U.S. DEPARTMENT OF ENERGY

Energy Efficiency & Renewable Energy

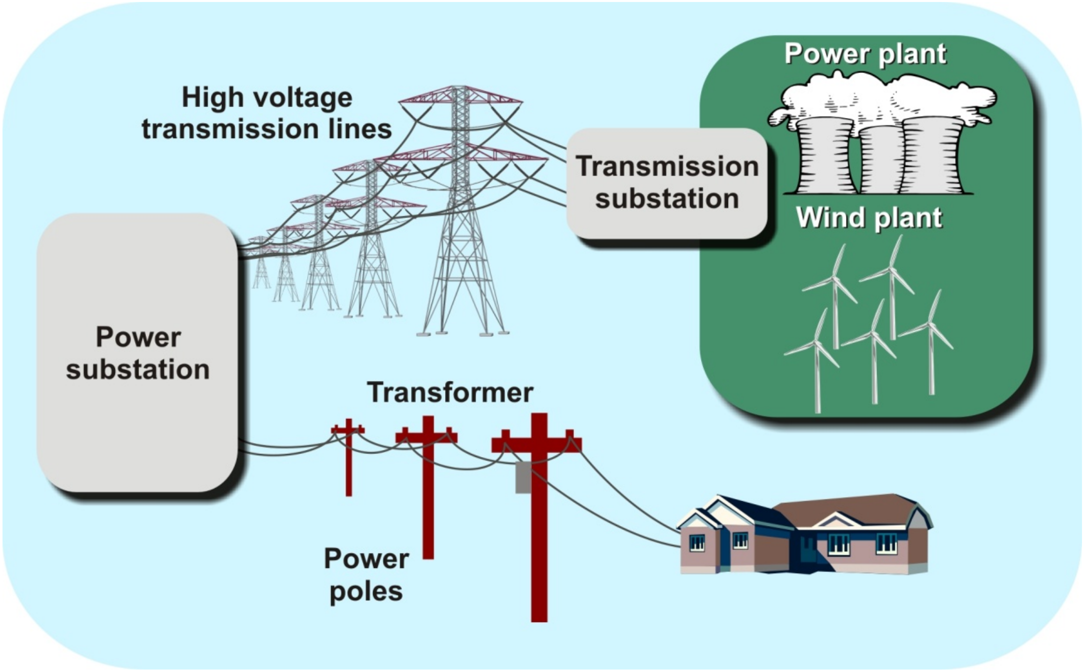
# 20% Wind Energy by 2030

## Chapter 4: Transmission and Integration into the U.S. Electric System

### Summary Slides

# Enhanced electricity delivery necessary with increased wind deployments

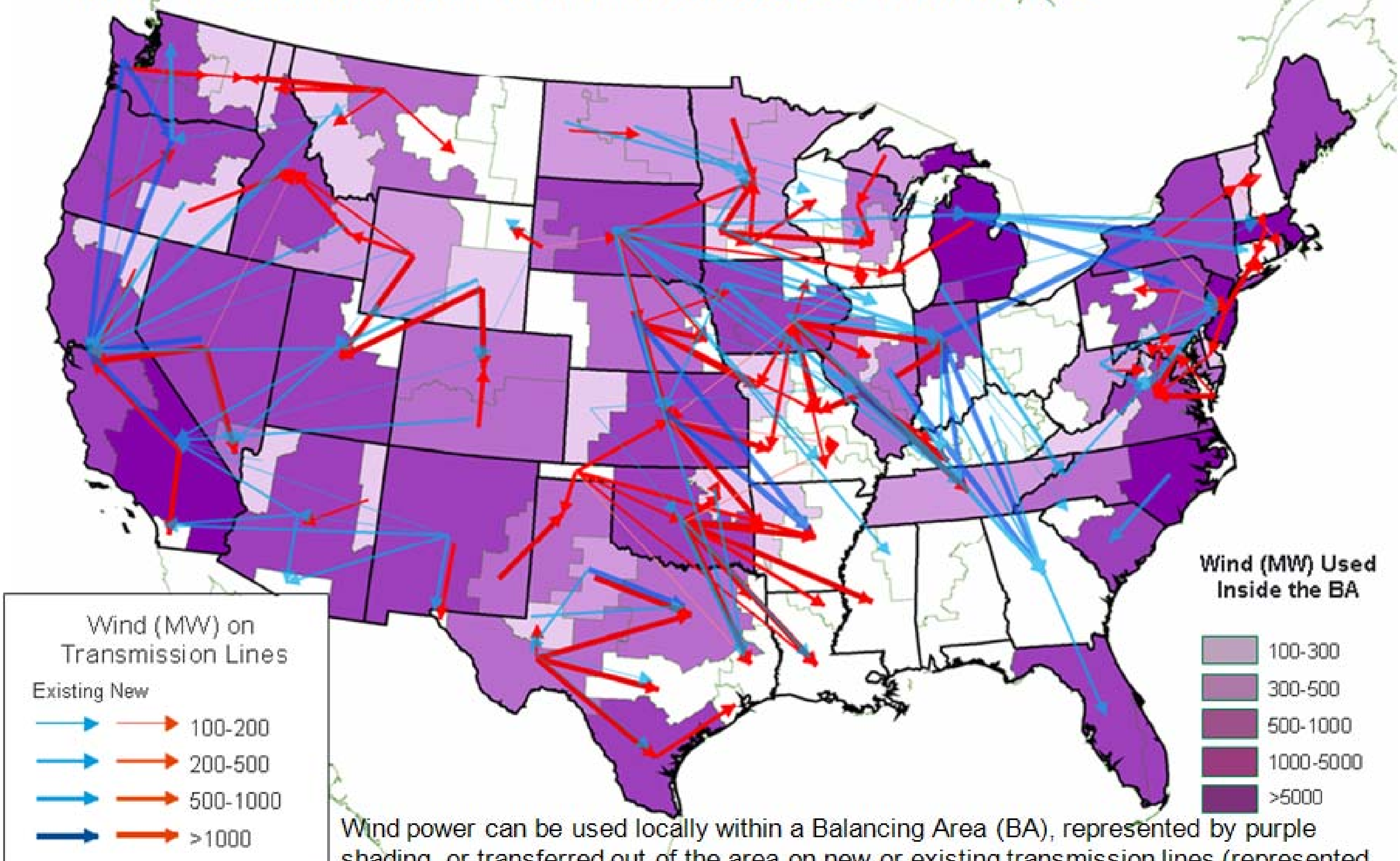
- Enhancement of electrical transmission system required in all electricity-growth scenarios, not just wind
- Transmission is needed to:
  - Relieve congestion in existing system
  - Improve system reliability for all customers
  - Increase access to lower-cost energy
  - Access new and remote generation resources




- Wind requires more transmission than some other options as best winds are often in remote locations

# New wind will require new transmission to deliver wind-generated electricity from high-resource areas to high-demand centers

- Remote resources can be brought to urban population centers when there is a concerted effort to work across boundaries

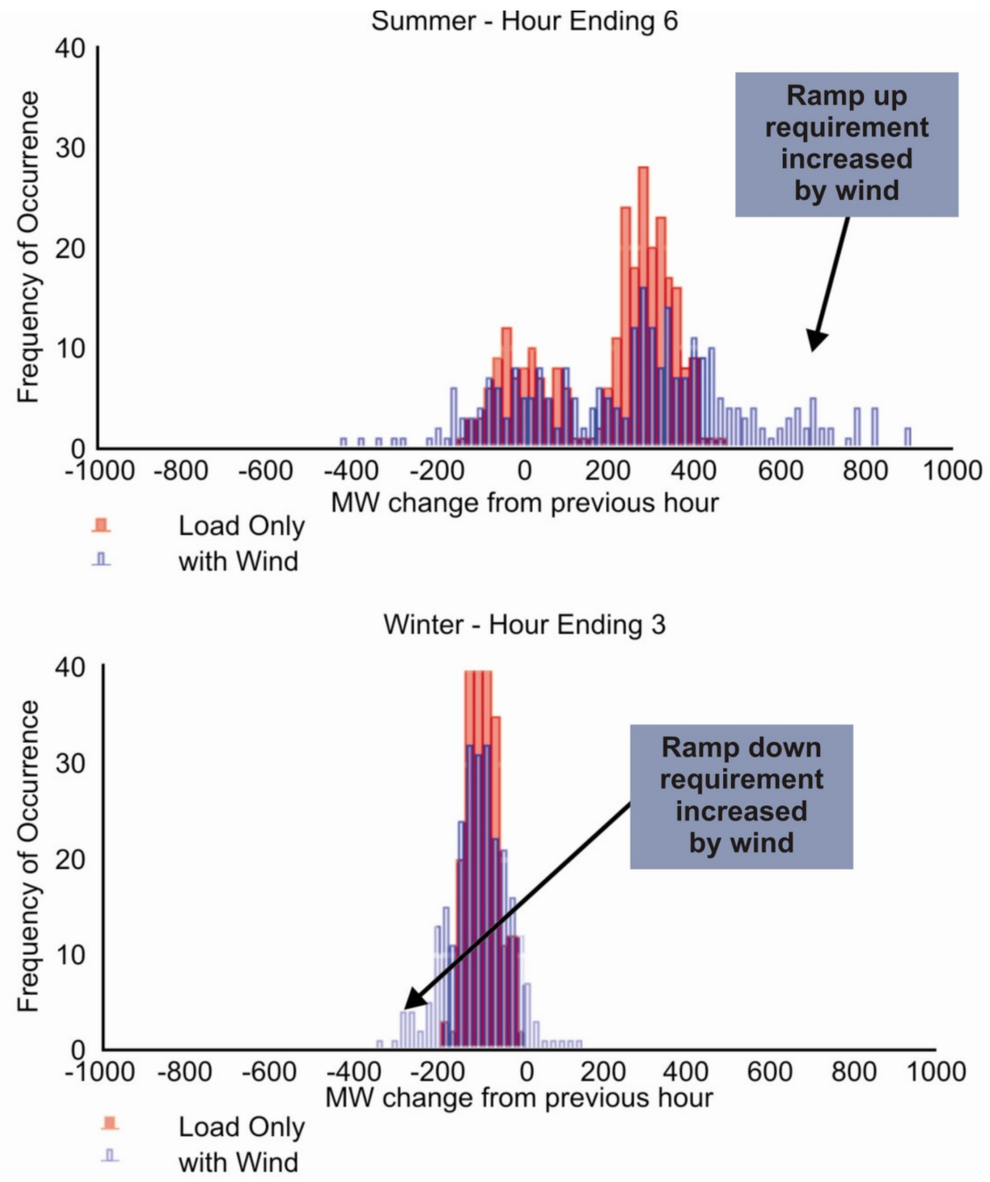



Wind power can be used locally within a Balancing Area (BA), represented by purple shading, or transferred out of the area on new or existing transmission lines (represented by red or blue arrows). Arrows originate and terminate at the centroid of the BA for visualization purposes; they do not represent physical locations of transmission lines.

# A system with wind generation needs more active load-following generation capability

- More high-ramp requirements with wind than without wind
- A system with wind generation needs more active load-following generation capability

*Impact of wind on load-following requirements*

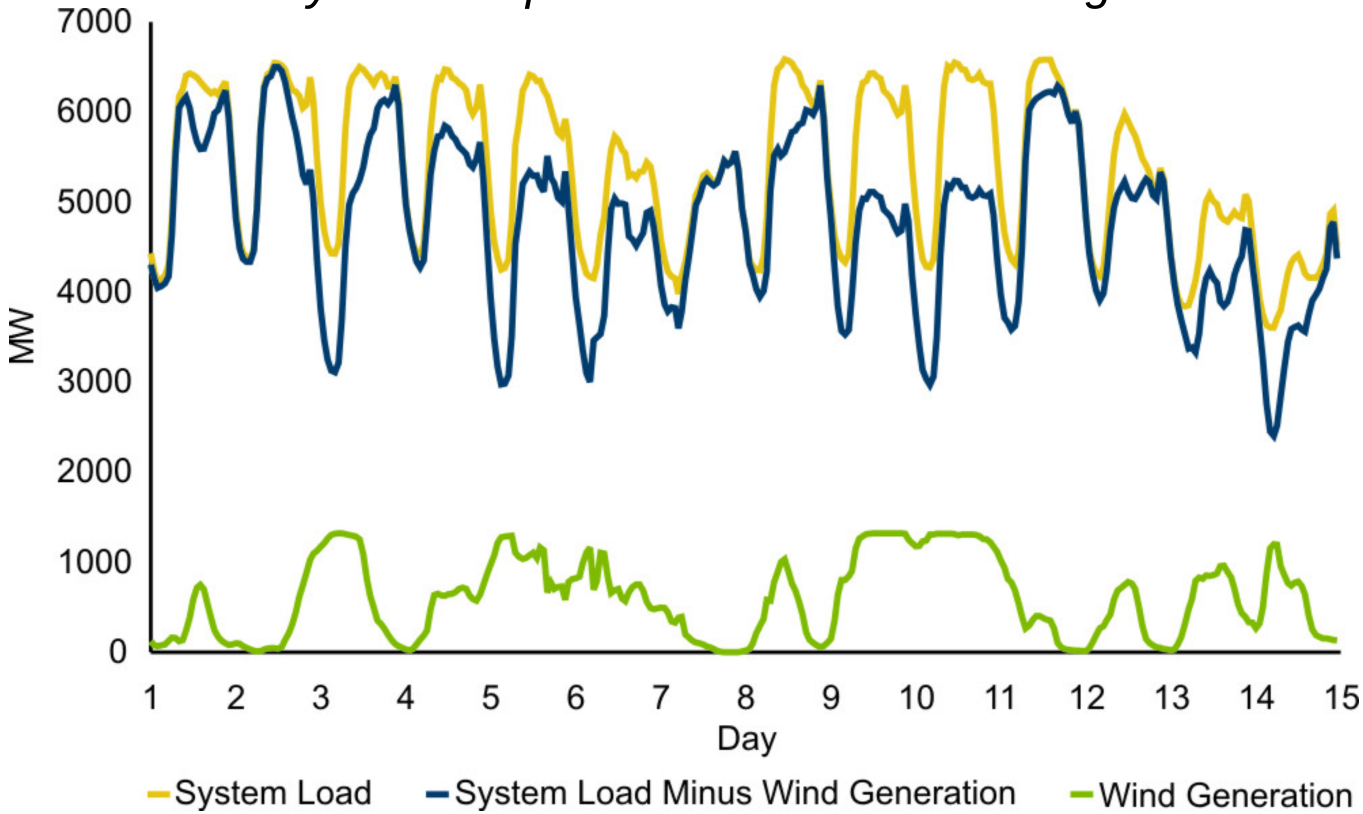



This figure illustrates the incremental load-following impact of wind on an electrical system, as determined in the work of Zavadil and colleagues (2004). The histograms show more high-ramp requirements with wind than without wind, and a general reduction in small-ramp requirements with wind than without wind, and a general reduction in small-ramp requirements compared to the no wind case.

# Integration of wind-plant output forecasting is critical

- Seamless integration of wind-plant output forecasting is a critical next step in accommodating large penetrations of wind power
- Price responsive load markets and associated technologies are components of a well-functioning electricity market and increase accommodation of wind's variability

*Hourly load shapes with and without wind generation*



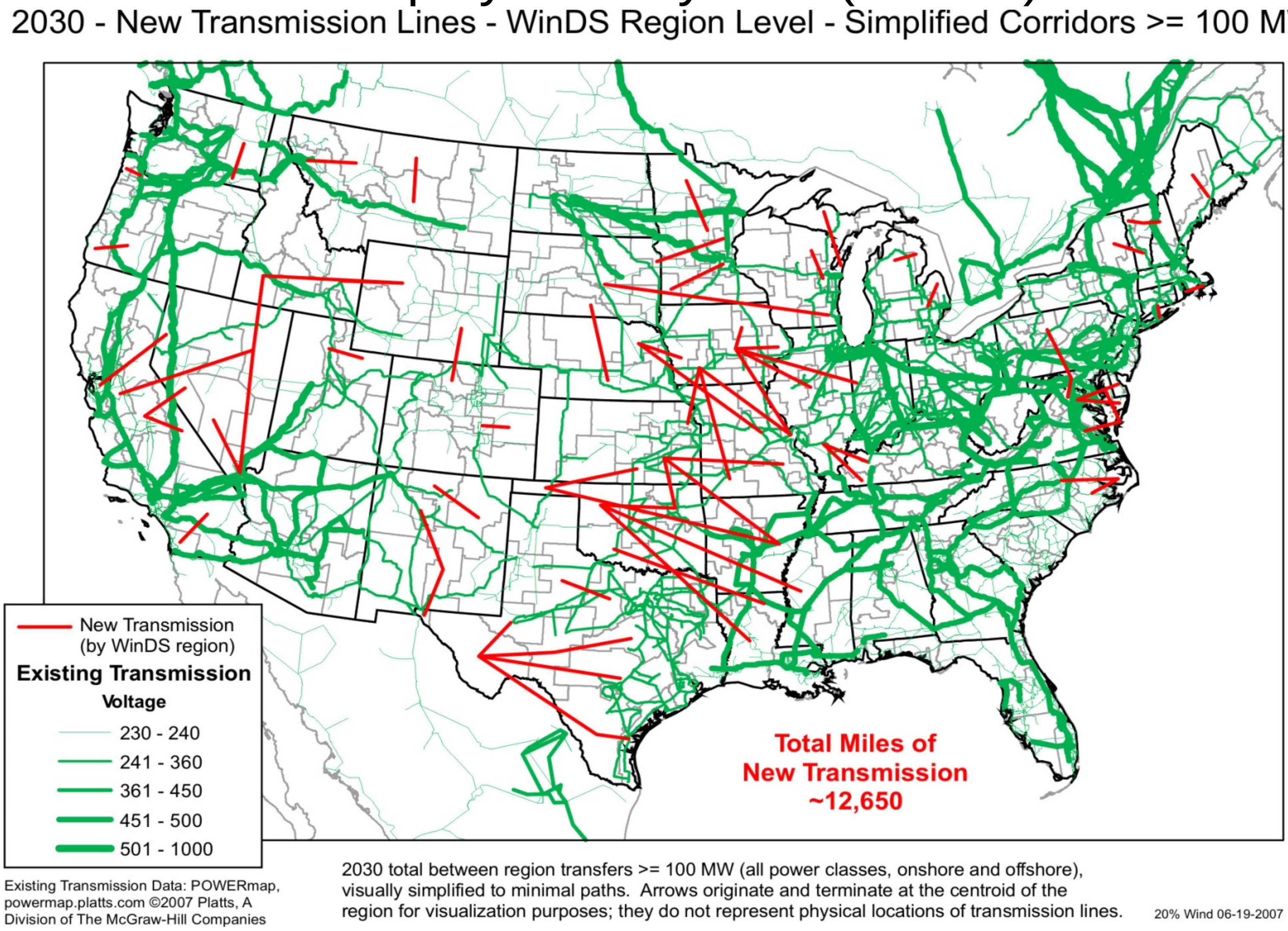

This figure shows a two-week period of system loads in the spring of 2010 for the Xcel system in Minnesota. This system has 1500 MW of wind capacity on a 10,000 MW peak-load system. Because both load and wind generation vary, it is the resulting variability-load net of wind generation-that system operators must manage, and to which the non-wind generation must respond.

# Wind system interconnection presents challenges

- **Cost:** investment of approximately $60 billion in transmission is needed between now and 2030, or $3 billion per year for 22 years
- **Planning:** transmission developers are reluctant to step forward until generator interconnection requests have been filed ("chicken or the egg conundrum")
- **Cost allocation:** transmission is a "public good" and its benefits are often widely dispersed
- **Cost recovery:** new transmission facilities will not be built unless there is certainty that the cost will be recovered in a predictable manner
- **Siting:** public engagement about expanding the grid is often a major long-term challenge to transmission expansion

# 12,650 total miles of new transmission needed to accommodate wind in scenario

- Conceptual New Transmission Line Scenario using NREL's Wind Deployment System (WinDS) Model




WinDS model looks at distance from point of production to point of consumption and cost-effectiveness of production near load versus in remote locations based on transmission costs. WinDS finds that it is more cost-effective to site projects remotely.

# Recent studies suggest wind integration costs would be generally less than 10% wholesale cost of energy

| Date | Study | Wind Capacity Penetration (%) | Regulation Cost ($/MWh) | Load Following Cost ($/MWh) | Unit Commit-ment Cost ($/MWh) | Gas Supply Cost ($/MWh) | Total Operating Cost Impact ($/MWh) |
|---|---|---|---|---|---|---|---|
| May 03 | Xcel-UWIG | 3.5 | 0 | 0.41 | 1.44 | na | 1.85 |
| Sep 04 | Xcel-MNDOC | 15 | 0.23 | na | 4.37 | na | 4.60 |
| Nov 06 | MN/MISO | 35 (25% energy) | 0.15 | na | 4.26 | na | 4.41 |
| July 04 | CA RPS Multi-year Analysis | 4 | 0.45 | na | na | na | na |
| June 03 | We Energies | 4 | 1.12 | 0.09 | 0.69 | na | 1.90 |
| June 03 | We Energies | 29 | 1.02 | 0.15 | 1.75 | na | 2.92 |
| 2005 | PacifiCorp | 20 | 0 | 1.6 | 3.0 | na | 4.6 |
| April 06 | Xcel-PSCo | 10 | 0.20 | na | 2.26 | 1.26 | 3.72 |
| April 06 | Xcel-PSCo | 15 | 0.20 | na | 3.32 | 1.45 | 4.97 |

# Paths forward to reduce interconnection challenges

## Enhance wind forecasting and system flexibility

- Deploy more flexible generation and load technologies
- Aggregate wind plant output over large regions
- Improve balancing area consolidation and area control error sharing
- Improve wind plant models
- Integrate wind forecasts into power system operation

## Expand market flexibility

- Develop well-functioning hour-ahead and day-ahead energy and price responsive load markets and expand access to those markets
- Develop broad geographical markets and inter-area trading

Photo courtesy of NREL

# Resolving challenges presented by wind interconnection can be overcome

- **Cost:** significant expansion of the transmission grid will be required under any future electric industry scenario
- **Planning:** utilize a regional collaborative planning process instead of individual entities
- **Cost allocation:** FERC should continue to determine allocations of transmission costs
- **Cost recovery:** FERC and state regulatory approval of a cost-allocation plan and a rate of return are essential
- **Siting:** DOE is addressing siting through National Interest Electric Transmission Corridors. Extensive regional collaboration will be needed.