

Getting Connected: Utility Scale Wind



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Utility-Scale Renewable Energy

Integrating Wind and Solar
Generation



Market Outlook

Grid Interconnection

Impact of Transmission Constraints

MARKET OUTLOOK

Market forces reshaping the renewables outlook



Major Shifts on the Horizon

- Retirement of Aging Generators
 - Coal: 60,000 MW scheduled to retire by 2015.
 - Nuclear: 23MW up for License Renewal by 2024.
- Natural Gas generation will replace majority of coal and nuclear
- Quick start/stop NatGas technology compliments variable energy resources

Economics of Renewables

- Grid Parity *without tax incentives* possible in near future
- ~20% Performance Increases with new technology
- Significant Component Cost Reductions
- No new generation source can be built for less money or in less time
- Of the 80GW potentially retiring, wind can conservatively replace 15-20%

Table 1. Estimated Levelized Cost of New Generation Resources, 2016.

Plant Type	Capacity Factor (%)	U.S. Average Levelized Costs (2009 \$/megawatthour) for Plants Entering Service in 2016				
		Levelized Capital Cost	Fixed O&M	Variable O&M (including fuel)	Transmission Investment	Total System Levelized Cost
Conventional Coal	85	65.3	3.9	24.3	1.2	94.8
Advanced Coal	85	74.6	7.9	25.7	1.2	109.4
Advanced Coal with CCS	85	92.7	9.2	33.1	1.2	136.2
Natural Gas-fired						
Conventional Combined Cycle	87	17.5	1.9	45.6	1.2	66.1
Advanced Combined Cycle	87	17.9	1.9	42.1	1.2	63.1
Advanced CC with CCS	87	34.6	3.9	49.6	1.2	89.3
Conventional Combustion Turbine	30	45.8	3.7	71.5	3.5	124.5
Advanced Combustion Turbine	30	31.6	5.5	62.9	3.5	103.5
Advanced Nuclear	90	90.1	11.1	11.7	1.0	113.9
Wind	34	83.9	9.6	0.0	3.5	97.0
Wind – Offshore	34	209.3	28.1	0.0	5.9	243.2
Solar PV ³	25	194.6	12.1	0.0	4.0	210.7
Solar Thermal	18	259.4	46.6	0.0	5.8	311.8
Geothermal	92	79.3	11.9	9.5	1.0	101.7
Biomass	83	55.3	13.7	42.3	1.3	112.5
Hydro	52	74.5	3.8	6.3	1.9	86.4

Clean Coal: 136.2

Nuclear: 113.9

Wind: 97.0

PV: 210.7

Source: Energy Information Administration, Annual Energy Outlook 2011

Trends

- Wind
 - Multi-megawatt turbines capture more wind with fewer towers
 - Offshore development increasing
- Solar
 - Attractive for its load-following production patterns
 - Easier siting
 - Best solar resources are in high-price electricity markets
 - Look for future solar development in conjunction with combined cycle gas turbine sites

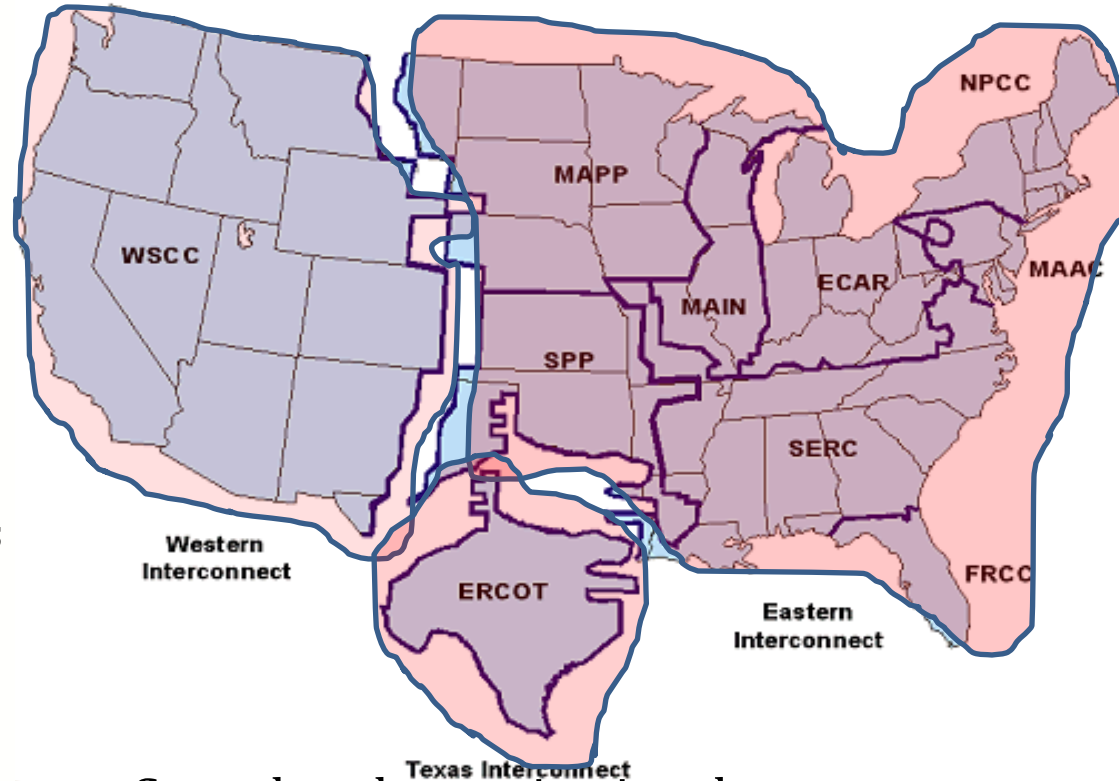
GRID INTERCONNECTION

Getting new generation to the market



What is “The Grid”?

- Three major Interconnects in US (extends into Canada)
- The Eastern Interconnect: The largest, most complex machine ever built
 - Thousands of generators, millions of miles of transmission
 - Billions of load units
 - All operating in synchrony



- Convoluted organizational structures and control boundaries
- Fragile; Still relying on infrastructure from the 50s

Tricky Balancing Act

- Supply must precisely equal demand at all times to prevent grid collapse
- Need the capacity of a freight train and the agility of a Ferrari
- “Load Balancing Authorities” constantly monitor and adjust, using generator dispatch and curtailment
- Map is further divided into ISO regions which govern transmission planning and new generator interconnections
- To accept new generation into the grid, the ISO must do a series of complex studies

Interconnection Studies

- Feasibility Study
 - Any transmission constraints?
- System Impact Study
 - Can be subjective—what fault scenarios should be modeled?
 - What network upgrades are required for entire study group
 - Allocates cost of network upgrades to each new generator
- Definitive Planning
 - Must meet significant financial milestone to proceed
 - Restudy System Impacts, based on who drops out and re-allocate costs
- Facilities Study
 - Study project on individual basis to arrive at firm cost quote
- Negotiate Generator Interconnection Agreement

Challenges for Renewable Developers

- Each ISO has its own tariff and process
- All of them lengthy and expensive!
- Approximately \$500,000 to fund transmission studies
- 2-3 years in theory, 5+ years in practice
- “Black box”: Hard to estimate feasibility, cost in advance
- New generation pays for the network upgrades
 - Last car entering the highway pays for it all
 - Exceptions made for reliability, public policy
- Queues bogged down by more new generation than the grid can handle. Speculative?

TRANSMISSION CONSTRAINTS

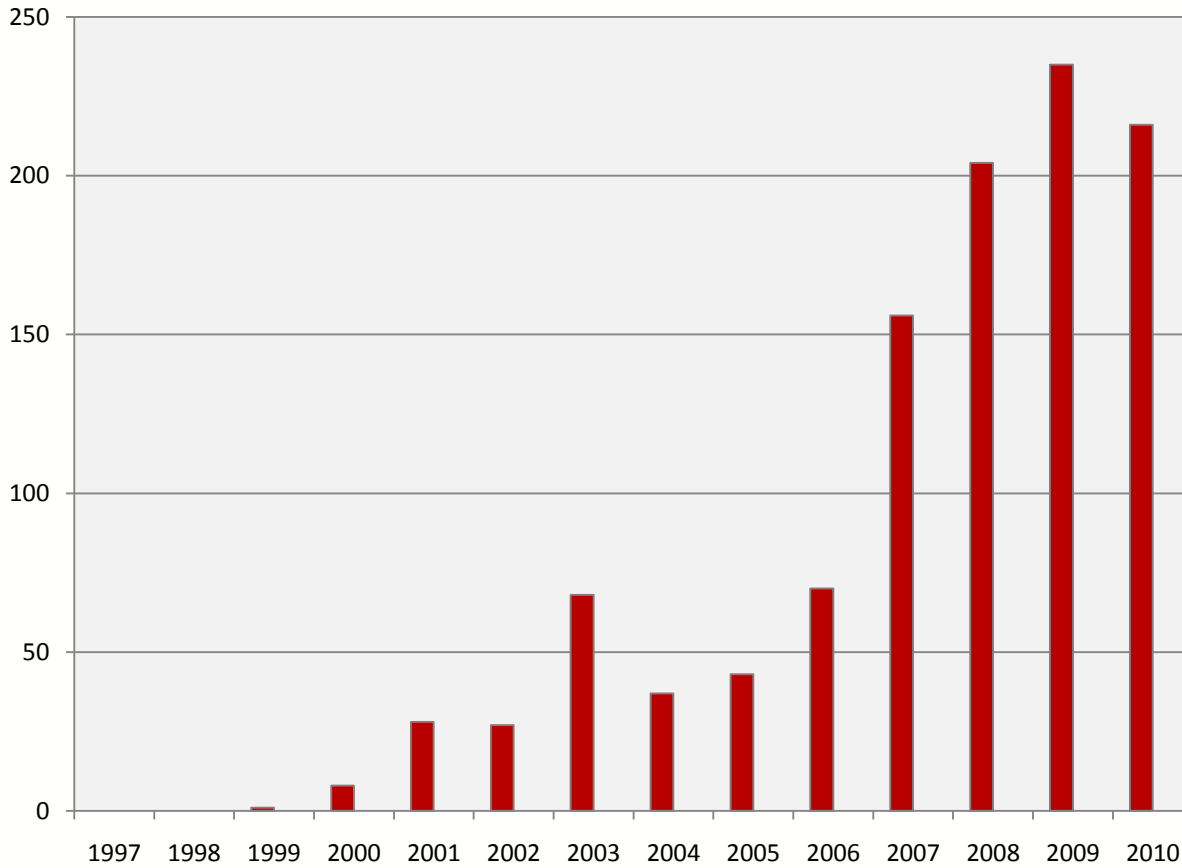
Not just a “Renewables Problem”



Transmission Congestion

- Important limiting factor in expanding the benefits of renewable energy
- Decades-long decline in transmission investment = overloaded infrastructure
- Poses Economic and security threat
- Causes Long-term market inefficiency
 - Congestion favors existing generators over lower cost new generation
 - Great variance in regional prices

Transmission Loading Relief (TLR) Events



- TLR protocol goes into effect during Congestion (grid overload) emergencies.
- Cutting off customers is last resort, so we're not aware of the crisis
- Severity of response escalates from 1-6.
- Chart shows level 5 and higher events in US since 1997
- 2010 declines are mainly due to economy, not grid improvements
- **Bottom line: We have major capacity constraints!**

Transmission Expansion

- Driven by both policy and market forces
- Midwestern initiatives will encourage exporting windpower
 - CapEx2020
 - ~675 miles high voltage lines in upper midwest
 - Cost split 90% generators / 10% utilities
 - Multi Value Projects (MVP)
 - Backbone transmission to support reliability, market efficiency, public policy (including renewable mandates)
 - Cost “goes to load” – Cost allocation dispersed throughout MISO region
- Difficult Obstacles
 - State and sometimes local control over siting
 - Coal industry states sit between wind and load centers
 - **No one likes transmission**

Looking Ahead

- Wind and Solar poised to achieve grid parity
- Despite current difficult market, expect major investment in next 5-10 years
- Consistent policy needed to create investment-friendly business climate
- If you like renewables, get behind transmission



Questions?



Thank you!