IoT Sensor Integration in Smart Buildings for Monitoring & Control

Invited Lecture
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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
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#e1a

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:
Implements energy efficiency and facilitates peak load savings in buildings
Services Provided by BEMOSS

- BEMOSS accepts an OpenADR signal and performs control of HVAC, lighting and 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 Profile (SEP)
- 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.

Platform Architecture

User Interface Layer
- Web-based Control
- Smartphone App
- Control

Application Management Layer
- Data & Analytics
- Open ADR for Demand Response
- Metadata DB

Device Connectivity Layer
- API Translators for Energy and IoT Devices

Data & Analytics Layer
- Time Series DB (Cassandra)
- Machine Learning Algorithms

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

Utility/DR Aggregator

- DR Event
- Pricing
- Billing

Encrypted Data Link

Router

Customers/Operators

Buildings

HVAC
- Lighting loads
- Plug loads
- Sensors/power meters

Water meters
- PV & storage
- Security camera

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 designed for large commercial buildings:** Incumbents have focused on large buildings (>100K sq. feet), and the technology is not cost effective for small/medium-sized 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 allows WiseBldg to integrate multi-vendor hardware:** WiseBldg leverages leading edge machine learning models for occupant comfort and energy savings, and has been tested for more than 25 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 equipment failures.

**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: 2500 SqM
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
**Indoor Environmental Monitoring**

Using WiseBldg, the building operator reduced HVAC consumption by 27%.

**Energy Savings from HVAC Control**

- **Location:** Alexandria, VA
- **Area:** 2500 square meter
- **Deployed Devices:**
  - 6 Thermostats
  - 6 Power meters
  - 1 Li-ion battery
  - 1 Environmental sensor

Using WiseBldg, the building operator saved 27% on HVAC consumption alone.

### Summer Months (June-July-August)

<table>
<thead>
<tr>
<th>Description</th>
<th>2014 (Before WiseBldg)</th>
<th>2016 (After WiseBldg)</th>
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<tbody>
<tr>
<td>Air Conditioner consumption</td>
<td>8,340 kWh</td>
<td>6,071 kWh</td>
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<tr>
<td>Average savings</td>
<td>26.8% savings</td>
<td></td>
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</tbody>
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**Base case (w/o WiseBldg)**
- Setpoint: 74 deg F
- Energy usage = 2.72kWh
- Max demand = 3.95kW

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

Office building floor size: 500 sqm

Energy Savings from Lighting Control

Location: Arlington, VA
Area: 500 sq meter

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>Average 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>35.9%</td>
</tr>
<tr>
<td>Mar 2017</td>
<td>36.2%</td>
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<tr>
<td>Apr 2017</td>
<td>36.0%</td>
</tr>
<tr>
<td>May 2017</td>
<td>36.0%</td>
</tr>
<tr>
<td>Jun 2017</td>
<td>36.3%</td>
</tr>
<tr>
<td><strong>AVERAGE</strong></td>
<td><strong>34.5%</strong></td>
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Energy Management in a Museum Building

WiseBldg App
Solar PV System Monitoring and Control

WiseBldg User Interface
Managing Battery Storage from WiseBldg Platform

Battery Cells
LG Chem

Battery Storage Monitoring & Control
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.

www.bemcontrols.com

Thank You

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www.bemcontrols.com
www.saifurrahman.org