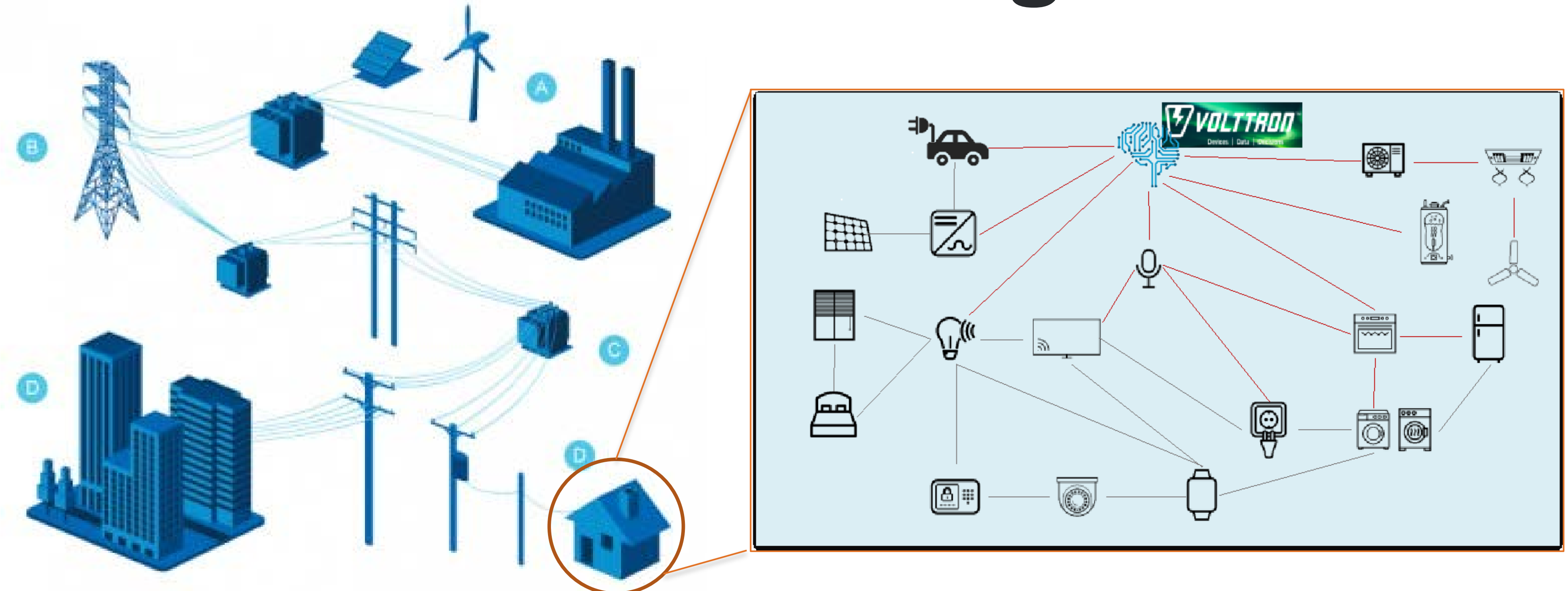
U.S. DEPARTMENT OF
ENERGY
Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Connected Homes & Neighborhoods



Pacific Northwest National Laboratory
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Project Summary

Timeline:

Start date: 01/01/2016

Planned end date: 09/30/2018

Key Milestones

- Publish simulation study on in-home load coordination using transactive control 10/31/2017
- Complete platform development and demonstrate integration in test home 06/30/2018
- Validate savings and peak reduction in test home 09/30/2018

Budget:

Total Project $ to Date:

- DOE: $1.5M
- Cost Share: $0

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Key Partners:

National Rural Electric Cooperative Association
Oak Ridge National Laboratory
SkyCentric
Kisensum

Project Outcome:

Develop transactive-control based solutions for grid-interactive efficient homes:

- Proof of concept for connected homes through a secured software solution
- Validation of the energy-efficiency and demand response potentials of integrated connected home technologies

Team (funded by the project)

Nora Wang, Ph.D., R.A., (*Project lead)*

A variety of research experience in energy efficiency and sustainability; developed Buildings of the Future vision; leading the DOE Asset Score tool development

Karan Kalsi, Ph.D.; **Jianming Lian,** Ph.D.; **Yingying Tang**, Ph.D. *(Control Algorithm Development)*

Experienced electrical engineers; specialized in controls.

Jereme Haack, Raj Singh, Joe Chapman *(Software platform development and device integration)*

Experienced software engineers; Jereme is leading DOE VOLTTRON core development.

Challenge

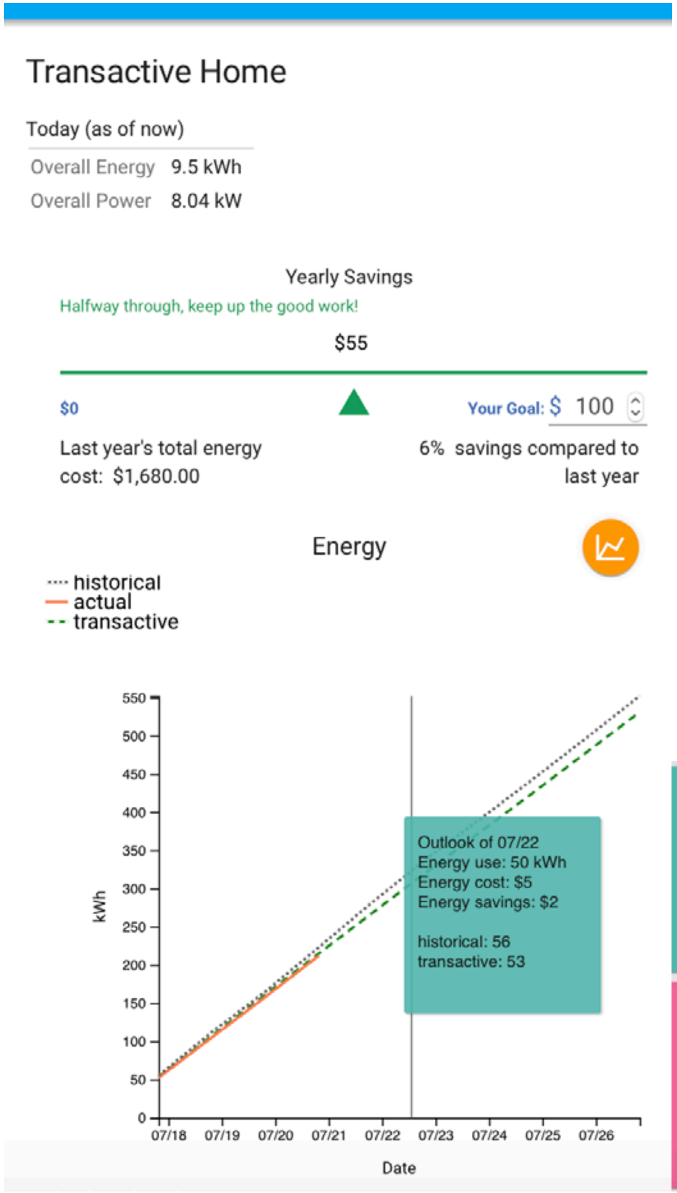
Problem: Traditional Demand Response program has low participation rates because utilities directly control heating/cooling equipment, hot water heaters, or even whole house electricity supply based on grid needs and with little knowledge of customer preference and priority.

Opportunity: Tremendous growth in number of internet-connected and -controllable devices in homes, such as smart thermostats, smart appliances, and smart meters.

Challenges:

- **Customer side:** Capital cost of equipping existing homes with connected devices for “limited” energy savings.
- **Utility side:** Difficulty in predicting load patterns in individual houses and lack of quantified energy-efficiency and demand reduction potentials of connected homes and neighborhood

Approach



Transactive Home

Today (as of now)

Overall Energy 9.5 kWh

Overall Power 8.04 kW

Yearly Savings

Halfway through, keep up the good work!

$55

$0

Your Goal: $ 100

Last year's total energy cost: $1,680.00

6% savings compared to last year

Energy

Outlook of 07/22
Energy use: 50 kWh
Energy cost: $5
Energy savings: $2

historical: 56
transactive: 53

Challenge: Connected devices do not pay back.

However, customers are willing to pay for convenience, comfort, and fun.

Approach: An open-source solution that makes energy efficiency effortless and nearly invisible.

- A platform for various home applications.
- Energy reduction goals can be set by household residents.
- User preference of comfort or convenience over energy reduction is considered as local constraint and reflected in the control strategy.

Pay My Bill

Pay your electric bill online at the utility's website

Report Electric Outage

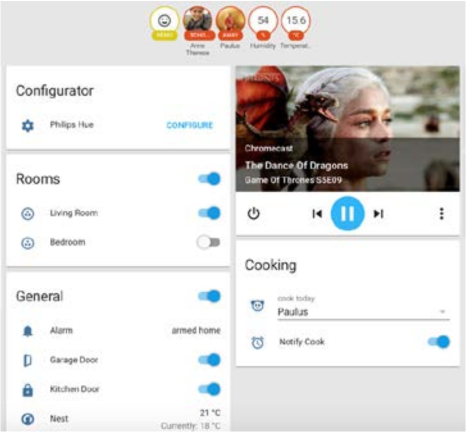
Report an electric outage to the utility

Report Gas Outage

Report a gas outage to the utility

Rebates

Find rebate offers from the utility



Configurator

Philips Hue CONFIGURE

Rooms

Living Room

Bedroom

General

Alarm armed home

Garage Door

Kitchen Door

Nest 21 °C Currently: 18 °C

Chromecast

The Dance Of Dragons

Game Of Thrones S5E09

Cooking

cook today

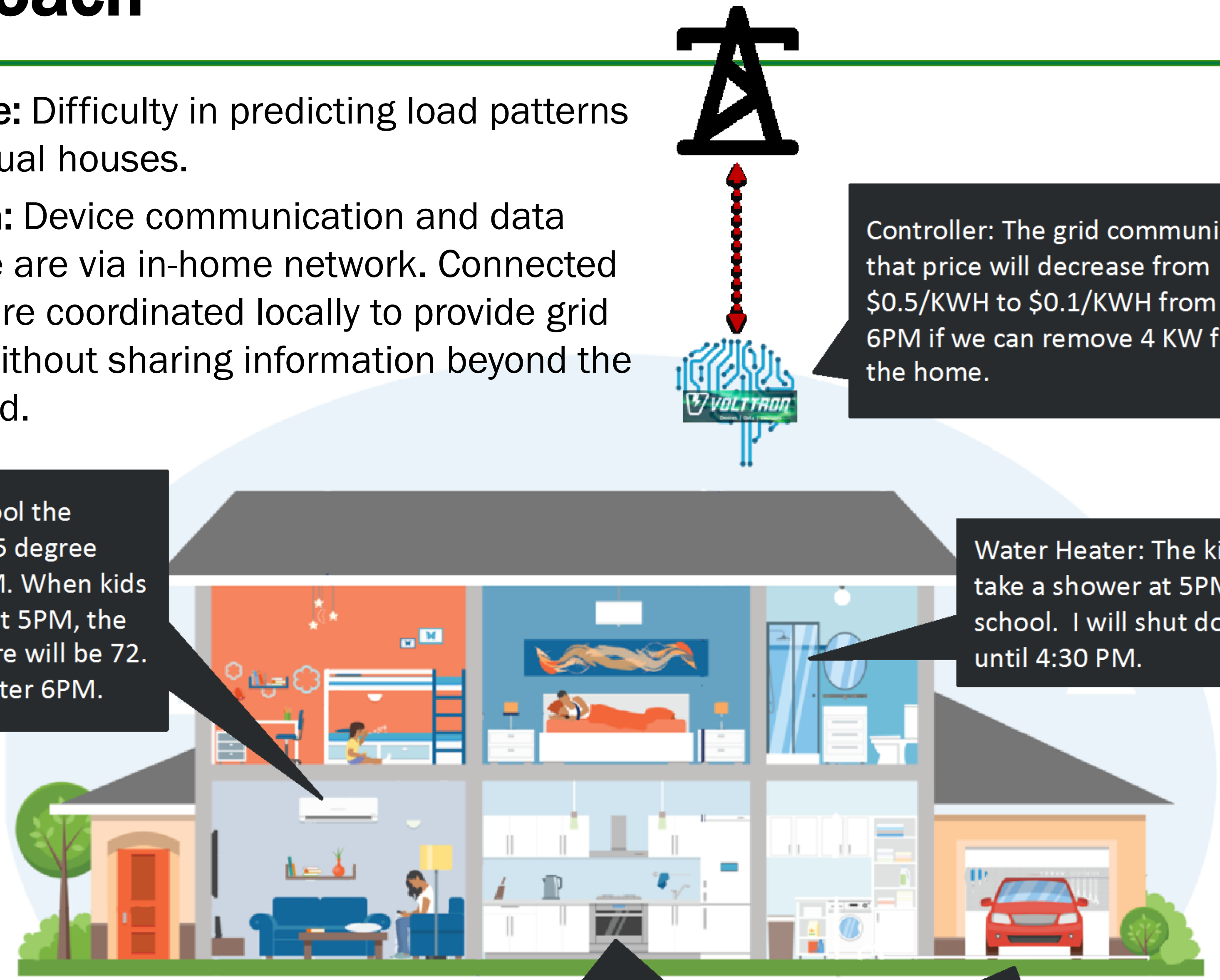
Paulus

Notify Cook

Approach

Challenge: Difficulty in predicting load patterns in individual houses.

Approach: Device communication and data exchange are via in-home network. Connected devices are coordinated locally to provide grid service without sharing information beyond the household.



Controller: The grid communicates that price will decrease from $0.5/KWH to $0.1/KWH from 2 to 6PM if we can remove 4 KW from the home.

AC: I will cool the house to 65 degree before 2PM. When kids get home at 5PM, the temperature will be 72. I will run after 6PM.

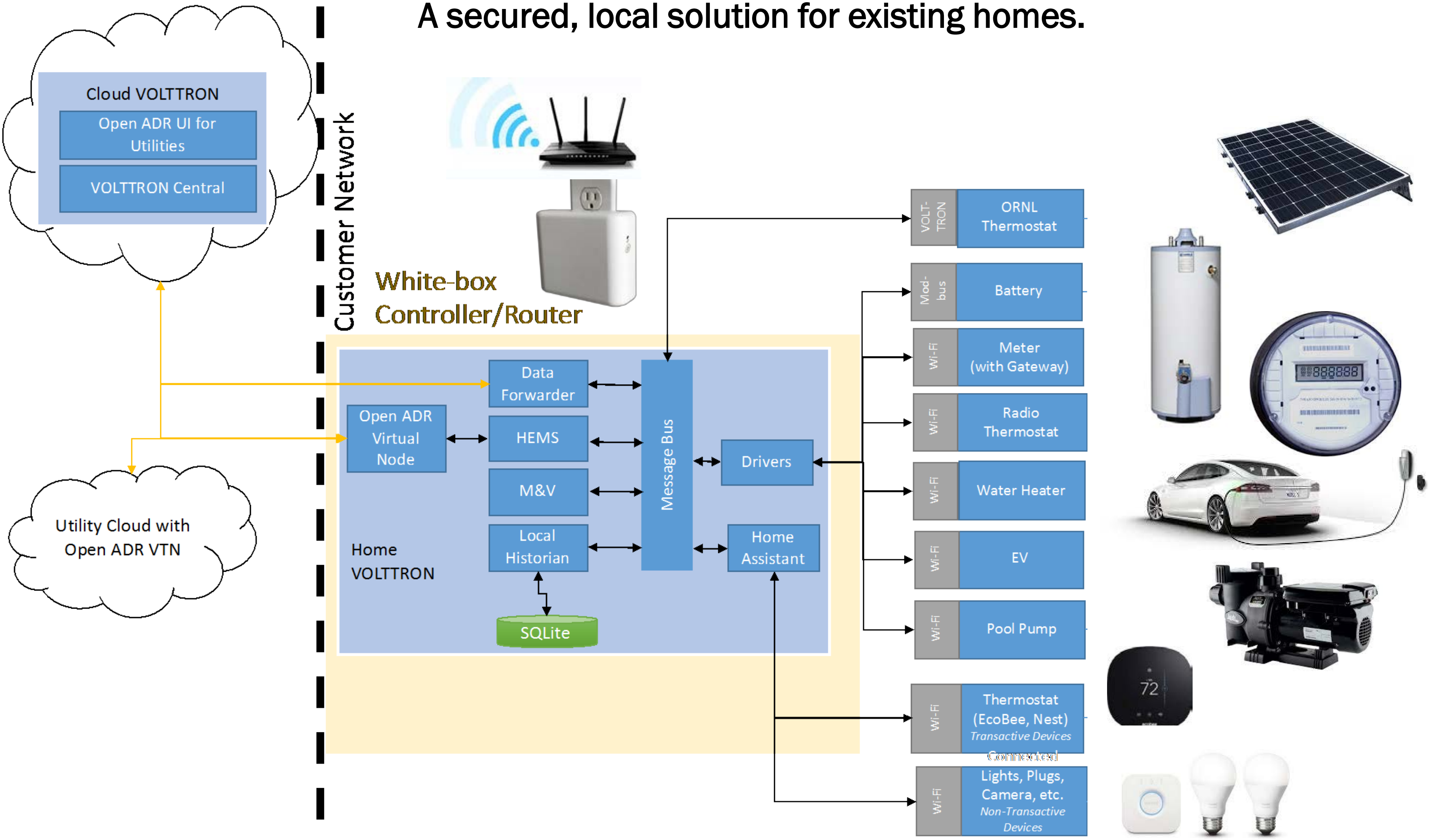
Water Heater: The kids will take a shower at 5PM after school. I will shut down until 4:30 PM.

Dishwasher: I don't need to run until 8PM.

EV: I won't start charging until 7PM.

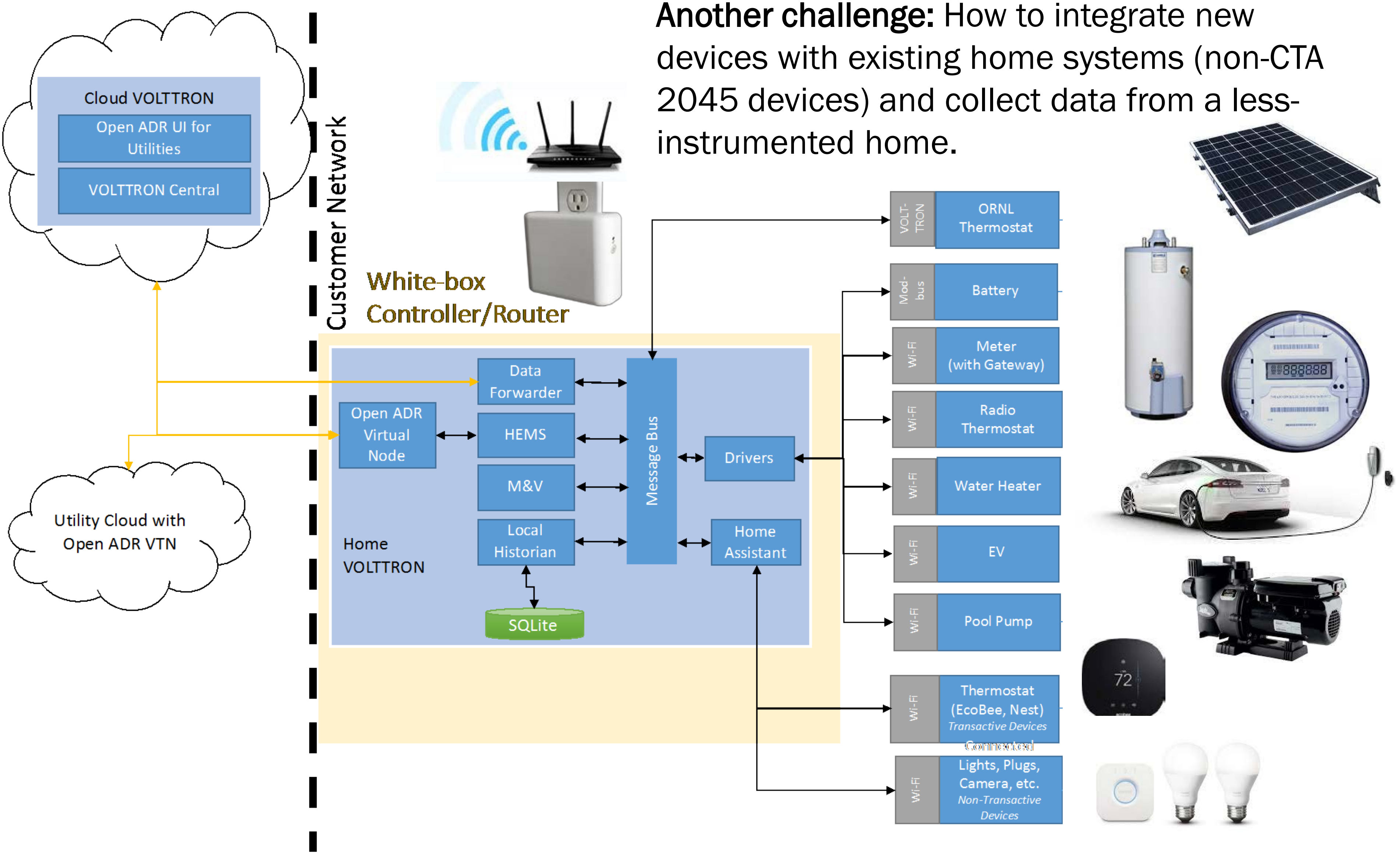
Approach

A secured, local solution for existing homes.



Approach

Another challenge: How to integrate new devices with existing home systems (non-CTA 2045 devices) and collect data from a less-instrumented home.



Cloud VOLTTRON

Open ADR UI for Utilities

VOLTTRON Central

Customer Network

White-box Controller/Router

Utility Cloud with Open ADR VTN

Home VOLTTRON

Open ADR Virtual Node

Data Forwarder

HEMS

M&V

Local Historian

SQLite

Message Bus

Drivers

Home Assistant

VOLT-TRON | ORNL Thermostat

Mod-bus | Battery

Wi-Fi | Meter (with Gateway)

Wi-Fi | Radio Thermostat

Wi-Fi | Water Heater

Wi-Fi | EV

Wi-Fi | Pool Pump

Wi-Fi | Thermostat (EcoBee, Nest) *Transactive Devices*

Connected

Wi-Fi | Lights, Plugs, Camera, etc. *Non-Transactive Devices*

Impact

Potential: New revenue streams for home owners that can provide grid services have a huge potential to be unleashed.

The Federal Energy Regulation Commission estimated 138 GW could be dispatched via demand response by 2019; however, only 3.6 in demand reduction was provided in the residential market based on the EIA 2016 data.

This project aggressively pushes the state-of-art technologies (i.e., connected hardware devices, secured software solutions, and advanced control strategies) and looks to validate value streams by:

- proving that existing homes can be cost effectively upgraded to be grid-interactive efficient.
- quantifying and verifying the energy-efficiency and demand response potentials of connected homes and neighborhoods for utilities.

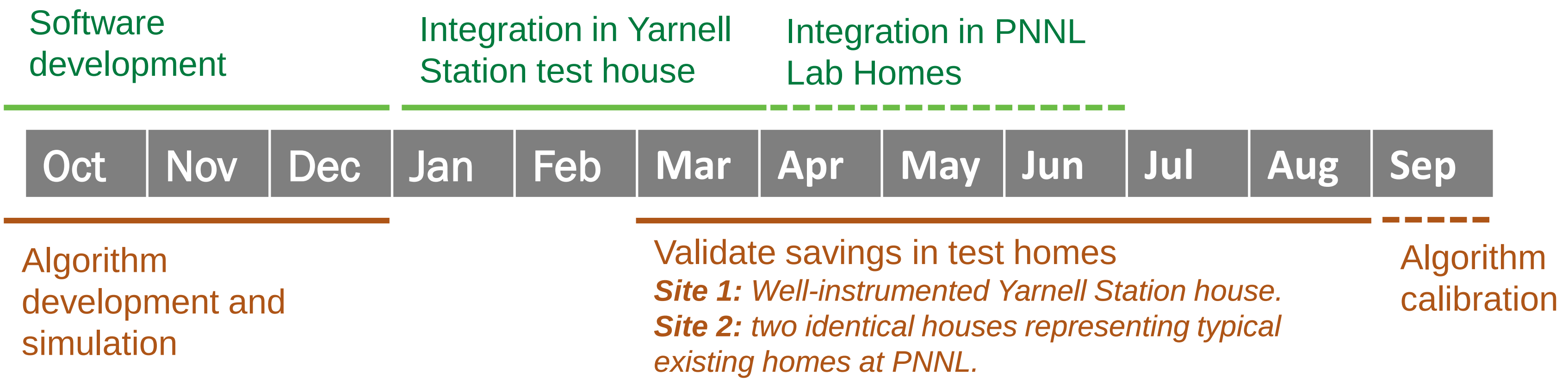
Expected Outcome: With evidence of cost benefits and open-source technology solutions, utilities can develop corresponding rate structures and demand response programs. This will in return give incentives to manufactures and venders to provide lower-cost and more interoperable equipment (such as thermostats/HVAC, hot water heaters, pool pumps, electric vehicle charging stations) for dispatchable energy.

Progress

The team has moved from ideation in simulations to validation in a well-instrumented test home.

- **Platform:** Integrated VOLTTRON with HomeAssistant (HA)
- **Setup:** VOLTTRON and HomeAssistant have local url to simplify user login
- **Drivers:** Skycentrics drivers (CTA-2045) talk directly to VOLTTRON; Other connected devices talk to HA.
- **Data collection:** Data can be sent to a cloud VOLTTRON instance
- **Privacy setting:** UI will allow user to stop data transfer
- **Maintenance:** Utilize Skycentrics service to allow remote troubleshooting
- **Device integration:**
  - Thermostat: Ecobee
  - Hot water: AO Smith
  - Pool pump: Pentair
  - EV charger: Siemens

Integration in the Yarnell test home further revealed the technological risk to large-scale market adoption: difficulty in integrating a new connected platform with existing home systems. Additional test site is being set up at PNNL.



Validate savings in test homes

Site 1: *Well-instrumented Yarnell Station house.*

Site 2: *two identical houses representing typical existing homes at PNNL.*

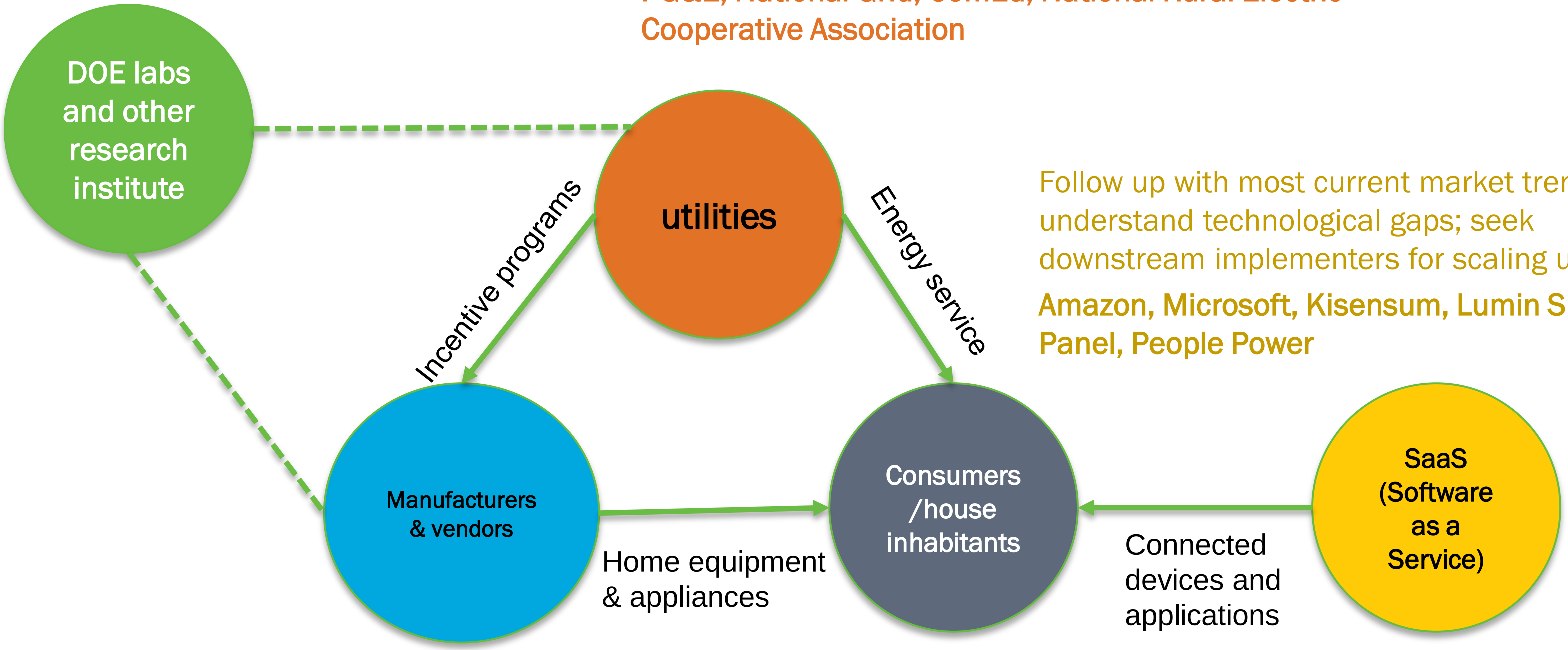
Stakeholder Engagement

Leverage existing effort; exchange experience and resource

Oak Ridge National Laboratory, Northeast Energy Efficiency Partnerships (Home Energy Management Working Group)

Follow up with utility interest and concerns; receive feedback on platform development; get early buy-in for field trials

Consortium for Energy Efficiency (Connected Committee), PG&E, National Grid, ComEd, National Rural Electric Cooperative Association



Follow up with most current market trend; understand technological gaps; seek downstream implementers for scaling up.

Amazon, Microsoft, Kisensum, Lumin Smart Panel, People Power

Integrate with existing systems

SkyCentric

Engaging all players in the “connected homes” ecosystem.

Stakeholder Engagement

Kisensum *(Develop a web application to deliver demand response signals across the internet)*

Specialized in software solutions to integrate, control, and optimize distributed energy resources

National Rural Electric Cooperative Association *(Provide feedback and select voluntary members for field trials)*

Representing more than 900 consumer-owned, not-for-profit electric cooperatives, public power districts, and public utility districts

Oak Ridge National Laboratory (Share test home "Yarnell Station" and provide onsite support; exchange codes and experience)

SkyCentrics *(Provides CTA-2045 module and software for connecting home devices)*

Innovative service provider aiming to empower connected, conscious buildings

Remaining Project Work

Now – September 2018

- Continue data collection and testing in Yarnell Station test home
- Conduct additional testing in PNNL Lab homes (baseline home and controlled home)
- Validate predicted energy-efficiency and demand response potentials in test homes
- Organize a utility advisory group to review developed software/hardware package and test results to prepare for field trials

Beyond FY18

- Develop security solution for any device that could be added to the platform
- Calibrate control algorithms based on test results
- Enhance software platform to be compatible with more existing home devices
- Conduct field studies in 3-5 different climate zones, utility territories, and socioeconomic context
- Conduct large-scale pilot test with utilities

Thank You

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REFERENCE SLIDES

Project Budget

Project Budget: Total project budget $1.5M

Cost to Date: $1.2M

Additional Funding: TBD

Budget History					
1/1/2016– FY 2017 (past)		FY 2018 (current)		FY 2019 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$.8M	$0	$.7M	$0	TBD	TBD

Project Plan and Schedule

- Start date: 1/2016; planned completion date 9/30/2018. Current budget to be spent by end of FY18.
- Go/no-go decision point: Results from the test homes will be presented to a utility advisory group to received (due: 7/30/2018)

Project Schedule

Project Start: 01/2016

Projected End: TBD

▨ Completed Work

■ Active Task (in progress work)

♦ Milestone/Deliverable (Originally Planned) use for missed

◆ Milestone/Deliverable (Actual) use when met on time

	FY2016			FY2017				FY2018			
Task	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work											
Connected Buildings Challenge Demo	▨	▨	▨ ◆								
Focus Groups Report	▨	▨	▨ ◆								
Connected Buildings Action Plan				▨ ◆							
Market outlook of connected homes and neighborhoods					▨ ◆						
Prototype of transactive home energy management system						▨	▨ ◆				
Technical strategies and roadmap transactive residential buildings						▨	▨ ◆				
Current/Future Work											
Complete simulation study on inhome load coordination using transactive control and publish a peer-review paper. This is to demonstrate the potential for EE and DR scenarios							▨	▨ ◆			
Complete development of an inhome load coordination platform that is locally accessible and that can automatically connect to grid-connected devices and support home application using open source tools. Demonstrate the integration of the developed platform and home devices in the PNNL test homes that represent existing homes								■	■	■	
Go/No-Go: Home-load control and coordination platform testing in test home									■	■	
Complete testing the inhome load coordination algorithms in the PNNL test home to validate the potential for EE and DR scenarios										■	■