



Measurement, Control and Protection in a Robust Smart Grid with a reference to Energy Management Systems for Smart Buildings in a Smart City

Professor Saifur Rahman

Director, Virginia Tech Advanced Research Inst., USA

President, IEEE Power & Energy Society 2018 & 2019

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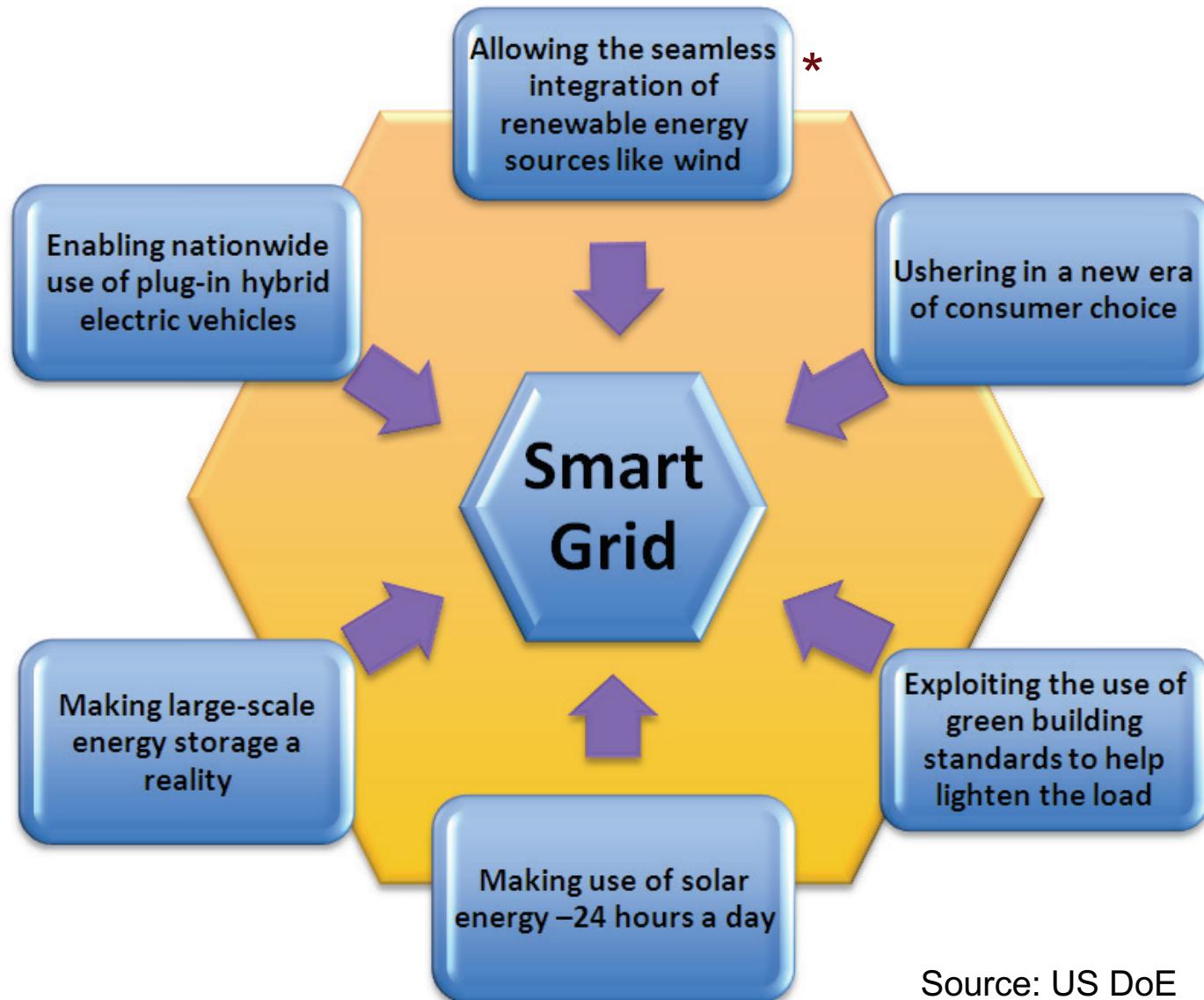


"Smart grid" is a concept with many elements where monitoring and control of each element in the chain of **generation, transmission, distribution and end-use** allow the electricity delivery and use to be more efficient.

Motivation for a Smart Grid

Desire to make the grid smarter, safer, reliable and more cost-effective using advanced sensors, communication technologies and distributed computing.

Potentials of the Smart Grid





Characterization of a Robust Smart Grid

1. Increased use of digital information and control technologies
2. Dynamic optimization of grid operations and resources with full cybersecurity
3. Deployment and grid-integration of distributed energy resources
4. Operation of demand response and energy efficiency programs
5. Deployment of “smart technologies” for metering, communications concerning grid operations and status including distribution automation
6. Integration of consumer-owned smart devices and technologies (transactive energy) and
7. Deployment and control of electric vehicles and storage – thermal, mechanical and electrical

Source: US Energy Independence and Security Act (EISA) of 2007 Section 1301



Advanced Control is Needed

The smart grid requires advanced control at both component and system levels. Different non-linear controls, such as back-stepping control, feedback linearization, model predictive control, and sliding mode control are applied to manage **DERs**, and their grid integration.

Relying on Smart Grid Communications



As speedy communication facilities, such as fibreoptics, microwave, GSM/GPRS, 3G/4G are becoming the integral parts of the functioning smart grid. The integration of **multi-agent systems (MAS)** in smart grid applications is becoming simple and feasible.



What are Multi-agent Systems (MAS)

- Agent is a piece of software that is designed to accomplish a certain objective.
- Multi-agent system (MAS) consists of multiple agents, each of which works independently to achieve a common system goal.
- MAS features are **adaptive, proactive and autonomous** and can respond to external environment rapidly without human intervention.



Value for Multi-agent Systems

Multi-agent systems (MAS) provide **autonomy, reactivity and proactivity**. MAS are complex systems composed of several autonomous **agents with only local knowledge and limited abilities**, but are able to interact in order to achieve a global objective. MAS use a new programming paradigm to implement agents.



Broad Applications

- Building automation
- Demand response
- DER monitoring and control (PV, storage)
- Fault detection
- Illuminance-based control
- Transactive energy

An Open Architecture Platform for Building Energy Efficiency

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

www.bemcontrols.com

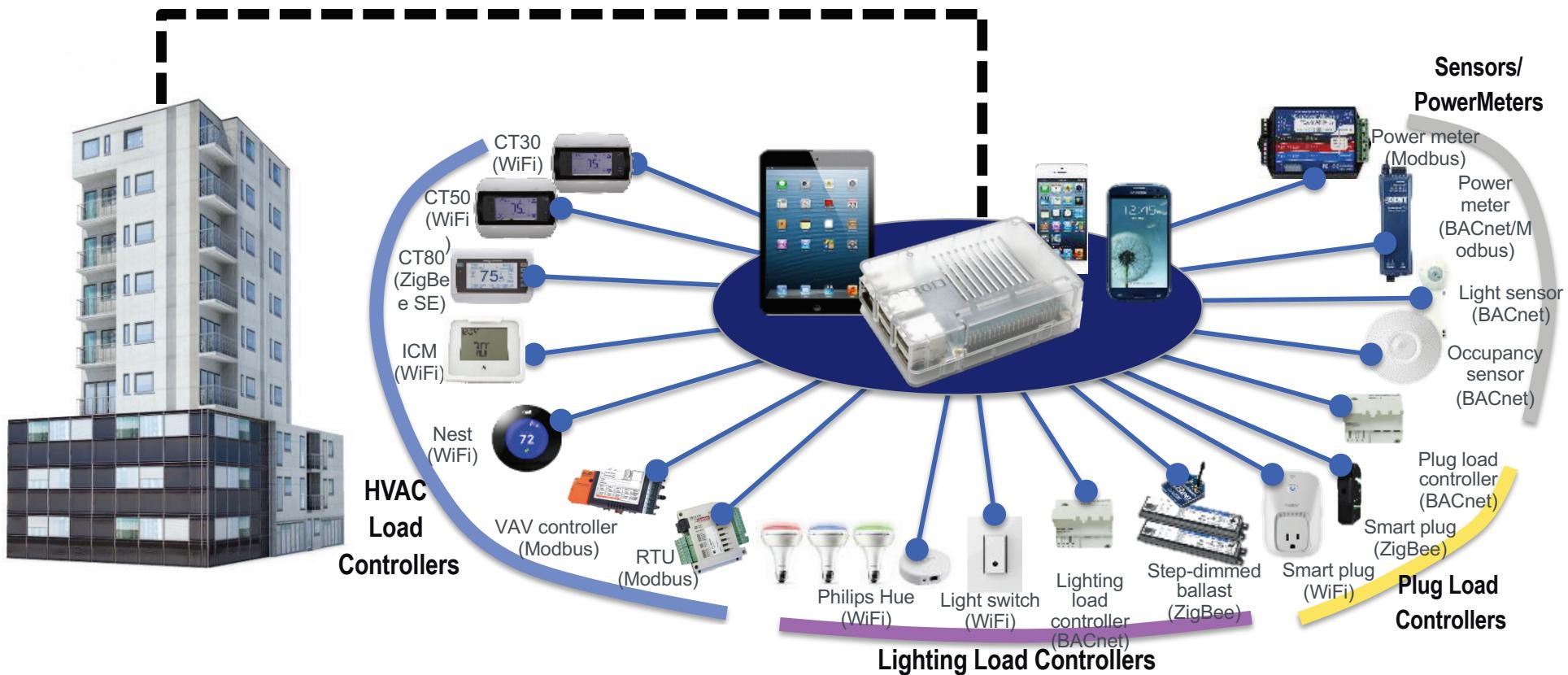
Monitoring and control:

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

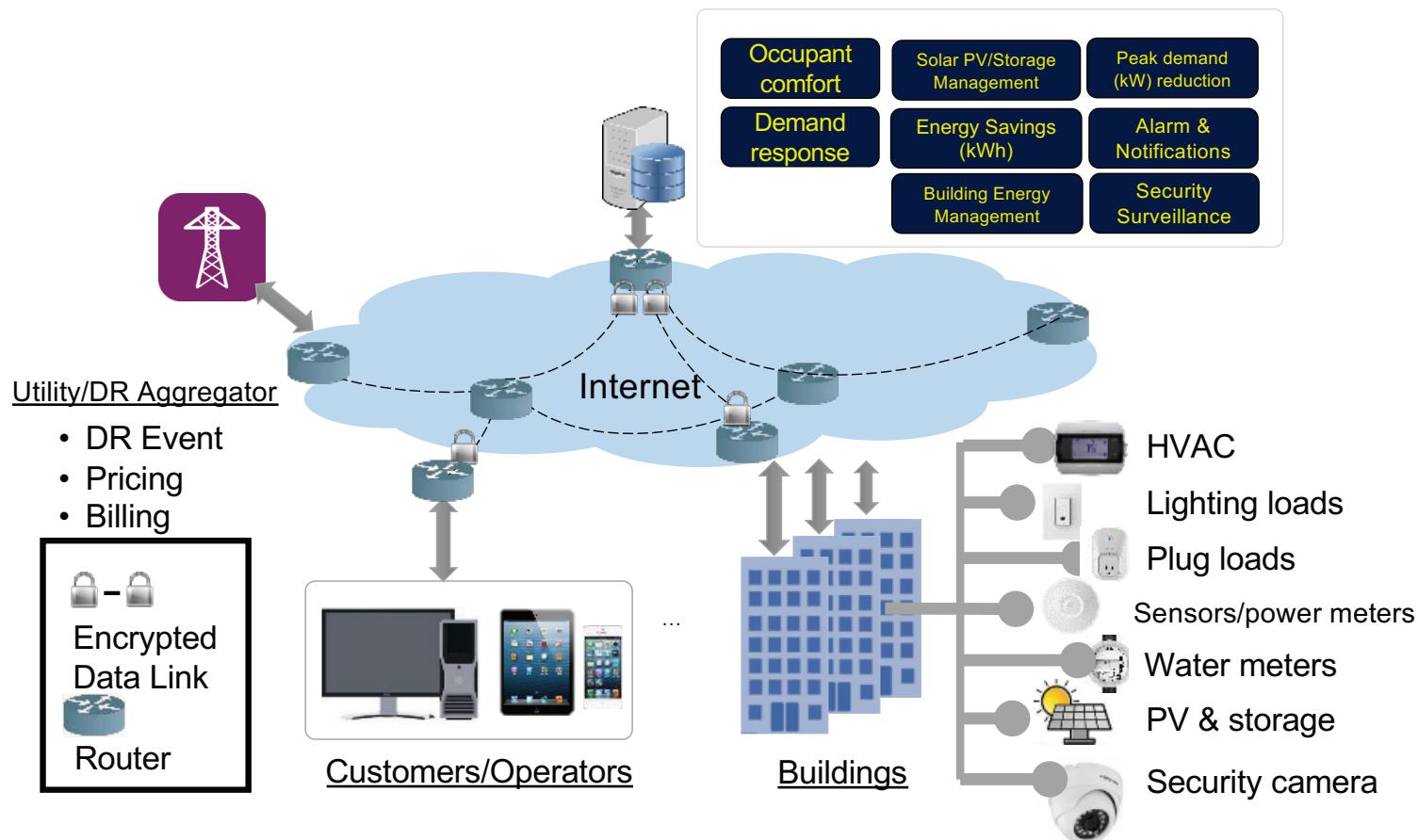
Value:

Improves energy efficiency and facilitates peak load savings in buildings

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



WiseBldg Platform Built by BEM Controls





WiseBldg platform can make
an old building smart

WiseBldg Deployments in Four Buildings



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

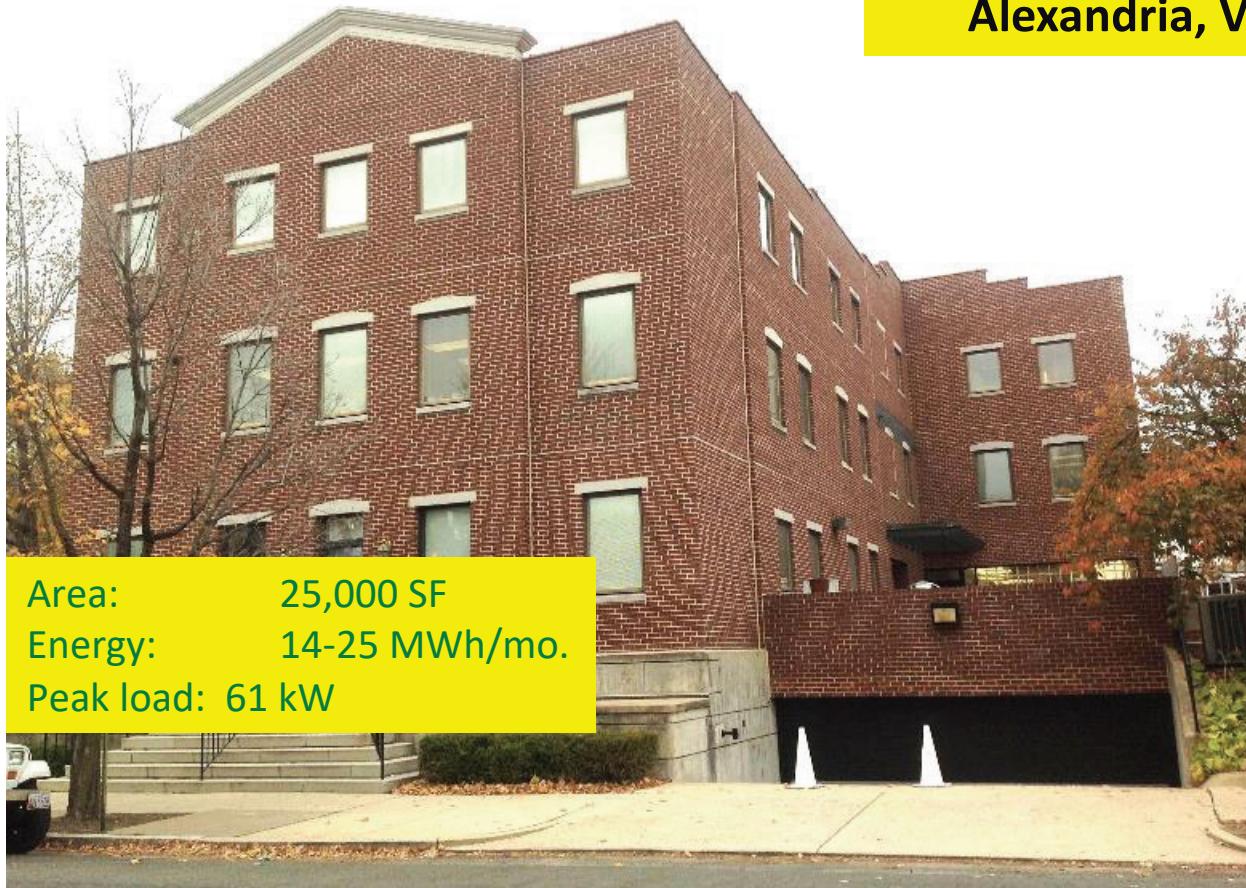
- Location: **Blacksburg, VA**
- Demonstration: HVAC control



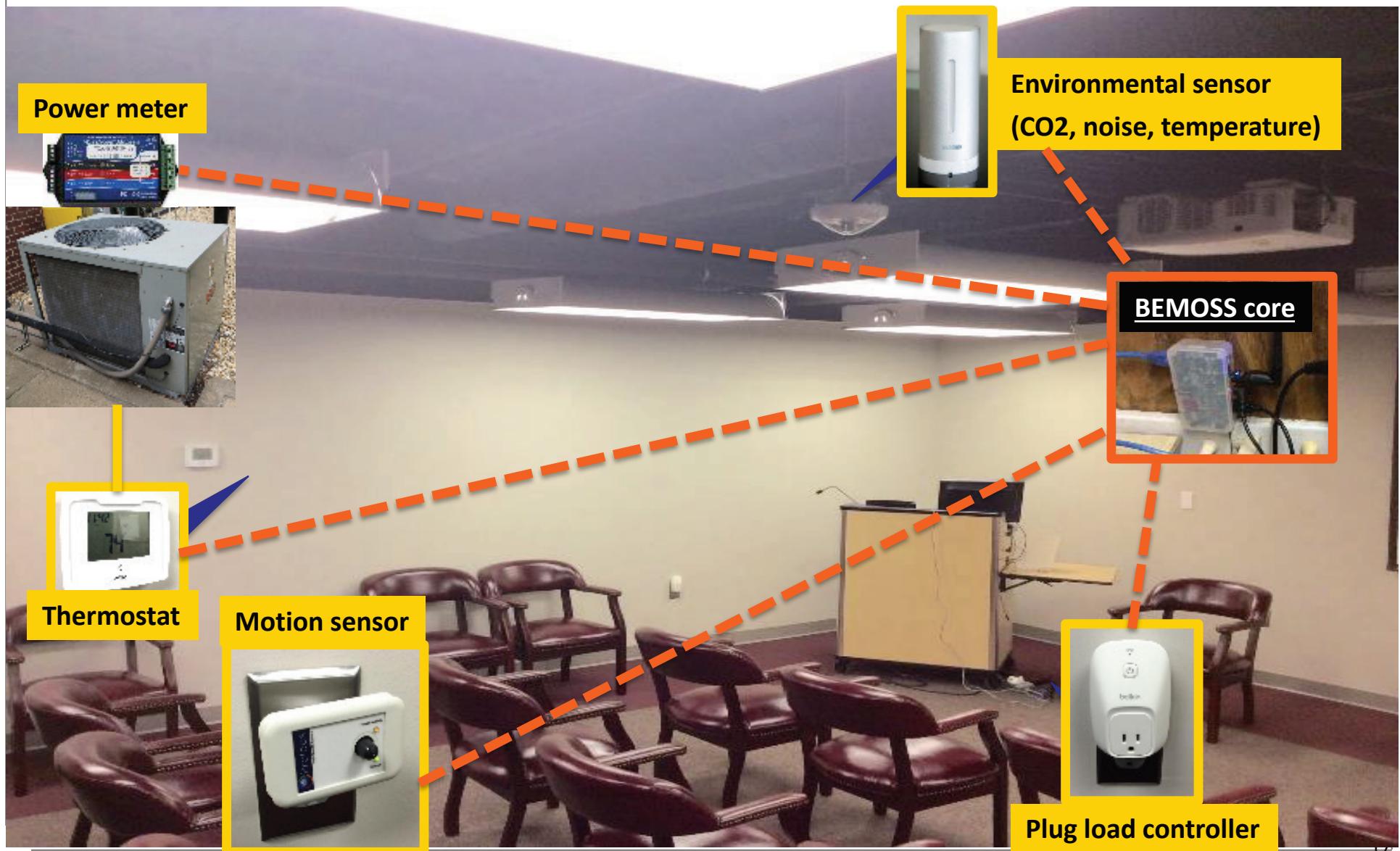
Building 4 – PG County Community Building

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

Building 1 - VT Building in Alexandria, VA



Classroom under Real-time Monitoring



Indoor Environmental Monitoring

BEMOSS

HOME DISCOVER NEW DEVICES DISCOVER/MANAGE 6 NETWORK STATUS ALARMS & NOTIFICATIONS MANAGE USERS 1 MISC SETTINGS BEMOSS CORE

Bemoss Core : Weather_Sensor21

Indoor Environment Status

TEMPERATURE 71.4 °F	HUMIDITY 22.0 %
PRESSURE 30.65 Pa	CO2 484.0 ppm
NOISE 47.0 db	

Outdoor Environment Status

TEMPERATURE 74.3 °F	HUMIDITY 49.0 %
MAXIMUM RECORDED TEMPERATURE 74.3 °F	MINIMUM RECORDED TEMPERATURE 74.3 °F
Date Recorded: Wed, 15 Jun 2016, 16:25	Date Recorded: Wed, 15 Jun 2016, 16:25



A large blue arrow points from the CO2 reading in the indoor status box to the CO2 graph below.

Weather_Sensor21 : CO2

CO2 (ppm)

Time

CO2

Approximate CO2 Data from Graph:

Time	CO2 (ppm)
03/22, 09:21	500
03/22, 12:46	550
03/22, 16:10	550
03/22, 19:35	650
03/22, 22:59	1100
03/23, 02:24	550
03/23, 05:48	500
03/23, 09:11	500

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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 WiseBldg, Building Operator saved 27% on HVAC consumption alone

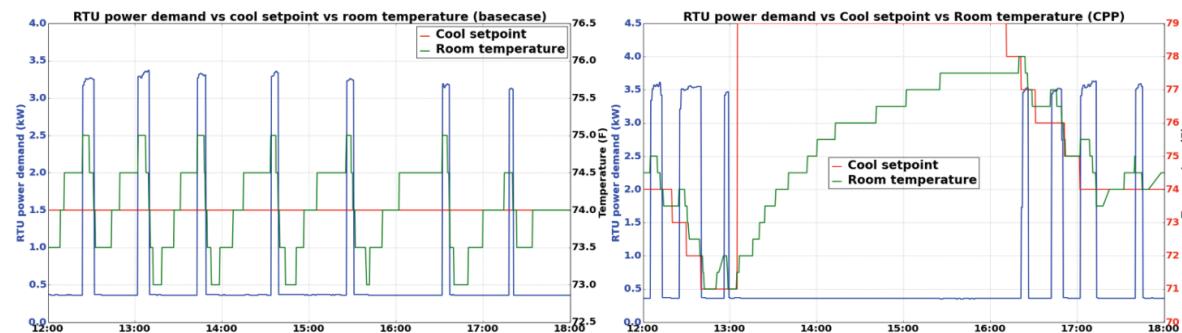
Summer Months (June-July-August)

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)

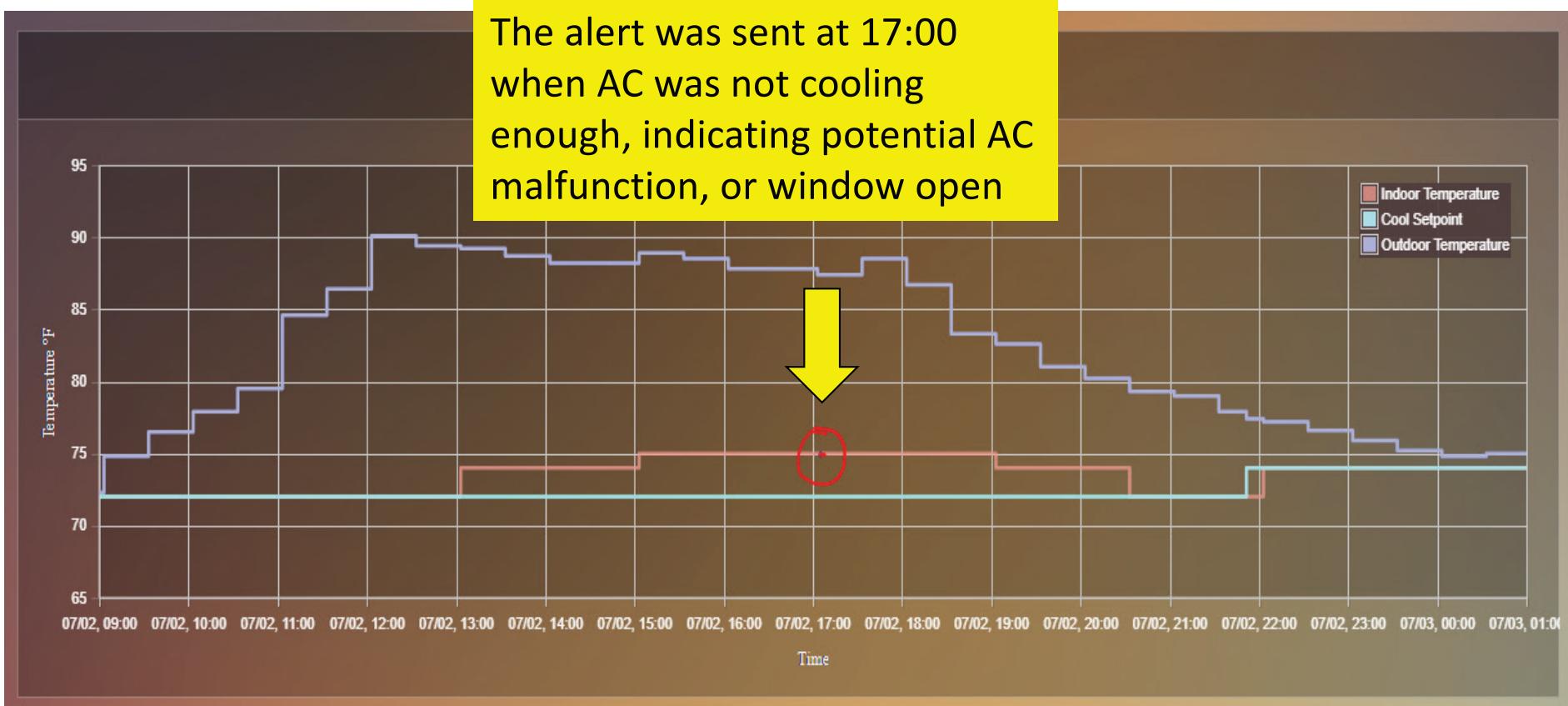
- **Setpoint:** 74 deg F
- **Energy usage** = 2.72kWh
- **Max demand** = 3.98kW

Managed by WiseBldg

- **Setpoint:** 77 deg F
- **Energy usage** = 1.42kWh
- **Max demand** = 0.5kW

Fault Detection

- WiseBldg sends alerts on abnormal indoor temperature behaviors
- WiseBldg sends alerts when indoor temperature goes above/below certain thresholds
- Similar applications possible for circuit fault detection



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

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



Solar Panels in Winter



WiseBldg User Interface

The screenshot displays the BEMOSS user interface for Node1: Der1. The left sidebar includes links for HOME, DISCOVER NEW DEVICES, DISCOVER/MANAGE (with 1 notification), NETWORK STATUS, ALARMS & NOTIFICATIONS, MANAGE USERS (with 0 notifications), MISC SETTINGS, APPLICATIONS, NODE1 (with 18 notifications), and LOG OUT.

The main dashboard shows the following data:

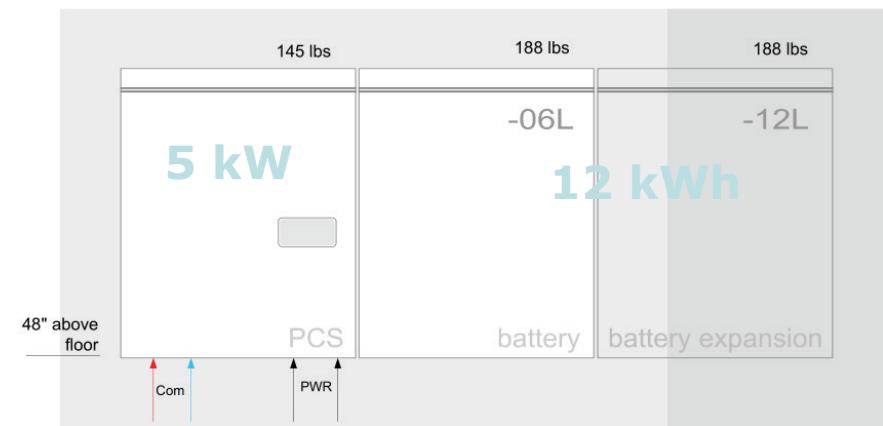
- Power:** INCIDENT: 35361.2 W, DC: 5140.15 W, AC: 4958.0 W
- Efficiency:** PANEL: 14.54 %, INVERTER: 96.46 %, TOTAL: 14.03 %
- Voltage:** DC: 357.7 V, AC: 212.3 V
- Current:** DC: 14.37 A, AC: 23.51 A
- Energy:** TOTAL: 6.52 MWh, TODAY: 14.41 kWh
- Irradiance:** ARRAY: 865.0 W/m², HORIZONTAL: W/m²
- Temperature:** AMBIENT: 84.0 °F, MODULE: 93.0 °F
- Wind Velocity:** 0.0 m/s
- CO2 Saved:** 10105.01 lbs

A yellow box highlights the **Smart inverter control** section, which contains two sliders for **REAL POWER CONTROL** and **POWER FACTOR**. Both sliders have a limit of 100% and are currently set to 100. Below the sliders are buttons for **Submit All Changes** and **View Past Usage and Set Points**.

Managing Battery Storage from WiseBldg Platform



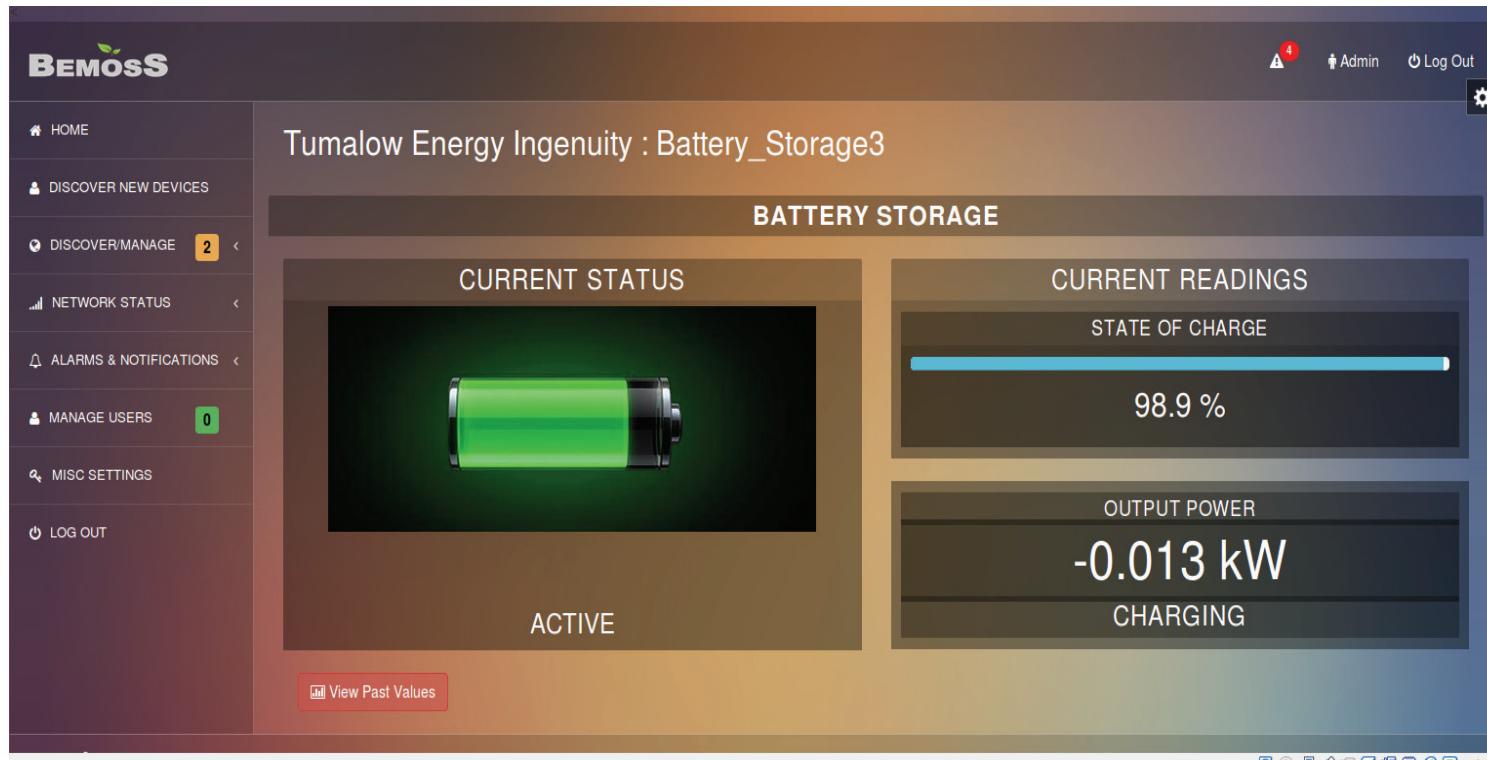
Battery Cells **LG Chem**



Battery Storage Data Access from WiseBldg



Battery Storage Monitoring & Control



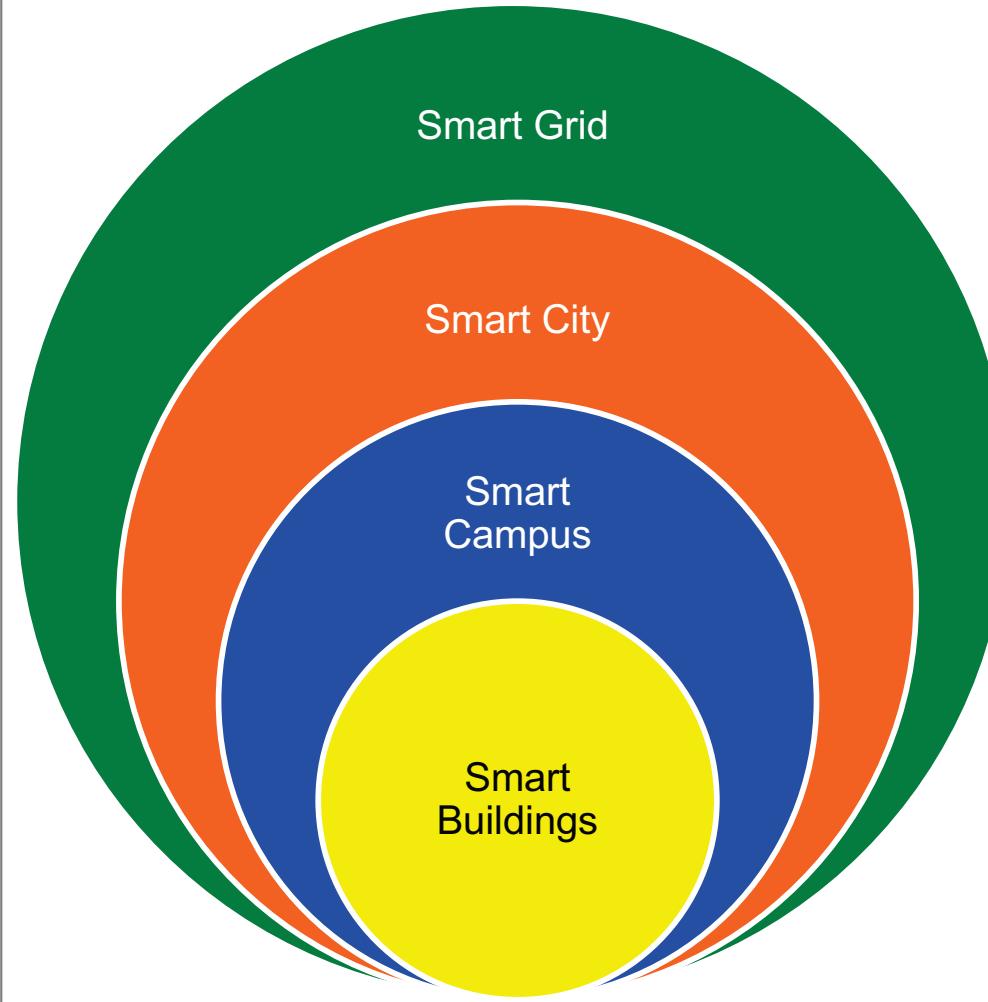
What makes a Building Smart



A single platform for monitoring and control of HVAC, lighting, water supply, sensor networks, security camera & fire emergency

Source: Smart Building Market To Grow 30% by 2020, <http://www.iotsolutionprovider.com/smart-building/smart-building-market-to-grow-30-by-2020>, December 2015
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THE SMART GRID ECOSYSTEM



Smart grid: Bi-directional flows of energy, remote control/automation of power, integrated distributed energy...

Smart city: Complex system of interconnected infrastructures and services...

Smart Campus: A collection of buildings managed by the same facility manager...

Smart buildings: Intelligent building automation systems, smart devices, productive users, grid integration...

Supported by ICT and distributed networks
of intelligent sensors, data centers/clouds



I would like to see a broader IEEE

We need to ensure that we are “READY FOR RECOVERY”, when we get back to the “NEW NORMAL” after COVID-19. Let us enhance cooperation, collaboration and community spirit.

For this we need to make IEEE broader so that IEEE is more relevant to the work our members do regardless where they work.

We need more participation from volunteers globally in IEEE governance. A broader based IEEE will make the Institute more relevant to technologists and academics from all parts of the world.

Prof. Saifur Rahman (s.rahaman@ieee.org)



Past-President of IEEE Power & Energy Society
Past-Chair, IEEE Publication Services & Products Board

PES accomplishments:

PES University

PES Corporate Engagement Program

PES Chapters' Councils in China, India, Africa and Latin America

Website: <https://www.srahman.org>.

