Building Energy Management Open-Source Software (BEMOSS)

2014 Building Technologies Office Peer Review

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Project Summary

Timeline:
Start date: November 1, 2013
Planned end date: October 31, 2014

Key Milestones
1. First cut of the BEMOSS software – 10/31/2014
2. User interface app – 10/31/2014
3. Functioning plug & play compatible controllers – 10/31/2014

Key Partners:
Arlington County, VA
Danfoss Corporation
Virginia Tech Foundation

Budget:
Total DOE $ spent to date: $163,454
Total future DOE $: $336,491

Project Goal:
To develop the Building Energy Management Open Source Software (BEMOSS) platform, along with the user interface for three plug-and-play compatible controllers – one each for HVAC, lighting and plug load control. The BEMOSS platform is expected to improve energy efficiency in buildings and facilitate demand response implementation.

Target Market/Audience:
Small- and medium-sized commercial buildings
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: Improve energy efficiency and help implement demand response in buildings

1. Project endpoint: Open-source software platform that allows automatic discovery and control of HVAC, lighting and plug load controllers

2. Expected achievements after Year 1:
   - Successful operation of HVAC, lighting and plug load controllers in a simulated environment
   - Successful integration of all three hardware controller interfaces with BEMOSS
   - Software apps that display sufficient maturity to allow testing BEMOSS functionality
   - Plug & play capable hardware controller interface devices
Approach:

- Task 1: BEMOSS open source software development in consultation with Industry
- Task 2: BEMOSS user interface and software tool design
- Task 3: Plug & play device integration

Key Issues:

- Availability of Application Programming Interface (API)

Distinctive Characteristics:

- Discovering and controlling device controllers without any user inputs
Progress and Accomplishments

Lessons Learned:

- As many smart devices, together with associated APIs, are becoming available in the market, our BEMOSS platform will provide the space for application developers and device manufacturers to integrate building load controllers with smart devices for remote and automated monitoring and control.

Accomplishments: From the start of the project in Nov 2013, the following tasks have been carried out:

- Establish BEMOSS advisory board
- Design preliminary BEMOSS software architecture
- Develop BEMOSS open source software (on-going)
- Design user interface (on-going)
- Perform hardware selection/evaluation (on-going)
- Interface selected load controllers with BEMOSS (on-going)

Market Impact:

- Software/hardware under development

Awards/Recognition: N/A
BEMOSS System Architecture

- Smart meter
- Firewall
- Internet
- Web services
- Cloud Network
- DR signal from utility
- Wireless/IP Customer Network
- Local monitoring & control unit(s)

BEMOSS Architecture

- Zone 1
  - Smart Thermostat(s)
  - Dimmable Ballast(s)
  - Smart plug(s)
  - Sensor(s)
- Zone 2
  - Smart Thermostat(s)
  - Dimmable Ballast(s)
  - Smart plug(s)
  - Sensor(s)
- Zone n
  - Smart Thermostat(s)
  - Dimmable Ballast(s)
  - Smart plug(s)
  - Sensor(s)

- BEMOSS Lite
- BEMOSS Lite
- BEMOSS Lite

Remote Utility Control Center

- Celluar modem
- Ethernet Switch
- Firewall
- Text/email

Utility Control Center

- Local monitoring & control unit(s)
BEMOSS Software Architecture

User interface layer

Web UI

Mobile UI

User management

Application & data management

Application & data management layer

Demand response

Price-based management

Operation monitoring

Planning and scheduling

Energy consumption analysis

Data visualization & web services

Alarming/notifications

Database

- User profile
- Preference settings
- Device information

SMAP

Time series data, such as:
- Device status
- V, I, P, kW, etc..
- Room temperature
- Real-time pricing
- Demand response signals

Cloud sources (e.g., OpenADR)

Operating system and framework

Volttron – Linux-Ubuntu

Resource manager

Crypto Module

Communication services

Directory services

Agent services

Hardware devices

BEMOSS Lite (Zone 1)

BEMOSS Lite (Zone 2)

BEMOSS Lite (Zone n)

Communication Technologies (WiFi, Ethernet)
BEMOSS Agent

Adopted from Volttron Lite

Information Exchange Bus

- Database Agent
- Discovery Agent
- Demand Response Agent
- OpenADR Agent
- OpenADR

Agents already developed
Agents to be developed

- 3M-50 Thermostat Agent
- CT-30 Thermostat Agent
- CT-80 Thermostat Agent
- BACnet Thermostat Agent
- Nest Thermostat Agent
- Philips Hue Agent
- Step Dim Ballast Agent
- Smart Plug Agent
- Xbee Sensor Agent

Thermostats (WiFi/ZigBee/BACnet)
Light controllers (WiFi/ZigBee)
Plug load controllers (ZigBee)
Sensors (ZigBee)
BEMOSS Successfully Integrated with Five Thermostats and One Light Controller

BEMOSS

PC

Embedded System
(Exploring:
- Raspberry Pi
- Beagle bone
- Panda board)

Wireless/IP Customer Network

ZigBee Coordinator

ZigBee - SEP

Radio Thermostat (CT-80)

WiFi

Filtrete (3M-50)

Radio Thermostat (CT-30)

Nest

Philips Hue

BACnet (EXL01610)

WiFi ↔ Ethernet/IP ↔ BACnet MS/TP

WiFi ↔ Ethernet/IP ↔ BACnet MS/TP
## BEMOSS Progress To Date

<table>
<thead>
<tr>
<th>Feature</th>
<th>3M-50 WiFi</th>
<th>CT-30 WiFi</th>
<th>Nest WiFi</th>
<th>CT-80 ZigBee</th>
<th>BACnet</th>
<th>Philips Hue</th>
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</thead>
<tbody>
<tr>
<td>Interface with IP/MAC address</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Interface with Volttron</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>Device discovery</td>
<td>✔</td>
<td>✔</td>
<td>API to be released</td>
<td>✔</td>
<td>✔</td>
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Project Integration and Collaboration

Project Integration:

- The BEMOSS advisory committee with 15 individuals 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>
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<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:

Next Steps and Future Plans:

- Continue the development of BEMOSS open source software
- Continue user interface design
- Interface selected load controllers with BEMOSS
- Perform user acceptance and software tool evaluation
- Deploy BEMOSS in a living laboratory
Project Budget


Variances: N/A

Cost to Date:  $198,873 (from Nov 1, 2013 to Mar 31, 2014)

Additional Funding: N/A

<table>
<thead>
<tr>
<th>Budget History</th>
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<td>DOE</td>
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## Project Plan and Schedule

### Project Schedule

**Project Start:** November 1, 2013  
**Projected End:** October 31, 2014

<table>
<thead>
<tr>
<th>Task</th>
<th>FY2014</th>
<th>FY2015</th>
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<tbody>
<tr>
<td></td>
<td>Nov-13</td>
<td>Dec-13</td>
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<tr>
<td><strong>Current/Future Work</strong></td>
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<tr>
<td><strong>Task 1: BEMOSS open source software development in consultation with industry</strong></td>
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<tr>
<td>1.1) Establish BEMOSS advisory committee</td>
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<tr>
<td>1.2) BEMOSS advisory committee meeting</td>
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<tr>
<td>1.3) Design BEMOSS preliminary architecture</td>
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<td>1.4) Develop BEMOSS open source software</td>
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<td><strong>Task 2: BEMOSS user interface and software tool design</strong></td>
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<td>2.1) User interface and tool design</td>
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<td>2.2) User acceptance and software tool evaluation</td>
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<td><strong>Task 3: Plug &amp; play device integration</strong></td>
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<td>3.1) BEMOSS hardware selection/evaluation</td>
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<tr>
<td>3.2) BEMOSS hardware acquisition</td>
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<tr>
<td>3.3) Plug &amp; play device interface</td>
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<tr>
<td>3.4) BEMOSS deployment in living laboratory</td>
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<tr>
<td><strong>Submit deliverables to DOE</strong></td>
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