Invited Lecture

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National University of Singapore, Singapore, 22 May 2018

All Buildings should be Smart Buildings

Building Automation Systems (BAS) can slash power consumption and energy bills significantly, but they are too expensive for most buildings.

*BEM Controls breaks through this barrier.*

Our Wise Building (WiseBldg) platform is affordable and works with any existing loads to make any building smart, no matter the size or age.

PPT slides will be available at www.bemcontrols.com
Vision/Problem
Bringing custom energy control to small & medium commercial buildings

95%
U.S. Commercial Properties are less than 5,000 square meters
Current systems are too expensive, so energy is wasted

Virginia Tech Focus
Develop an open source, low cost, low power consumption platform that can monitor and control majority of loads in buildings to improve energy efficiency and facilitate demand response implementation.

Electricity Usage in Buildings
Source: EIA - Commercial Building Energy Consumption Survey (CBECS)
http://www.eia.gov/consumption/commercial/data/2003/index.cfm?view=consumption#eta

Three major loads in buildings:
• HVAC
• Lighting loads
• Plug loads

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An Open Architecture Platform for Building Energy Efficiency

BEMOSS is a Building Energy Management Open Source Software (BEMOSS) solution that is engineered to improve sensing and control of all IoT-enabled equipment in commercial buildings.

BEMOSS monitoring and control:

- Heating, Ventilation, AC
- Lighting loads
- Plug loads

BEMOSS value:

Improves energy efficiency and facilitates peak load savings in buildings.

BEMOSS www.bemoss.org

Three major loads in buildings

- Heating, Ventilation, AC
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- Plug loads

U.S. Department of Energy Facebook Page

Buildings automation systems are key to reducing energy use in America since commercial buildings consume 20% of all the energy sold in the United States. A major problem we're working to solve is that 50% of all commercial buildings are 50,000 square feet or less in size and most of these smaller buildings can't use energy-saving automation systems designed and priced for larger buildings. Learn how we're supporting researchers at Virginia Tech who are building an open source solution that can make buildings more energy efficient and enhance occupants’ comfort. http://go.usa.gov/3x7nt.
Services Provided by BEMOSS

- BEMOSS accepts an OpenADR signal and performs control of HVAC, lighting, and plug loads.

- Demand limit (kW) & time/duration
- Pre-set knowledge of load priority and occupant preference

• HVAC agents
• Lighting load agent
• Plug load agent

- Increase setpoint
- Reduce brightness
- Turn off selected plug loads

Multiple-protocol 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)
WiseBldg: Building Energy Management Platform

Overview

WiseBldg (pronounced “Wise Building”) is BEM Controls’ powerful, low-cost, open-architecture software platform that can monitor and optimally control major electrical loads (e.g., HVAC, lighting and plug loads), as well as solar PV systems, energy storage units and other IoT sensors in commercial buildings. It is built on the DoE-sponsored BEMOSS platform developed at Virginia Tech.

WiseBldg supports multiple IoT devices through industry standard protocols and communications technologies.
WiseBldg Platform Built by BEM Controls

End-users, owners and vendors looking to control energy usage

- Facilities Managers
- Property Owners
- Energy Auditors
- Product Vendors
WiseBldg brings energy monitoring and control to small and medium-sized commercial buildings

Current Market Practice

Offerings are not designed for small and medium commercial buildings: Incumbents have focused on large buildings (>100K sq. feet) or residential markets which are not cost effective at scale for small/medium commercial building market.

Closed Hardware + Software Solutions: Existing offerings require customers to acquire both hardware and software from the same vendor in order to control building systems. Existing Energy Management Systems cannot control devices from multiple vendors.

WiseBldg Differentiators

WiseBldg is made for small and medium commercial buildings: WiseBldg is an enterprise-grade monitoring and control software platform that serves this market whose applications can organically grow as requirements evolve over time.

Open architecture makes WiseBldg easy to adapt to new technologies: WiseBldg leverages leading edge machine learning models for occupant comfort and energy savings, and has been tested more than 20 different devices and protocols.

Customers already controlling buildings optimized for savings

Measured energy savings across deployments

| 20% | HVAC Energy Savings |
| 25% | Lighting Energy Savings |

Improved operations and maintenance: WiseBldg analytical platform enables operators to detect faults when devices operate outside standard thresholds enabling building operators to investigate prior to device failure.

Occupant satisfaction: spaces controlled by WiseBldg have been more comfortable due to more consistent temperature profiles and healthier air quality through consistent monitoring of environmental factors (CO2 levels, PM 2.5).
WiseBldg Deployments in Four Buildings

Building 1 – Virginia Tech Architecture Building
- Location: Alexandria, VA
- Demonstration: HVAC, plug load control

Building 2 – Equipment Bureau
- Location: Arlington, VA
- Demonstration: Lighting control

Building 3 – Virginia Tech building
- Location: Blacksburg, VA
- Demonstration: HVAC control

Building 4 – PG County building
- Location: Camp Springs, MD
- Demonstration: HVAC control

WiseBldg can make an old building smart
Building 1 – VT Building in Alexandria, VA

Alexandria, Virginia, USA

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

Classroom under Real-time Monitoring

- Power meter
- Environmental sensor (CO2, noise, temperature)
- BEMOSS core
- Plug load controller
- Thermostat
- Motion sensor
Weather Sensor Integration
Indoor Environmental Monitoring
Using WiseBldg the building operator reduced HVAC consumption by 27%

Energy Savings from HVAC Control

Location: Alexandria, VA
Area: 25,000 square feet
Deployed Devices
- 6 Thermostats
- 6 Power meters
- 1 Li-ion battery
- 1 Environmental sensor

Using WiseBldg, Building Operator saved 27% on HVAC consumption alone

<table>
<thead>
<tr>
<th>Summer Months (June-July-August)</th>
<th>Compressor consumption 2014 (Before WiseBldg)</th>
<th>Compressor consumption 2016 (After WiseBldg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8,340 kWh</td>
<td>6,071 kWh</td>
</tr>
<tr>
<td>Average savings</td>
<td>26.8% savings</td>
<td></td>
</tr>
</tbody>
</table>

Compressor consumption 2014
Base case (w/o WiseBldg)
- Setpoint: 74 deg F
- Energy usage = 2.72kWh
- Max demand = 3.98kW

Managed by WiseBldg
- Setpoint: 79 deg F
- Energy usage = 1.42kWh
- Max demand = 0.5kW
Office Building, Arlington, Virginia

Office building size: 5,000 sqft

Energy Savings from Lighting Control

Location: Arlington, VA
Area: 5,000 sq ft

Deployed Devices
• 3 Lighting controllers
• 1 Power meter

An average energy savings of 35% was achieved through dimming control

<table>
<thead>
<tr>
<th>Month</th>
<th>Energy Savings</th>
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<tbody>
<tr>
<td>Oct 2016</td>
<td>33.7%</td>
</tr>
<tr>
<td>Nov 2016</td>
<td>33.9%</td>
</tr>
<tr>
<td>Dec 2016</td>
<td>34.4%</td>
</tr>
<tr>
<td>Jan 2017</td>
<td>33.4%</td>
</tr>
<tr>
<td>Feb 2017</td>
<td>36.9%</td>
</tr>
<tr>
<td>Mar 2017</td>
<td>36.2%</td>
</tr>
<tr>
<td>Apr 2017</td>
<td>35.0%</td>
</tr>
<tr>
<td>May 2017</td>
<td>36.0%</td>
</tr>
<tr>
<td>Jun 2017</td>
<td>36.3%</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>34.5%</td>
</tr>
</tbody>
</table>
Energy Savings by controlling light intensity

<table>
<thead>
<tr>
<th>Month</th>
<th>Total Measured Energy Consumption (kWh)</th>
<th>Total Calculated Energy Consumption without Dimming (kWh)</th>
<th>Energy Savings by Dimming (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 2016</td>
<td>264.37</td>
<td>399.90</td>
<td>33.89%</td>
</tr>
<tr>
<td>November 2016</td>
<td>278.13</td>
<td>423.78</td>
<td>34.37%</td>
</tr>
<tr>
<td>December 2016</td>
<td>280.76</td>
<td>426.40</td>
<td>34.16%</td>
</tr>
<tr>
<td>Total (October-December)</td>
<td>823.26</td>
<td>1250.08</td>
<td>34.14%</td>
</tr>
</tbody>
</table>

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.

Energy Management in a Museum Building
WiseBldg App

Solar PV System Monitoring and Control
Solar PV and Smart Inverter Integration

WiseBldg User Interface
Managing Battery Storage from WiseBldg Platform

Battery Cells
LG Chem

5 kW 12 kWh

Battery Storage Monitoring & Control

Turnsley Energy Incentive: Battery Storage

Battery Storage
CURRENT STATUS
STATE OF CHARGE
98.9%

CURRENT READINGS
OUTPUT POWER
-0.013 kW
CHARGING
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Thank You

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