

# Role of the Smart Grid in Facilitating the Integration of Renewables

Invited Speech

University of Technology and Applied Sciences OMAN

Webinar

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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



Source: [www.sxc.hu](http://www.sxc.hu)





# 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.

# Difference Between a Normal Grid And a Smart Grid



Normal Phone



Smart Phone

# Starting and End Points of a Smart Grid

**From Generator to Refrigerator**



Power Plant



Transmission



Distribution



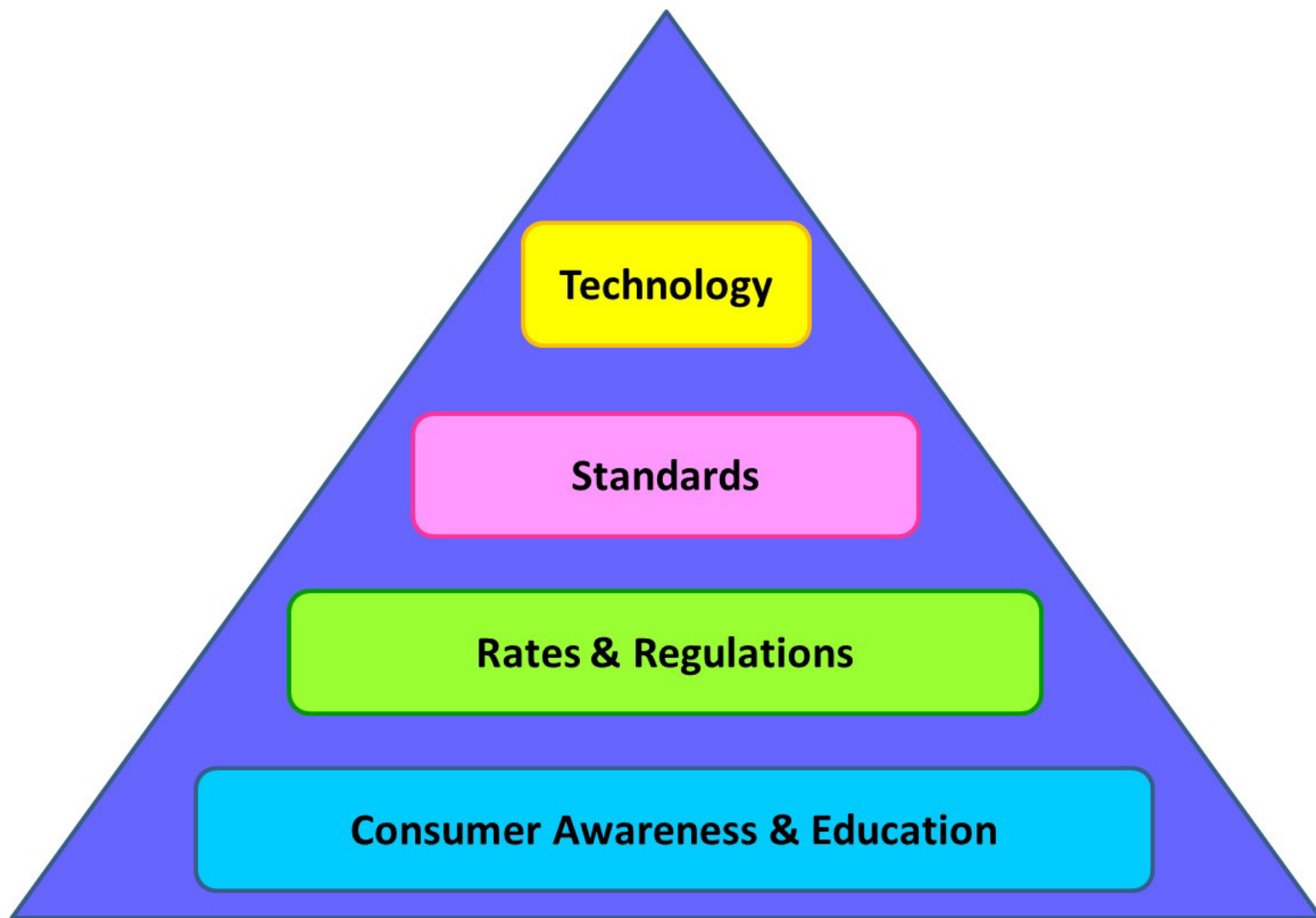
Home  
Business



End-use  
Appliances



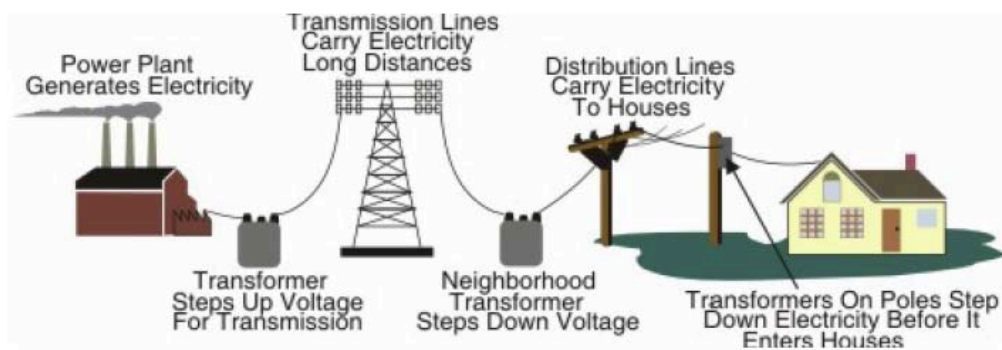
# Smart Grid Building Blocks



# Evolution of the Grid

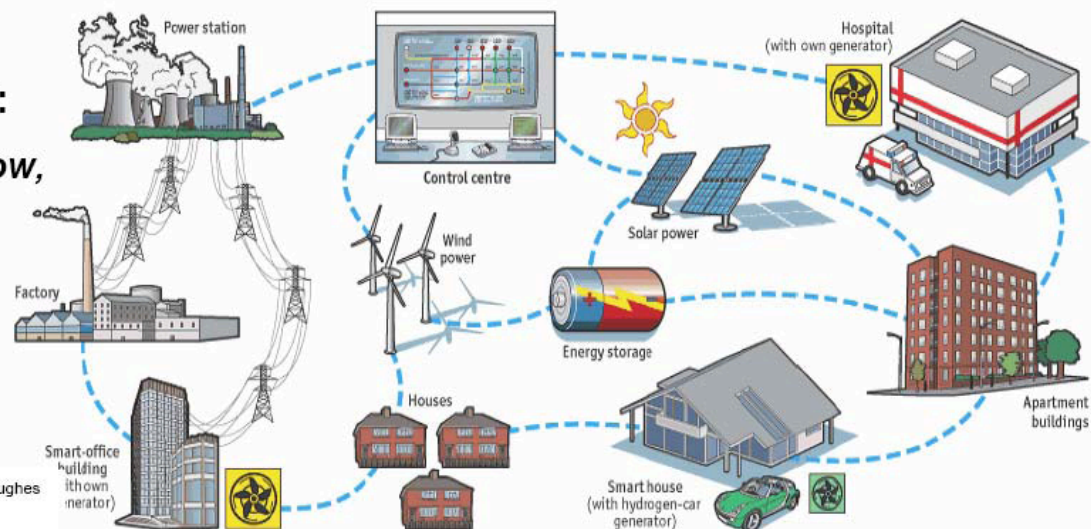
## **Before** Smart Grid:

*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



# Intelligent Interconnected Microgrids

## Intelligent Load

Demand or price-driven control of appliances

## Distribution Network

Interconnected micro grids

## Sensors

Detect outages, fluctuations, and disturbances

## Microgrid

## Local Monitoring and Control

## Distributed Arch.

## Bulk Power Plant

## Wind Power Park

## Smart Inverters and Storage

Minimize voltage and power fluctuations

## Control Room Functions

Balance electricity Supply/demand across the grid

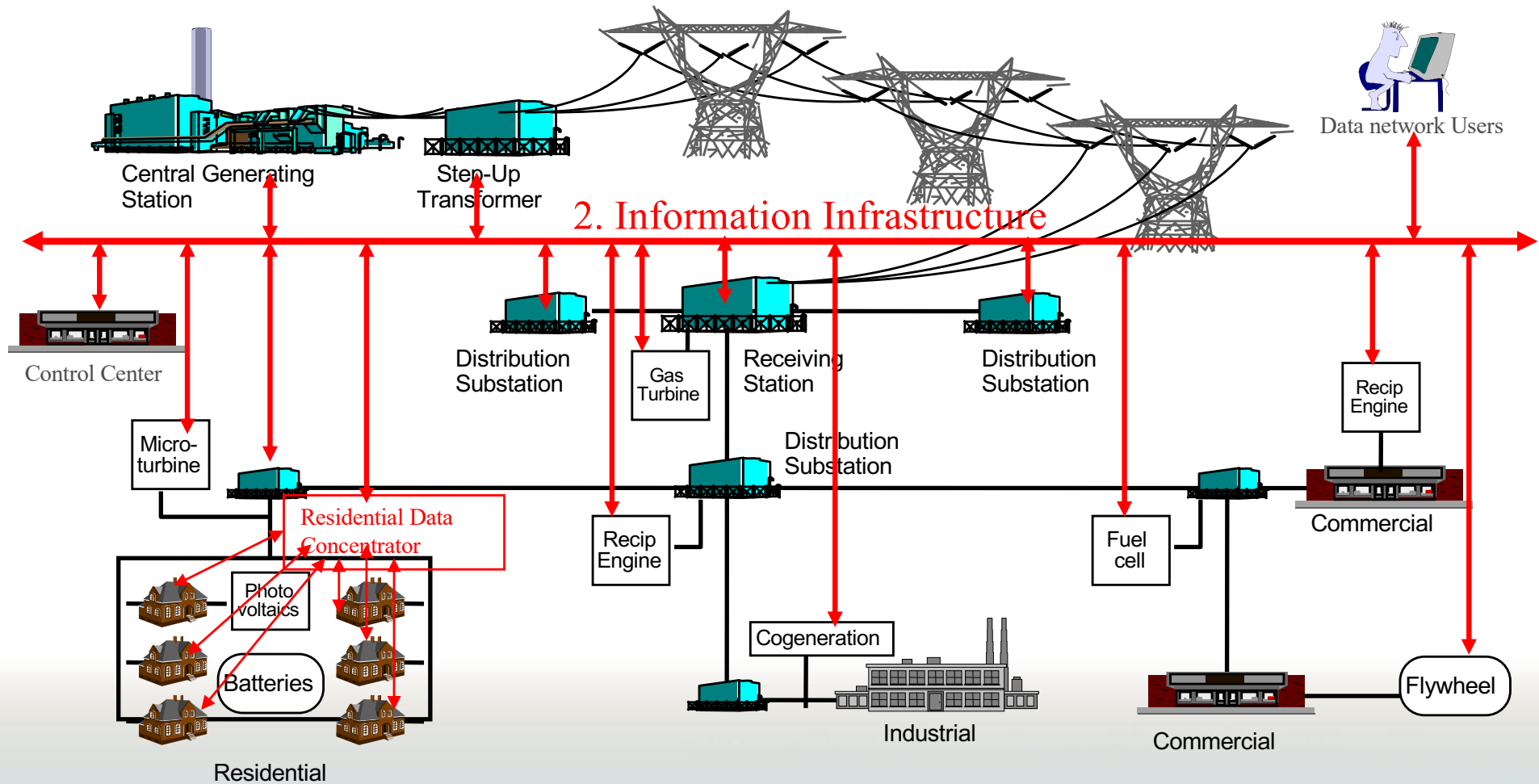


# Merging Power Flow with Information Flow:

## Integrated Communications

# Electric Power & Communication Infrastructures

## 1. Power Infrastructure





# 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

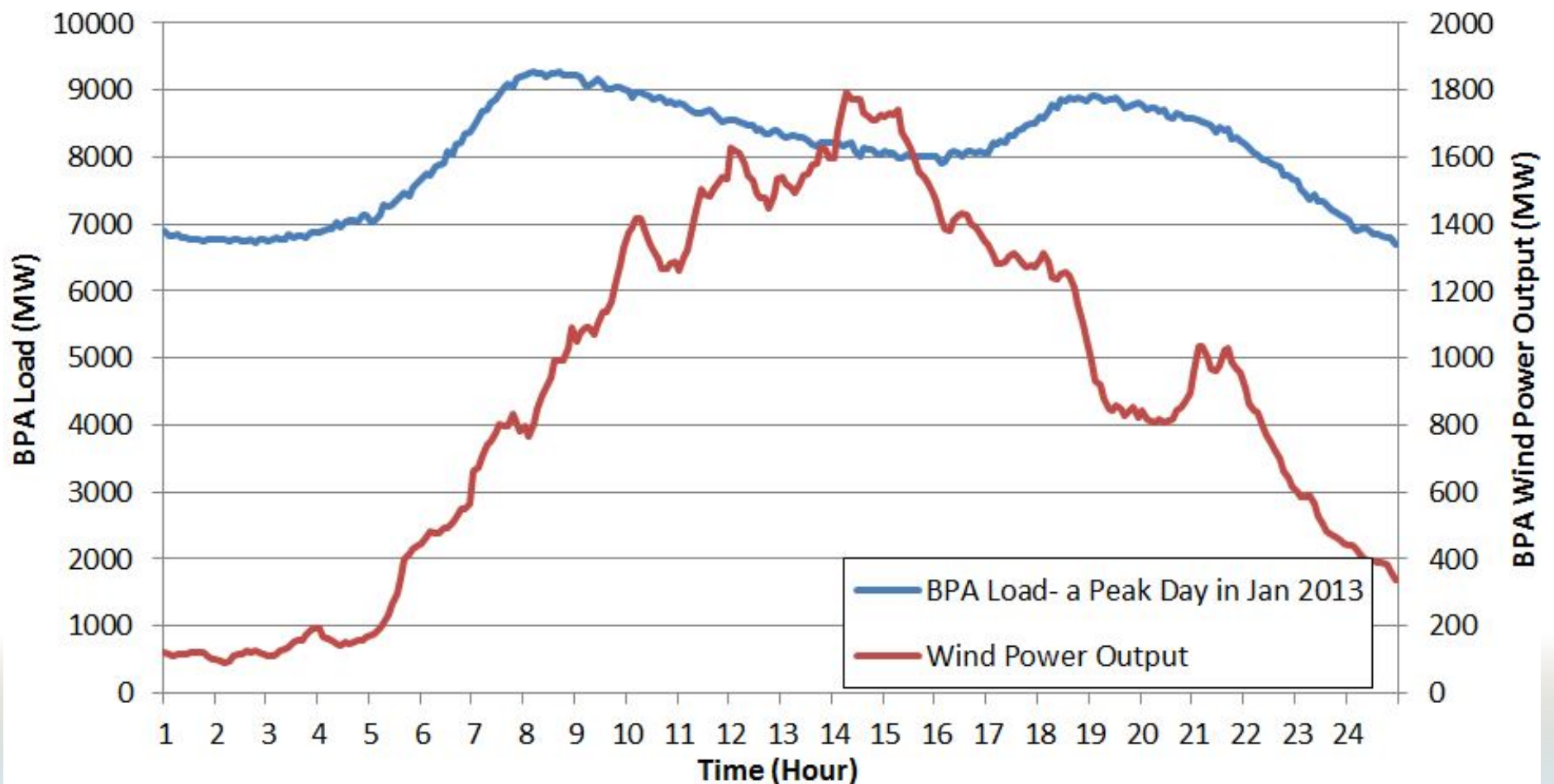


# Wind Energy

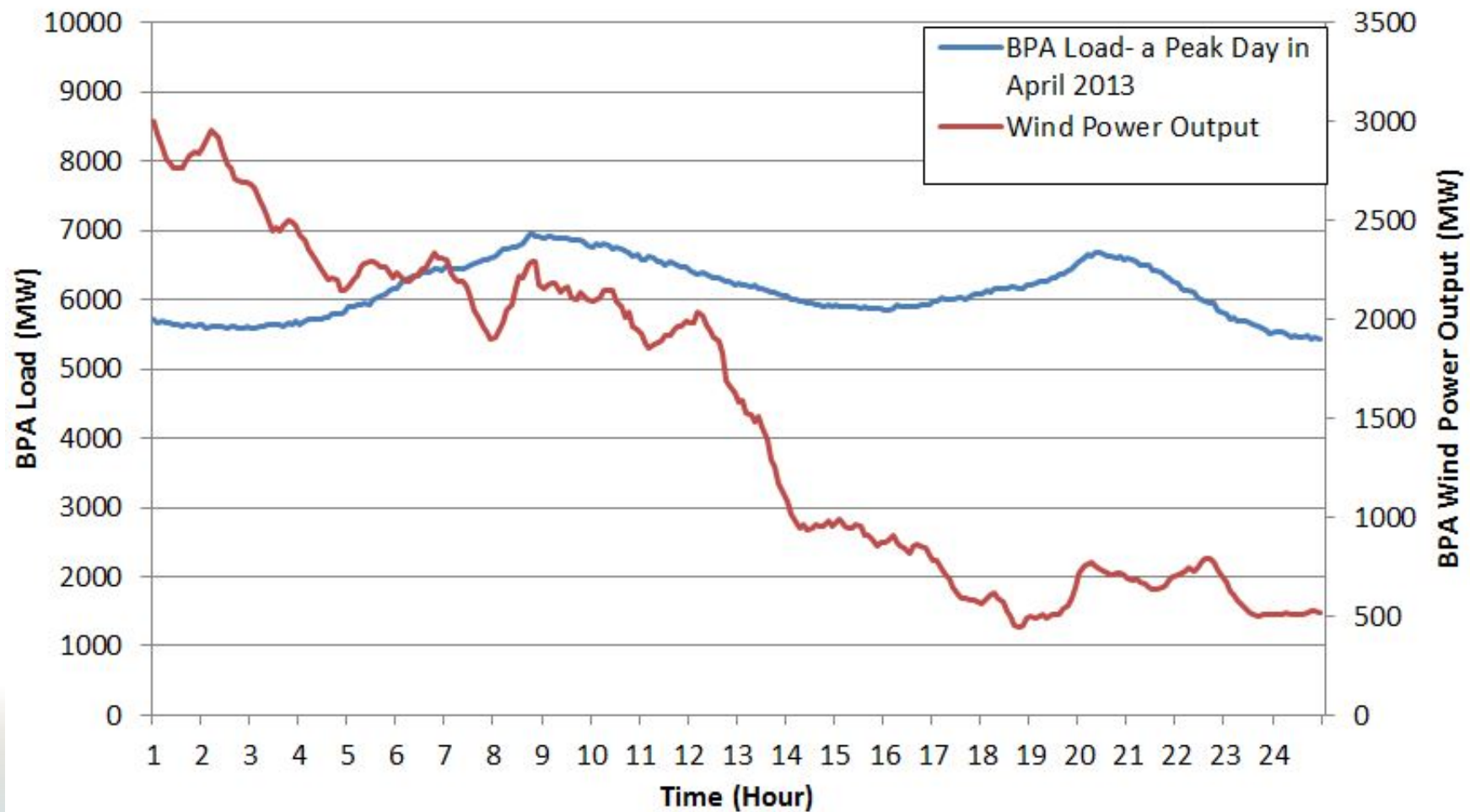
Off-shore Wind turbines, Blyth, U.K.



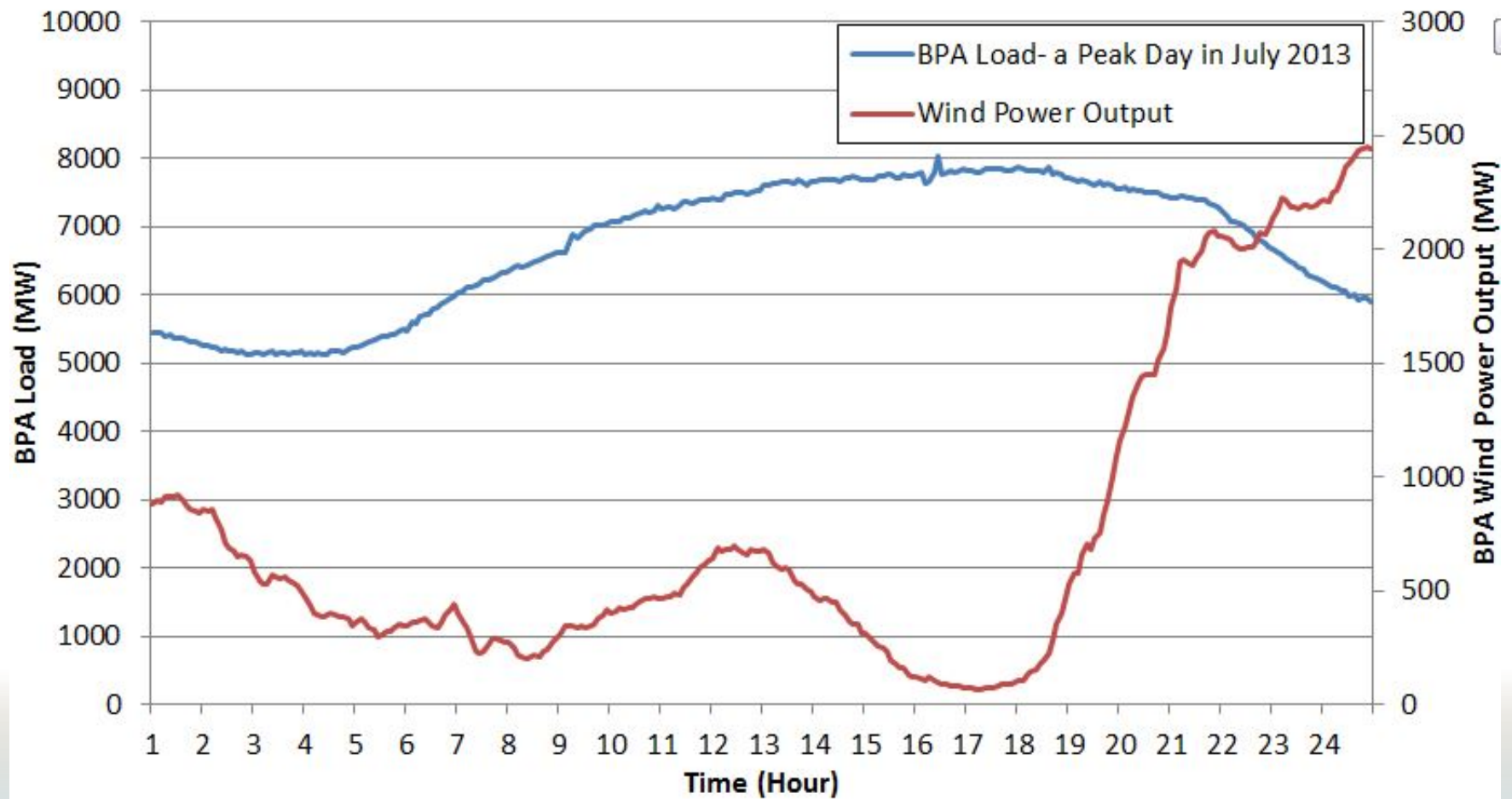
# BPA Wind Output and Load Mismatch (January 2013)



# BPA Wind Output and Load Mismatch (April 2013)

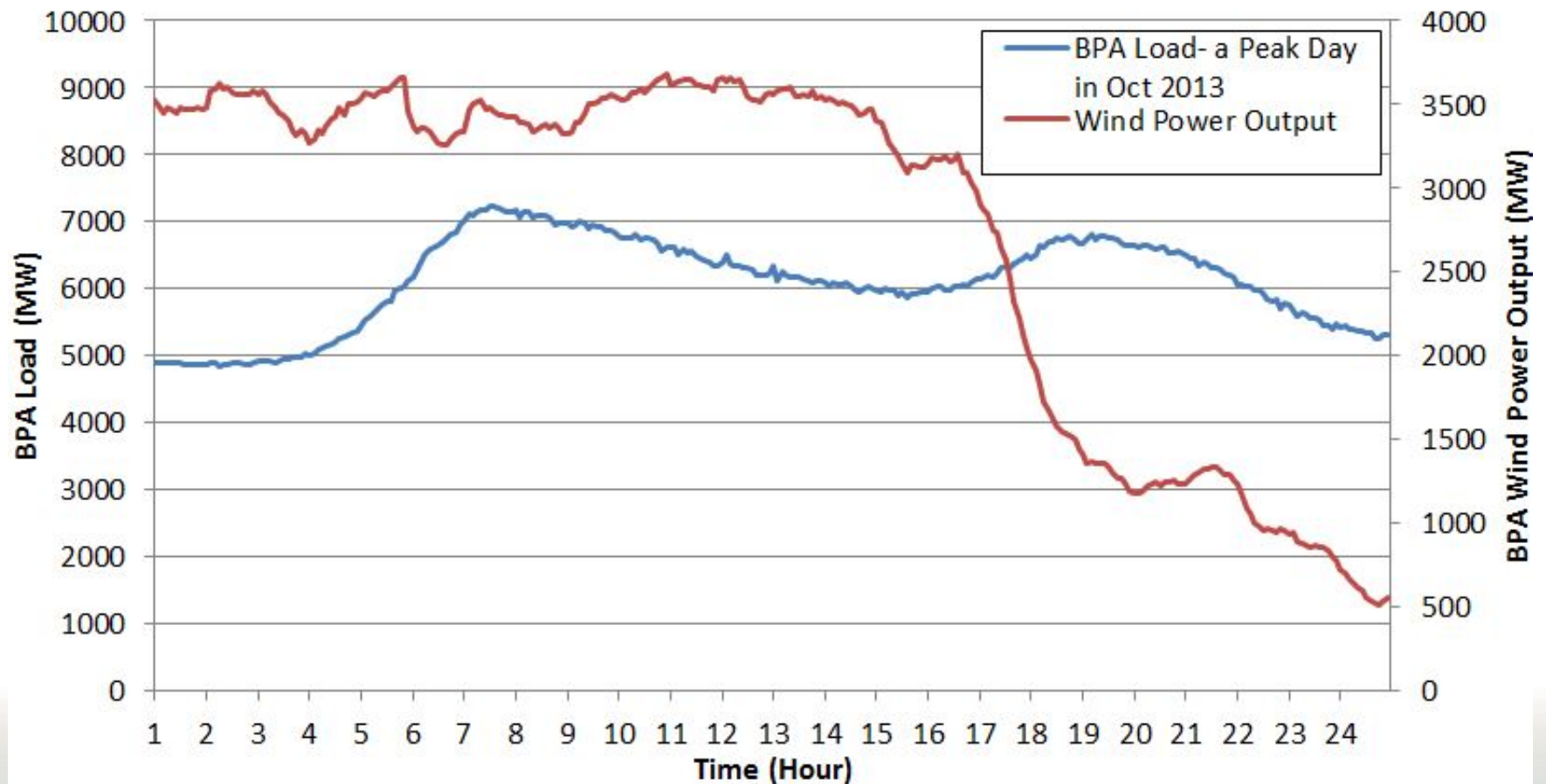


# BPA Wind Output and Load Mismatch (July 2013)

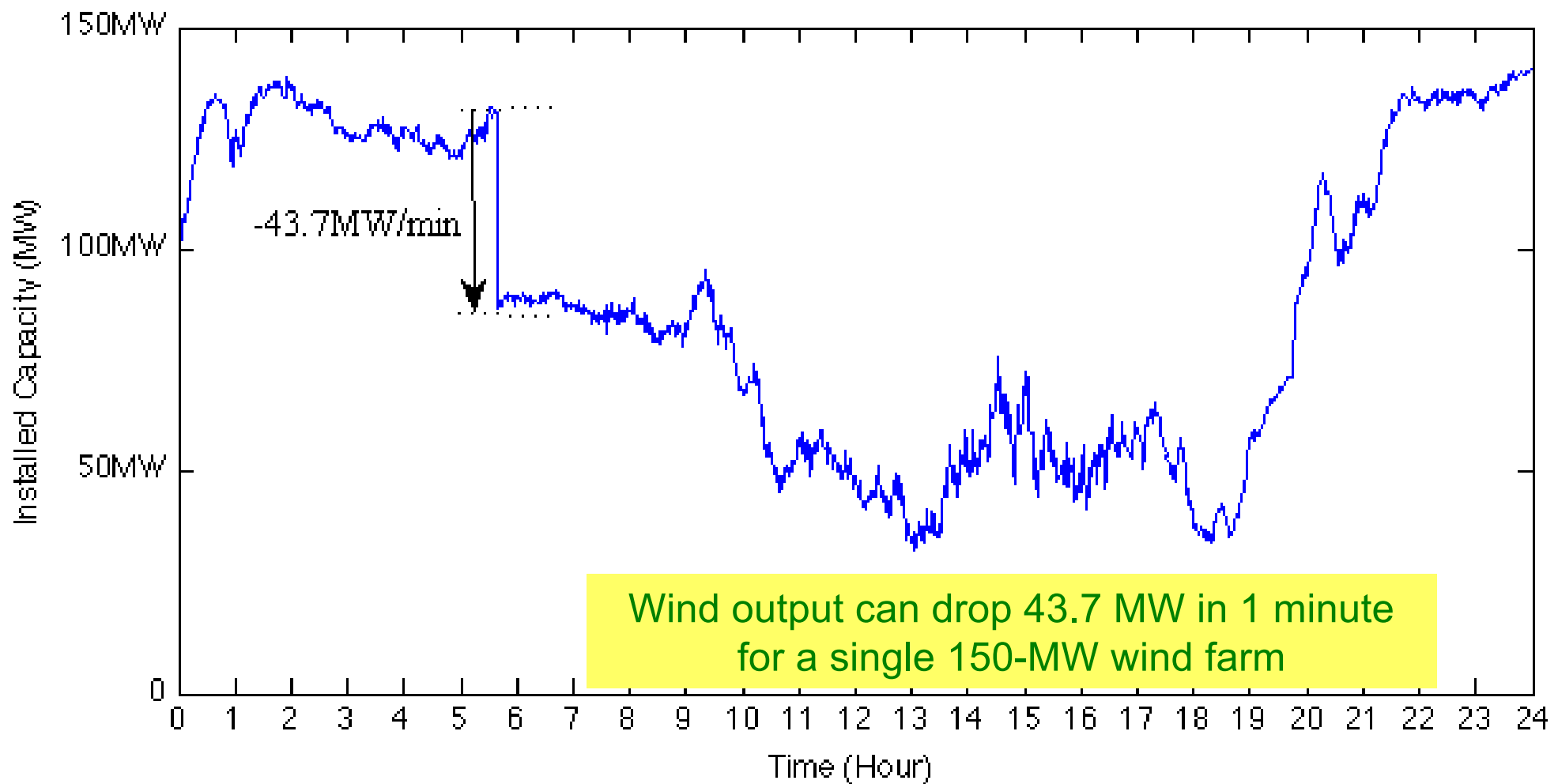




# BPA Wind Output and Load Mismatch (Oct 2013)

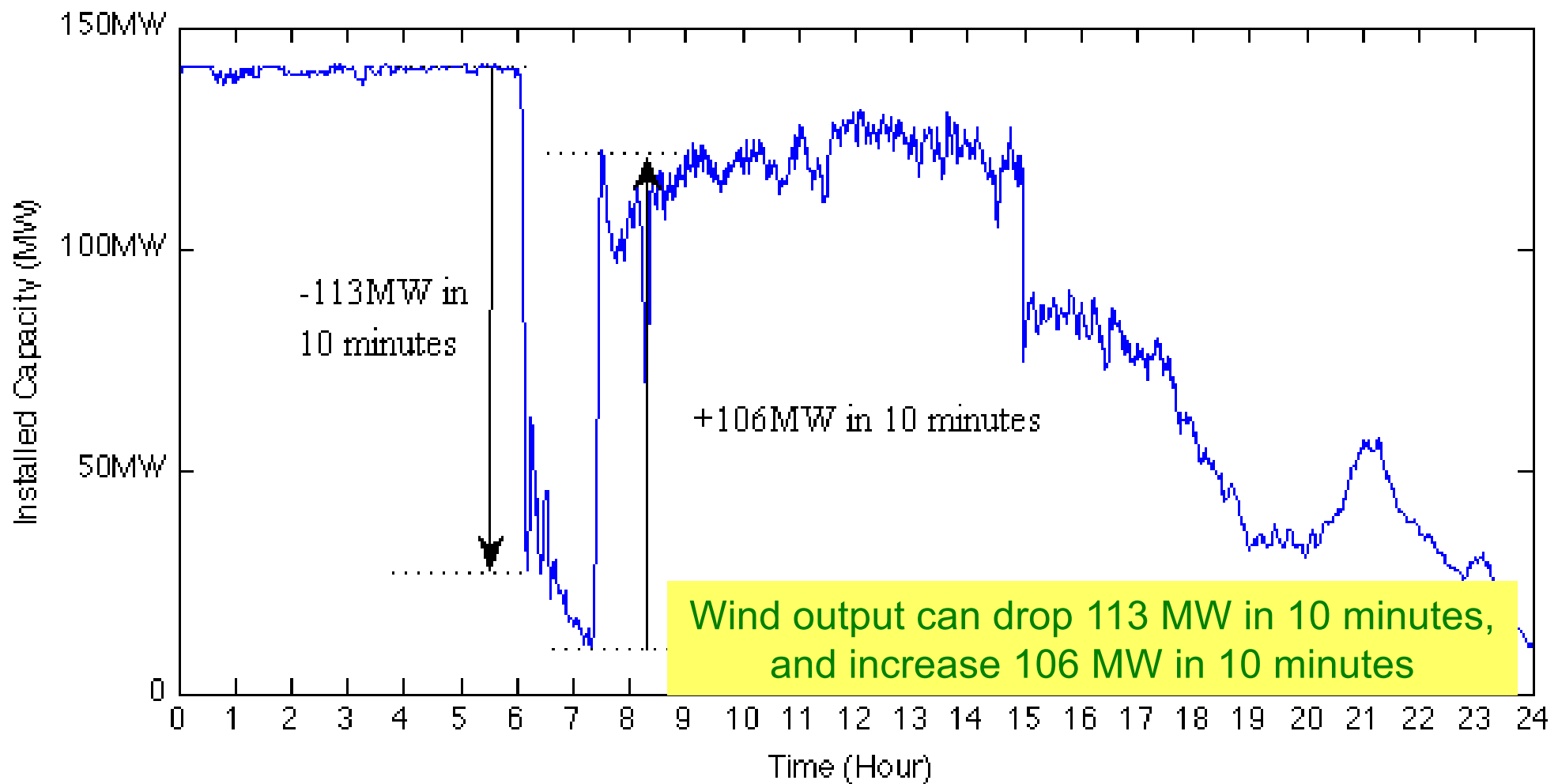


# 1-minute Variation of a 150MW Wind Farm Output in Texas, 2008



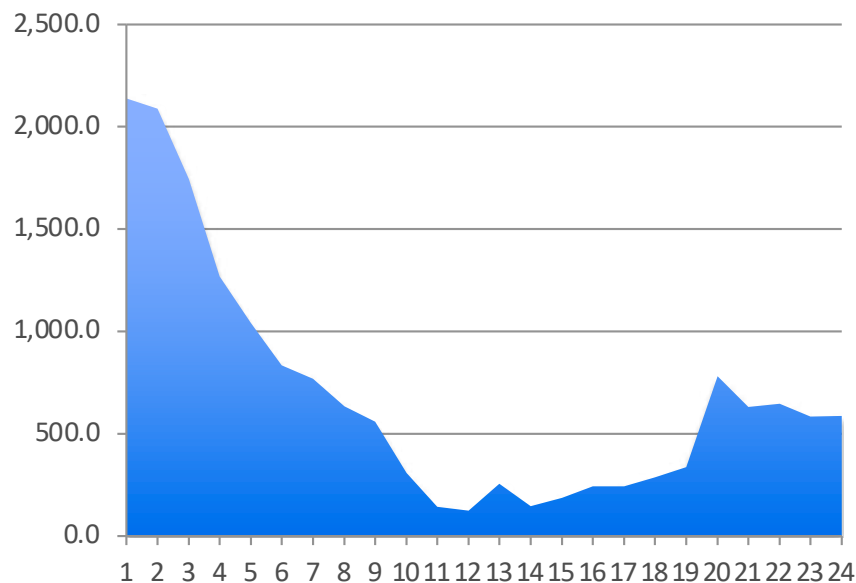
Source: NREL

# 10-min Variation of a 150MW Wind Farm Output in Texas, 2008

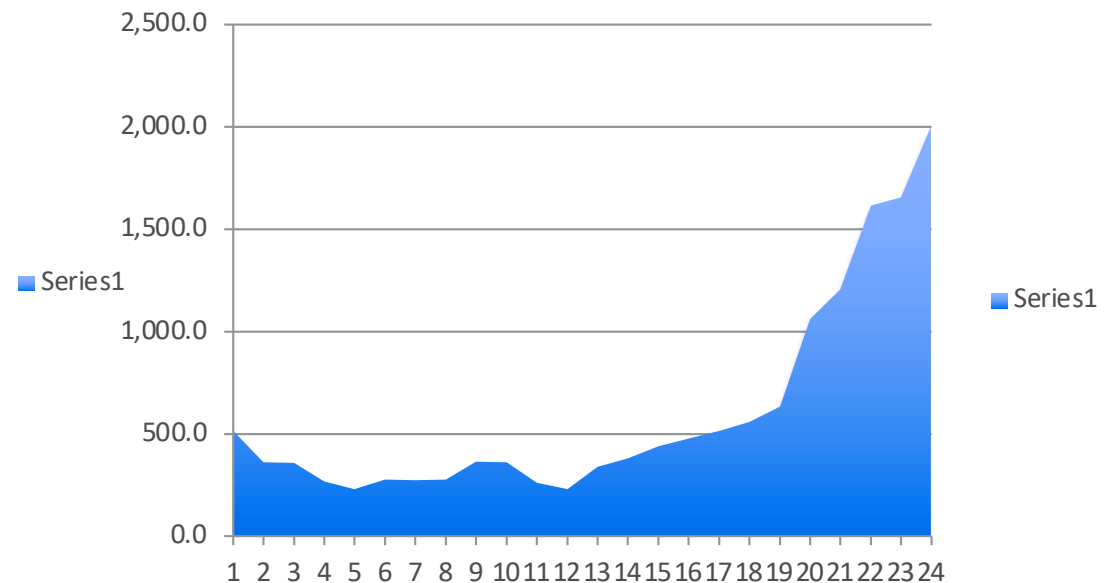




# Hourly wind power variation (MW) in Texas, USA (01 and 02 Jan 2008)



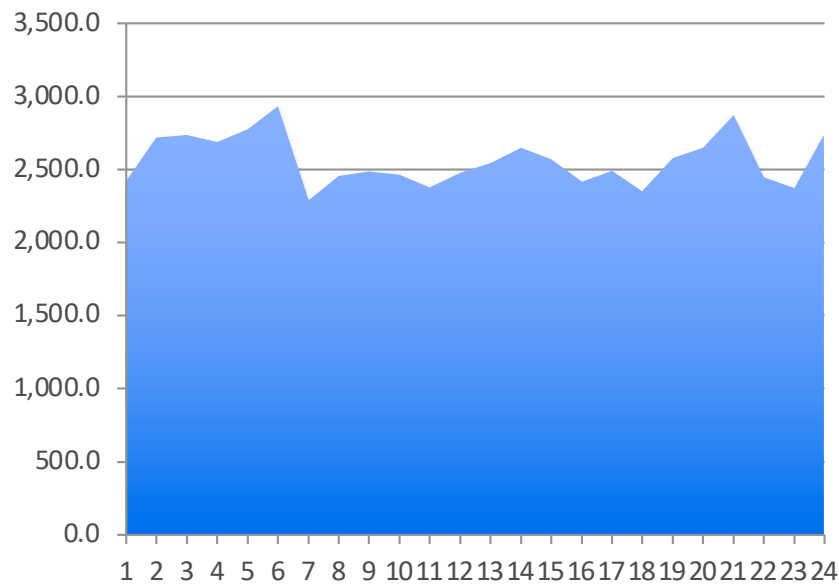
01 Jan 2008



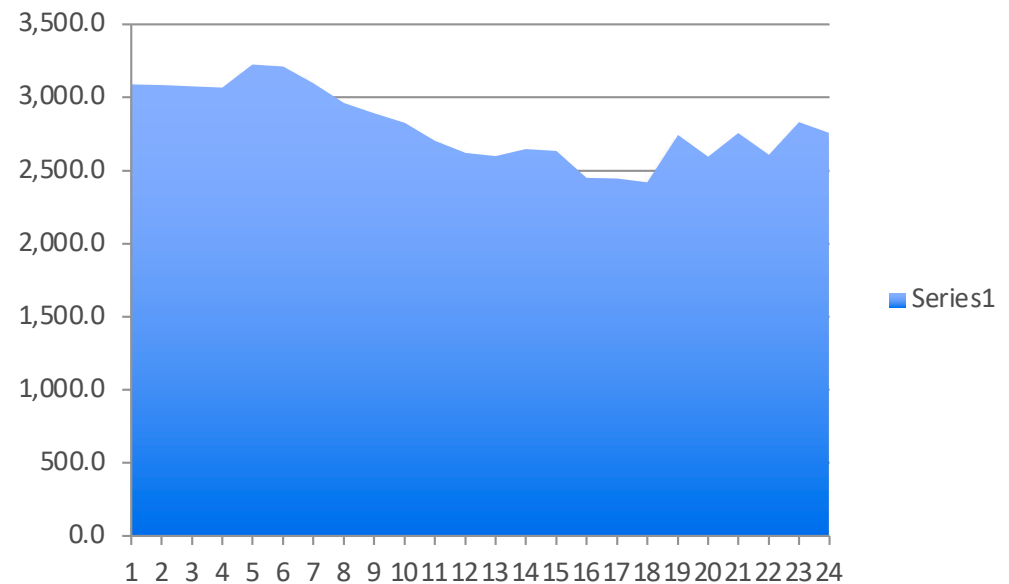
02 Jan 2008

Installed Capacity 4,541 MW

# Hourly wind power variation (MW) in Texas, USA (03 and 04 Jan 2008)



03 Jan 2008



04 Jan 2008

Installed Capacity 4,541 MW



# Roof-top Solar Photovoltaics in Virginia



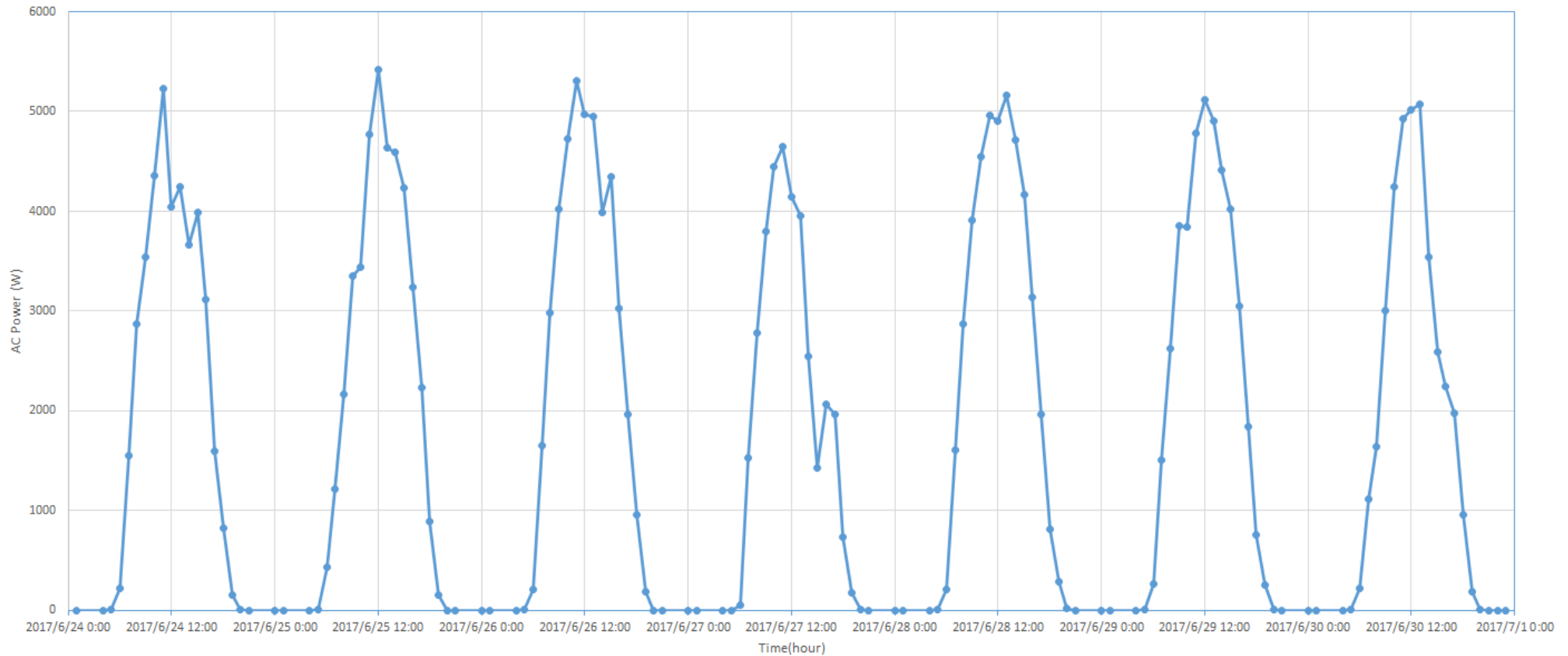


# Solar Panels in Winter



# 7-Day Solar PV Output

PV AC Power Output During One Sunny Week



Day 1

Day 2

Day 3

Day 4

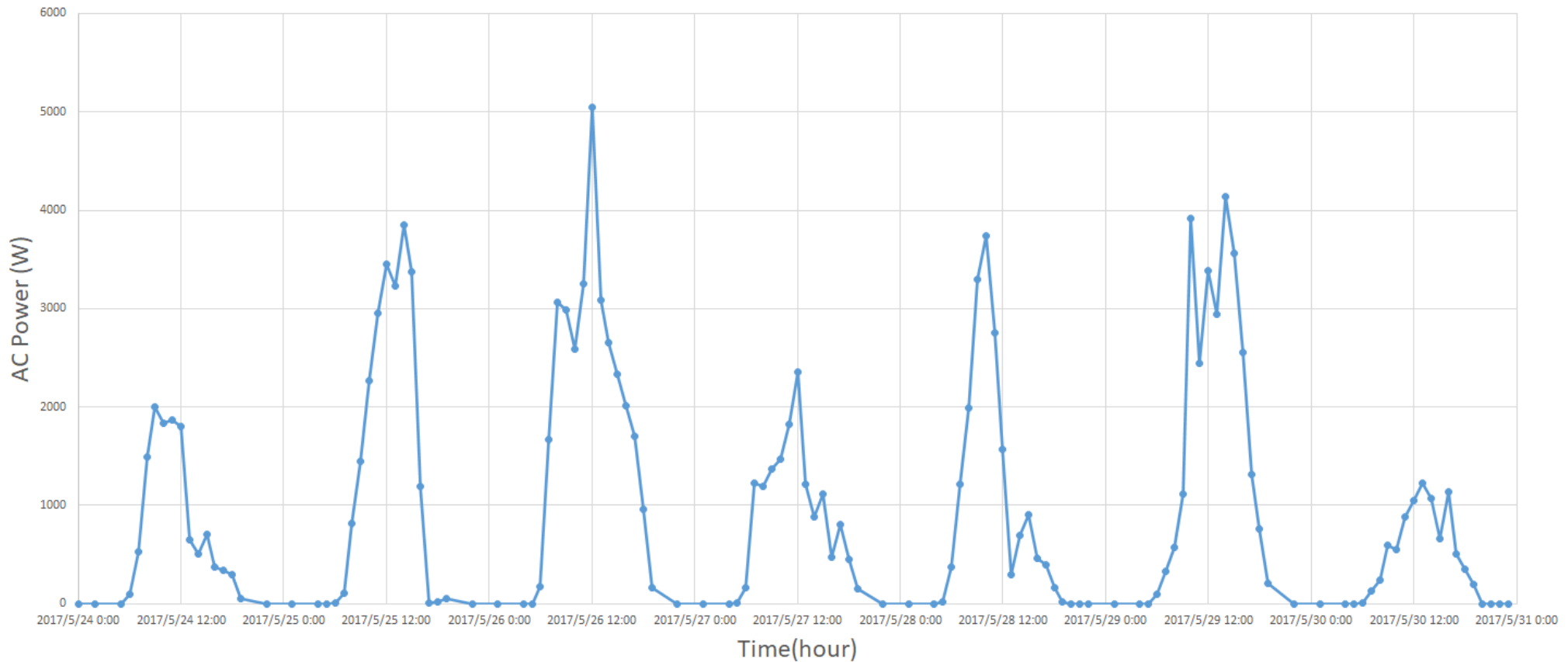
Day 5

Day 6

Day 7

# 7-Day Solar PV Output (intermittent)

PV AC Power Output During One Cloudy Week



Day 1

Day 2

Day 3

Day 4

Day 5

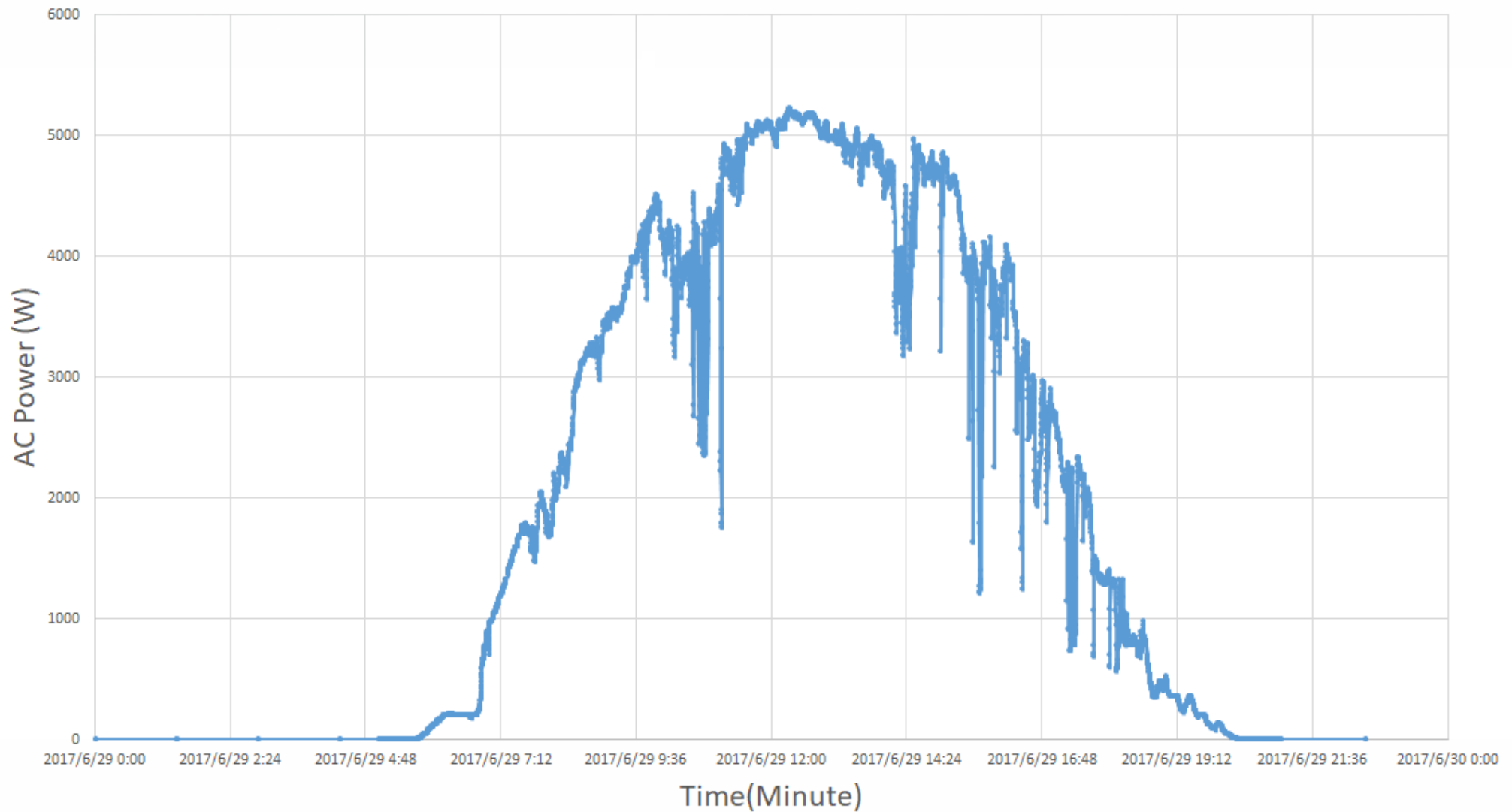
Day 6

Day 7



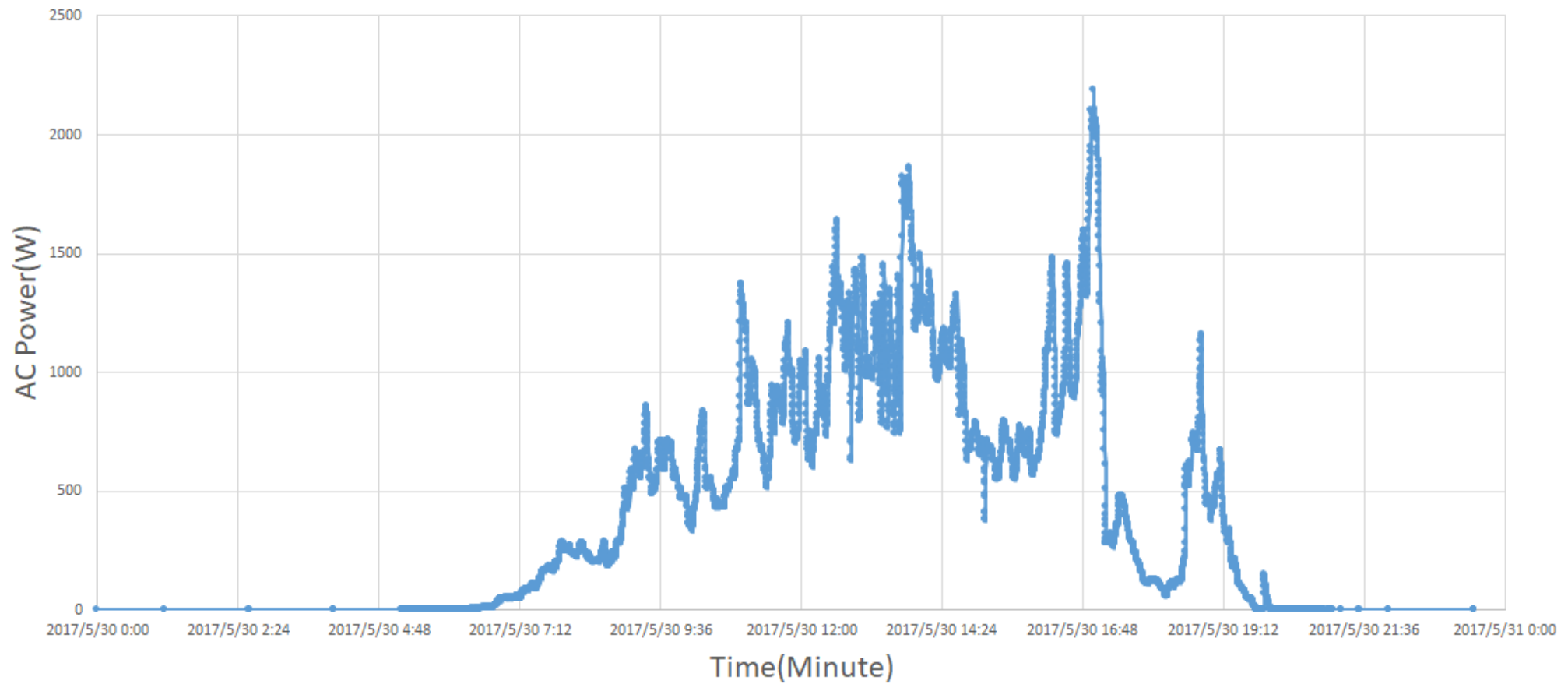
# Daily PV Output

PV AC Power Output During One Sunny Day



# Daily PV Output (intermittent)

PV AC Power Output During One Cloudy Day



# Can the Intermittency be Absorbed by the Network?

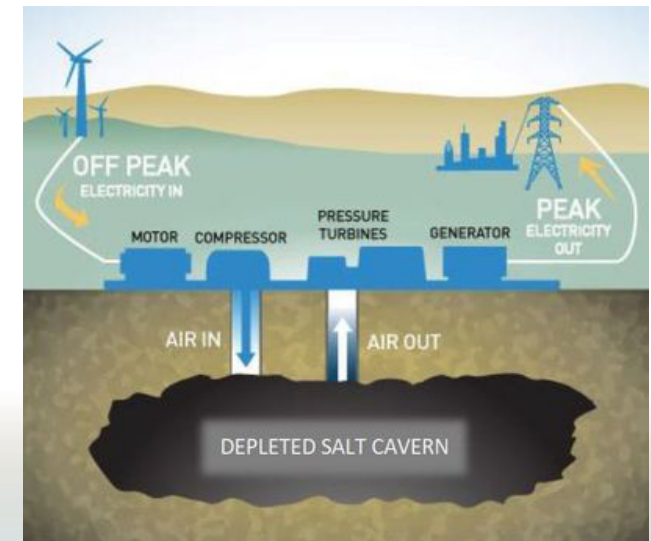


Battery storage



Pumped Storage

Compressed Air Storage







# Demand Response

“Demand Response is a customer action to control load to meet a certain target. Here the customer chooses what load to control and for how long”.

This is different from Demand Side Management (DSM) where the load is controlled by the electric utility and the customer has no control beyond the initial consent.

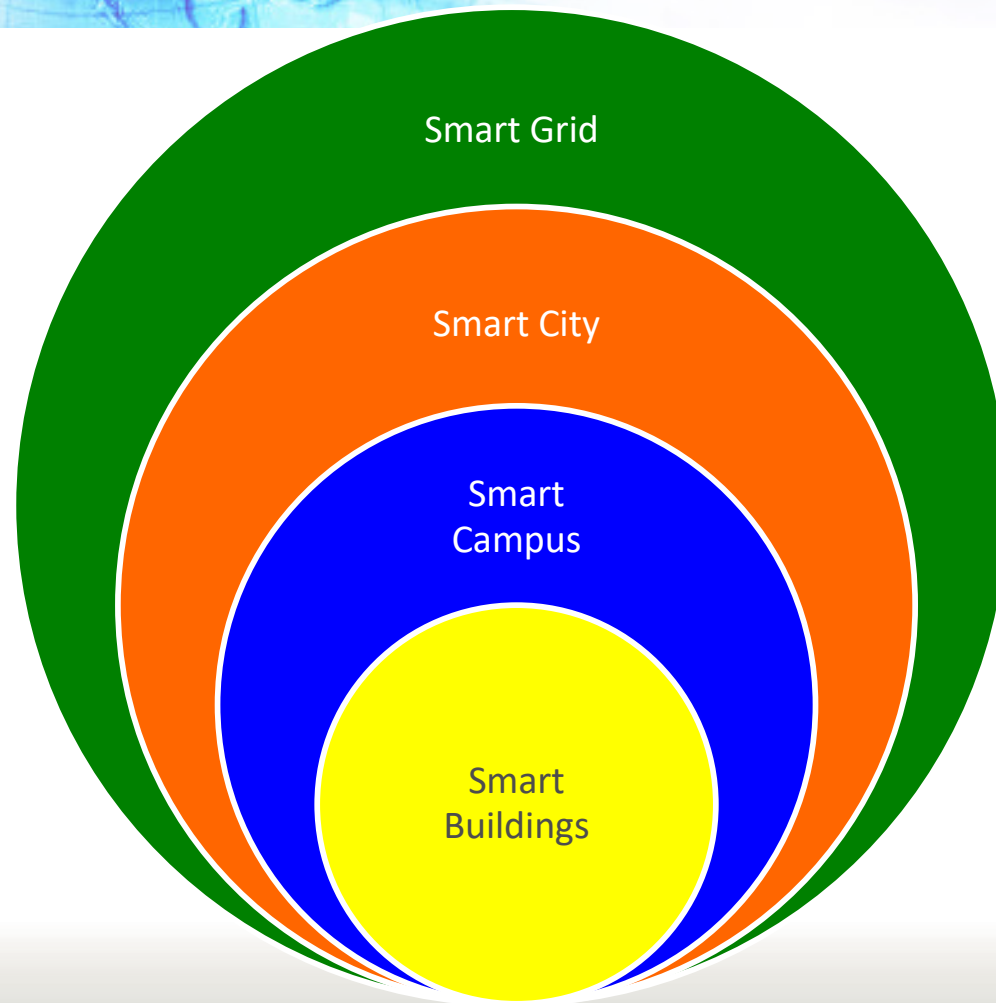


# New Paradigm for the Power System

- 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...



# What makes a Building Smart



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



# Cumulative Benefits of Building Load Control

- A large number of buildings can be controlled to absorb large fluctuations of supply in the short term
- Minimal storage is required
- Investment is for monitoring and control



# Addressing the Intermittency in Renewable Generation

- Smart vs. not-so-smart load control  
(adjust temperature set points in an air conditioner or water heater vs. turning the unit off)
- Size the storage to take advantage of demand dynamics
- Control the renewable generation to avoid instability (output control from PV inverters)





# 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.

I would like to see more **IEEE Senior Members** and **IEEE Fellows** from Regions 8, 9 & 10

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