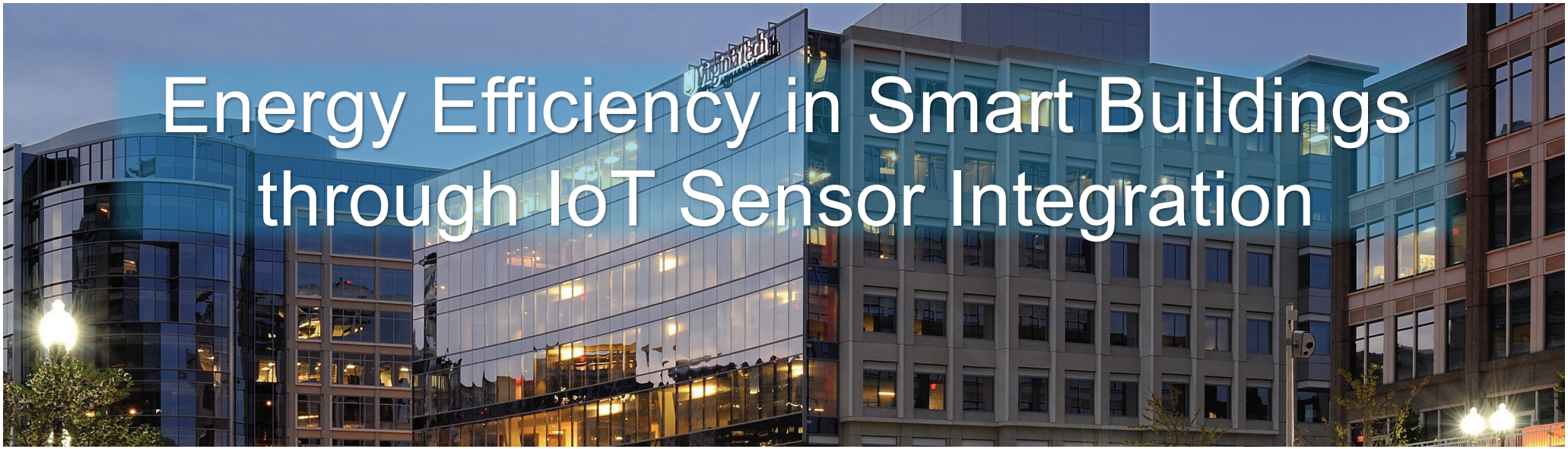

Energy Efficiency in Smart Buildings through IoT Sensor Integration

Keynote Speech

Prof. Saifur Rahman

Director, Virginia Tech Advanced Research Inst., USA

2022 IEEE President-elect

Malaviya National Inst of Tech

27 May 2022, Jaipur, India

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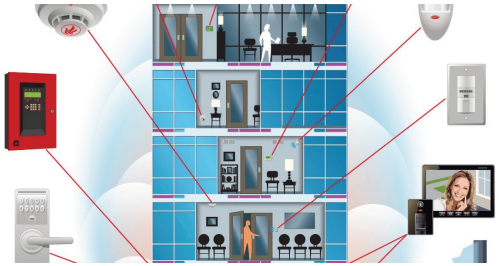
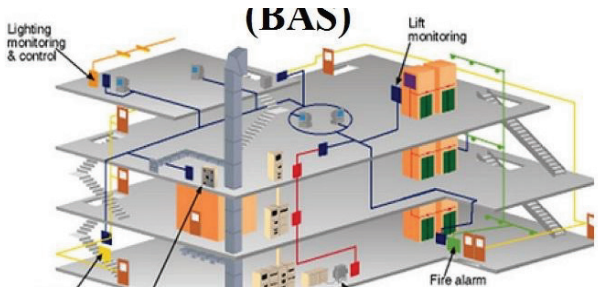


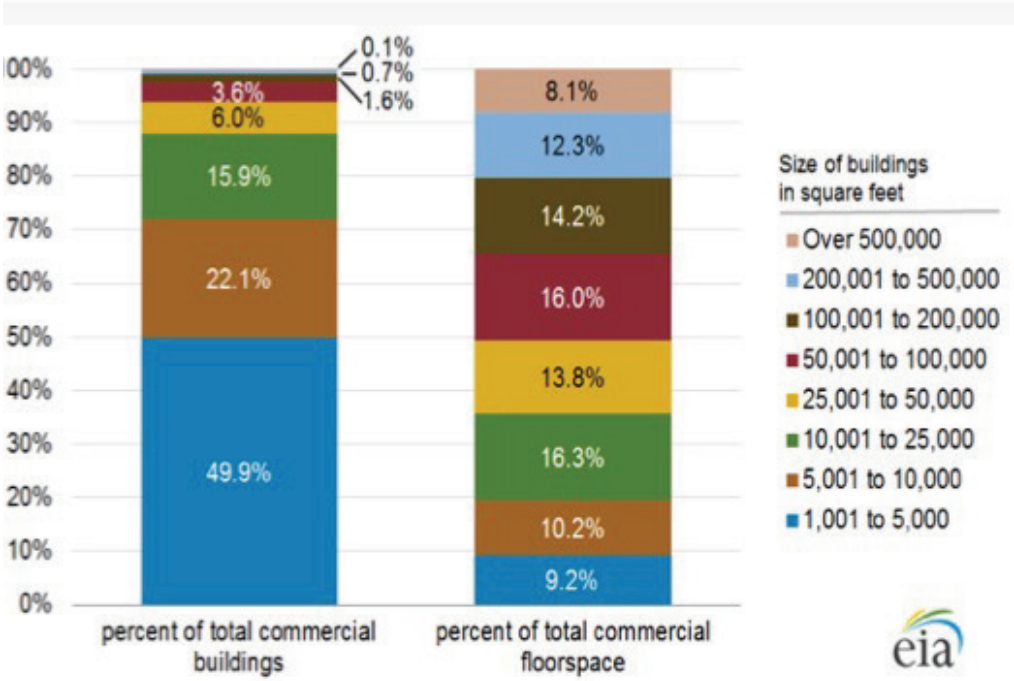
Purpose & Objectives

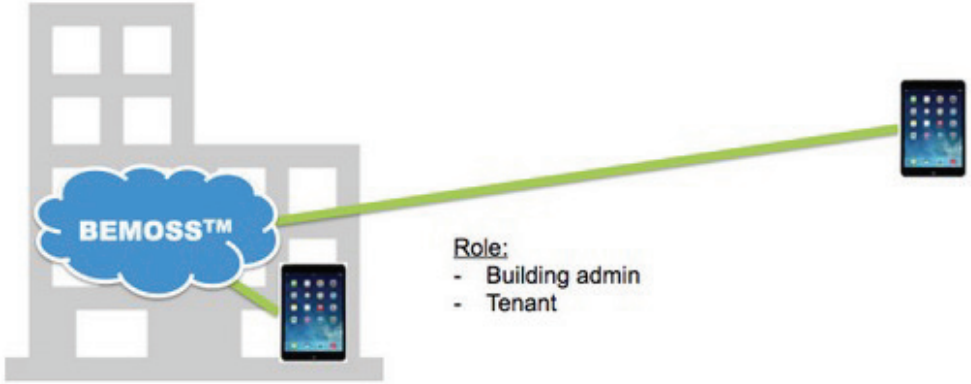


- Buildings consume over 40% of the total energy consumption in the U.S. Over 90% of the buildings in the U.S. are either small-sized (<500 square met.) or medium-sized (between 500 sqm and 5,000 sqm).
- These buildings typically do not use Building Automation Systems (BAS) to monitor and control their 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**

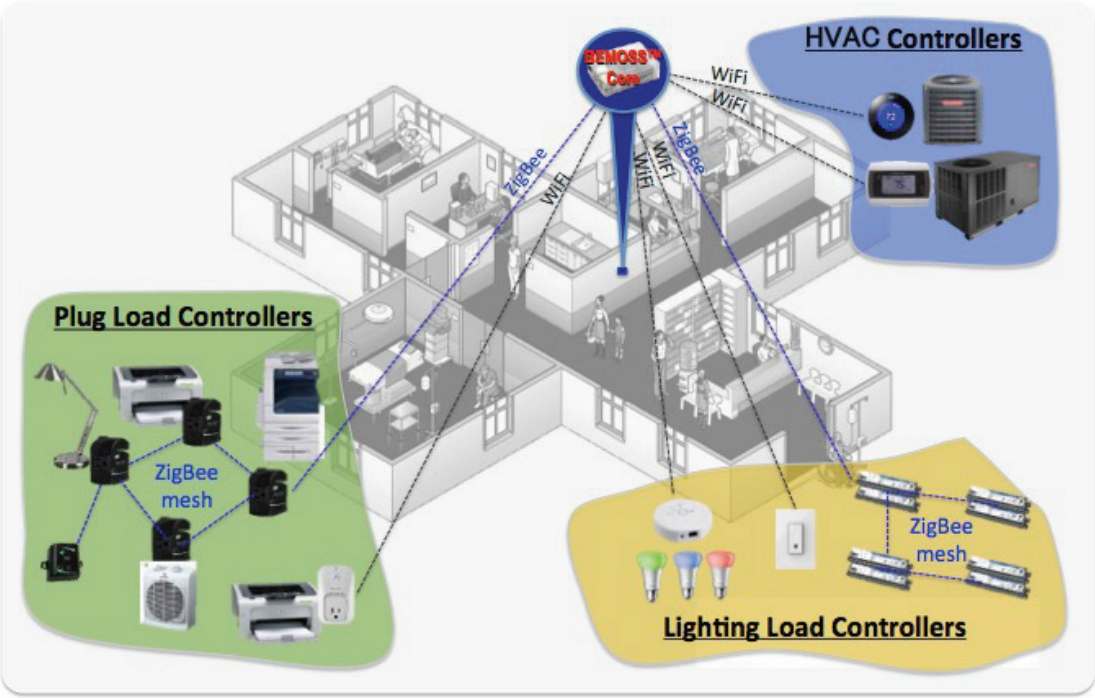
- Heating, Ventilation, AC
- Lighting loads
- Plug loads

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

www.bemoss.org

Architecture (Small Commercial Building)

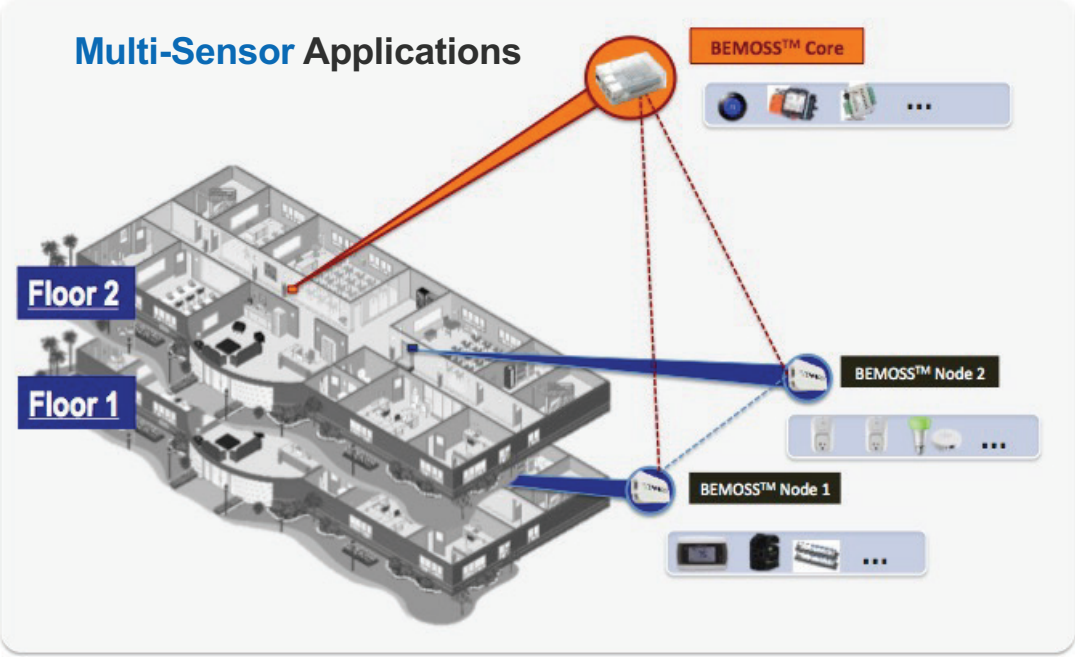
- The BEMOSS™ architecture for a small commercial building with a few load controllers of each type.
- In this architecture, only one single-board computer (e.g., Odroid) embedded with the BEMOSS™ software platform is used to enable monitoring and control features of all load controllers in the building.
- This embedded system can communicate with different types of load controllers, i.e., thermostats, lighting load controllers, 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.



BEMOSS™ system architecture for small buildings with a few load controllers

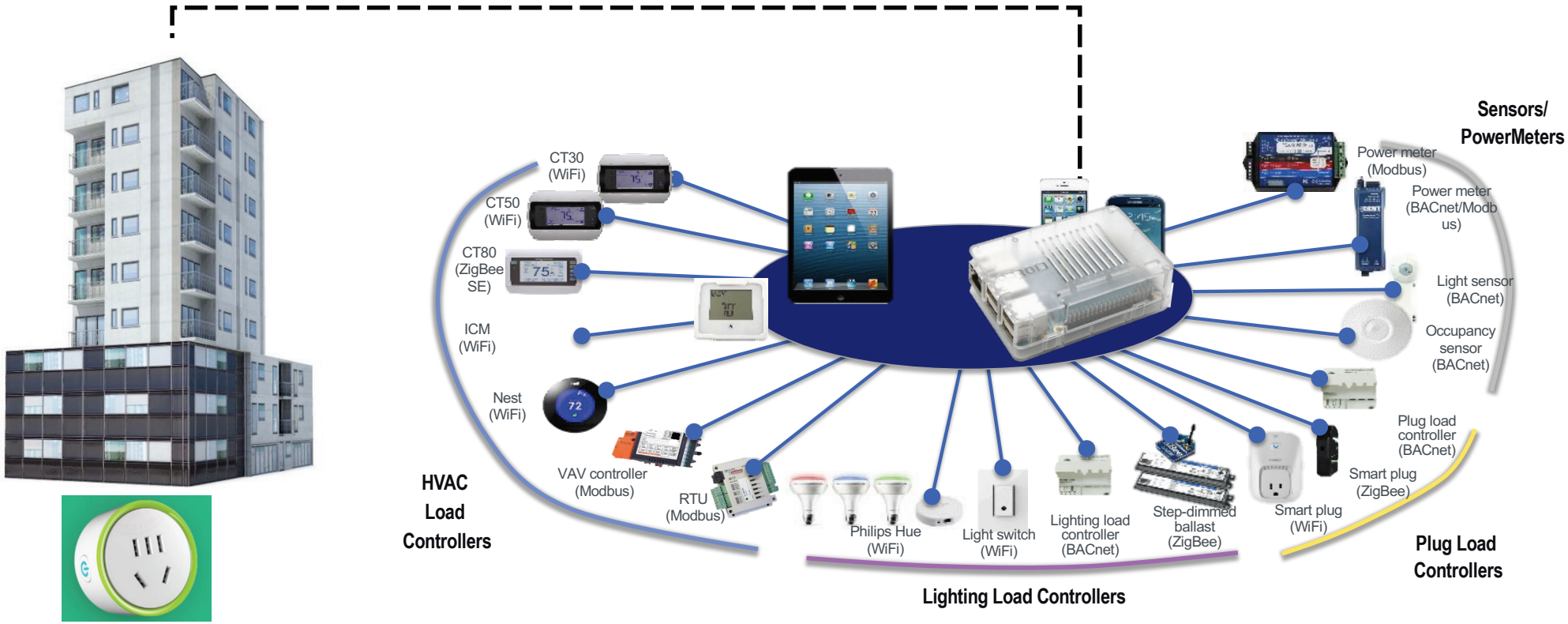
Architecture (Multi-Floor Building)

- 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.



BEMOSS™ system architecture for larger 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)

IEEE 802.3

IEEE 802.11 abg WiFi n ac

IEEE 802.15.4

RS-485

IOT

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)

ASHRAE BACnet™

OpenADR

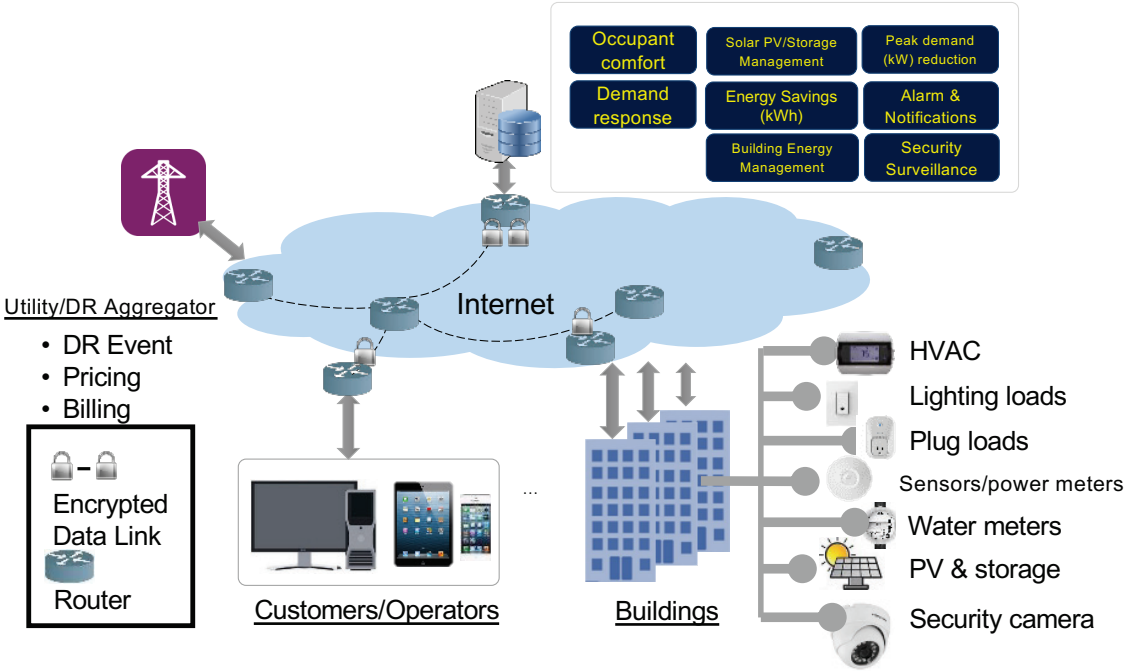
WEB

Modbus

ZigBee®

Smart Energy Profile (SEP)

Campus-wide Application



www.bemconrtrols.com

How to make an old building smart

Customers Controlling Buildings Optimized for Savings

Measured energy savings across deployments

Improved operations and maintenance: The 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 (CO_2 levels, PM 2.5).

Sample Examples

Building 1

VT Classroom Building

- Location: Alexandria, VA
- Demonstration: HVAC, plug load control

Building 2

Equipment Bureau Building

- Location: Arlington, VA
- Demonstration: Lighting control

Building 3

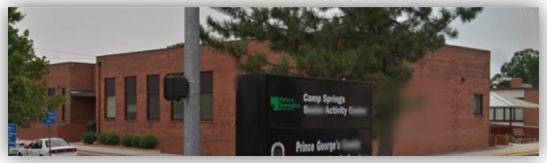
VT Lab Building

- Location: Blacksburg, VA
- Demonstration: HVAC control

Building 4

PG County Community Building

- Location: **Camp Springs**, MD
- Demonstration: HVAC control

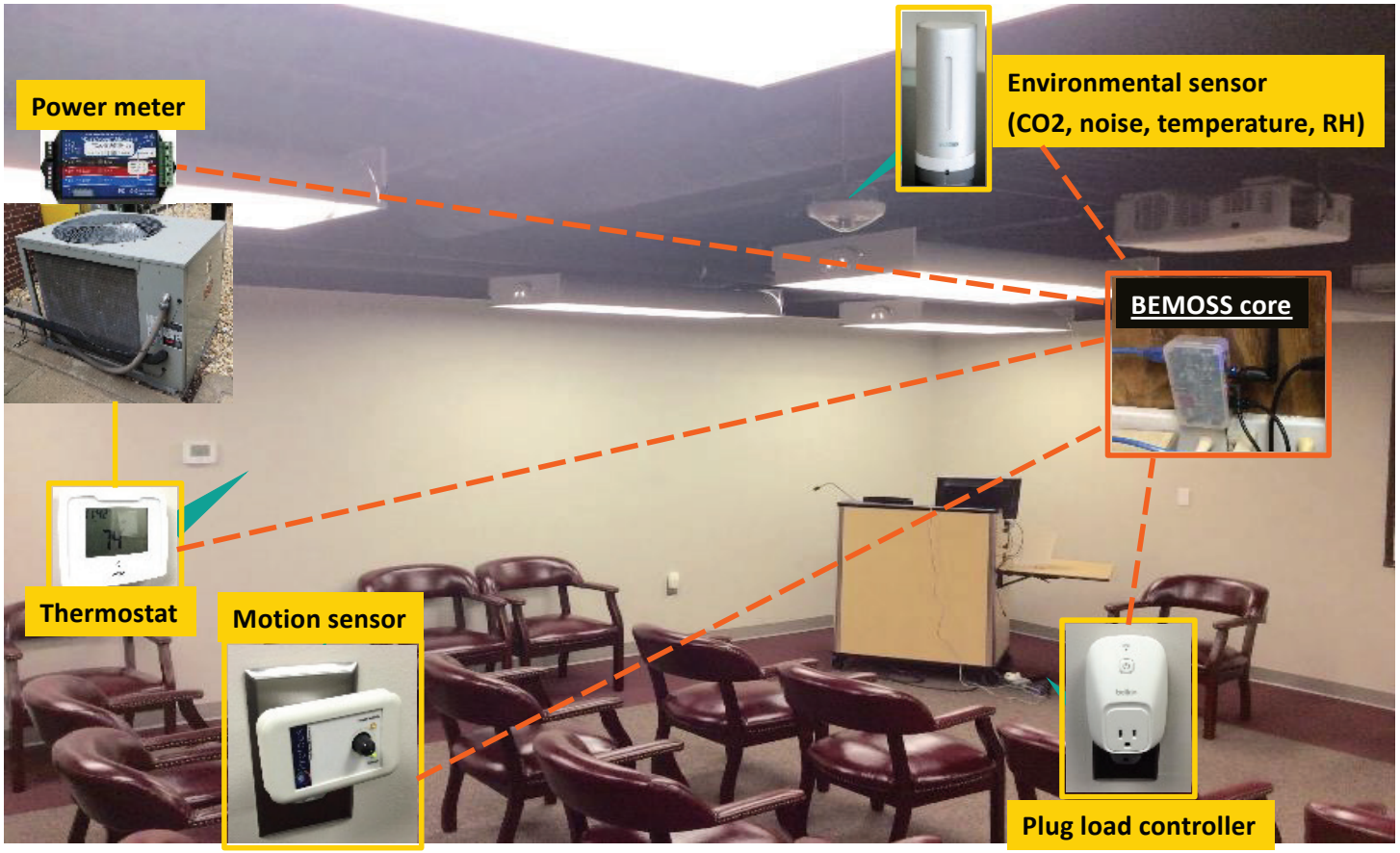


Building 1 – VT Building in Alexandria, VA

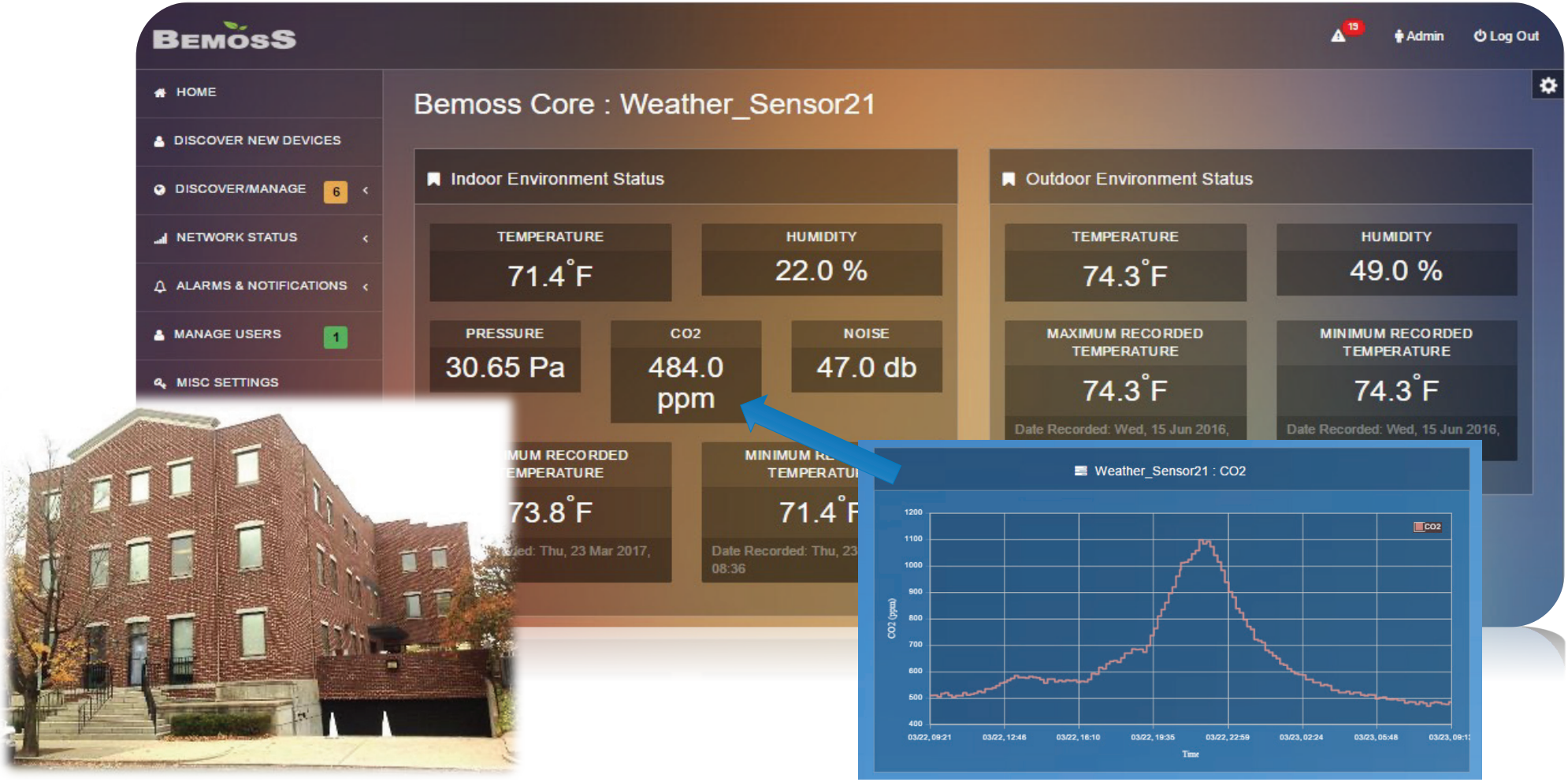
Area: 2500 sqm
Energy: 14-25 MWh/mo.
Peak load: 61 kW

Alexandria, Virginia, USA

Classroom Under Real-time Monitoring



Indoor Environmental Monitoring



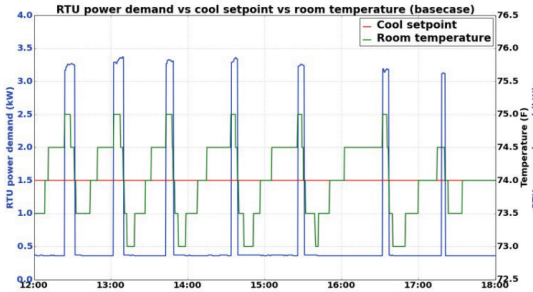
Energy and Peak Savings from HVAC Control

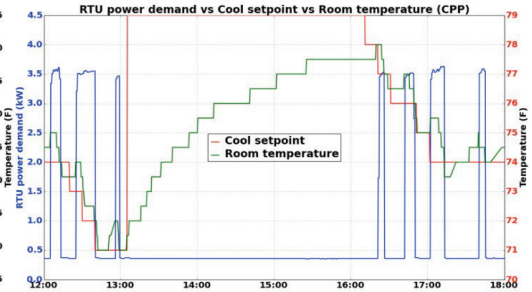
Location: Alexandria, VA
Area: 2,500 square meter
Deployed Devices
- 6 Thermostats
- 6 Power meters
- 1 Li-ion battery
- 1 Environmental sensor




Temperature profile BEFORE BAS Demand Reduction

Temperature profile AFTER BAS Demand Reduction





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**

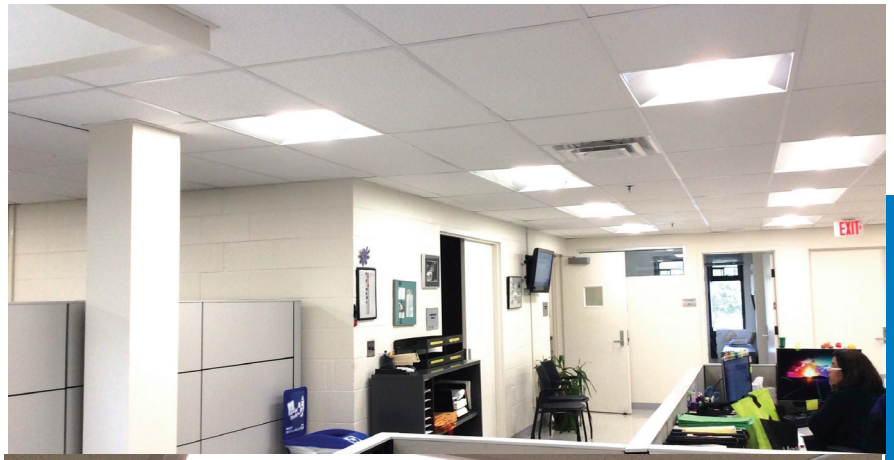
Base case (w/o WiseBldg)

- **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



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%**

Energy Savings By Controlling Light Intensity

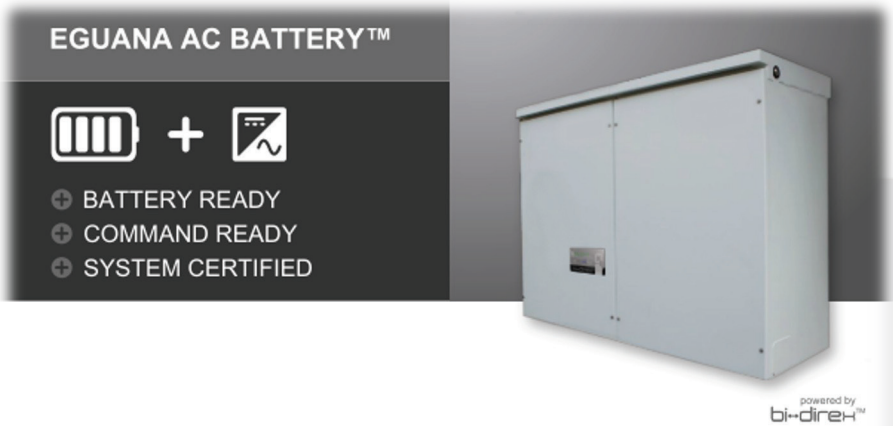
Month	Total Measured Energy Consumption (kWh)	Total Calculated Energy Consumption without Dimming (kWh)	Energy Savings by Dimming (%)
October 2016	264.37	399.90	33.89%
November 2016	278.13	423.78	34.37%
December 2016	280.76	426.40	34.16%
Total (October-December)	823.26	1250.08	34.14%

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.

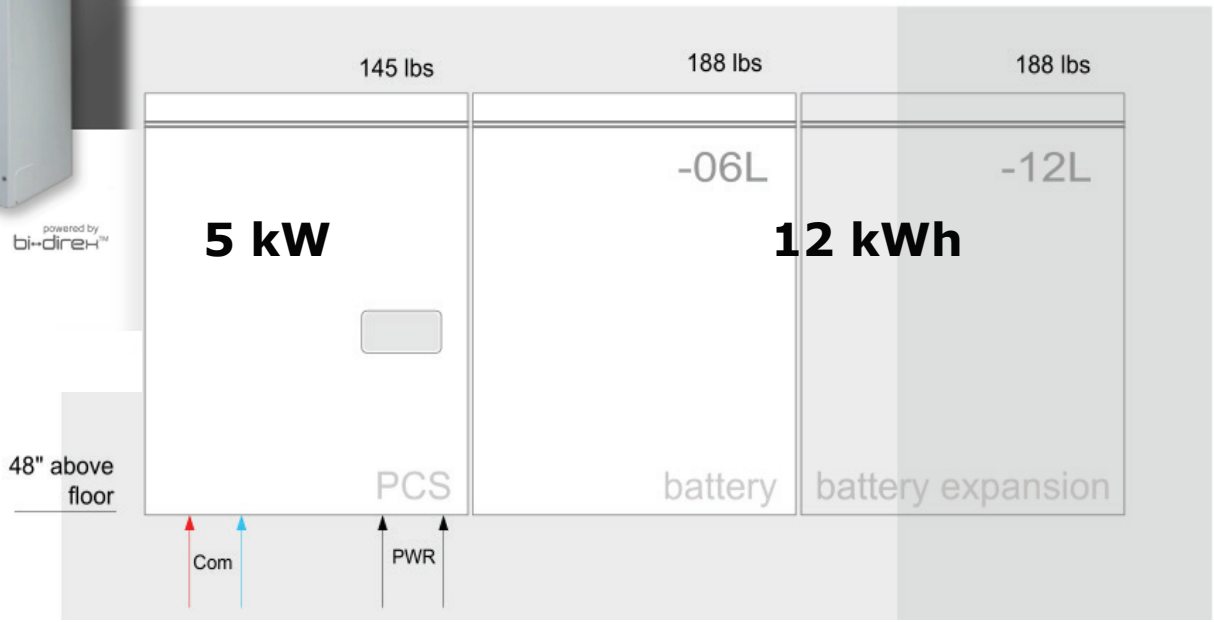
Solar PV System Monitoring and Control

DER Devices (Rooftop Solar)

Managing Battery Storage

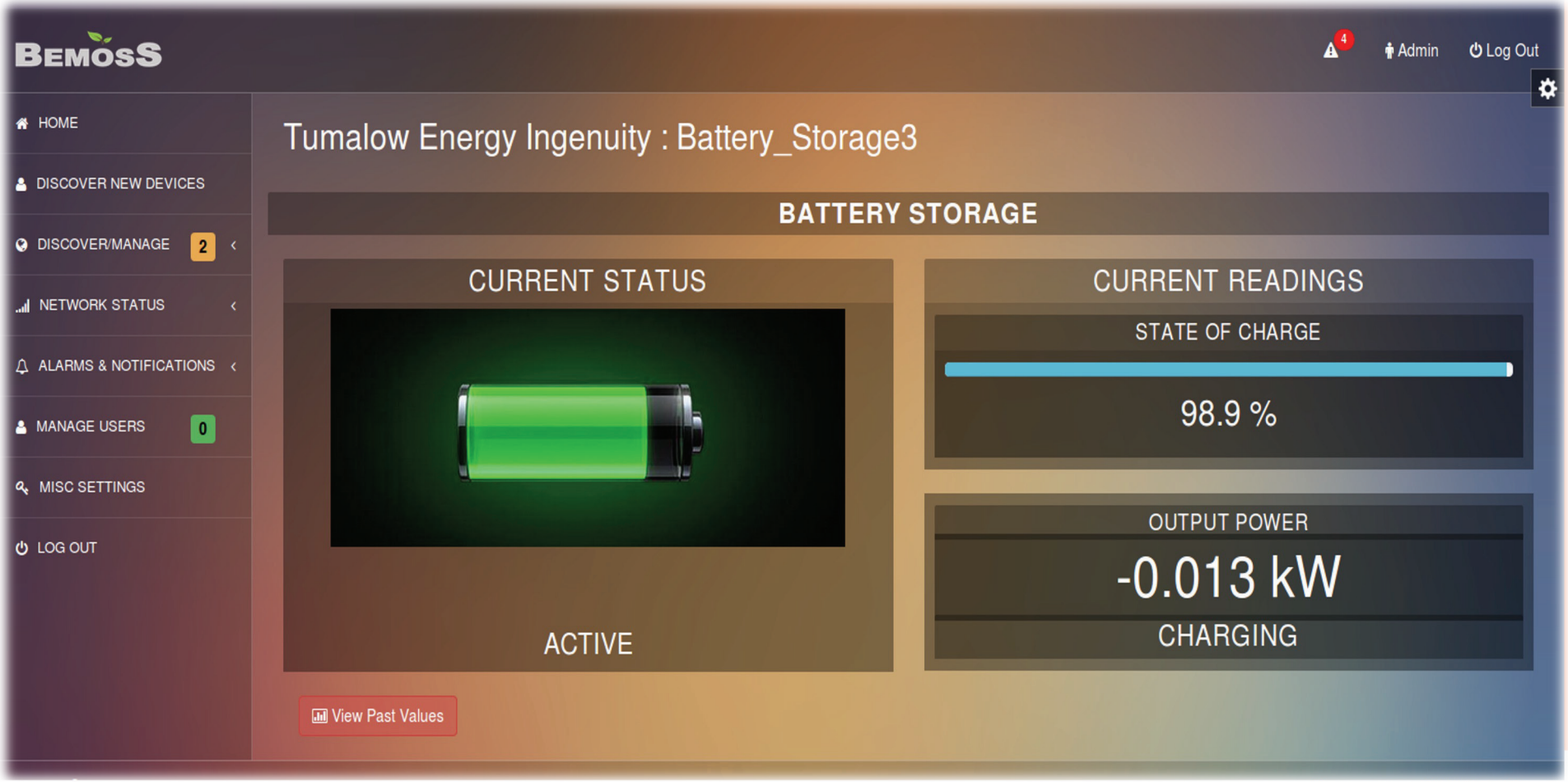


Battery Cells LG Chem



Battery Storage Setup

Battery Storage Monitoring & Control



www.srahman.org

Thank You