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IoT Sensor Integration In Smart Buildings for Monitoring & Control

Invited Lecture

Professor Saifur Rahman
Director, Virginia Tech Advanced Research Inst., USA
President, IEEE Power & Energy Society

National University of Singapore, Singapore, 22 May 2018

BEMCONTROLS

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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

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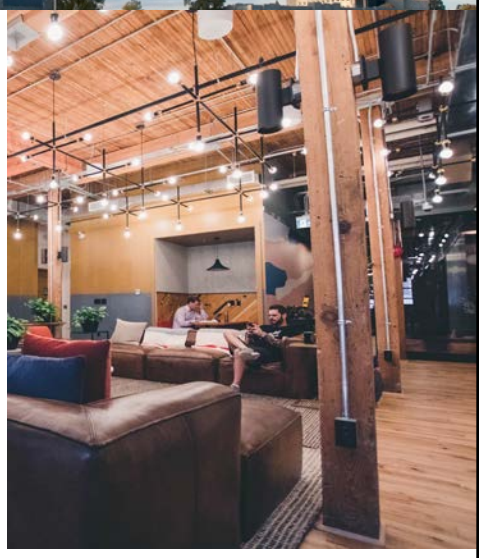
Vision/Problem

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

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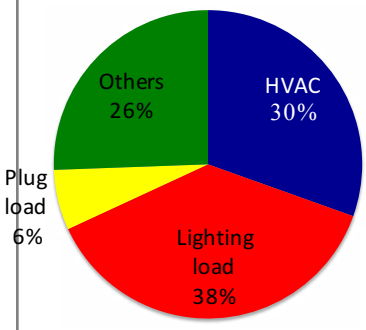
Virginia Tech Focus

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

Three major loads in buildings:

- HVAC
- Lighting loads
- Plug loads

Source: EIA - Commercial Building Energy Consumption Survey (CBECS)
http://www.eia.gov/consumption/commercial/data/2003/index.cfm?view=consumption#e1a

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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

www.bemoss.org

BEMOSS monitoring and control:

Three major loads in buildings
- Heating, Ventilation, AC
- Lighting loads
- Plug loads

BEMOSS value: Improves energy efficiency and facilitates peak load savings in buildings

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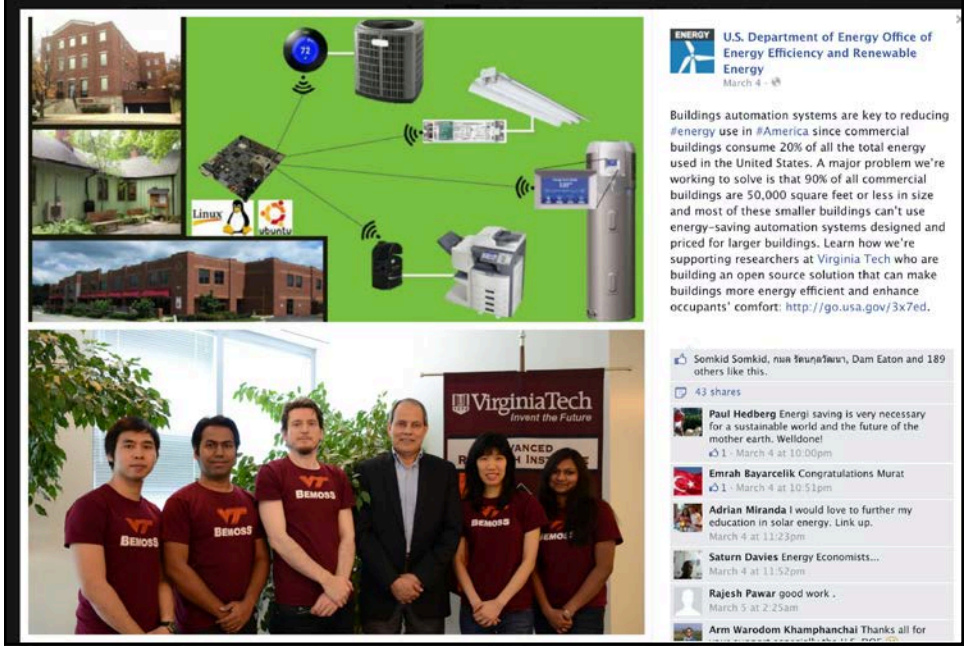
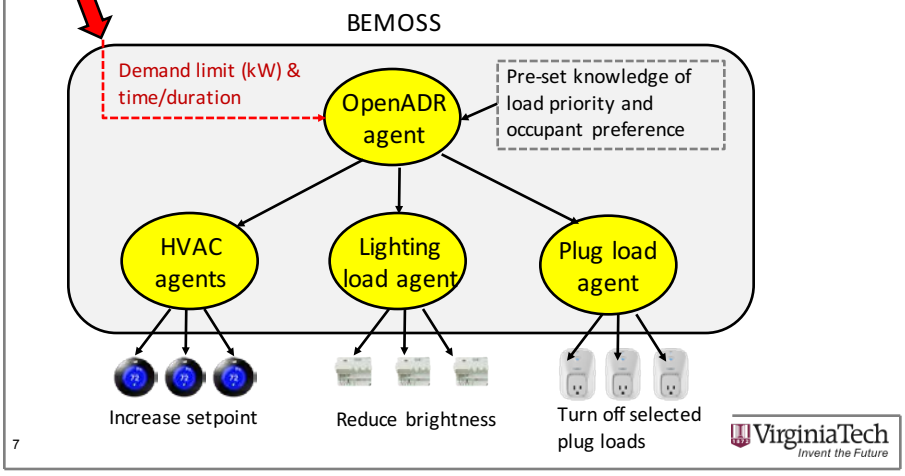
U.S. Department of Energy Facebook Page



Services Procided by BEMOSS

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



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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)

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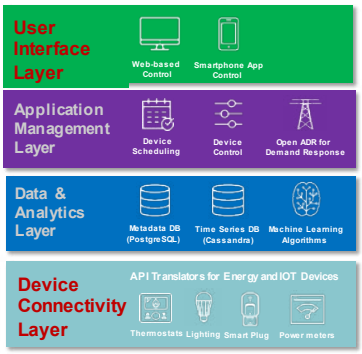
WiseBldg: Building Energy Management Platform

Platform Architecture



Overview

WiseBldg

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.

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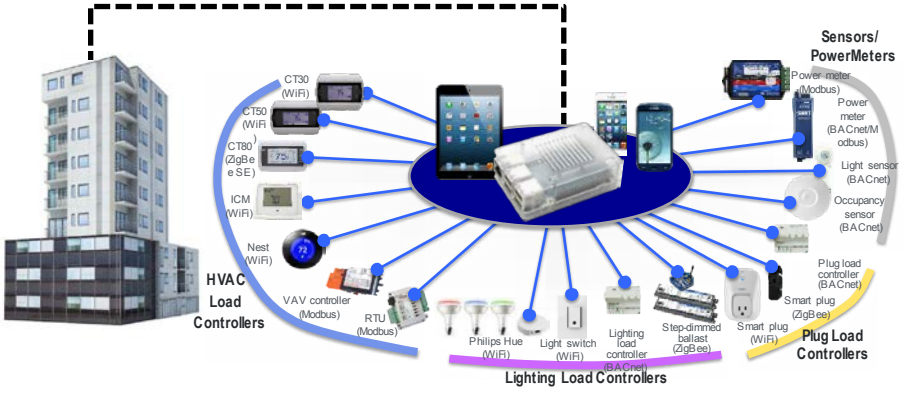
WiseBldg supports multiple IoT devices through industry standard protocols and communications technologies



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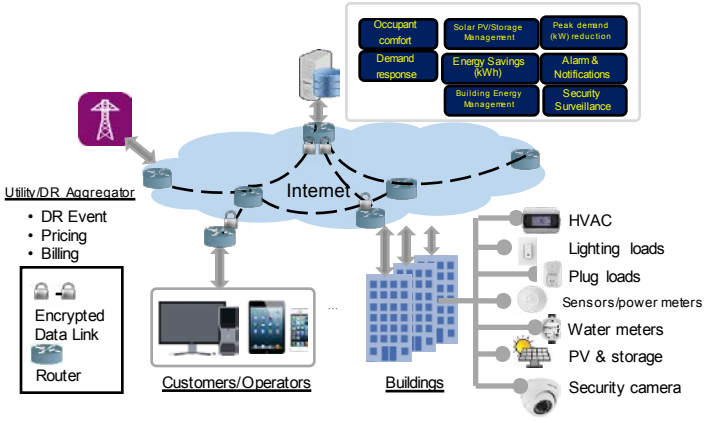
WiseBldg Platform Built by BEM Controls



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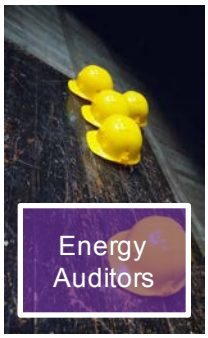
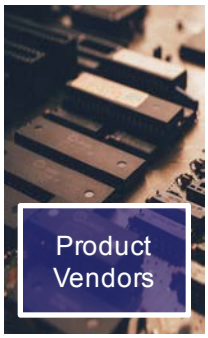
End-users, owners and vendors looking to control energy usage





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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 (CO_2 levels, PM 2.5).

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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

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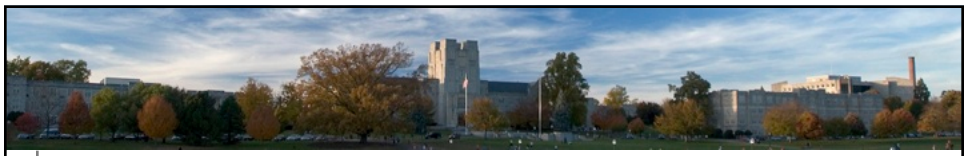

WiseBldg can make an old building smart

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Building 1 – VT Building in Alexandria, VA

Alexandria, Virginia, USA

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

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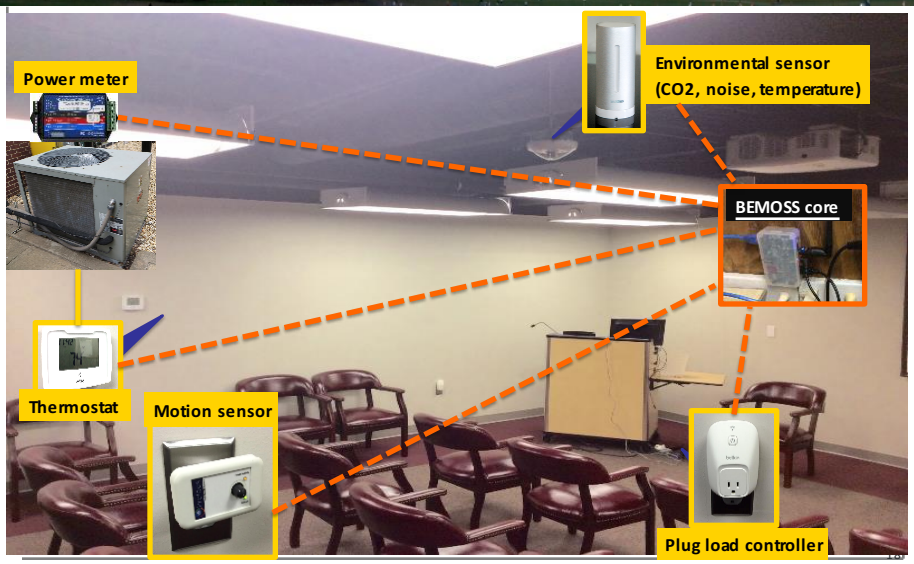
Classroom under Real-time Monitoring



Indoor Environmental Monitoring

Energy Savings from HVAC Control

Location: Alexandria, VA
Area: 25,000 square feet
Deployed Devices

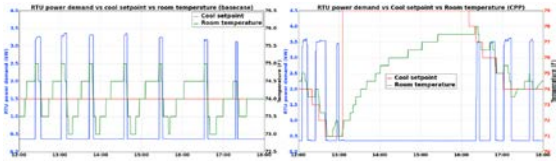
- 6 Thermostats
- 6 Power meters
- 1 Li-ion battery
- 1 Environmental sensor

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

Summer Months (June-July-August)	
Compressor consumption 2014 (Before WiseBldg)	8,340 kWh
Compressor consumption 2016 (After WiseBldg)	6,071 kWh
Average savings	**26.8% savings**

Temperature profile BEFORE WiseBldg Demand Reduction

Temperature profile AFTER WiseBldg Demand Reduction



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

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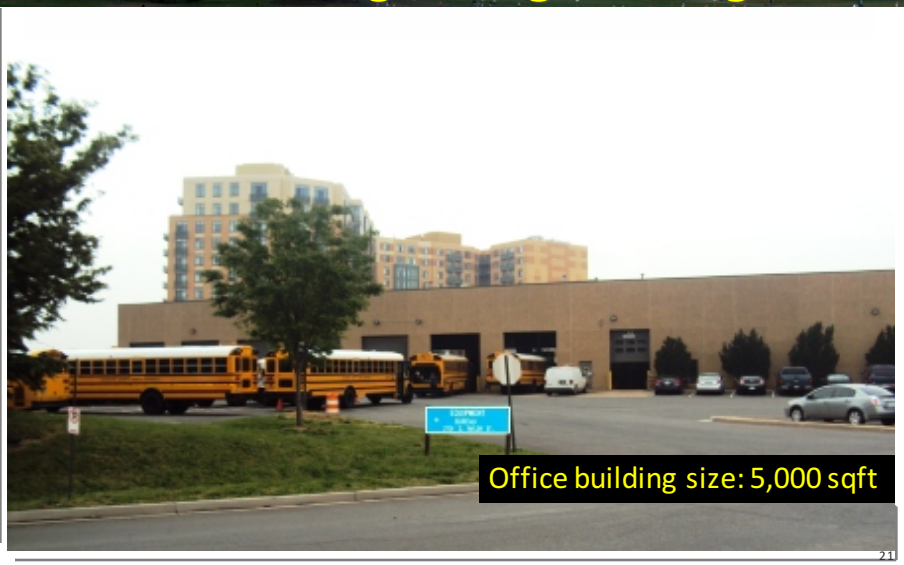
Office Building, Arlington, Virginia



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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

Oct 2016	Nov 2016	Dec 2016	Jan 2017	Feb 2017	Mar 2017	Apr 2017	May 2017	Jun 2017	AVERAGE
33.7%	33.9%	34.4%	33.4%	35.9%	36.2%	35.0%	36.0%	36.3%	**34.5%**

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Energy Savings by controlling light intensity

Month	Total Measured Energy Consumption (kWh)	Total Calculated Energy Consumption without Dimming (kWh)	Energy Savings by Dimming (%)
October 2016	264.37	399.90	33.89%
November 2016	278.13	423.78	34.37%
December 2016	280.76	426.40	34.16%
Total (October-December)	823.26	1250.08	34.14%

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.

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Energy Management in a Museum Building

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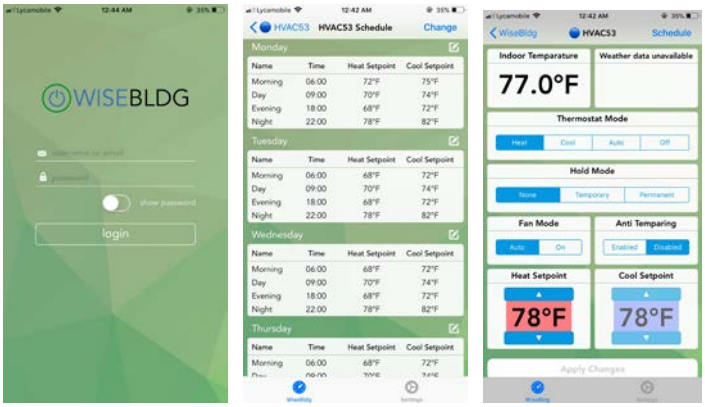
WiseBldg App



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Solar PV System Monitoring and Control

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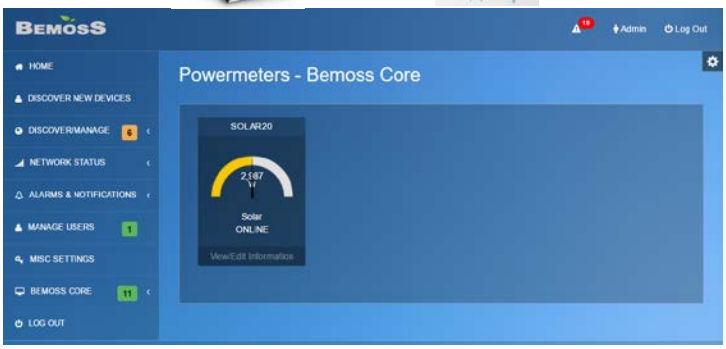
Solar PV and Smart Inverter Integration



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WiseBldg User Interface

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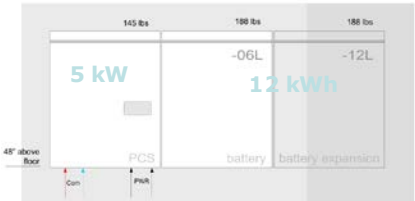
Managing Battery Storage from WiseBldg Platform

Battery Cells LG Chem



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Battery Storage Monitoring & Control

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