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# How Can a Smart Power Grid Help to Integrate Diverse Sources of Generation & Storage



Keynote Speech

1<sup>st</sup> IES Online Conference (ONCON), 09 Dec 2022

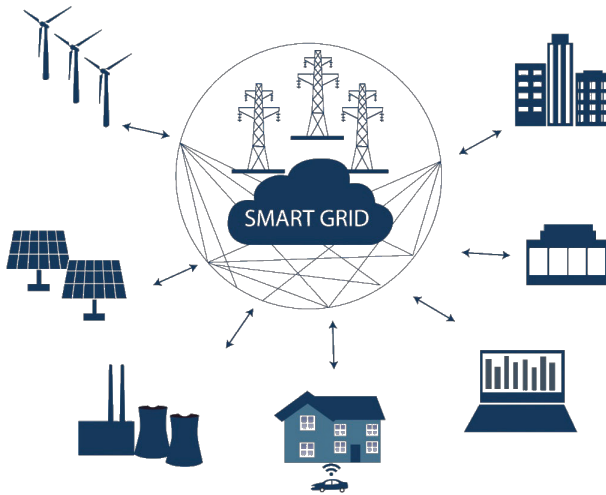
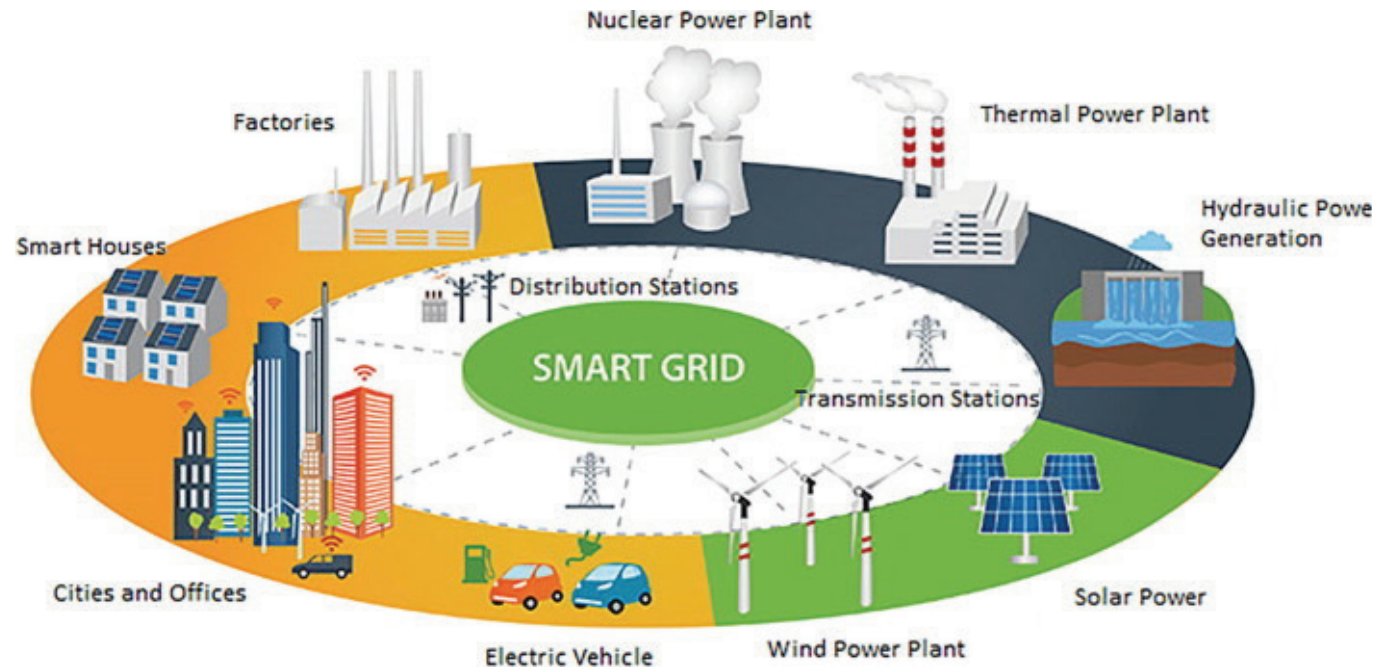


# Outline



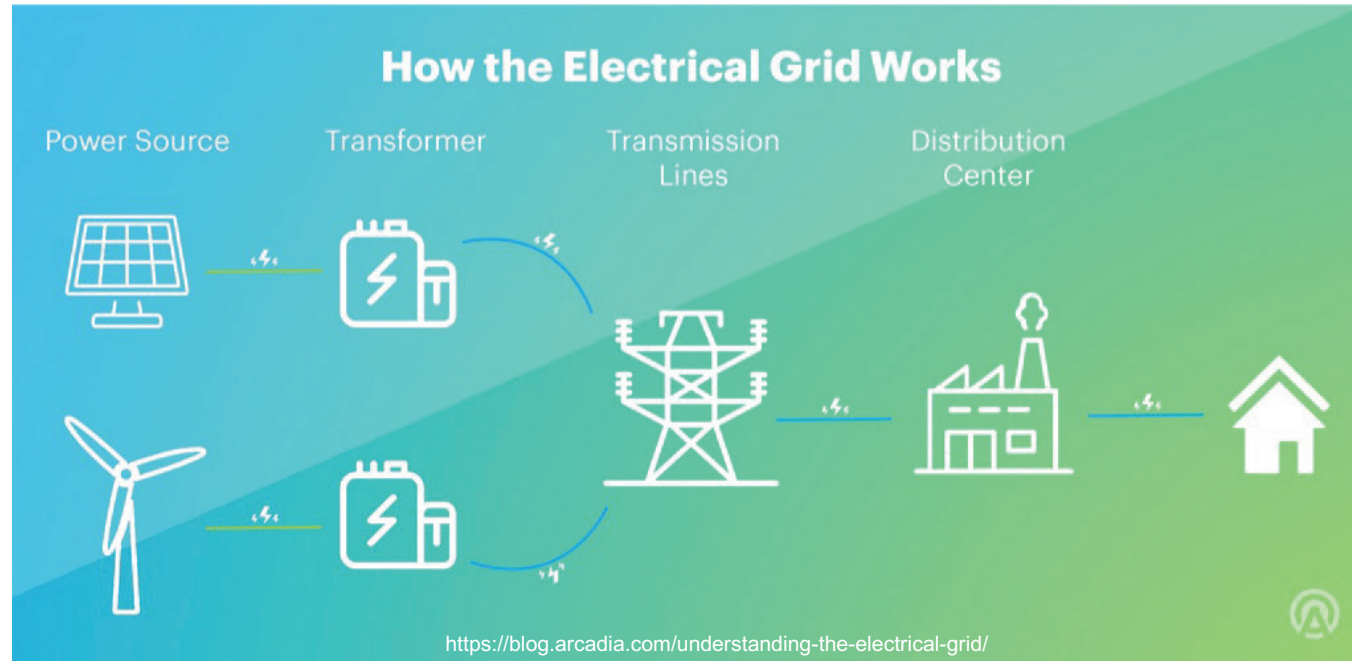
- 01** What is a Smart Grid?
- 02** Motivation for a Smart Grid
- 03** Difference Between a Normal / Smart Grid
- 04** Smart Grid Building Blocks
- 05** Evolution of the Grid
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# What is a Smart Grid



"**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

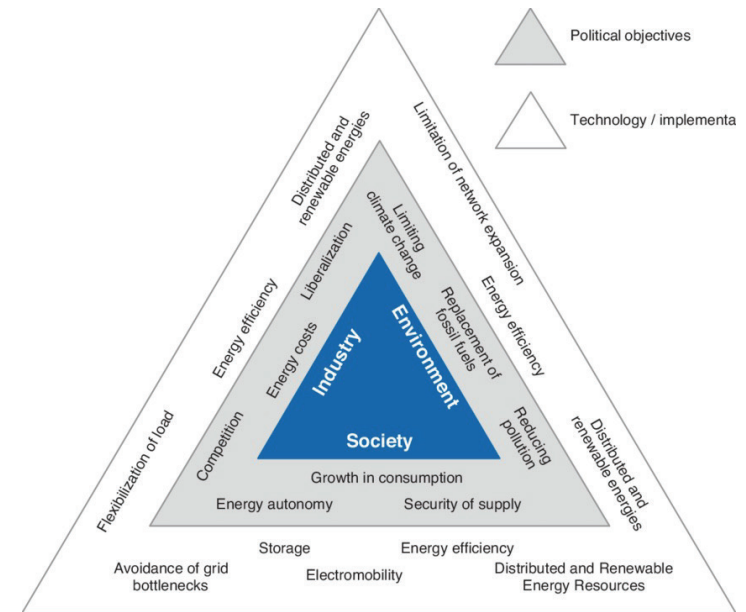


## How Does the Electrical Grid Work?

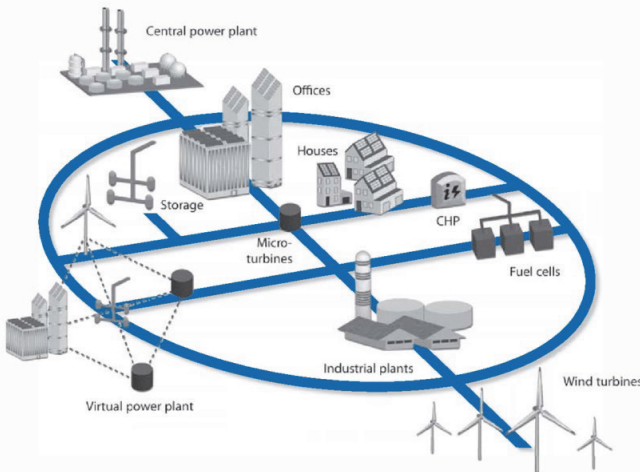
- Power Sources
- Transformers
- Transmission lines
- Distribution centers

# 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](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.

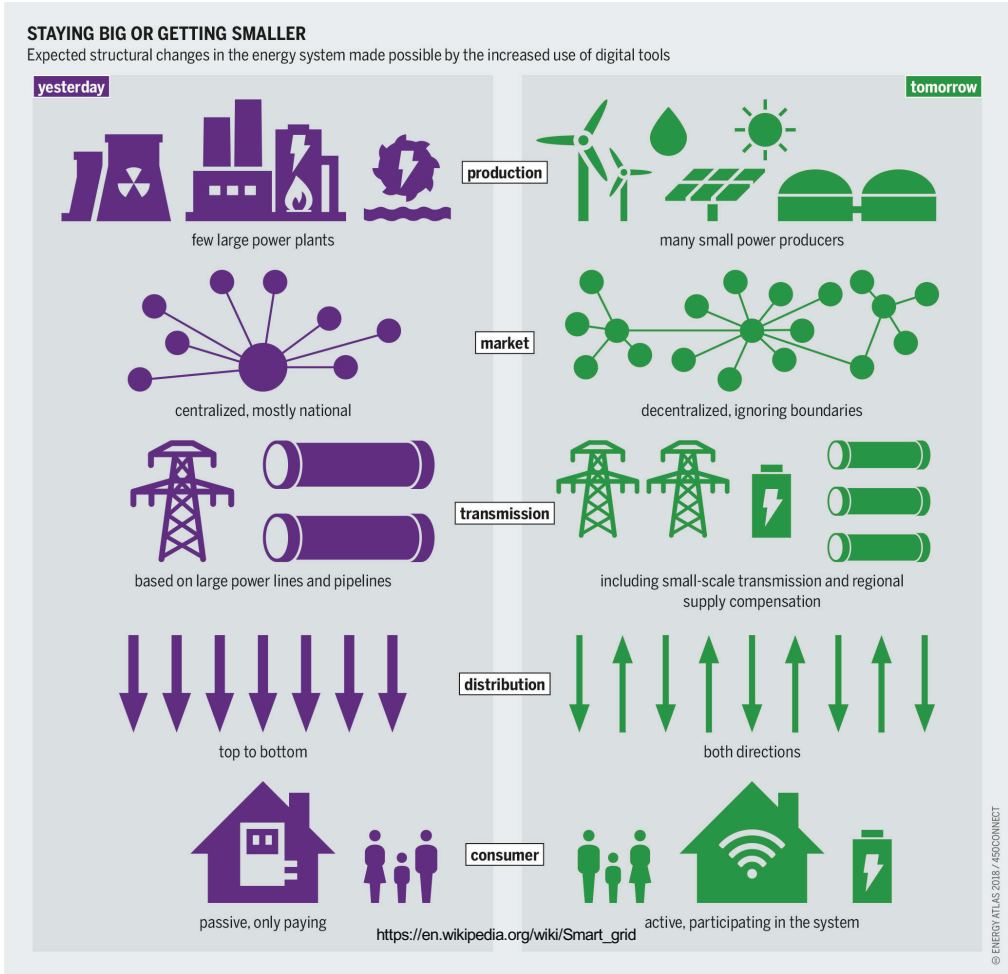
# Difference Between a Normal Grid And a Smart Grid



Normal Phone



Smart Phone



# Starting and End Points of a Smart Grid



Power Plant



Transmission



Distribution



Home Business



End-use Appliances



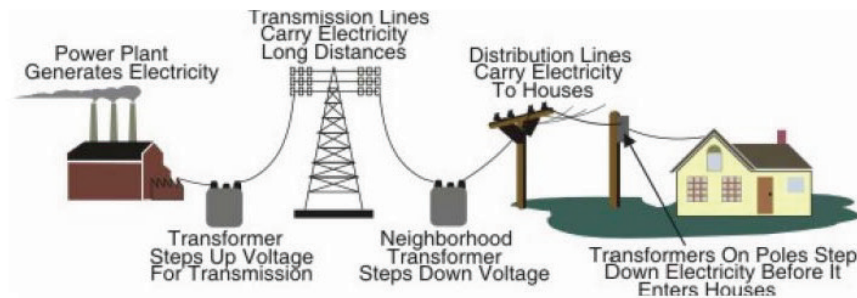
# Smart Grid Building Blocks



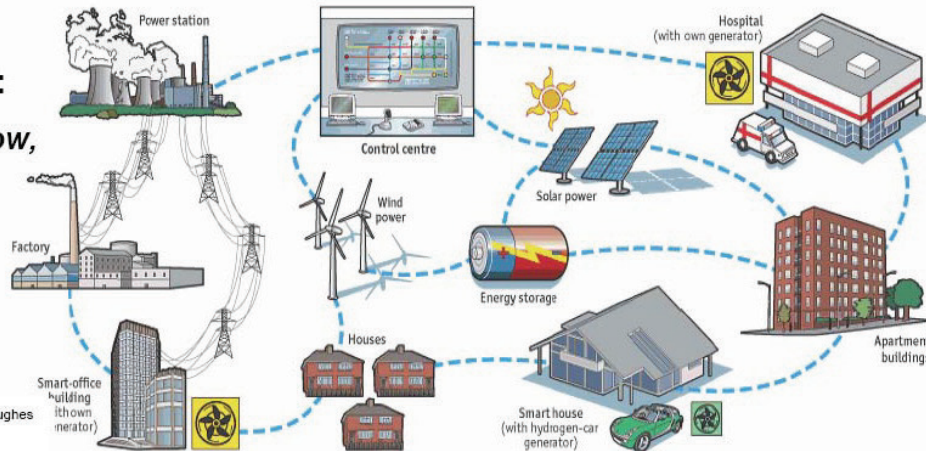
# Evolution of the Grid

## 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: Altalink, Alberta, Canada

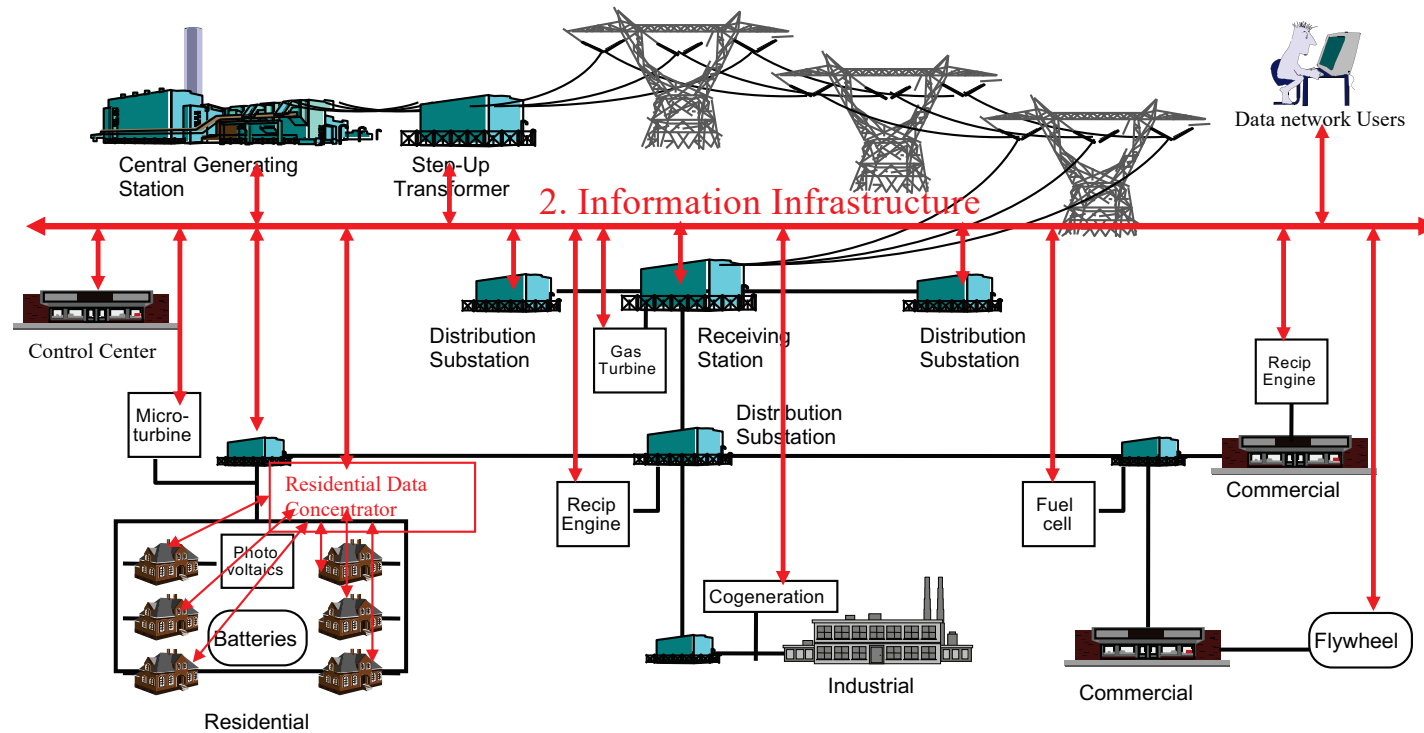


**Merging Power Flow with Information Flow:**

**Integrated Communications**

# Electric Power & Communication Infrastructures

## 1. Power Infrastructure



Source: EPRI

# Changing Landscape for the Electric Utility

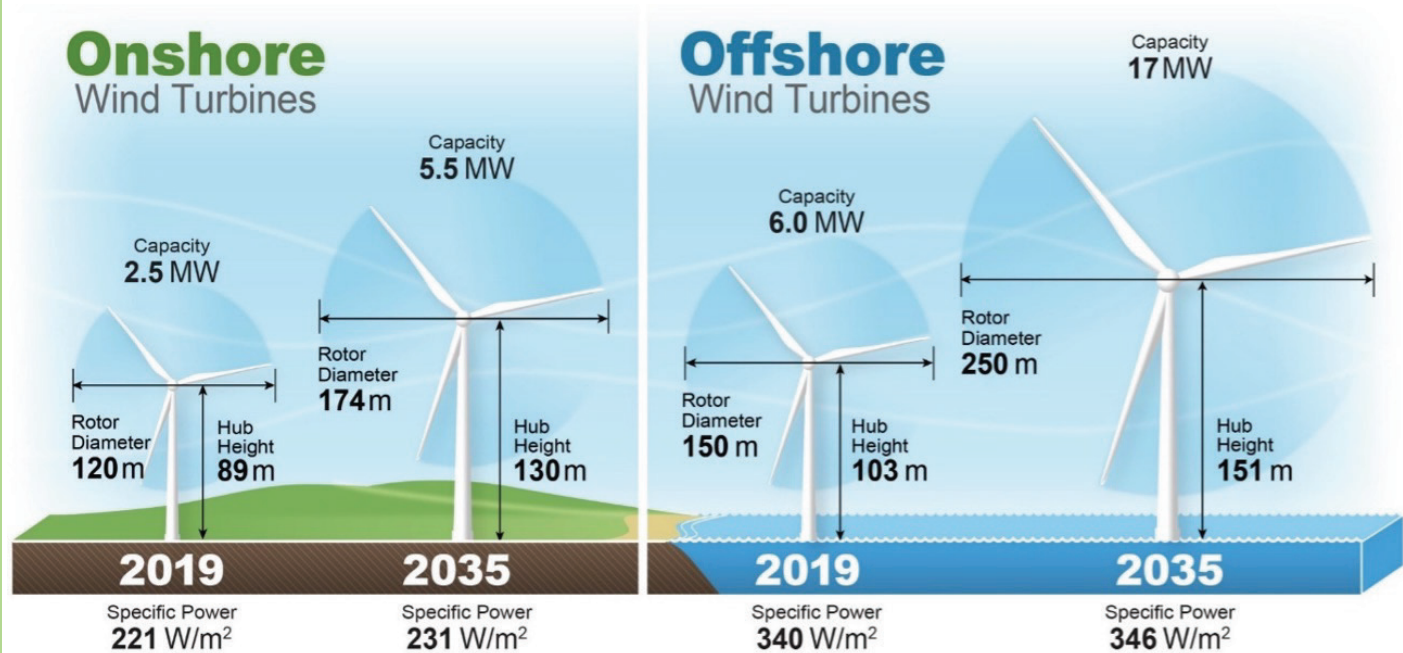


A photograph of a wind farm with a long line of white wind turbines stretching along a coastline. The sky is clear and blue, and the ocean is visible in the distance. The turbines are arranged in a perspective that leads the eye from the foreground towards the horizon.

## Issues with Distributed Generation

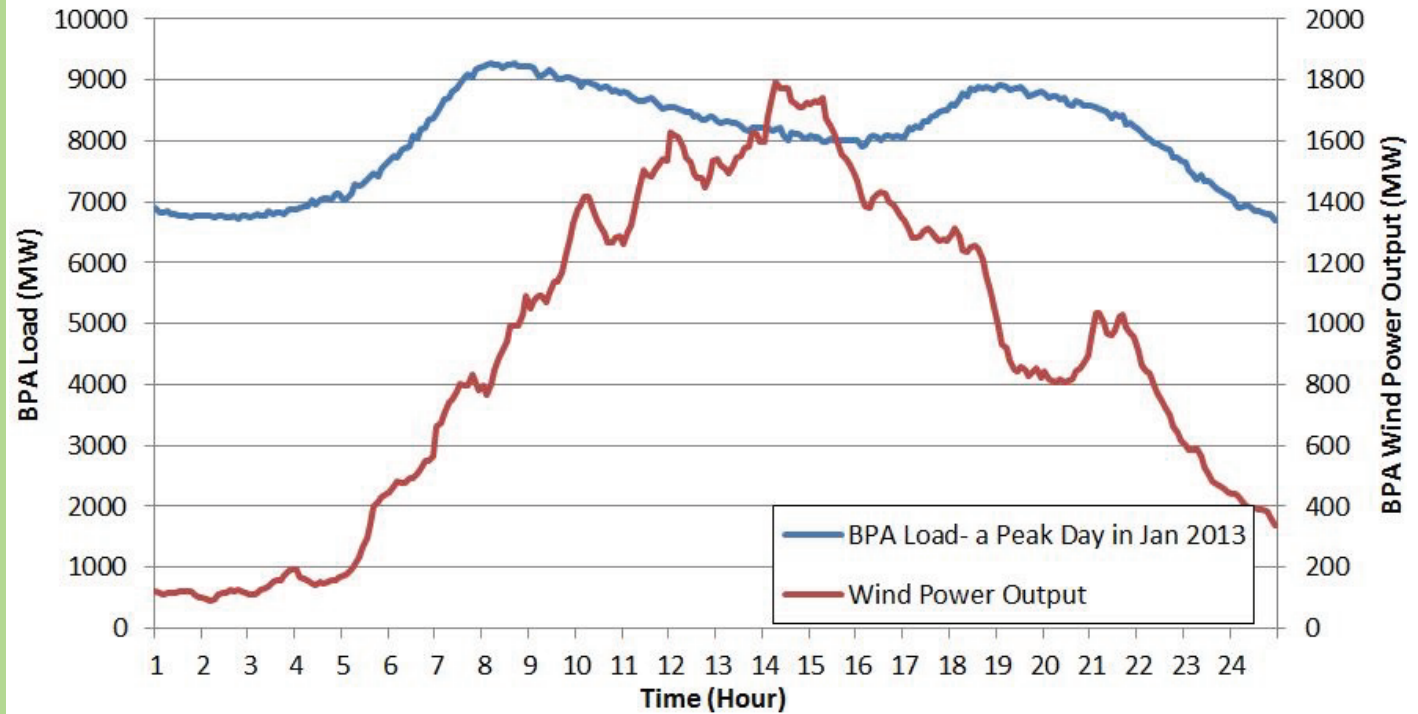
- Wind and solar are intermittent
- Hydro is space limited
- Resource is free but not always usable

# Wind Energy



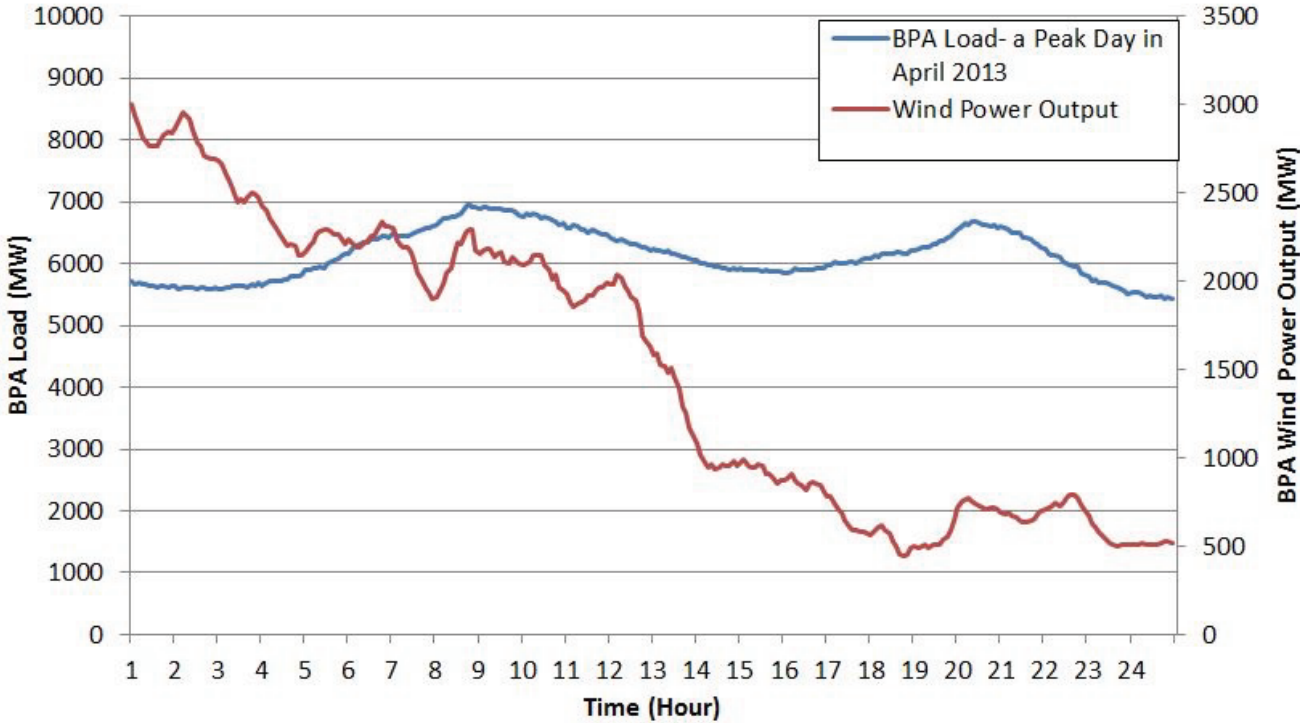
<https://www.renewableenergyworld.com/wind-power/wind-power-experts-expect-wind-energy-costs-to-decline-up-to-35-by-2035/#gref>

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





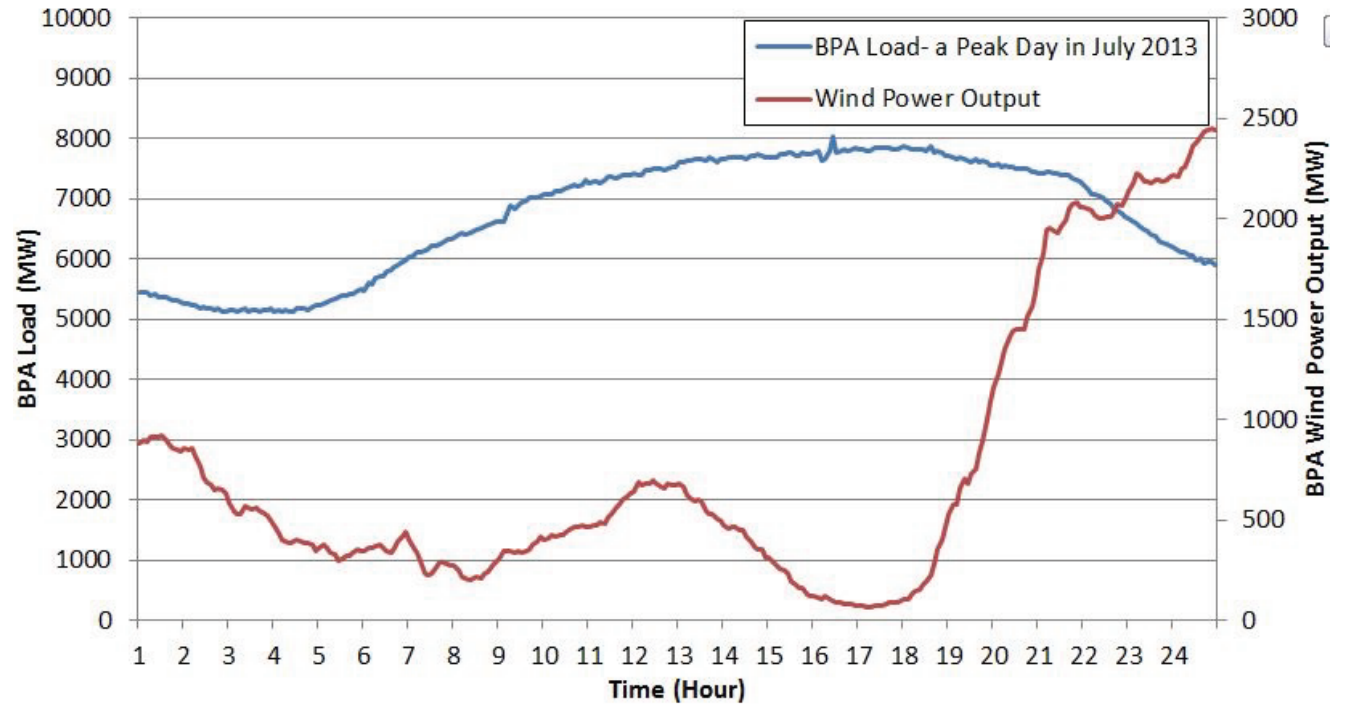
# BPA Wind Output and Load Mismatch (A typical day in April)





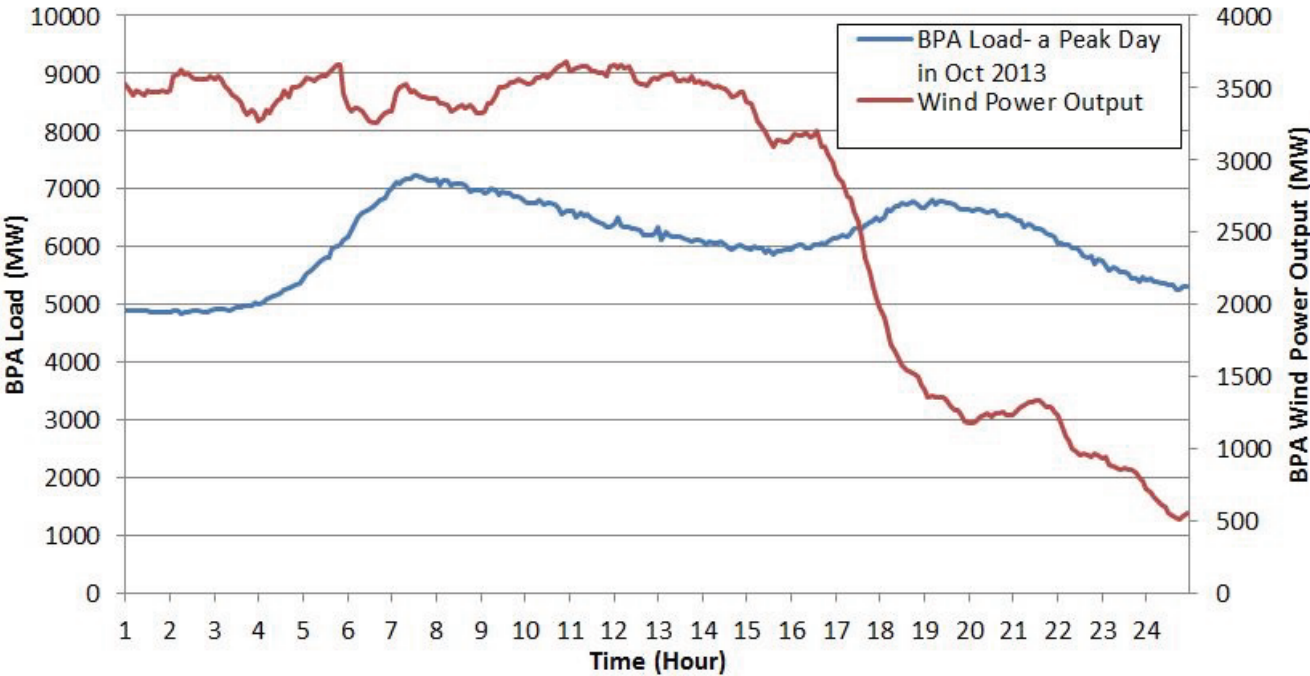


## BPA Wind Output and Load Mismatch (A typical day in July)

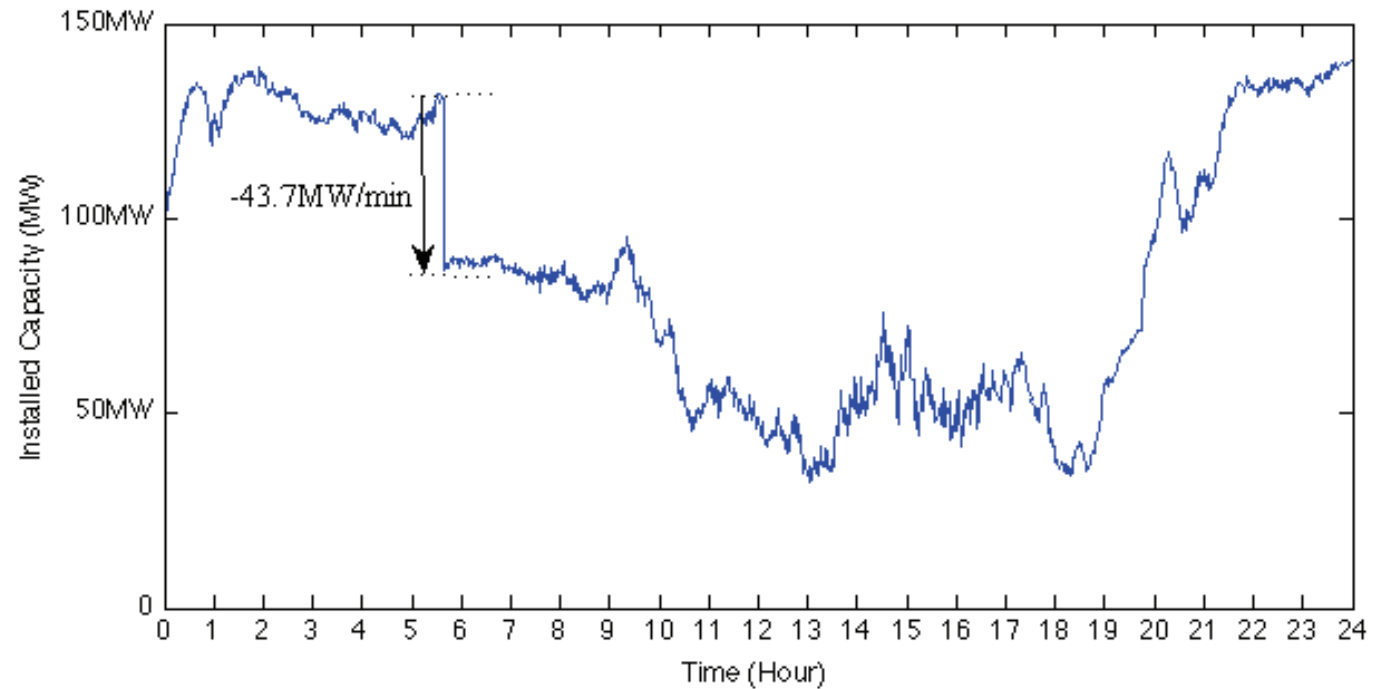




# BPA Wind Output and Load Mismatch (A typical day in October)



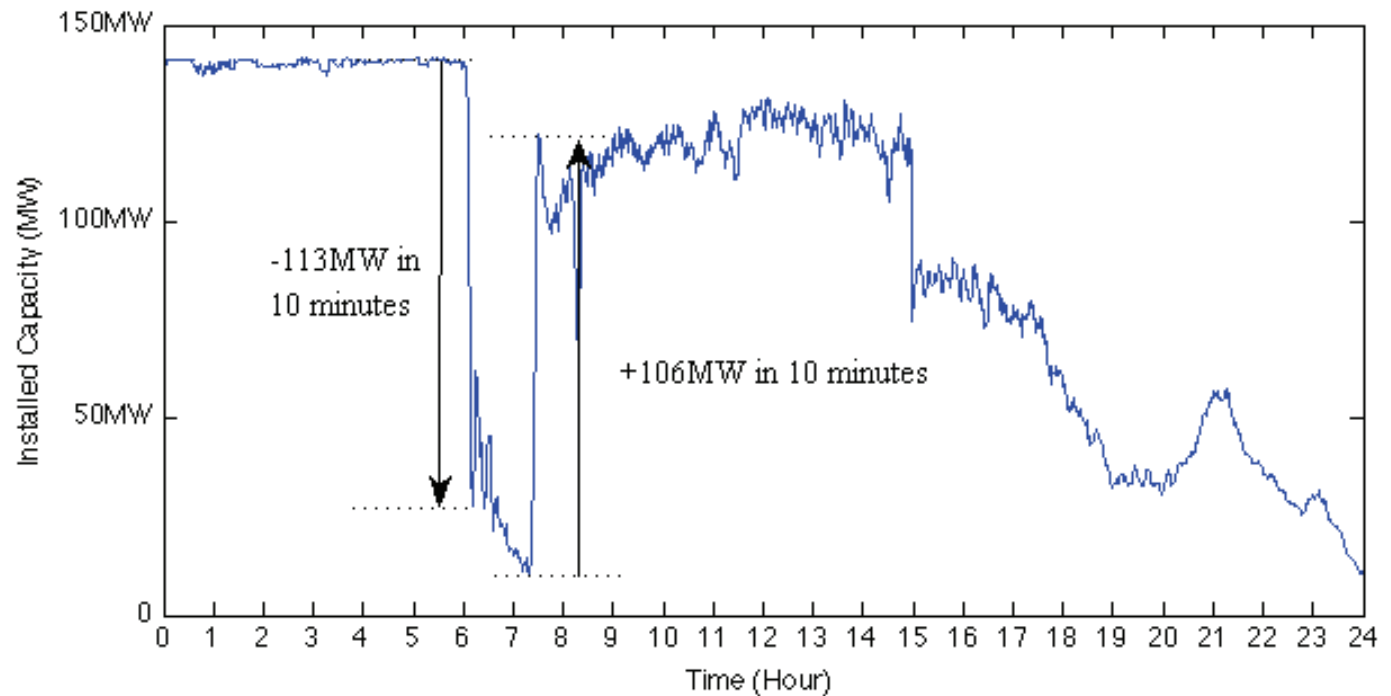
# 1-minute Variation of a 150MW Wind Farm Output in Texas



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

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# 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



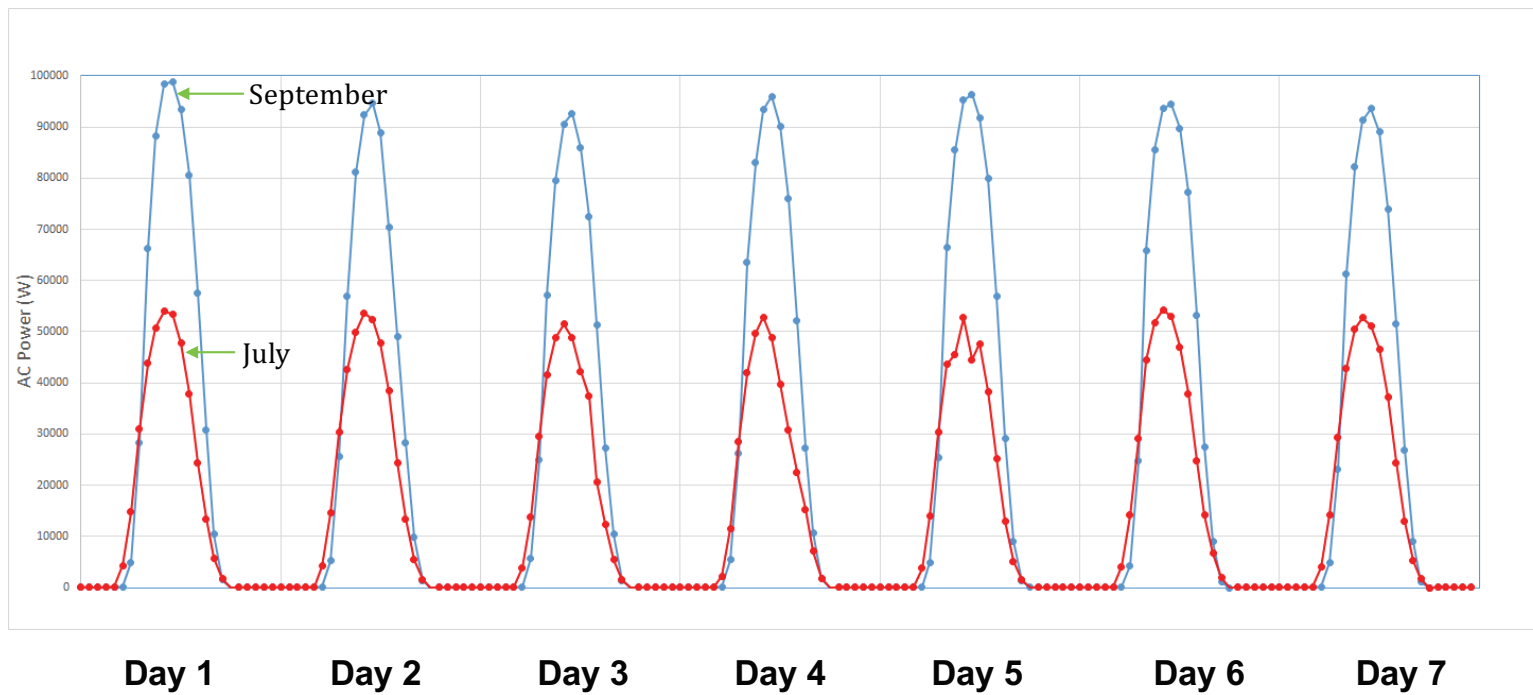
2-MW Roof-top Solar PV plant at KAUST

# Solar PV Panels in Saudi Arabia

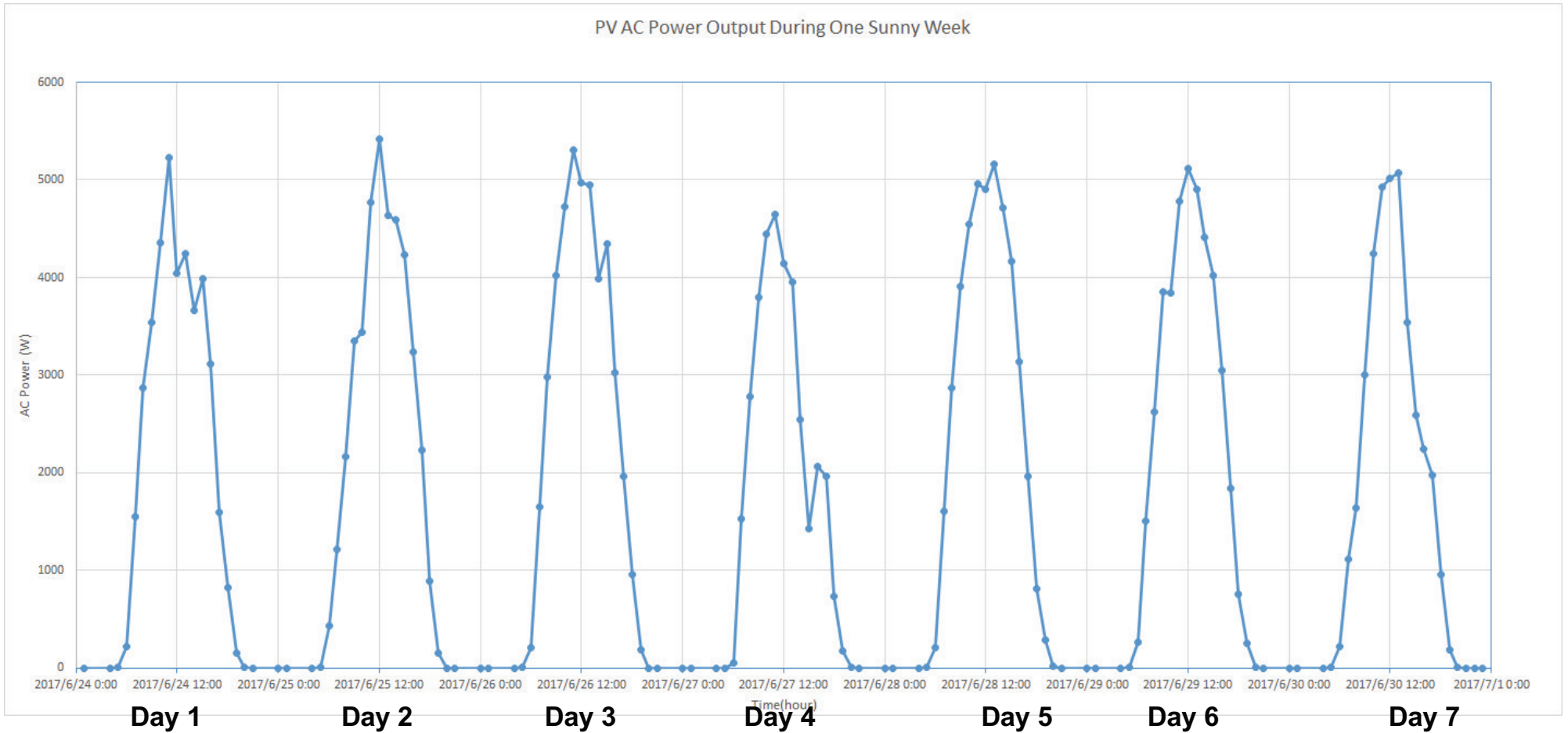


Reality Check

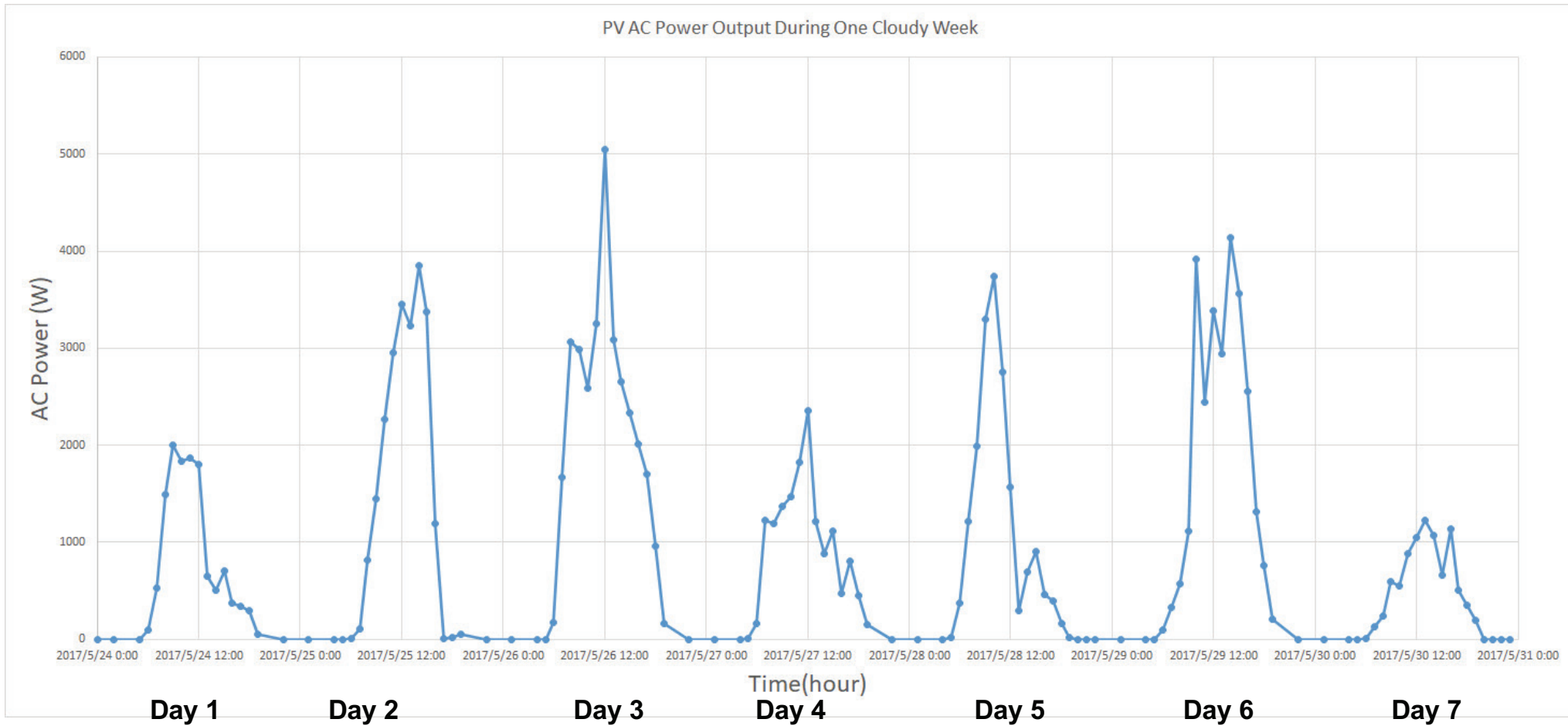
# Solar PV Array (100kWp) Riyadh Area



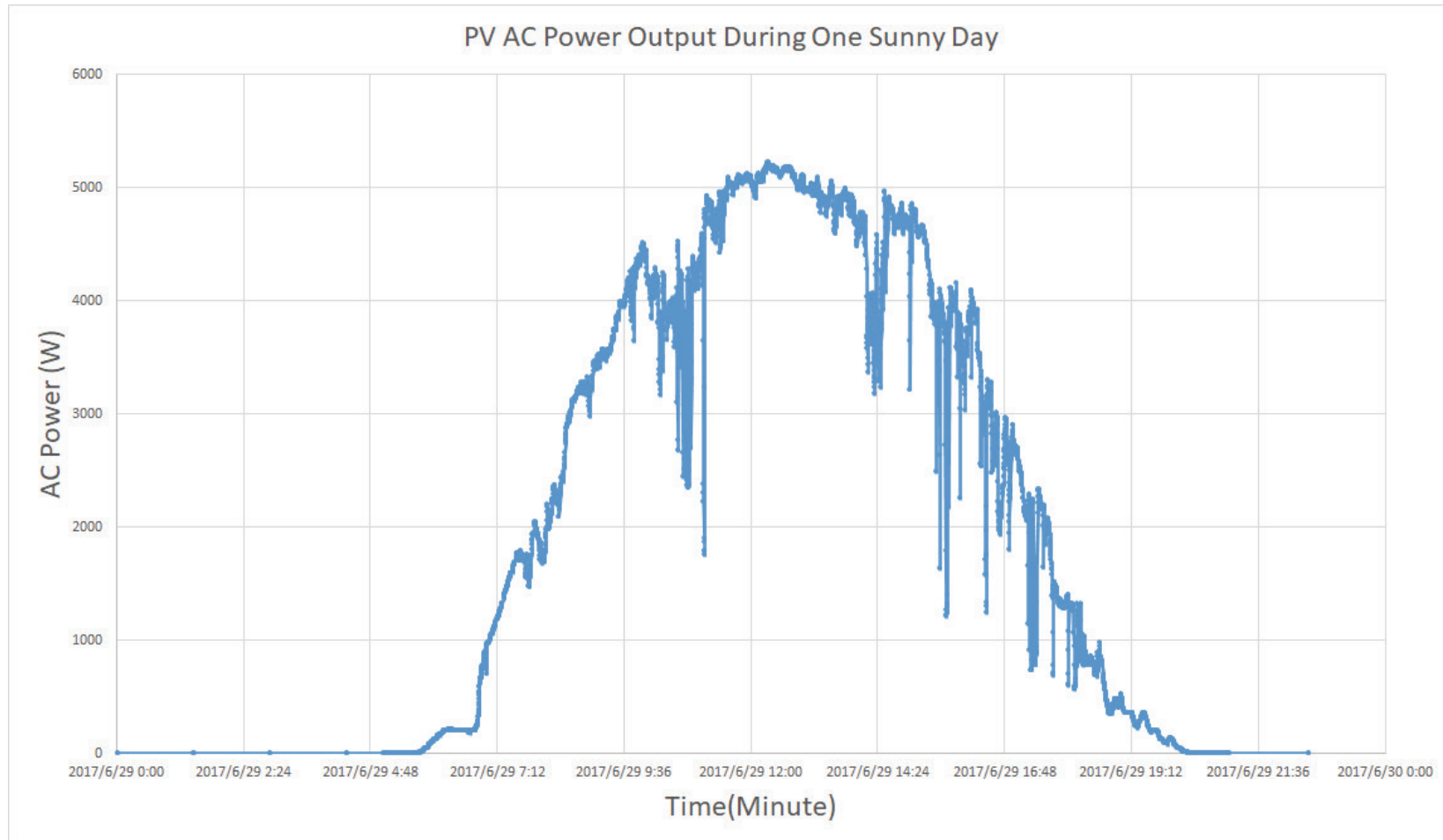
# 7-Day Solar PV Output (Virginia)



# 7-Day Solar PV Output (Virginia cloudy)

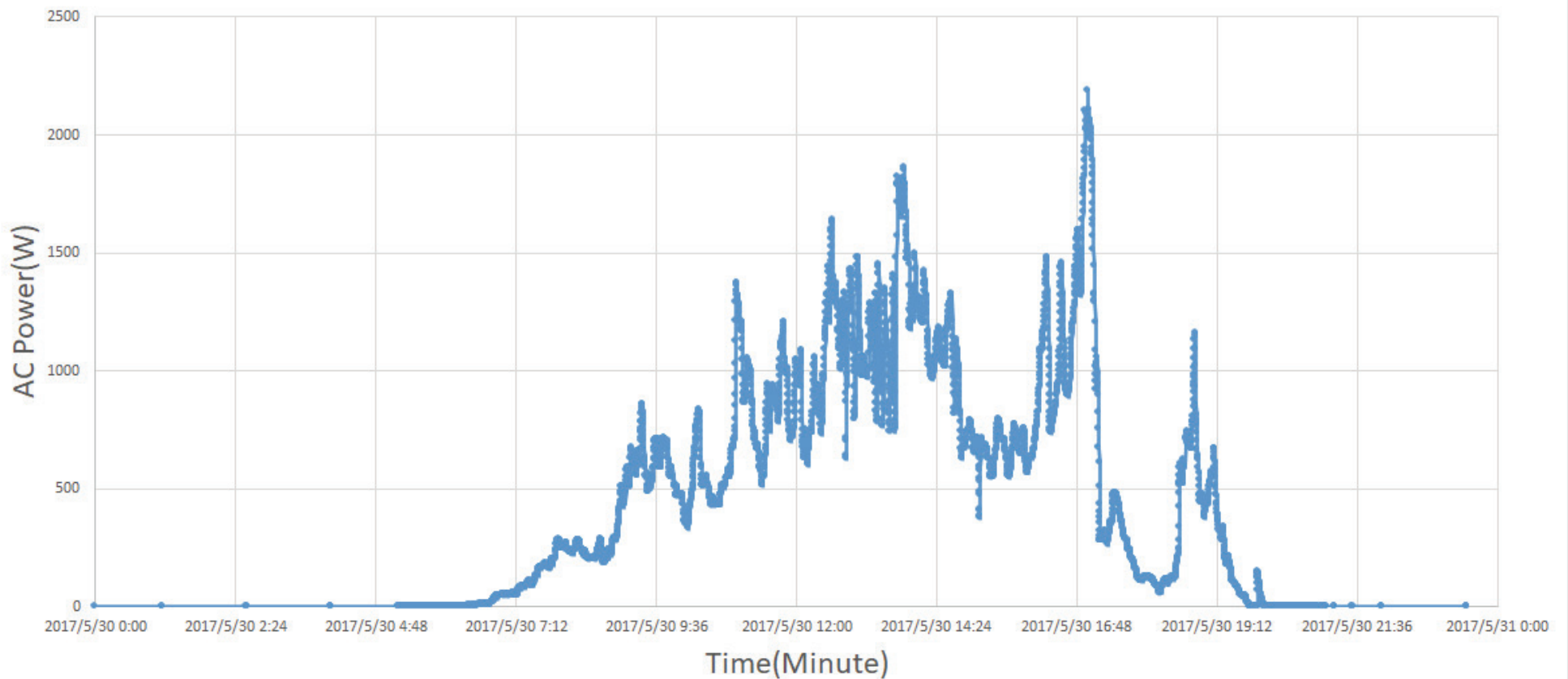


# Daily PV Output (Virginia)

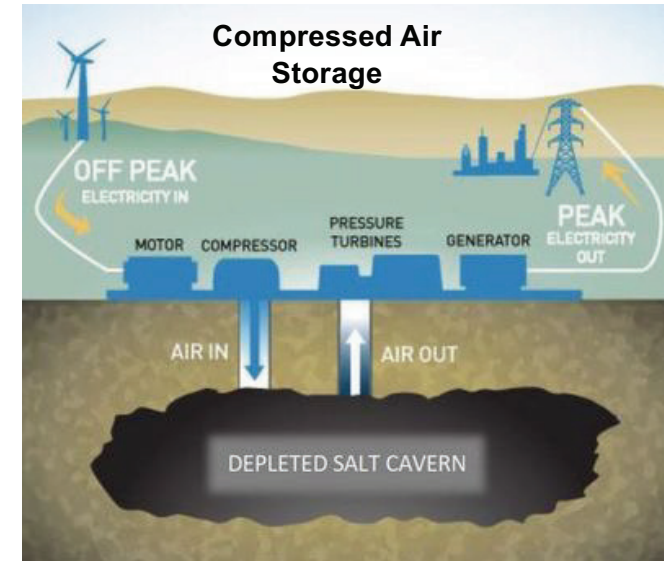


# Daily PV Output (Virginia, intermittent)

PV AC Power Output During One Cloudy Day



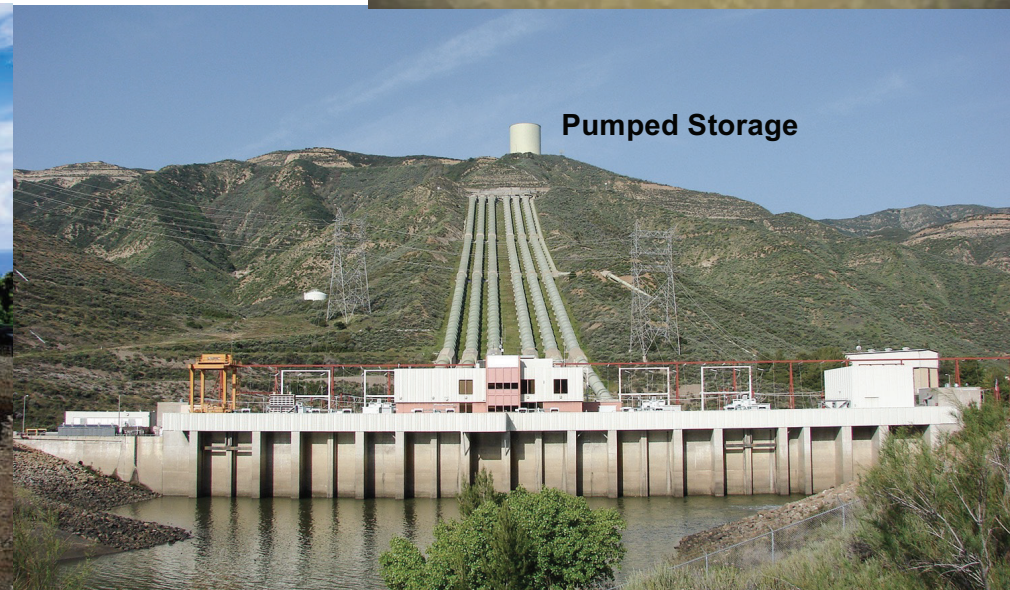
# Can the Intermittency be Absorbed by the Network?



**Battery storage**



**Pumped Storage**





Historically: Demand driven supply (supply responds to demand)

## New Paradigm for the Electric Power System



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

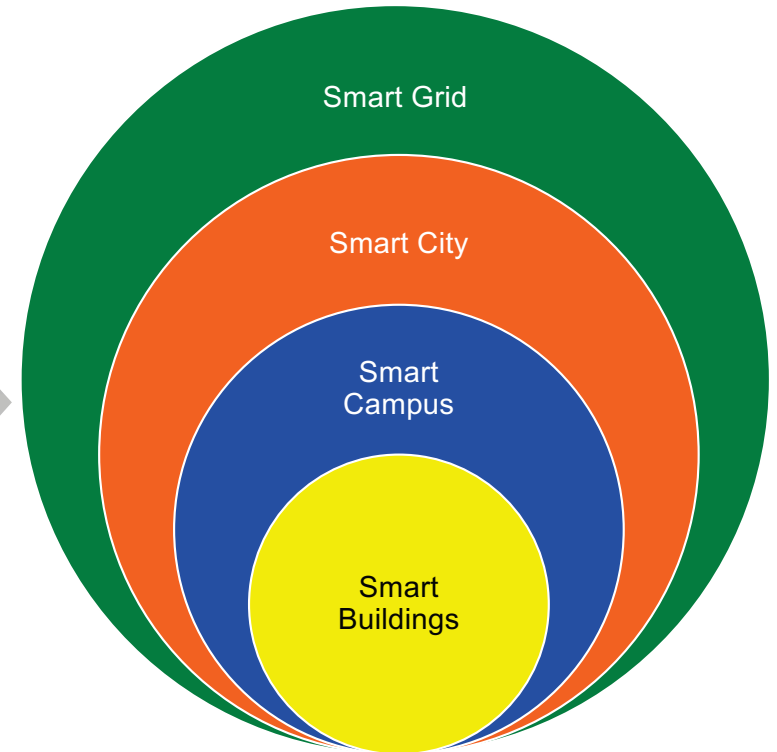
**Smart grid:** Bi-directional flows of energy, remote control/automation of power, integrated distributed energy...

**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 →

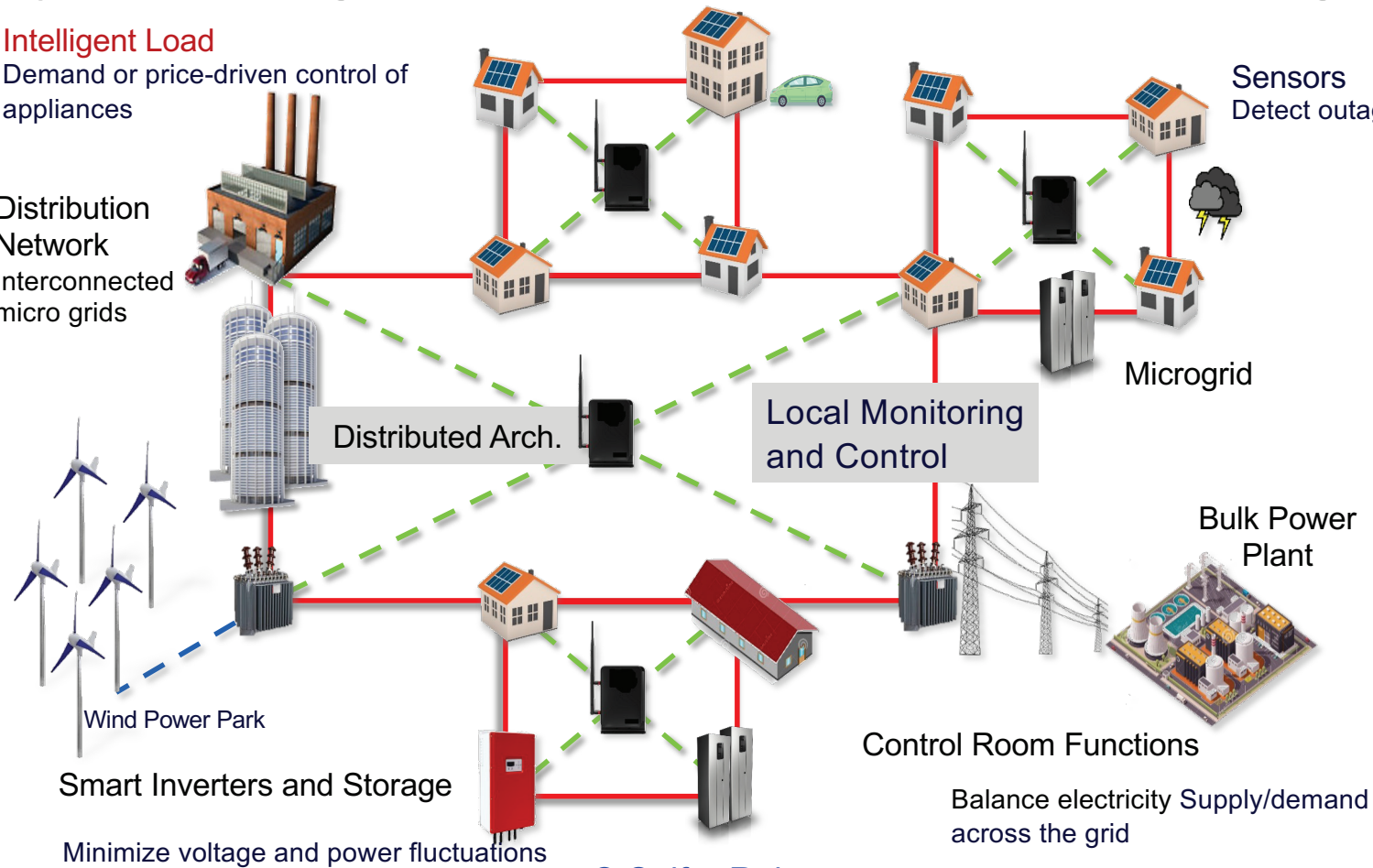
# Shape of Things to come: Interconnected Microgrids

## Intelligent Load

Demand or price-driven control of appliances

Distribution Network  
Interconnected micro grids

Sensors  
Detect outages, fluctuations,



Smart Inverters and Storage

Minimize voltage and power fluctuations

Local Monitoring and Control

Microgrid

Bulk Power Plant

Control Room Functions

Balance electricity Supply/demand across the grid

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# Thank You

Role of Smart Grid in Facilitating the Integration of Renewables

Prof. Saifur Rahman

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