

Role of Smart Grid in Facilitating the Integration of Renewables

Keynote Speech

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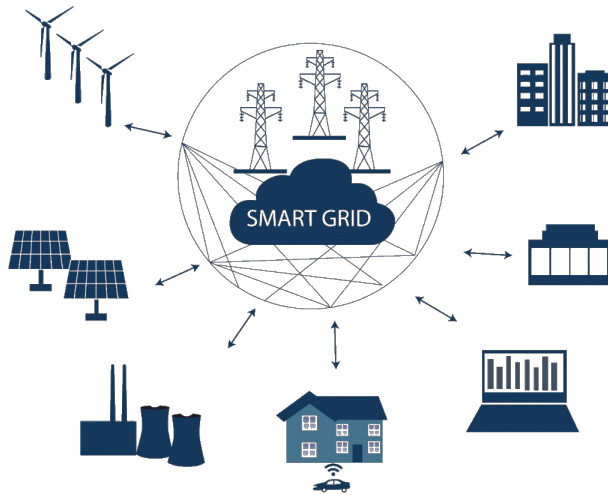
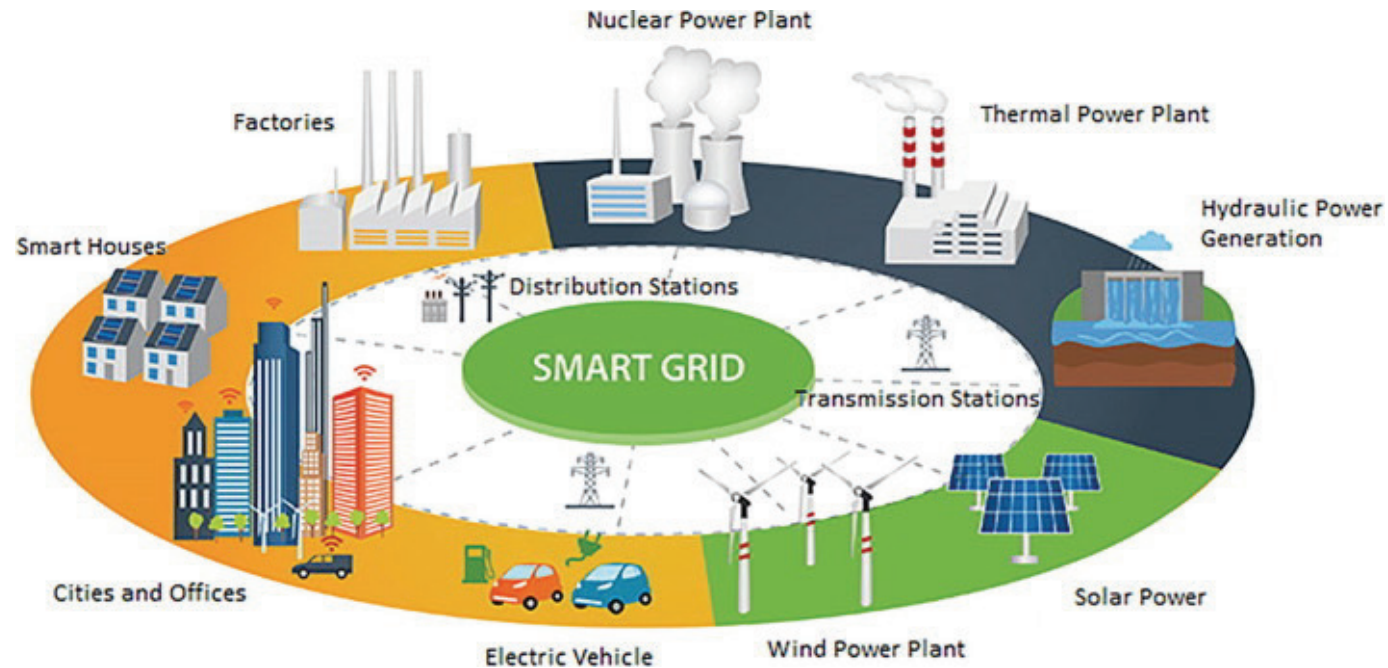
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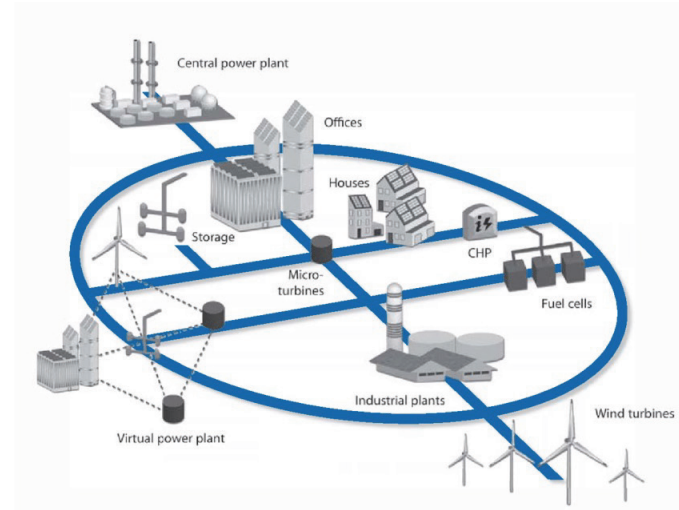


What is a Smart Grid



"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.

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.

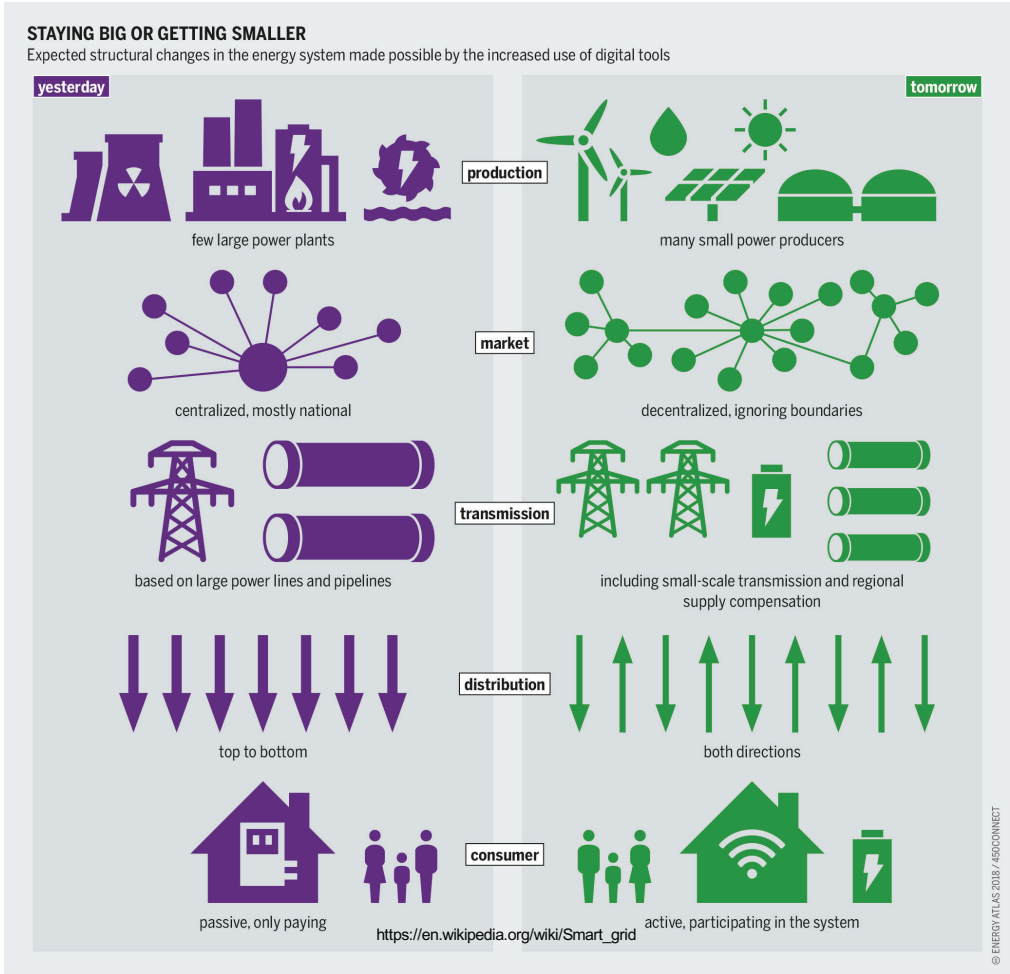
Difference Between a Normal Grid And a Smart Grid



Normal Phone



Smart Phone



Starting and End Points of a Smart Grid

It starts at the Generator and ends at the Refrigerator



Power Plant



Transmission



Distribution



Home Business

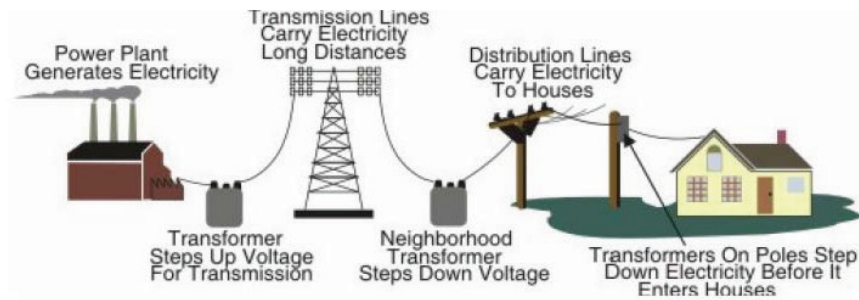


End-use Appliances

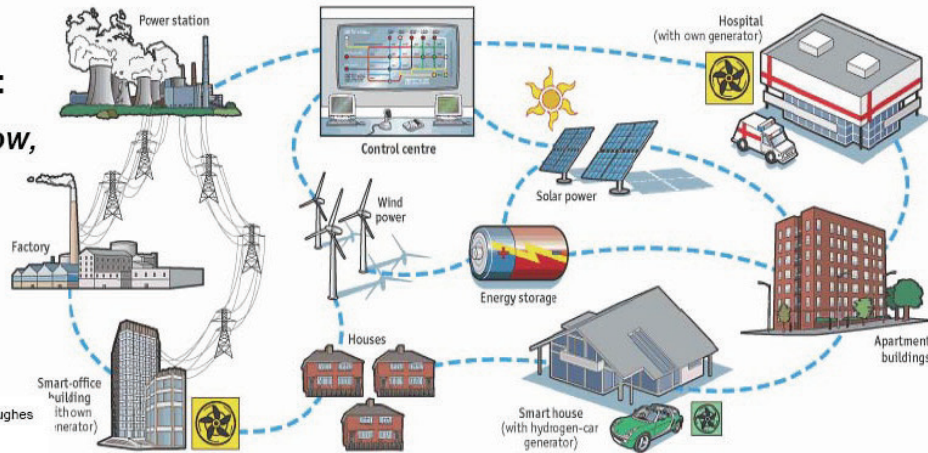
Evolution of the Grid

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

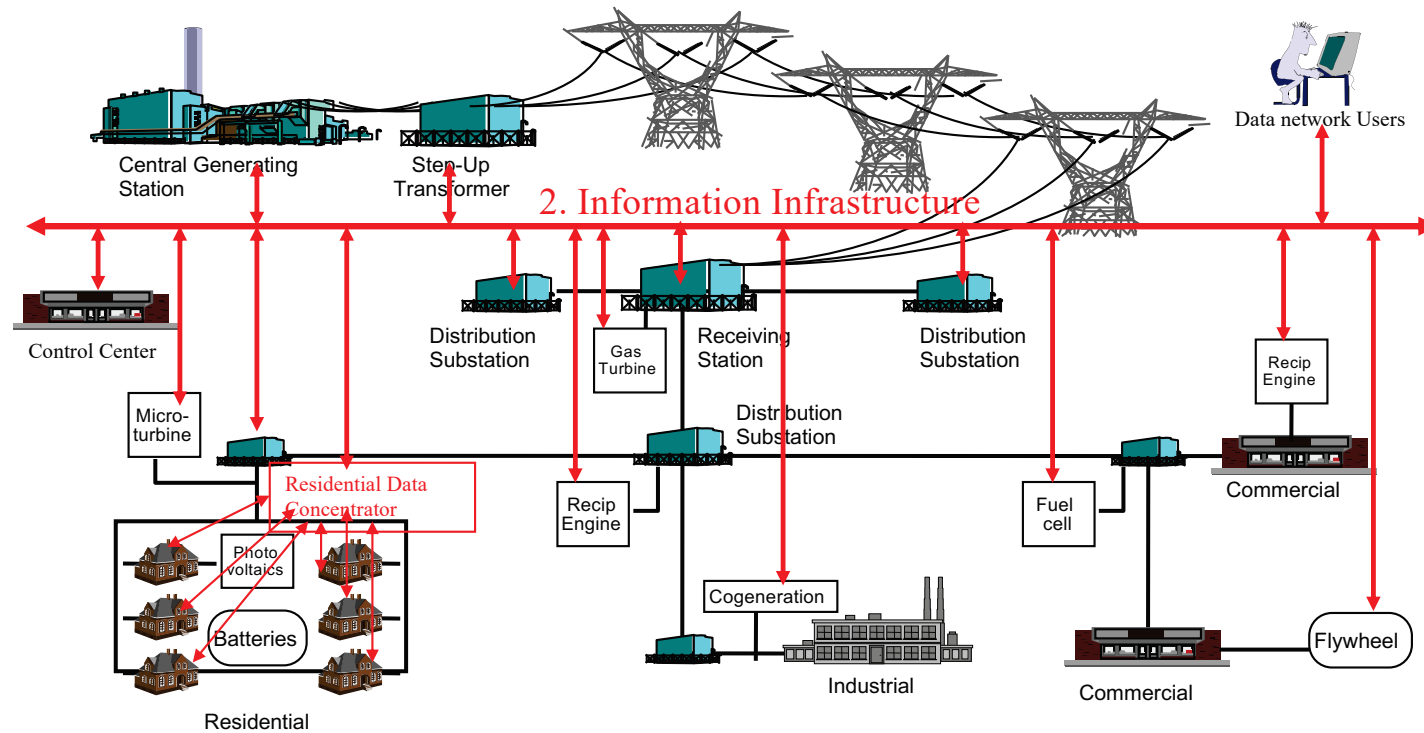


Merging Power Flow with Information Flow:

Integrated Communications

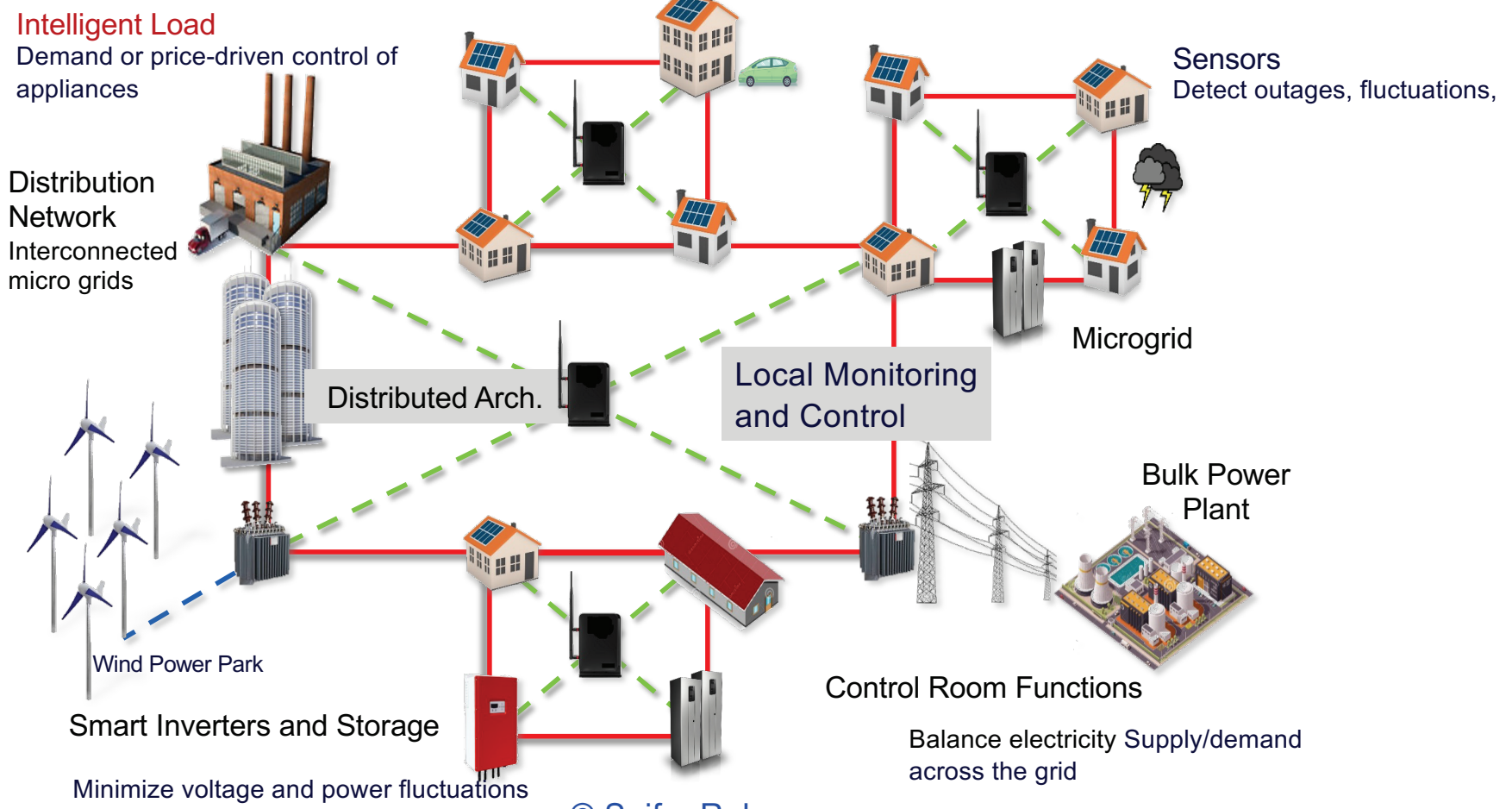
Electric Power & Communication Infrastructures

1. Power Infrastructure



Source: EPRI

Intelligent Interconnected Microgrids



Changing Landscape for the Electric Utility

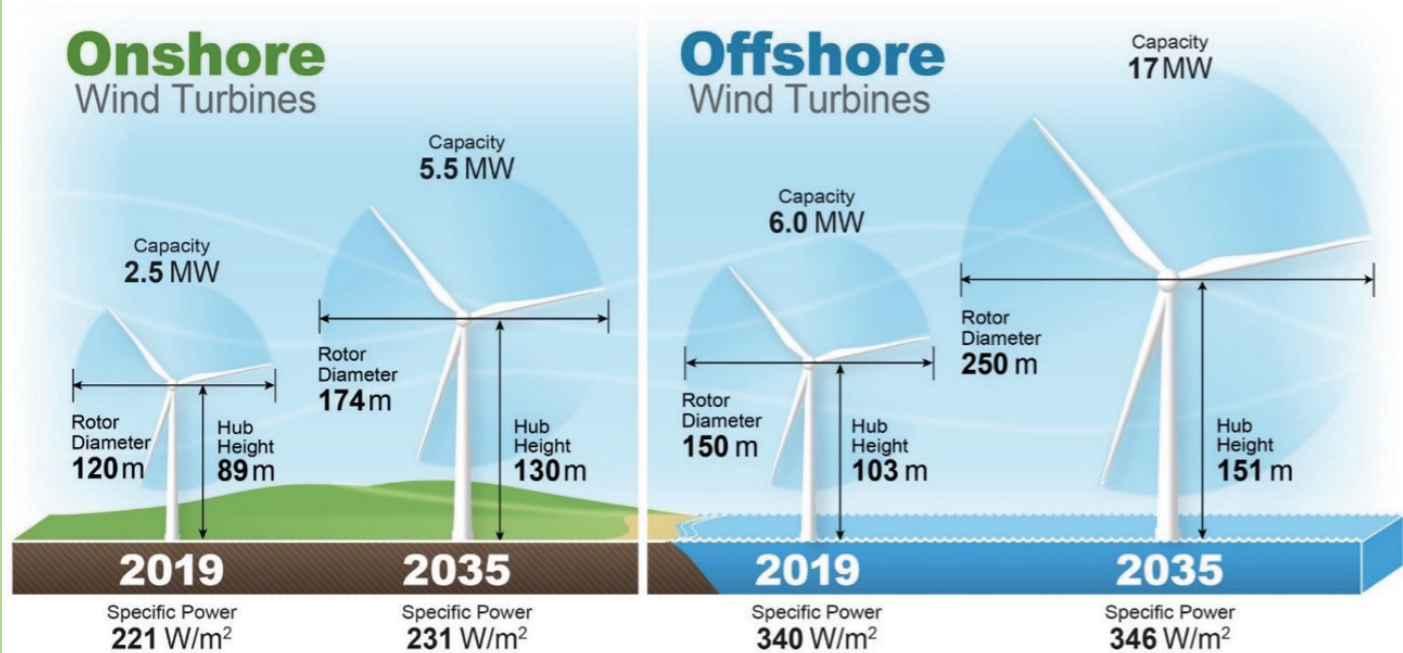




Issues with Distributed Generation

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

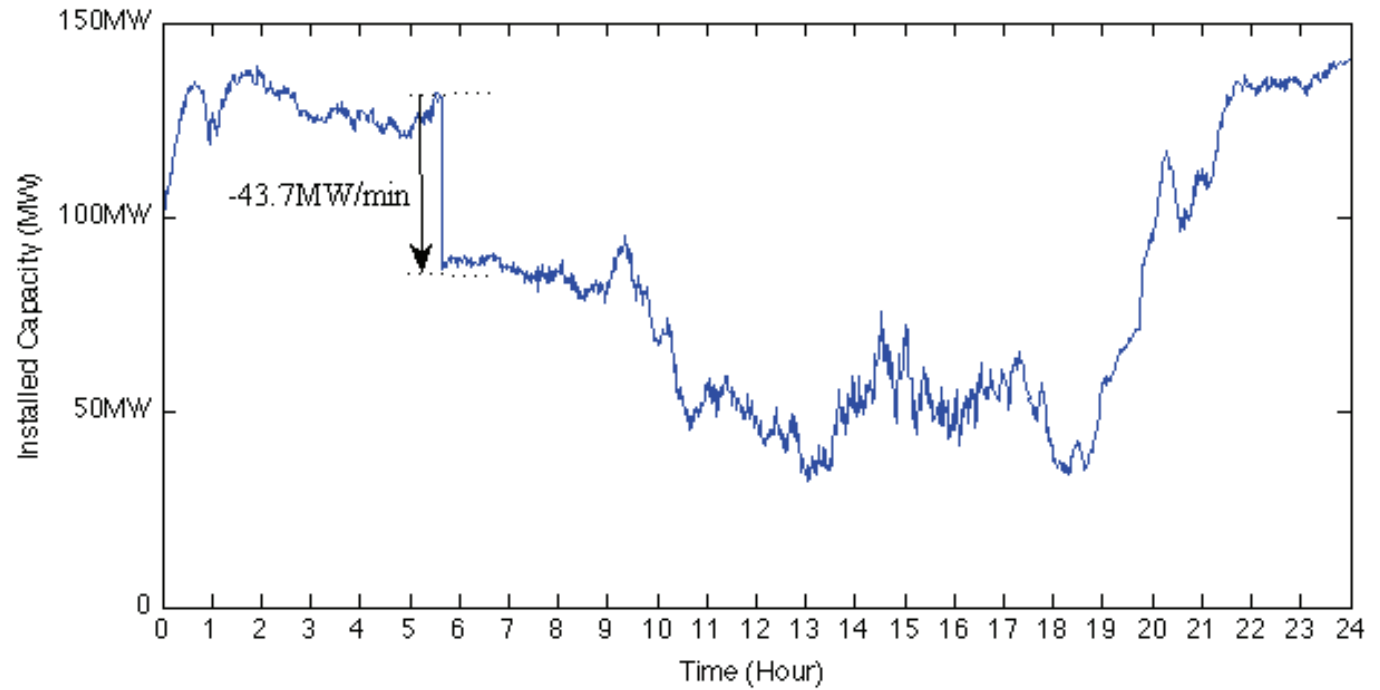
Wind Energy



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



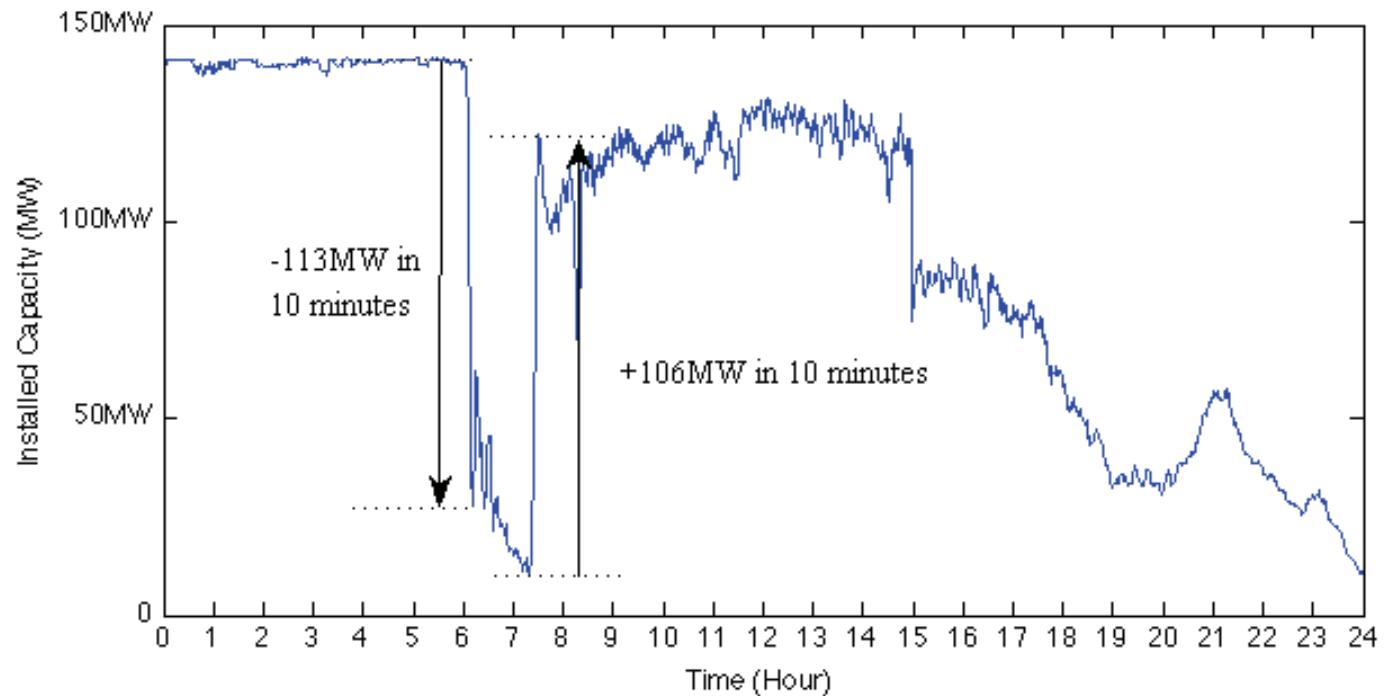
1-minute Variation of a 150MW Wind Farm Output in Texas



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

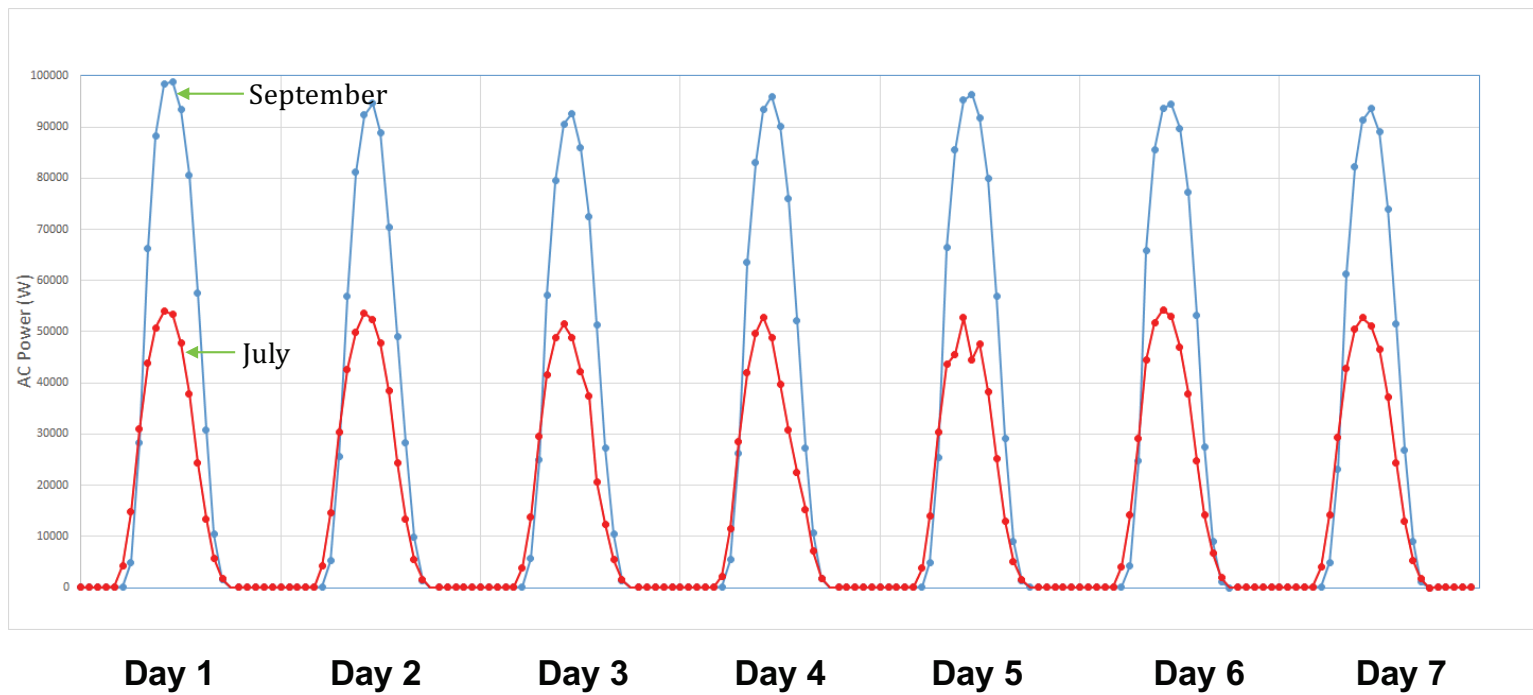
Solar Photovoltaic Plant - when New



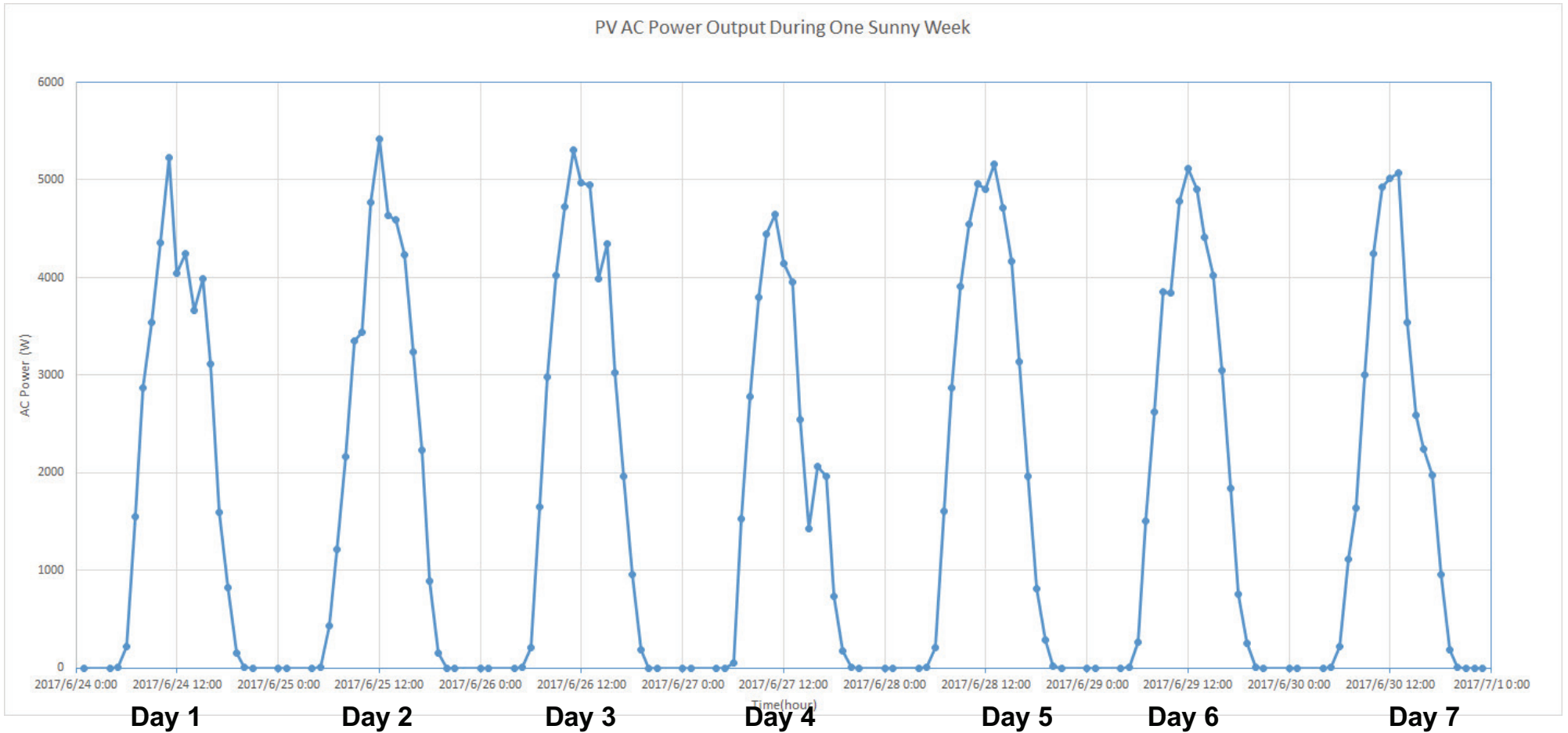
Solar PV Power Plant - A few months Old



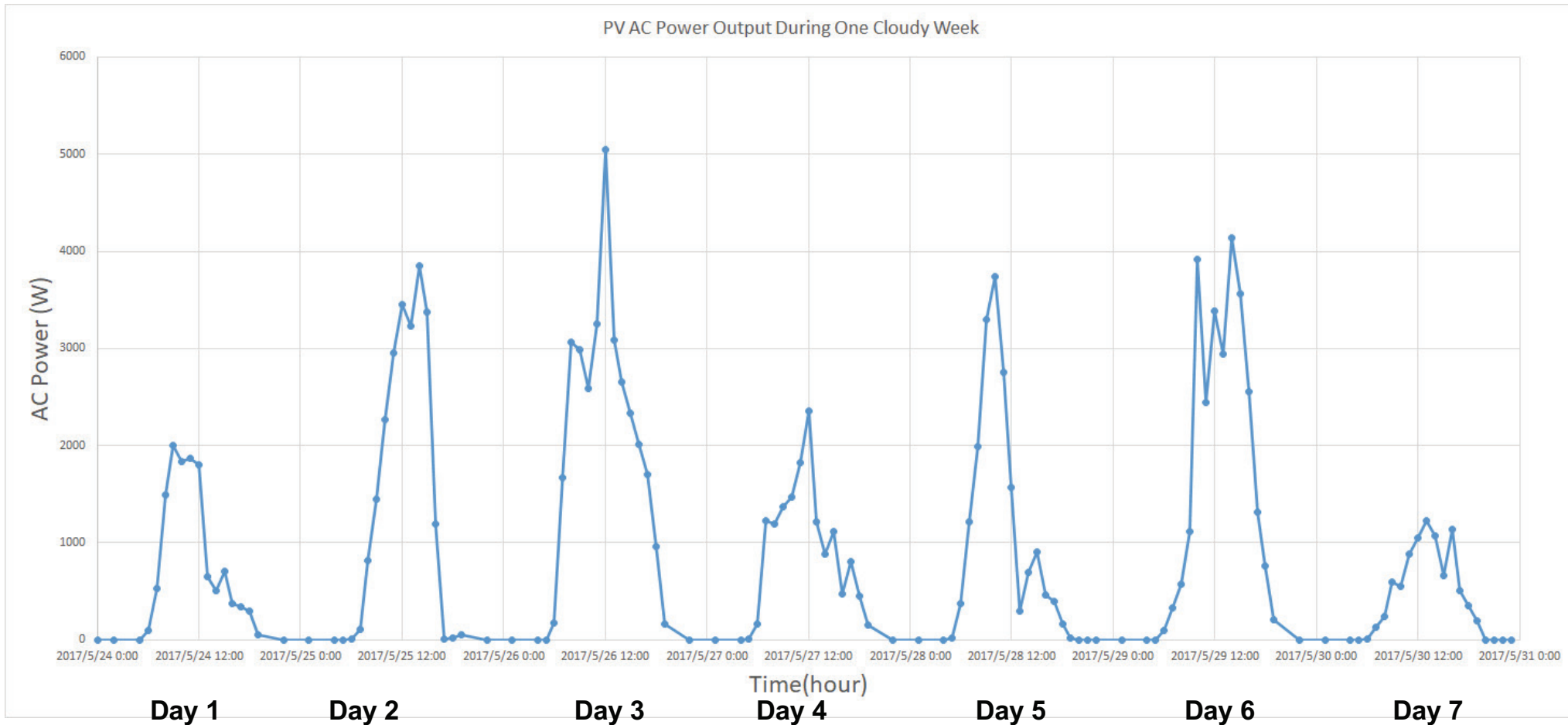
Solar PV Array (100kWp) Riyadh Area



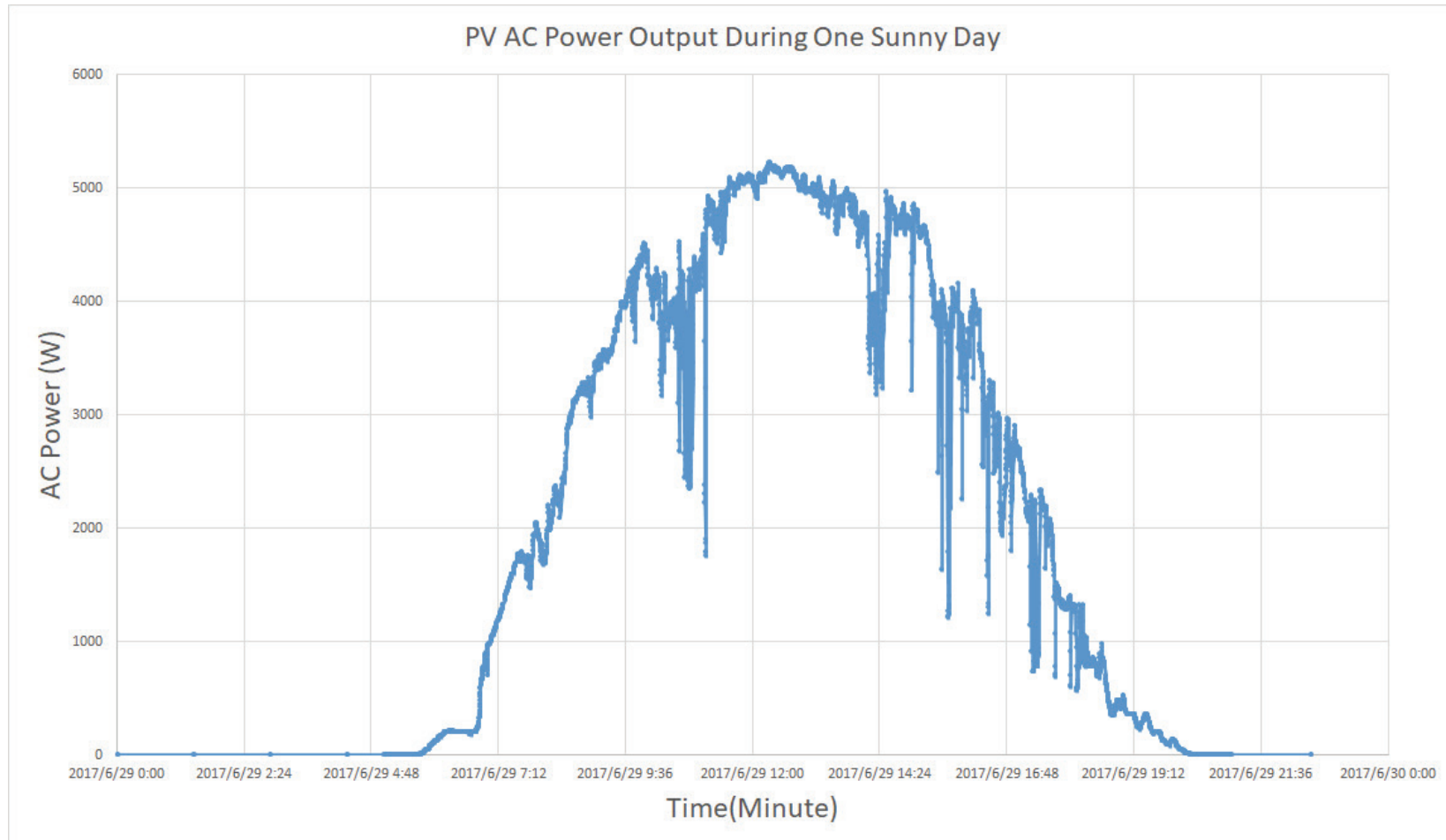
7-Day Solar PV Output (Virginia)



7-Day Solar PV Output (Virginia cloudy)

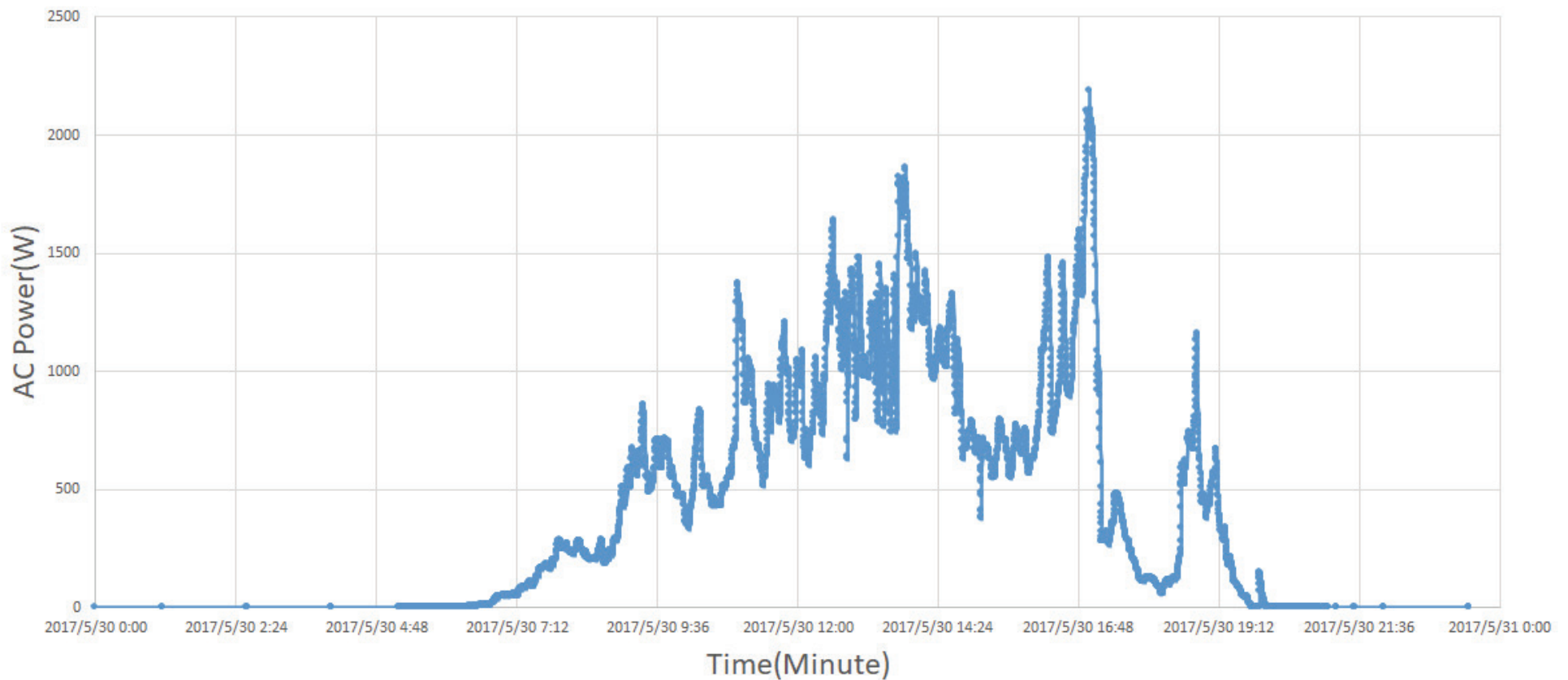


Daily PV Output (Virginia)

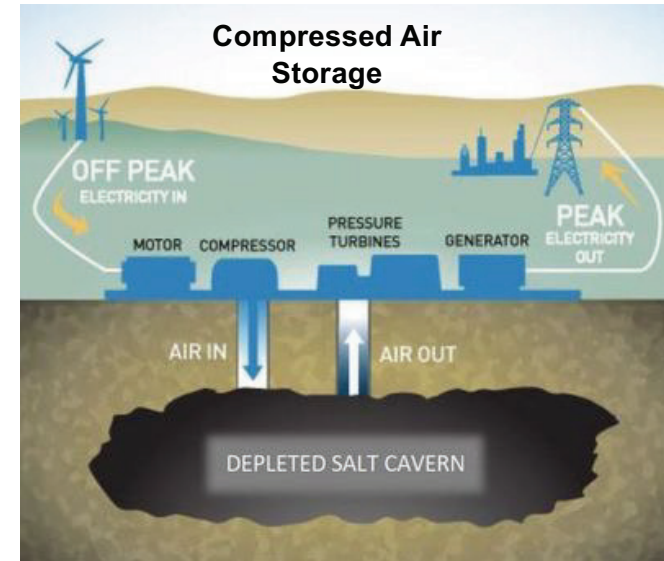


Daily PV Output (Virginia, intermittent)

PV AC Power Output During One Cloudy Day



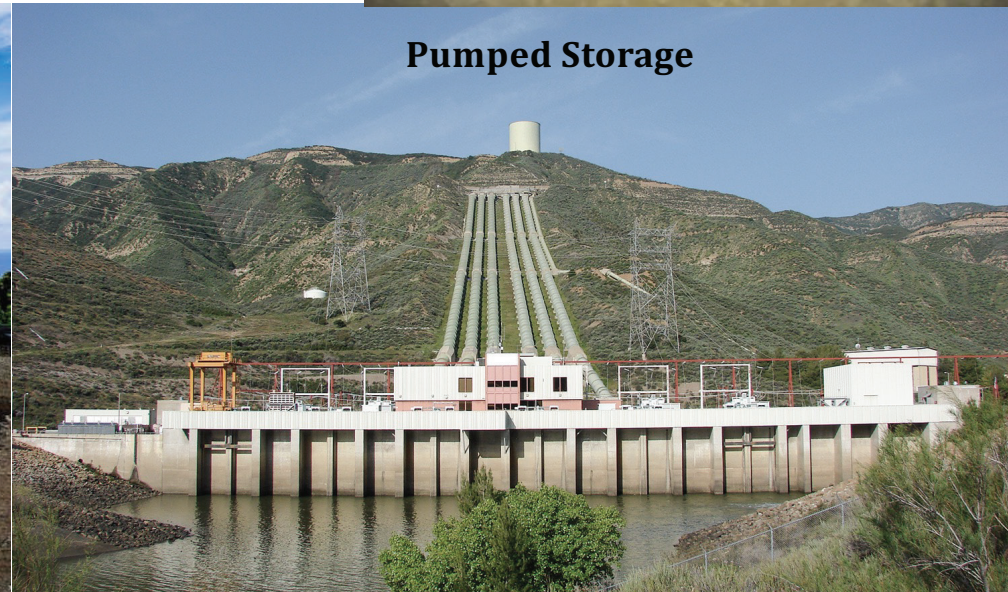
Intermittency Can be Absorbed by Storage and Demand-side Resources



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 can look both into the Supply and Demand sides

Predict Variable Availability of Supply
Make other Supply including Storage Available
Adjust Short-term Demand using AI Applications

The Smart Grid Ecosystem

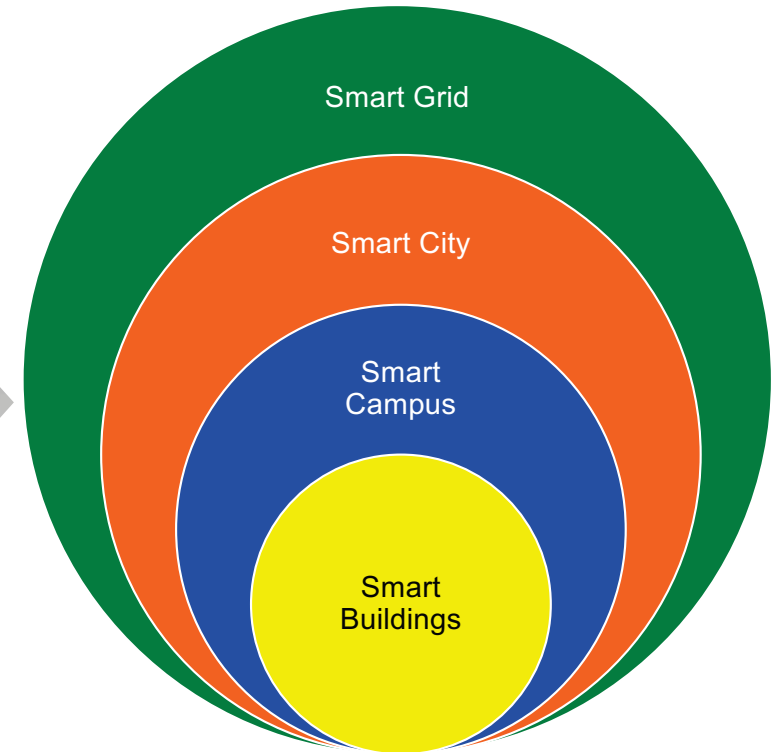
Smart grid: Bi-directional flows of energy, remote control/automation of power, integrated distributed energy...

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 →

Climate Change

IEEE: Enabling Innovation and Technology Solutions



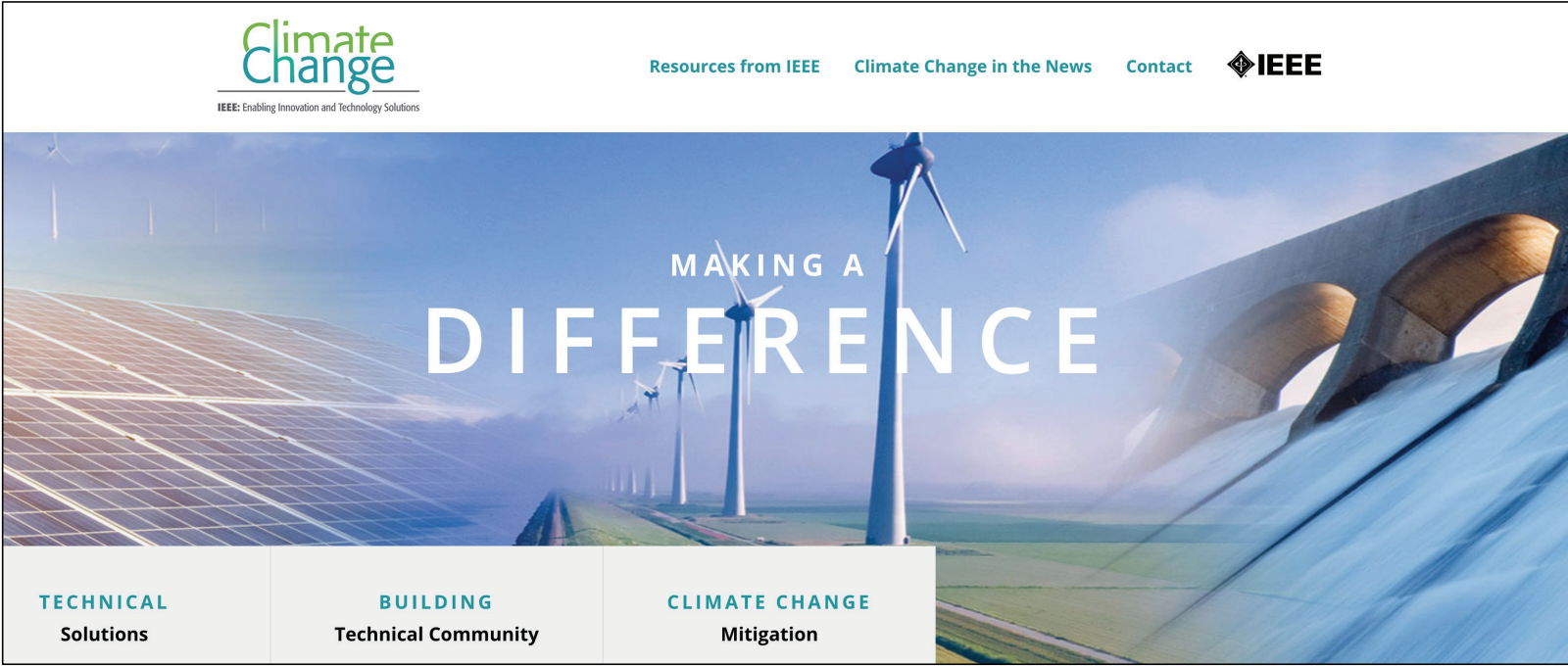
*Advancing Technology
for Humanity*

What Can you Do to Serve Humanity?

Clean-Tech Solutions for Climate Sustainability

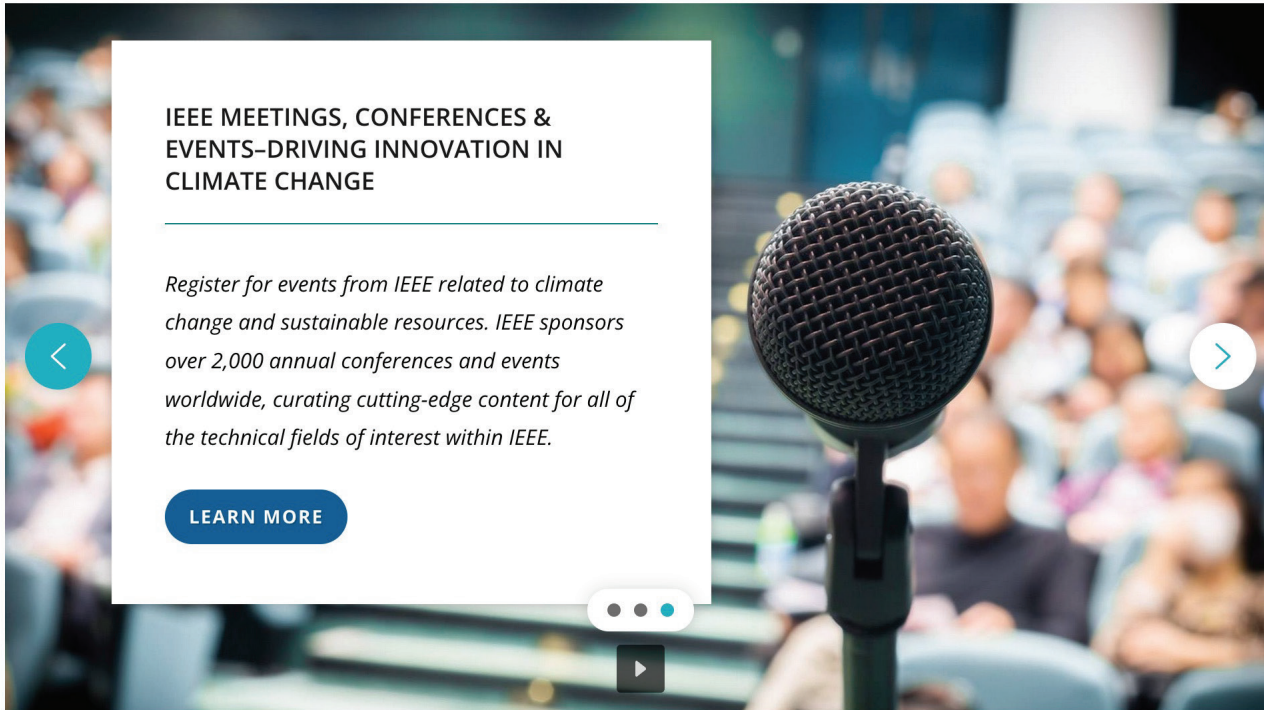
IEEE Climate Change Website

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



IEEE: Enabling Innovation and Technology Solutions

Email: ccircc@ieee.org



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Ecosystem for IEEE's Climate Sustainability Work

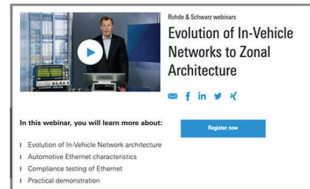
IEEE Spectrum: Climate Change News Feed; Podcasts; Features; Archives; Journal Watch Posts (Xplore); The Institute (Engineers of Climate Change); Coverage of Conferences and Standards



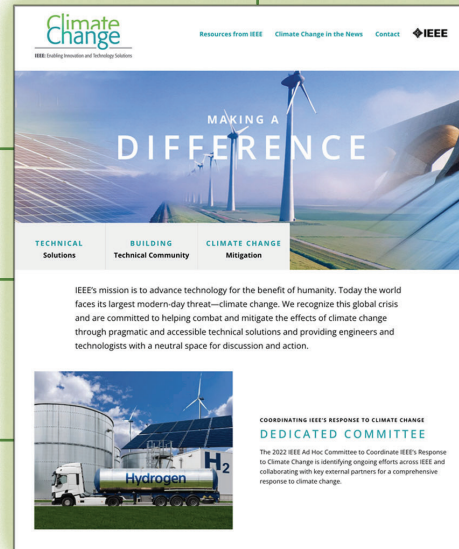
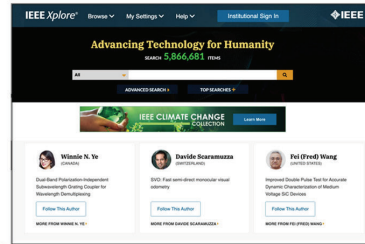
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