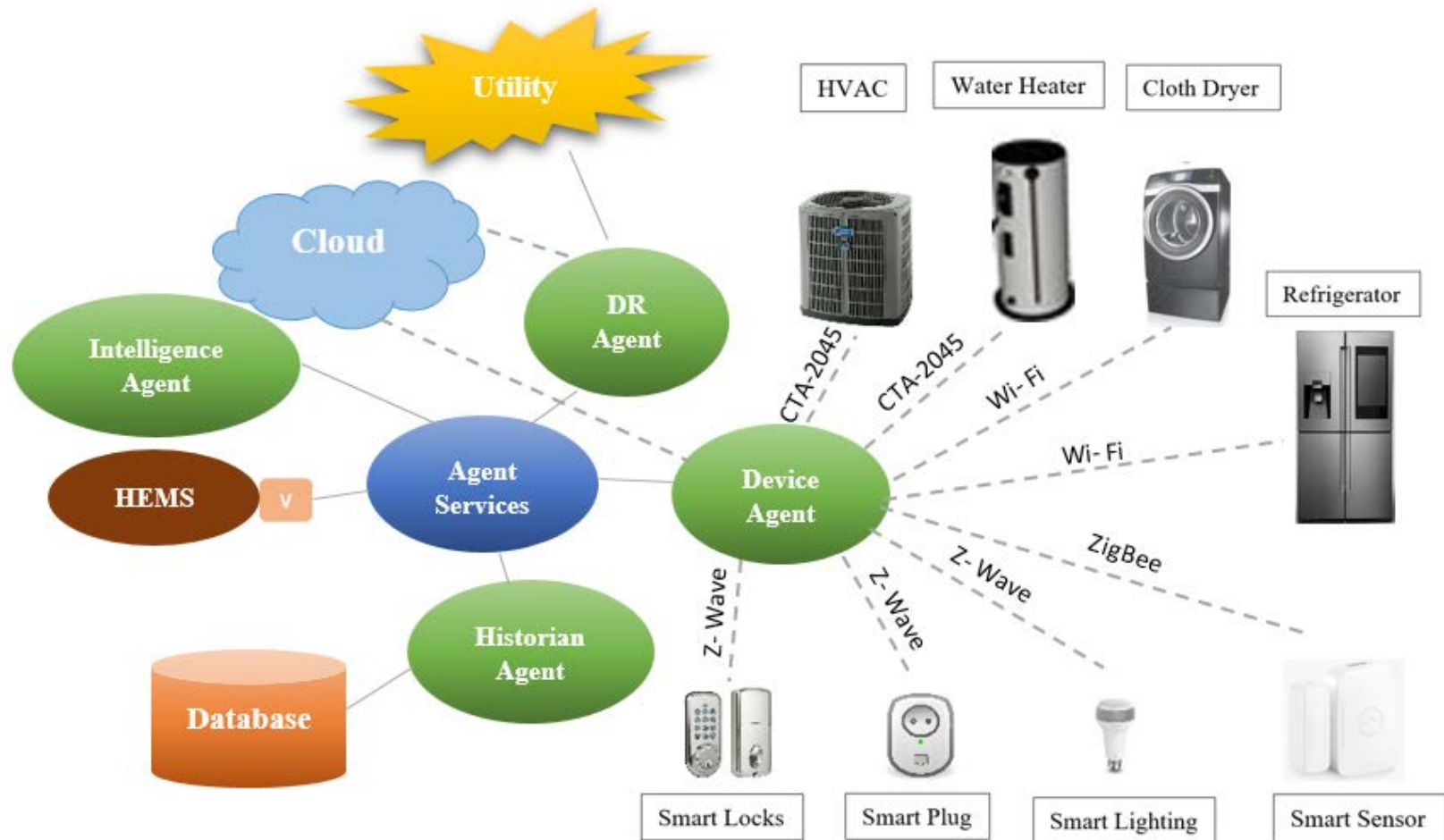


Connected Homes

2017 Building Technologies Office Peer Review



Project Summary

Timeline:

Start date: 03/01/2016

Planned end date: 02/28/2019

Key Milestones:

1. Complete literature review and develop work plan for open-source Home Energy Management System (HEMS) 12/31/2016
2. Integrate an existing HEMS with VOLTTRON™ 3/31/2017
3. Report on stakeholders meeting for harmonizing HEMS, documenting interoperability concerns, 6/30/2017

Budget:

Total Project \$ to Date:

- DOE: \$1,370,000
- Cost Share: \$0

Total Project \$:

- DOE: \$3,000,000
- Cost Share: \$2,000,000

Key Partners:

Emerson	A.O. Smith
Southern Company	PNNL
SkyCentrics	National Assn. of Realtors
EPRI	Haier (GE)

Project Outcomes:

Develop a monitoring and supervisory control system based on VOLTTRON™ that enables the full potential of connected equipment in residential buildings.

- improve efficiency
- reduce peak demand
- reduce energy cost
- increase user amenities

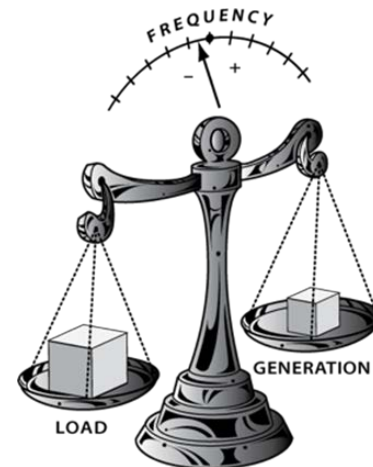
Purpose and Objectives

Problem Statement: Balancing demand and reliability with the variability characteristics from renewable and distributed sources; addressing market gaps with existing HEMS; building a business case for HEMS.

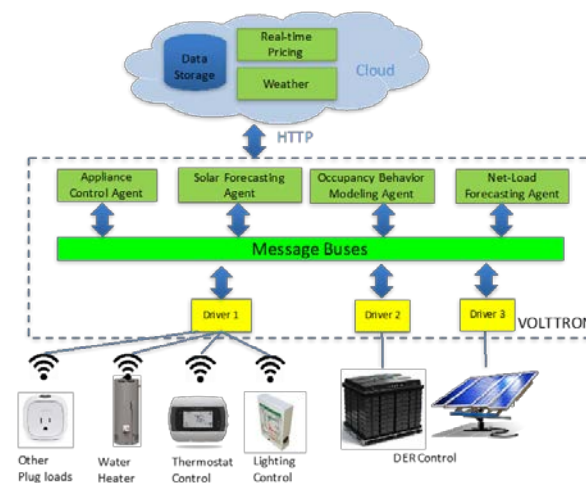
Target Market and Audience: Target market is residential buildings, which account for 22% (14.5 Quads primary) of the nation's total energy consumption. Target audience is homeowners and utilities.

Impact of Project: An easy to deploy, open-source HEMS that enables grid-responsiveness, reduces energy cost, addresses existing market gaps, and improves homeowner amenities.

- Near-term outcomes - Demonstrate end-to-end technology and engage partners to facilitate low-cost deployment and develop market strategy.
- Intermediate outcome – Collaborate with smart device and automation partners for commercialization and deployment.
- Long-term outcomes - Demonstrate homeowner amenities and grid reliability realized by widespread adoption.



Buildings projected to be 80% of load growth through 2040



Approach

Approach: Demonstrate deployment capability of residential end-use connectivity and coordinated control to provide novel grid services at scale through partnerships with the building equipment industry and utilities. (BTO goal)

Key Issues:

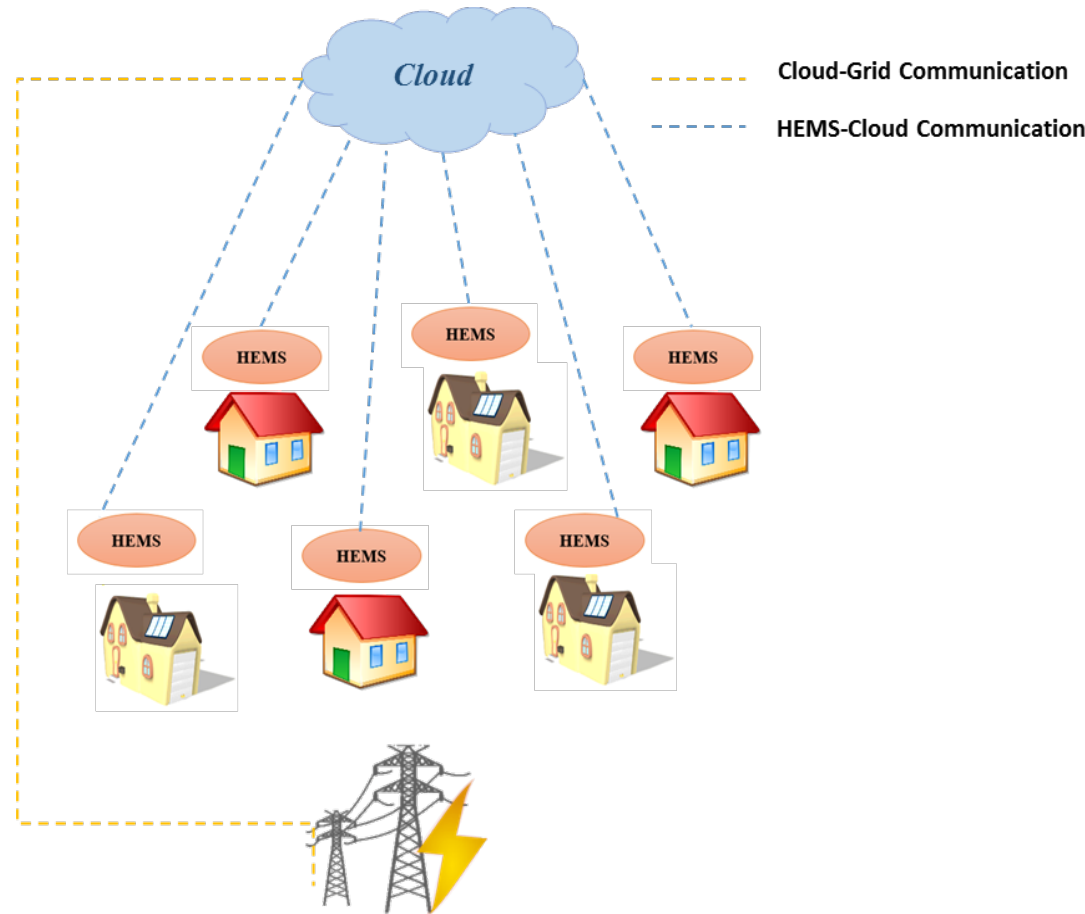
- Enable interoperability by developing multi-protocol device drivers. (HIGH SIGNIFICANCE)
- Enable easy deployment using retrofit-compatible hardware/software. (HIGH SIGNIFICANCE)
- Leverage existing HEMS, hardware, and communications to accelerate deployment. (MED SIGNIFICANCE)

Distinctive Characteristics: Open-source solution addresses key market gaps such as coordinated demand response, ease of deployment, and cross communication among devices.



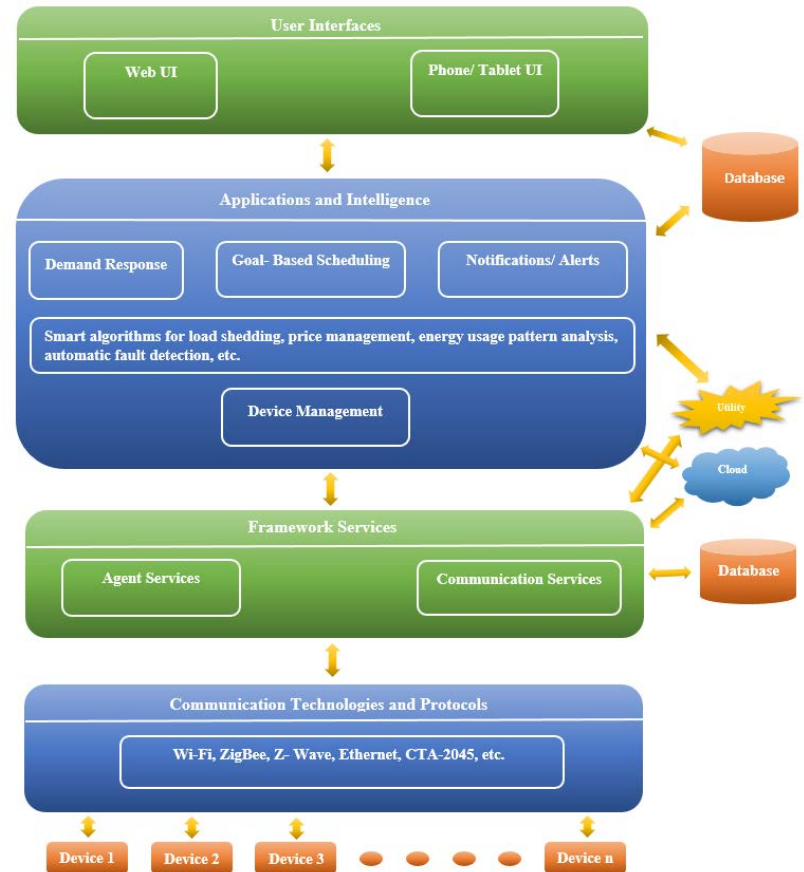
Approach – HEMS Market Gaps

- Based on literature review of existing HEMS, the following market gaps exist:
 - Easy deployment
 - Seamless communication between devices
 - Coordinated demand response
 - Intelligence to act on signal from utility
 - Limited or no security



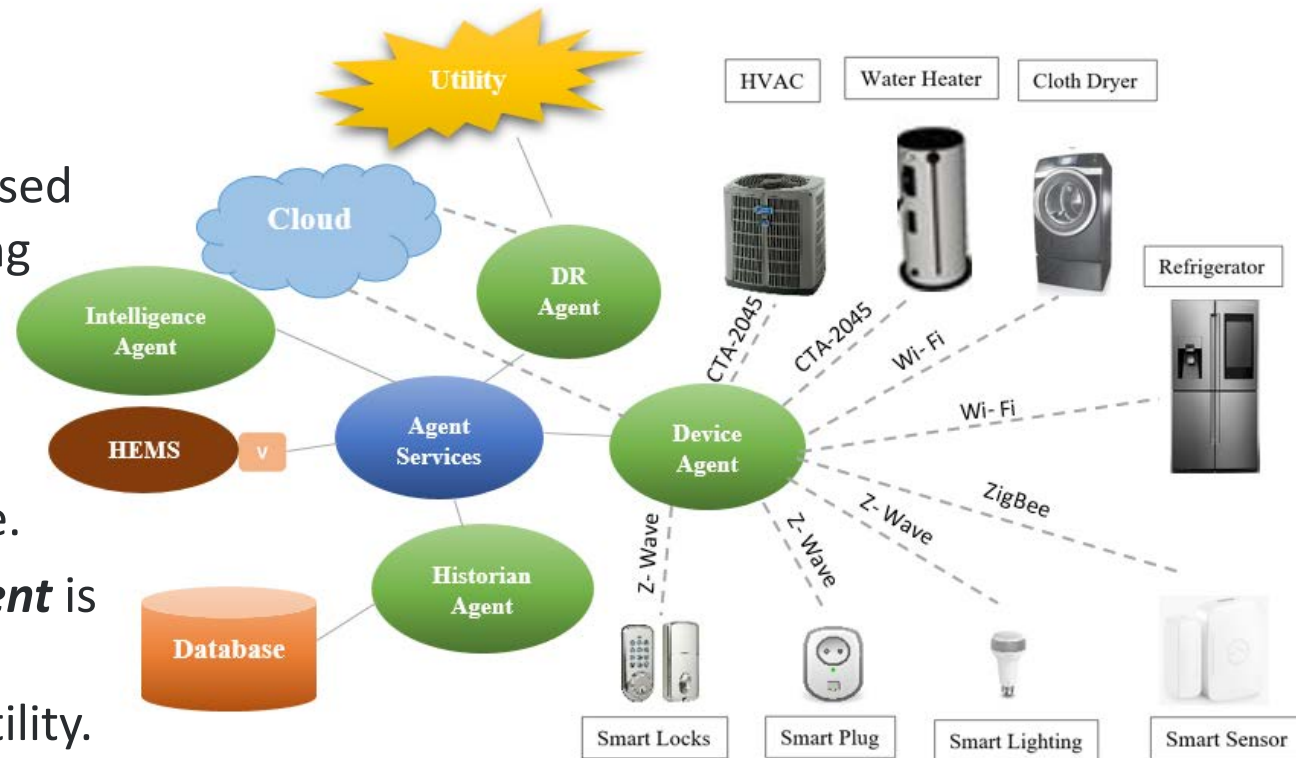
Approach – Addressing HEMS Market Gaps

- Interoperability – Multiple device drivers in VOLTTRON™ allow for all types of communication (e.g., Zigbee, Wi-Fi, Z-wave).
- Intelligence – Coordinated control of devices for scheduling and reducing peak demand (not just on/off).
- Device additions – Supports all types of devices (not just vendor specific).
- Security – Uses vendor API credential and security embedded in VOLTTRON™ which requires key.
- Easy Deployment – Uses existing vendor hardware and user-friendly interface.

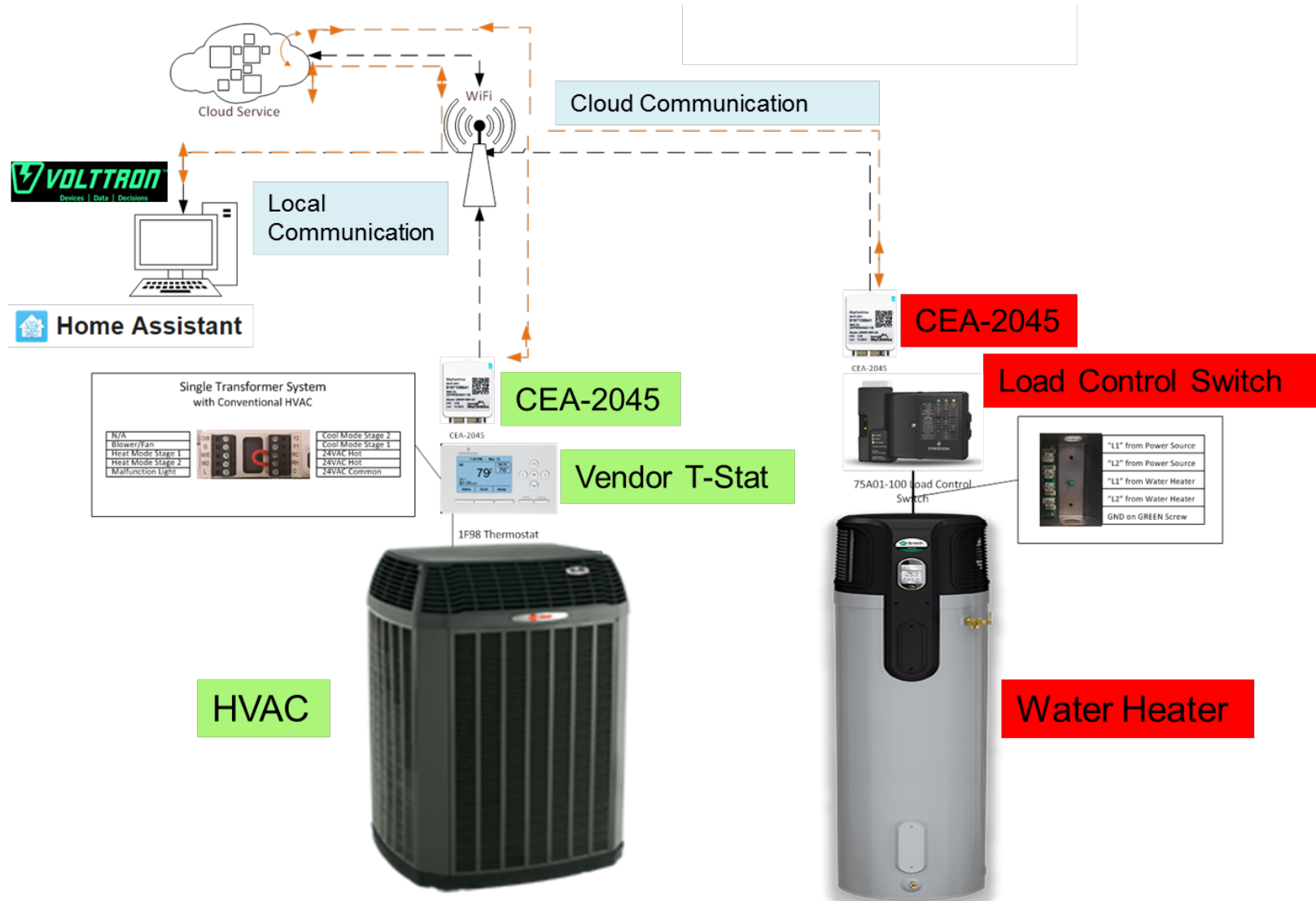


Approach – Using VOLTTRON™ as the Backbone for Services

- All agent services are implemented on top of VOLTTRON™.
- **Intelligent Agent** is responsible for goal-based scheduling and notifying appropriate devices.
- **Historian Agent** is responsible for data retrieval from database.
- **Demand Response Agent** is responsible for communication with utility.
- **Device Agent** is responsible for monitoring and controlling devices.



Approach – Employ Cloud and Local Communication



Progress and Accomplishments

Accomplishments:

- Performed an extensive literature review of existing HEMS to identify gaps.
- Developed HEMS work plan to address gaps (ORNL/TM-2016/756).
- Established local communication with CEA-2045 communication module.
- Developed a means for controlling thermostat with VOLTTRON™.
- Completed the first step of integrating VOLTTRON™ with Home-assistant/NEST thermostat.

Market Impact:

- 2 Publications – IEA Heat Pump Conference, 9th International Conference Energy Efficiency in Domestic Appliances and Lighting
- Invention Disclosure – Smart Transactive Energy Management Scheduler
- Developed partnerships to evaluate market (NAR), coordinate R&D (EPRI), develop low-cost solutions (Emerson, A.O. Smith, Haier, SkyCentrics) and deploy (Southern Company)

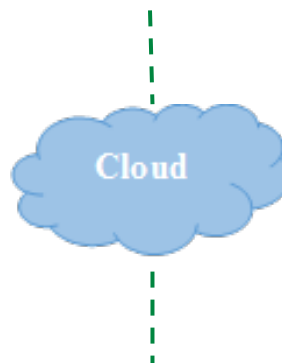
Lessons Learned:

- Existing products require vendor cloud service; no local communication
- Existing HEMS requires an additional software piece to integrate HEMS software with VOLTTRON™

Progress and Accomplishments

HVAC/WH Connections

- Obtained hardware (CEA-2045 plug, Emerson (White Rodgers) thermostat, A.O. Smith load control switch).
- Evaluated communication options
 - vendor cloud service
 - local communication
- Established connection with Emerson T-stat and CEA-2045 plug using SkyCentrics cloud service.
- Established connection with Emerson T-stat locally.



Progress and Accomplishments

HEMS/ VOLTTRON™ Integration

- Goal: control all devices using VOLTTRON™.
- Completed integration of VOLTTRON™ platform with Home Assistant.
- Established connection with Nest thermostat.



Home Assistant



Project Integration and Collaboration

Project Integration: 1) ORNL has an interdisciplinary team to address issues that arise in developing the HEMS; 2) weekly meetings are conducted to address problems and ensure progress against milestones; 3) phone conferences with partners are conducted on an as needed basis; 4) regular (quarterly) project reviews are held with industry partners to report on progress and discuss challenges; and 5) leverages work at PNNL and Connected Neighborhood at ORNL.

Partners, Subcontractors, and Collaborators:

- PNNL – partner lab for VOLTTRON™ coordination
- Southern Company (utility – large scale demo)
- A.O. Smith (manufacturer – water heater)
- Emerson (manufacturer – thermostat)
- EPRI (utility R&D – CEA-2045 plug)
- National Association of Realtors (market assessment and transformation)
- SkyCentrics (manufacturer – Wi-Fi module)
- Haier (GE) (manufacturer – appliances)

Communications: VOLTTRON workshop in Seattle (July 2016), Connected Devices Working Group (Mar, Jun, Oct, Dec 2016), NAR – Jul 2016, CEE Connected Breakout Committee (Jan, Jun 2016)

Next Steps and Future Plans

- Complete end-to-end communication with water heater.
- Demonstrate HVAC/WH control via local and cloud communication in laboratory.
- Develop demand response control algorithms.
- Develop fault detection and diagnostics capability.
- Add additional devices/components to the HEMS.
- Deploy HEMS in test house to evaluate functionality, reliability, and energy/demand control/cost savings.
- Develop partnerships and expand homeowner amenities (additional funding required).



Project Budget

Project Budget: Original project plan included \$1300K for 2016, followed by \$1400K for FY17 and \$300K for FY18.

Variances: FY16 funds actual funds received were \$1170K, of which \$70K was received in April, \$900K was received in July, and \$200K in August. Original FY17 request was \$1400K, of which \$200K was received in January 2017.

Cost to Date: Costs to date are \$493K. Scope and timing are reduced to align with timing and funds received.

Budget History

03/01/2016 – FY 2016 (past)		FY 2017 (current)		FY 2018 – 02/28/2019 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$1170K	\$0	\$200K	\$0	\$1800K	\$2M

Project Plan and Schedule

Project Schedule												
Project Start: March 2016												Completed Work
Projected End: December 2020												Active Task (in progress work)
												◆ Milestone/Deliverable (Originally Planned)
												◆ Milestone/Deliverable (Actual)
	FY2016				FY2017				FY2018			
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: Develop industry partnerships				◆								
Q4 Milestone: Develop market assessment partner					◆							
Q4 Milestone: Establish local communication w/CEA-2045					◆							
Current/Future Work												
Q1 Milestone: Complete work plan						◆						
Q2 Milestone: Integrate HEMS w/ Volttron							◆					
Q3 Milestone: Stakeholders Mtg report								◆				
Q4 Milestone: Connected Homes report									◆			