

Lessons Learned: Integrating Bulk Renewable Energy

Gridweek 2011
Integrating Renewables and DER
15 September 2011



EnerNex

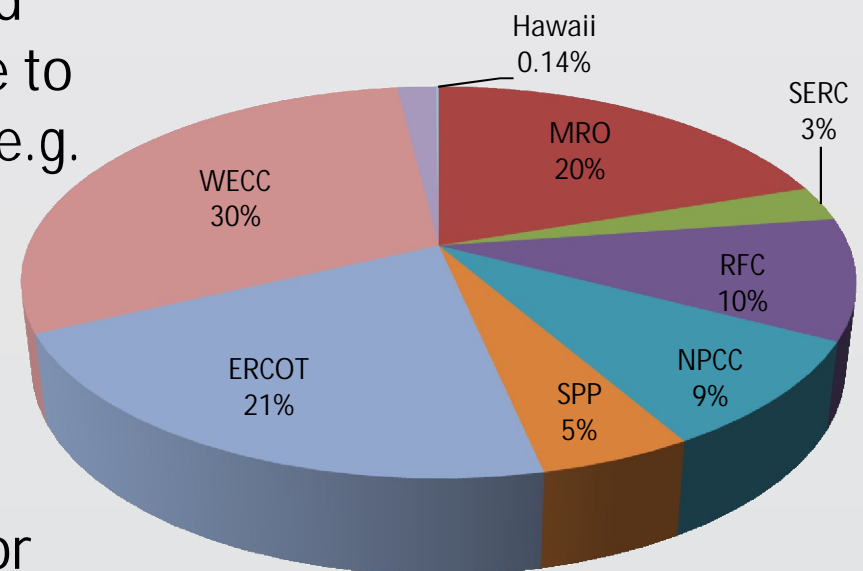
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GridWeek 2011

US Bulk Wind Generation - Status

- ▶ 40 GW of bulk wind generation in U.S. at end of CY2010
 - ~12 GW in WECC
 - ~8 GW in ERCOT
 - 20 GW in Eastern Interconnection
- ▶ Not uniformly distributed; some BAAs and RTOs have significant penetration relative to load and installed conventional capacity, e.g.
 - ERCOT
 - BPA
 - Xcel-PSCO, Xcel-SPS
- ▶ Wind generation, and anticipation of growing solar component, are catalysts for development of new analytical approaches and operational practices

Fraction of Total Installed U.S. Wind Capacity (by NERC Regional Entity)



Bulk System Impacts of Variable Renewable Generation

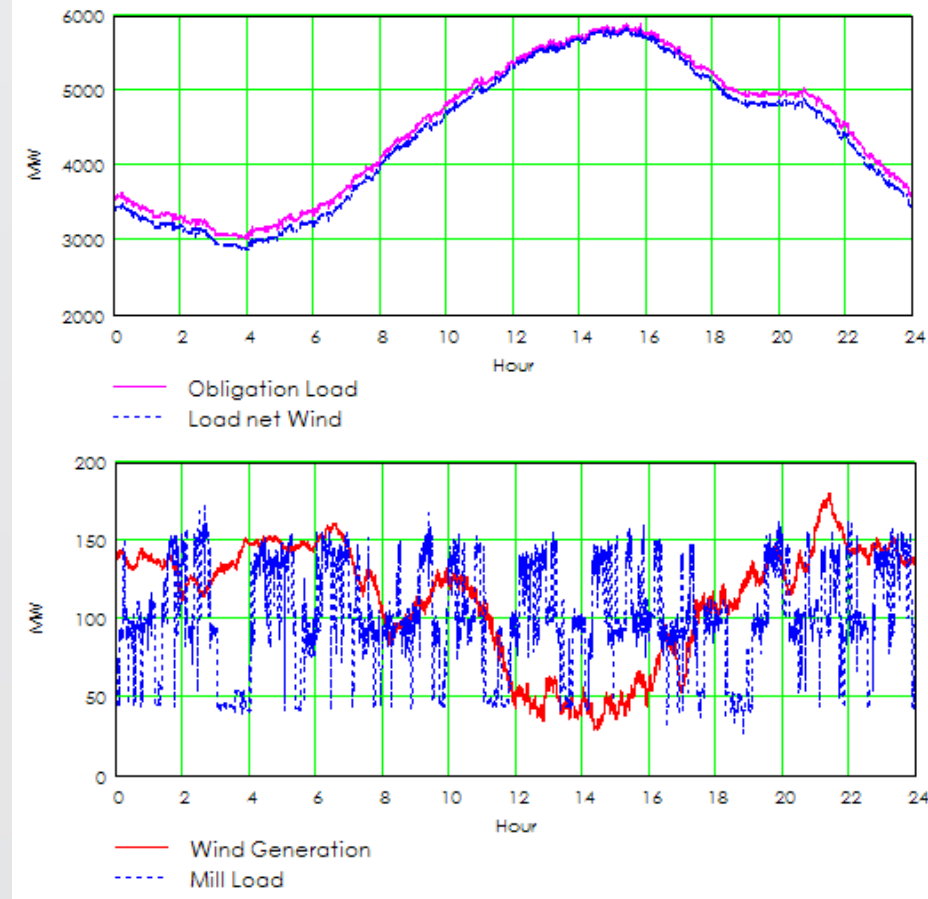
- ▶ Grouped into two major categories
 - Interconnection: emphasis on voltage, reactive power, stability impacts (planning and engineering)
 - Integration: determining how variable generation will change the roles and deployment of conventional resources (operations)
- ▶ Bulk wind generation initially posed some serious interconnection challenges
 - Large wind plants connected in remote/weak areas of transmission network
 - Early emphasis of wind industry was putting turbines in the ground, not engineering power plants
- ▶ Engineering practice for wind plant design has been accumulating for a decade.
- ▶ Wind plants can be designed to behave like conventional power plants – for the most part...

Wind Integration: Why the Concern?

- ▶ Wind generation is an attractive source of electric energy
- ▶ The electric power business is based on capacity
 - System planning
 - Reliability considerations
- ▶ Wind energy doesn't fit this model well
 - Variability
 - Uncertainty
- ▶ What are the technical and financial consequences of these attributes?

Dealing with Variability and Uncertainty

- ▶ We are accustomed to some degree of variability and uncertainty
 - Variability
 - Load varies by seconds, minutes, hours, by day type, and with weather
 - Supply resources may not be available or limited in capacity due to partial outages
 - Prices for power purchases or sales exhibit are not constant
 - Uncertainty
 - Operational plans are made on basis of best available forecasts of needs; some error is inherent
 - Supply side resource available with some probability (usually high)



Key Questions

- *How does wind generation affect this existing variability and uncertainty?*
- *What are the costs associated with the changes?*
- *Can we maintain the integrity of the system under these new conditions?*

Grid Integration: Status

- ▶ Significant experience has accumulated over the past decade
 - Through integration studies of increasing scope and complexity
 - From actual operating experience
- ▶ Lessons Learned
 - Integration costs are not zero, but so far they are shown to be modest (~\$5.00/MWH of wind)
 - Diversity has significant benefits
 - Wind production forecasting will play a critical role
 - Large balancing areas / market footprints facilitate wind integration
 - Larger number and type of supply resources
 - Optimization over larger footprint less sensitive to wind-introduced uncertainties
 - Fast and flexible market structures facilitate integration (e.g. sub-hour or RT energy markets, within-hour scheduling, well-designed ancillary services offerings, etc.)
 - Substantial penetrations (e.g. 20%+) are likely manageable with the existing conventional fleet

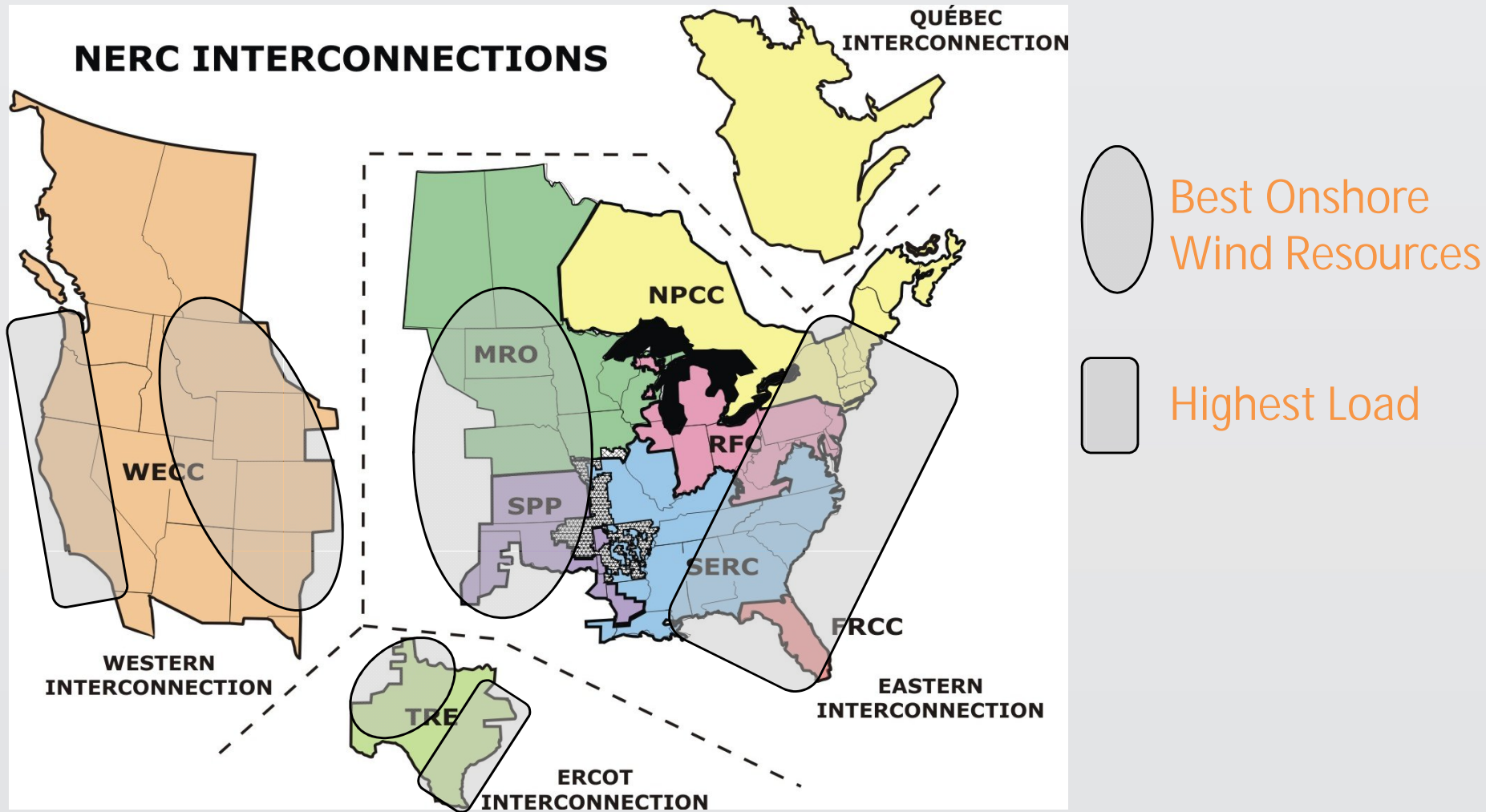


Going Forward

- ▶ Regional transmission can support some additional development in near term
- ▶ Further substantial wind energy development and transmission are tightly linked (other variable bulk renewables, such as solar, are also implicated)
 - Transmission congestion already limiting further development in high-quality resource areas
 - Some transmission expansion underway for expressed purpose of tapping bulk renewable energy (e.g. ERCOT, SPP)
- ▶ Aggressive development requires substantial grid modifications

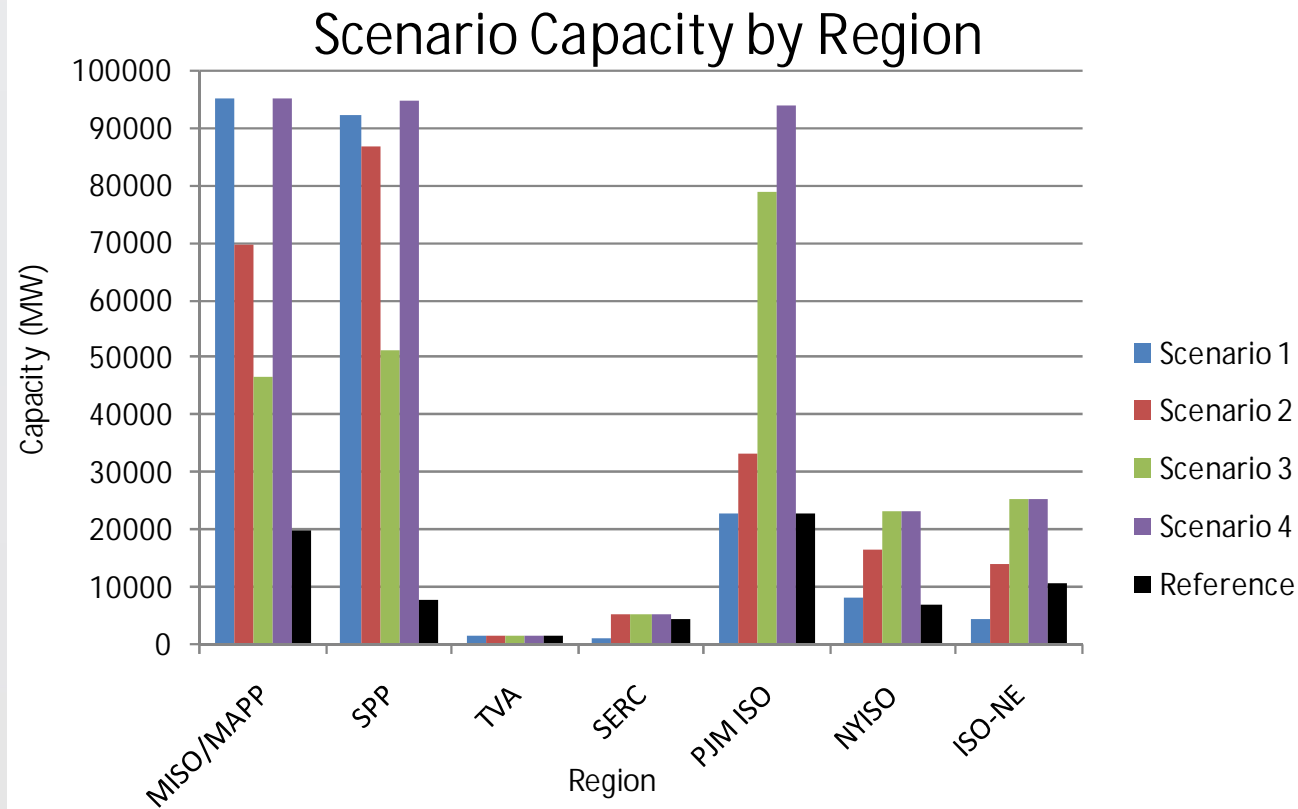


Lots of wind, Lots of load, Lots of distance

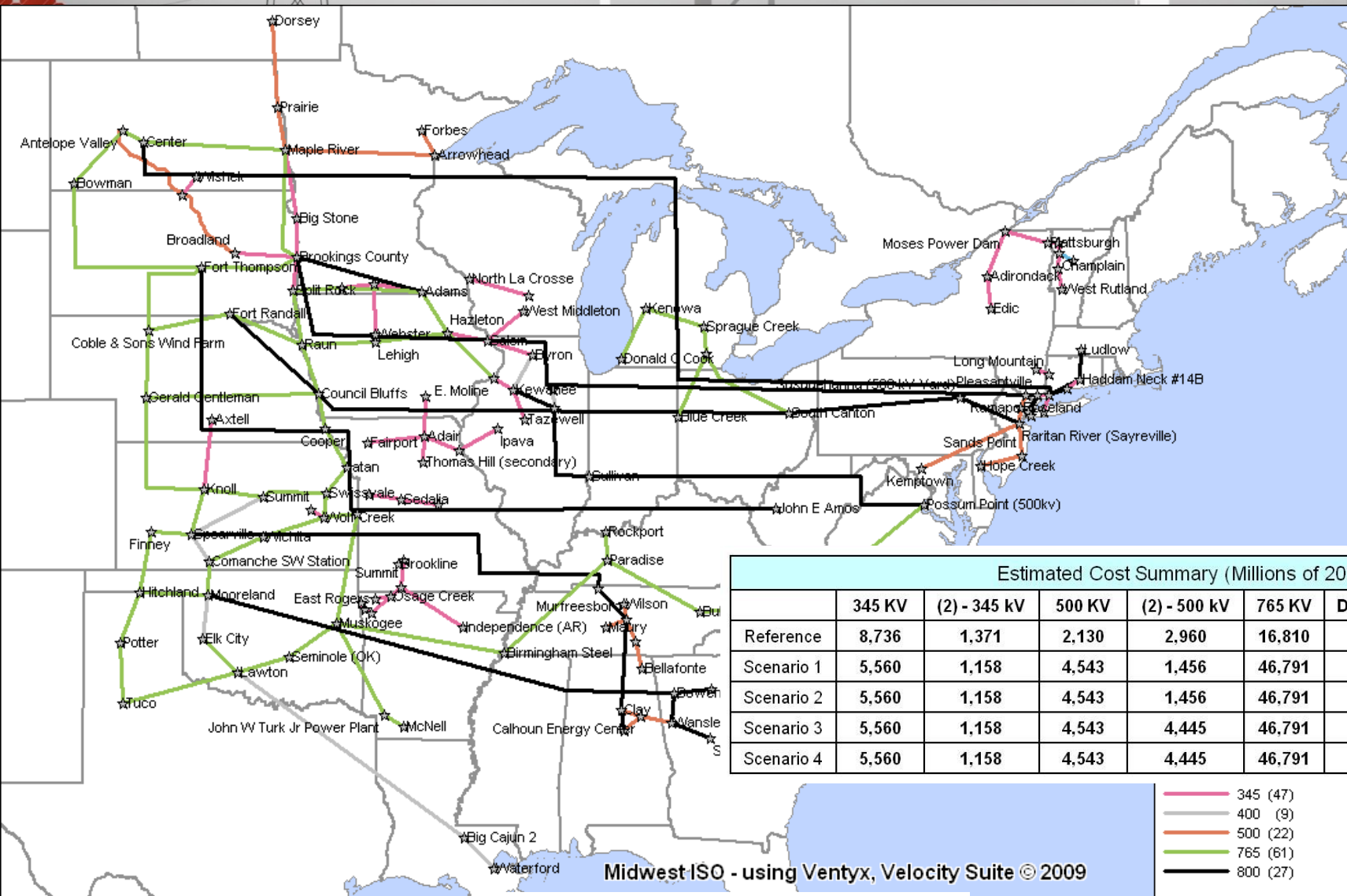


A look at 20% Wind Energy in the EI

- ▶ Eastern Wind Integration and Transmission Study
- ▶ Installed wind generation capacity
 - 20% \approx 230 GW
 - 30% \approx 330 GW
- ▶ Considered multiple scenarios for reaching 20% EI energy from wind
- ▶ High-quality wind resources in Great Plains were a significant part of each scenario



Transmission as a tool for integration



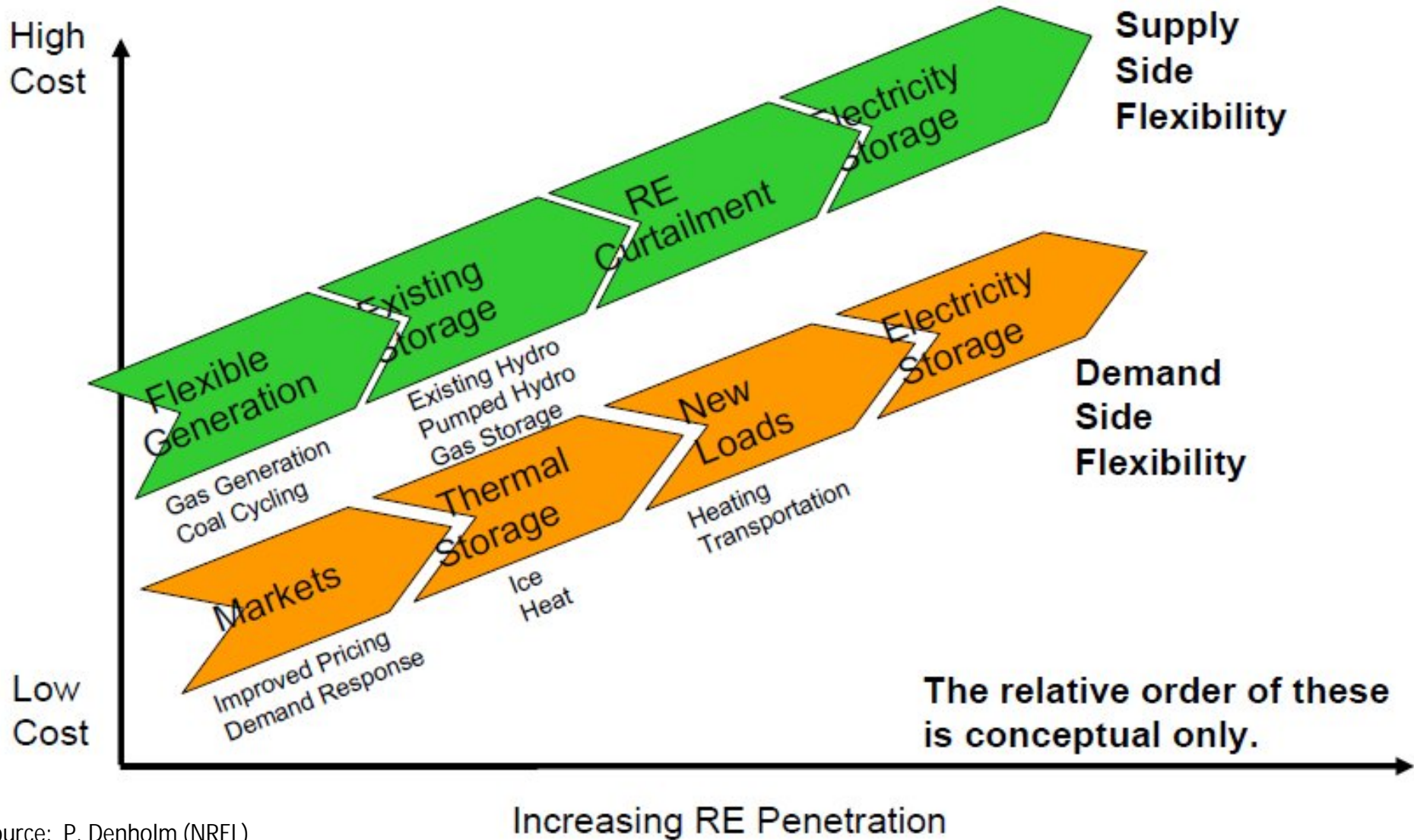
Estimated Cost Summary (Millions of 2024\$)

	345 KV	(2) - 345 kV	500 KV	(2) - 500 kV	765 KV	DC - 400 kV	DC - 800 kV	Total
Reference	8,736	1,371	2,130	2,960	16,810	2,155	14,400	48,562
Scenario 1	5,560	1,158	4,543	1,456	46,791	2,397	83,265	145,169
Scenario 2	5,560	1,158	4,543	1,456	46,791	2,397	62,640	124,544
Scenario 3	5,560	1,158	4,543	4,445	46,791	2,957	35,603	101,056
Scenario 4	5,560	1,158	4,543	4,445	46,791	2,397	79,298	144,191

- 345 (47)
- 400 (9)
- 500 (22)
- 765 (61)
- 800 (27)

\$100+ Billion for 20% +

Flexibility is the key for bulk renewable integration



Source: P. Denholm (NREL)

Increasing Emphasis on Interoperability

- ▶ Exchange of data and information among stakeholders in real-time will be critical
 - Wind plant operators
 - Grid operators
 - Forecasting entities
- ▶ Current architecture for this information exchange is difficult to scale – propriety, many vendors, actors
- ▶ Standards are available (e.g. 61400-25 “Wind Plant Communications and Control”)
 - not widely used in U.S.
 - being addressed in SGIP PAP-16

Summary

- ▶ Moderate penetrations of bulk renewable energy can be accommodated through
 - Operational/market changes
 - Enhanced forecasting applications
 - Interoperability
- ▶ Wind (and, presumably, bulk solar) plants can be designed to behave like conventional plants, excepting control of real power production
- ▶ Transmission is a major barrier going forward – regional and extra-regional
- ▶ Growing penetrations of bulk renewable energy will increase the premium for operational flexibility
- ▶ Economics will be the major criteria in increasing flexibility