Energy Efficiency in Smart Buildings through IoT Sensor Integration

Keynote Speech
Prof. Saifur Rahman
Director, Virginia Tech Advanced Research Inst., USA
IEEE President-elect 2022

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• Buildings consume over 40% of the total energy consumption in the U.S. Over 90% of the buildings in the U.S. are either small-sized (<5,000 square feet) or medium-sized (between 5,000 sf and 50,000 sf).

• These buildings typically do not use Building Automation Systems (BAS) to monitor and control their building systems from a central location.

• **Need to** facilitate energy efficiency applications in commercial buildings using a very simple and scalable building automation system (BAS).
Targeted Buildings & Loads

- With respect to load types, there are three major loads in commercial buildings: HVAC, lighting and plug loads.

- According to the data from EIA published in 2008, electricity use by HVAC equipment, i.e., space heating, cooling and ventilation accounts for 30% of the total electricity consumption in buildings.

- Lighting loads constitute the majority share of electricity use at 38%.

- Electricity use by plug loads, i.e., office equipment, computers, etc. accounts for 6% of total electricity use in buildings.

- Other loads include water heating, refrigeration, elevators, etc. The figure below illustrates electricity use in buildings by load type.
An Open Architecture Platform for Building Energy Efficiency

BEMOSS

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

Monitoring & Control

Three major loads in buildings

• Heating, Ventilation, AC
• Lighting loads
• Plug loads

Value

Improves energy efficiency and facilitates peak load savings in commercial buildings.

www.bemoss.org
• The BEMOSS™ architecture for a small commercial building with a few load controllers of each type.

• In this architecture, only one single-board computer (e.g., Odroid) embedded with the BEMOSS™ software platform is used to enable monitoring and control features of all load controllers in the building.

• This embedded system can communicate with different types of load controllers, i.e., thermostats, lighting load controllers and plug load controllers, and sensors/power meters via wireless signals (either Wi-Fi or ZigBee).

• Local and remote monitoring and control via a smart phone or a tablet are also enabled.
Multi-Sensor Applications

For multi-floor buildings with larger number of devices, BEMOSS™ can be set up to deploy its multi-layer architecture feature.

In this architecture, a BEMOSS™ node is responsible for monitoring and control devices on one floor.

Each BEMOSS™ node communicates with each other and also communicates with the BEMOSS™ Core.

The BEMOSS™ Core is responsible for supervising the overall system operation, managing multiple BEMOSS™ nodes, and allowing local and remote access for monitoring and control of all devices in buildings.
Supports multiple IoT devices through industry standard protocols and communications technologies.
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)

RS-485

IOT

WEB

Smart Energy Profile (SEP)
Campus-wide Application

- Occupant comfort
- Solar PV/Storage Management
- Peak demand (kW) reduction
- Energy Savings (kWh)
- Alarm & Notifications
- Building Energy Management
- Security Surveillance

- Customers/Operators
- HVAC
- Lighting loads
- Plug loads
- Sensors/power meters
- Water meters
- PV & storage
- Security camera

- Utility/DR Aggregator
  - DR Event
  - Pricing
  - Billing
  - Encrypted Data Link
  - Router

- www.bemconrots.com
How to make an old building smart
Customers Controlling Buildings Optimized for Savings

Measured energy savings across deployments

- **20%** HVAC Energy Savings
- **25%** Lighting Energy Savings

**Improved operations and maintenance:** Building automation system (BAS) 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 BAS 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).
### Sample Examples

<table>
<thead>
<tr>
<th>Building</th>
<th>Description</th>
<th>Location</th>
<th>Demonstration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building 1</td>
<td>VT Classroom Building</td>
<td>Alexandria, VA</td>
<td>HVAC, plug load control</td>
</tr>
<tr>
<td>Building 2</td>
<td>Equipment Bureau Building</td>
<td>Arlington, VA</td>
<td>Lighting control</td>
</tr>
<tr>
<td>Building 3</td>
<td>VT Lab Building</td>
<td>Blacksburg, VA</td>
<td>HVAC control</td>
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<tr>
<td>Building 4</td>
<td>PG County Community Building</td>
<td>Camp Springs, MD</td>
<td>HVAC control</td>
</tr>
</tbody>
</table>
Building 1 – VT Building in Alexandria, VA

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

Alexandria, Virginia, USA
Classroom Under Real-time Monitoring
Indoor Environmental Monitoring
Energy and Peak 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 BAS, Building Operator saved 27% on HVAC consumption alone**

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

| Compressor consumption 2014 (Before BAS) | 8,340 kWh |
| Compressor consumption 2016 (After BAS) | 6,071 kWh |
| Average savings | 26.8% savings |

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

**Managed by WiseBldg**
- Setpoint: 77 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

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<tbody>
<tr>
<td></td>
<td>33.7%</td>
<td>33.9%</td>
<td>34.4%</td>
<td>33.4%</td>
<td>35.9%</td>
<td>36.2%</td>
<td>35.0%</td>
<td>36.0%</td>
<td>36.3%</td>
<td>34.5%</td>
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## Energy Savings By Controlling Light Intensity

<table>
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<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>
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<tr>
<td>November 2016</td>
<td>278.13</td>
<td>423.78</td>
<td>34.37%</td>
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<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>
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**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.
Solar PV System Monitoring and Control
DER Devices
(Rooftop Solar)
Managing Battery Storage

EGUANA AC BATTERY™

Battery Cells

LG Chem

5 kW 12 kWh

145 lbs 188 lbs 188 lbs

5 kW

12 kWh

-06L

-12L

48" above floor

Com

PWR

battery

battery expansion
Battery Storage Setup
Battery Storage Monitoring & Control

Tumalow Energy Ingenuity: Battery_Storage3

Battery Storage

Current Status

Current Readings

State of Charge

98.9%

Output Power

-0.013 kW

Active Charging
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@SRahmanVT

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