Wind Technologies and Evolving Opportunities

Robi Robichaud
Senior Engineer

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NREL is a national laboratory of the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy operated by the Alliance for Sustainable Energy, LLC

Opportunities for Wind Technology

- National Wind Technology Center – Research
  - Blades
  - Generators
  - Wind resource
- Wind Market Update
  - Recession impacts
  - PTC
  - RPS
- Wind Technology Overview
  - Larger rotors
  - Taller towers
- Wind Resource
  - Improved wind maps & assessment

National Wind Technology Center Overview

- Turbine testing since 1977
- Leader in development of design and analysis codes
- Pioneers in component testing
- Unique test facilities
    - Blade testing
    - Dynamometer
    - CART turbines
- Modern utility-scale turbines
- Approx. 150 staff onsite
- Budget approx. $35M
- Many CRADAs with industry
- Leadership roles for international standards.

Photo by Lee Jay Fingersh, NREL 24349

Photo by Scott Hughes, NREL 14708

Photo by Dennis Schroeder, NREL 28229

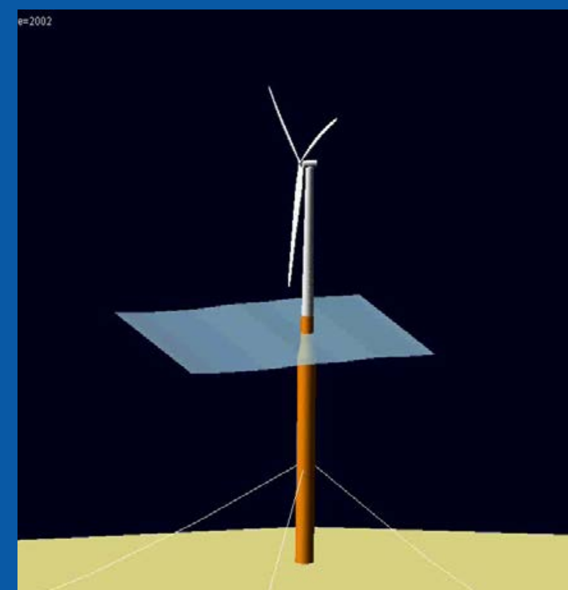


Image from Jason Jonkman, NREL

National Wind Technology Center Vision

The NWTC will be an essential partner for the technical development and large-scale deployment of wind power.

Goals:

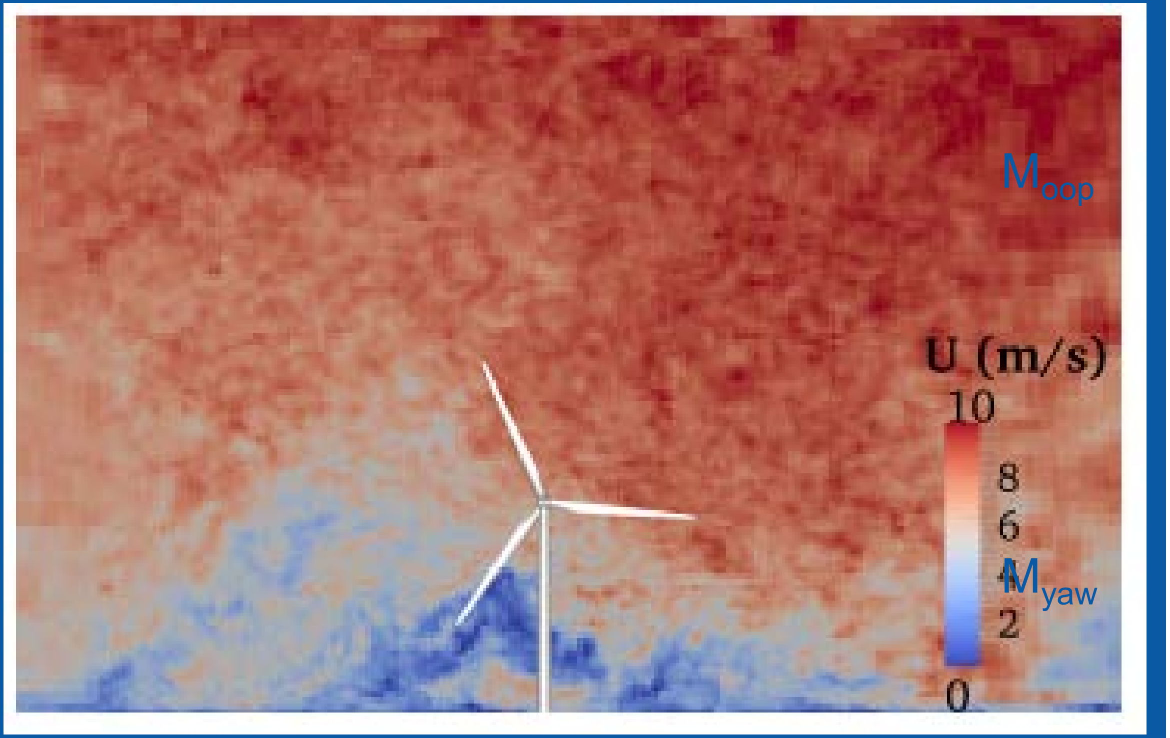
- Improve windplant power production
- Reduce windplant capital cost
- Improve windplant reliability and lower O&M cost
- Eliminate barriers to large-scale deployment.

LCOE

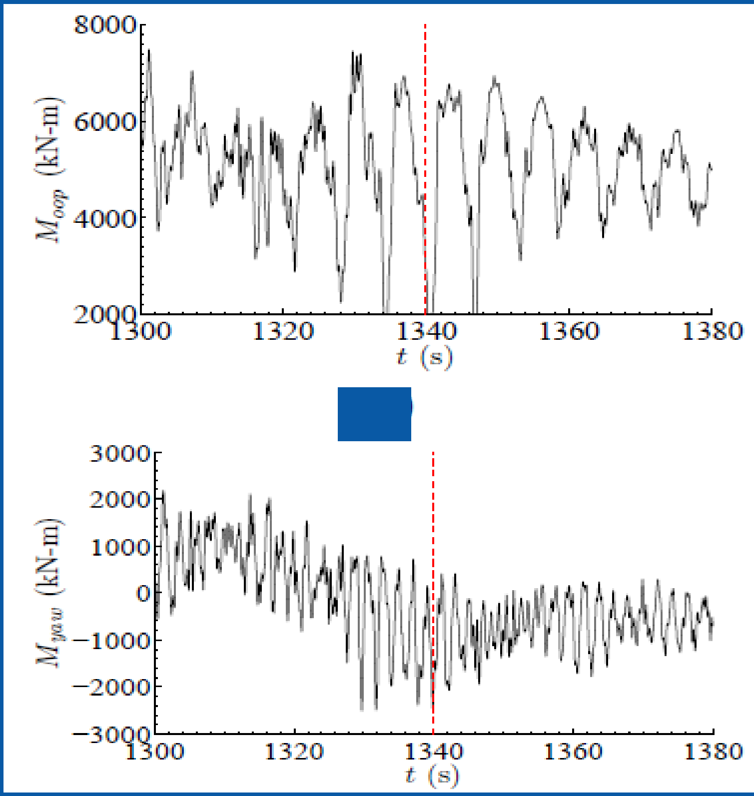
Windplant Aerodynamics Problem

- Power performance and reliability influences are reduced in arrays.
- Understanding inflow / array interaction is key.
- Computational models, control paradigms, and hardware development will be required.
- A detailed understanding of the following is required:
  - Rotor wake interactions
  - PBL characteristics
  - Inflow / wind farm interaction
  - Complex terrain effects.

Physics-Based Array Aerostructural Dynamics



Images from Matt Churchfield and Sang Lee, NREL



Interaction with low-speed streak

Wind Energy Market Trends

Worldwide Wind Market Update

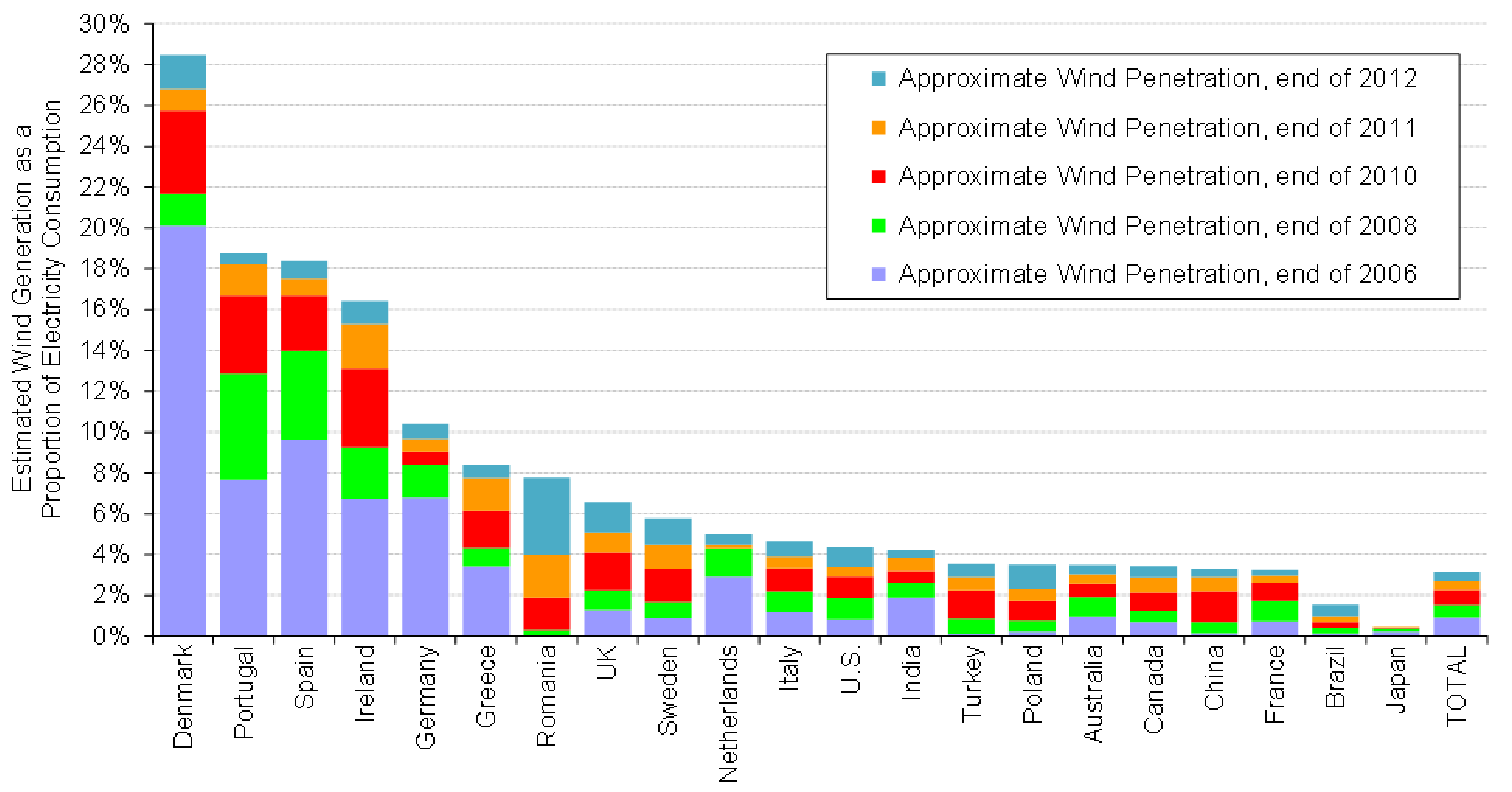
Table 1. International Rankings of Wind Power Capacity

Annual Capacity (2012, MW)		Cumulative Capacity (end of 2012, MW)	
United States	13,131	China	75,372
China	12,960	United States	60,005
Germany	2,415	Germany	31,467
India	2,336	Spain	22,462
United Kingdom	1,958	India	18,602
Italy	1,272	United Kingdom	9,113
Spain	1,112	Italy	7,998
Brazil	1,077	France	7,593
Canada	936	Canada	6,214
Romania	923	Portugal	4,363
Rest of World	6,838	*Rest of World*	42,368
TOTAL	**44,958**	**TOTAL**	**285,558**

Source: Navigant; AWEA project database for U.S. capacity

Source: www.windpoweringamerica.gov/pdfs/workshops/2013_summit/wiser.pdf
2012 Wind Technologies Market Report Summary; WPA All-States Summit; May 8, 2013

Wind as a Percentage of Electricity Consumption



Source: www.windpoweringamerica.gov/pdfs/workshops/2013_summit/wiser.pdf
2012 Wind Technologies Market Report Summary; WPA All-States Summit; May 8, 2013

Wind Power Additions Hit a New Record in 2006

PTC-Driven Results

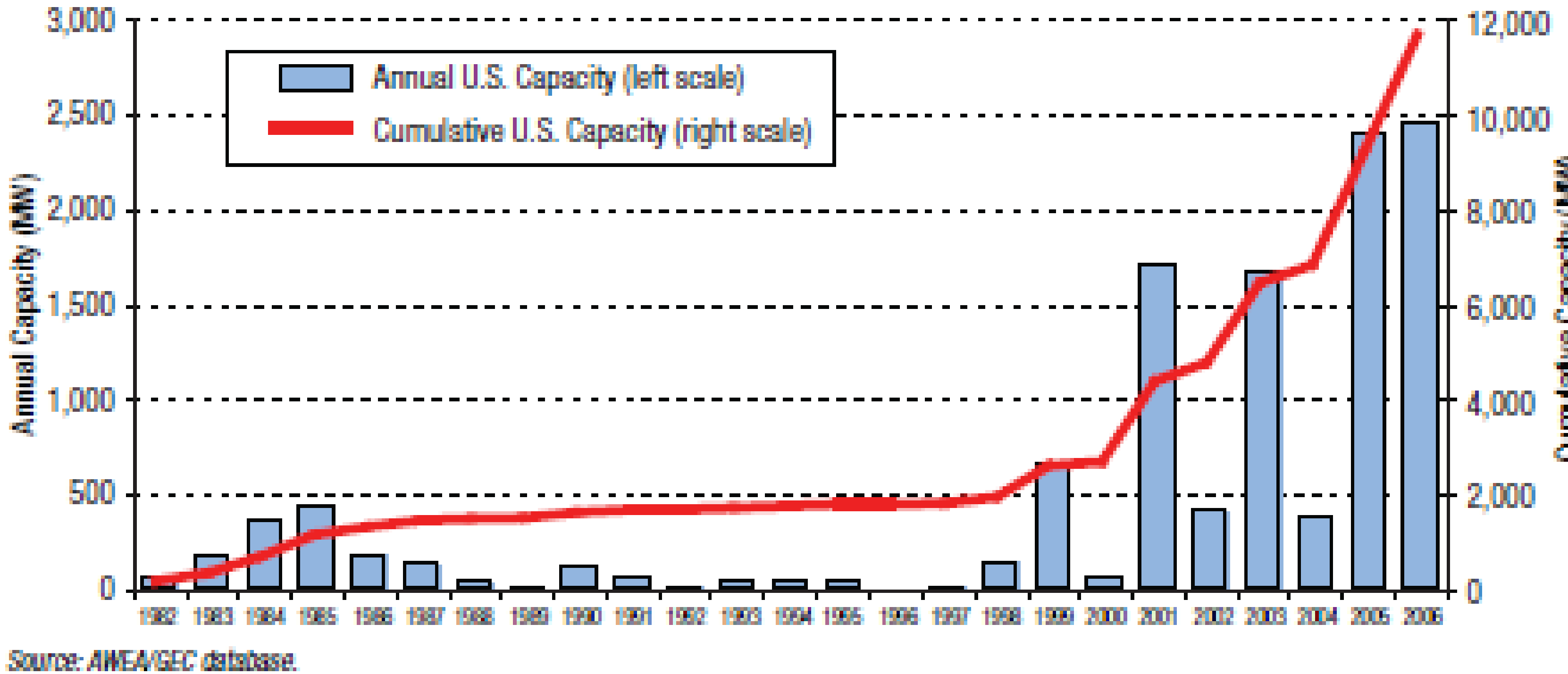
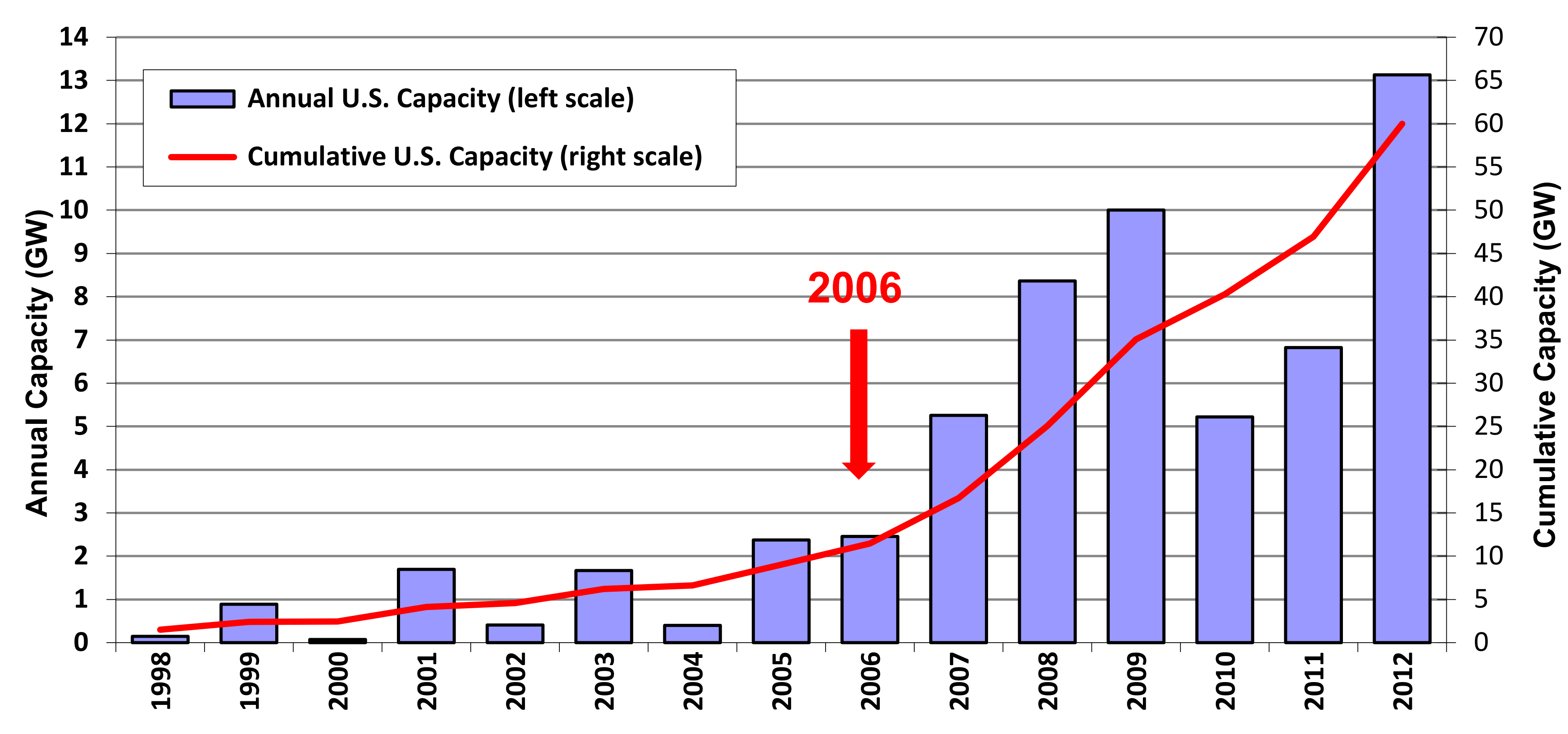


Figure 1. Annual and Cumulative Growth in U.S. Wind Power Capacity

Source: www.windpoweringamerica.gov/pdfs/workshops/2006_summit/wiser.pdf
2006 Wind Technologies Market Report Summary

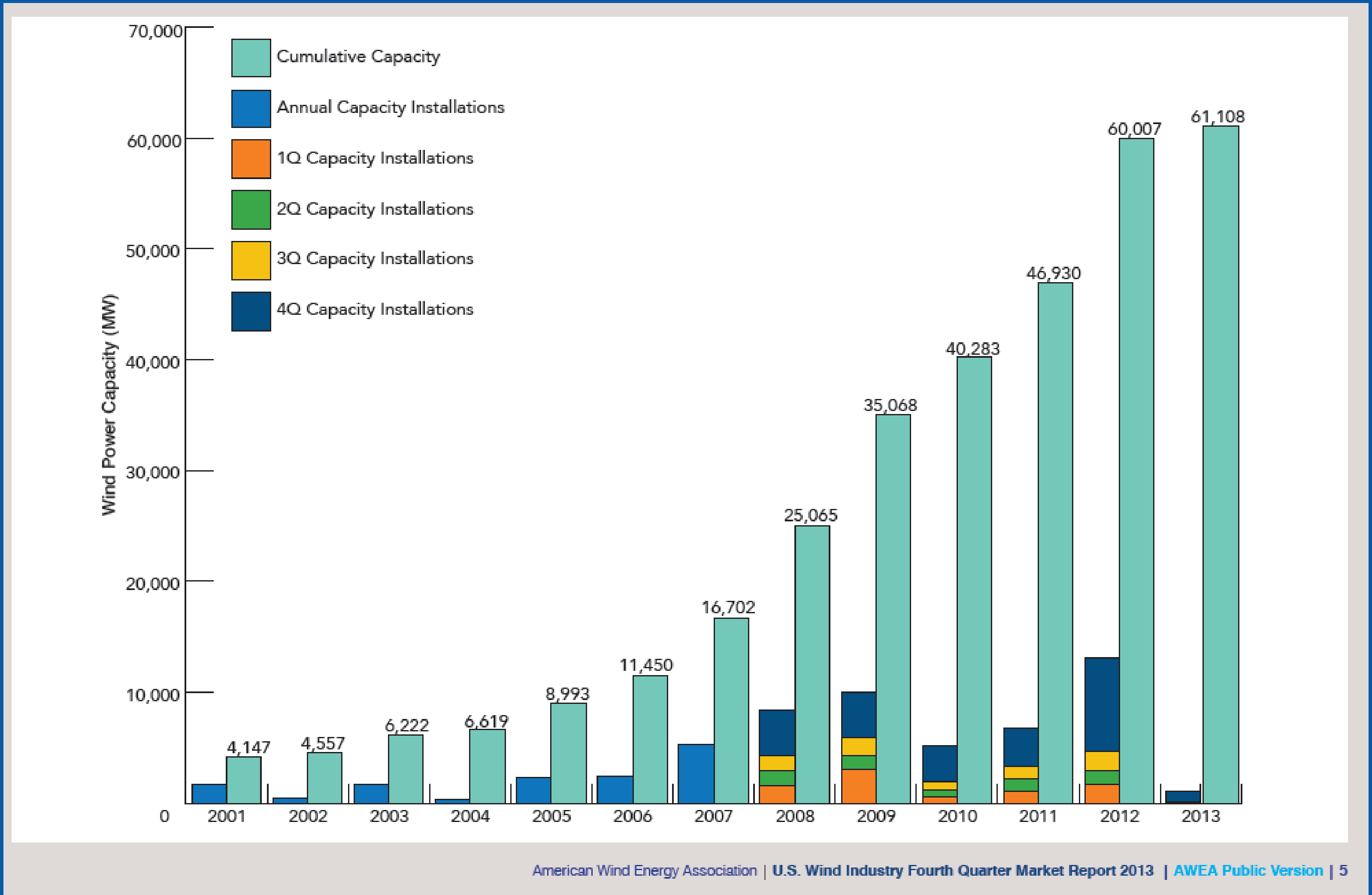
Wind Power Additions: New Record in 2012

Expiring PTC-Driven Results



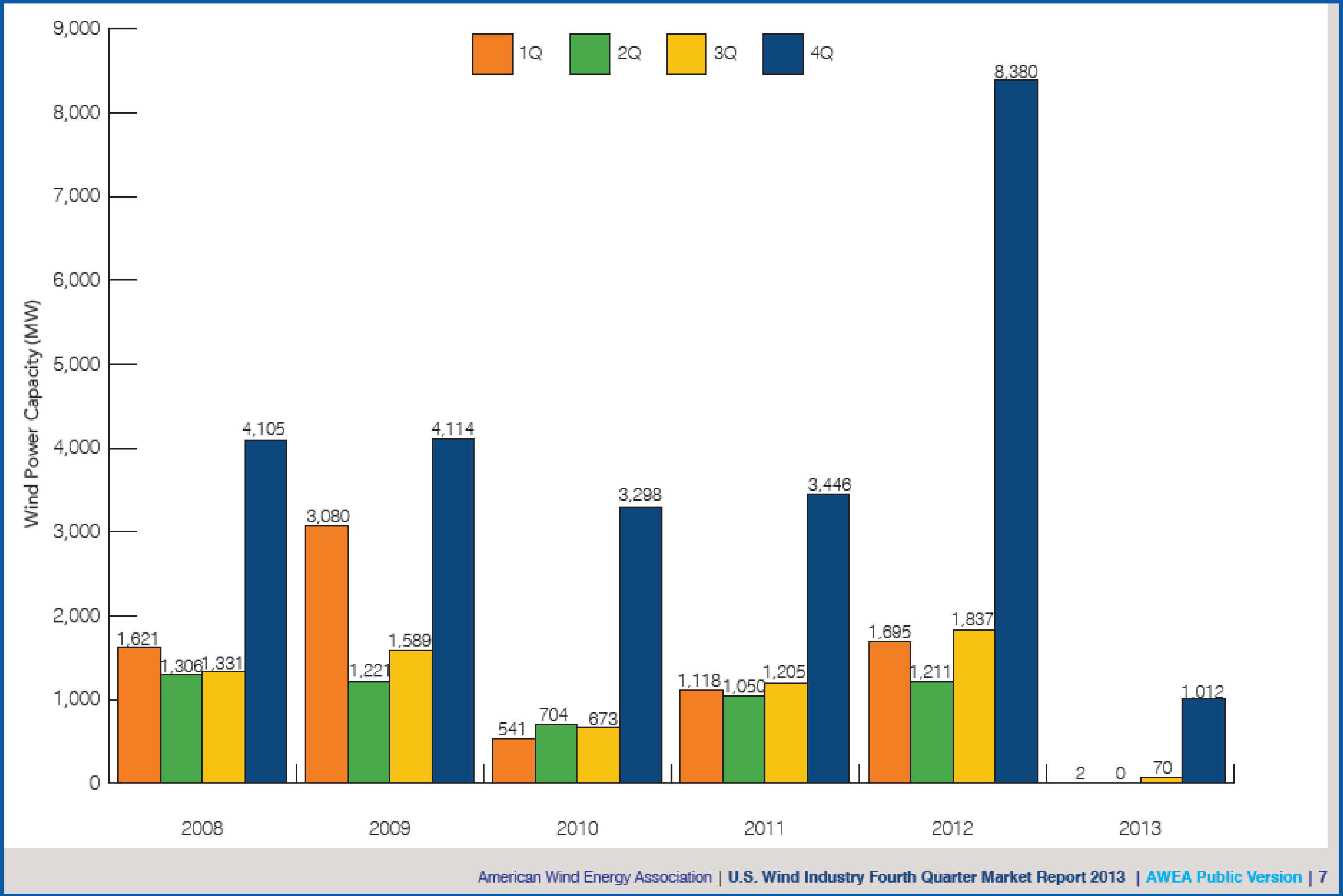
Source: www.windpoweringamerica.gov/pdfs/workshops/2006_summit/wiser.pdf
2006 Wind Technologies Market Report Summary

U.S. Wind Power Capacity Growth



Source: http://awea.files.cms-plus.com/FileDownloads/pdfs/AWEA%204Q2013%20Wind%20Energy%20Industry%20Market%20Report_Public%20Version.pdf
AWEA U.S. Wind Industry - Fourth Quarter 2013 Market Report; January 30, 2014

Wind Power Capacity Completions by Quarter



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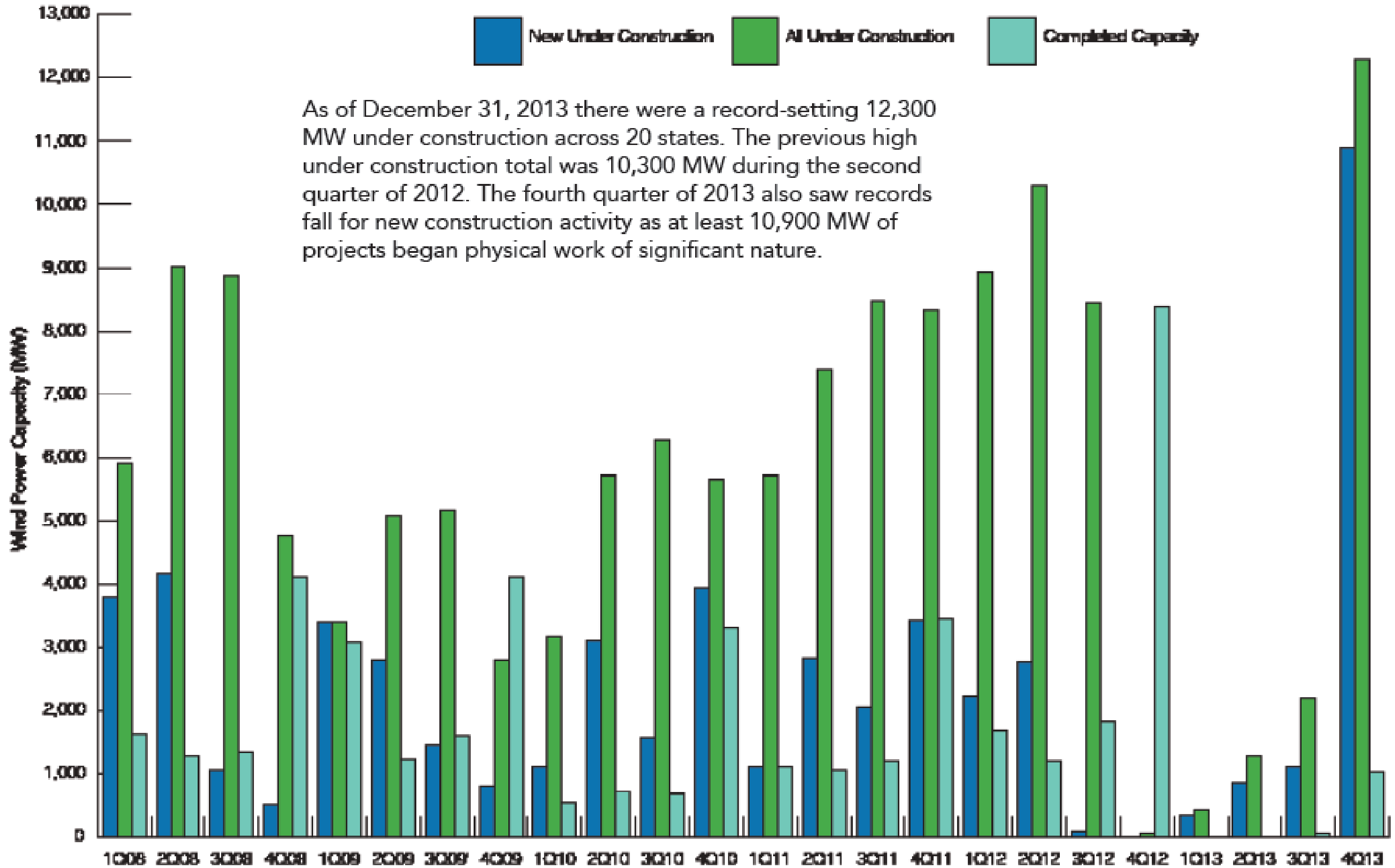
Wind Power Capacity under Construction



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Source: http://awea.files.cms-plus.com/FileDownloads/pdfs/AWEA%204Q2013%20Wind%20Energy%20Industry%20Market%20Report_Public%20Version.pdf
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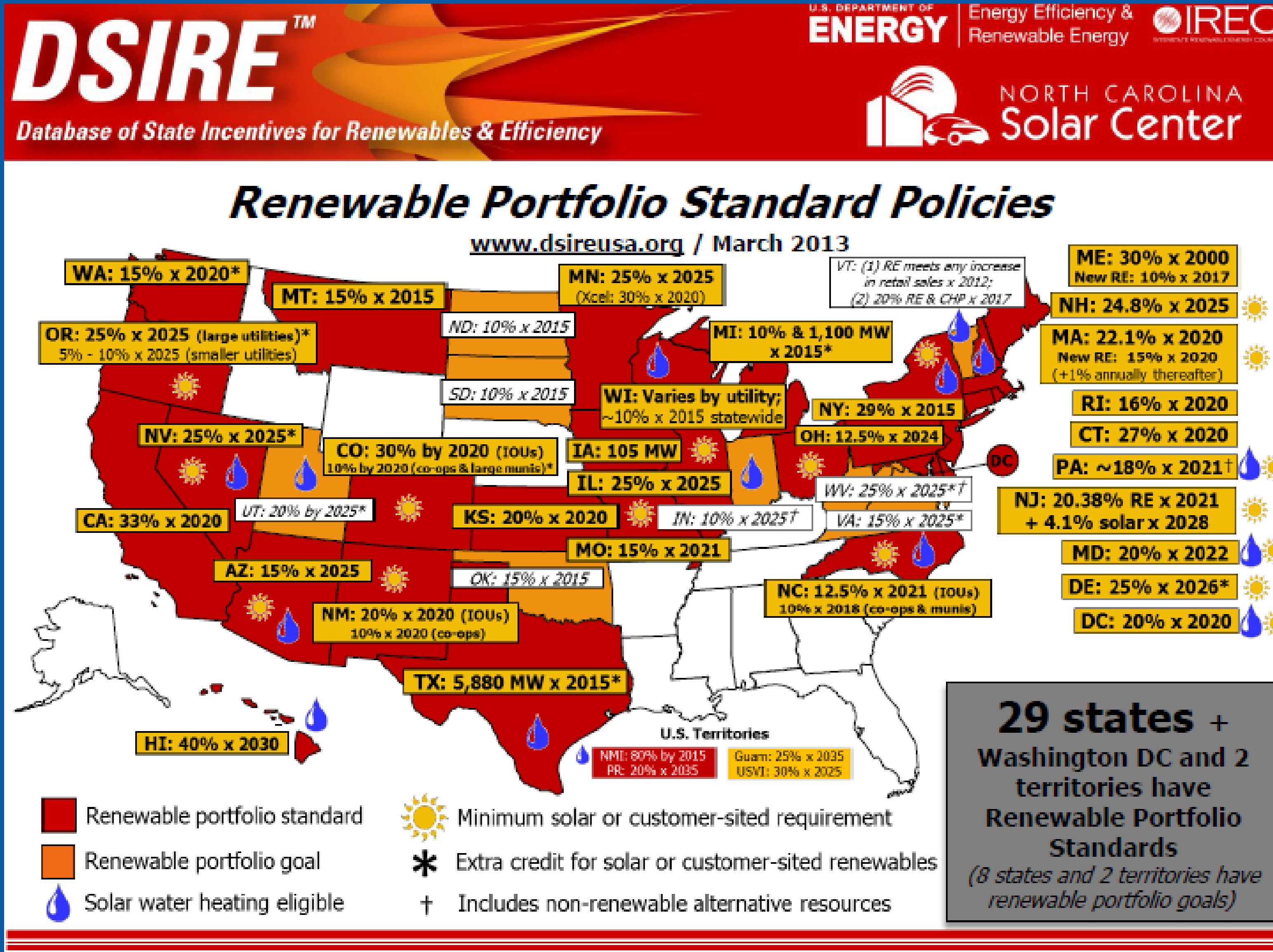
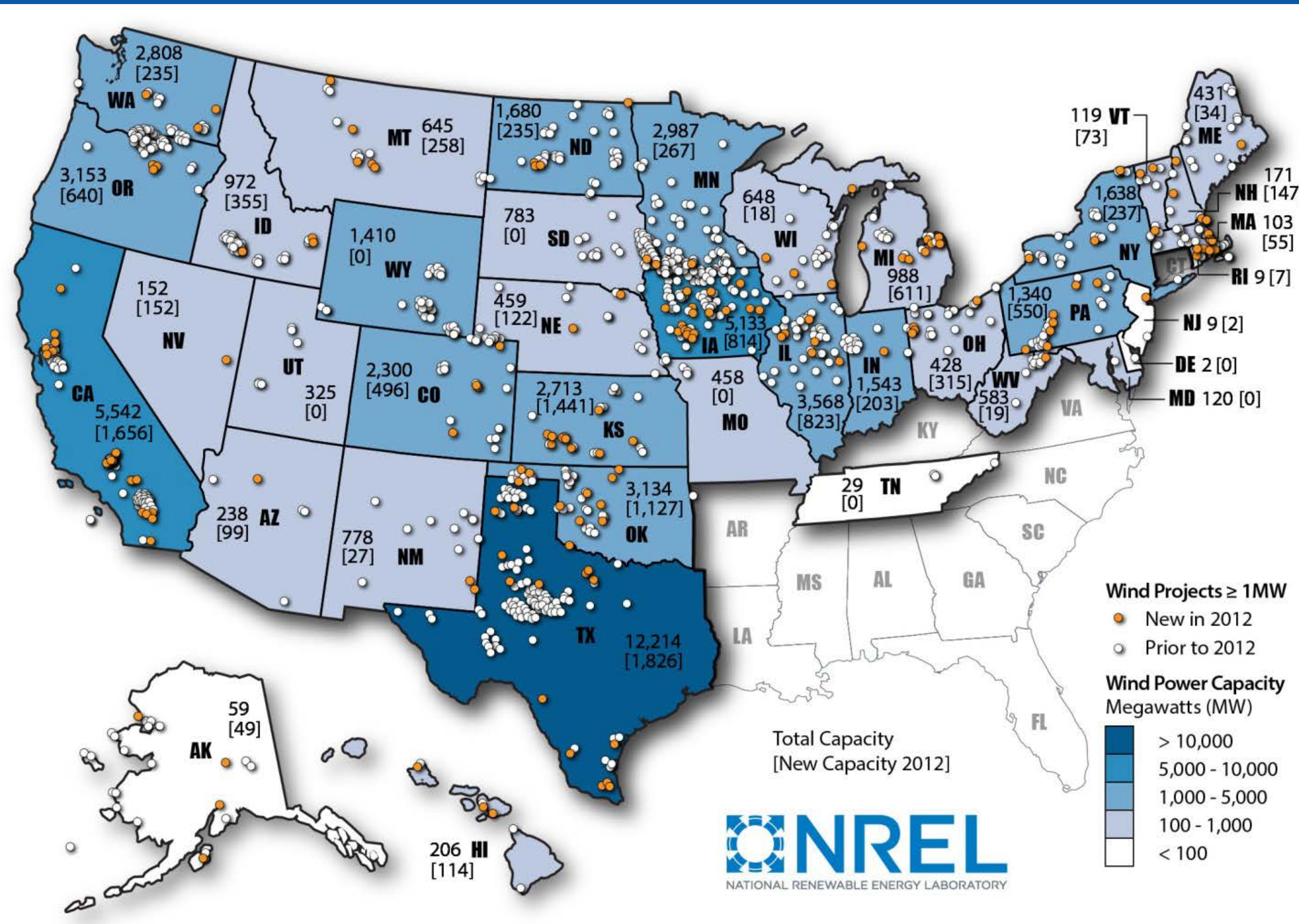
Incentives – Renewable Portfolio Standards (RPS)



Source: Database of State Incentives for Renewables & Efficiency (funded by the U.S. Department of Energy)

Wind Capacity by State



At end of 2012:

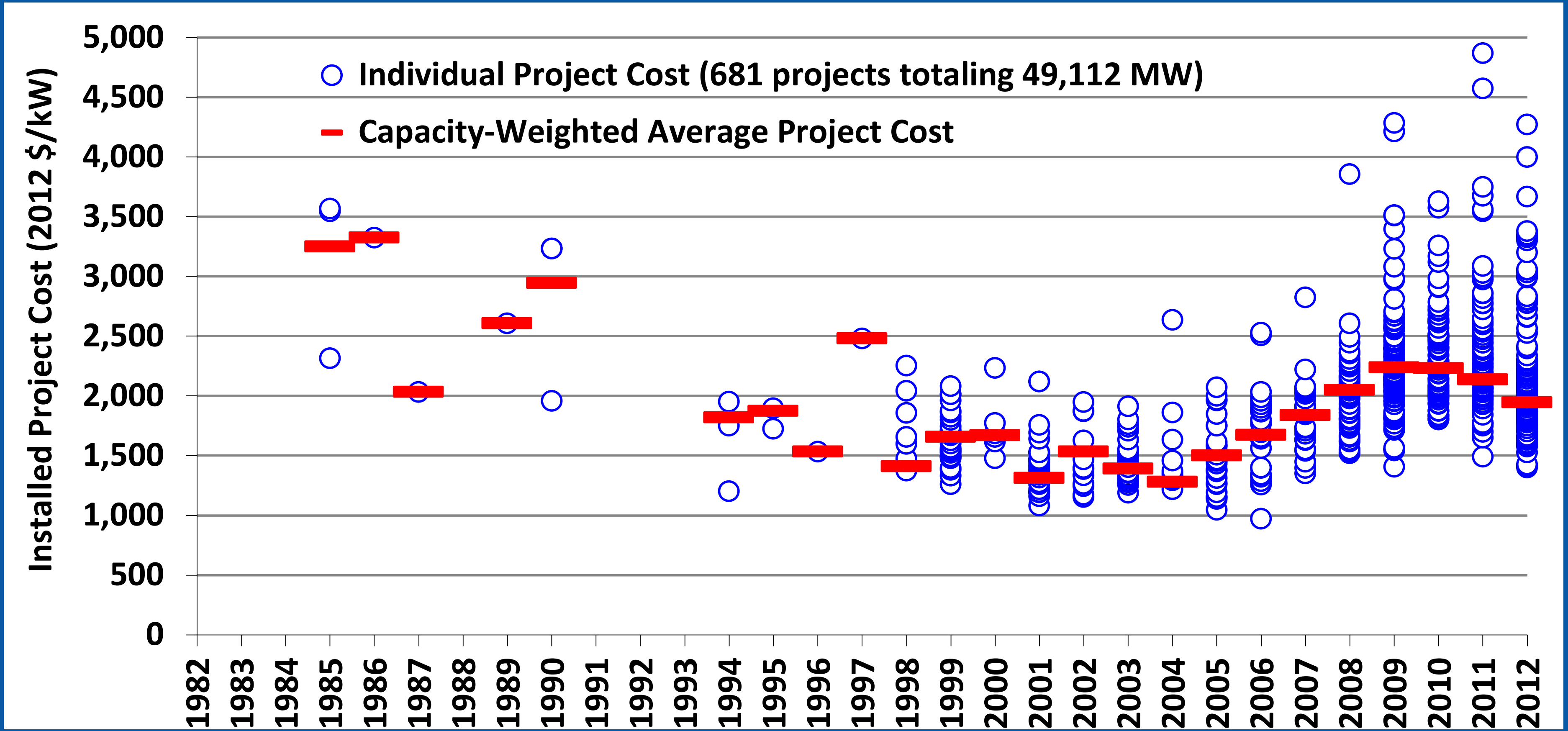
- Texas > 2 X wind capacity of any other state
- 22 states had >500 MW of capacity (15 > 1 GW, 10 > 2 GW)
- 2 states >20% of total in-state generation from wind

(9 > 10%, 17 > 5%)

Source: www.windpoweringamerica.gov/pdfs/workshops/2013_summit/wiser.pdf
2012 Wind Technologies Market Report Summary; WPA All-States Summit; May 8, 2013

Lower Turbine Pricing

Starting to Appear in Reported Total Project Costs



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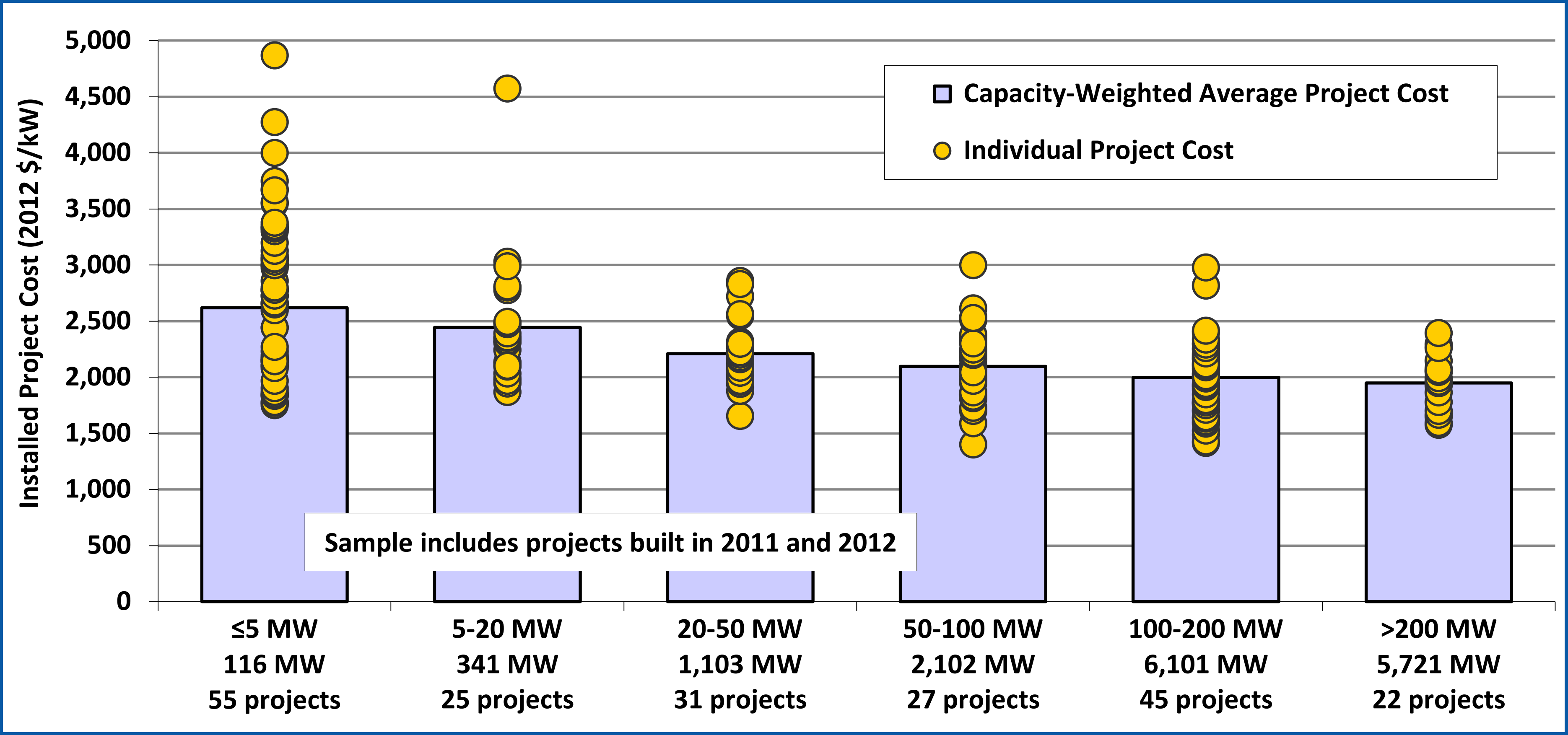
Economies of Scale – Project Size Matters



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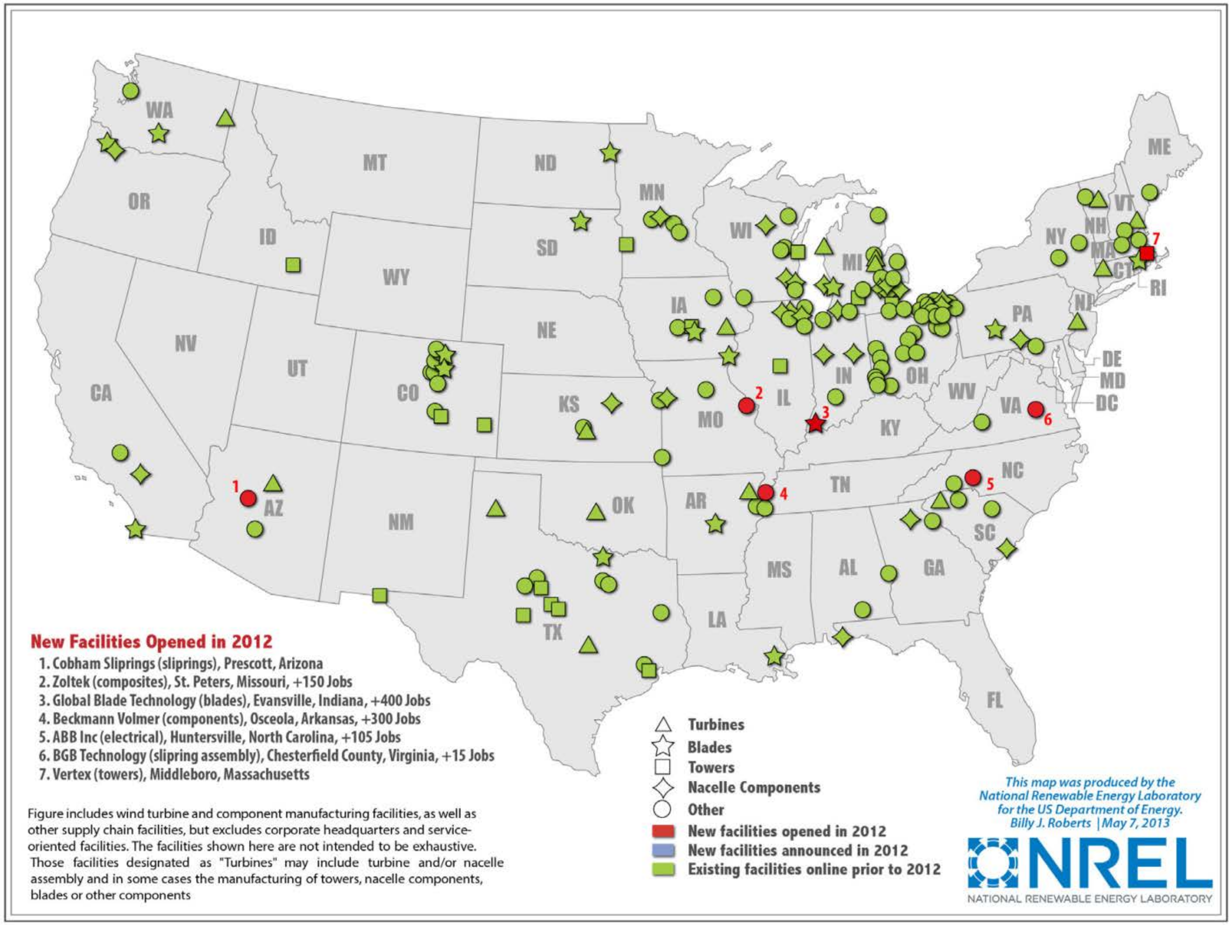
Domestic Wind-Related Manufacturing



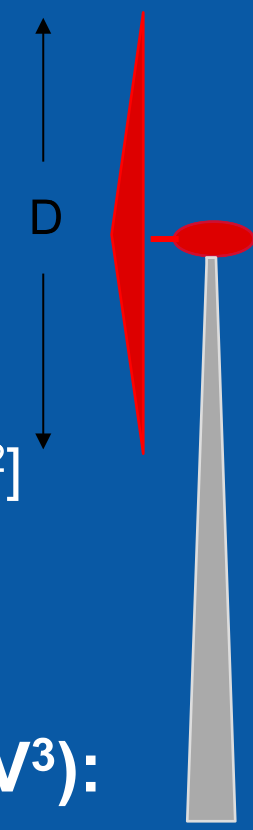
More than 160 manufacturing plants capable of producing 12 GW/yr

Source: www.windpoweringamerica.gov/pdfs/workshops/2013_summit/wiser.pdf
2012 Wind Technologies Market Report Summary; WPA All-States Summit; May 8, 2013

Wind Turbine Technology Trends

Power in Wind Equation

Wind energy is kinetic energy – mass and momentum



Derived from K.E. = $\frac{1}{2} mv^2$

$$P = A * \rho * V^3/2$$

- P = Power of the wind [Watts]
- A = Windswept area of rotor (blades) = $\pi D/4 = \pi r^2$ [m^2]
- ρ = Density of the air [kg/m^3] (at sea level at 15°C)
- V = Velocity of the wind [m/s]

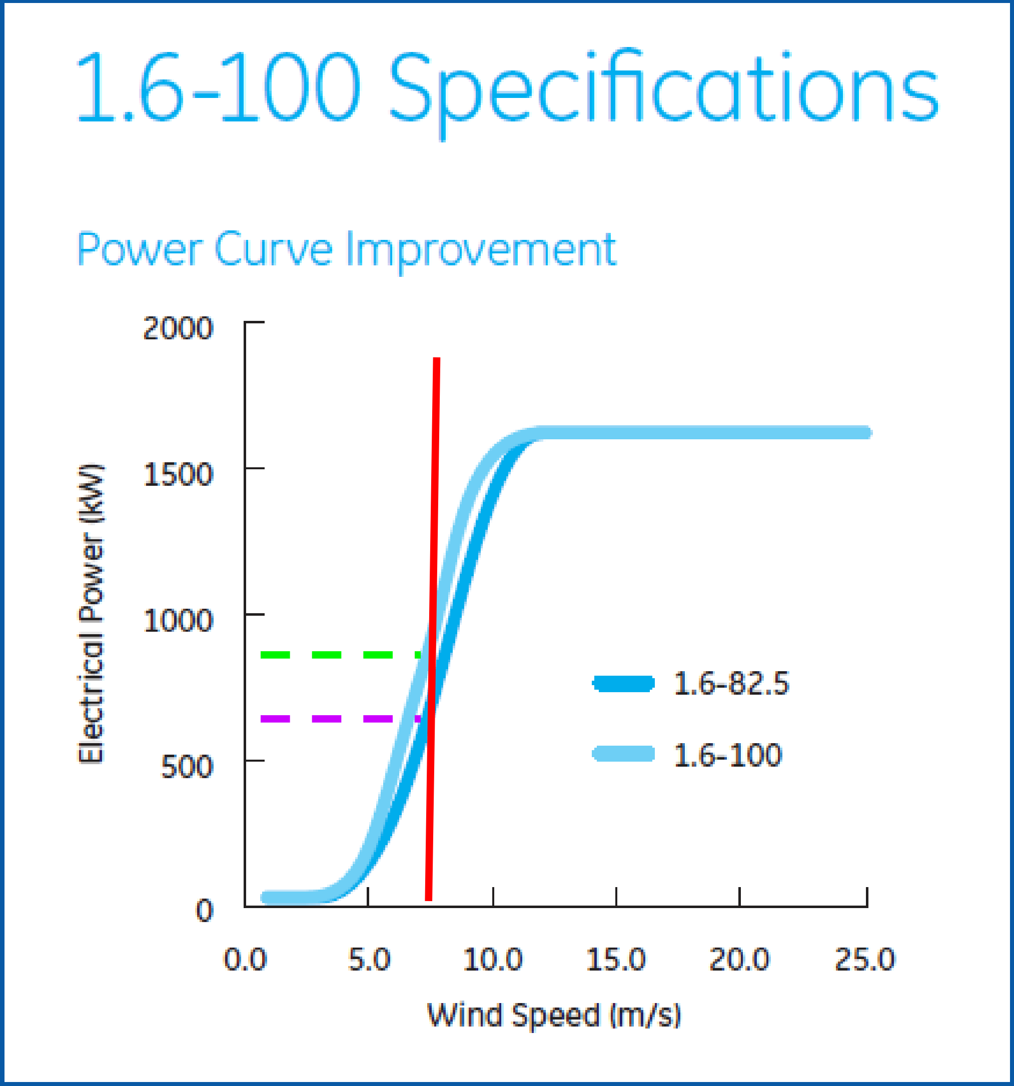
Wind energy is proportional to velocity cubed (V^3):

– 25% higher wind speed ≈ 2 times the power available

–If wind speed is doubled, power increases by a factor of 8 ($2^3 = 8$)!

Small differences in average speed cause
big differences in energy production!

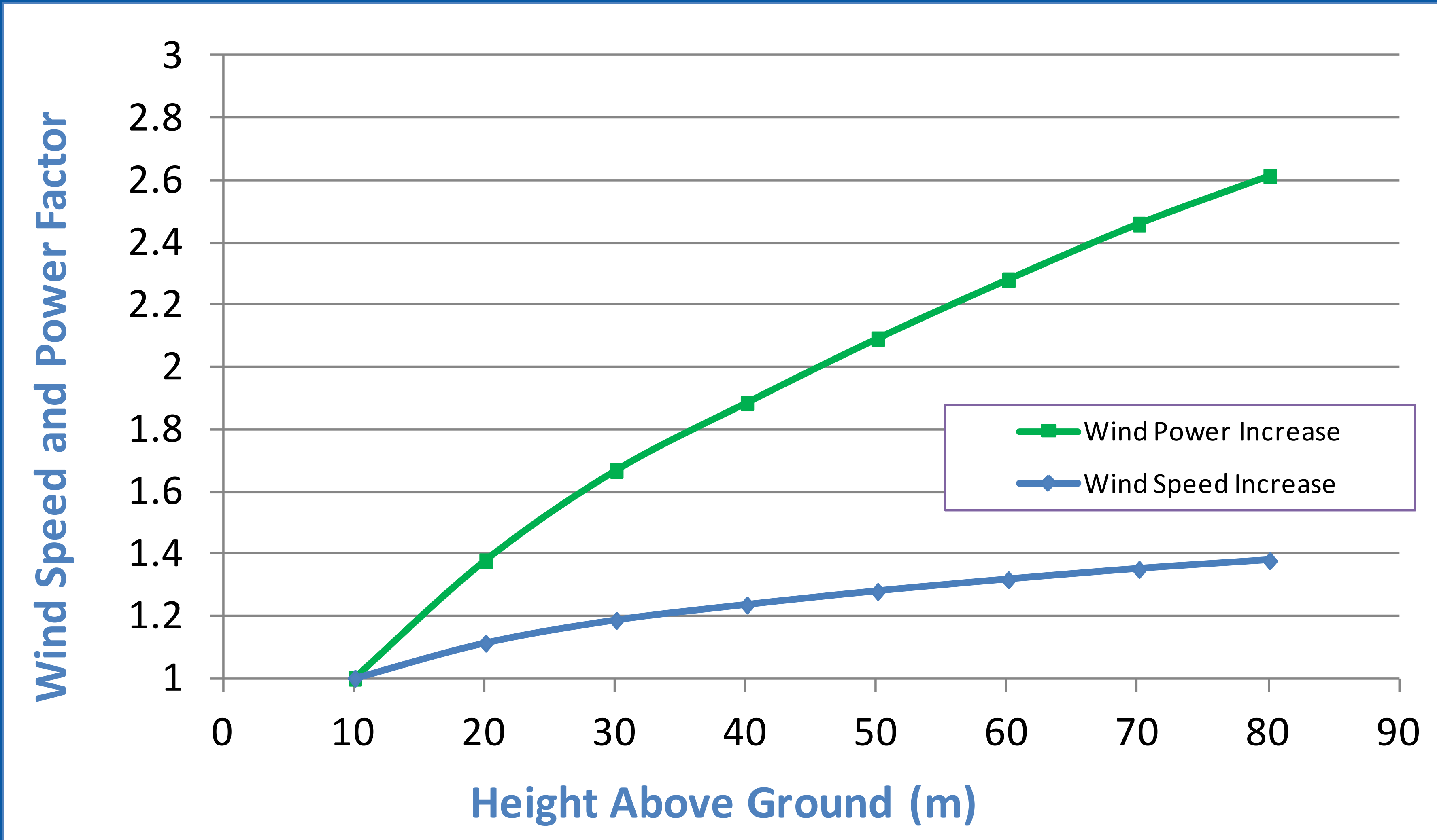
GE 1.6-MW Wind Turbine



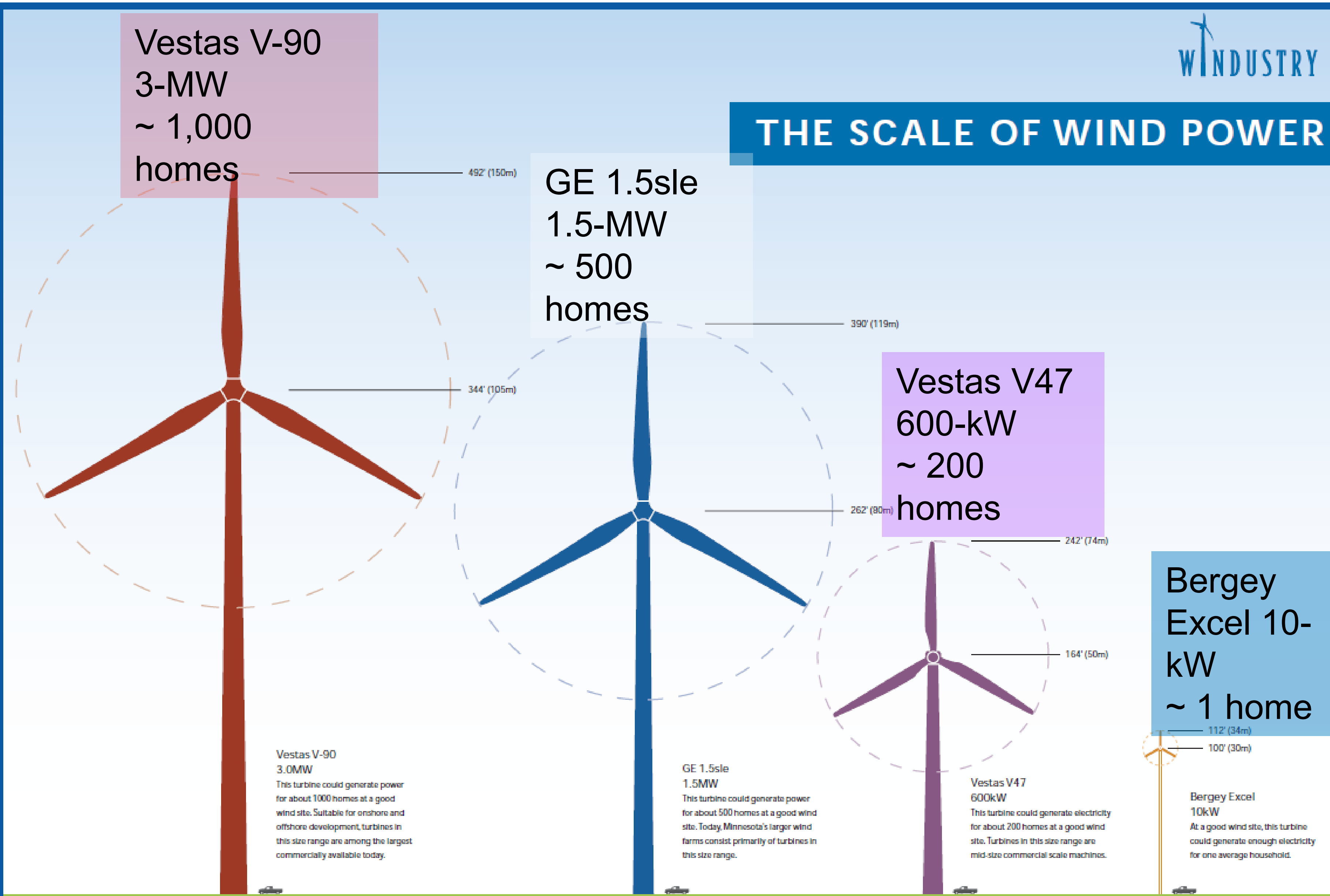
This power curve graph illustrates the GE 1.6-100 1.6-MW with 100-m rotor (low wind speed turbine – suitable for Kaneohe) and an 82.5-m rotor (suitable for sites without extreme wind or turbulence). The enlarged rotor moves the power curve to the left so the turbine produces more power (and energy) at lower wind speeds.

At 7 m/s, it might have produced ~500 kW with an 82.5-m rotor, but with a 100-m rotor it will produce ~700 kW – **a 40% increase !!**

Wind Speed and Power Increase with Height above the Ground



Turbine – Sized to Economic Project Goals

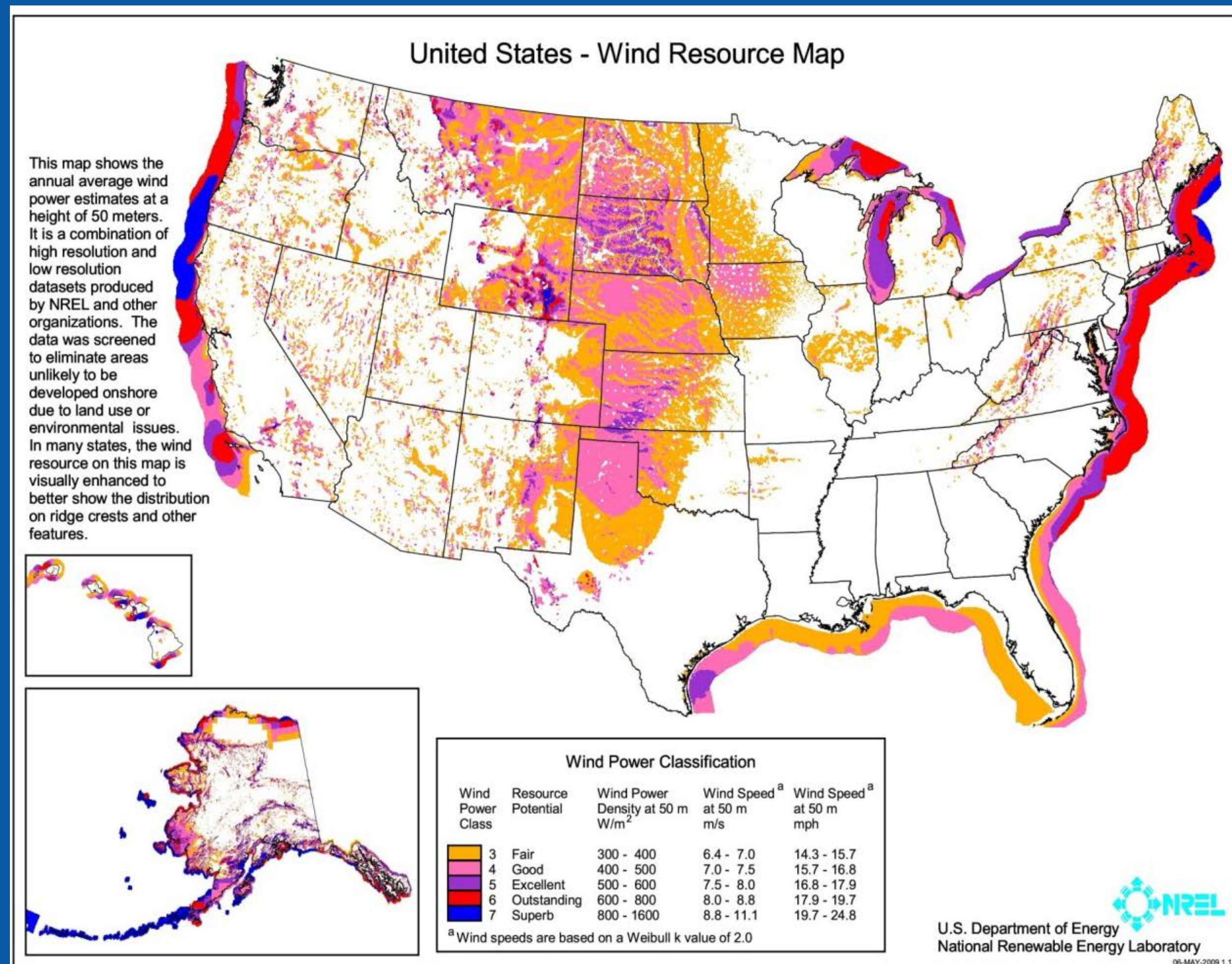


Wind Resource – Improved Tools

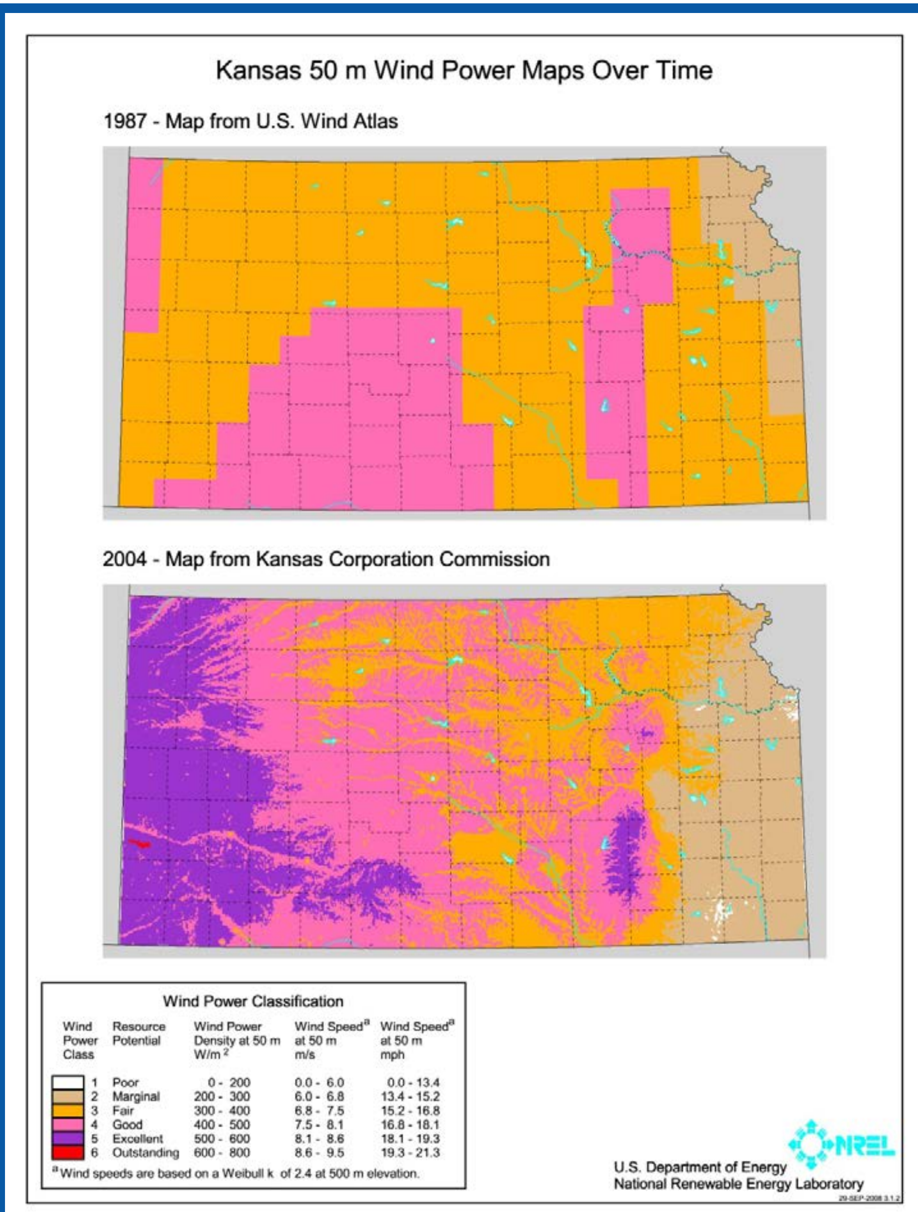
Wind Resource Mapping: Wind Class at 50-m Height

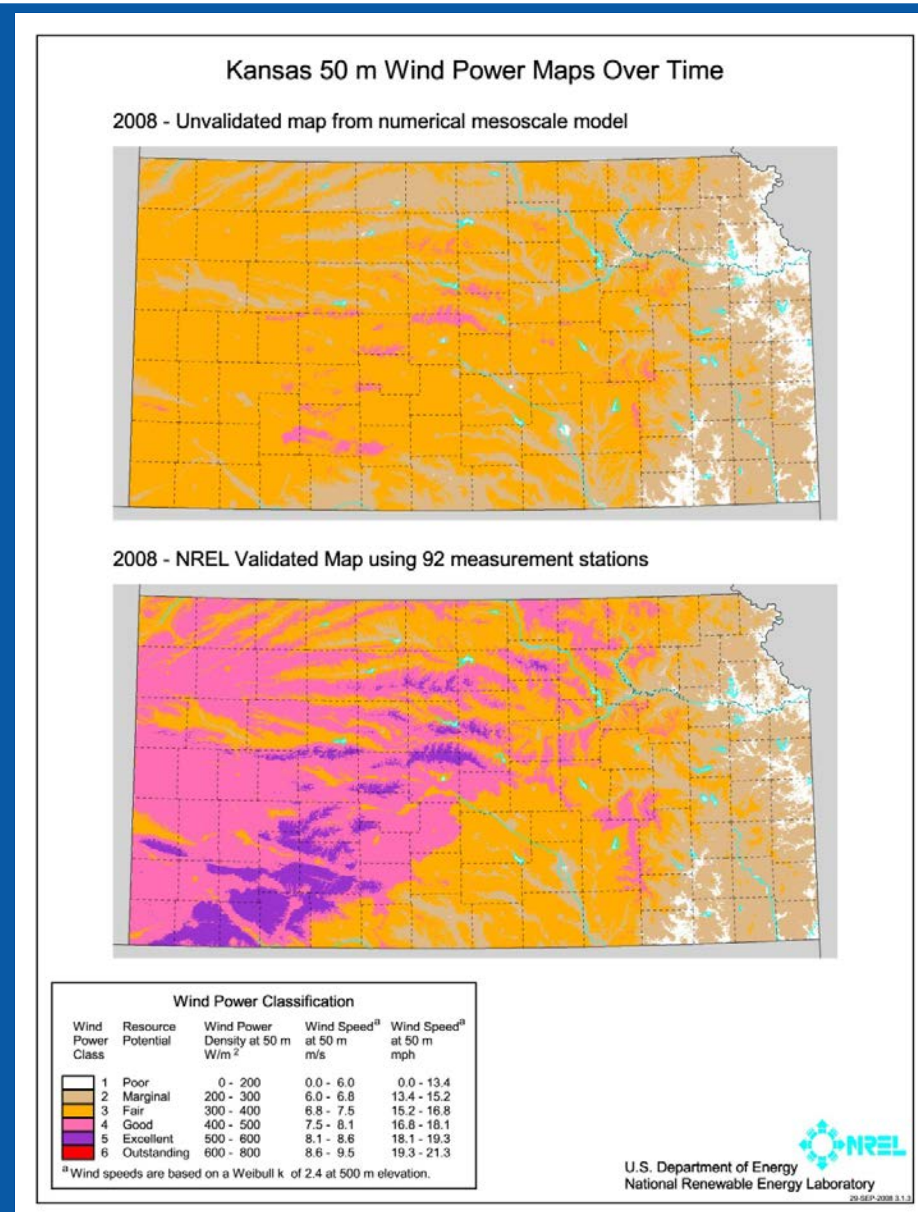
50-m wind mapping (2001-2009)

- Culmination of long-term project that began in 2001; jointly funded by states and DOE/WPA
- Comprehensive validation of maps using available measurement data
- Incorporated state maps by others to produce a national wind map ("patchwork quilt" evident in some regions)
- 50-m wind potential estimates to support U.S. 20% wind scenario study.

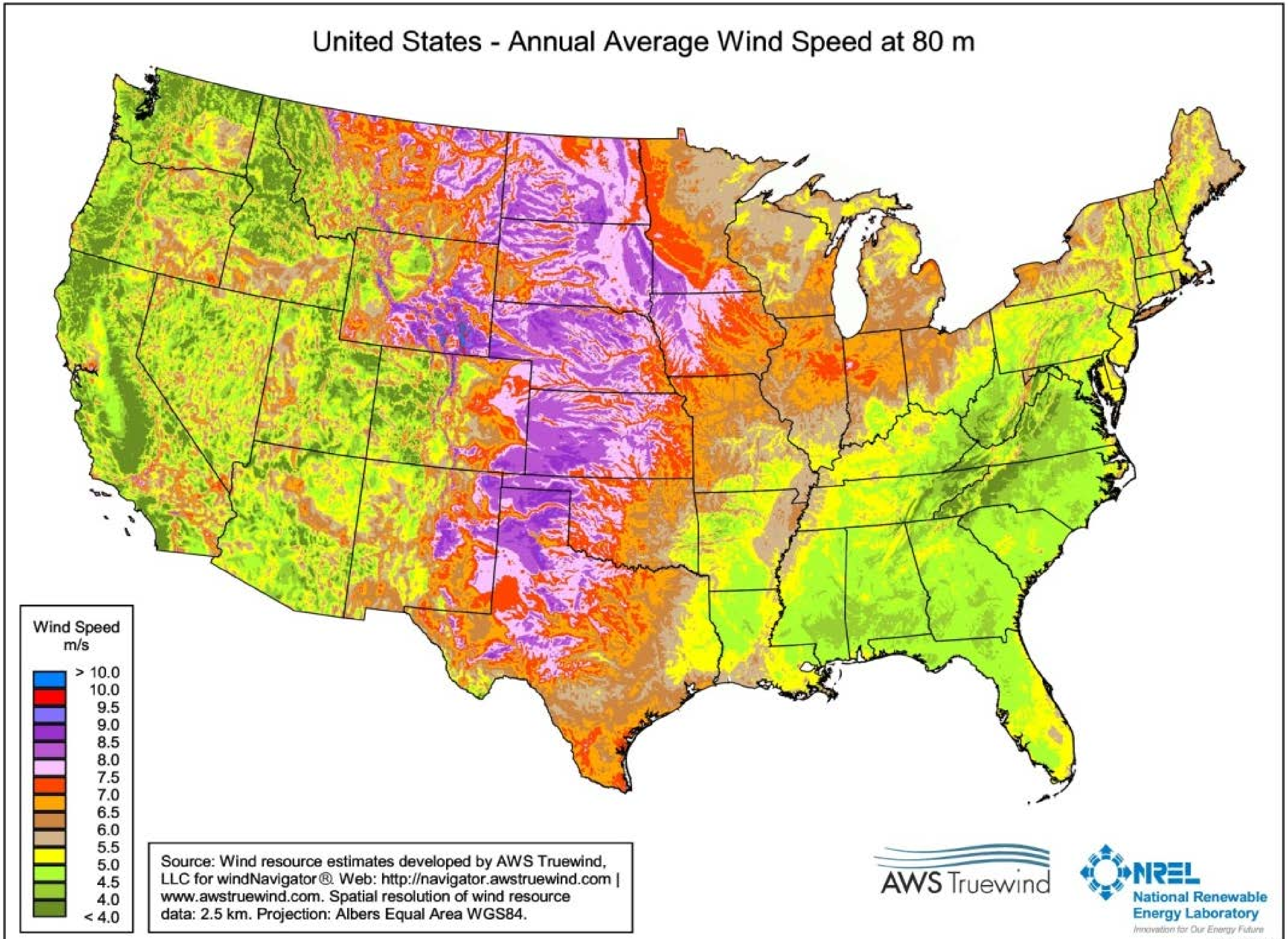


Changes in Wind Maps over Time: Kansas Example

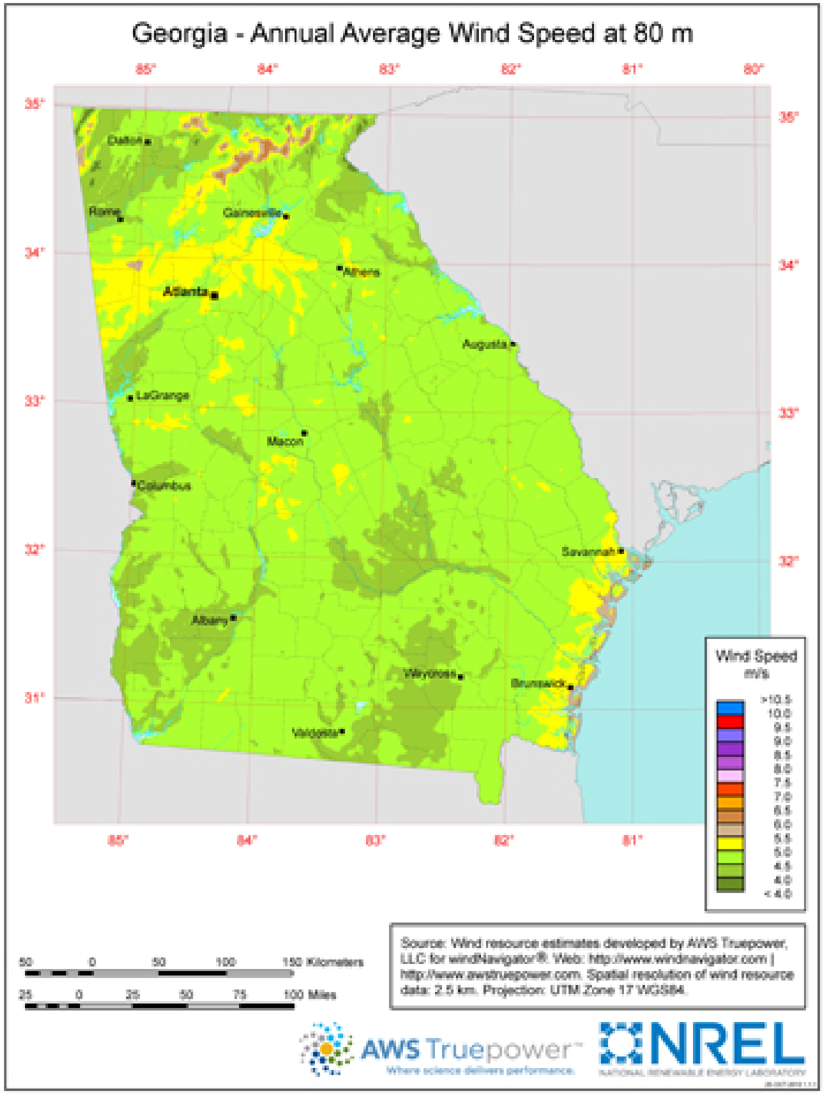




New U.S. Wind Resource Map: Wind Speed at 80 m



Georgia: New Turbines Provide Greater Wind Potential



Increasing hub height from 80 to 100 m:

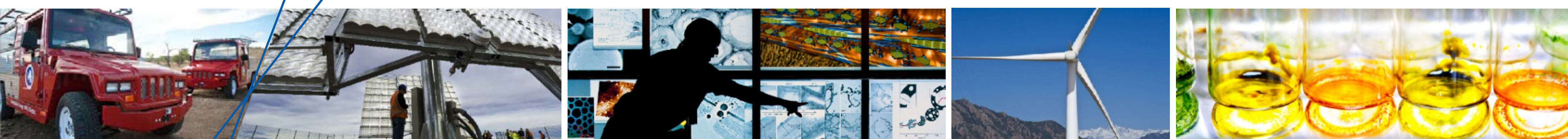
•Doubles the potential wind capacity in Georgia at sites with a 30% capacity factor, from 200 to 400 MW

•Quadruples potential wind capacity at 25% capacity factor sites, from 500 to 2,000 MW

Opportunities for Wind Technology

- National Wind Technology Center – research
- Wind – incentives & markets
- Wind technology improvements
- Wind resource assessment improvements.

Questions?



For more info:

www.nrel.gov/wind

www.windpoweringamerica.gov

www.awea.org

www.nrel.gov/wind/resource_assessment.html

Robi Robichaud
robi.robichaud@nrel.gov

Senior Engineer
Federal Wind - Wind Exchange & Wind Deployment
National Wind Technology Center
National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401