/test transactive controls for campus buildings, thermal storage and battery storage.

CETC Progress: WSU

- **PV system**: Install a solar system and integrate it to help power critical Pullman city infrastructure in an outage
  - System requirements established; procurement proceeding
  - Initiated testing of PV inverter module.
- **Auction mechanisms**: Enable real-time power and cost negotiations between buildings on campus
  - Auction mechanisms identified and evaluated.

Artist’s rendering of 75kW solar array at WSU