Building Energy Management Open-Source Software (BEMOSS)

2016 Building Technologies Office Peer Review

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Virginia Tech
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:
- Python
- C++
- Django
- Bootstrap
- jQuery
- JavaScript
- PostgreSQL
- Cassandra
- 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 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

User Interface
- Web UI
- Mobile UI

User Management

Application
- Scheduling
- Demand response
- Monitor/Notification
- Price-based management
- Load management
- Behavior analysis

Operating System and Agent
- Device Discovery agent
- Monitoring agents
- OpenADR agent
- Network agent
- Control agents
- Platform agent

VOLTTRON™ - Information Exchange Bus (IEB)

API Translator
- API Translator for RadioThem.
- API Translator for Wattstopper
- API Translator for WeMo

Metadata Database (PostgreSQL)

Time-Series Database (Cassandra)

Cloud sources (e.g. OpenADR)
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

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

- Power meter
- Thermostat
- Motion sensor
- Environmental sensor (CO2, noise, temperature)
- BEMOSS core
- Plug load controller
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
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:

- 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.
Partners, Subcontractors, and Collaborators:

<table>
<thead>
<tr>
<th>Partner</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arlington County</td>
<td>Offers access to Long Branch Nature Center for energy consumption data</td>
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<tr>
<td>Danfoss Corp.</td>
<td>Supports in modeling the performance of HVAC units under different operating conditions</td>
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<tr>
<td>VT Foundation</td>
<td>Offers access to buildings in Alexandria and Blacksburg, VA for BEMOSS demonstration</td>
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Communications:

- 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:

- 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
# 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

<table>
<thead>
<tr>
<th></th>
<th>Budget Year 2</th>
<th>Budget Year 3</th>
<th>Future (planned)</th>
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</thead>
<tbody>
<tr>
<td>DOE Cost-share</td>
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<td>DOE</td>
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U.S. DEPARTMENT OF ENERGY  
Energy Efficiency & Renewable Energy
# Project Plan and Schedule

## Project Schedule

- **Project Start:** November 2013
- **Projected End:** March 2017

### Completed Work
- Active Task (in progress work)
- Milestone/Deliverable (Originally Planned) *use for missed milestones*
- Milestone/Deliverable (Actual) *use when met on time*

<table>
<thead>
<tr>
<th>Task</th>
<th>FY2014</th>
<th>FY2015</th>
<th>FY2016</th>
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<tbody>
<tr>
<td><strong>Past Work</strong></td>
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<tr>
<td>Task 1: BEMOSS Open Source Software Development</td>
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<td>Task 2: BEMOSS user interface and software tool design</td>
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<td>Task 3: Plug &amp; play device integration</td>
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<td>Task 4: Incorporate additional software feature</td>
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<td>Task 5: BEMOSS software open source access and survey</td>
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<td>Task 6: BEMOSS advanced algorithm development</td>
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<td>Task 7: BEMOSS lab scale testing</td>
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<td>Task 8: Engineering design for BEMOSS deployment</td>
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<td><strong>Current/Future Work</strong></td>
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<td>Task 9: Demonstration in three buildings</td>
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<tr>
<td>Task 10: Estimation of electricity savings potential</td>
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<td>Task 11: BEMOSS demonstration for fault detection</td>
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<td>Task 12: Transition of BEMOSS to v3.0</td>
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<td>Task 13: Delivery of BEMOSS software tools</td>
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<td>Task 14: Project management and reporting</td>
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BEMOSS accepts OpenADR signals (CPP or DR)

- BEMOSS can accept simulated OpenADR signals and take actions.

**Diagram:**

1. **STEP1:** DR aggregator sends DR/price signal to BEMOSS platform via an OpenADR agent through TCP/IP.
2. **STEP2:** OpenADR agent interprets the signal and publishes DR information to the IEB.
3. **STEP3:** DR agent obtains information from IEB and makes control decisions.
4. **STEP4:** Control commands from the DR agent are sent to control agents via IEB.
BEMOSS Security

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

**Device Security**
- Rely on existing device security, e.g., SSL, TLS (if available)
- Add additional protection:
  - Tampering checking
  - Abnormal control behavior checking
  - Device approval process

**Platform Security**
- Rely on VOLTTRON security:
  - Agent validation
  - Agent packaging
  - Resource management
- Add additional protection:
  - BEMOSS core authorization
  - BEMOSS node authorization

**UI Security**
- Role-based access control
- Password protected with SHA256 encryption
- User input validation
- Error handling