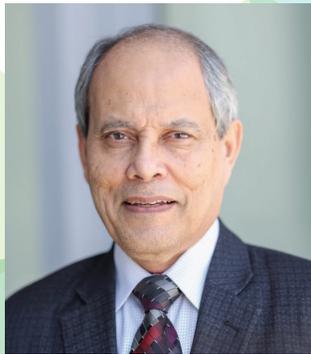


Prof. Saifur Rahman
2022 IEEE President-elect

Director, Virginia Tech Advanced
Research Inst., USA



Role of Smart Grid in Facilitating the Integration of Renewables



Distinguished Lecture

IEEE PES Chapter, Delhi, India, 17 December 2022

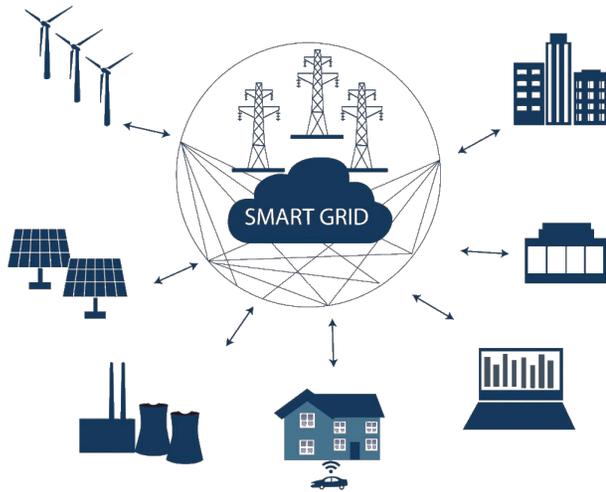
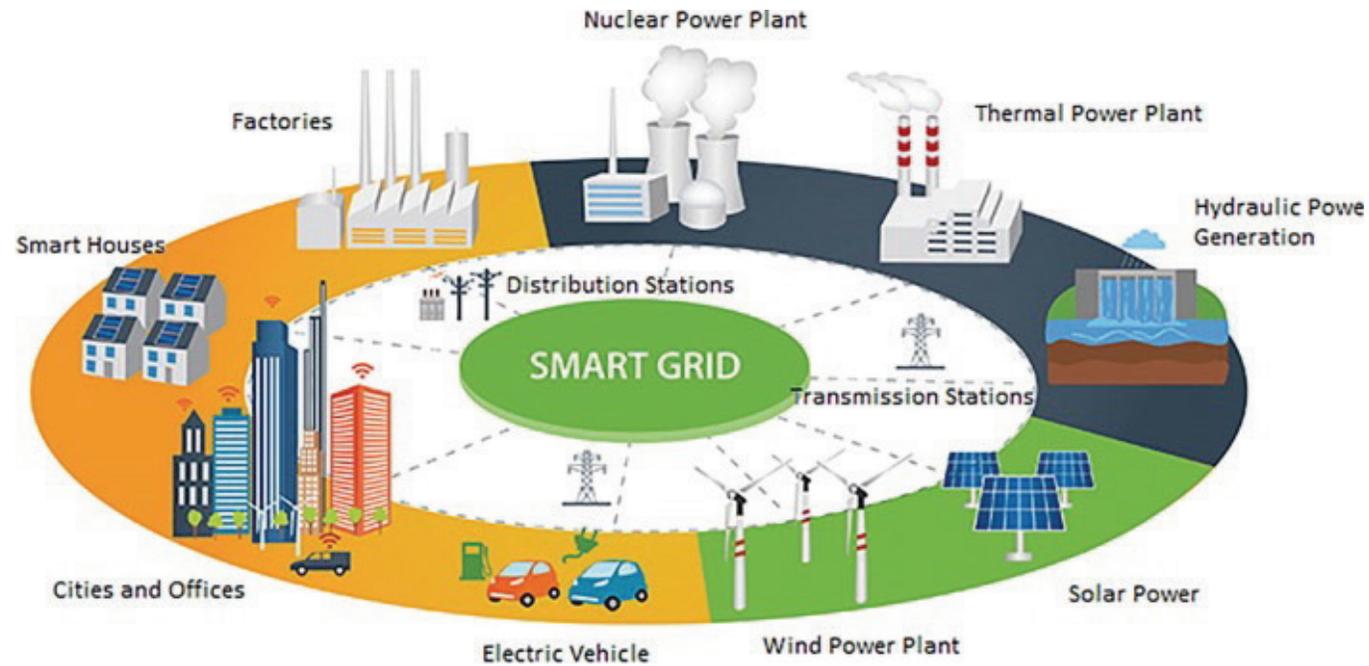


Outline



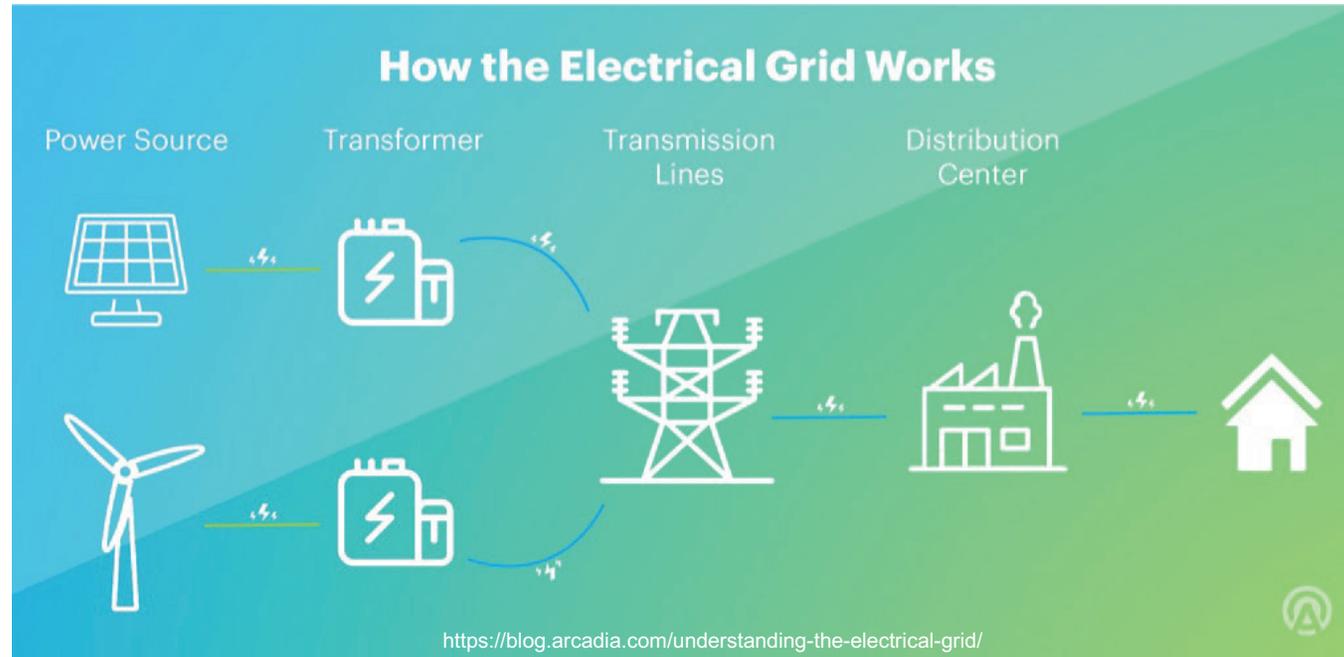
- 01** What is a Smart Grid?
- 02** Motivation for a Smart Grid
- 03** Difference Between a Normal / Smart Grid
- 04** Smart Grid Building Blocks
- 05** Evolution of the Grid
- 06** Merging Power Flow with Information Flow
- 07** Changing Landscape for the Electric Utility
- 08** Wind / Solar Energy
- 09** The Smart Grid Ecosystem
- 10** Intelligent Interconnected Microgrids

What is a Smart Grid



"**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.

Electric Power Grid

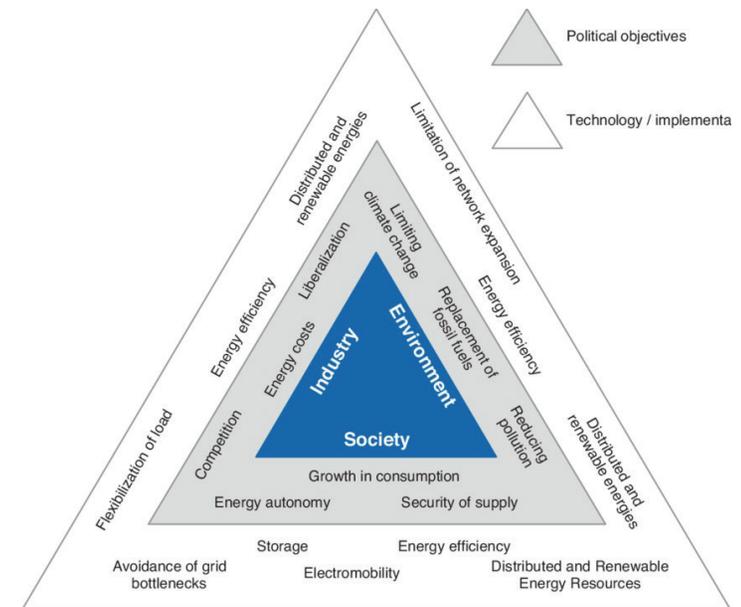


How Does the Electrical Grid Work?

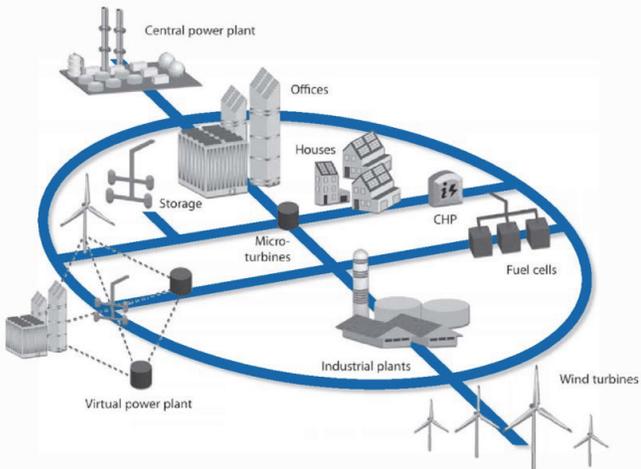
- Power Sources
- Transformers
- Transmission lines
- Distribution centers

Motivation for a Smart Grid

Motivation for a Smart Grid on the basis of the energy management triangle - political objectives and technical implementation.



https://www.researchgate.net/figure/Motivation-for-a-Smart-Grid-on-the-basis-of-the-energy-management-triangle-political_fig1_263264024



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

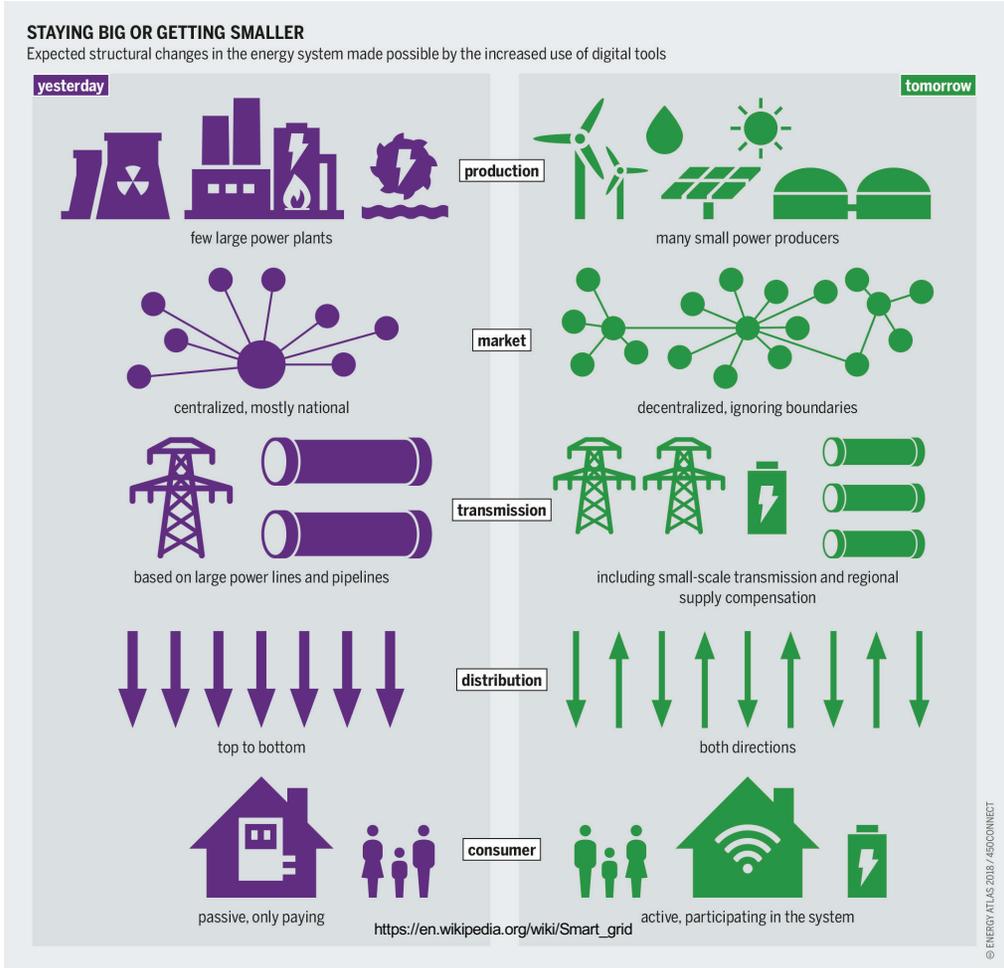
Difference Between a Normal Grid And a Smart Grid



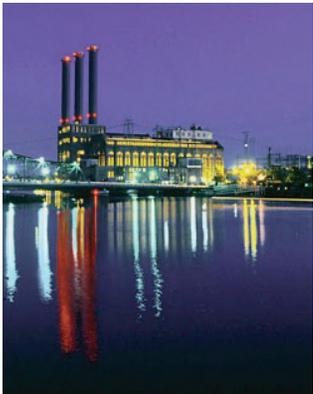
Normal Phone



Smart Phone



Starting and End Points of a Smart Grid



Power Plant



Transmission



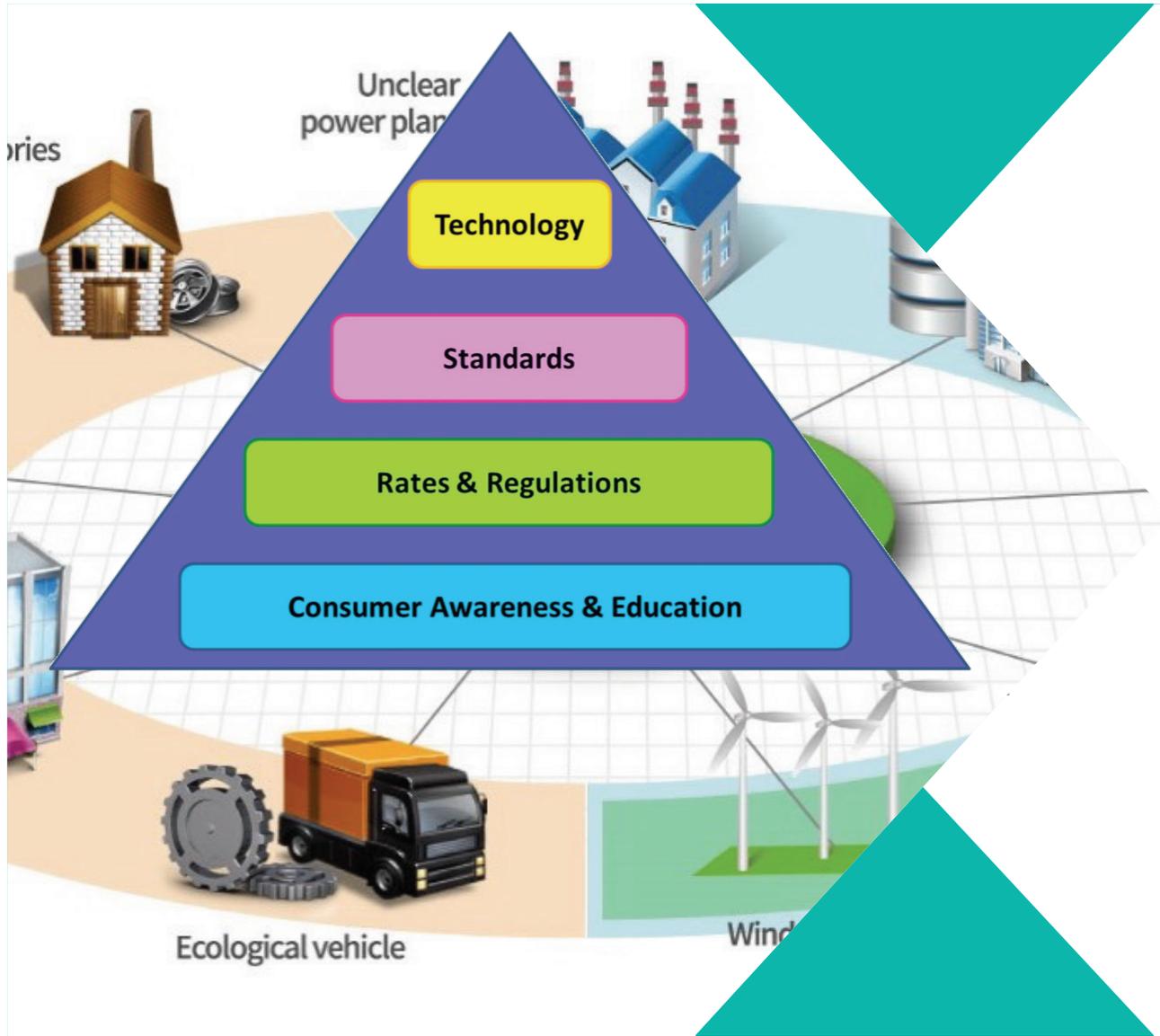
Distribution



Home Business



End-use Appliances

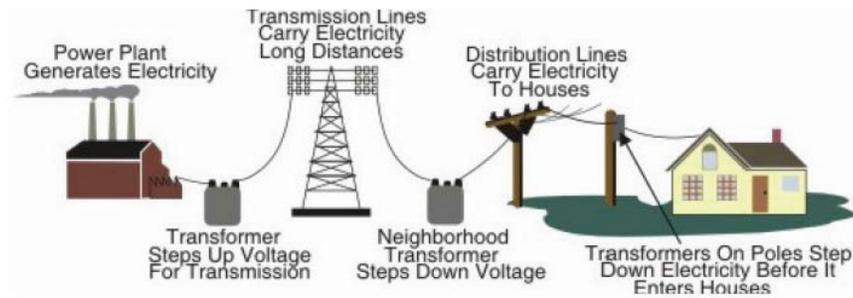


Smart Grid Building Blocks

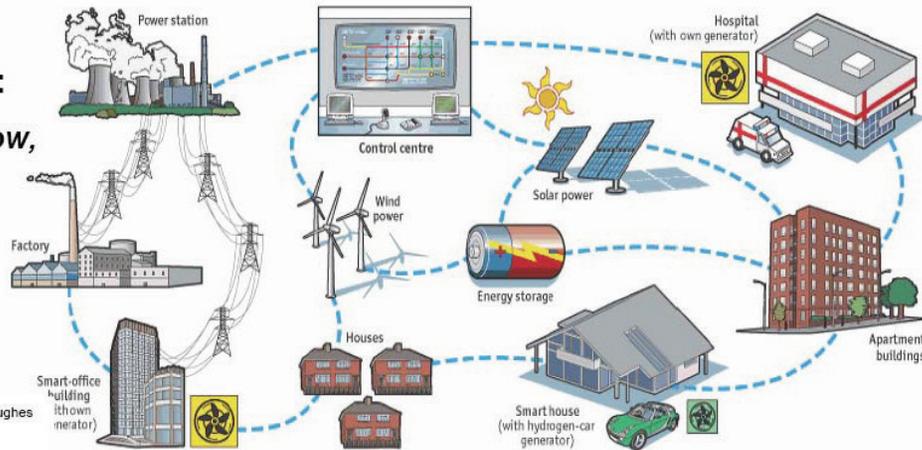
Evolution of the Grid

Smart Grid

Before Smart Grid:
*One-way power flow,
simple interactions*



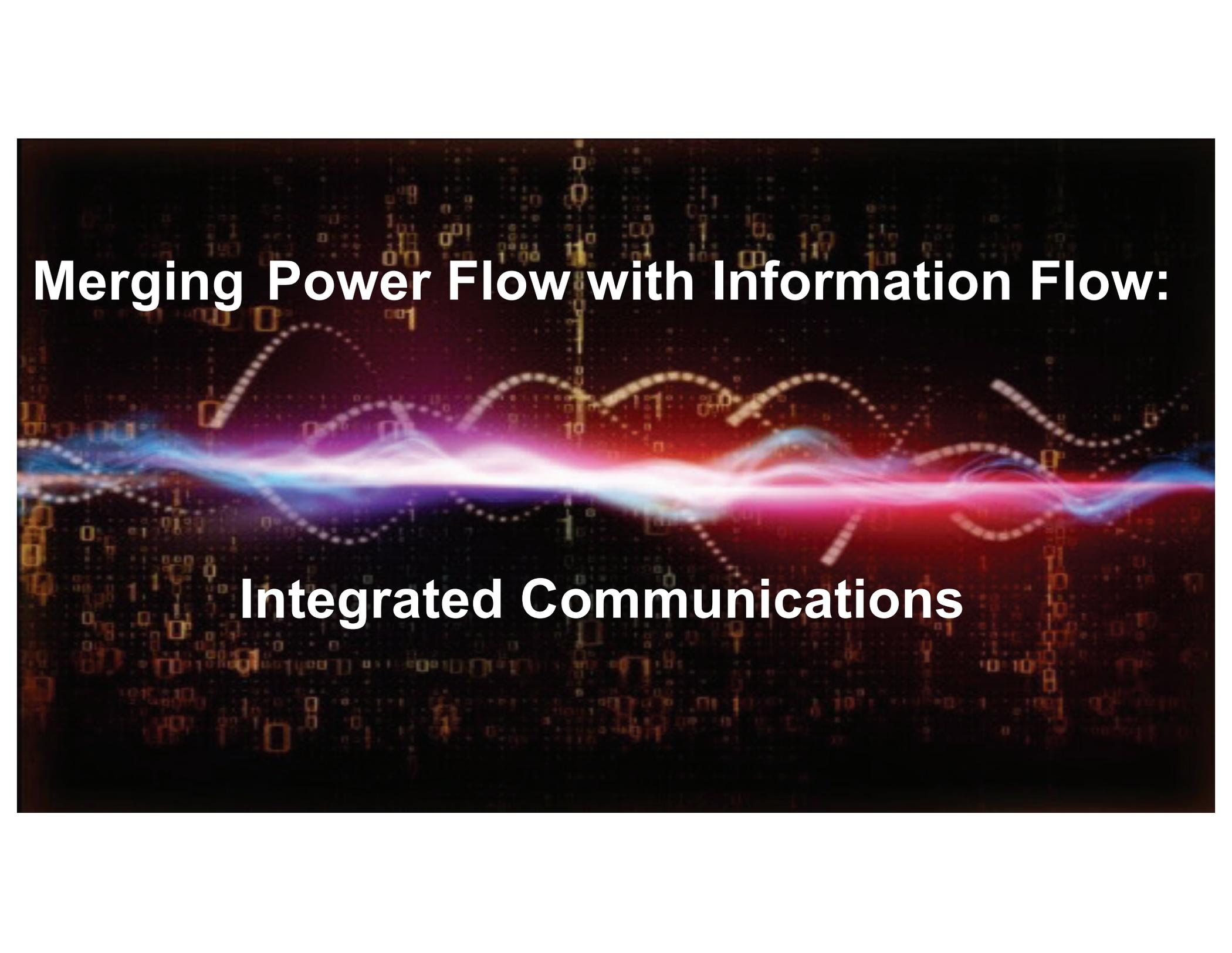
After Smart Grid:
*Two-way power flow,
multi-stakeholder
interactions*



Adapted from EPRI Presentation by Joe Hughes
NIST Standards Workshop
April 28, 2008

Sources: *The Economist*; ABB

Source: Altlink, Alberta, Canada

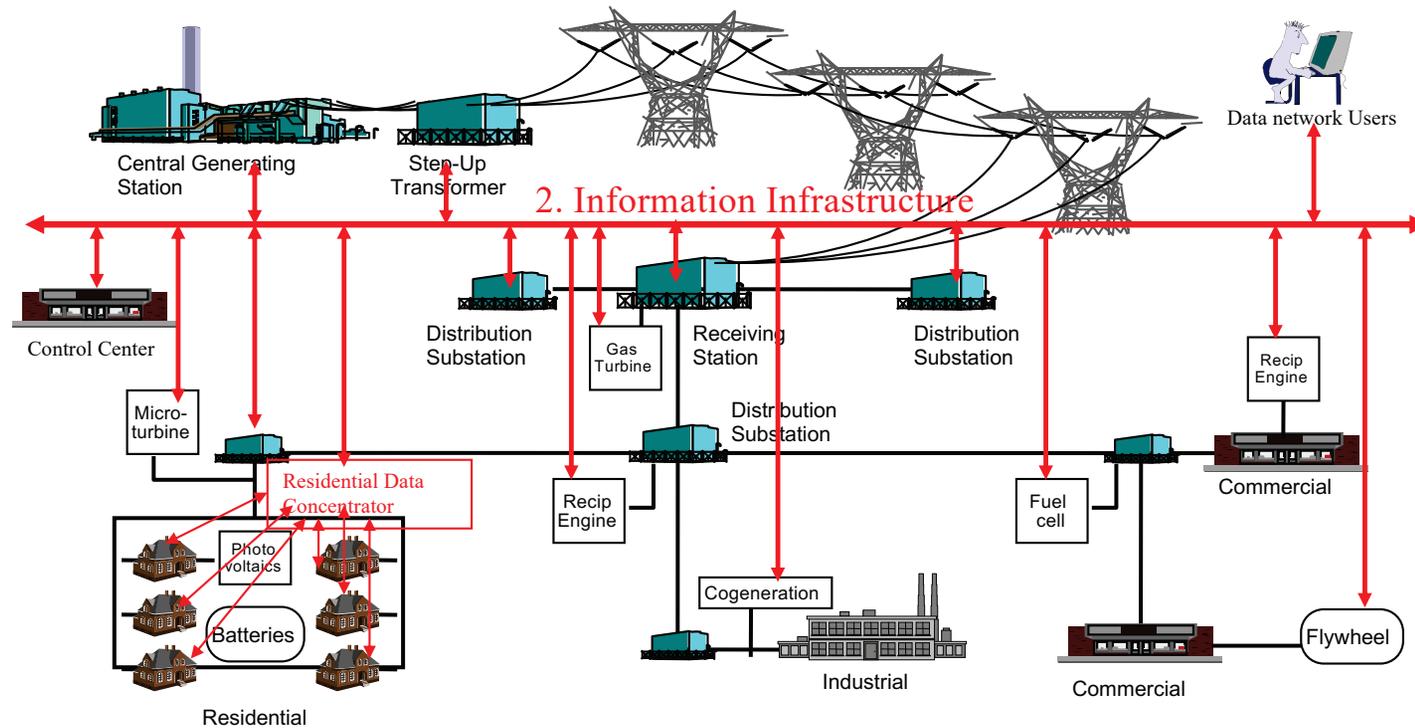


Merging Power Flow with Information Flow:

Integrated Communications

Electric Power & Communication Infrastructures

1. Power Infrastructure



Source: EPRI

Changing Landscape for the Electric Utility

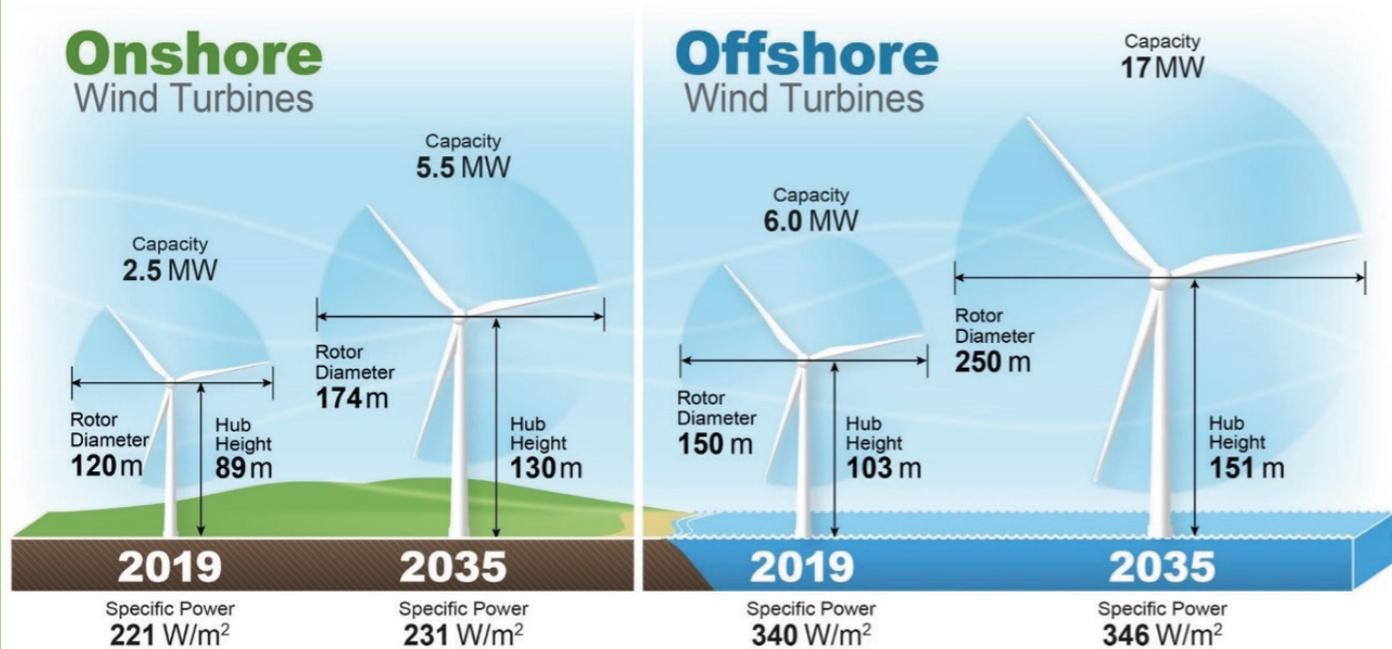




Issues with Distributed Generation

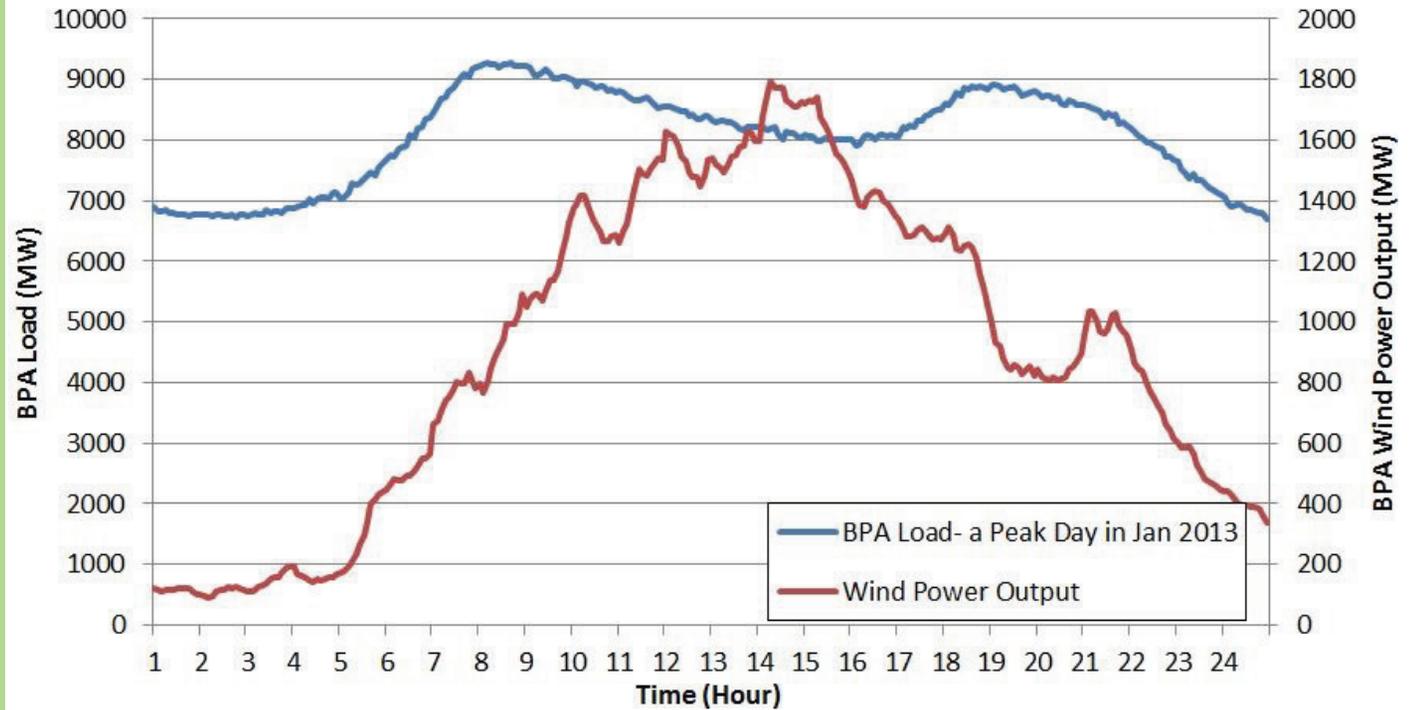
- Wind and solar are intermittent
- Hydro is space limited
- Resource is free but not always usable

Wind Energy



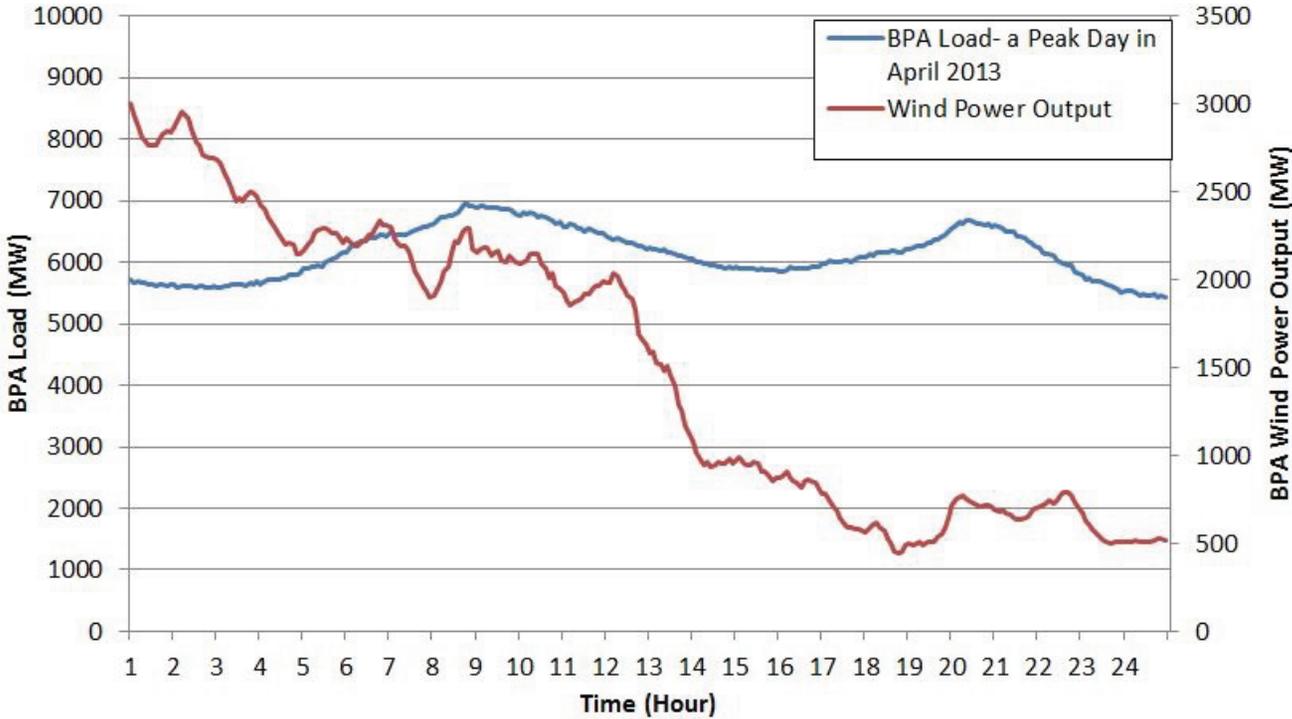
<https://www.renewableenergyworld.com/wind-power/wind-power-experts-expect-wind-energy-costs-to-decline-up-to-35-by-2035/#gref>

BPA Wind Output and Load Mismatch (A typical day in January)



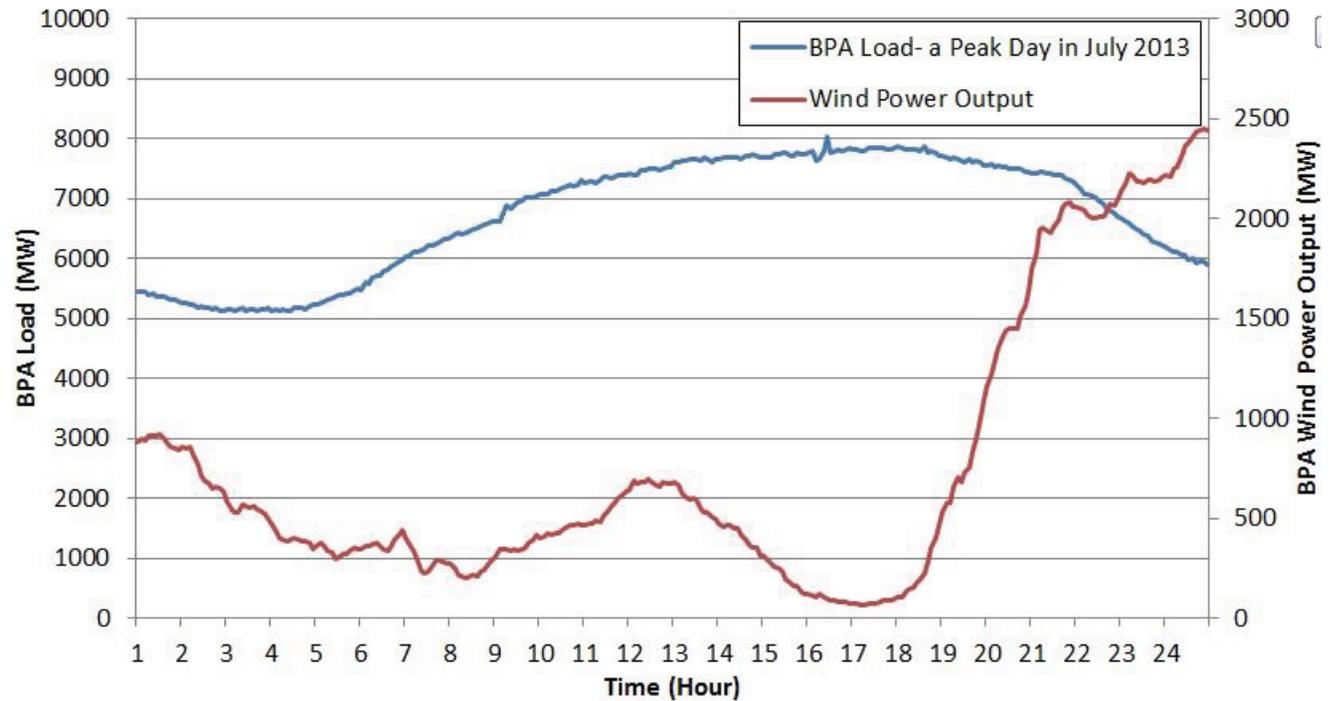


BPA Wind Output and Load Mismatch (A typical day in April)



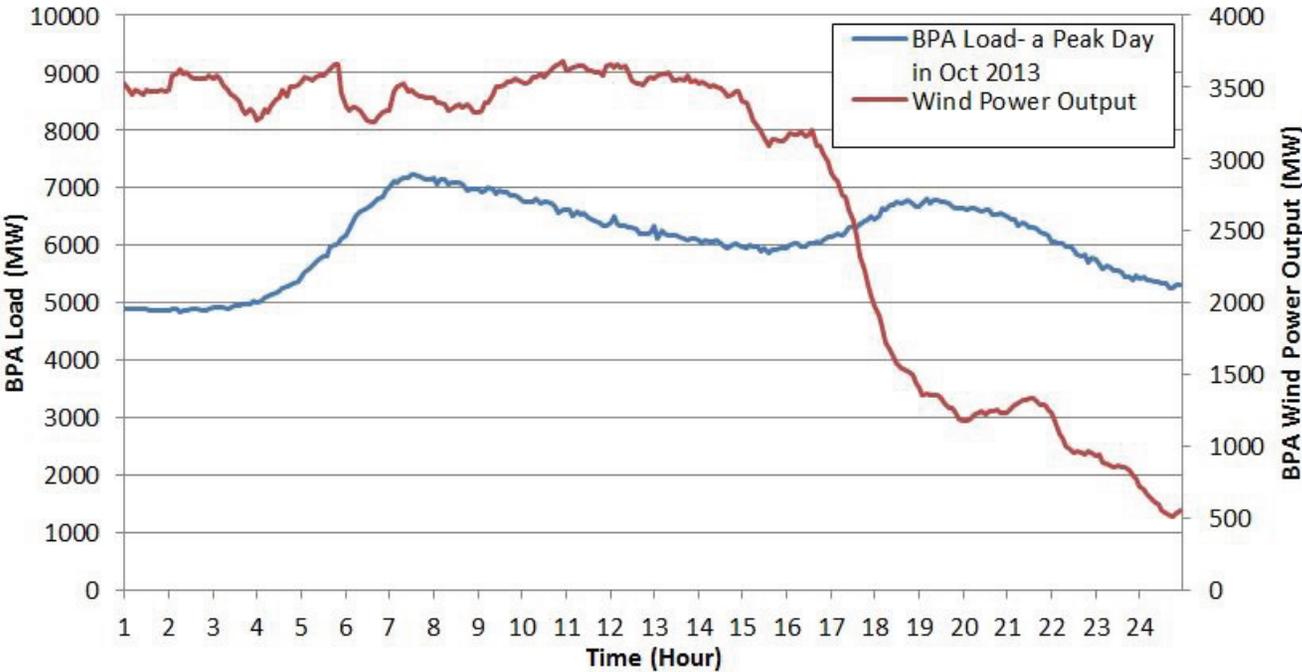


BPA Wind Output and Load Mismatch (A typical day in July)

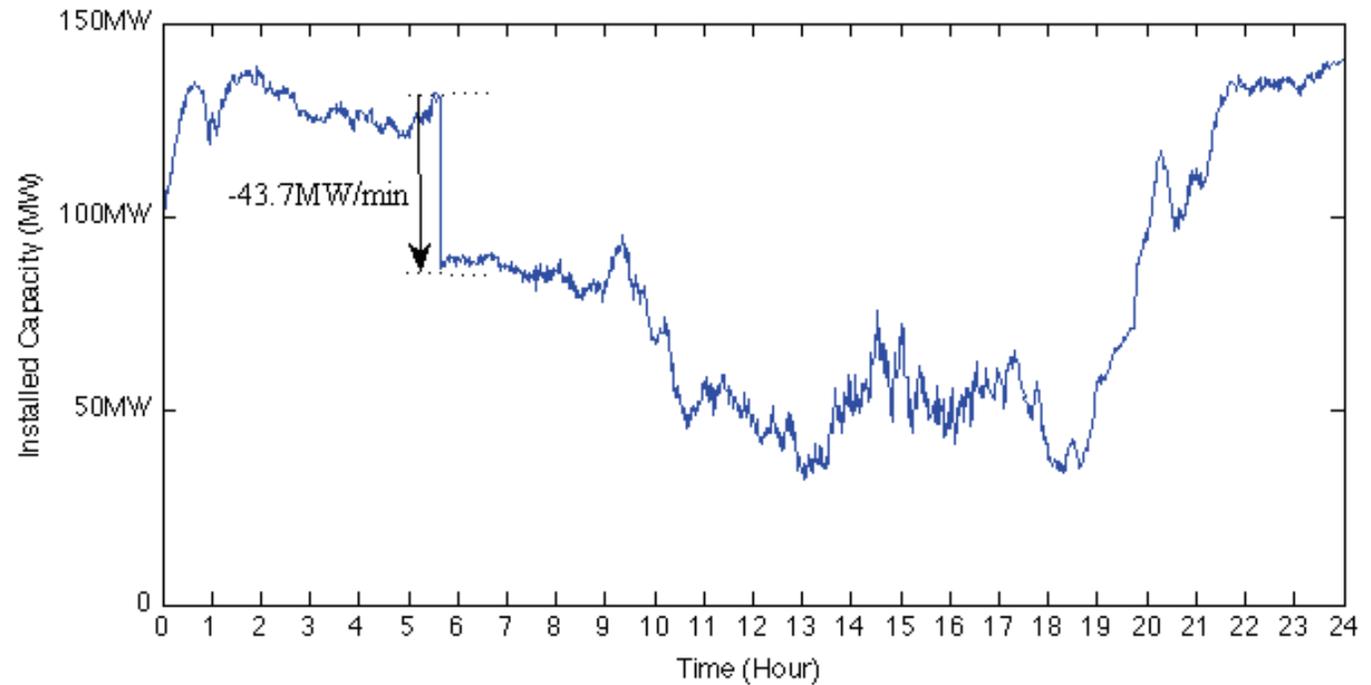




BPA Wind Output and Load Mismatch (A typical day in October)



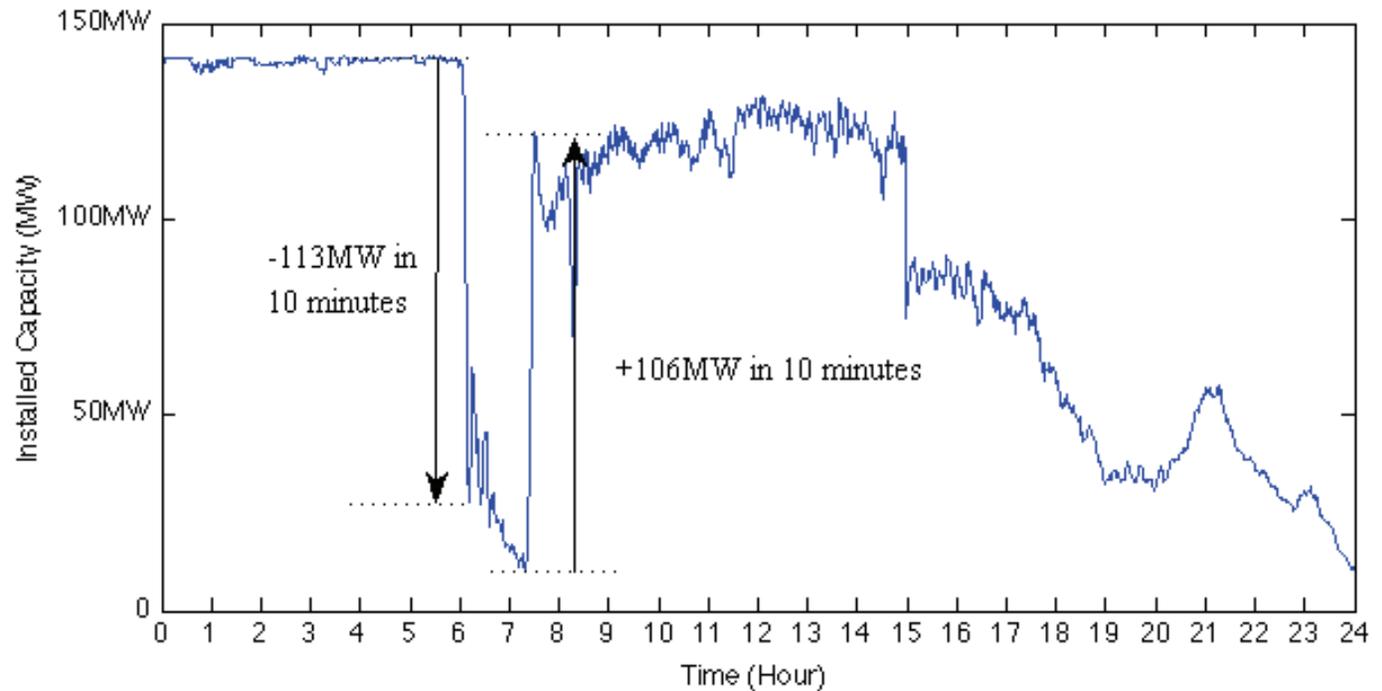
1-minute Variation of a 150MW Wind Farm Output in Texas



Wind output can drop 43.7 MW in 1 minute for a single 150-MW wind farm

Source: NREL

10-min Variation of a 150MW Wind Farm Output in Texas



Wind output can drop 113 MW in 10 minutes, and increase 106 MW in 10 minutes

Source: NREL



Solar Energy



Roof-top Solar Photovoltaics in Virginia



Solar Panels in Winter



Intermittency Caused by Weather Events



Solar PV Project in UAE



Sand Storm in Abu Dhabi

In-depth look at Solar PV in Saudi Arabia



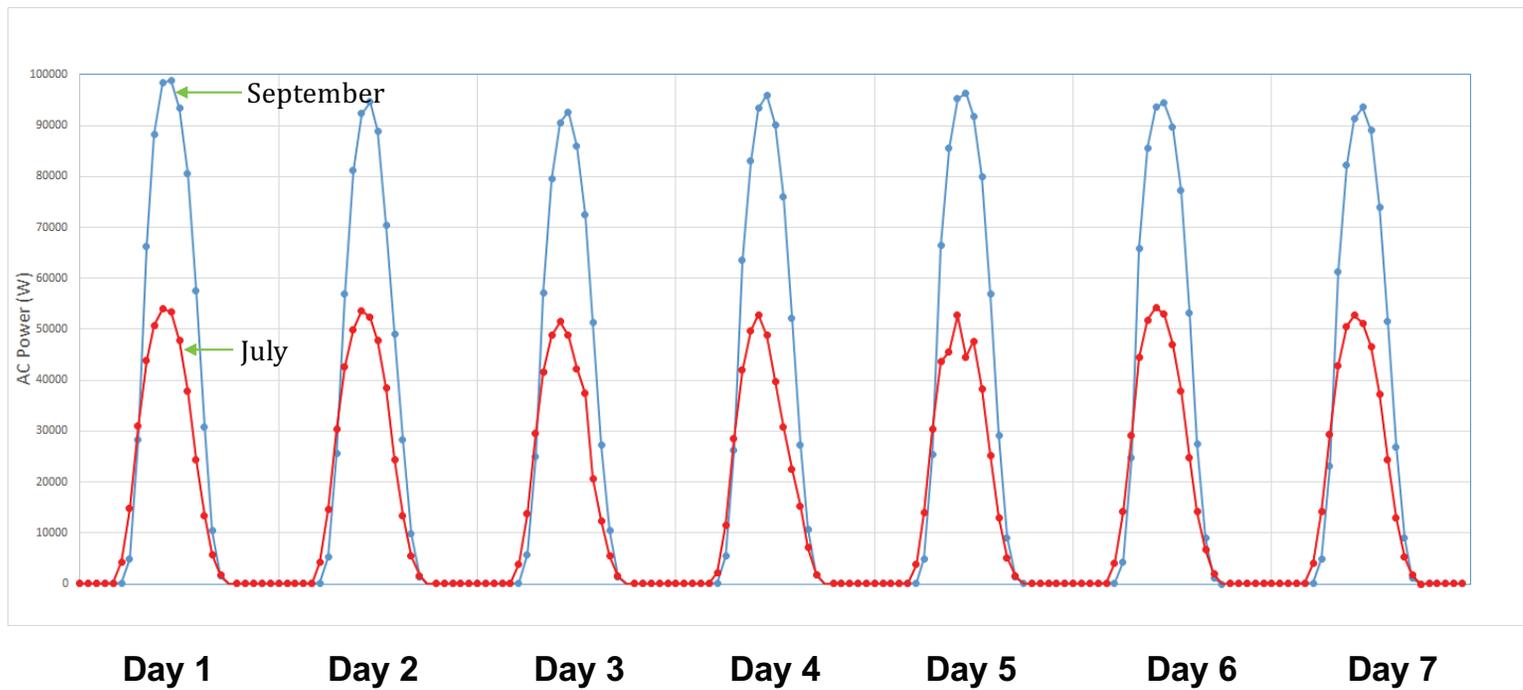
2-MW Roof-top Solar PV plant at KAUST

Solar PV Panels in Saudi Arabia

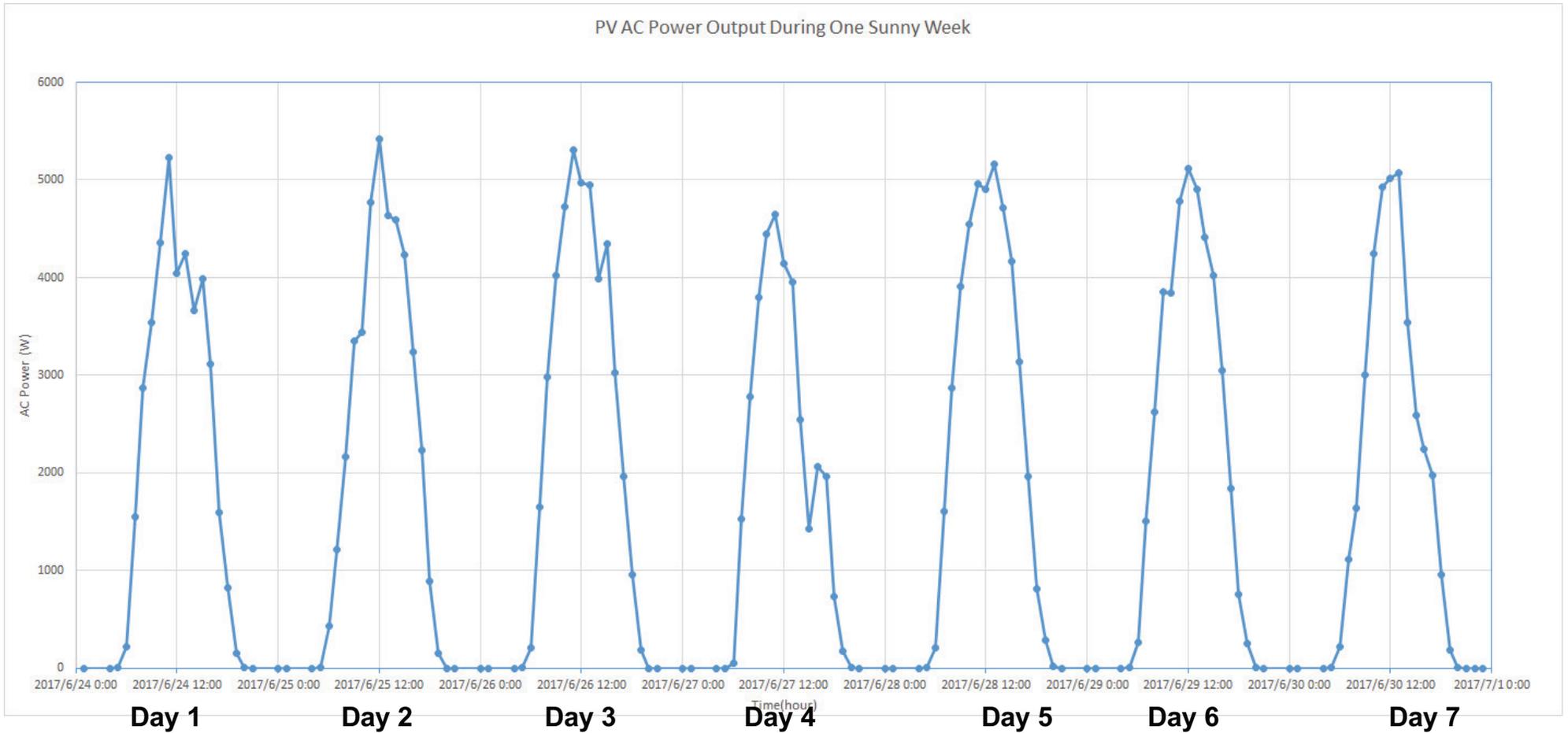


Reality Check

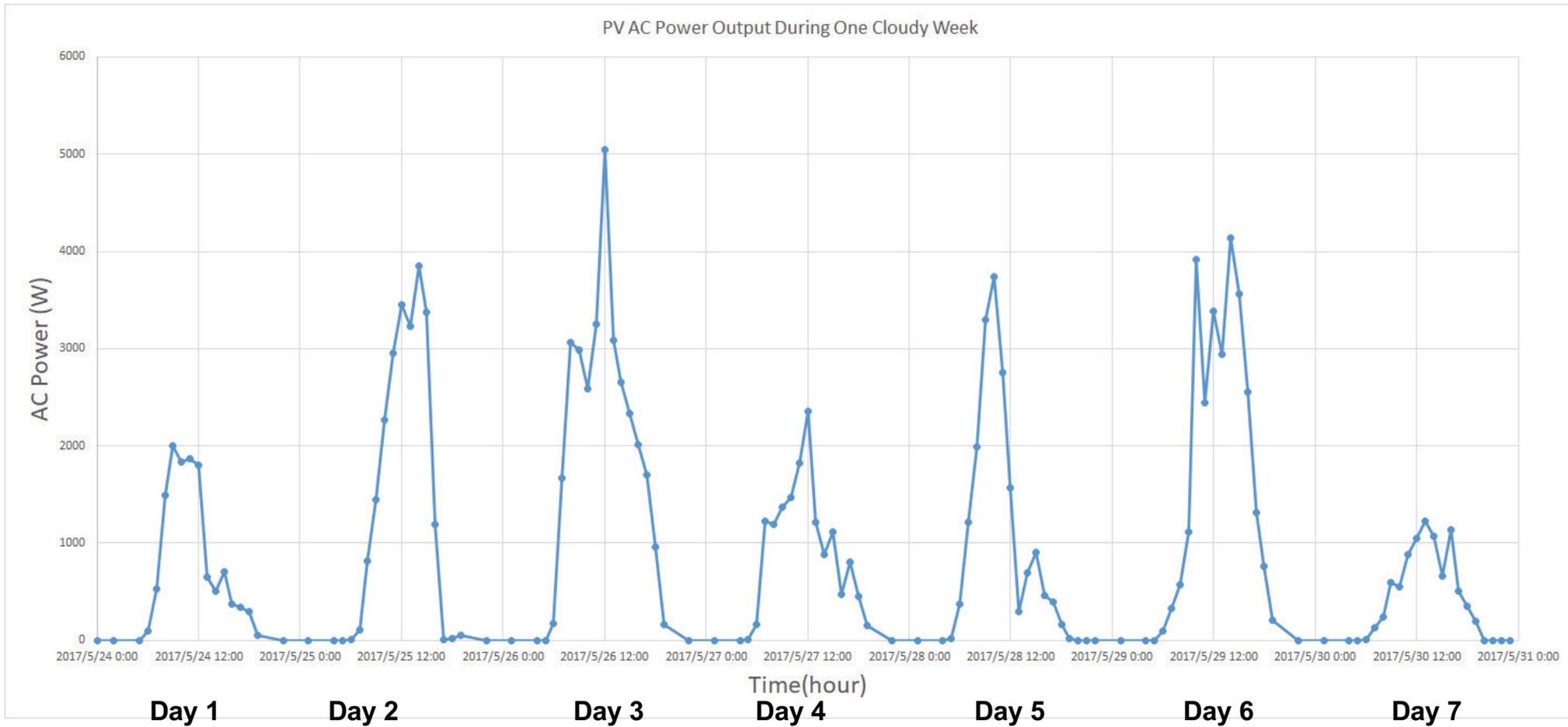
Solar PV Array (100kWp) Riyadh Area



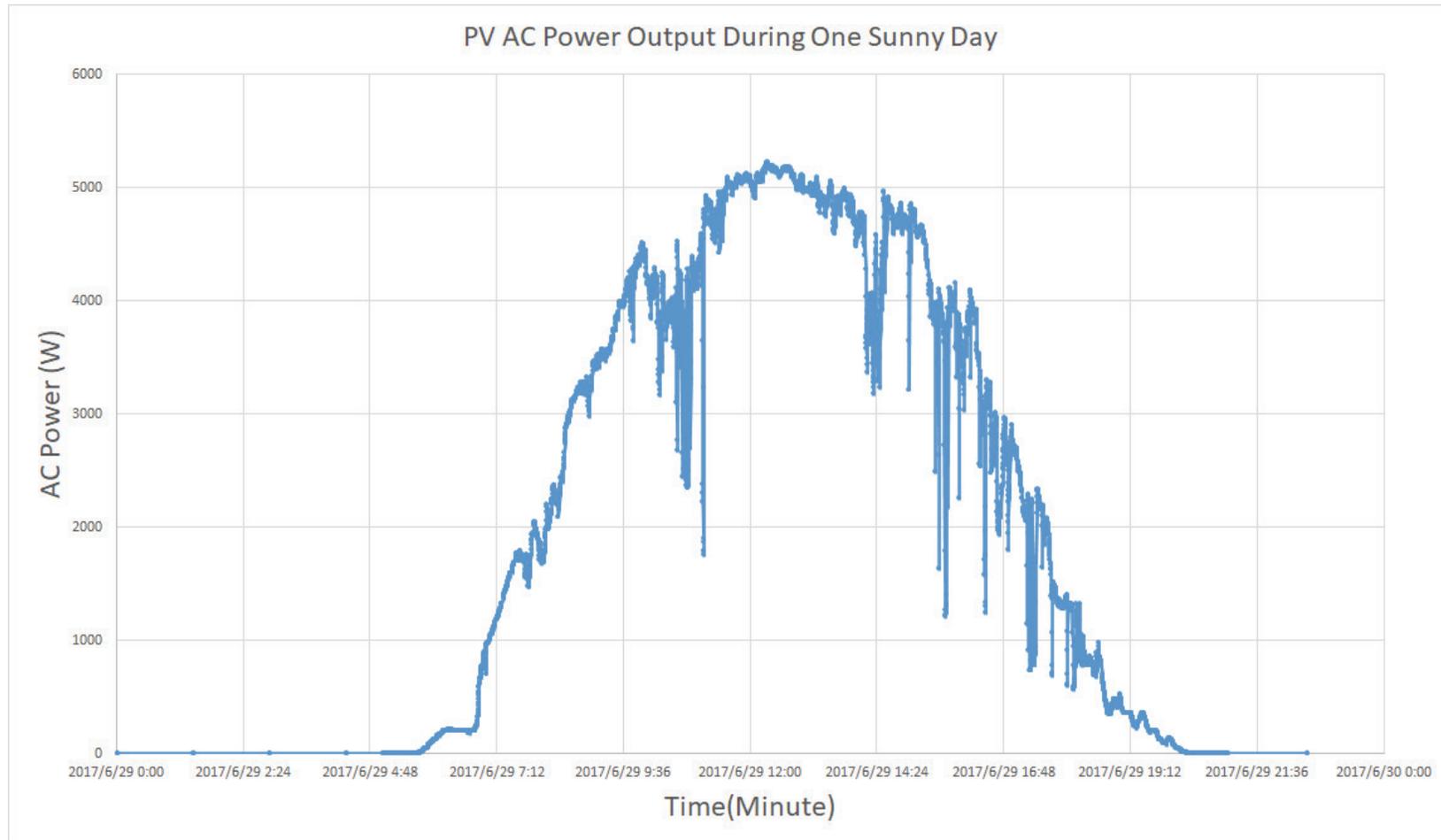
7-Day Solar PV Output (Virginia)



7-Day Solar PV Output (Virginia cloudy)

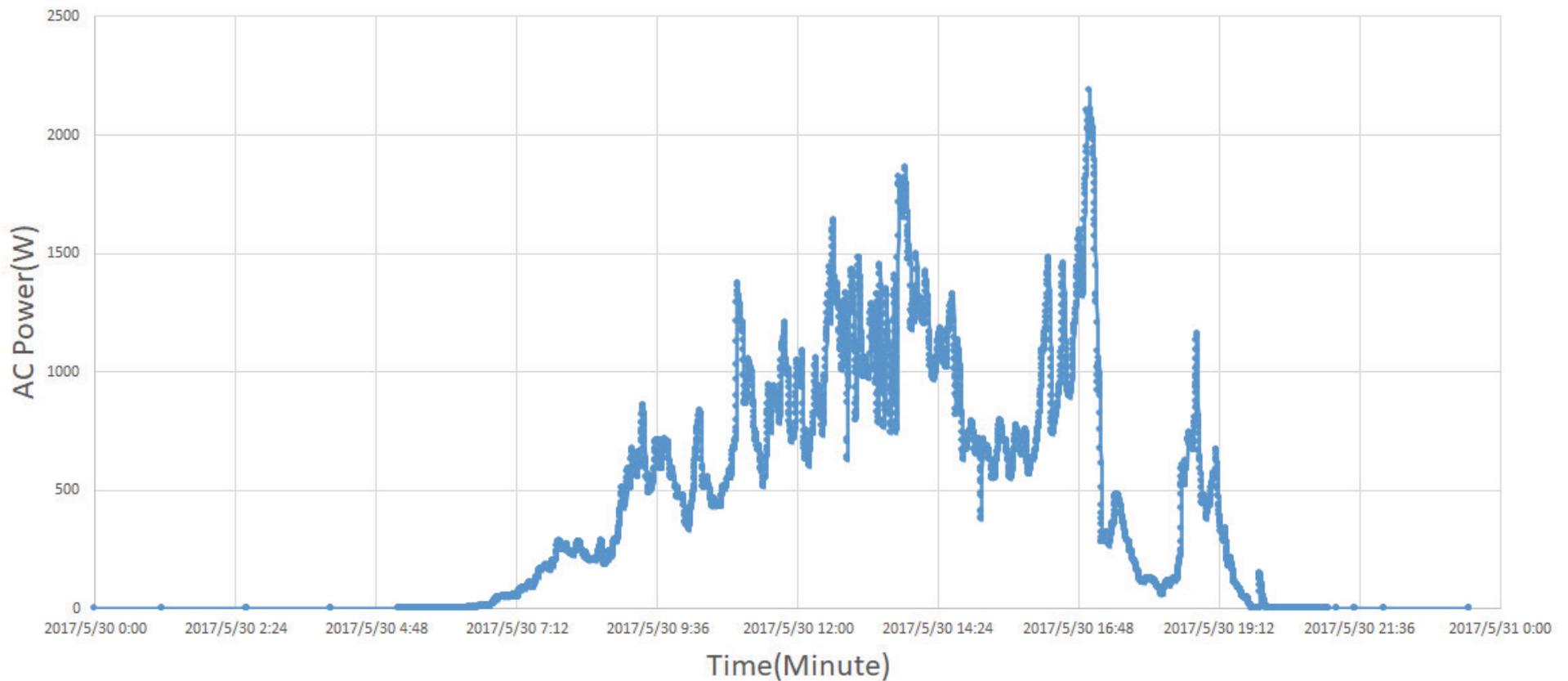


Daily PV Output (Virginia)

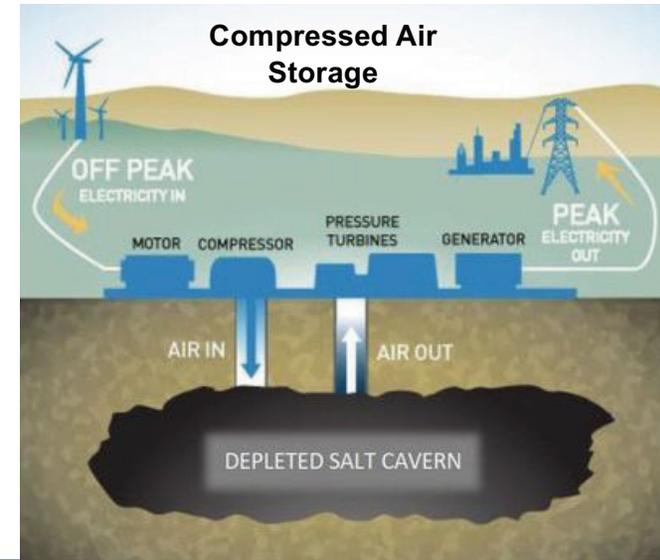


Daily PV Output (Virginia, intermittent)

PV AC Power Output During One Cloudy Day



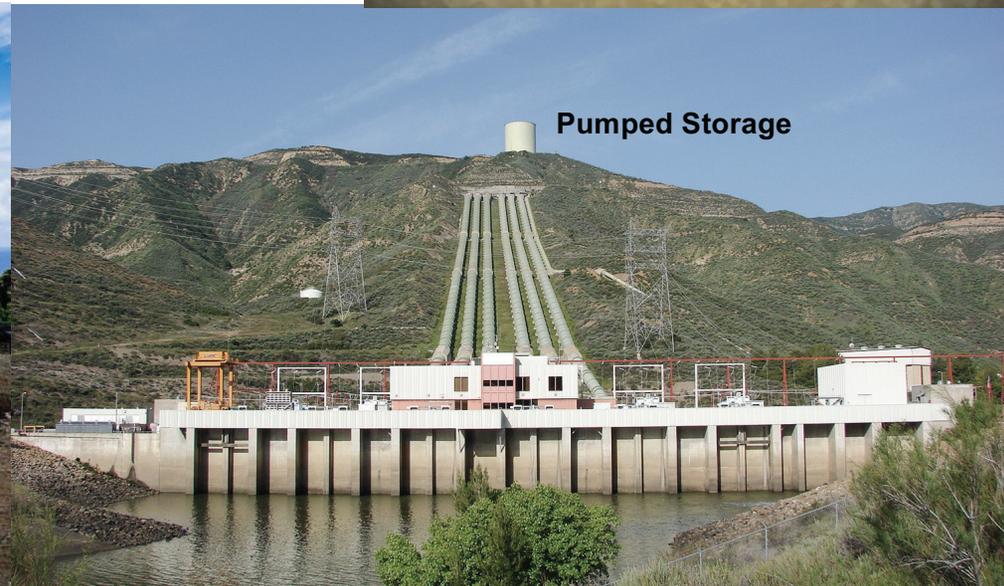
Can the Intermittency be Absorbed by the Network?



Battery storage



Pumped Storage



Historically: Demand driven supply (supply responds to demand)

New Paradigm for the Electric Power System



Smart Grid Ecosystem

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

THE SMART GRID ECOSYSTEM

The Smart Grid Ecosystem

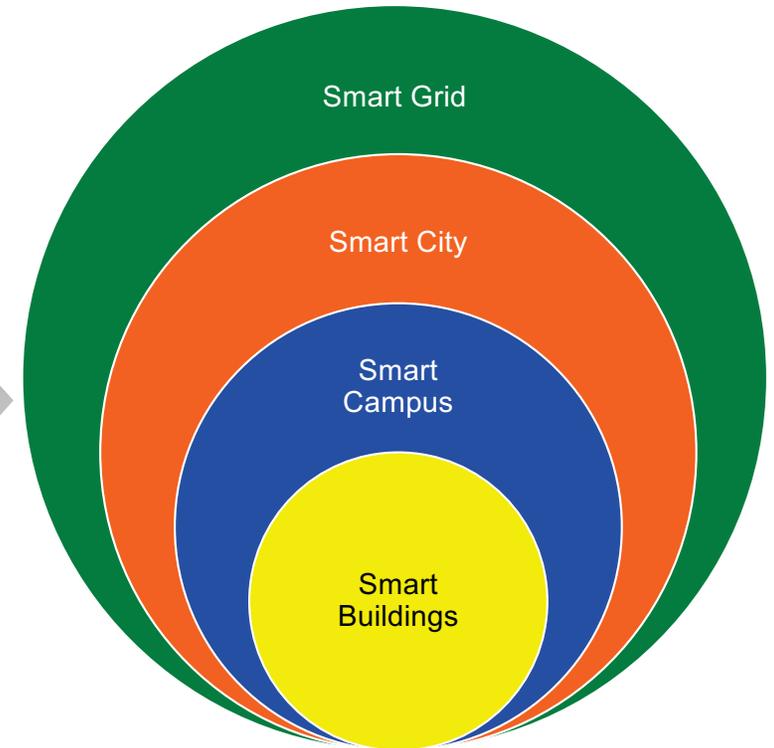
Smart grid: Bi-directional flows of energy, remote control/automation of power, integrated distributed energy...

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

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

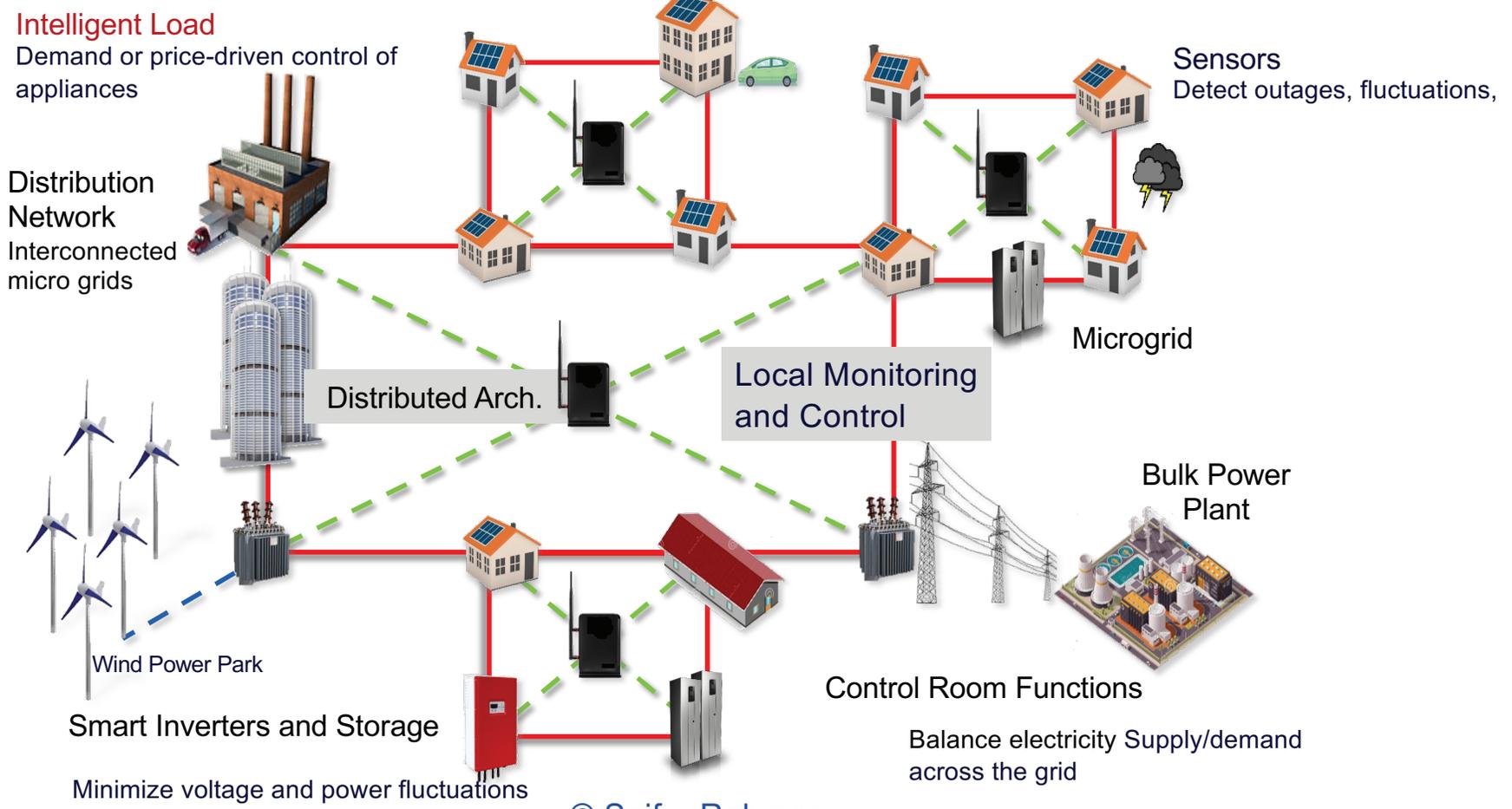
Smart buildings: Intelligent building automation systems, smart devices, productive users, grid integration...

Ecosystem



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

Intelligent Interconnected Microgrids



Reduce Carbon Emissions from Electricity Production



Reduce Carbon Emissions

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

IEEE Climate Change Website

<https://climate-change.ieee.org>



Resources from IEEE

Climate Change in the News

Contact



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DIFFERENCE

TECHNICAL Solutions	BUILDING Technical Community	CLIMATE CHANGE Mitigation
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Thank You

Role of Smart Grid in Facilitating the Integration of Renewables

Prof. Saifur Rahman

www.srahman.org