Prof. Saifur Rahman
2022 IEEE President-elect
Director, Virginia Tech Advanced Research Inst., USA

www.srahman.org

Role of Smart Grid in Facilitating the Integration of Renewables

Invited Talk

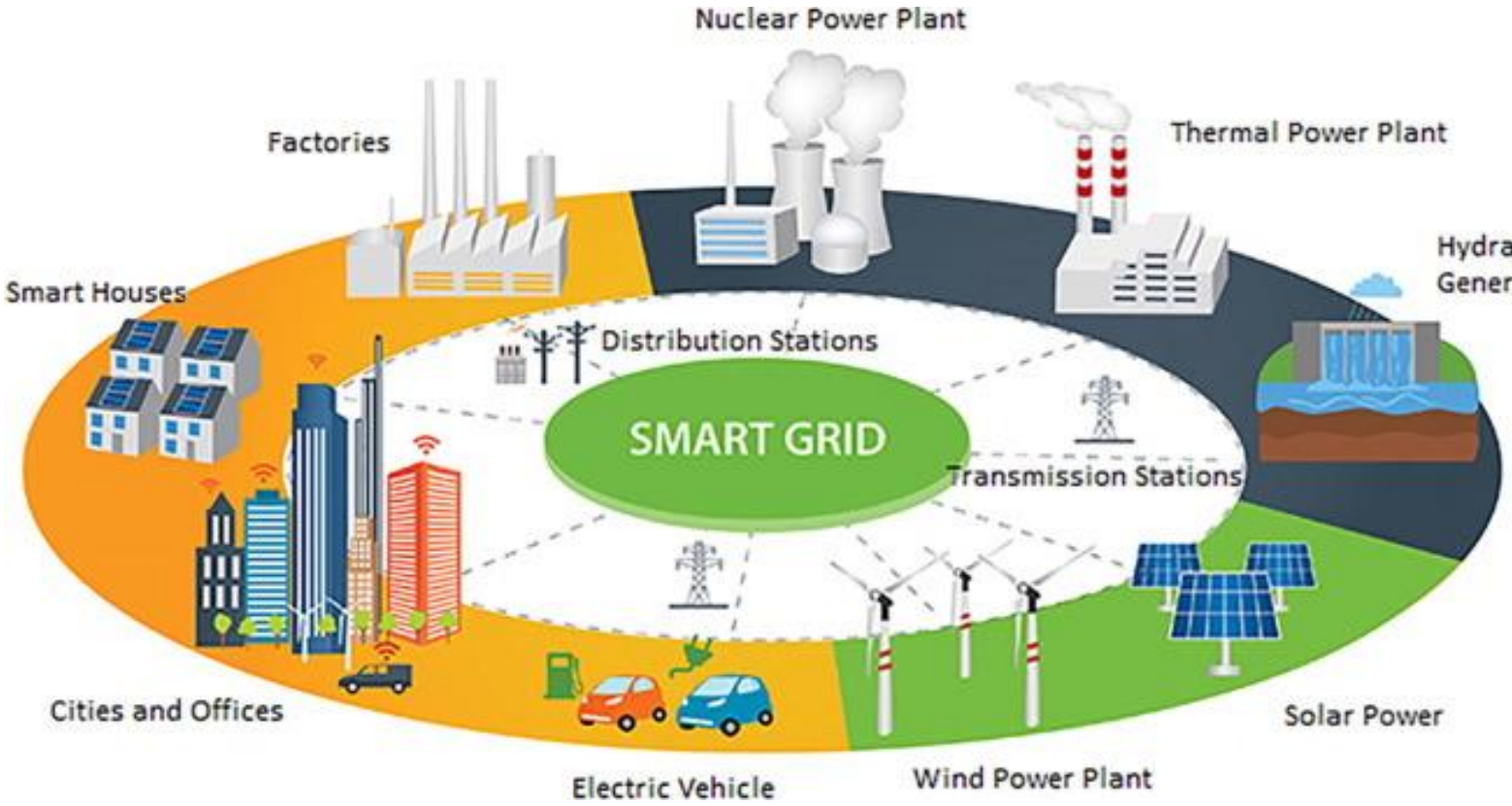
Technical University, Delft, Netherlands, 07 April 2022

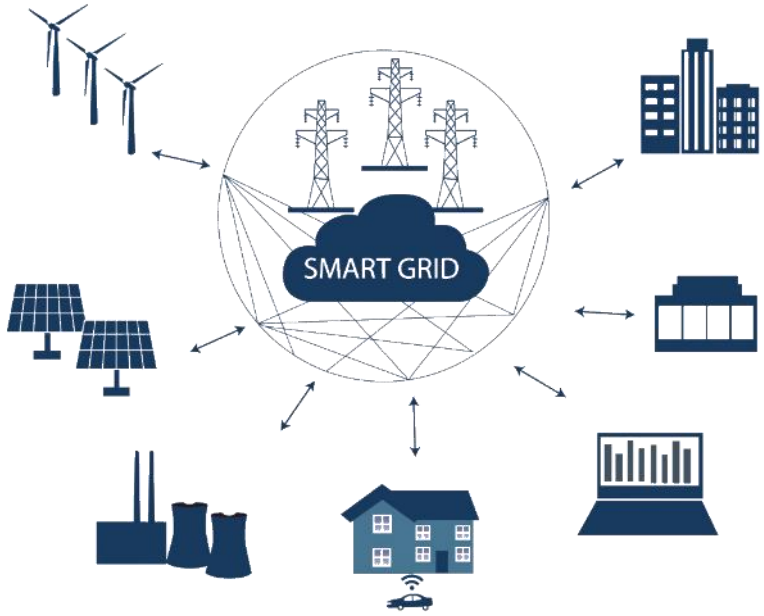
Virginia Tech

ARI

Outline

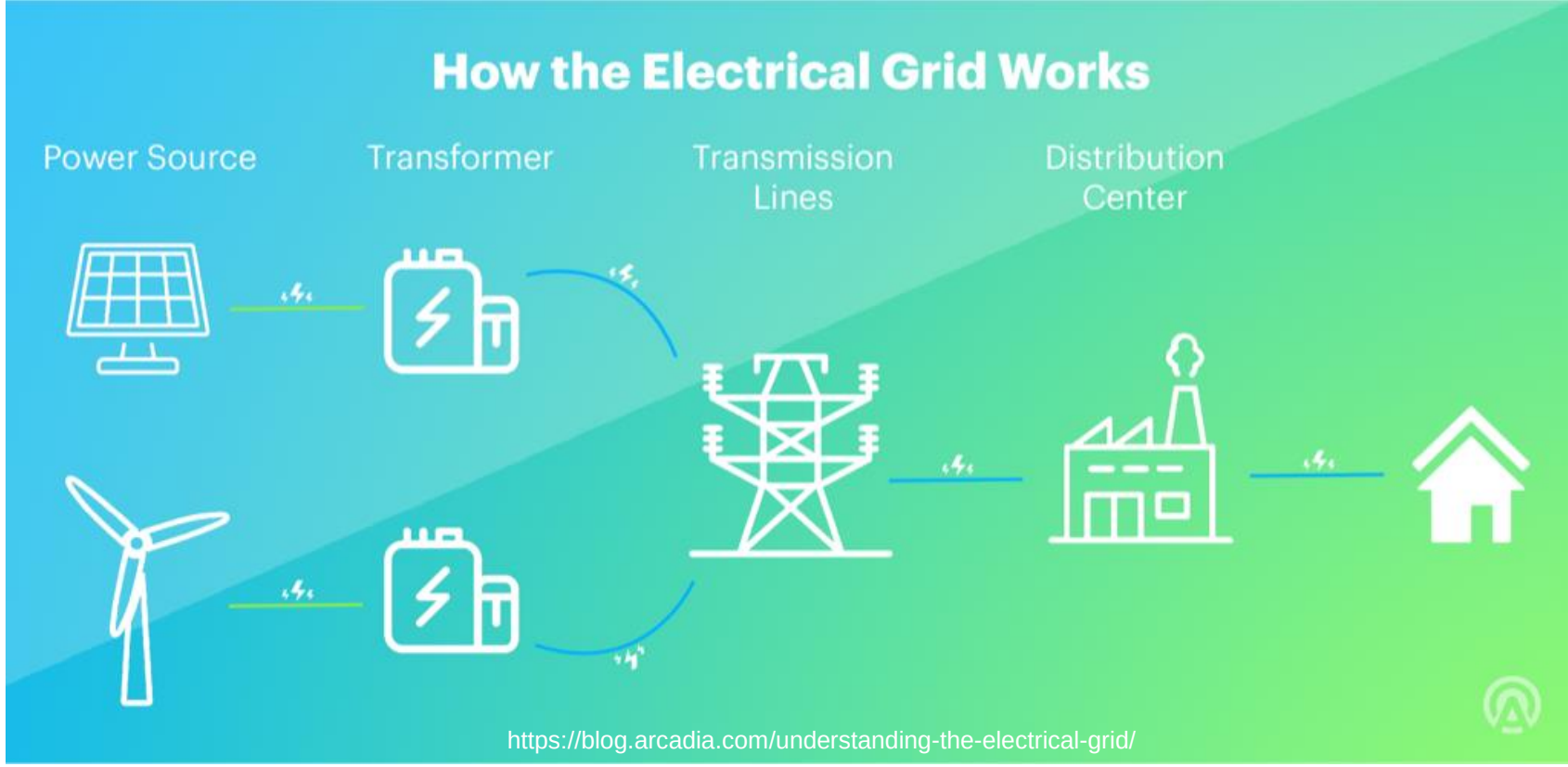
What is a Smart Grid





"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

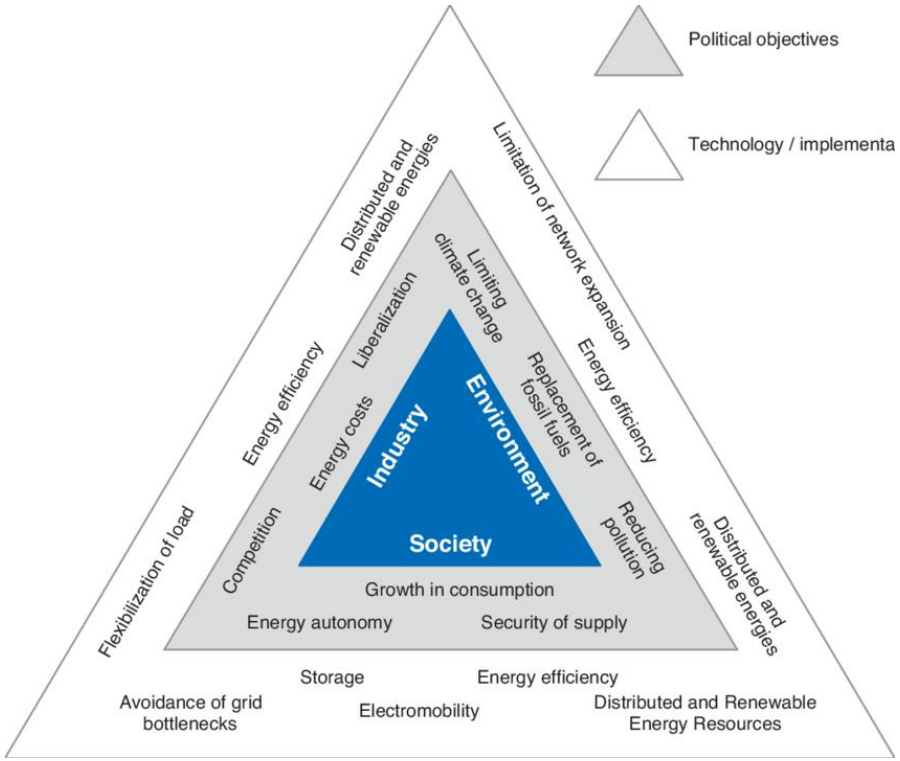


How Does the Electrical Grid Work?

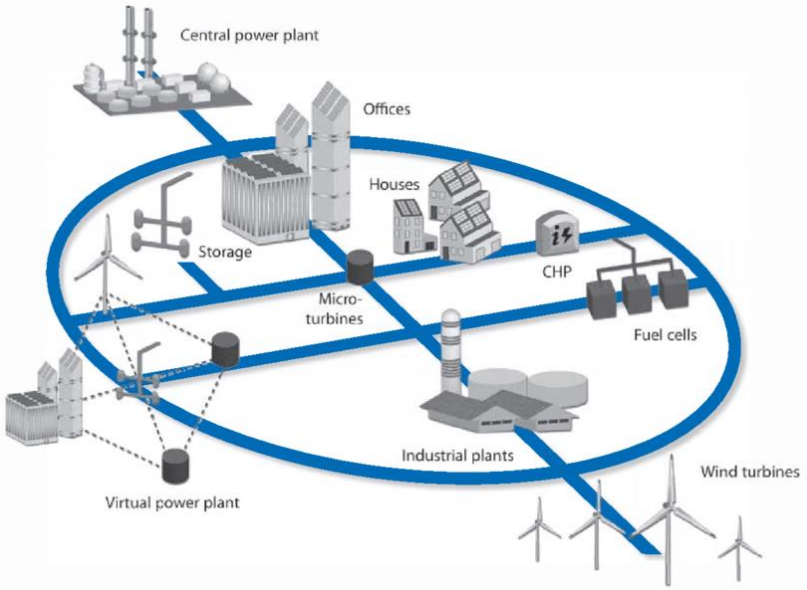
- Power Sources
- Transformers
- Transmission lines
- Distribution centers

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

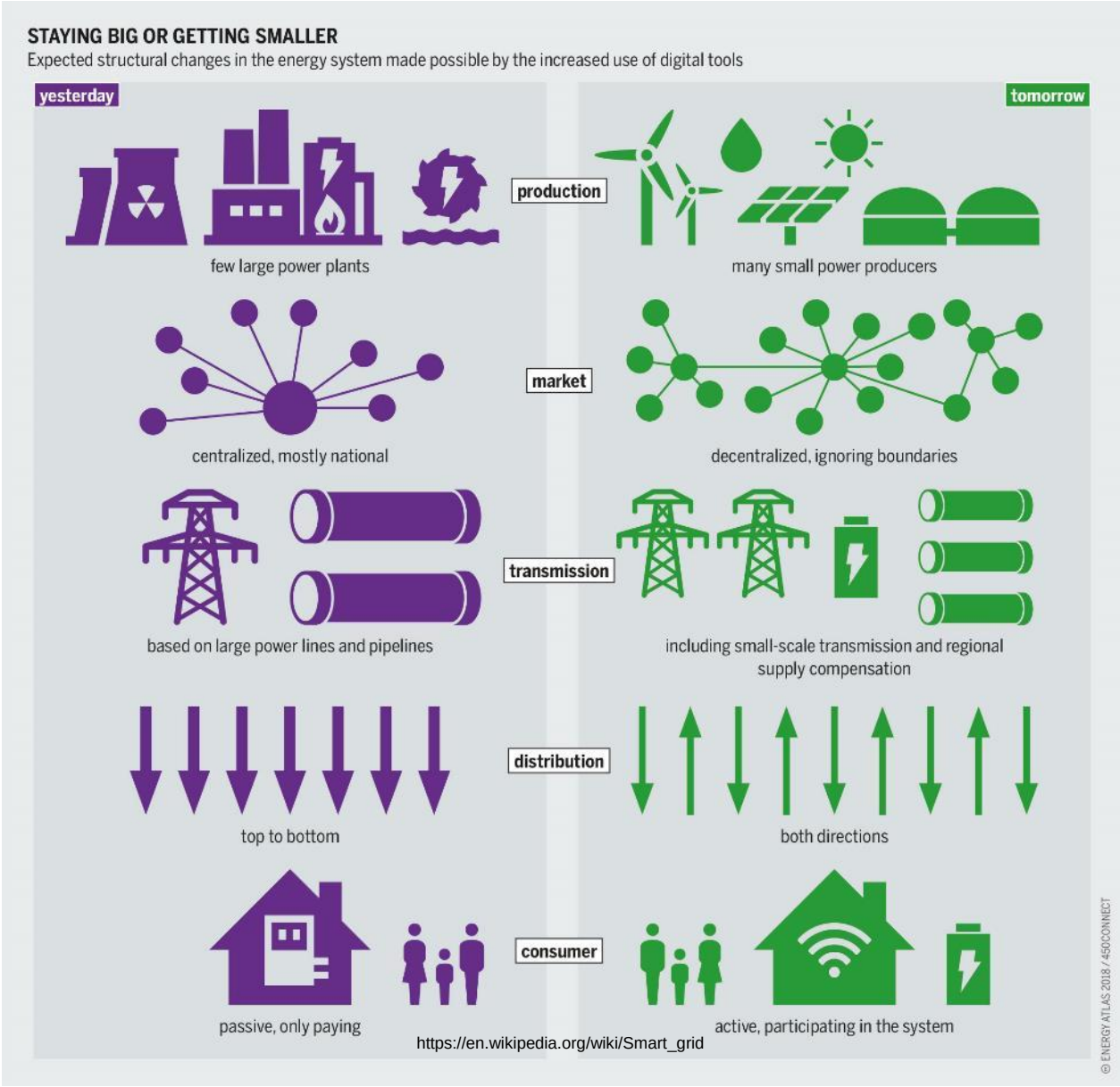


Desire to make the grid smarter, safer, reliable and more cost-effective using advanced sensors, communication technologies and distributed computing.

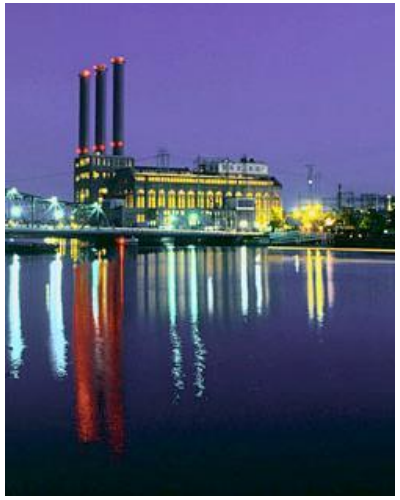
Difference Between a Normal Grid And a Smart Grid

Normal Phone

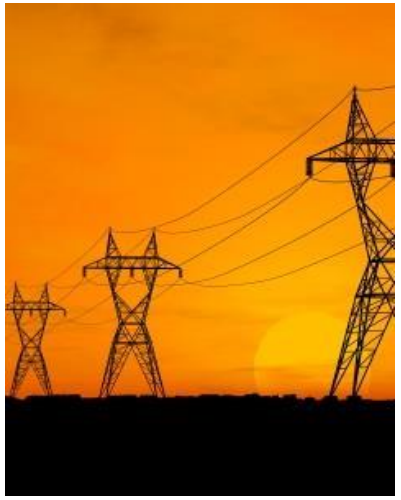
Smart Phone



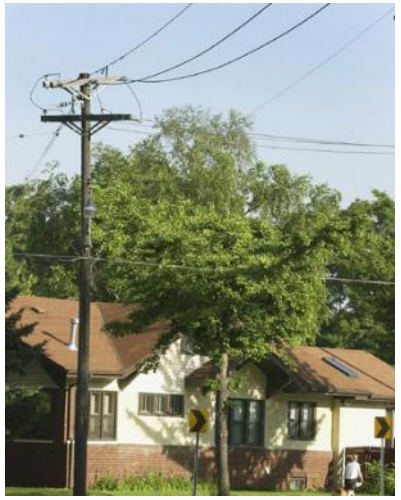
Starting and End Points of a Smart Grid



Power Plant



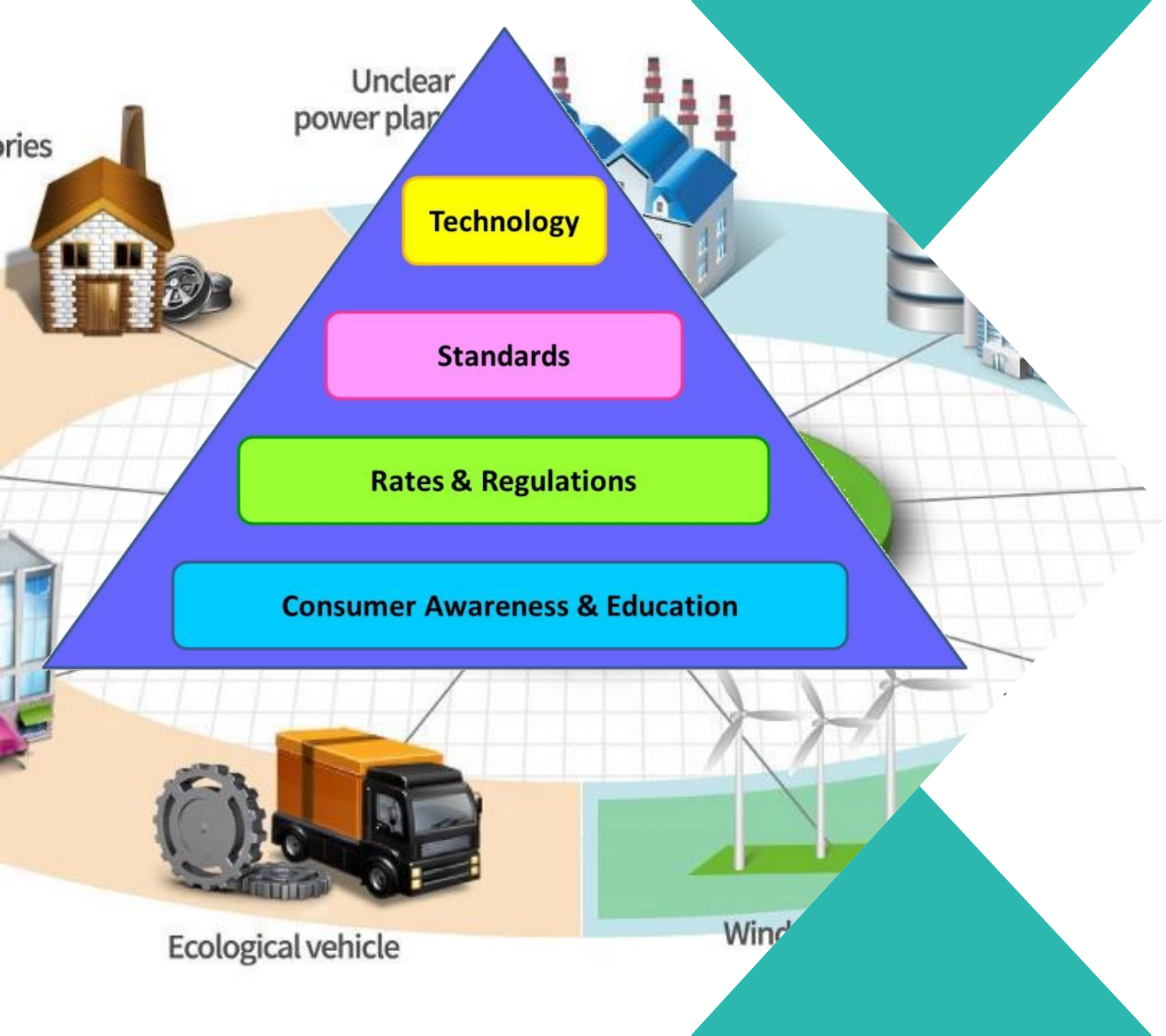
Transmission



Distribution

Home Business

End-use Appliances



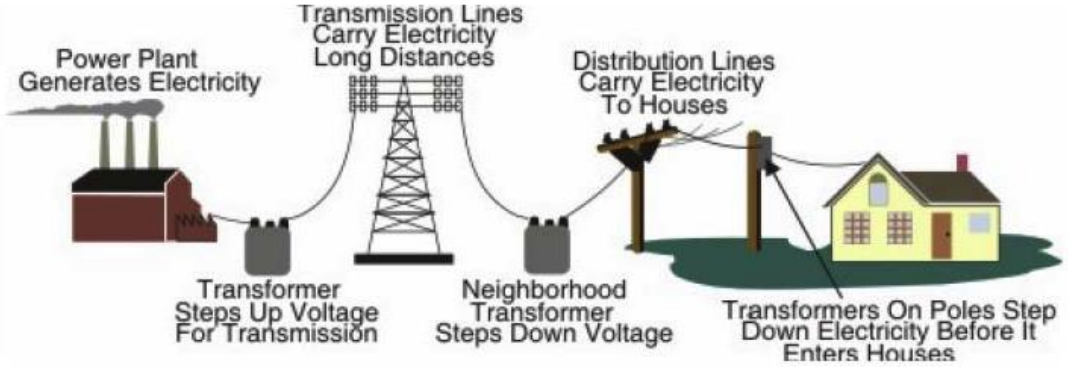
Smart Grid Building Blocks

Evolution of the Grid

Smart Grid

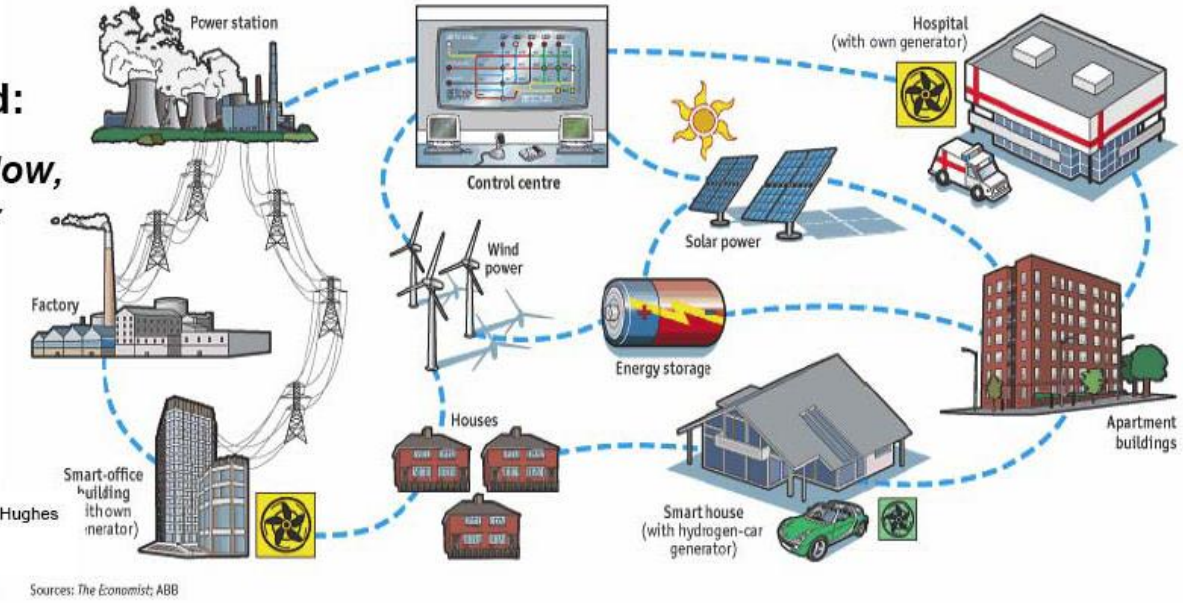
Before **Smart Grid:**

One-way power flow, simple interactions



After **Smart Grid:**

Two-way power flow, multi-stakeholder interactions

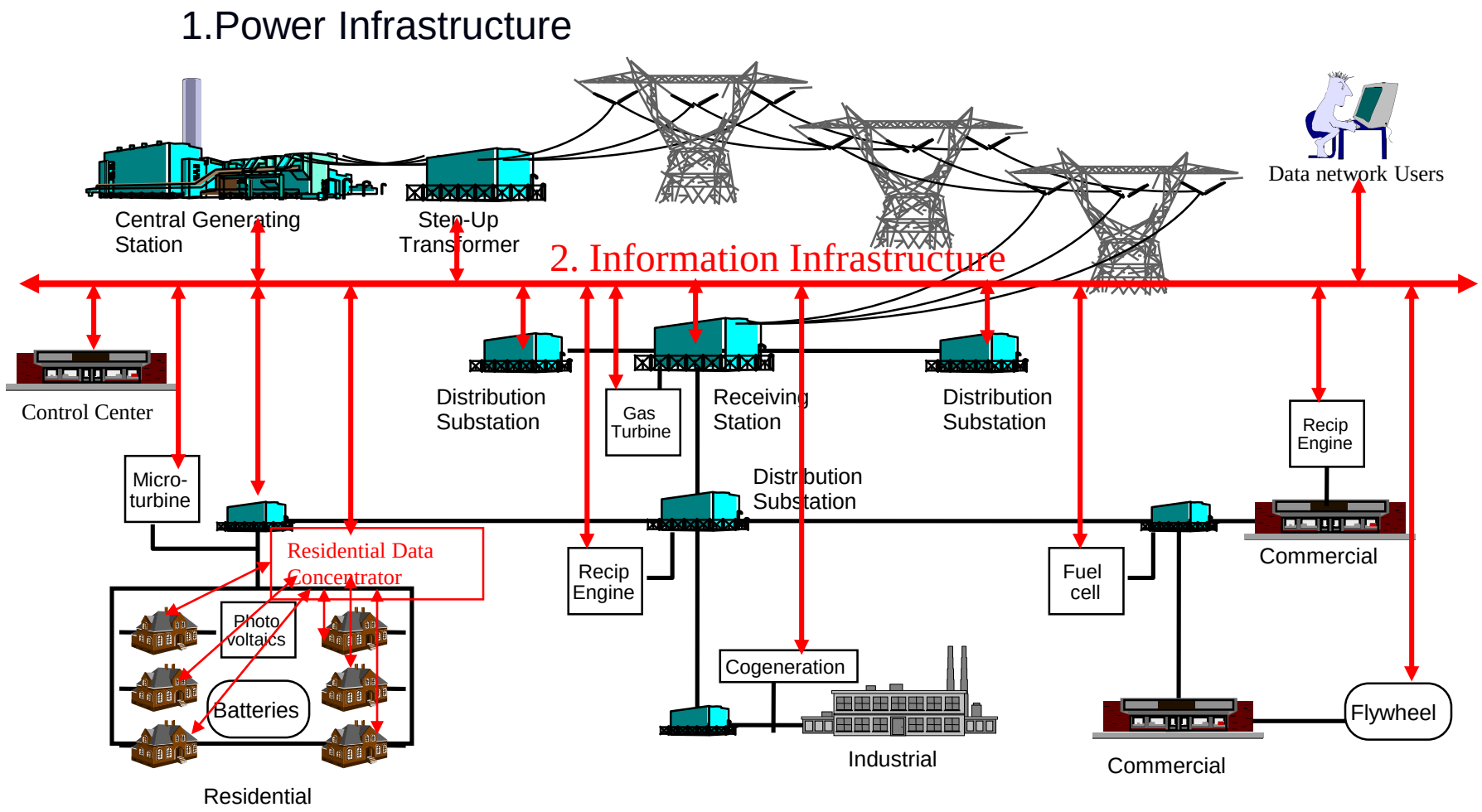


Adapted from EPRI Presentation by Joe Hughes
NIST Standards Workshop
April 28, 2008

Source: Altalink, Alberta, Canada

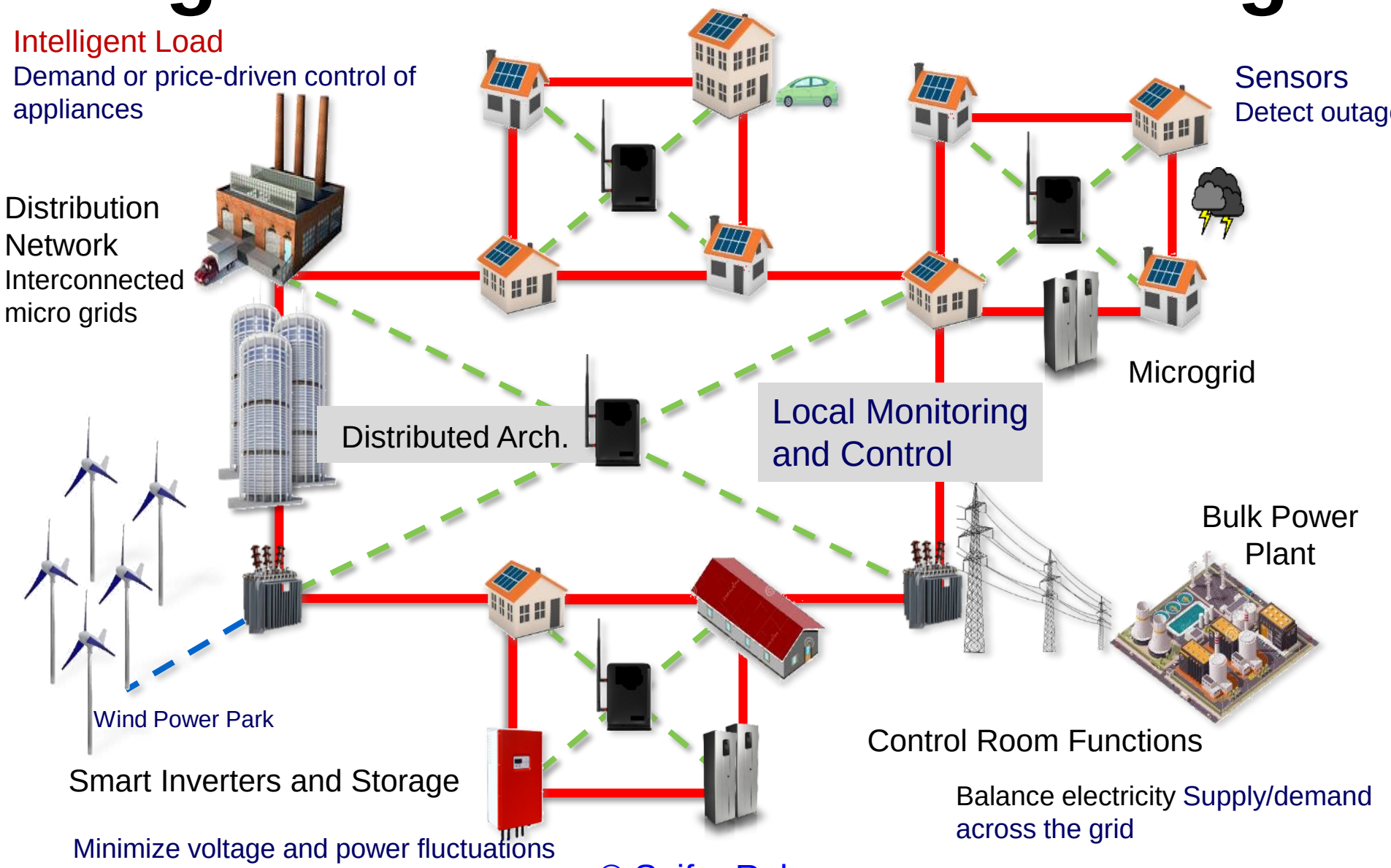

Merging Power Flow with Information Flow:
Integrated Communications

Electric Power & Communication Infrastructures



Source: EPRI

Intelligent Interconnected Microgrids

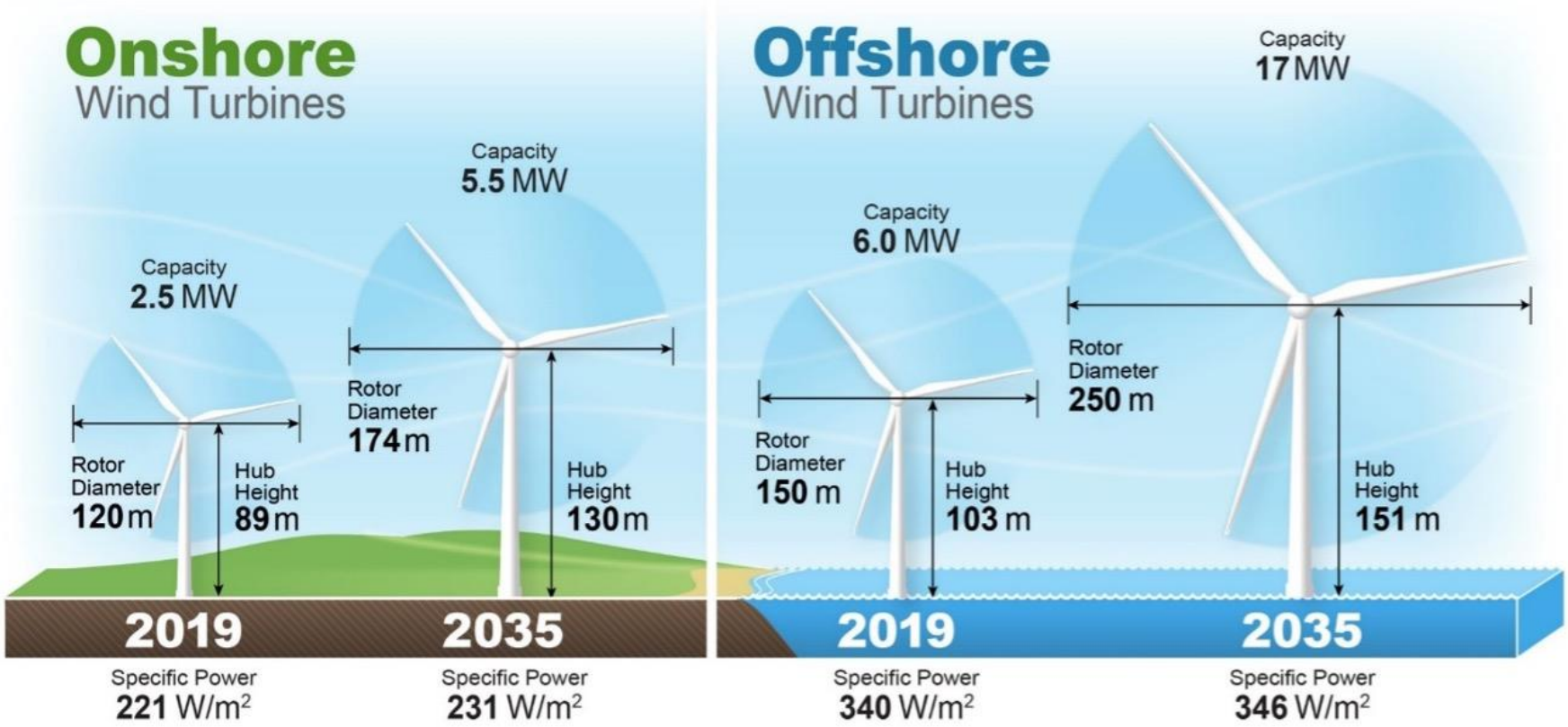


Changing Landscape for the Electric Utility

Issues with Distributed Generation

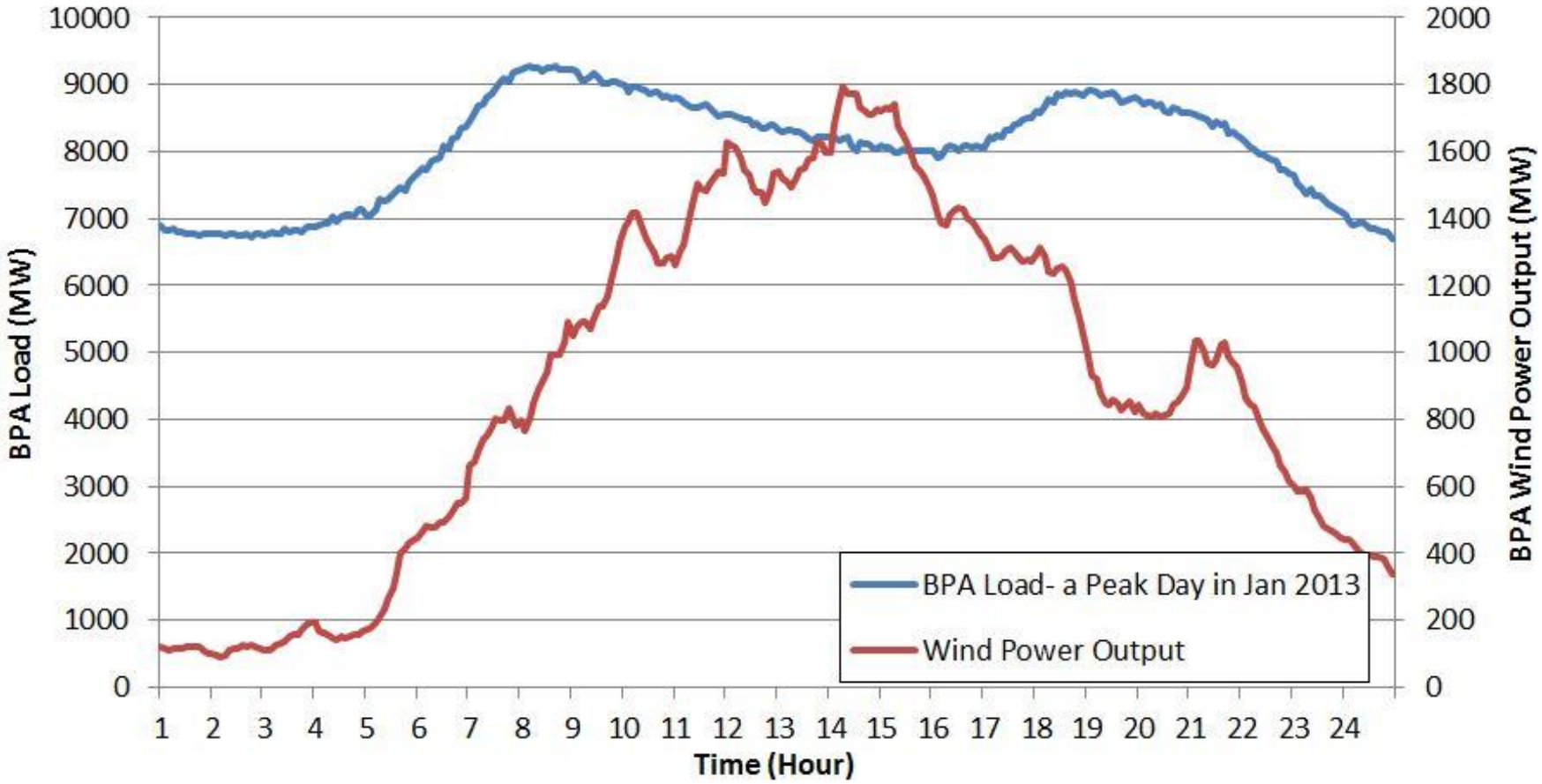
- Wind and solar are intermittent
- Hydro is space limited
- Resource is free but not always usable

Wind Energy

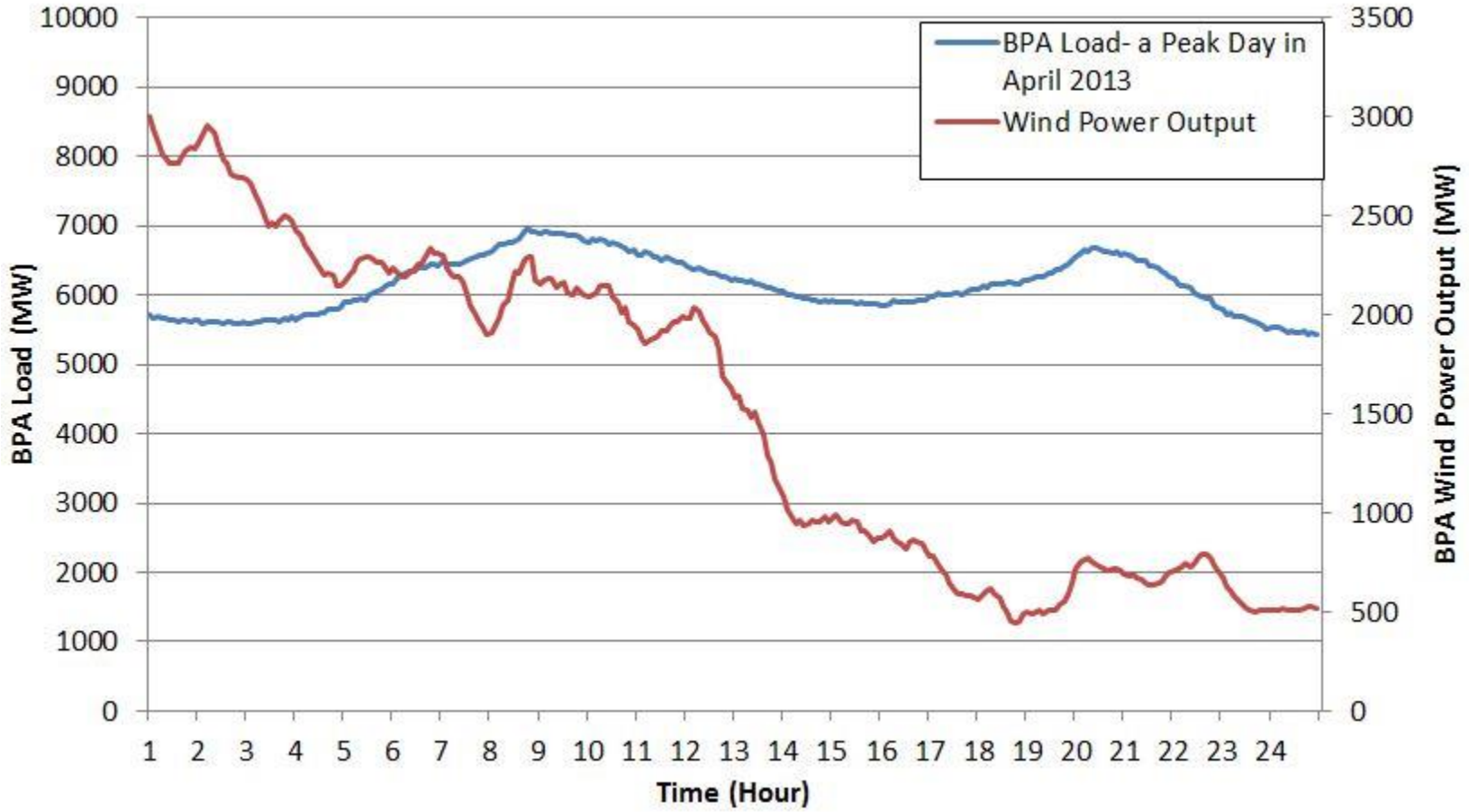


https://www.renewableenergyworld.com/wind-power/wind-power-experts-expect-wind-energy-costs-to-decline-up-to-35-by-2035/#gref

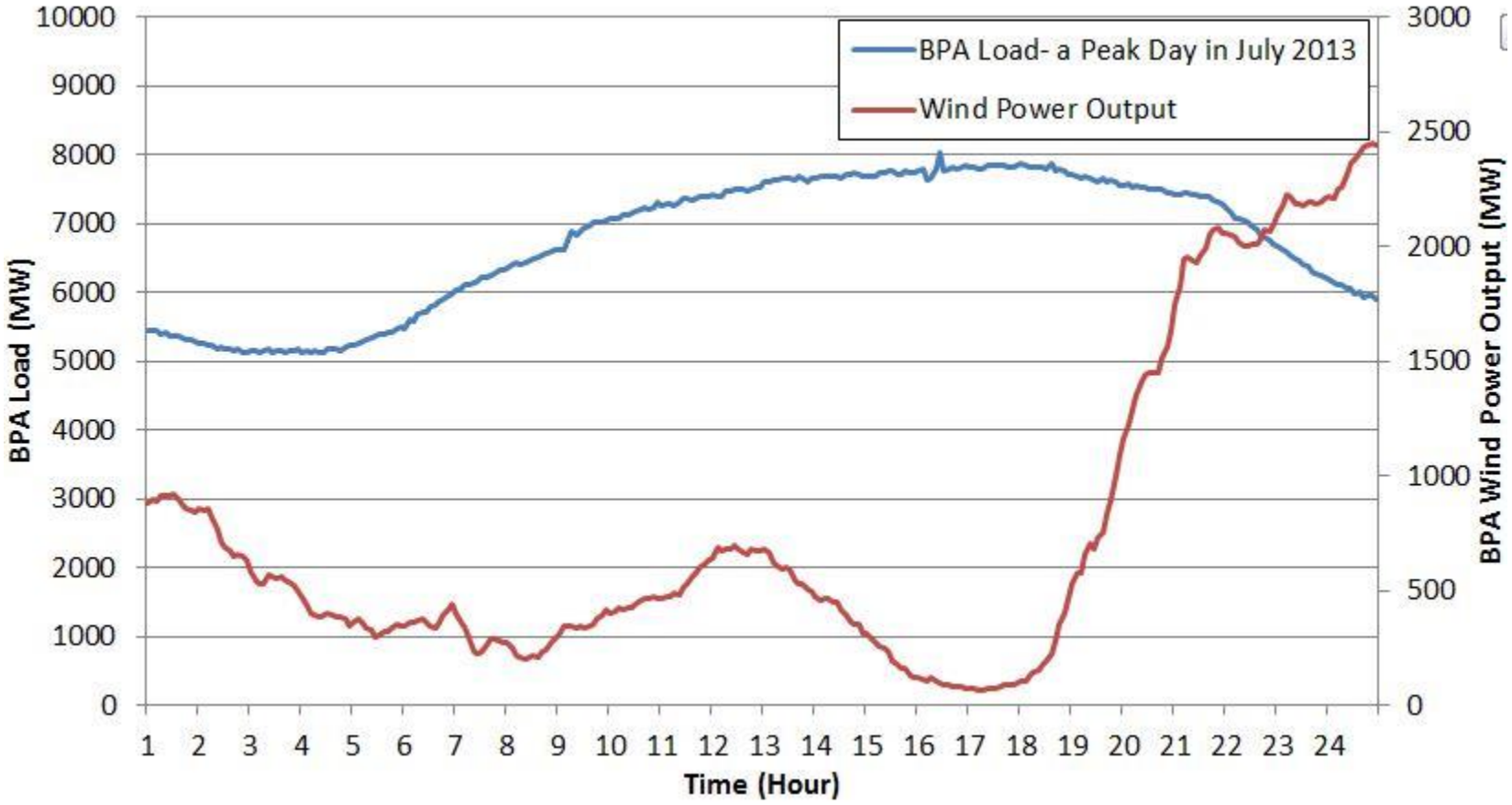
BPA Wind Output and Load Mismatch (A typical day in January)



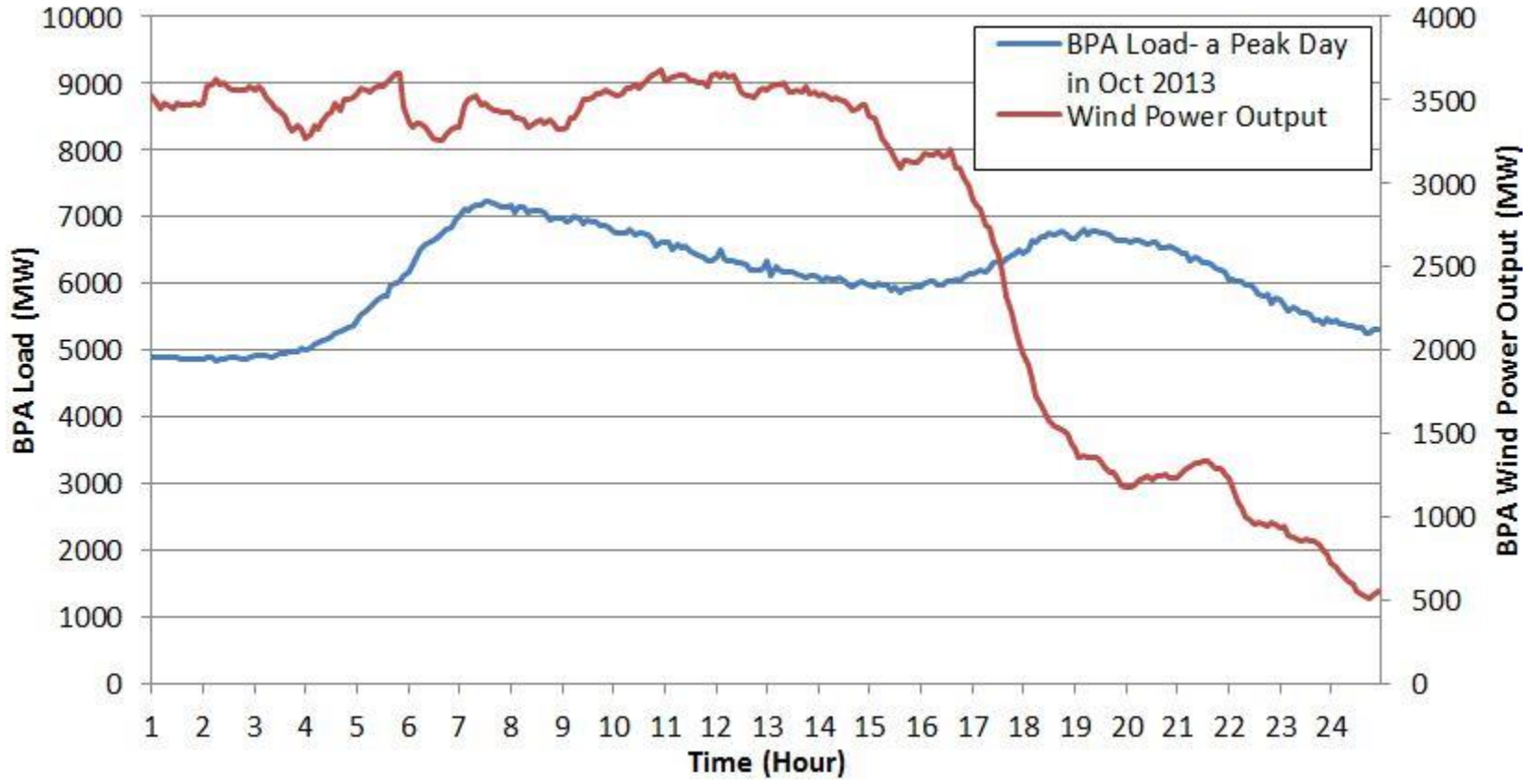
BPA Wind Output and Load Mismatch (A typical day in April)



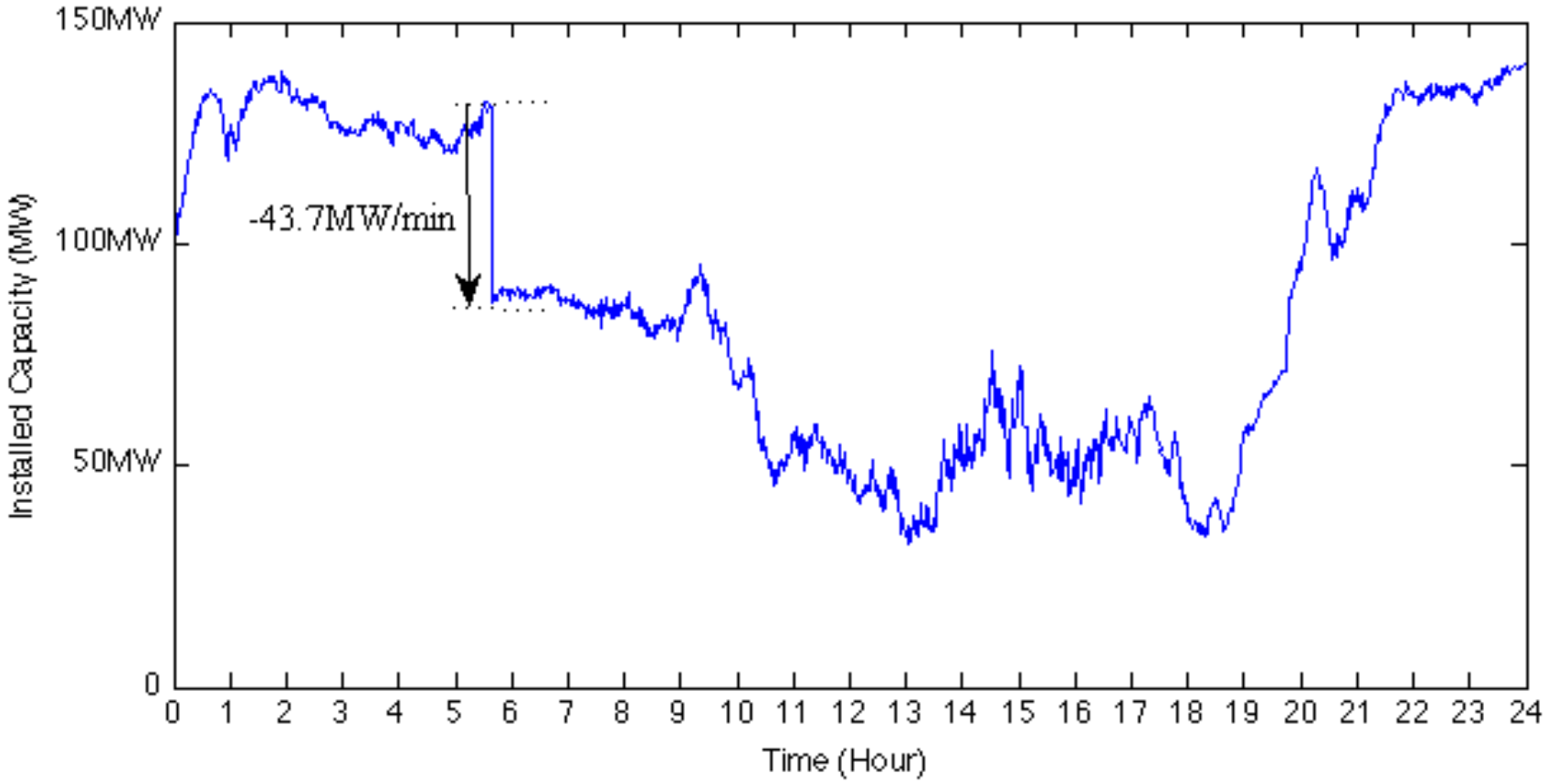
BPA Wind Output and Load Mismatch (A typical day in July)



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



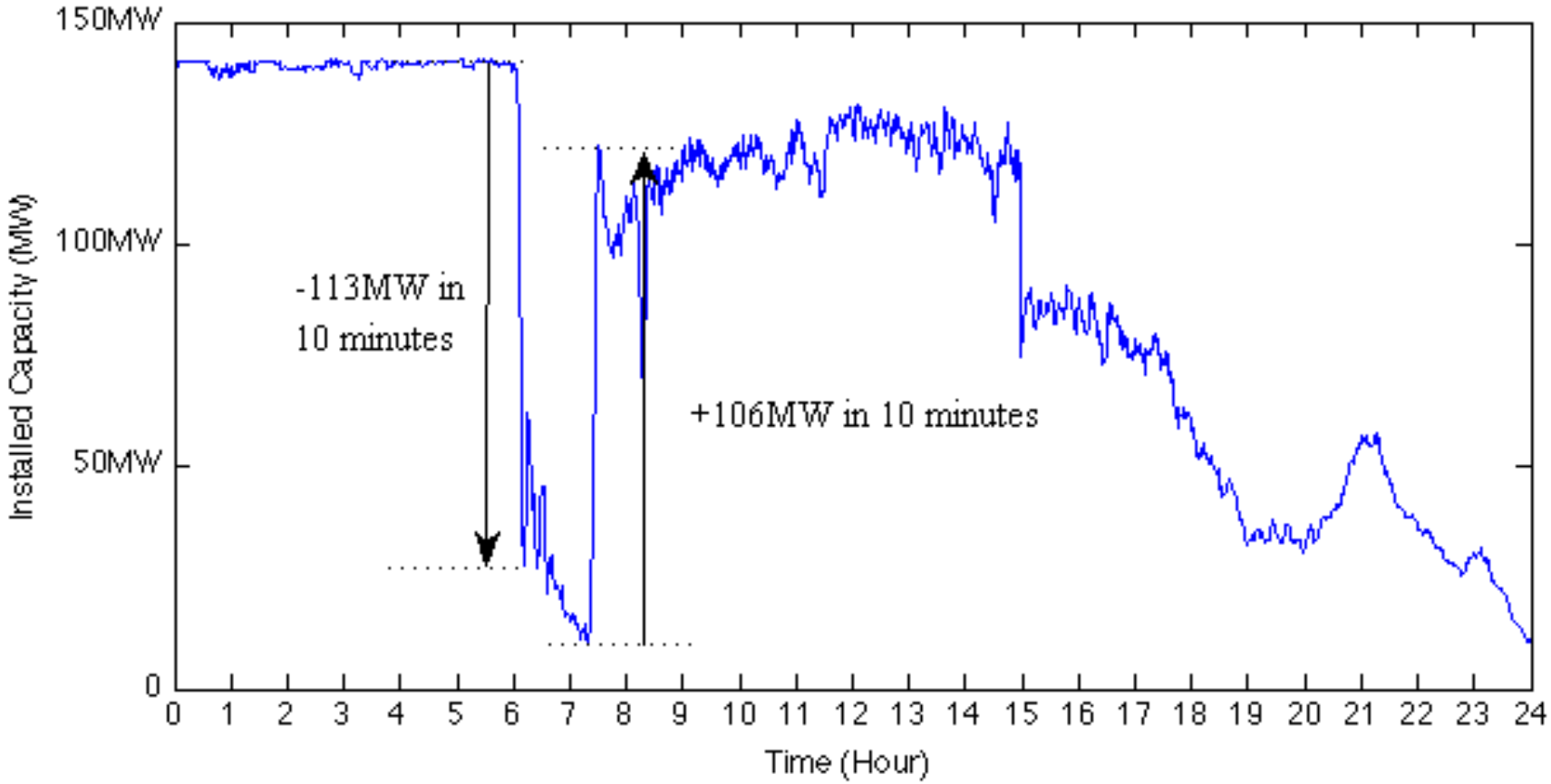
1-minute Variation of a 150MW Wind Farm Output in Texas



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

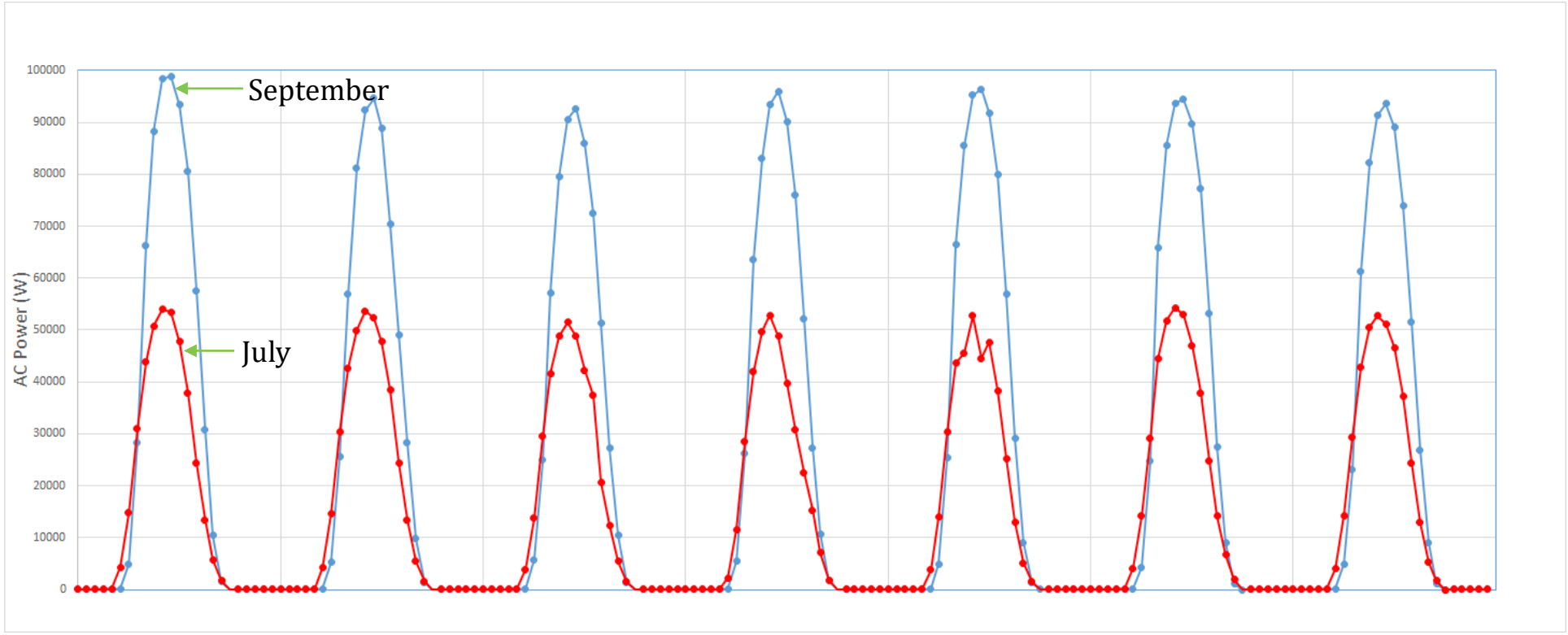
In-depth look at Solar PV in Saudi Arabia

2-MW Roof-top Solar PV plant at KAUST

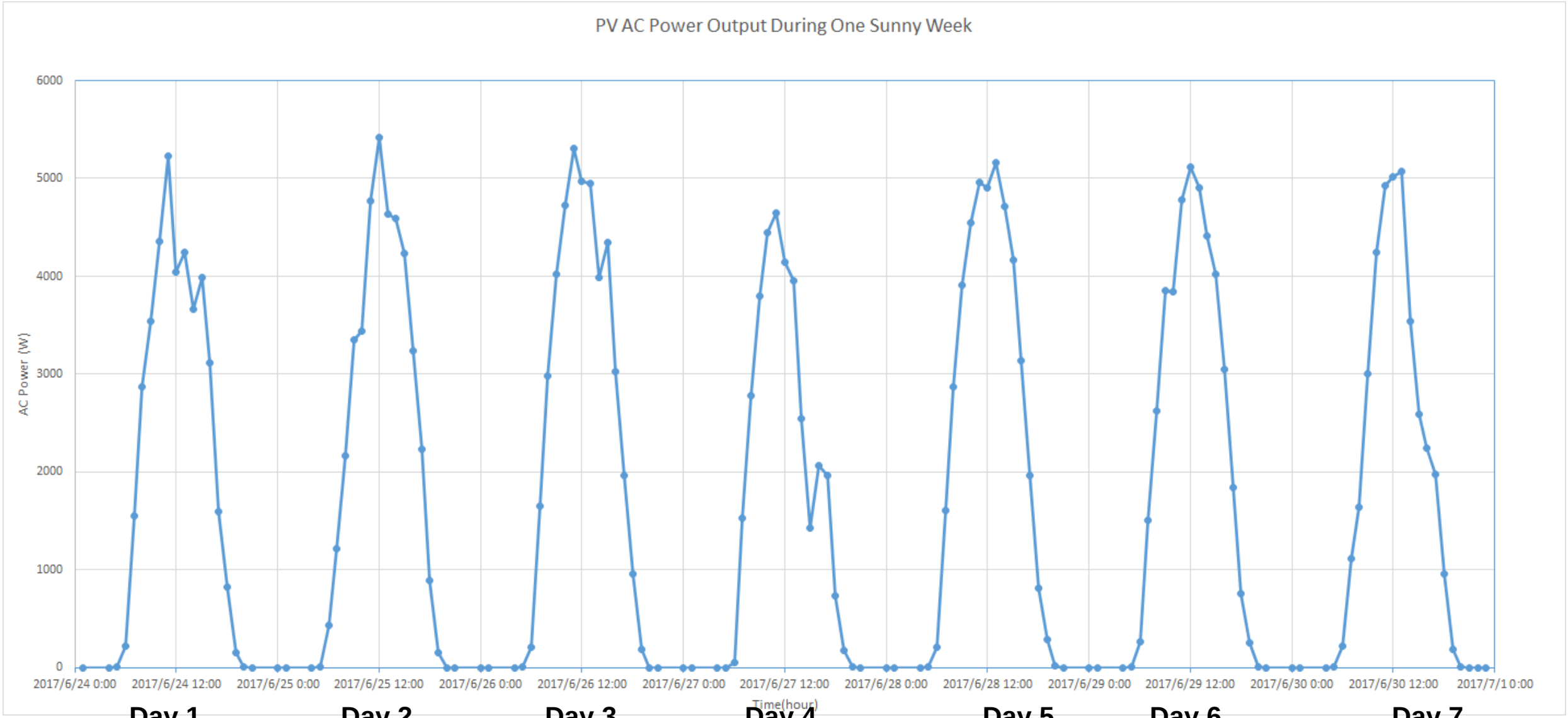
Solar PV Panels in Saudi Arabia

Reality Check

Solar PV Array (100kWp) Riyadh Area

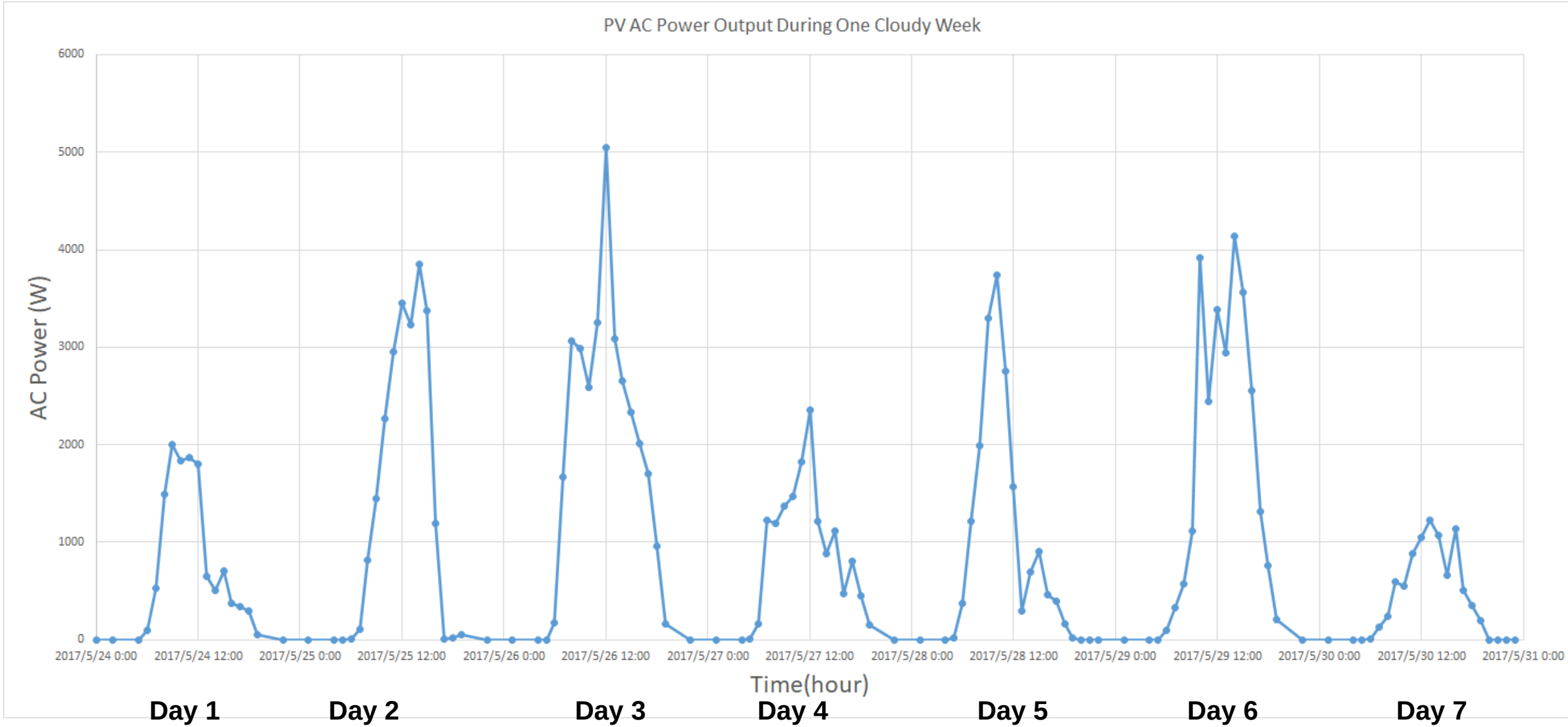


7-Day Solar PV Output (Virginia)

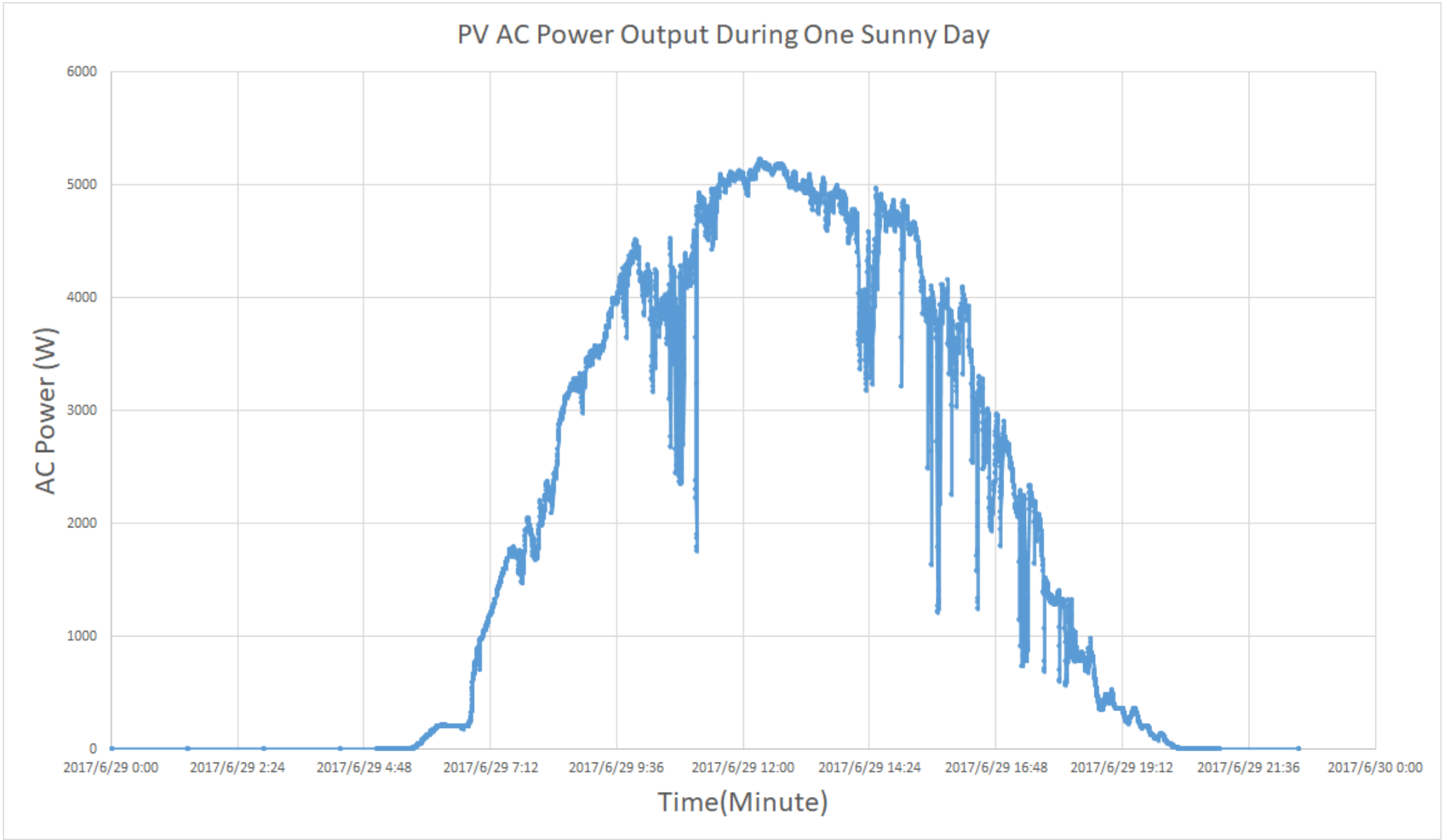


Day 1 **Day 2** **Day 3** **Day 4** **Day 5** **Day 6** **Day 7**

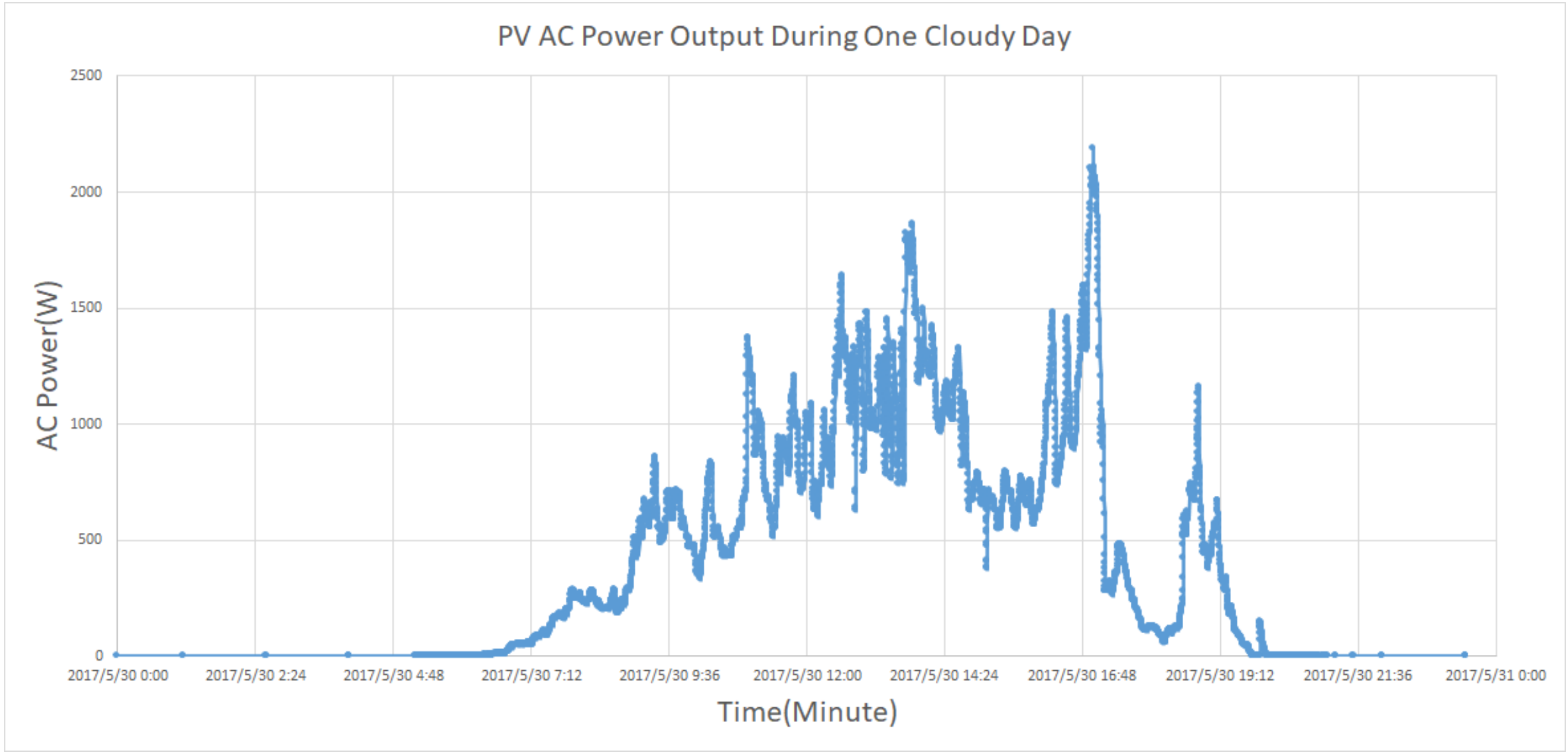
7-Day Solar PV Output (Virginia cloudy)



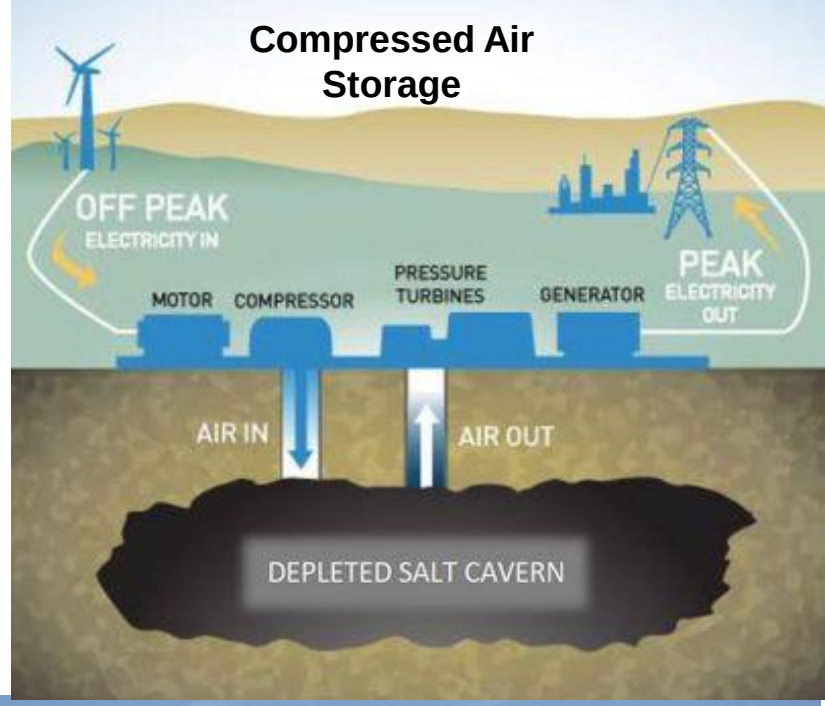
Daily PV Output (Virginia)



Daily PV Output (Virginia, intermittent)



Can the Intermittency be Absorbed by the Network?



New Paradigm for the Electric Power System

Historically: Demand driven supply (supply responds to demand)

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

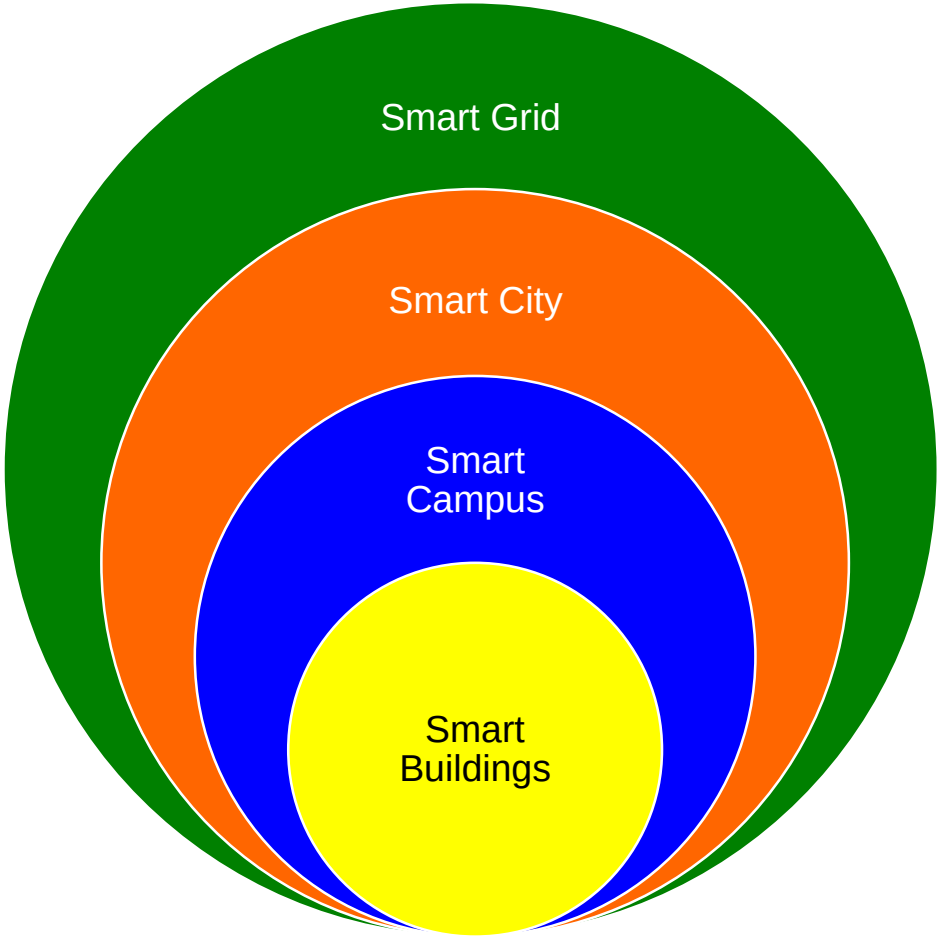
Smart grid: Bi-directional flows of energy, remote control/automation of power, integrated distributed energy…

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

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