Building Energy Management Open-Source Software (BEMOSS)

2017 Building Technologies Office Peer Review

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

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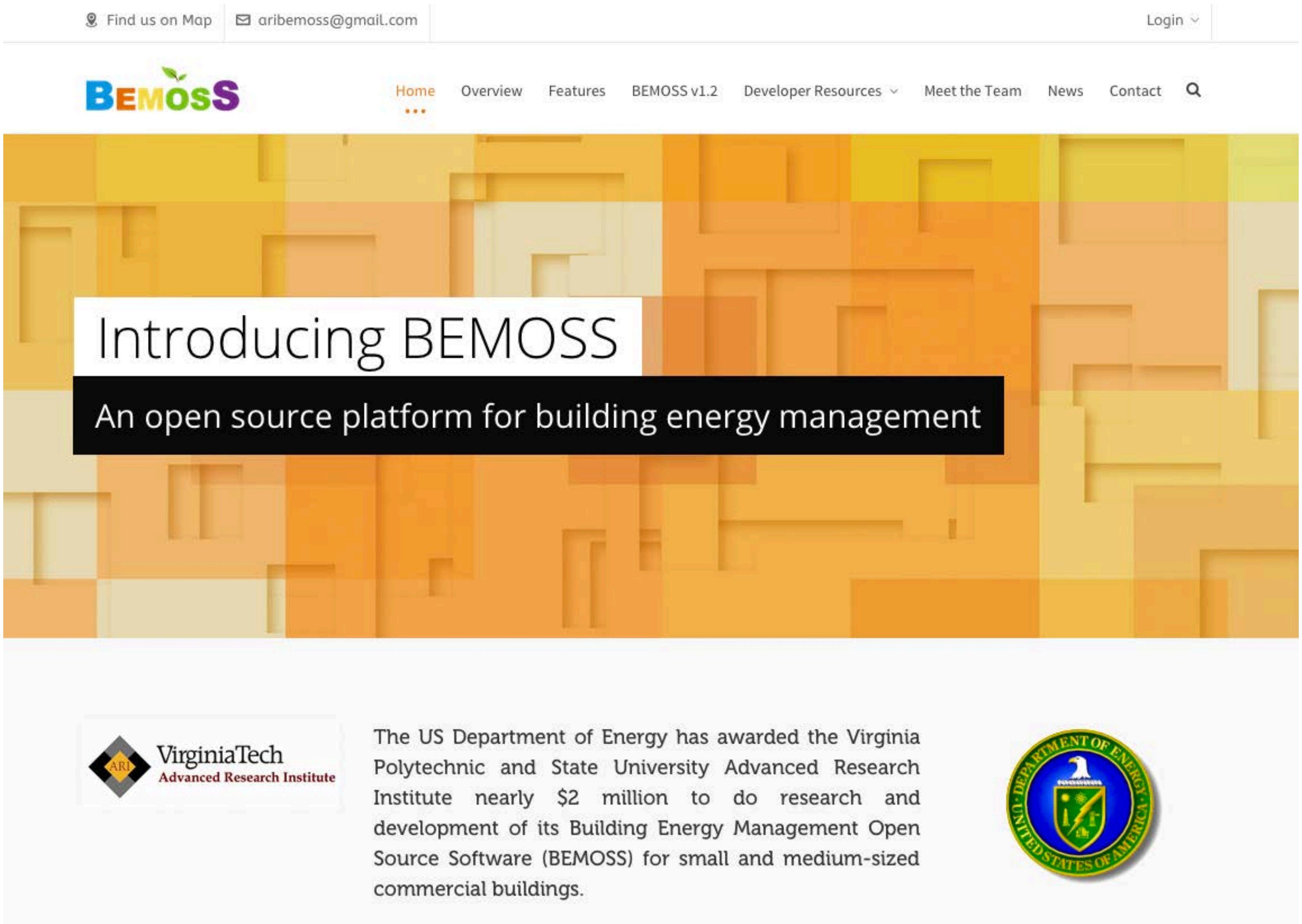
BEMOSS Website: www.bemoss.org



Project Summary

Timeline:

Start date: November 1, 2013

Planned end date: June 30, 2017

Key Milestones

1. Complete BEMOSS deployment in three small and medium sized buildings - 03/31/2017
2. Release BEMOSS v3.5 on Github - 06/30/2017

Key Partners:

Arlington County, VA
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 optimize their electricity usage to reduce energy consumption and facilitate their demand response (DR) implementation.

Budget:

Total Project $ to Date:

- DOE: $1,665,942
- Cost Share: $75,643

Total Project $:

- DOE: $1,985,795
- Cost Share: $75,643

Purpose and Objectives

Problem Statement: Lack of cost-effective and interoperable 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 (50,000 sqft or less)

Impact of Project:

1. Project endpoint: Make available an open-source, cost-effective and scalable 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 implementations.
   b. Intermediate outcomes: (1-3yr): Growing number of BEMOSS deployment in buildings; and software developers building apps for commercial building operations.
   c. Long-term outcomes(3yr+): BEMOSS expands into an open-architecture platform for monitoring and control of large number of IoT devices

Approach

Approach:

Phase 1: BEMOSS software development (2014)

Phase 2: Lab testing and software enhancement (2015)

Phase 3: Demonstration in buildings (2016/2017)

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, improving energy efficiency 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.

Linux

ubuntu

Other software used:

python

C++

PostgreSQL

django

Bootstrap

jQuery
write less, do more.

JavaScript

ZeroMQ

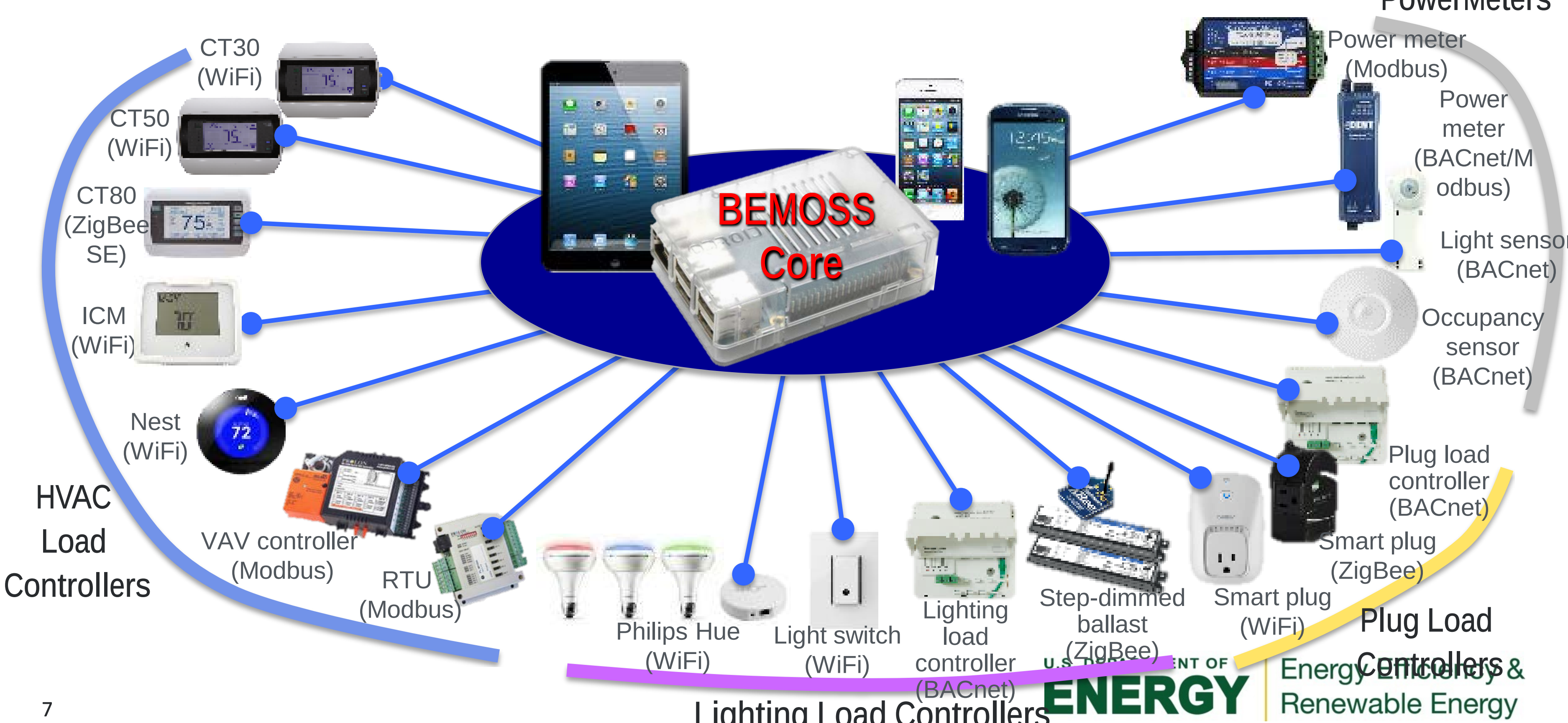
Cassandra

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 Interoperability

Communication Technologies

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

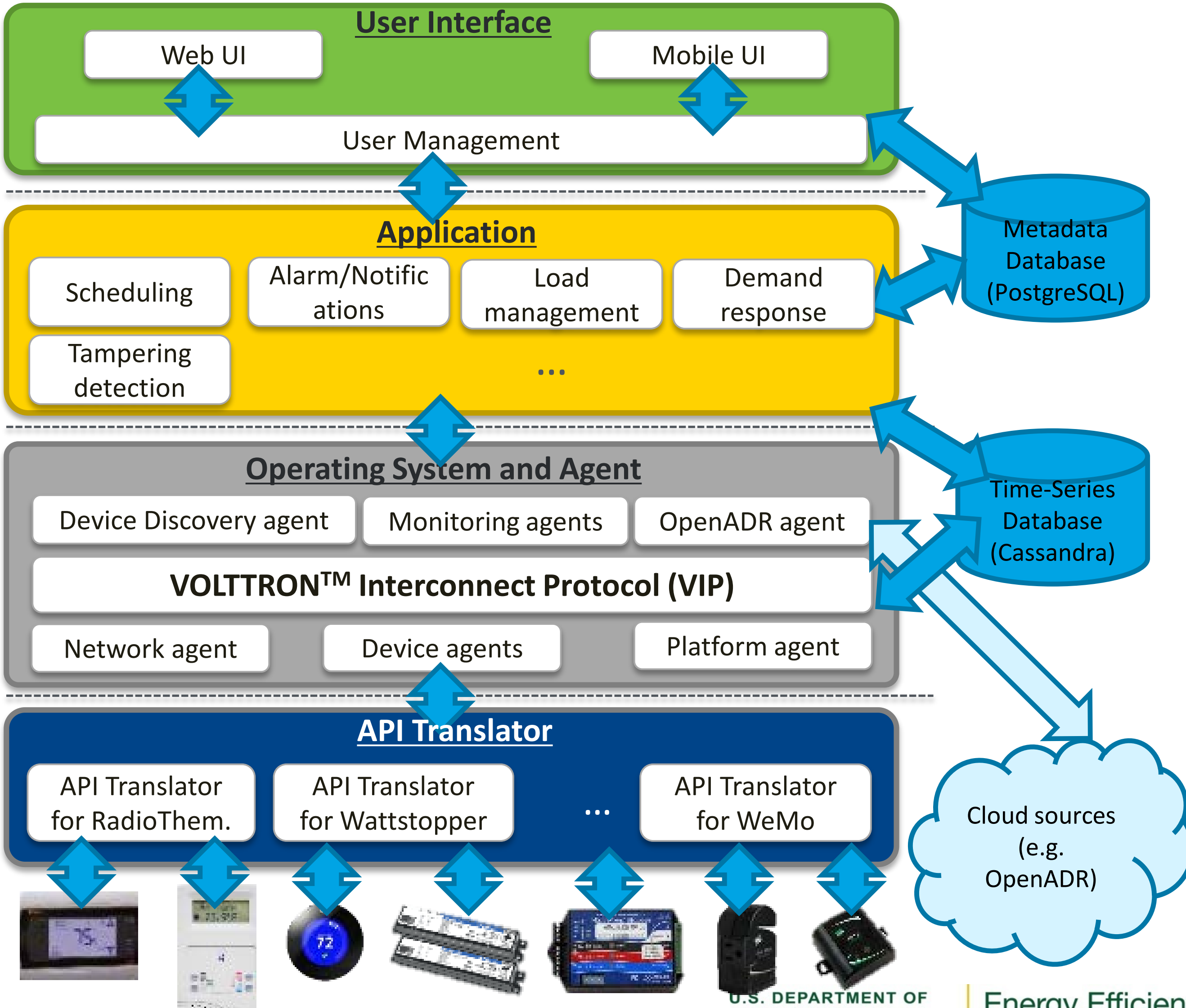
IEEE 802.3 | IEEE 802.11 | WiFi | IEEE 802.15.4 | RS-485

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)

BACnet | OpenADR | WEB | Modbus | ZigBee | Smart Energy Profile (SEP)

BEMOSS Software Architecture



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BEMOSS Deployment in small and medium sized buildings

BEMOSS is being deployed in three buildings

Building 1 – Virginia Tech Academic Building

- Location: Alexandria, VA
- Demonstration: HVAC, plug load control

Building 2 – Equipment Bureau

- Location: Arlington, VA
- Demonstration: Lighting control

Building 3 – Retail Office building

- Location: Blacksburg, VA
- Demonstration: HVAC control

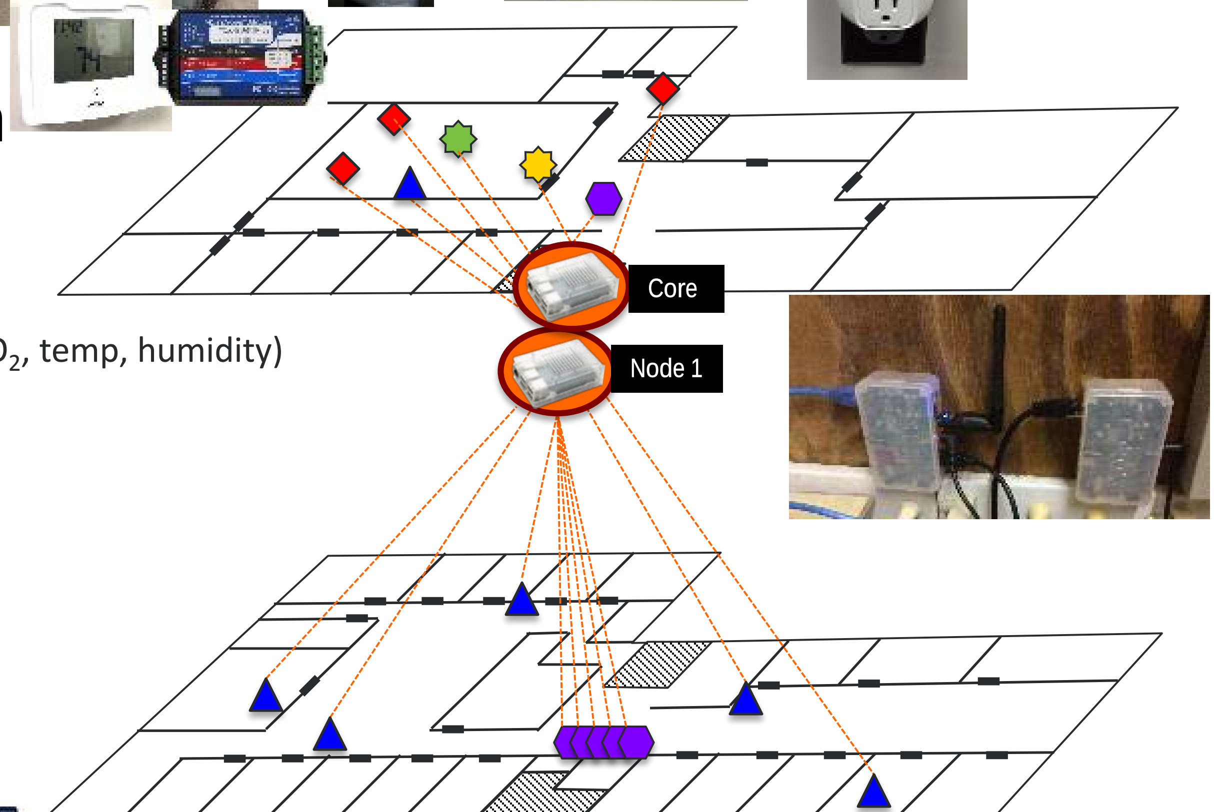
Deployment Setup

Thermostats (WiFi)
Plug load controllers (WiFi)
Motion sensor (WiFi)
Environment sensor (WiFi)
Power meter (Modbus)




Floor 3 – Classroom

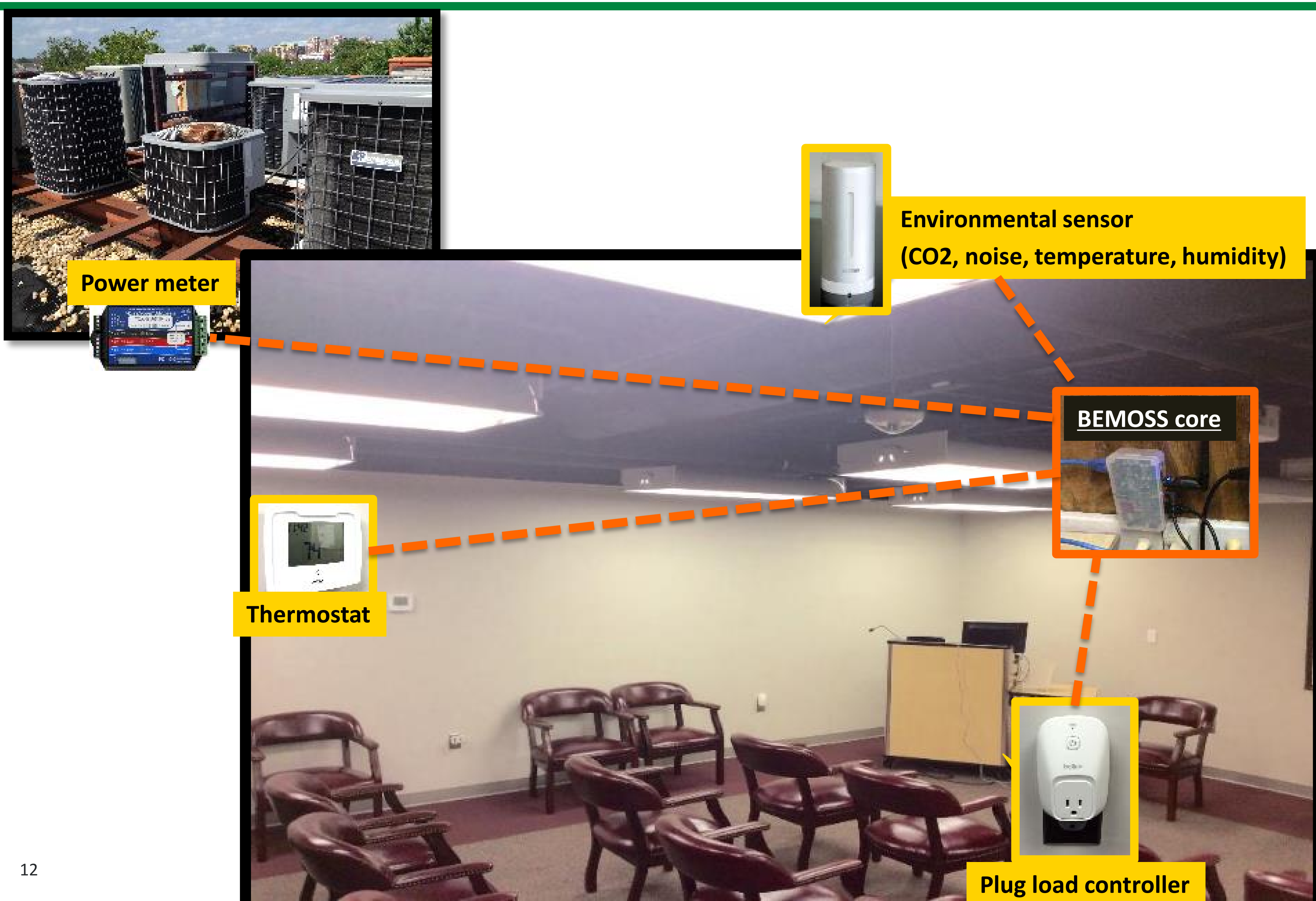
- 1 thermostat
- 3 plug load controllers
- 1 motion sensor
- 1 environment sensor (CO_2, temp, humidity)
- 1 power meter
- BEMOSS core
- BEMOSS node



Floor 2

- 5 thermostats
- 5 power meters

Building 1: Alexandria

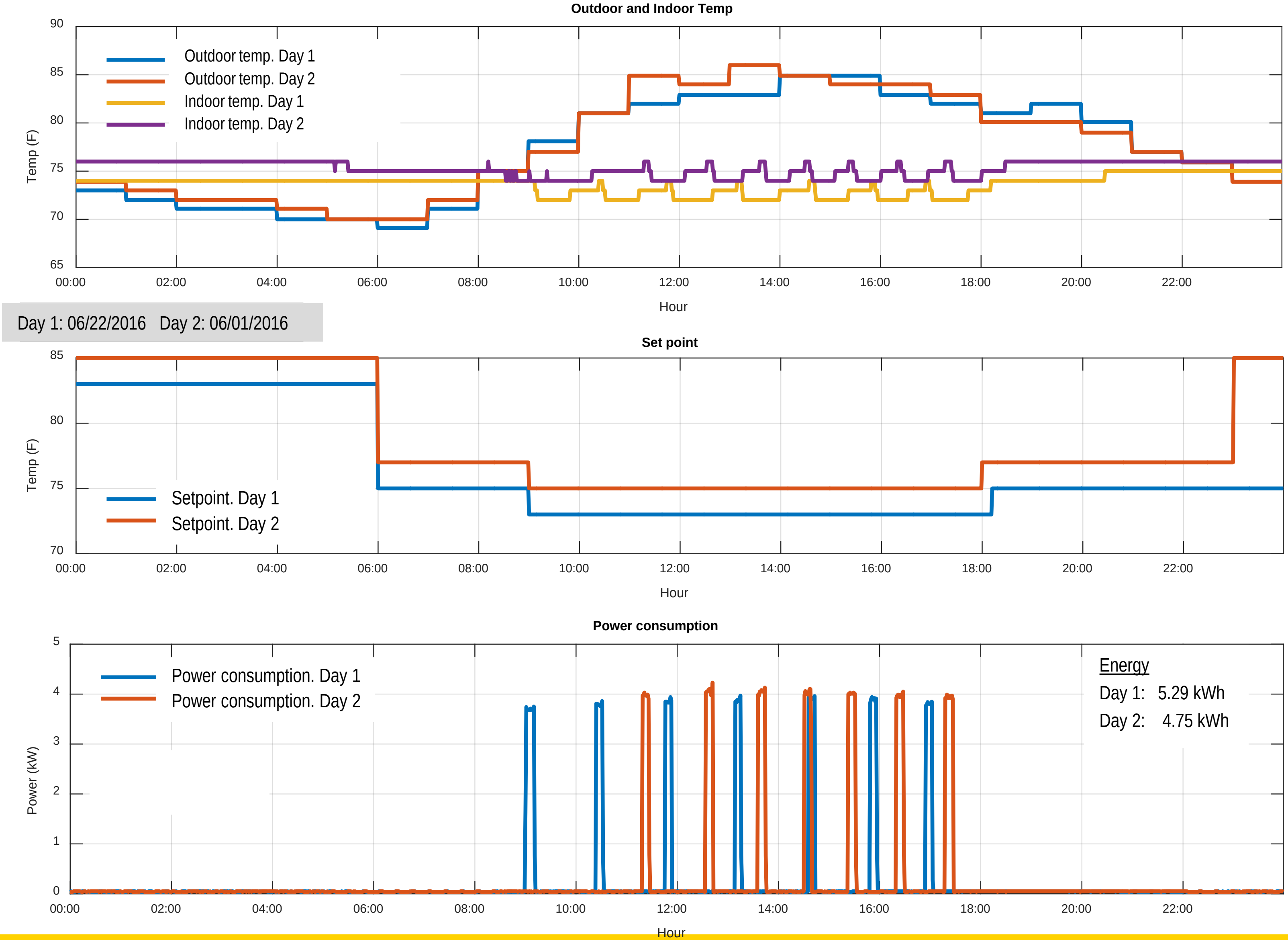


Building 1: Alexandria

Dashboard – All Devices

Building 1: Alexandria

Energy Savings – by increasing set points by 2 deg F in a classroom



Day 1: 6/22/2016, 5.29kWh/day

Day 2: 6/01/2016, 4.75kWh/day (10% energy savings with 2 deg set point increase)

Building 2 – BEMOSS Deployment

Building 2: Arlington
Dashboard – Lighting Power Consumption

Building 2: Arlington

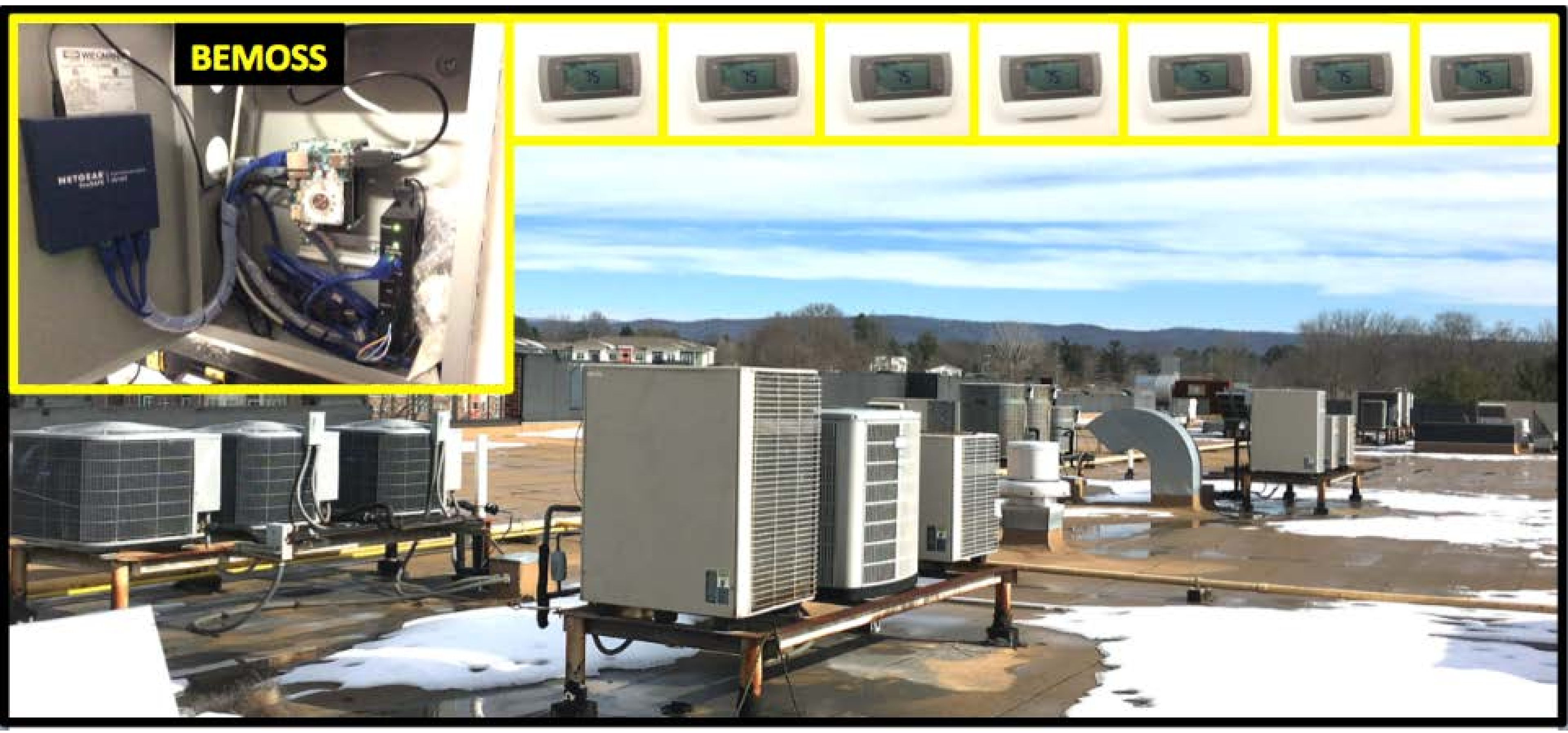
Energy Savings by controlling light intensity

Based on occupant requirements, light intensity level was reduced during October – December 2016. Results indicate **the average kWh savings of about 34%**.

Month	Total Measured Energy Consumption (kWh)	Total Calculated Energy Consumption without Dimming (kWh)	Energy Savings by Dimming (%)
October 2016	264.37	399.90	33.89%
November 2016	278.13	423.78	34.37%
December 2016	280.76	426.40	34.16%
Total (October-December)	823.26	1250.08	34.14%

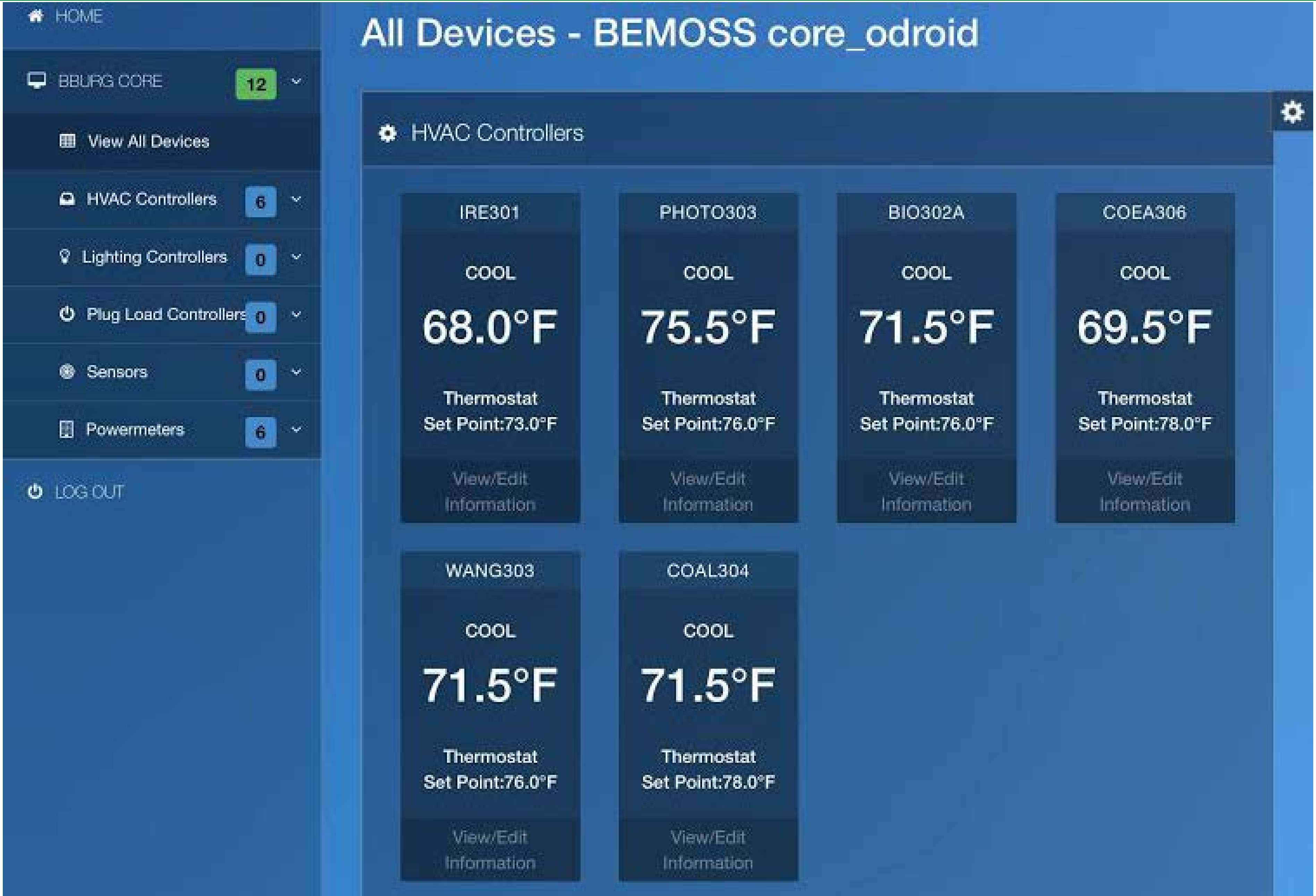
Note: Scheduled dimming level from 6:30am to 9:00pm. Open office area A: 50%; Open office area B: 45%; Chief office's desk area: 60%; Chief office's meeting area: 50%; Conference room A: 50%; Conference room B: 45%. Lights are off after 9:00pm.

Building 3: Blacksburg Retail Office Building



Building 3: Blacksburg Retail Office Building

Dashboard – All Devices

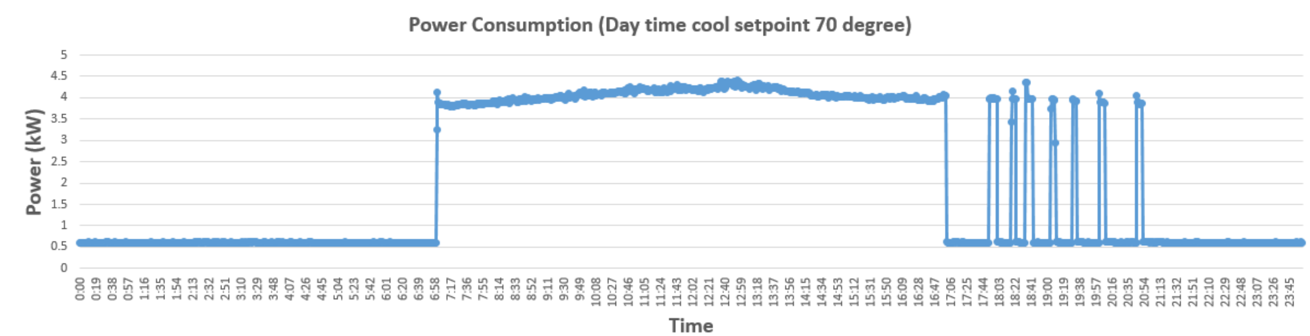


Building 3: Blacksburg Retail Office Building

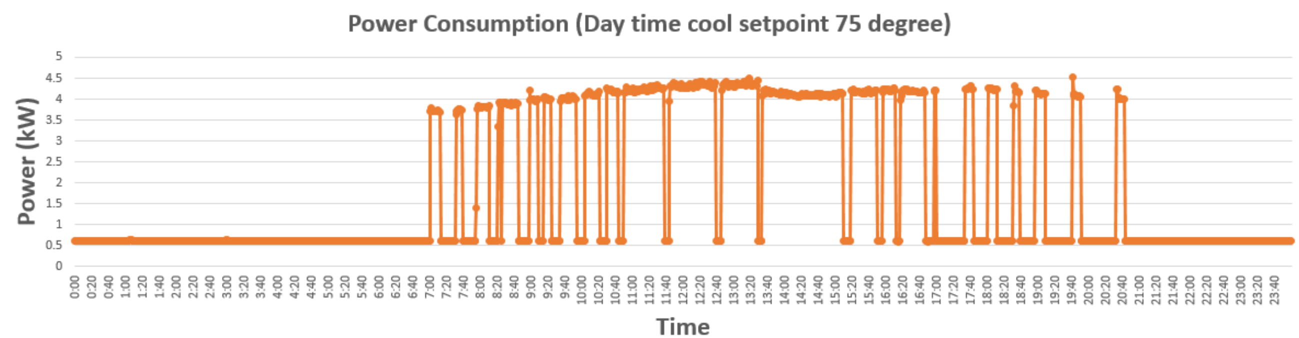
Energy savings by increasing set point by 5 deg F in one suite

- Similar weather conditions on two weekdays (average ambient temperature 71 deg F).

<u>June 6, 2016:</u>
day-time cool set point 70 deg F.



<u>May 27, 2016:</u>
day-time cool set point 75 deg F.



Case	Day time cool set point	Total daily energy usage	Energy saving
June 6, 2016	70	52.1	7.4 kWh (14.2%)
May 27, 2016	75	44.7	

Increasing temperature set points by 5 deg F results in **14% energy savings** for this particular case, when the ambient temperature is 71 deg F on average.

Progress and Accomplishments

Accomplishments:
Completed BEMOSS deployment in three small and medium-sized buildings using BEMOSS v2.0 and v3.5

Market Impact:
A cost-effective building energy management solution allowing energy savings from adjusting thermostat set points and light intensity.

1. 10-15% energy savings for HVAC systems by increasing the temperature set-point
2. 30-35% energy savings for lighting by reducing light intensity level

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.
- Stringent IT security can impact device operation. This issue is currently being investigated.

Project Integration and Collaboration

Project Integration:

- BEMOSS is developed in consultation with industry, and its advisory committee with representatives from 22 organizations from government and Industry has been established.

Project Integration and Collaboration (Cont'd)

Partners, Subcontractors, and Collaborators:

Partner	Role
Arlington County	Offered access to Equipment Bureau Building in Arlington, VA for BEMOSS deployment, LED lighting application
VT Foundation	Offered access to buildings in Alexandria and Blacksburg, VA for BEMOSS demonstrations for HVAC and plug load controls

Communications:

- "Security Concerns and Countermeasures in IoT-Integrated Smart Buildings", accepted for presentation at IEEE PES Innovative Smart Grid Technologies (ISGT), April 23-26, 2017, Arlington, VA, USA.
- "Deploying IoT devices to make buildings smart: Performance evaluation and deployment experience", In Proc. the IEEE World Forum on Internet of Things (WF-IoT), December 12-14, 2016, Reston, VA, USA.
- "Energy Efficiency Applications in Commercial Buildings in the US", IEEE PES Distinguished Lecture, North Carolina State University, Raleigh, NC, 18 February 2016, 36p.
- "BEMOSS: An agent platform to facilitate grid-interactive building operation with IoT devices" In Proc. the IEEE Innovative Smart Grid Technologies (ISGT)-Asia, November 4-6, 2015, Bangkok, Thailand.
- Invited talk at Arlington Public Library, Arlington, VA, sponsored by the joint Northern Virginia/Washington IEEE PES Chapter in Northern Virginia, 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", presented at NSF Workshop on Big Data Analytics in CPS: Enabling the Move from IoT to Real-Time Control, April 6, 2015, Seattle, WA.

Next Steps and Future Plans

Next Steps and Future Plans:

- ❑ Completion of BEMOS functionality and robustness tests
- ❑ Estimation of electricity savings (kWh)
- ❑ Delivery of BEMOSS software tool v3.5 in Github