The grid integration of renewables for filling the gap to reach the goal of doubling renewable energy in the APEC Region

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Workshop on Filling the Gap to Reach the Goal of Doubling Renewable Energy in the APEC Region

March 27-28, 2017 Jeju, Republic of Korea

EWG 05 – 2015A: Workshop on experiences and plans to double renewable energy utilization by 2030 in the APEC region

Daegu, Republic of Korea, November 10 – 11 2015

- Currents trends and barriers: policy, technical, and social to advancing renewable energy
- Opportunities and strategies for strengthening renewable energy implementation: emerging technologies, innovative financing, public-private partnership, and business strategies
- Best practices for advancing renewable energy: training for capacity building, reducing soft costs, resources for information sharing, and stakeholder engagement
- Guidelines for economies to prepare a roadmap to double renewable in the energy mix by 2030.

Workshop Agenda

- Presentations by experts on global projections for renewable energy, projections and consequences for the APEC region, system integration and flexibility issues, renewable energy for buildings, and green technologies
- Experiences and plans by delegates from Korea, China, Chinese Taipei, Japan, Malaysia, Papua New Guinea, Peru, Philippines, Thailand, and Vietnam
- Breakout Sessions: Brainstorming to define a pathway for the future

Top Five Issues for the future with number of votes

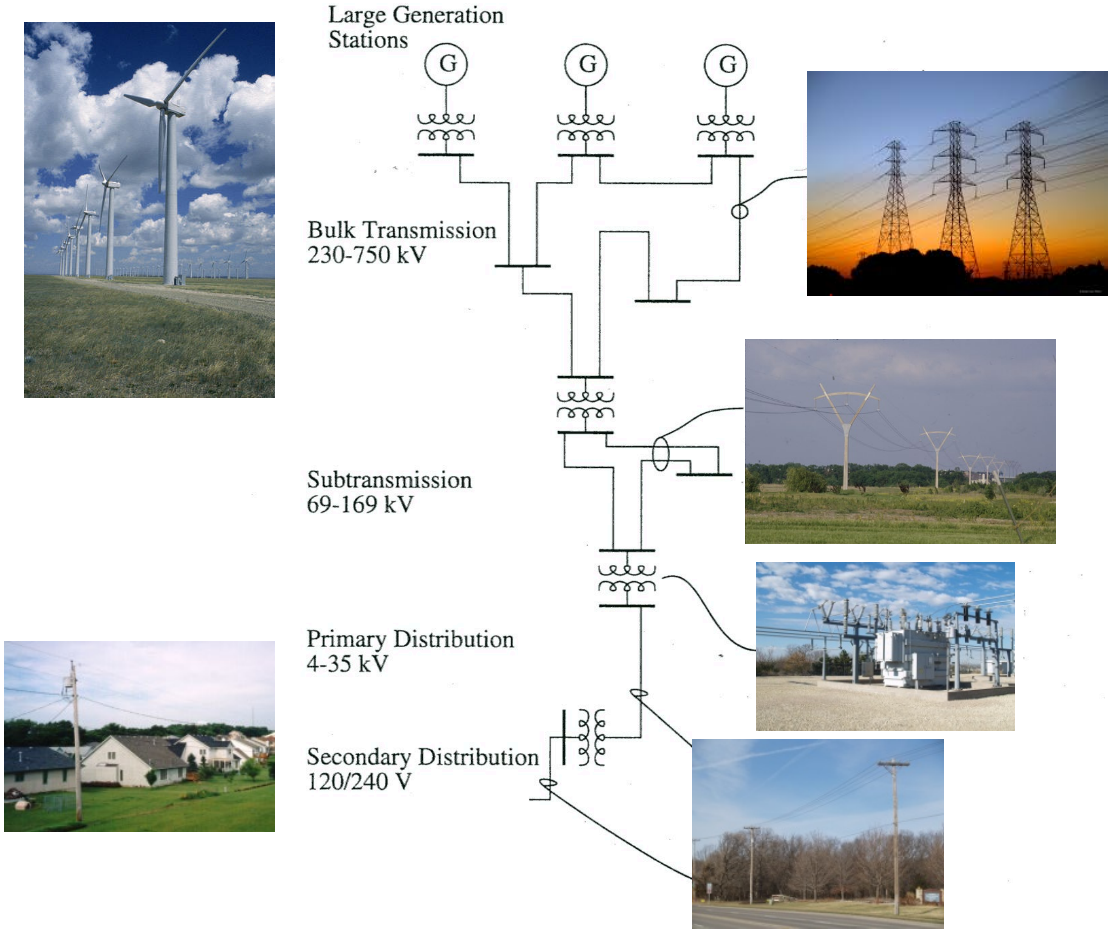
1. Education, training, collaboration, and information exchange (24)
   - Education and training (10)
   - Encourage international and interregional information exchange (7)
   - APERC could work on reporting of progress towards RE goals (4)
   - More collaboration among different APEC working groups (3)
2. Policies (23)
   - Keep policymakers informed (7)
   - Policies unstable or lacking (7)
   - Classification of doubling RE targets by sector is needed (4)
   - Renewable are not a priority (3)
   - More coordinated approach to achieving doubling RE goal (2)

Top Five Issues for the future with number of votes

3. Market reforms (18)
   - Cost of renewable energy for developers and consumers (9)
   - Subsidy removal in the electricity market (8)
   - Foothold of fossil fuels industry (1)
4. Technology (13)
   - Leverage advances in smart grid and energy storage (6)
   - Integration of RE both in buildings and the grid is challenging (3)
   - Maintain compliant and licensed service providers (3)
   - Lengthening local manufacturing chain (1)
5. Strategic and innovative financing(7)
   - Creating bankable projects (4)
   - Eliminate upfront costs (3)

Link to the full report: http://publications.apec.org/publication-detail.php?pub_id=1752

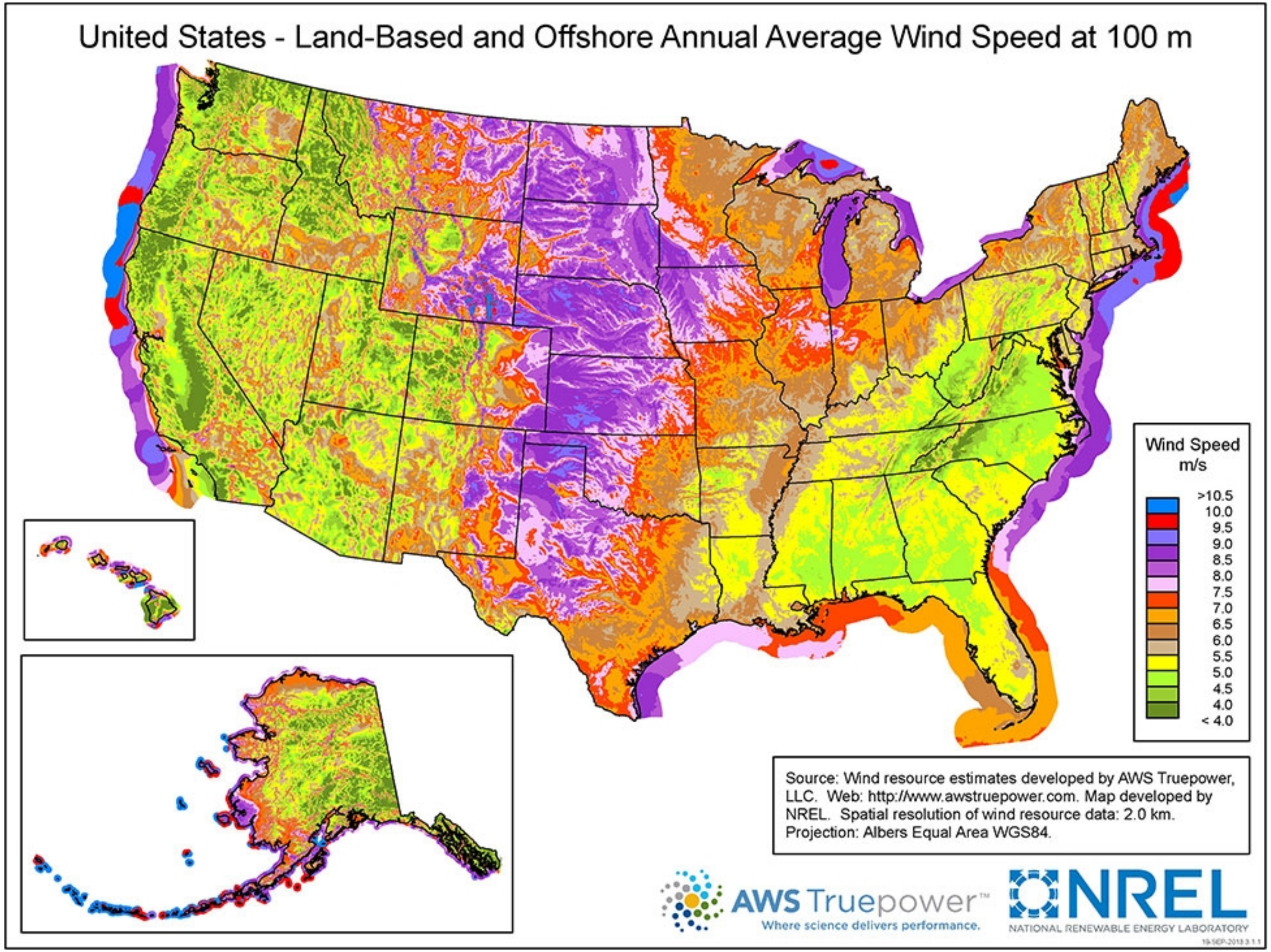
Grid

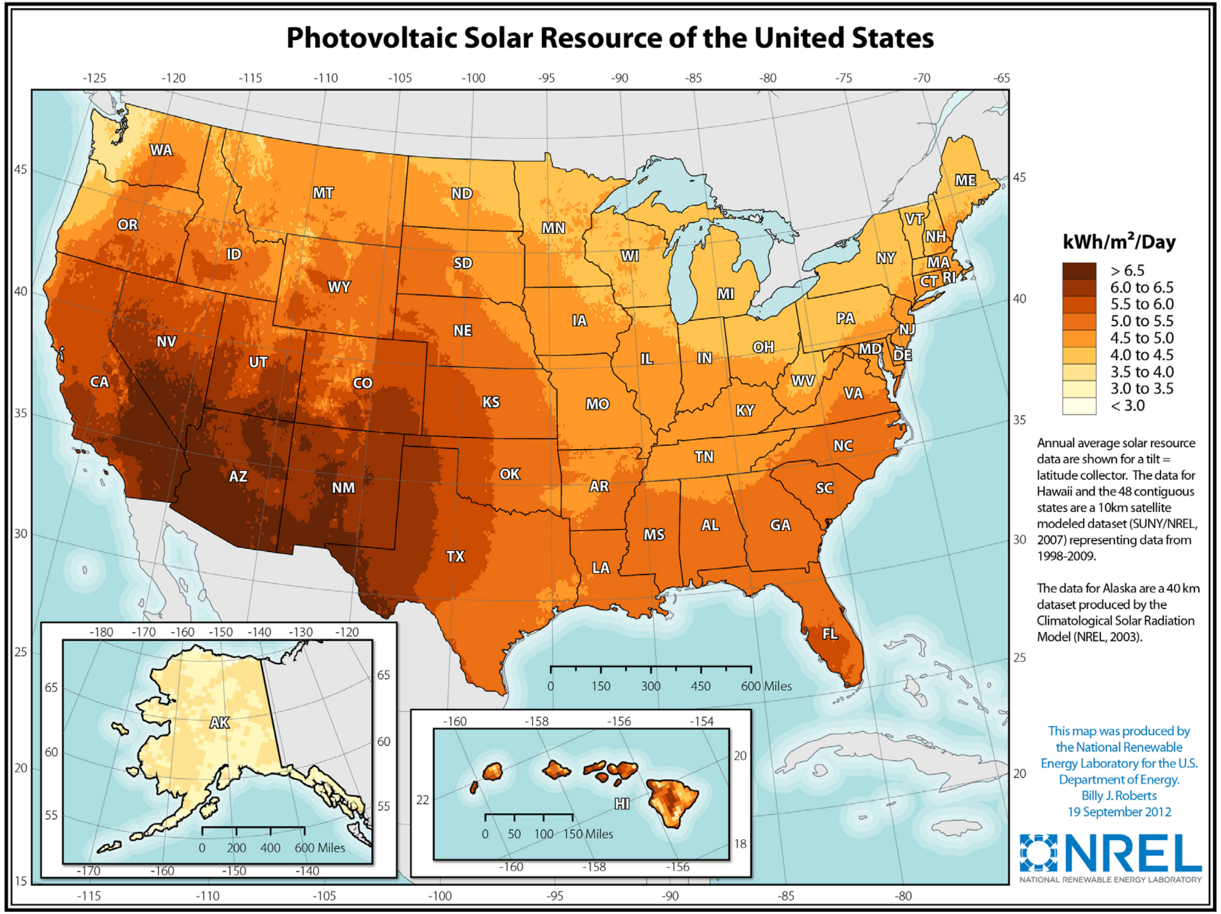

Large Generation Stations
G
G
G
Bulk Transmission 230-750 kV
Subtransmission 69-169 kV
Primary Distribution 4-35 kV
Secondary Distribution 120/240 V

Factors Affecting Grid Integration of Renewable Generation

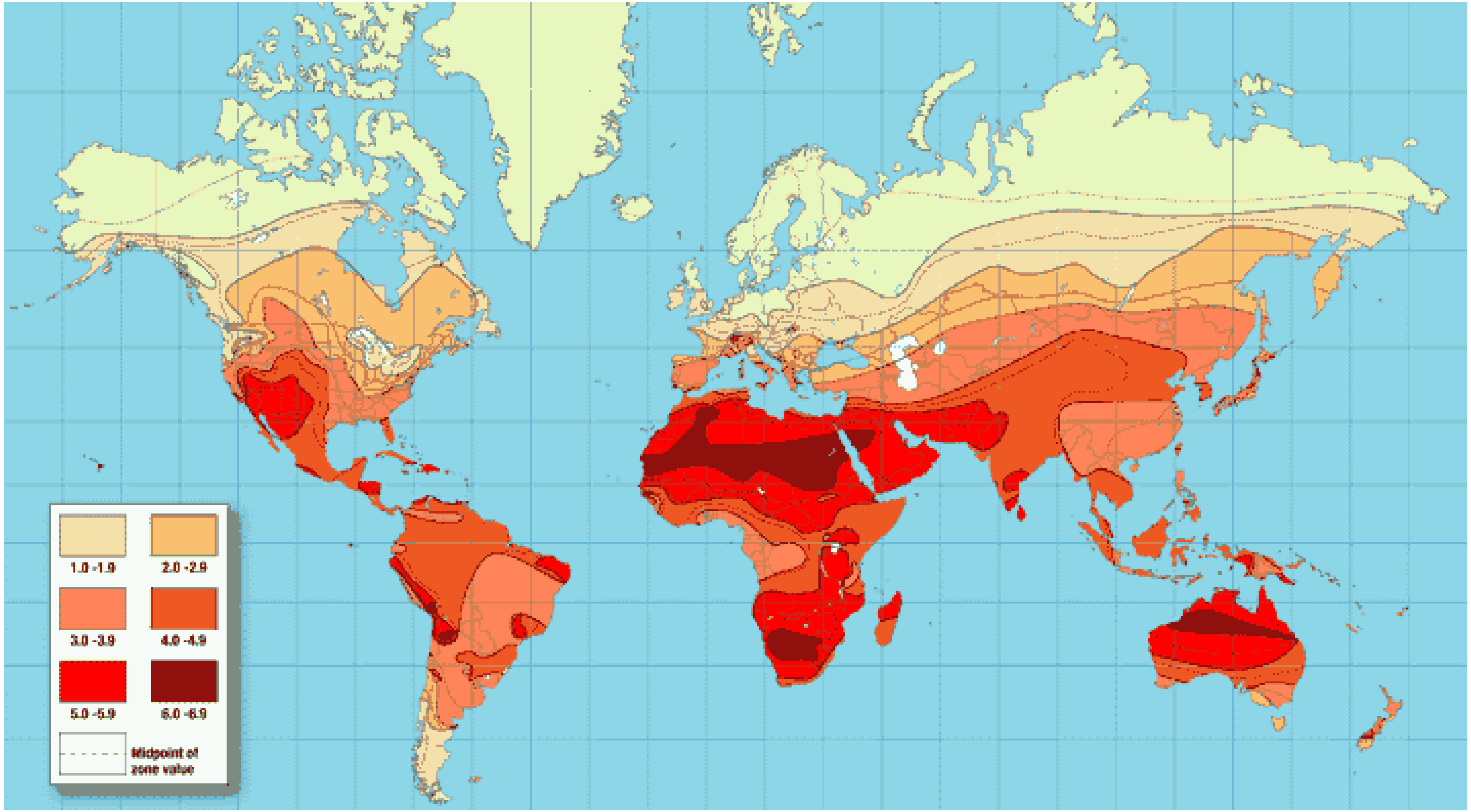
- Geography - Availability of resources
- Cost
- Capacity Factor
- Grid Access – Points of interconnection
- Market and Subsidies
- Dispatchability – Cannot be dispatched like fossil resources
- Intermittency – Fluctuations
- Regulation
- Tariffs

Geography


United States - Land-Based and Offshore Annual Average Wind Speed at 100 m
Wind Speed m/s
>10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
< 4.0
Source: Wind resource estimates developed by AWS Truepower, LLC. Web: http://www.awstruepower.com. Map developed by NREL. Spatial resolution of wind resource data: 2.0 km. Projection: Albers Equal Area WGS84.
AWS Truepower™
Where science delivers performance.
NREL
NATIONAL RENEWABLE ENERGY LABORATORY


Photovoltaic Solar Resource of the United States
kWh/m²/Day
> 6.5
6.0 to 6.5
5.5 to 6.0
5.0 to 5.5
4.5 to 5.0
4.0 to 4.5
3.5 to 4.0
3.0 to 3.5
< 3.0
Annual average solar resource data are shown for a tilt = latitude collector. The data for Hawaii and the 48 contiguous states are a 10km satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2009.
The data for Alaska are a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.
Billy J. Roberts
19 September 2012
NREL
NATIONAL RENEWABLE ENERGY LABORATORY
0 150 300 450 600 Miles
0 200 400 600 Miles
0 50 100 150 Miles
WA OR CA NV ID MT WY UT AZ NM CO ND SD NE KS OK TX MN IA MO AR LA WI IL MI IN OH KY TN MS AL GA SC NC VA WV PA NY MD DE NJ CT RI MA VT NH ME FL AK HI

Solar Irradiance

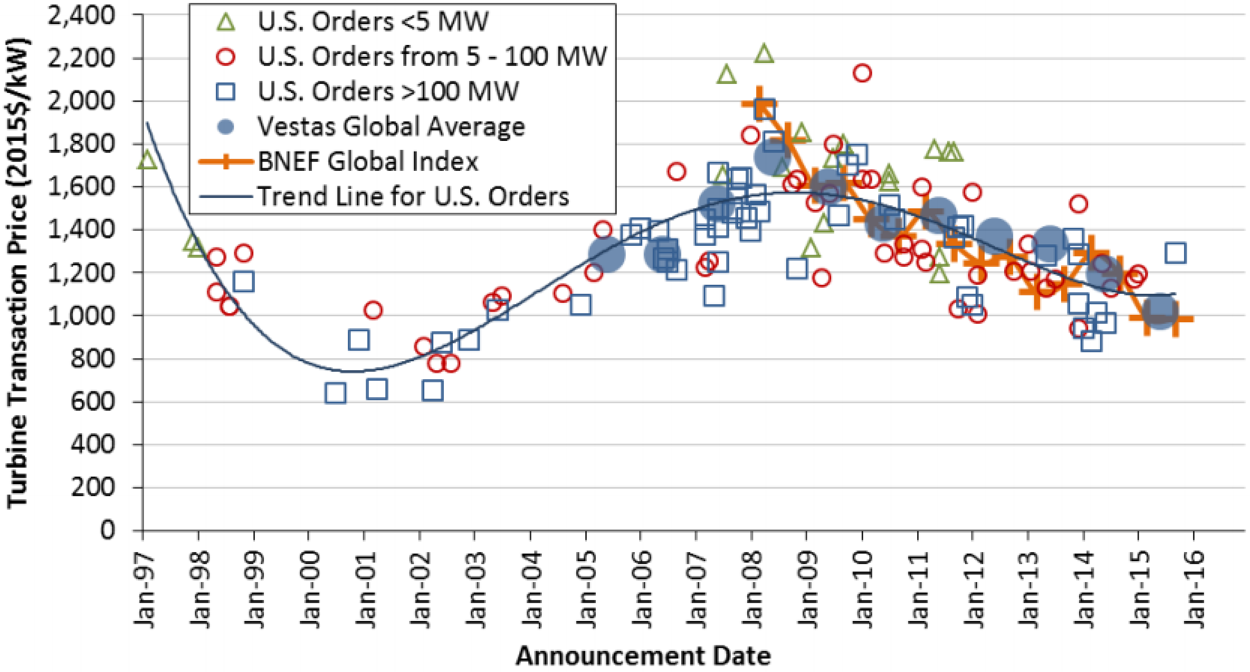


Cost Comparison (unsubsidized)

Energy Source	Capital Cost ($/kW)	Levelized Cost of Energy ($/MWh)
Wind	1250 - 1700	32 - 62
Rooftop Solar	2000 - 3750	88 - 222
Utility Solar	1300 - 1450	49 - 92
Combined Cycle Natural Gas	1000 - 1300	48 - 78
Coal	3000 - 8400	60 -143

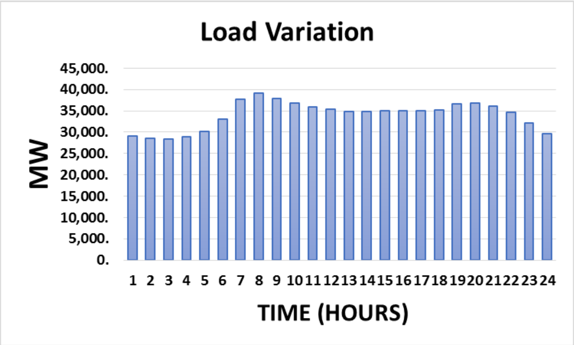
Source: LAZARD'S Levelized Cost of Energy Analysis Version 10.0 December 2016.

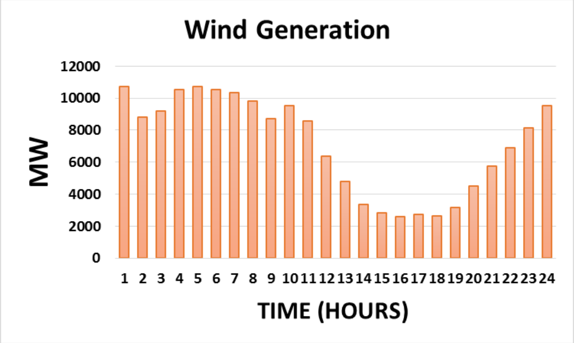
Wind Turbine Prices Remained Well Below the Levels Seen Several Years Ago

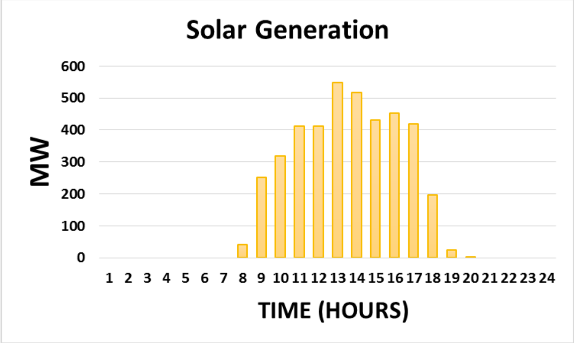


Recent turbine orders reportedly in the range of $850-1,250/kW

Typical Load and Renewable Generation in Winter (a site in Texas - ERCOT)



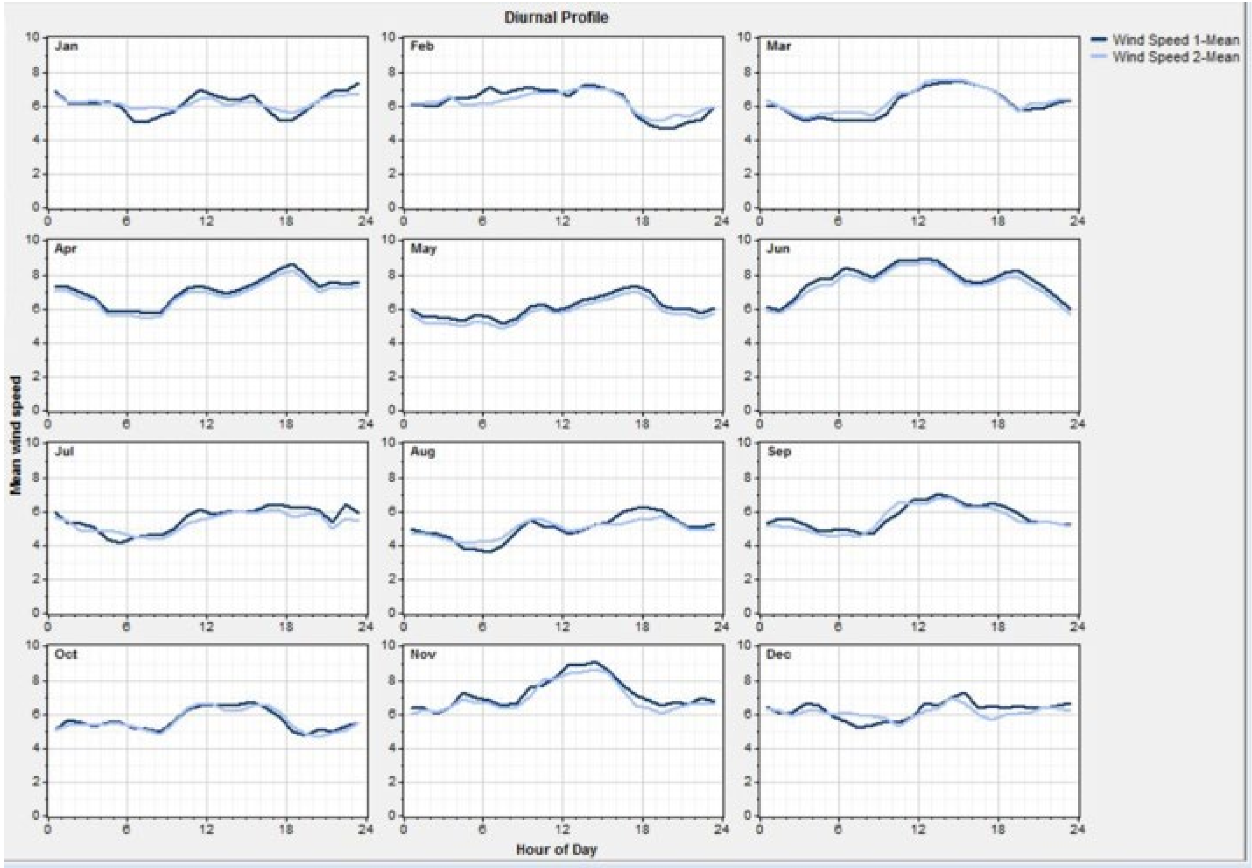




Observations

- Load is higher during the day
- Wind generation is higher during night (not always)
- Peak of wind generation does not coincide with the peak load duration
- Peak of solar generation coincides with peak load duration
- Wind and solar generation are not dispatchable
- Both wind and solar generation can change drastically from one hour to the next
- Both wind and solar have low capacity factor: 30 to 45% for wind.
- Wind can cover a large percentage of load in the night

A site in Kansas



Grid Integration Challenges

- Space availability
  - Agriculture can continue around wind farms. Source of income for farmers.
  - Utility scale solar needs exclusive real estate
- Grid connection
  - Extra cost to extend transmission system
- Lack of adequate transmission capacity
  - Kansas has huge wind energy potential, but lacks transmission lines
  - Wind curtailment when generation is very large as percentage of load (5 to 20% curtailment is possible)
- Ability to ramp up and down other generation to counter changes in renewable generation

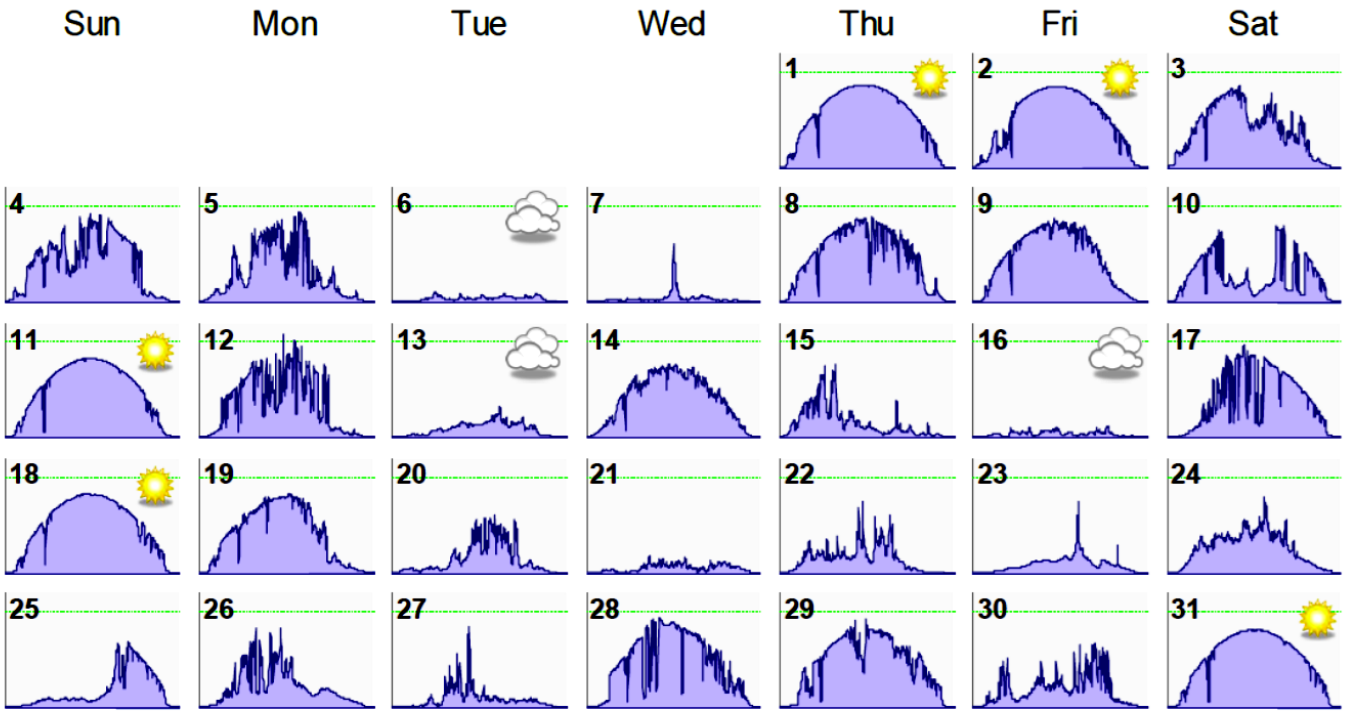
Rooftop Solar

- **Motivation**
  - Regions with abundant sunshine – Southwestern United States
  - Regions with high cost of electricity – California, Hawaii
  - Subsidies
  - Attractive tariffs
  - Desire to be green
- **Ownership Options**
  - Customers
  - Third party – First Solar, Solar City
  - Utility

Issues with Rooftop Solar

- Distribution systems not designed to handle large penetration – utilities use about 15% of peak load as a general guideline but it has not been proven by detailed analysis. Higher penetration is possible with proper planning and smart grid technology.
- Fluctuations in power and voltage due to intermittent clouds
- Reverse power flows into the grid
- Large power ramping needs during the morning and evening - Hawaii
- Loss of revenues for utilities – Some states require a monthly fixed fee to connect rooftop system to the grid - Arizona

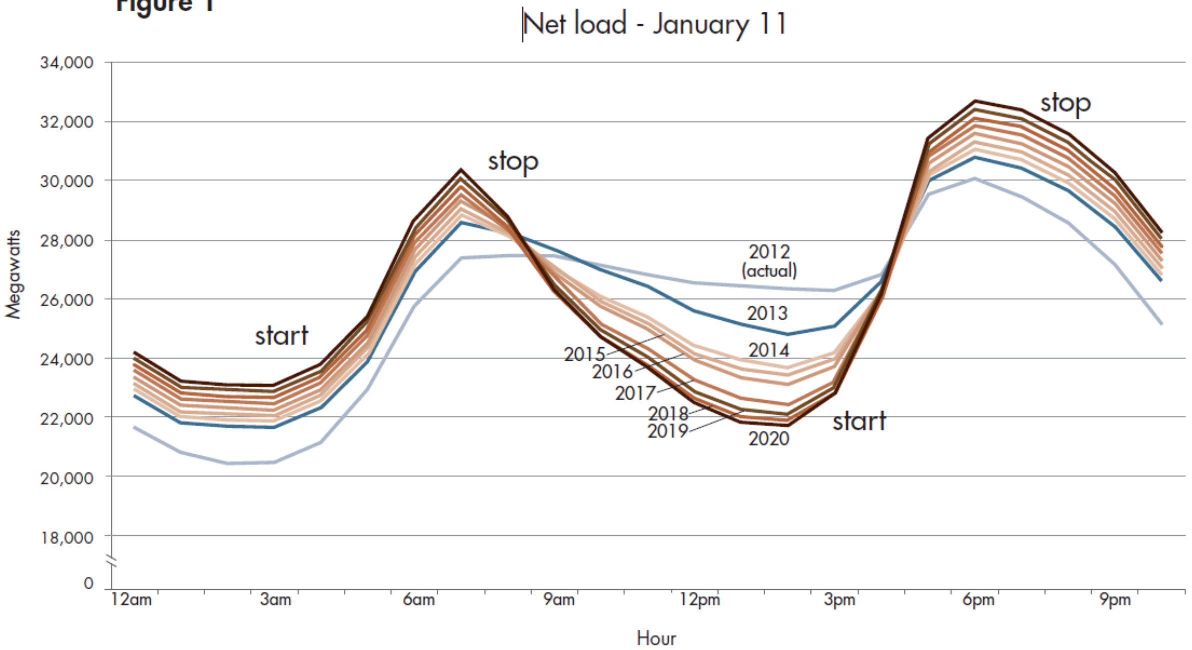
Solar Irradiance Variation



Source: K. Nicole, T. Key, C. Trueblood, “Distributed PV Monitoring: Highlights for PV Grid Integration Workshop ”, EPRI, Tucson, Arizona, 2012.

California ISO Duck Curve

Figure 1



- Steep ramps
- Oversupply risk
- Decreased frequency response

Net Load = Forecasted load – Variable Generation

Source: California ISO – Fast Facts: What the duck curve tells us about managing a green grid?, 2016. www.casio.com

Possible Remedies

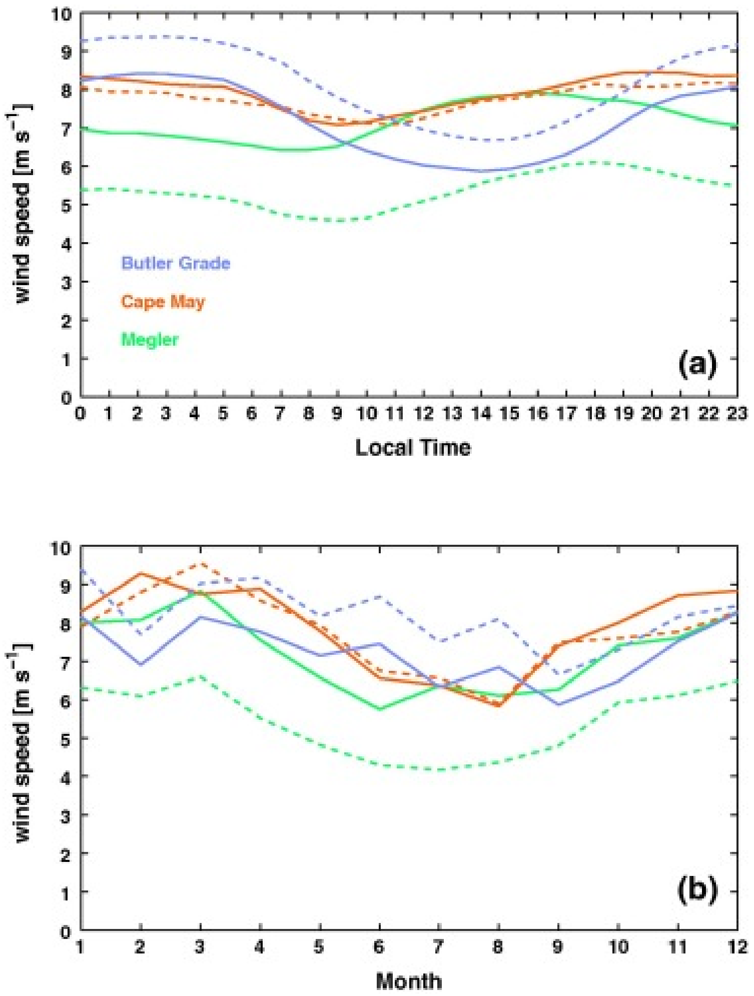
- Flexible Resource Capability
  - Upward and downward ramping
  - Ability to change direction quickly
  - Energy storage
  - Quick start
  - Start and stop multiple times in a day
- Coordination over a larger geographical area
  - Utilize resource diversity
- Better forecasting capabilities
  - Accurate forecasts of wind and solar energy availability allows better coordination with other resources
- Different rate designs to encourage higher use during mid-day
- Higher penetration of emerging loads – electric vehicles
- Batteries and other energy storage devices

Wind Forecasting

- A complex science
- Example:

Caroline Draxl, Andrew Clifton, Bri-Mathias Hodge, Jim McCaa, **The Wind Integration National Dataset (WIND) Toolkit,** Applied Energy, Volume 151, 2015, 355–366
http://dx.doi.org/10.1016/j.apenergy.2015.03.121

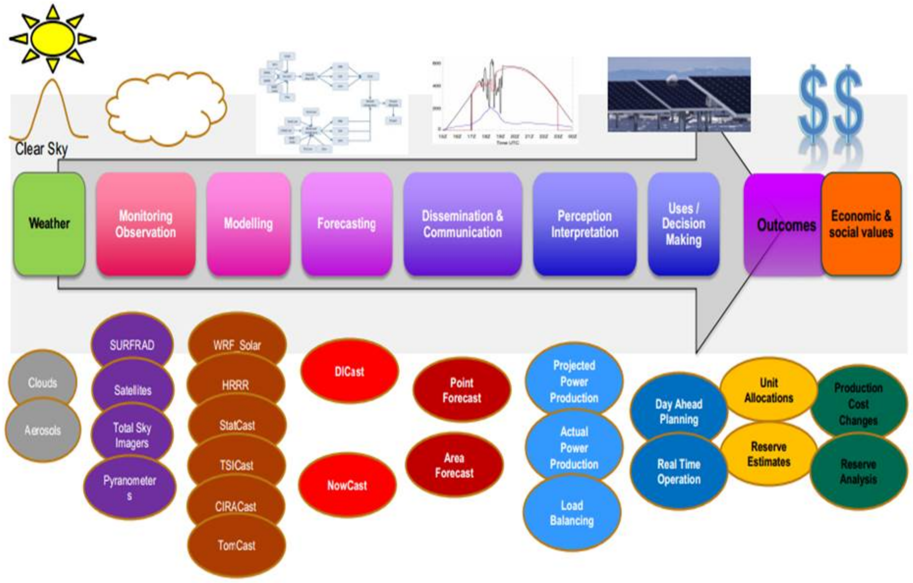
- Modeled wind speed follows the pattern of observed cycles
- The difference in magnitude of wind speeds depends on the site
- Annual cycles of modeled and observed wind speeds show the same trend



Solar Forecasting

A Public-Private-Academic Partnership to Advance Solar Power Forecasting

Sue Ellen Haupt & Sheldon Drobot
National Center for Atmospheric Research
DE-FOA-0000649/DE-EE0006016



SunShot
U.S. Department of Energy

R&D

The Watt-Sun Program Is Poised to Improve Weather Forecasting for Solar Energy

August 2014 | by Jim Utsler

A 20 megawatt solar farm in Tucson, Arizona, is one of the test sites for Watt-Sun.

Solar-power panels seem to be popping up on both residential and commercial rooftops like Morel mushrooms in the spring. And massive solar farms are being built in sun-friendly areas of the world. This is great news for renewable-energy proponents, who see solar—along with wind, waves and tides—as a way to wean the world off fossil fuels.

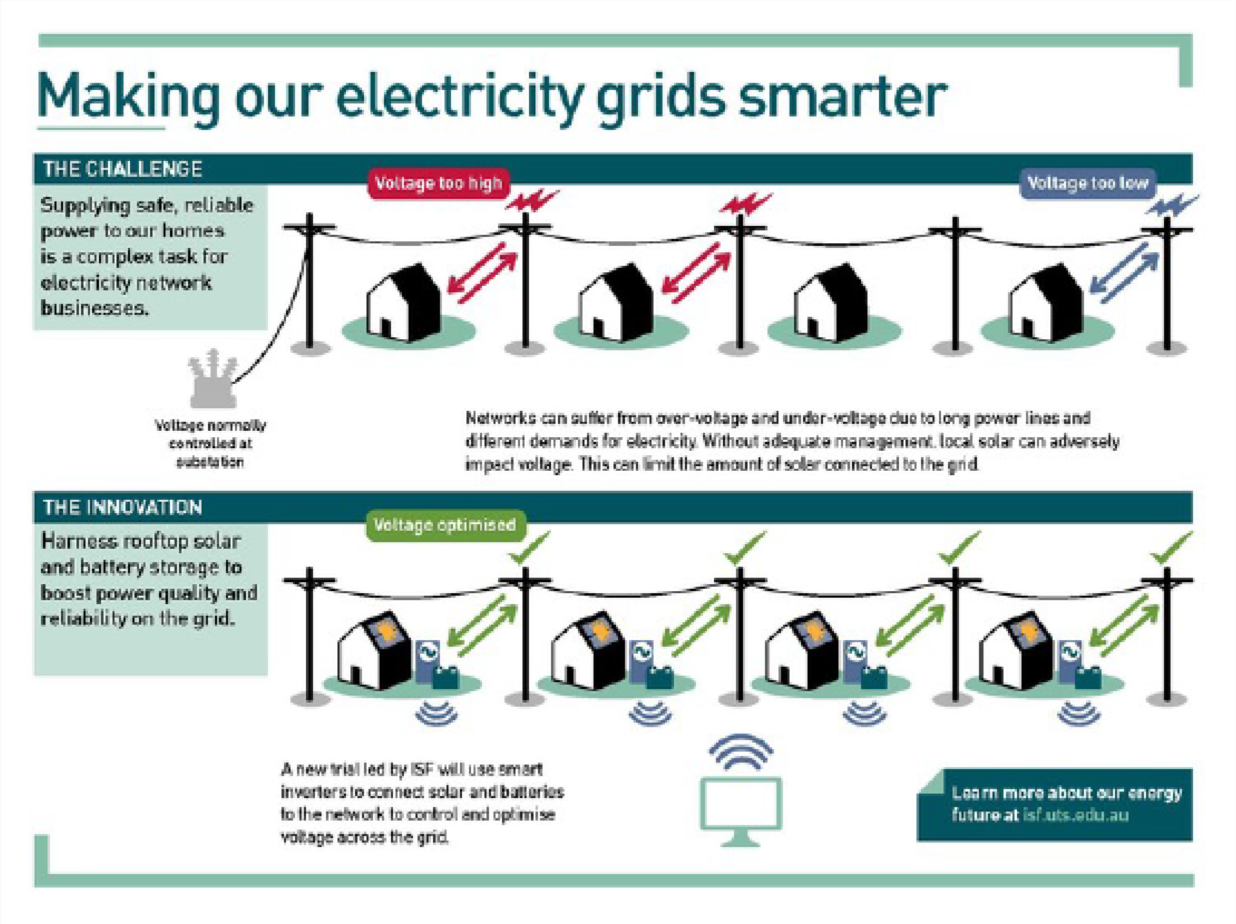
Crisis, what crisis? How smart solar can protect our vulnerable power grids

reneweconomy.com.au/crisis-crisis-smart-solar-can-protect-vulnerable-power-grids-42584/

Lawrence McIntosh & Dani Alexander 2/7/2017

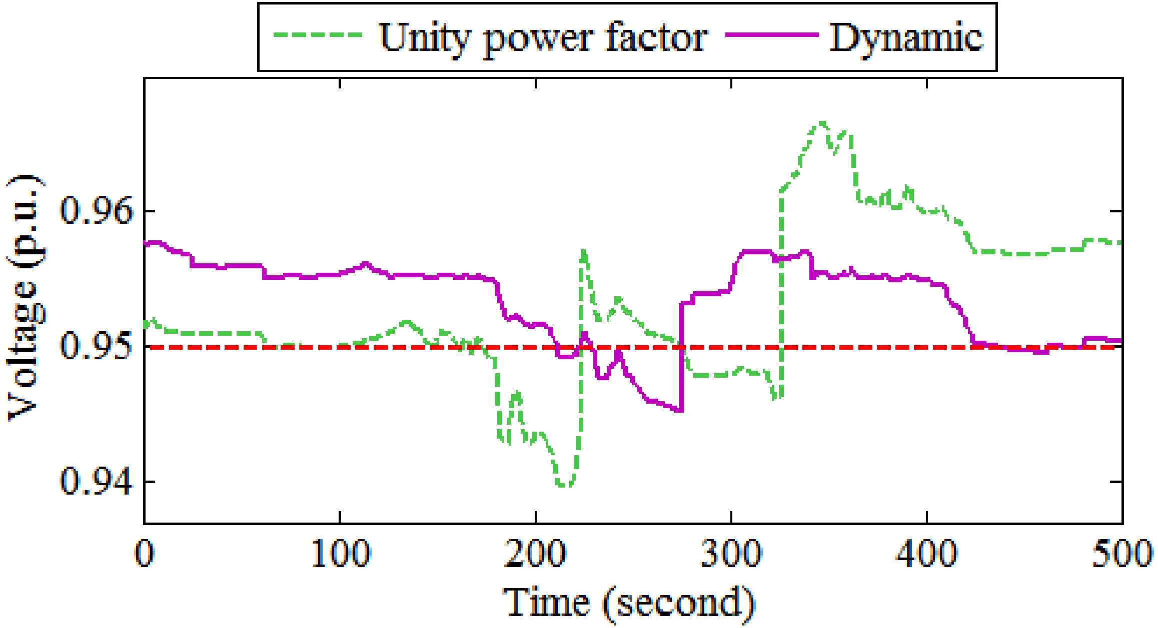
The Conversation

Solar panels can be both a headache and an opportunity for network companies. *AAP Image/Tracey Nearmy*



The innovation: smart inverters can control solar and batteries to help stabilise voltage on the grid.

Dynamic Control with Smart Inverters

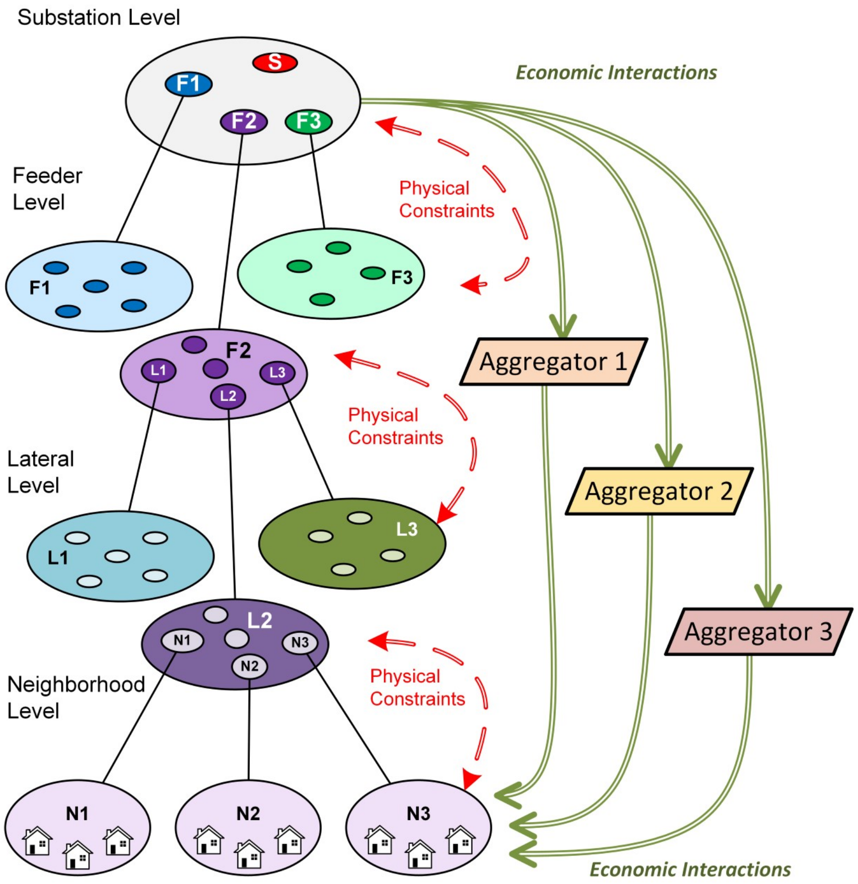


Source: A. Malekpour and A. Pahwa, “A Dynamic Operational Scheme for Residential PV Smart Inverters,” *IEEE Transactions on Smart Grid*,2016.

Regulation and Tariff

- Net Energy Metering (NEM) – Buy and sell at the same rate (Retail)
  - Is it fair?
  - Loss of revenues for utilities
- Cost and maintenance of assets for transmitting and distributing electricity
  - Wholesale rate for buying energy
- Value of reliability for consumers
  - Monthly connection charge - Arizona
- Proposed Changes in Time-of-Use Rates – California
  - Move peak rate from “Noon to 6 pm” to “4 to 9 pm” or “5 to 10 pm”

Retail Market



Anil Pahwa, Sanjoy Das, Bala Natarajan, Scott DeLoach, Dan Andresen, Philip Gayle, M.Nazif Faqiry, Pavel Janovsky, Kumarsinh Jhala, Haitham Kanakri, Ahmad Khaled Zarabie, “**Architecture for Future Distribution Systems Including Active Consumers with Rooftop Solar Generation,**” US National Science Project CNS – 1544705.

Conclusions

Grid Integration of Renewable Resources requires

- Appropriate siting of generation
  - Good potential for generation
  - Grid connection availability with strong transmission facilities
- Accurate wind and solar forecasting
- Dependence on flexible and agile resources
- Coordination over a larger geographical area
- Local and distributed control for rooftop solar
- Appropriate market conditions
- Compatible and fair rates - for both consumers and utilities