

Building Energy Management Open-Source Software (BEMOSS)

2016 Building Technologies Office Peer Review





Introducing BEMOSS

An open source platform for building energy management



The US Department of Energy has awarded the Virginia Polytechnic and State University Advanced Research Institute nearly \$2 million to do research and development of its Building Energy Management Open Source Software (BEMOSS) for small and medium-sized commercial buildings.



Project Summary

Timeline:

Start date: November 1, 2013

Planned end date: March 31, 2017

Key Milestones

1. Target release BEMOSS v2.0 on Github – 03/31/2016
2. Target release BEMOSS v3.0 on Github – 03/31/2017

Budget:

Total Project \$ to Date:

- DOE: \$1,206,348
- Cost Share: \$69,861

Total Project \$:

- DOE: \$1,985,795
- Cost Share: \$69,884

Key Partners:

Arlington County, VA

Danfoss Corporation

Virginia Tech Foundation

Project Outcome:

The **Building Energy Management Open Source Software (BEMOSS)** platform, along with the user interface for three plug-and-play compatible controllers –HVAC, lighting and plug loads, that can help small- and medium-sized commercial buildings to improve energy efficiency and facilitate their demand response implementation.

Purpose and Objectives

Problem Statement: Lack of inexpensive open-source building energy management (BEM) software solutions that allow seamless integration with device controllers (HVAC, lighting and plug loads) from various manufacturers.

Target Market and Audience: Small- and medium-sized commercial buildings

Impact of Project:

1. Project endpoint: Make available an open-source and cost-effective solution for building energy management.
2. Project outcomes:
 - a. Near-term outcomes (1yr): A few pilot sites demonstrating how BEMOSS can provide energy savings and peak demand reductions in buildings; and participation from software developers to build more App.
 - b. Intermediate outcomes: (1-3yr): Growing number of BEMOSS deployment in buildings; and founding of start-up company(ies) which commercializes BEMOSS and provides maintenance services.
 - c. Long-term outcomes(3yr+): Widespread use of BEMOSS in small- and medium-sized commercial buildings.

Approach

Approach:

Phase 1: BEMOSS software development (2014)

Phase 2: Lab testing and software enhancement (2015)

Phase 3: Demonstration in buildings (2016)

Key Issues: BEMOSS addresses plug & play and interoperability issues of selected HVAC, lighting and plug load controllers for energy savings and peak demand reduction in small- and medium-sized commercial buildings.

Distinctive Characteristics: Open source software that can provide low-cost deployment of building energy management, allowing energy savings and facilitating demand response implementation.

BEMOSS is Built upon Open-Source Software

VOLTTRON™ was used as a platform to host our BEMOSS solution. It is open-source and not hardware specific.



Other software used:



PostgreSQL

ZeroMQ



BEMOSS Interoperability

Communication Technologies

- Ethernet (IEEE 802.3)
- Serial Interface (RS-485)
- ZigBee (IEEE 802.15.4)
- WiFi (IEEE 802.11)



Data Exchange Protocols

- BACnet (IP and MS/TP)
- Modbus (RTU and TCP)
- Web (e.g., XML, JSON, RSS/Atom)
- ZigBee API
- Smart Energy (SE)
- OpenADR (Open Automated Demand Response)



BEMOSS Plug & Play

With BEMOSS discovery agent, we know:

- The device is present in the building.
- Device model number, e.g., 3M-50.
- What the device can do, e.g., monitor temperature and adjust set point.

BEMOSS automatically discovers new load controllers deployed in a building



BEMOSS on Various Embedded Devices

Cubieboard



CPU: Arm Cortex
A15x4 @2GHz, A7x4
@1.3GHz
RAM: 2 GB
Price: **\$138**
Size: 5.8"x5.6"

ODROID Hardkernel

XU4



CPU: Arm Cortex
A15x4 @2GHz, A7x4
@1.4GHz
RAM: 2 GB
Price: **\$74**
Size: 3.3"x2.3"

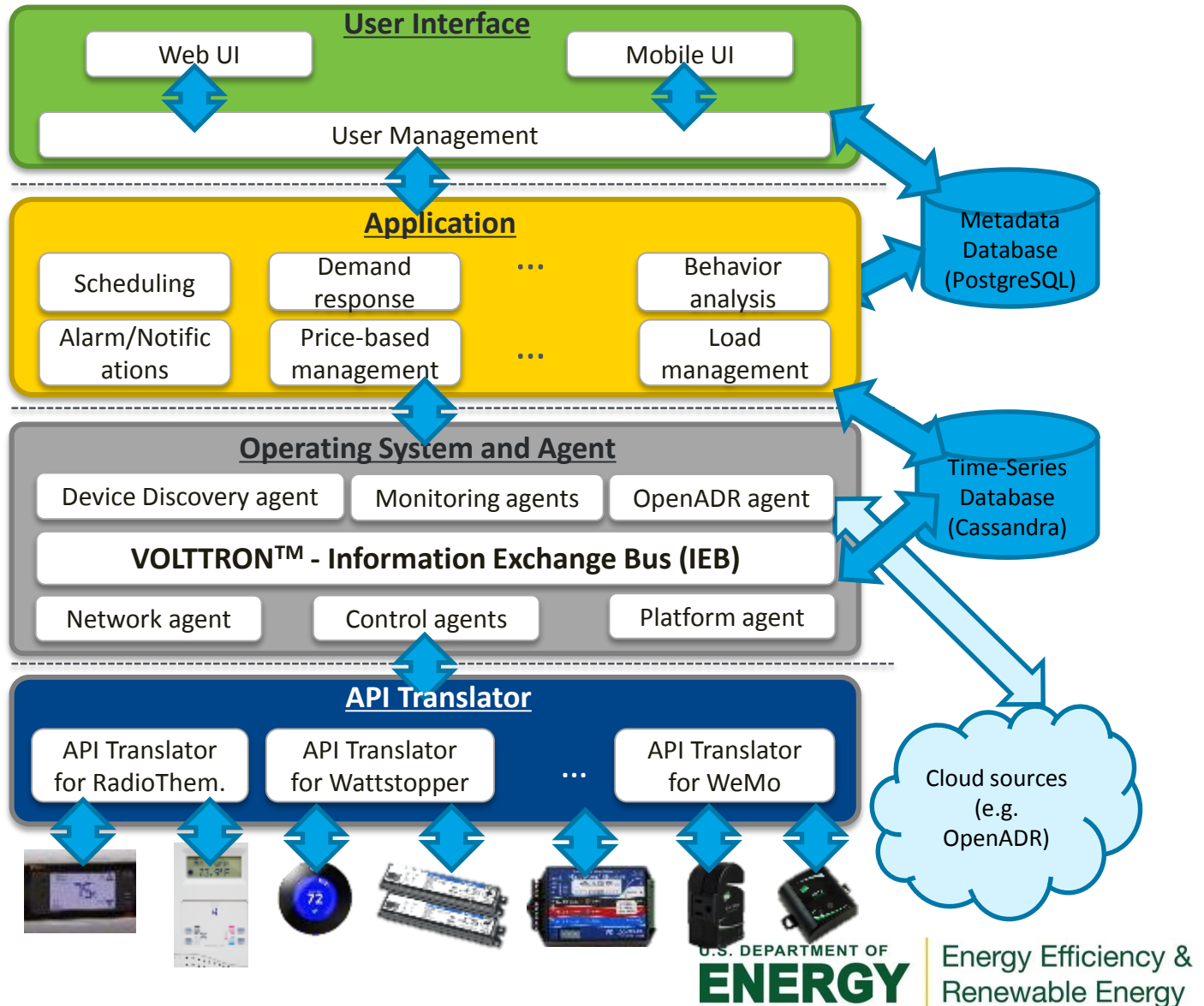
WANDBOARD.ORG



CPU: Arm Cortex A9
Quad core @ 1 GHz
RAM: 1 GB
Price: **\$129**
Size: 3.4"x2.4"

This enables low-cost deployment, and expandability.

BEMOSS Software Architecture



Living Laboratory – Building 1

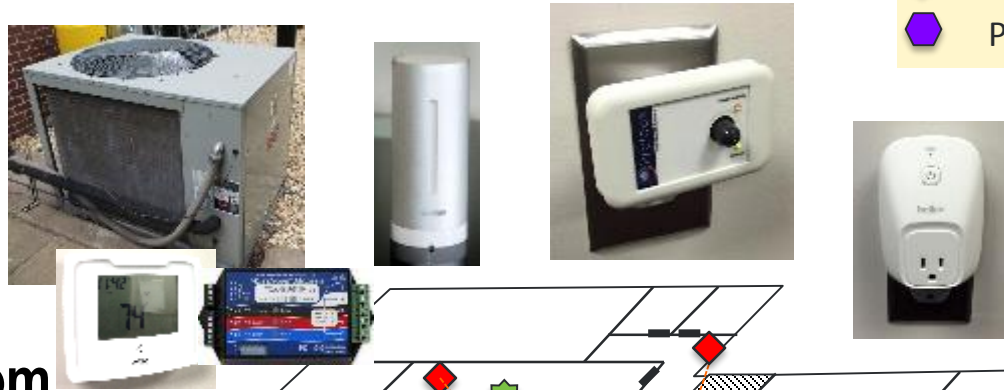
1021 Prince St.,
Alexandria, VA 22314



Area: 25,000 SF
Energy: 14-25 MWh/mo.
Peak load: 61 kW

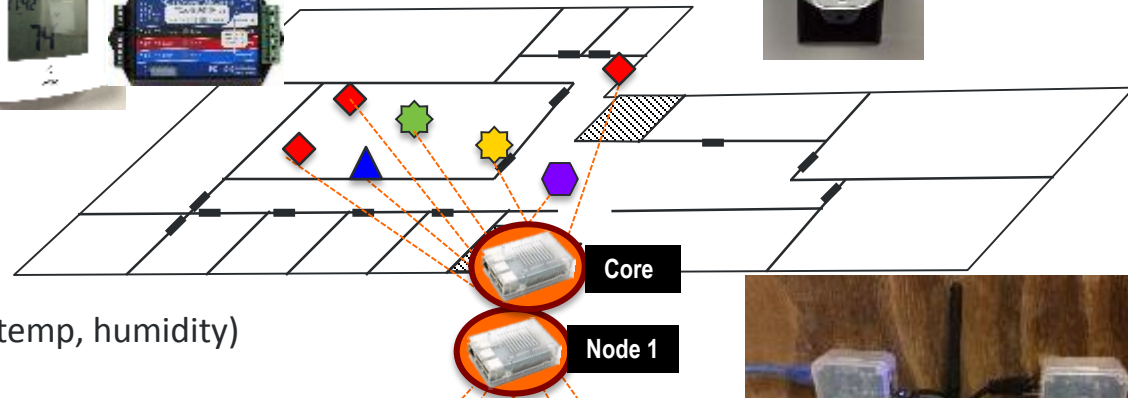
Living Laboratory Setup

- ▲ Thermostats (WiFi)
- ◆ Plug load controllers (WiFi)
- ★ Motion sensor (WiFi)
- ☆ Environment sensor (WiFi)
- ⬡ Power meter (Modbus)



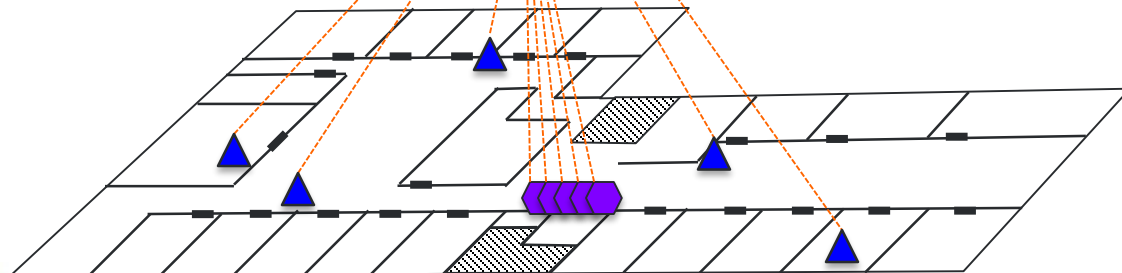
Floor 3 – Classroom

- 1 thermostat
- 3 plug load controllers
- 1 motion sensor
- 1 environment sensor (CO₂, temp, humidity)
- 1 power meter
- BEMOSS core
- BEMOSS node

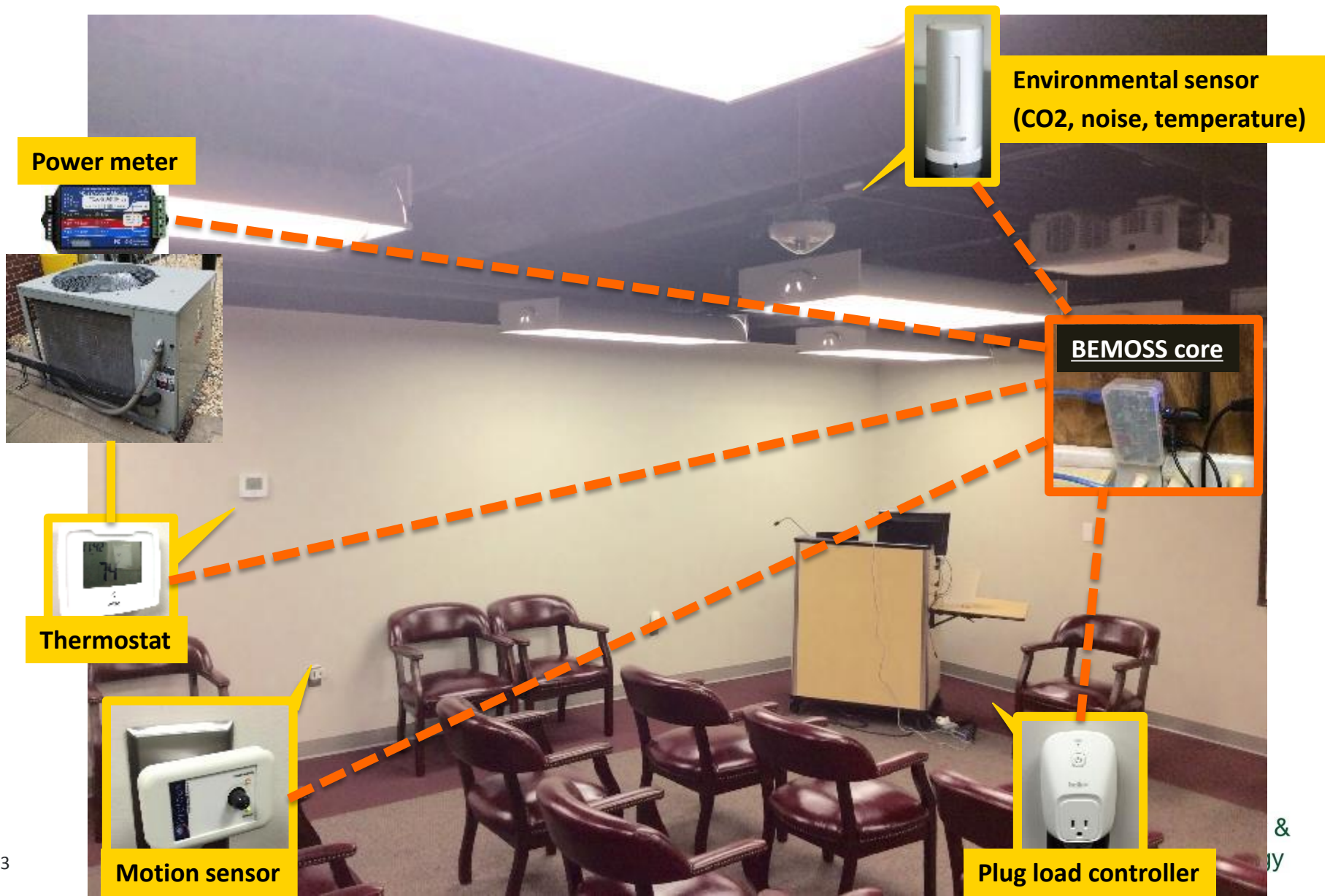


Floor 2

- 5 thermostats
- 5 power meters



Classroom being Monitored by BEMOSS Core



Building 2 – Equipment Bureau in Arlington, VA

2701 S Taylor St,
Arlington, VA 22206



Office building size: 5,000 sqft
Electricity consumption: N/A

Building 3 – Retails and Offices in Blacksburg, VA

460 Turner St
Blacksburg, VA 24060



Office building size: 41,301 sqft
Electricity consumption: 49,800-65,200kWh/month

Progress and Accomplishments

Accomplishments:

Target date for BEMOSS v2.0 release in Github: 3/31/2016

Market Impact:

Energy savings and peak demand reduction from adjusting thermostat set points, light intensity and status of plug loads.

Lessons Learned:

API of devices can change overtime. A possible mitigation approach is to sign a contract with device manufacturers to make the developer aware of any API changes before their release.

Project Integration and Collaboration

Project Integration:

- The BEMOSS advisory committee with representatives from 22 organizations from government and Industry has been established. The advisory committee members meet face-to-face on a quarterly basis with additional email exchanges based on work at hand.



Project Integration and Collaboration (Cont'd)

Partners, Subcontractors, and Collaborators:

Partner	Role
Arlington County	Offers access to Long Branch Nature Center for energy consumption data
Danfoss Corp.	Supports in modeling the performance of HVAC units under different operating conditions
VT Foundation	Offers access to buildings in Alexandria and Blacksburg, VA for BEMOSS demonstration

Communications:

- ❑ “BEMOSS: An agent platform to facilitate grid-interactive building operation with IoT devices” presented at ISGT Asia 2015, Nov 2015, Bangkok, Thailand.
- ❑ Invited talk at Arlington Public Library, Arlington, VA, sponsored by the joint Northern Virginia/Washington PES Chapter, in collaboration with the Industrial Applications and Control System Society Chapters in Northern Virginia and Washington, 24 June 2015, Arlington, VA.
- ❑ Invited Talk at Syracuse University, Co-organized by Dept. of EECS, Syracuse University & AP/MTT/EMC Chapter of the IEEE Syracuse Section Syracuse, NY, 19 June 2015, Syracuse, NY.
- ❑ “BEMOSS: An Agent Platform to Enable Grid-Interactive Building Operation with IoT Devices”, presentation at the Workshop on Big Data Analytics in CPS: Enabling the Move from IoT to Real-Time Control, 6 April 2015, Seattle, WA.

Next Steps and Future Plans

Next Steps and Future Plans:

- BEMOSS deployment in three small and medium-sized buildings
- Functionality test and operational availability evaluation
- Estimation of electricity savings potential
- Transition of BEMOSS to v3.0
- Delivery of BEMOSS software tool v3.0 in Github

REFERENCE SLIDES

Project Budget

Project Budget: DOE: \$1,985,795 VT: \$69,884
Variances: N/A
Cost to Date: DOE: \$1,206,348 VT: \$69,861
Additional Funding: N/A

Budget History

Budget Year 2		Budget Year 3		Future (planned)	
January 2015 – January 2016 (past)		March 2016 – March 2017 (current)			
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$706,403	\$0	\$779,448	\$23	\$0	\$0

Project Plan and Schedule

Project Schedule												
Project Start: November 2013	Completed Work											
Projected End: March 2017	Active Task (in progress work)											
	◆ Milestone/Deliverable (Originally Planned) use for missed milestones											
	◆ Milestone/Deliverable (Actual) use when met on time											
	FY2014				FY2015				FY2016			
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												
Task 1: BEMOSS Open Source Software Development					◆							
Task 2: BEMOSS user interface and software tool design					◆							
Task 3: Plug & play device integration					◆							
Task 4: Incorporate additional software feature											◆	
Task 5: BEMOSS software open source access and survey											◆	
Task 6: BEMOSS advanced algorithm development											◆	
Task 7: BEMOSS lab scale testing											◆	
Task 8: Engineering design for BEMOSS deployment											◆	
Current/Future Work												
Task 9: Demonstration in three buildings												
Task 10: Estimation of electricity savings potential												
Task 11: BEMOSS demonstration for fault detection												
Task 12: Transition of BEMOSS to v3.0												
Task 13: Delivery of BEMOSS software tools												
Task 14: Project management and reporting	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆

2016 BTO Peer Review - Presentation Instructions

(not a template slide – for informational purposes only)

- **Presentation Submission Requirements:**
 - MS PowerPoint format
 - Size Limit: 15 MB (prefer smaller file)
 - Due Date: Monday, March 14, 2016
 - Submit via email to BTOPeerReview@ee.doe.gov
 - Name your electronic MS PowerPoint presentation file as follows (use the first 4 letters of your title):
[Title_Organization_LastName.ppt]
- **NOTE:** We will send your presentations to reviewers prior to the meeting. To provide adequate time for the reviewers, you **MUST** submit your presentation by **Midnight (EDT) on March 14, 2016**. You may **NOT** bring a different presentation to the event. Reviewers will see the same presentation at the peer review event that they review off-line in advance.

2016 BTO Peer Review - Presentation Instructions

(not a template slide – for informational purposes only)

- **All red text** on the slides should be deleted (when it is instructional) or replaced with information (when it is placeholder text).
- **Do not** include any proprietary, copyrighted, or confidential information. Do not mark any slide with “Official Use Only” or any similar restriction used by your organization.
- **Do not** incorporate animation or special effects. All presentations will be saved as PDF files for presentation and for posting on the web. Animations critical to describing the project may be presented as separate files, however they must be approved by the Program and presented within your allotted time.
- The 2016 BTO Review is reviewing active projects. Emphasis should be on the activities and progress during the past year. For new projects, focus on activities and progress since project start (**be sure to clearly identify yourself as a new project**). However, presenters may include past progress to put current activities/progress into context. Presenters should also describe future activities/milestones that will bring the project to successful outcomes and conclusions.
- Use of graphics is encouraged. The presentation rooms will seat up to 70, please be mindful of your text size and visibility of presentation materials to attendees.

2016 BTO Peer Review - Presentation Instructions

(not a template slide – for informational purposes only)

- Your project will be scored by the peer reviewers on the following evaluation criteria:
 - Relevance to BTO needs and objectives (stand-alone metric)
 - Approach/Project Management (30%)
 - Progress, Accomplishments, and Impact or Potential Impact [for new projects] (40%)
 - Project Integration and Collaborations (20%)
 - Next Steps and Future Plans (if applicable) (10%)
- NOTE: You should allocate your slides and presentation time according to the scoring and weights noted above. Presenters will be held to their allotted time.

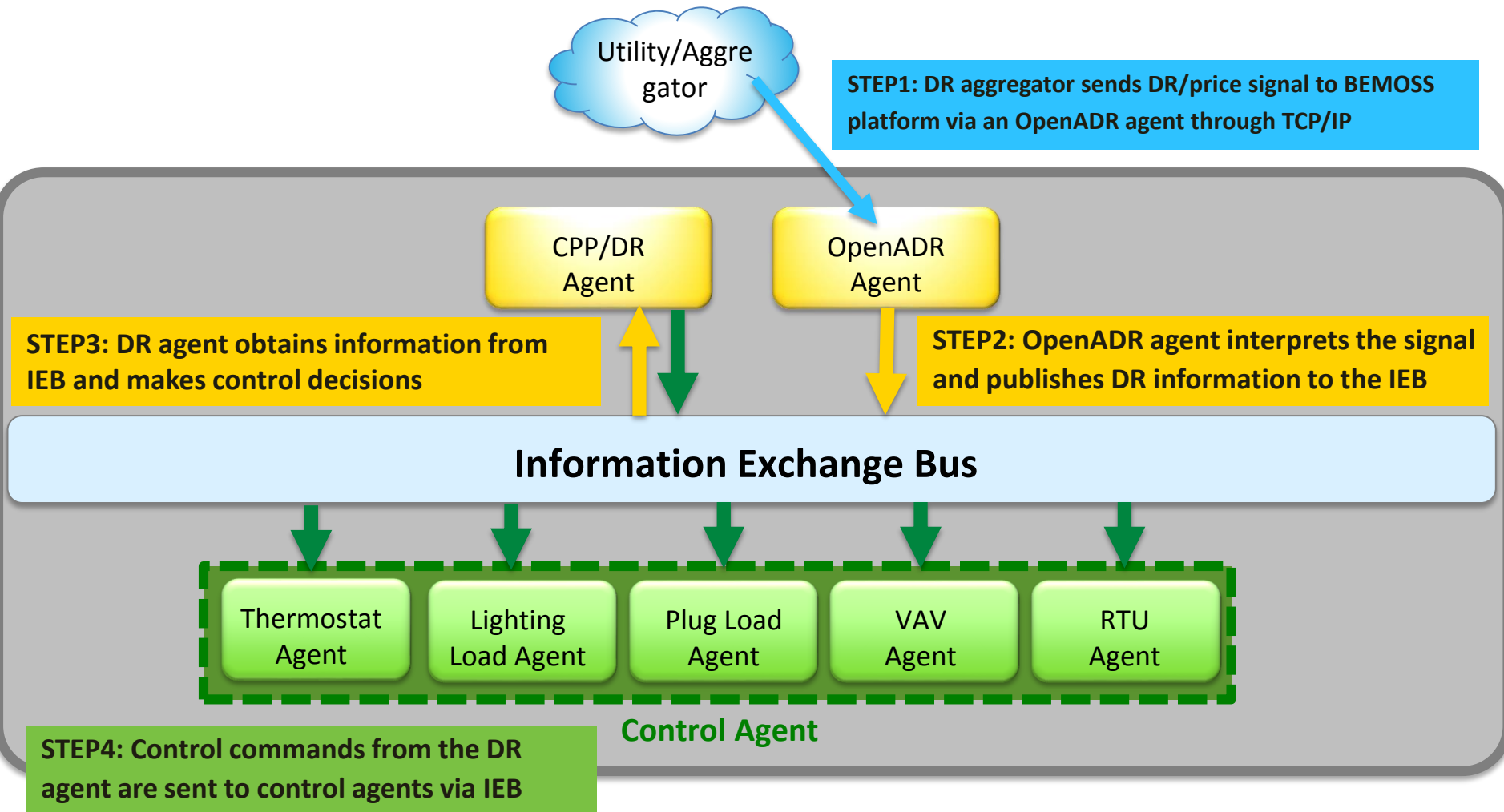
Key focus areas

TOTAL TIME	Actual Presentation	Q&A	# of Slides (not including title slide*)
30 minutes	20 minutes	10 minutes	No more than 15
1 hour	40 minutes	20 minutes	No more than 30

* Title, Project Summary, and REFERENCE SLIDES (i.e., the first 2 slides and last 3 slides) do not count towards slide count as these should be used as quick slides. The information on the project summary will be addressed in later slides, but there is value to providing them as snapshots up front.

BEMOSS accepts OpenADR signals (CPP or DR)

- BEMOSS can accept simulated OpenADR signals and take actions.



BEMOSS Security

BEMOSS utilizes built-in security features provided by VOLTTRON™, and provides enhanced security features.

