U.S. DEPARTMENT OF ENERGY

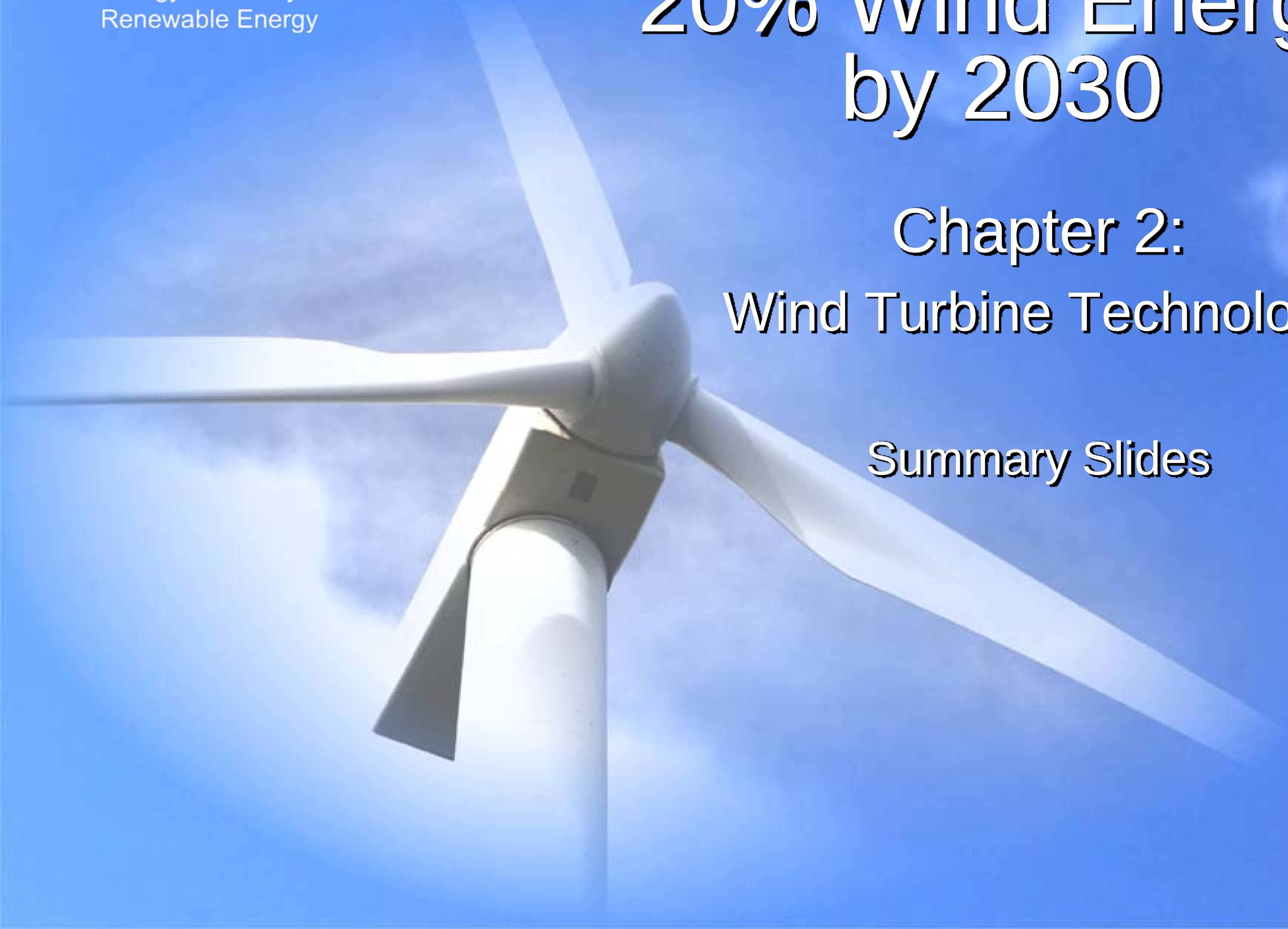
Energy Efficiency & Renewable Energy

20% Wind Energy by 2030

Chapter 2:

Wind Turbine Technology

Summary Slides



Anatomy of a 1.5-MW wind turbine

Rotor blades:
- Shown feathered
- Length, 37-m

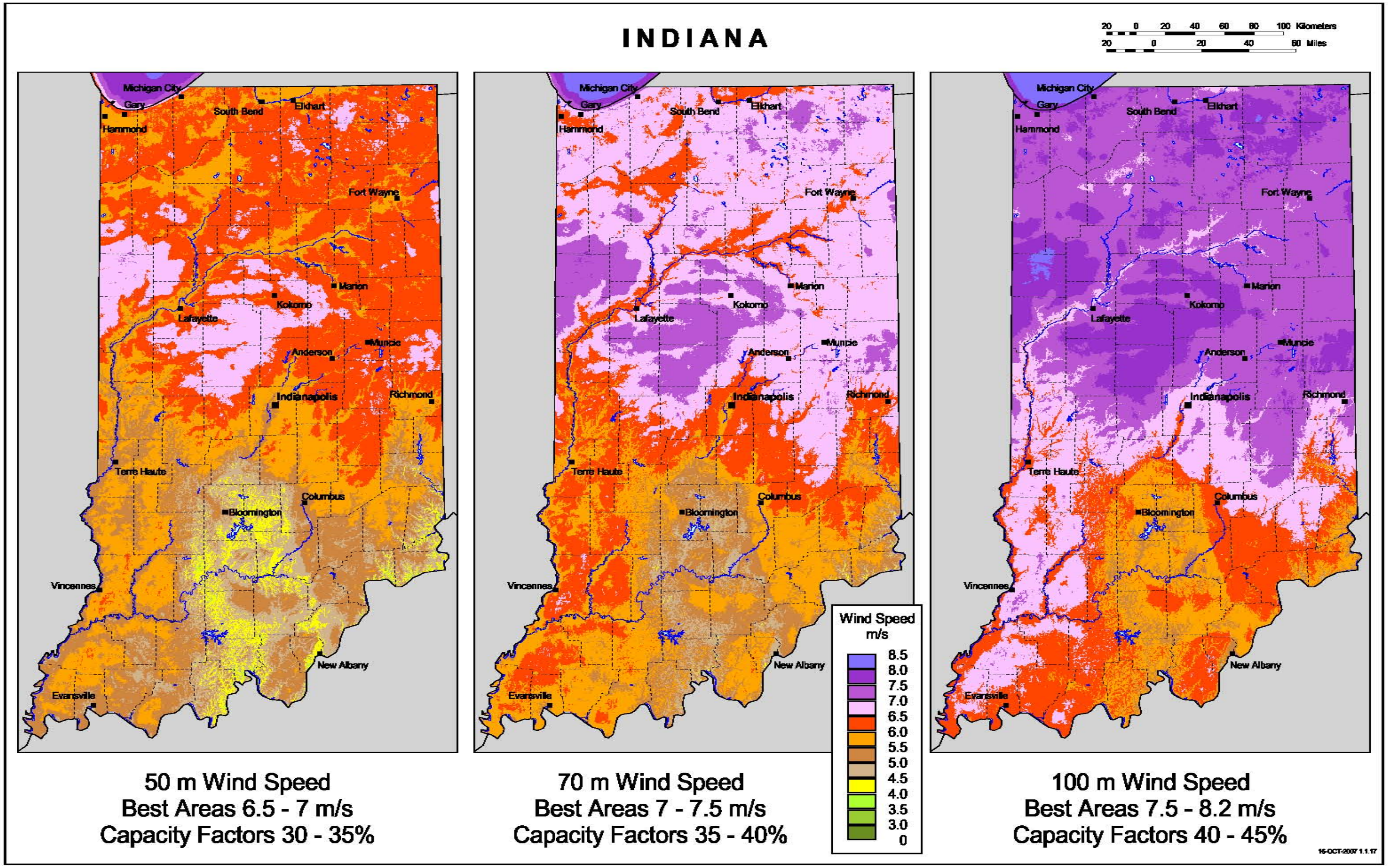
Rotor Hub

Nacelle enclosing:
- Low-speed shaft
- Gearbox
- Generator, 1.5 MW
- Electrical controls
- Blade pitch controls

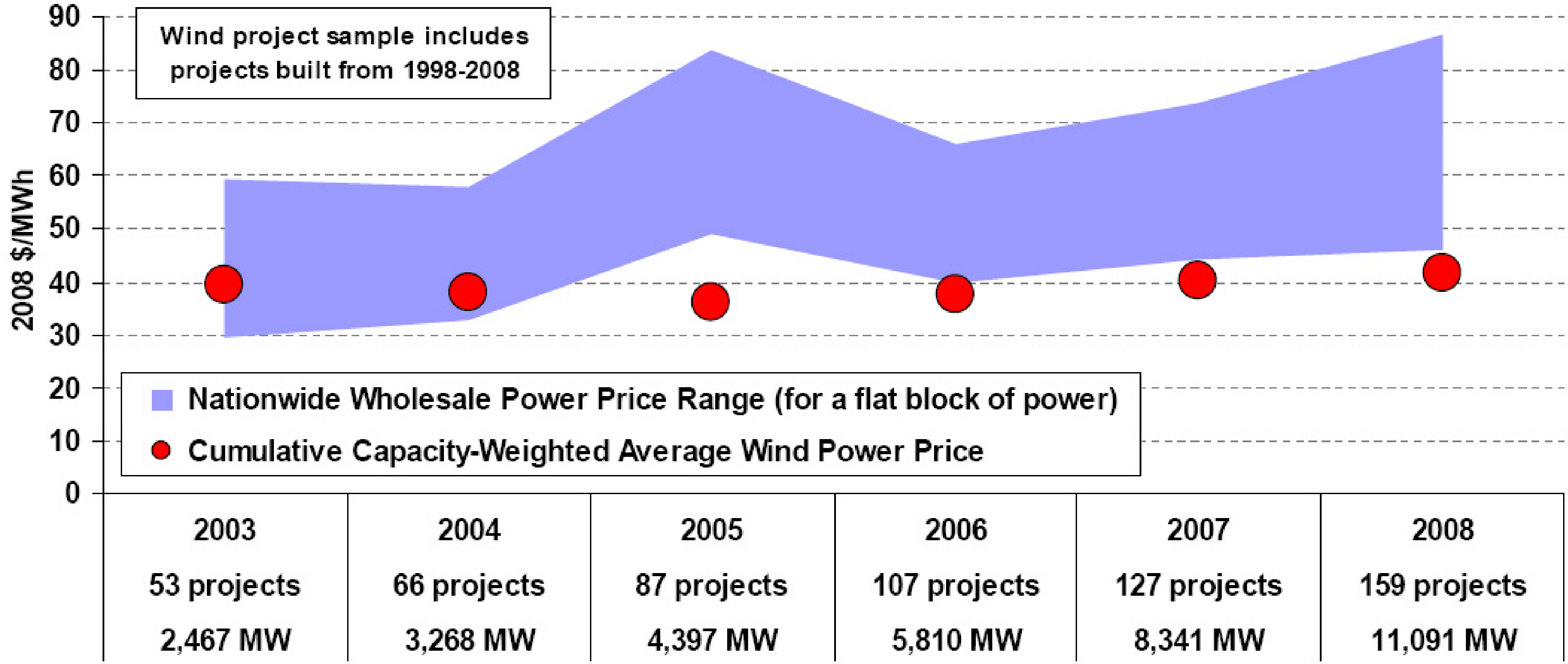
Tower, 80 m

Minivan

Larger and taller turbines are needed to capture optimal wind resources



Wind power is competitive with wholesale prices



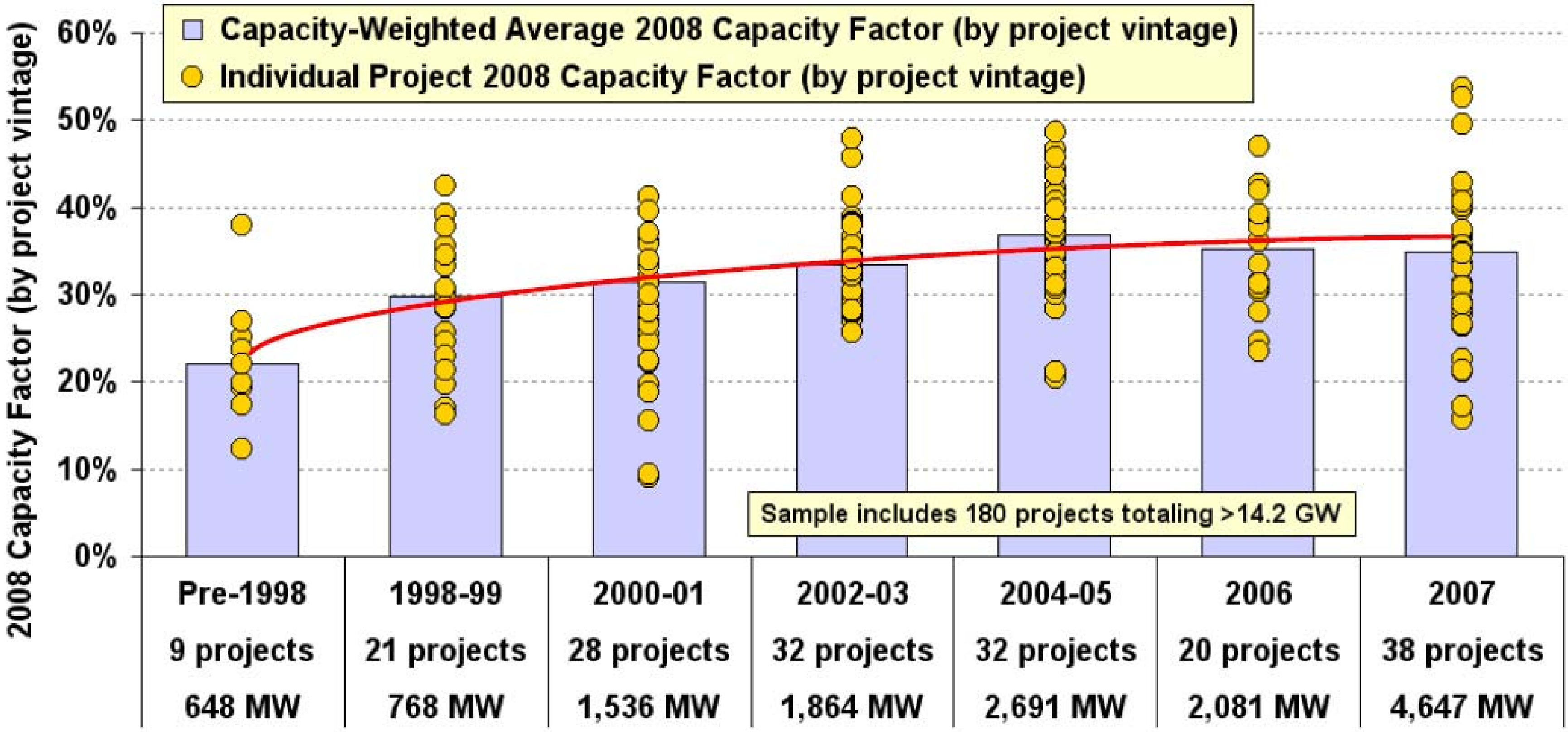
Source: FERC 2006 and 2004 "State of the Market" reports, Berkeley Lab database, Ventyx, ICE

Note: Wholesale price range reflects flat block of power across 23 pricing locations; wind costs represent capacity-weighted average price for wind power for entire sample of projects built from 1998-2008

Source: Wiser and Bolinger, 2009

Wind project performance has improved, but has been largely flat since 2004-05

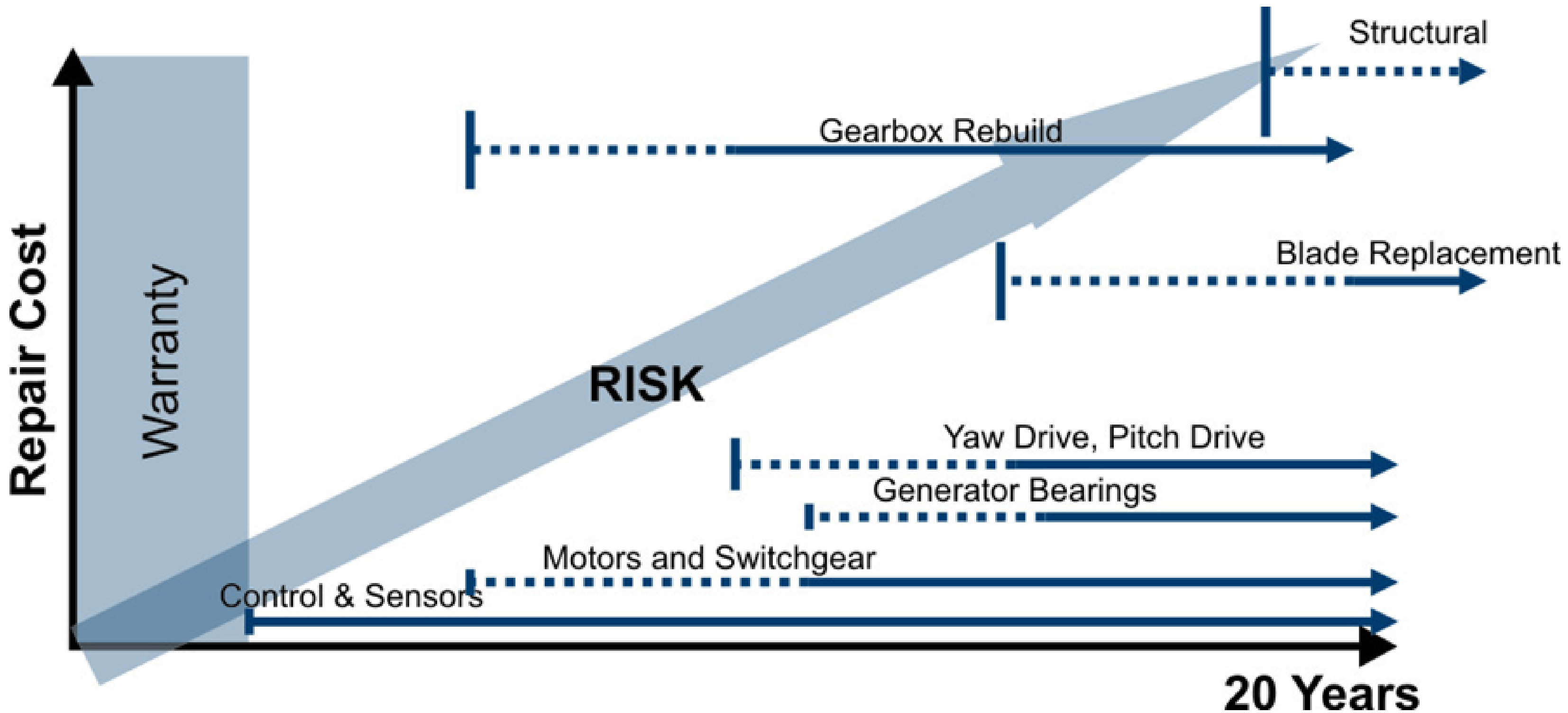
- 6% of projects installed prior to 2004 had capacity factors >40% in 2008
- 27% of projects installed from 2004-07 had capacity factors >40% in 2008



Source: Wiser and Bolinger, 2008

Gearbox performance is a major technology risk factor

- Although the wind industry has achieved high levels of reliability, unpredictable performance would threaten the credibility of wind power and lead to an increase in insurance and financing costs
- Operations and maintenance costs are increasing with the age of wind farms



Offshore wind technology challenges to achieve 54 GW of 20% Wind Scenario

- Offshore infrastructure is a major cost; ranging $2,400 to $5,000 per kW
- Short-term research, development, and deployment needs for offshore wind:
  - Large component test facilities
  - Defined exclusion zones
  - Certification and standards development
  - Development of design codes, tools, and methods
  - Siting and array configuration
  - Development of hybrid wind speed databases
- Long-term research and development needs:
  - Minimize work at sea
  - Enhance manufacturing, installation, and deployment strategies
  - Incorporate offshore service and accessibility features
  - Develop low-cost foundations, anchors, and moorings
  - Use resource modeling and remote profiling systems
  - Increase offshore turbine reliability
  - Assess the potential of ultra-large offshore turbines
- 26 of the 28 coastal states could meet 20% of their electric needs with wind

Photo courtesy of NREL

U.S. leads in distributed wind technologies

- Distributed wind technology: turbine installations that range in size from less than 1 kW to multi-megawatt, utility-scale machines
- U.S. manufacturers are world leaders in small wind systems (100 kW or less) in terms of both market and technology
- For a 1 kW system, hardware costs alone can be as high as $5,000 to $7,000/kW
- Recent innovations:
  - Alternative power and load control strategies, advanced blade manufacturing, rare-earth permanent magnets, reduced generator cogging, induction generators, grid-connected inverters, reduced rotor speeds, design standards and certification
- Areas needing further development:
  - Incorporate technology advances from large machines
  - Acoustic emissions
  - Improve reliability
  - Optimize aerodynamics
  - Novel tower and foundations
  - Application of IEC design and testing standards
  - Wind turbine testing, especially independent third-party testing

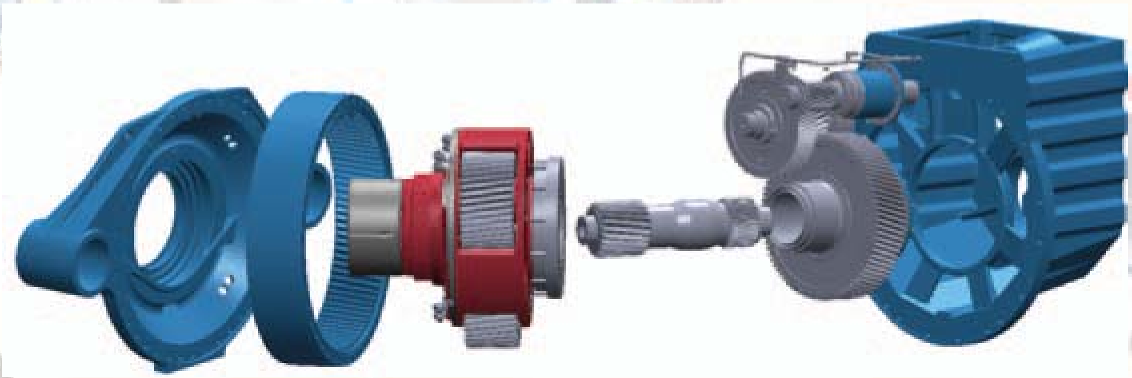
Photo courtesy of NREL

Path forward: increase capacity factors

- Pursue larger rotors and taller towers
- Continue improvements to blades, rotors, drive-train components and controls
- Enhance reliability of major components

Path forward: reduce capital costs

- Reduce aerodynamic and mechanical loads through advanced blade and rotor concepts
- Reduce turbine weight through judicious use of newer, high-strength materials
- Improve component manufacturability and manufacturing processes



Path forward: mitigate risks

- Evaluate performance to enable early identification of issues
- Track O&M needs to enhance experience base for turbines and components
- Conduct testing and certification activities

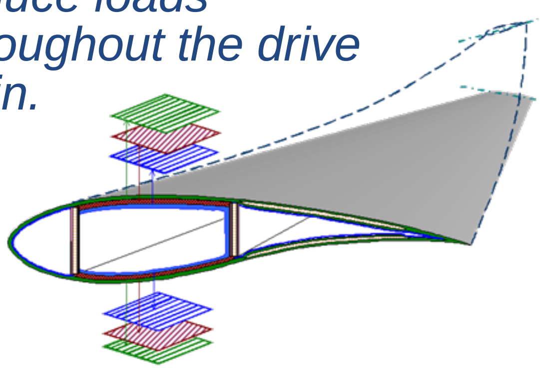
Path forward: technology improvement

Advanced, taller tower designs and new materials are important to capture wind resources and improve transportation.

Photo courtesy of NREL

Rotors are the number one target for improvement through advanced materials, controls, and power systems.

Blades that twist in high winds can reduce loads throughout the drive train.



Fundamental gearbox topology can also be improved, as shown in this multiple-drive-path gearbox.

Technology conclusion: improvements needed, but no major breakthroughs required

- No major technical breakthroughs in land-based technology are needed to achieve the 20% Wind Scenario, but improvements are needed
- Sustained R&D efforts will help reduce risk and enable the transfer of new technology to the marketplace
- Revitalized offshore wind R&D program needed