



Smart Buildings with IoT Sensors for Climate Sustainability

Keynote Speech

Professor Saifur Rahman

Director, Virginia Tech Advanced Research Inst.

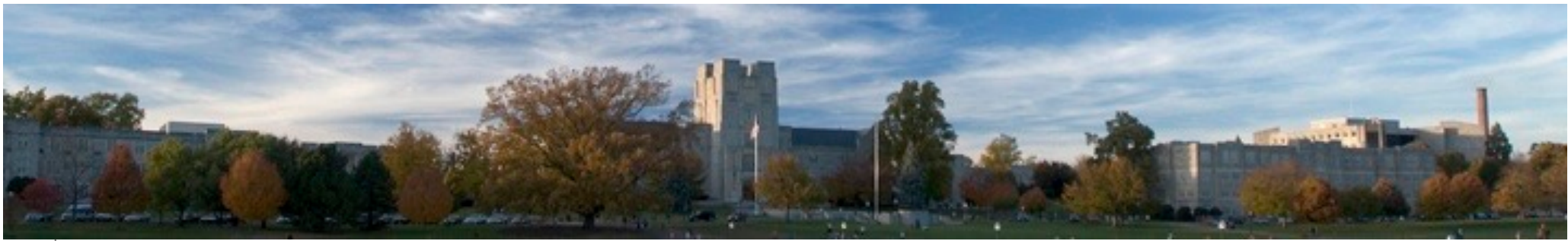
2023 IEEE President and CEO



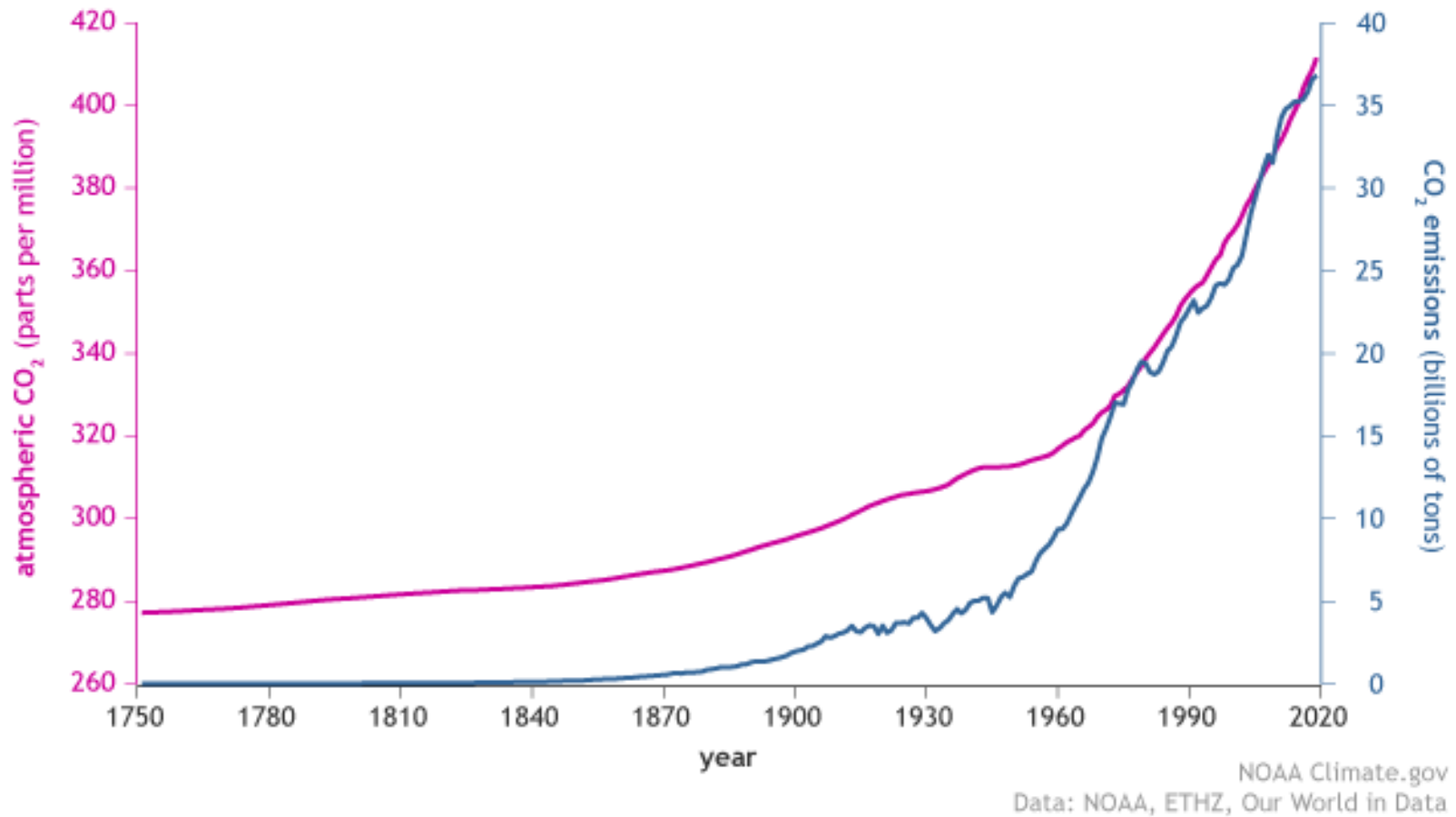
IEEE 13th ICCE-Berlin, 03 Sept. 2023



Why is Climate Sustainability a Challenge ?



CO₂ in the atmosphere and annual emissions (1750-2019)



Source: State of the Planet

<https://news.climate.columbia.edu/2021/02/25/carbon-dioxide-cause-global-warming/>



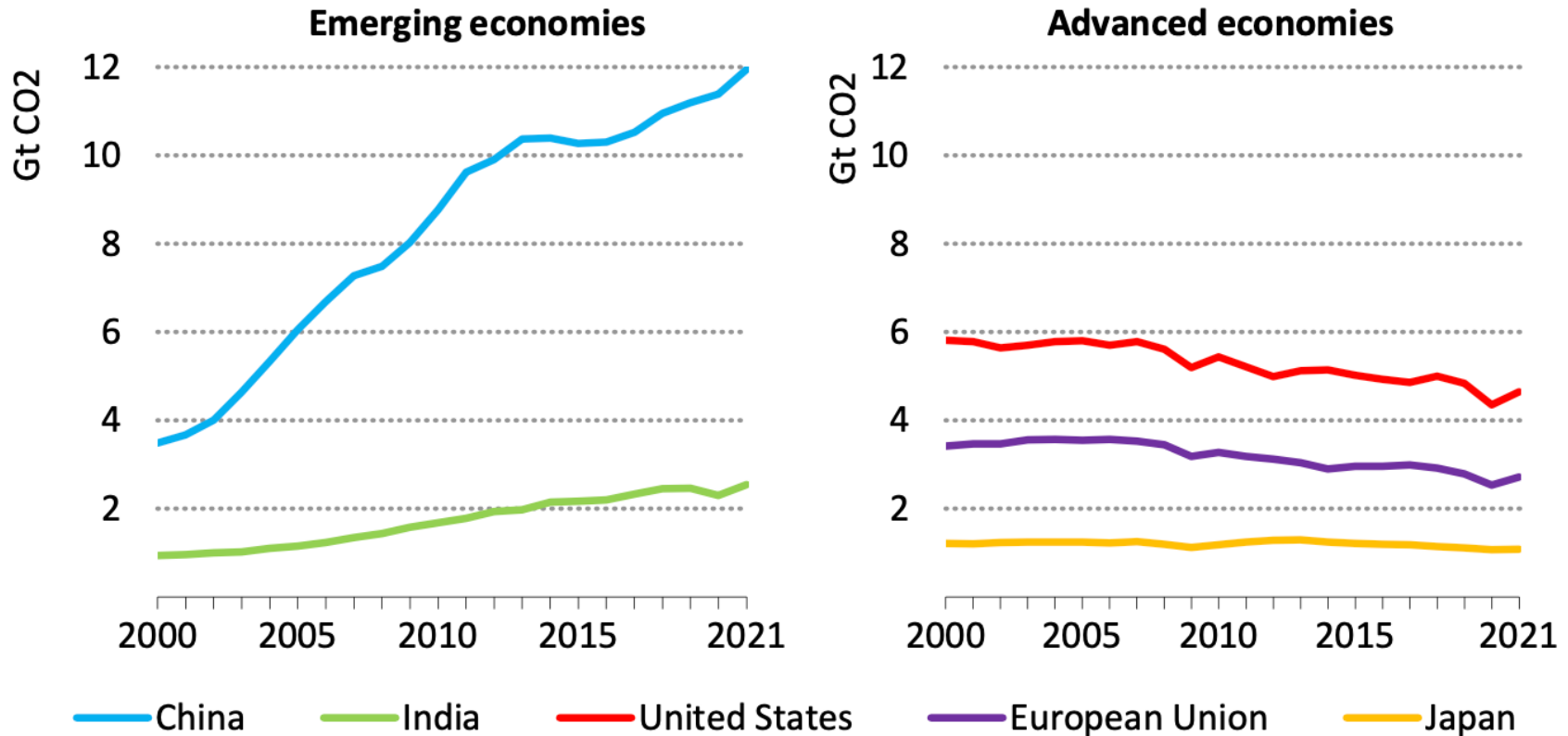


Global CO₂ Emissions Due to Fossil Fuel Use in 2021

Coal	15.3 billion tons
Natural Gas	7.5 billion tons
Oil	10.7 billion tons

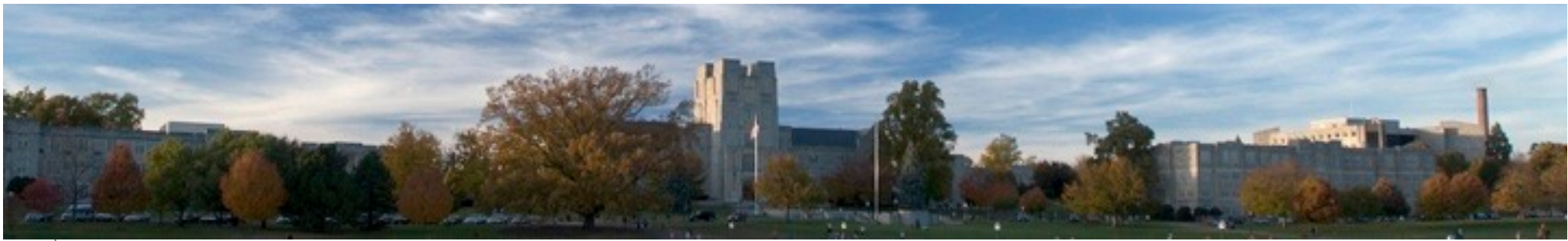
Source: IEA Global Energy Review: CO₂ Emissions in 2021
<https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2>

CO2 Emissions in Selected Emerging and Advanced Economies, 2000-2021



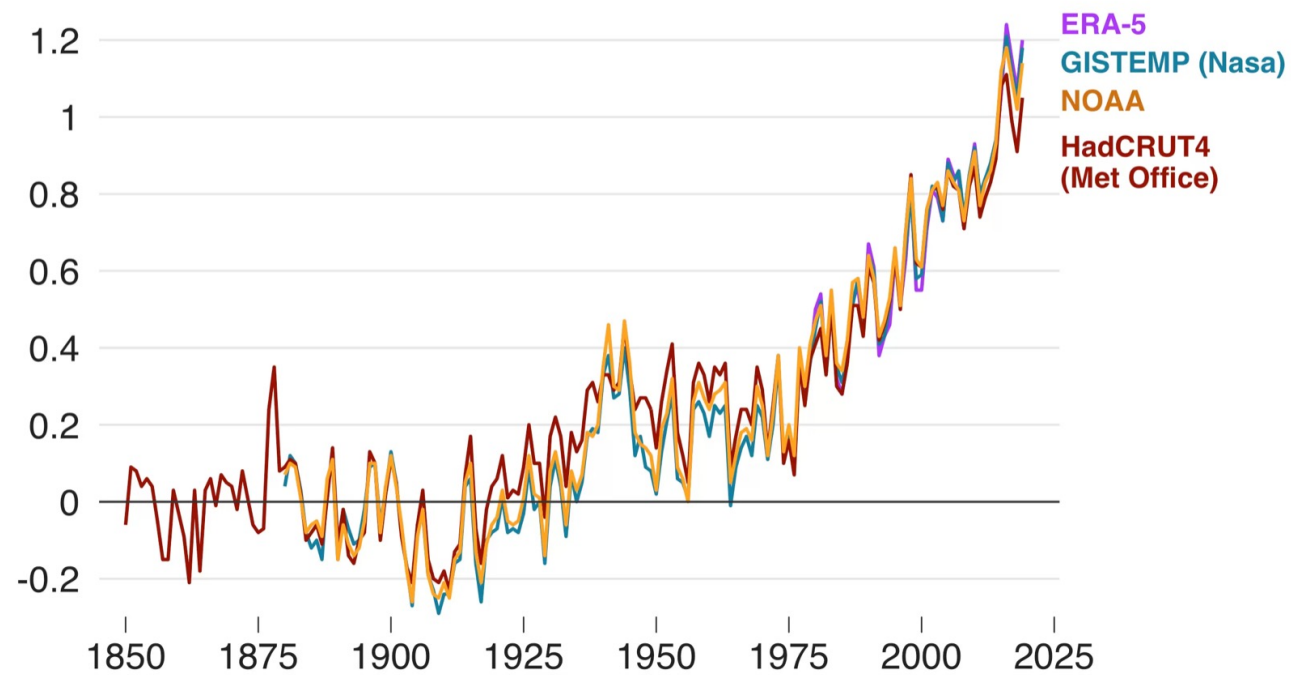
IEA. All rights reserved.

Source: IEA Global Energy Review: CO2 Emissions in 2021
<https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2>



Temperature rise since 1850

Global mean temperature change from pre-industrial levels, °C

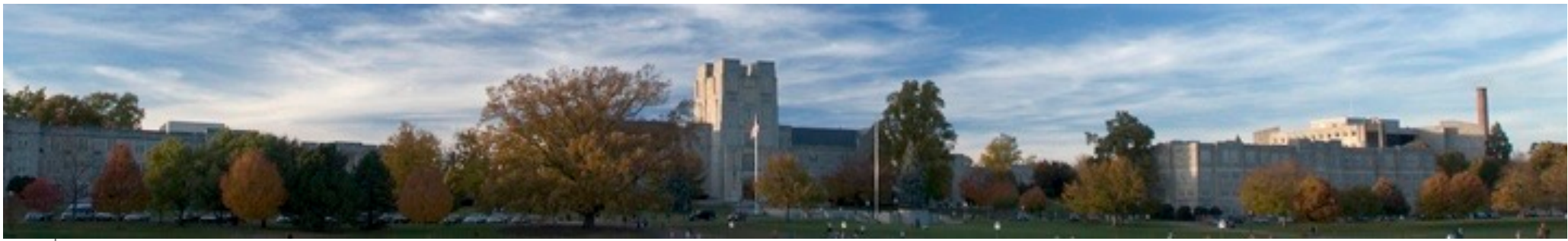


Source: Met Office

BBC

Temperature rise of 1.5 – 2.0 °C = Point of No Return

Source: <https://www.bbc.com/news/science-environment-51111176>



Floods

Climate
Change

IEEE: Enabling Innovation and Technology Solutions

 VirginiaTech
Invent the Future

Africa, China and Florida, USA



People leave the flooded community of Country Club Ridge in North Port Florida on September 29, 2022, after Hurricane Ian passed through the area a day earlier.



Vehicles are stranded after a heavy downpour in Zhengzhou city, central China's Henan province on Tuesday, July 20, 2021. Heavy flooding has hit central China following unusually heavy rains, with the subway system in the city of Zhengzhou inundated with rushing water. (Chinatopix Via AP)

The Associated Press



2023 January Flooding in New Zealand



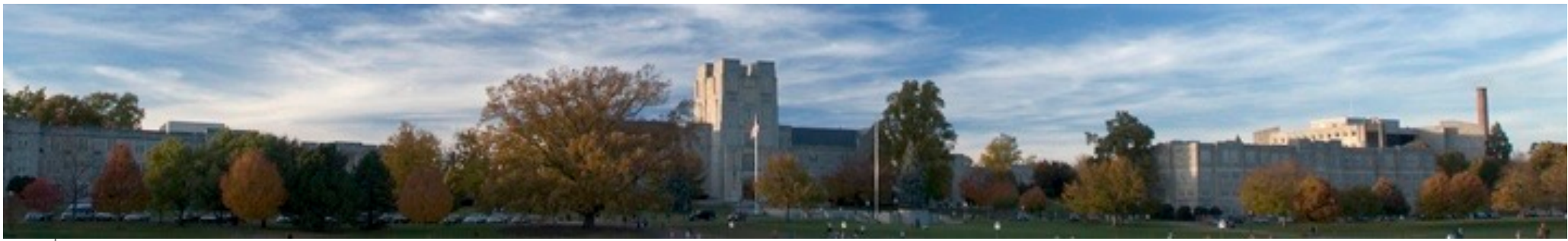
Aljazeera News, The Waiohiki Bridge is washed away in Napier. [Kerry Marshall/Getty Images]



Flash flood caused by torrential rains in Auckland area in late January 2023
<https://youtu.be/5r2AzxEvxM>

Superstorm Sandy New York, New Jersey 2012





Beijing Flood (August 2023)

Beijing



Floods inundate a village in Baoding city, Hebei province, on 02 August 2023.

Source: <https://www.cnn.com/2023/08/04/china/china-northeast-hebei-beijing-flooding-recovery-intl-hnk/index.html>



Zhuozhou, north China's Hebei Province, 02 August 2023

Source: <https://english.aawsat.com/world/4466926-beijing-records-heaviest-rainfall-least-140-years-causing-severe-flooding-and-21>

Beijing



Flooded street after heavy rains in Zhuozhou, in northern China's Hebei province August 2, 2023. (AFP)

Source: <https://english.aawsat.com/features/4470081-what-caused-record-rainfall-beijing-and-northern-china>



Residents are evacuated by rubber boats through flood waters in Zhuozhou in northern China's Hebei province, south of Beijing, Wednesday, Aug. 2, 2023. China's capital has recorded its heaviest rainfall in at least 140 years over the past few days. Among the hardest hit areas is Zhuozhou, a small city that borders Beijing's southwest. (Andy Wong/AP)

Source: https://www.stripes.com/theaters/asia_pacific/2023-08-02/beijing-china-rainfall-deaths-10925575.html/

Beijing



A man makes his way through a flooded road after the rains and floods brought by remnants of Typhoon Doksuri, in Zhuozhou, Hebei province, China August 3, 2023.

REUTERS/Tingshu Wang

Source: <https://www.reuters.com/world/china/what-caused-record-rainfall-beijing-northern-china-2023-08-04/>



Rescue workers from Shanxi province evacuate people through floodwaters with a boat after the rains and floods brought by remnants of Typhoon Doksuri, in Zhuozhou, Hebei province, China August 3. REUTERS/Tingshu Wang

Source: <https://www.reuters.com/world/china/chinas-hebei-raises-emergency-response-level-after-flooding-2023-08-03/>

Flooding in Pakistan – August 2022



Source: <https://www.npr.org/sections/pictureshow/2022/08/30/1119979965/pakistan-floods-monsoon-climate>



Source: <https://www.nytimes.com/2022/09/07/briefing/climate-change-heat-waves-us-europe.html>

Droughts in 2022



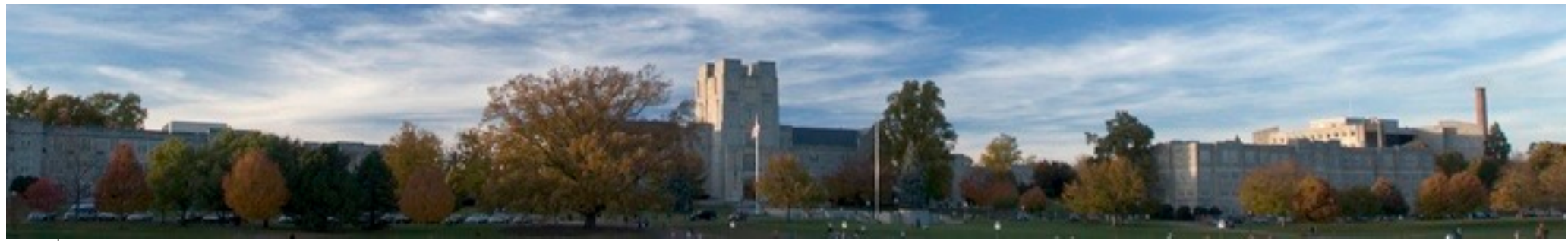
Dry river bed in **Italy** (Po River) due to worst drought in 70 years, June 2022

<https://idsb.tmgrup.com.tr/ly/uploads/images/2022/07/08/217454.jpg>

The Jialing Riverbed at the confluence with the Yangtze River is exposed due to drought on August 18, 2022 in Chongqing, **China**.

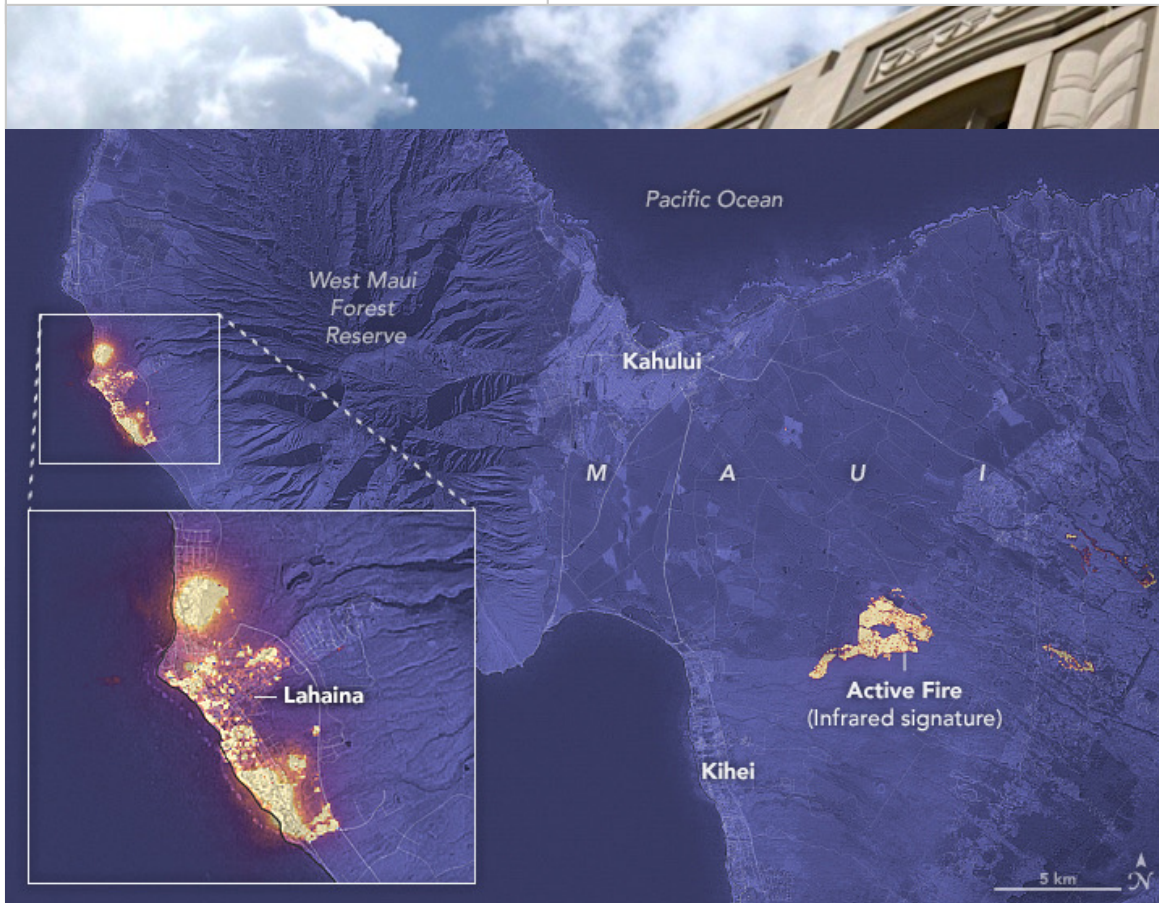


<https://image.cnbcfm.com/>



Hawaii Wildfire (August 2023)

Hawaii



NASA imagery showing the signature of the fire at 10:25 p.m. local time on August 8, 2023, as observed by the [Operational Land Imager](#) (OLI) on the [Landsat 8](#) satellite.

Much of Lahaina, a town with a resident population of nearly 13,000 people, appeared to be on fire at the time of the image.

Toll as of Aug 15, 2023

- At least 110 dead
- More than 11,000 people evacuated
- Widescale power outages
- Cell phone disruptions

Hawaii



Hawaii Fires This combination of satellite images provided by Maxar Technologies shows an overview of Lahaina Square on Maui, Hawaii, on June 25, 2023, left, and an overview of the same area on Wednesday, Aug. 9, following a wildfire that tore through the heart of the Hawaiian island. (Maxar Technologies via AP)

Maxar Technologies via AP

Hawaii



Complete destruction cause by wildfires in Lahaina,
Maui, Hawaii, U.S. August 10, 2023.

Source: Reuters



Greece Wildfire (July 2023)

Greece



Before/After image of Fire Damage in Kiotari Rhodes, Greece

Source: Maxar Technologies via BBC



Algeria/Tunisia Wildfire (July 2023)

Algeria/Tunisia



Burnt vehicles are pictured in the aftermath of a wildfire in Bejaia, Algeria July 25.
REUTERS/Ramzi Boudina

Source: <https://www.reuters.com/world/africa/deadly-fires-rage-along-algeria-coast-spread-tunisia-2023-07-25/>

- Death toll at least 34 fatalities, including 10 firefighters in Algeria
- At least 26 others have been injured.
- Over 1,500 people evacuated in Bejaia, Bouira, and Jijel, Algeria
- Over 2500 evacuated from Maloula and Tabarka in Tunisia

Wednesday 26/07/2023



A man inspects the remains of a burnt vehicle in the aftermath of a forest fire near the town of Melloula in northwestern Tunisia close to the border with Algeria, July 26, 2023. (AFP)

Source: <https://thearabweekly.com/tunisia-algeria-contain-wildfires-heatwave-sweeps-across-north-africa>

Algeria/Tunisia



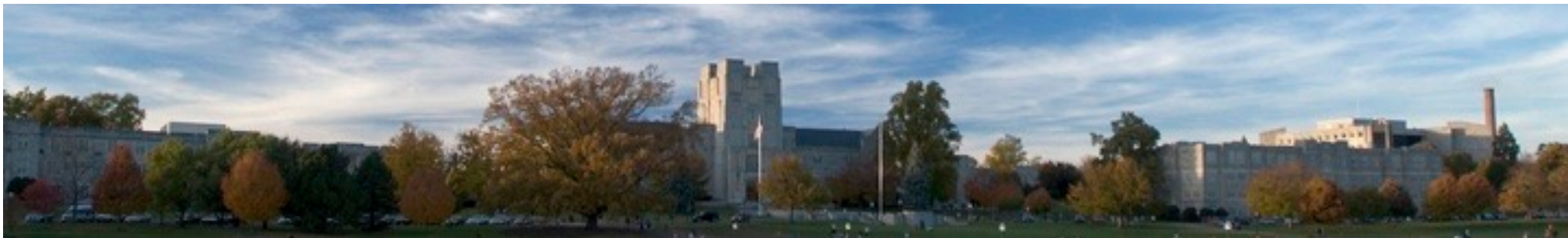
Fethi Belaid/Agence France-Presse — Getty Images

Forest fire in northwestern Tunisia, close to the border with Algeria, July 24, 2023



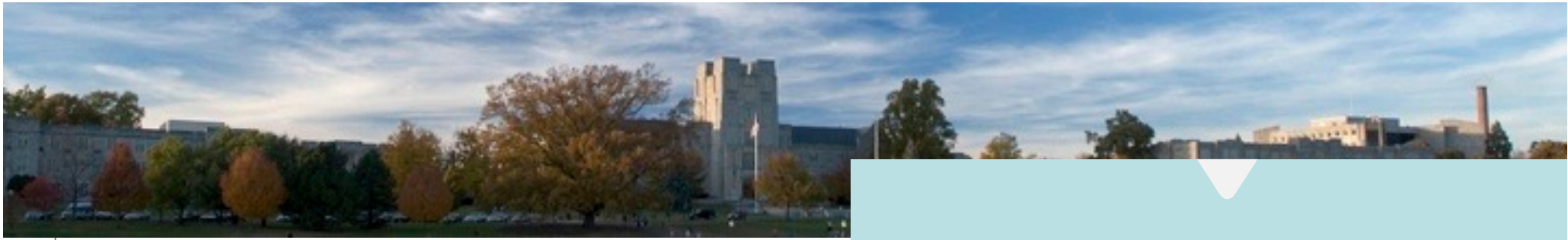
Aftermath of forest fire in northwestern Tunisia, close to the border with Algeria

Source: <https://www.nytimes.com/article/wildfires-greece-italy-algeria.html>



**Challenge is
Decarbonization**

**Promote Clean-tech Solutions
for Climate Sustainability**

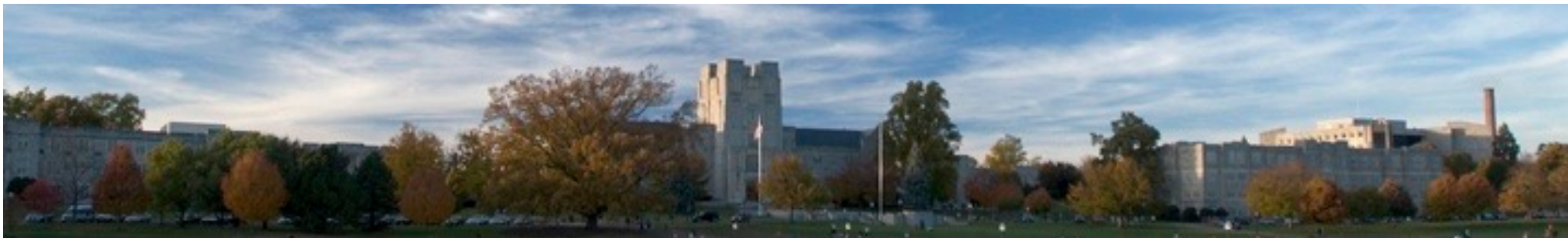


Reduce Carbon Emissions from Electricity Production

Carbon Emission Reduction Opportunities

1. Use less electricity, energy efficiency
2. Use low carbon fossil fuel power plants
3. Use H₂ & other storage technologies
4. Promote more renewables
5. Accept some nuclear
6. Promote cross-border power transfer





In the United States 70% of Electricity Usage is in Buildings



Customers Controlling Buildings Optimized for Savings



Measured energy savings across deployments

20% HVAC Energy Savings

30% Lighting Energy Savings

Occupant satisfaction: spaces controlled by a building automation systems are more comfortable due to more consistent temperature profiles and healthier air quality through consistent monitoring of environmental factors (CO₂ levels, PM 2.5).





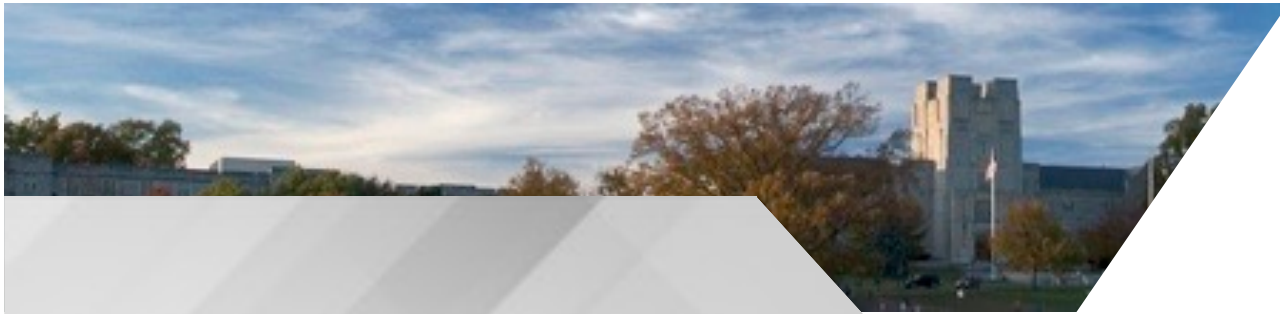
Grid-interactive Internet of Buildings (G-IoB)

A New Paradigm for the Electric Power System

Historically: Demand driven supply (supply responds to demand)

Smart Grid Ecosystem

New Reality: Supply driven demand (demand needs to adjust to meet fluctuating supply with help from storage)



The Smart Grid Ecosystem

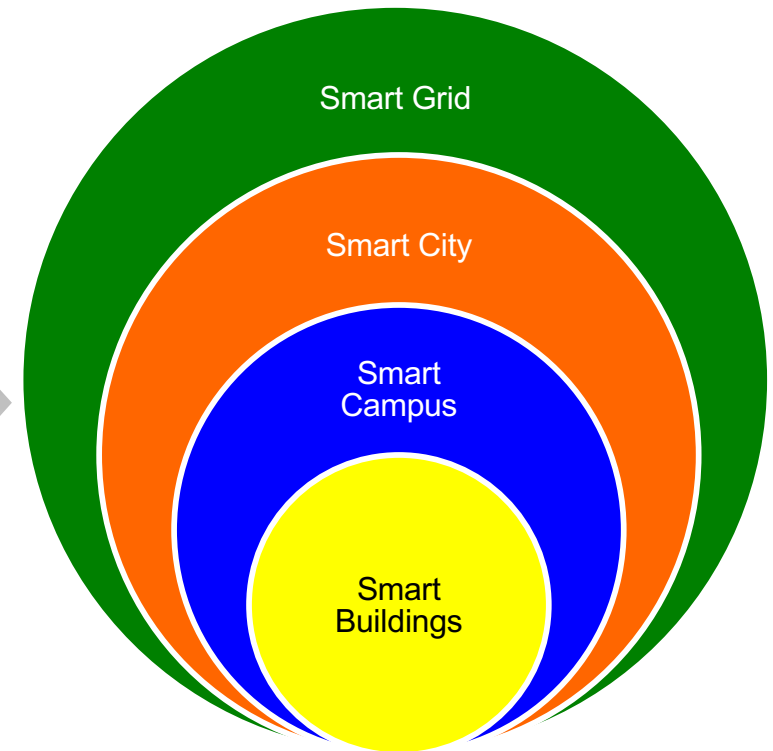
Smart grid: Bi-directional flows of energy, remote control/automation of power, integrated distributed energy...

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...

Ecosystem



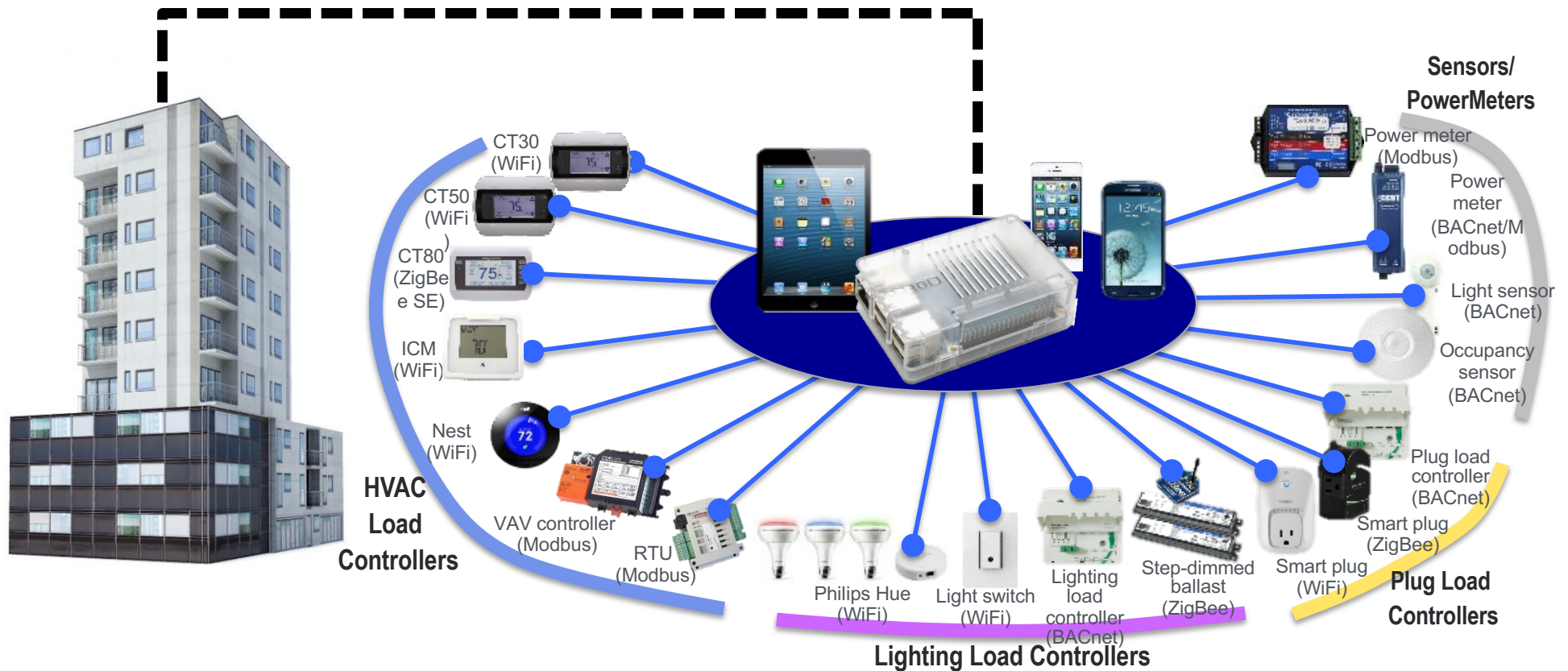
← Supported by ICT and distributed networks of intelligent sensors, data centers/clouds →

What makes a Building Smart

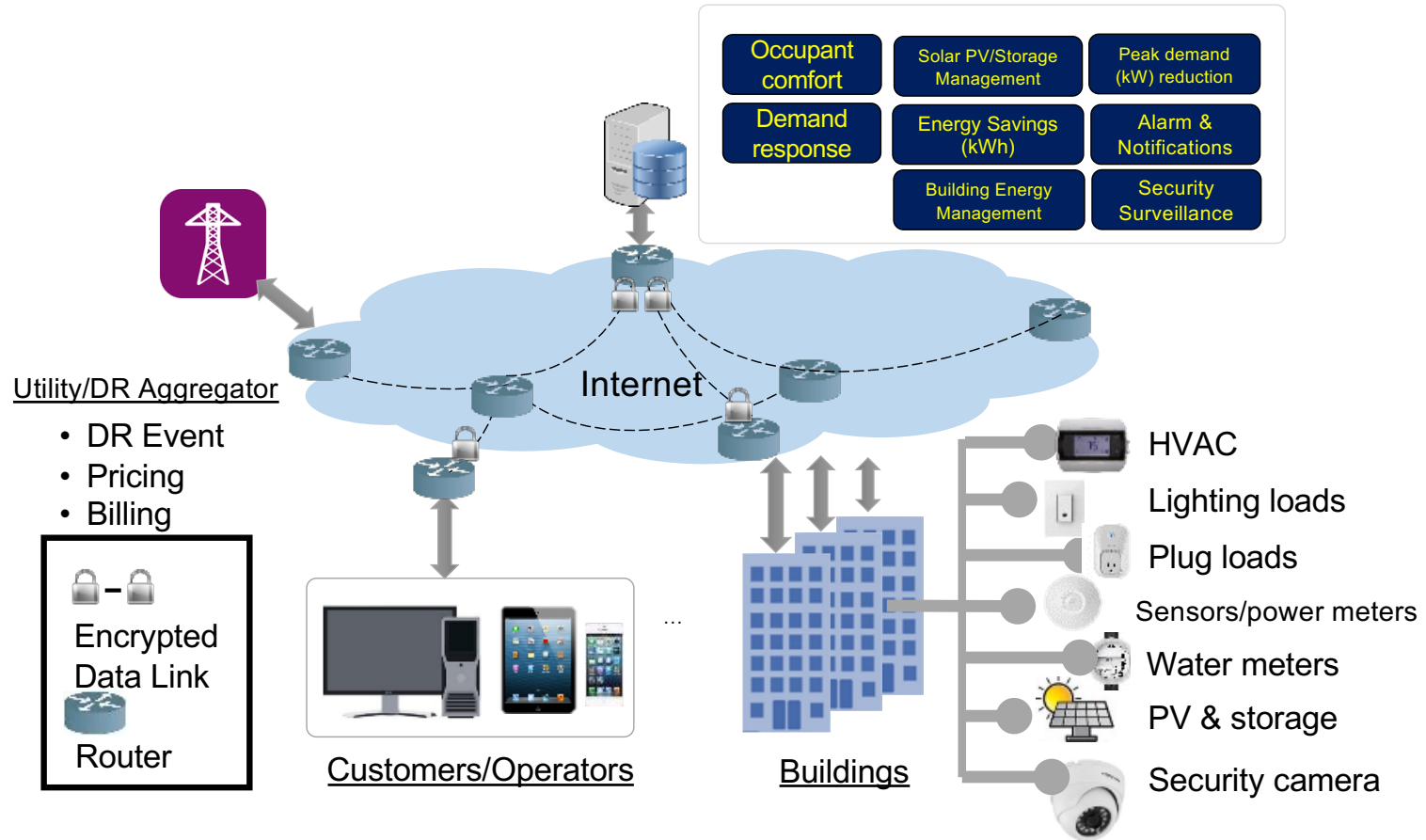


A single platform for monitoring and control of HVAC, lighting, water supply, sensor networks, security camera & fire emergency

IoT Device Integration Through Industry Standard Protocols and Communications Technologies



Smart Buildings on a Smart Campus

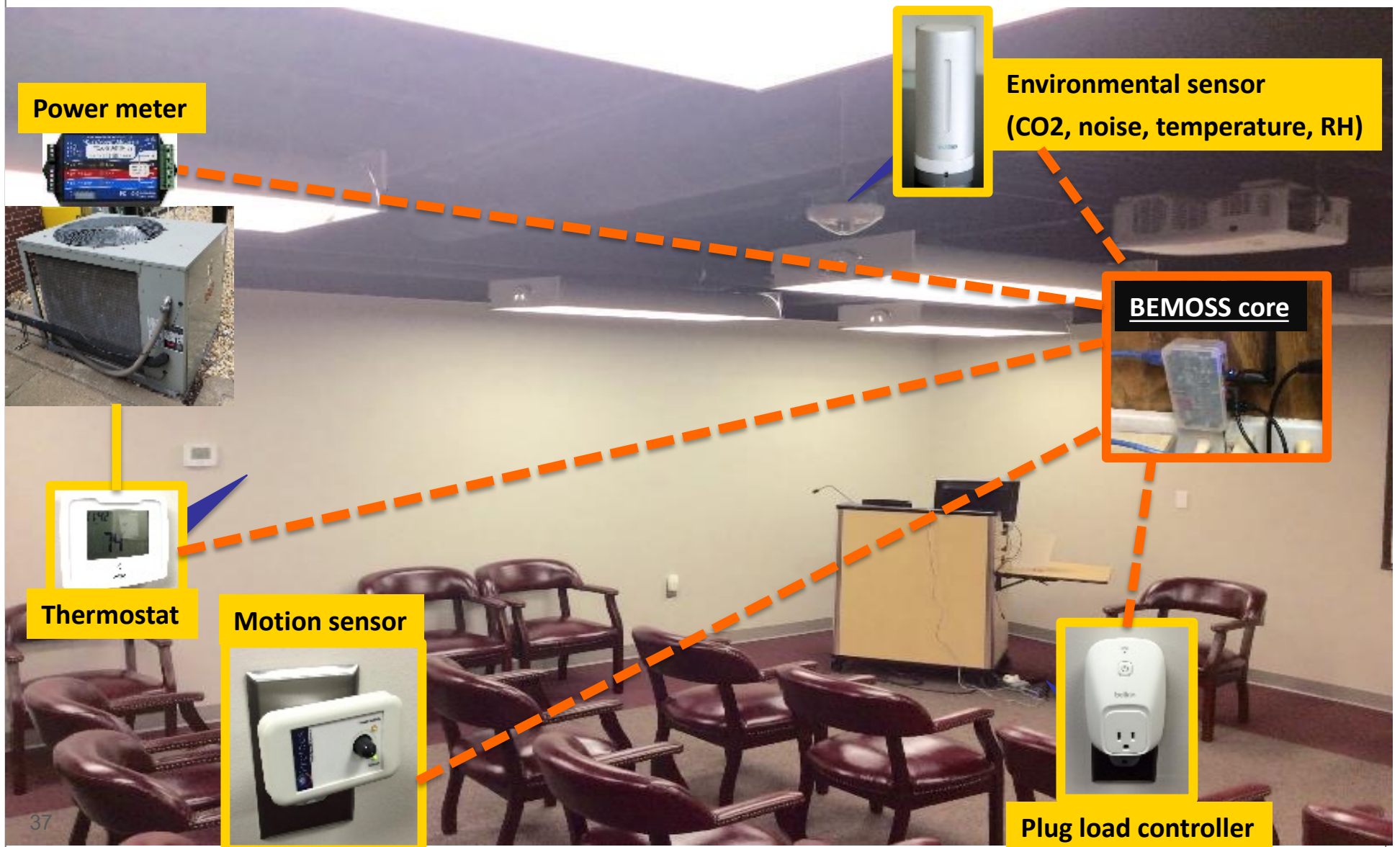


Academic Building in Alexandria, Virginia

Alexandria, Virginia, USA



Classroom under Real-time Monitoring



Indoor Environmental Monitoring

BEMOSS

Admin Log Out

- 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

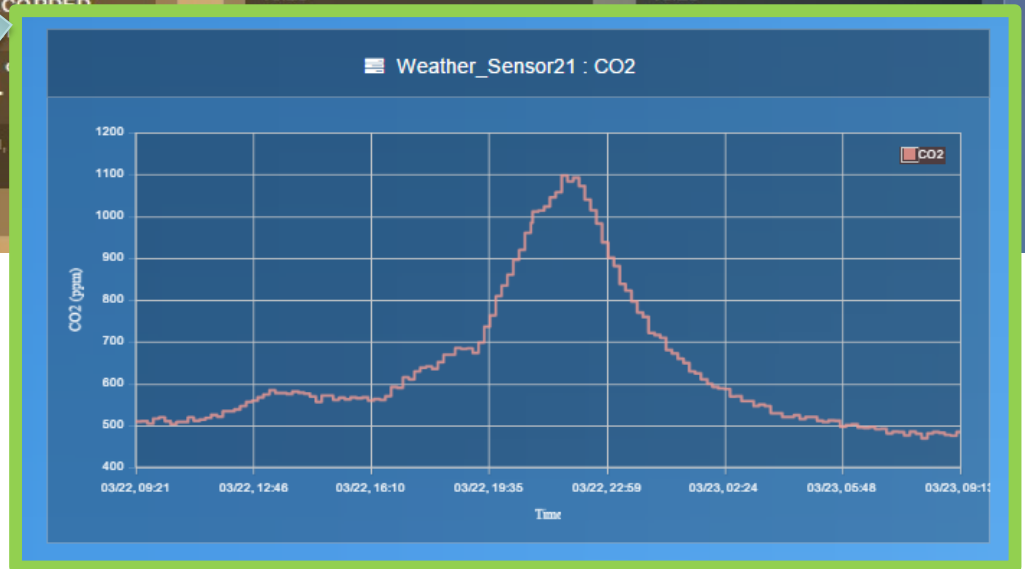
74.3°F

MINIMUM RECORDED TEMPERATURE

74.3°F

Date Recorded: Wed, 15 Jun 2016, 16:25

Date Recorded: Wed, 15 Jun 2016, 16:25



Office Building, Arlington, Virginia



Office building size: 500 sqm

Energy Savings from Lighting Control

Location: Arlington,
Virginia, USA

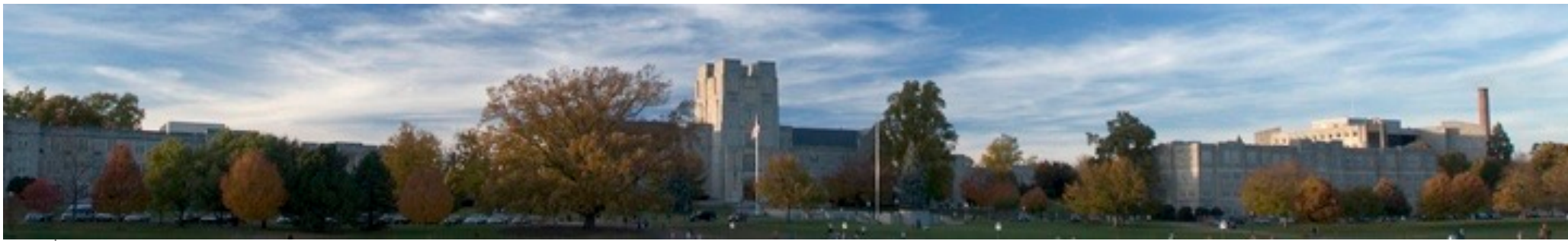
Area: 500 sq m

Deployed Devices

- 3 Lighting controllers
- 1 Power meter



An average energy savings of 35% was achieved through dimming control



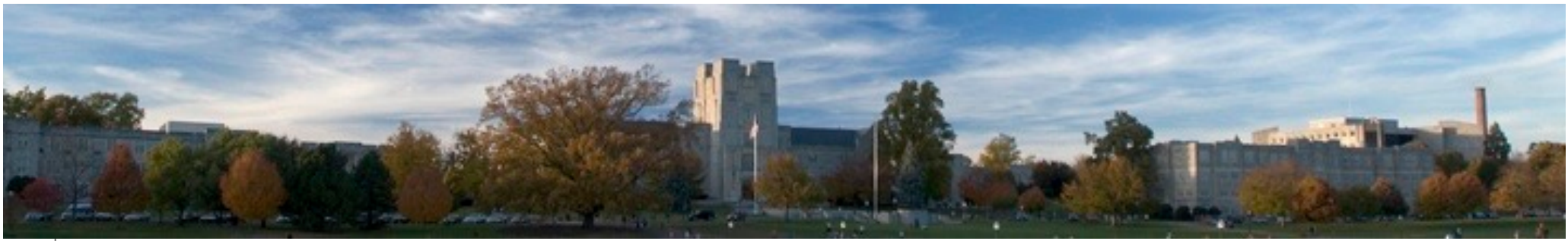
Reinforced Learning

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%

Machine Learning Applications

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.



Thank you

web: www.srahman.org