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ENG 505 - ENERGY SURETY AND SYSTEMS

Wind Energy

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Outline

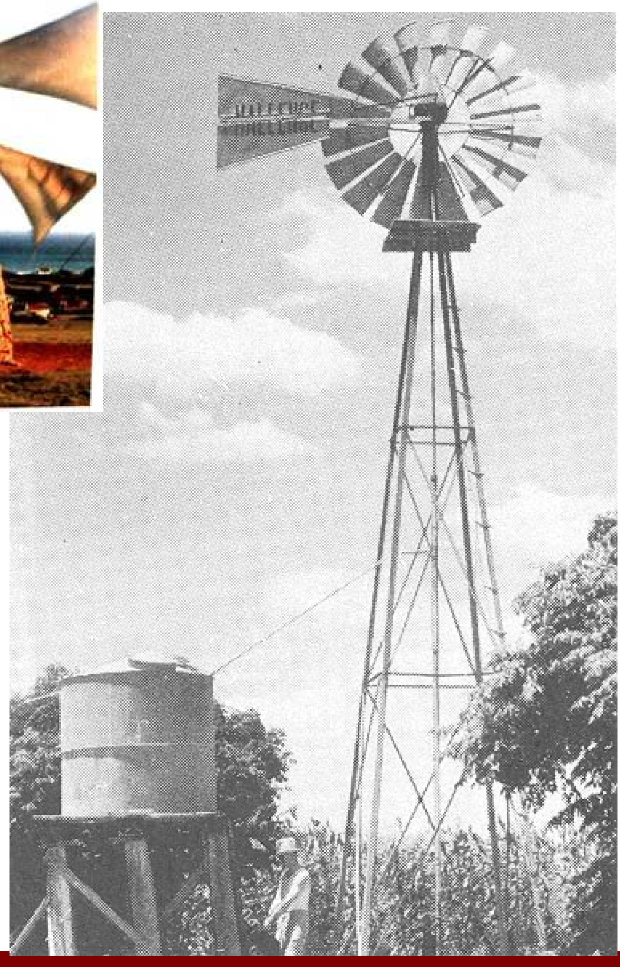
- Biographical Note
- Wind Energy Technology Background and History
- Wind Energy Basics
- Sandia Wind Program
- Opportunities and Challenges
- Question & Answer Session

Joshua Paquette

- Education:
  - BS Mechanical Engineering – Kansas State University
  - MS Engineering Mechanics – University of Texas at Austin
- Professional Experience in Energy Industry
  - 8 years as Staff Member in the Wind Energy Technologies Department
- Current Projects: Wind Turbine Blade Reliability Collaborative, Innovative Offshore Vertical Axis Wind Turbine Project, DOE Composite Materials Database, Low RCS Blades

History of Wind Energy

pre - 1970



- Prehistoric – Maritime (Greek, Viking)
- Medieval – Persian, Greek, England
- 20^{th} Century – Great Plains
- First Energy Shortage -- 1974

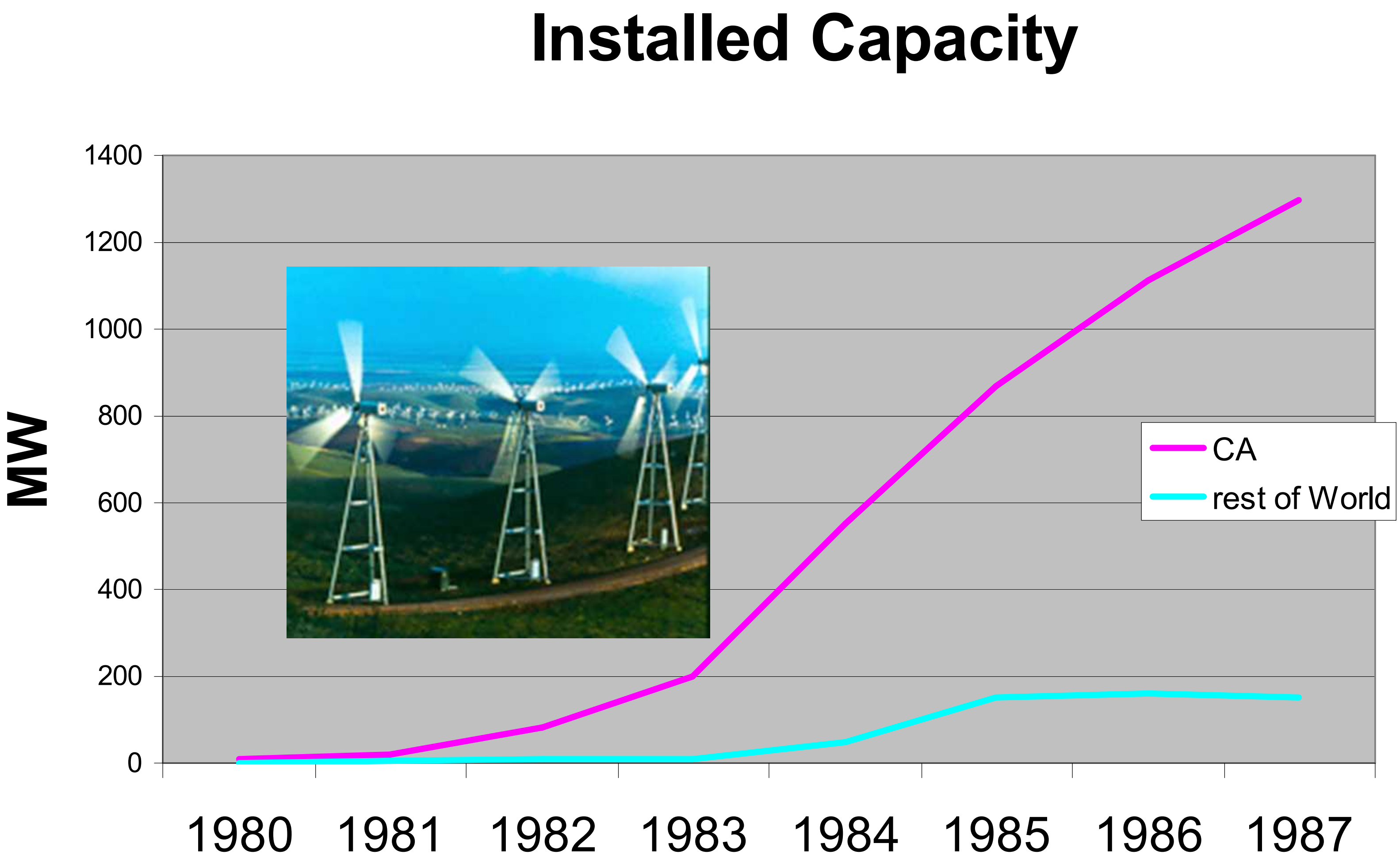
History of Wind Energy

post - 1970

U.S. DOE develops significant research program in response to the energy crisis of 1974

History of Wind Energy

California Boom



AWEA, CEC, Renewable Energy World, Power Engineering, Earth Policy Institute, UC-Irvine

Wind Power Basics

Wind Power output is proportional to the area swept by the blades ($A = \pi r^2$)

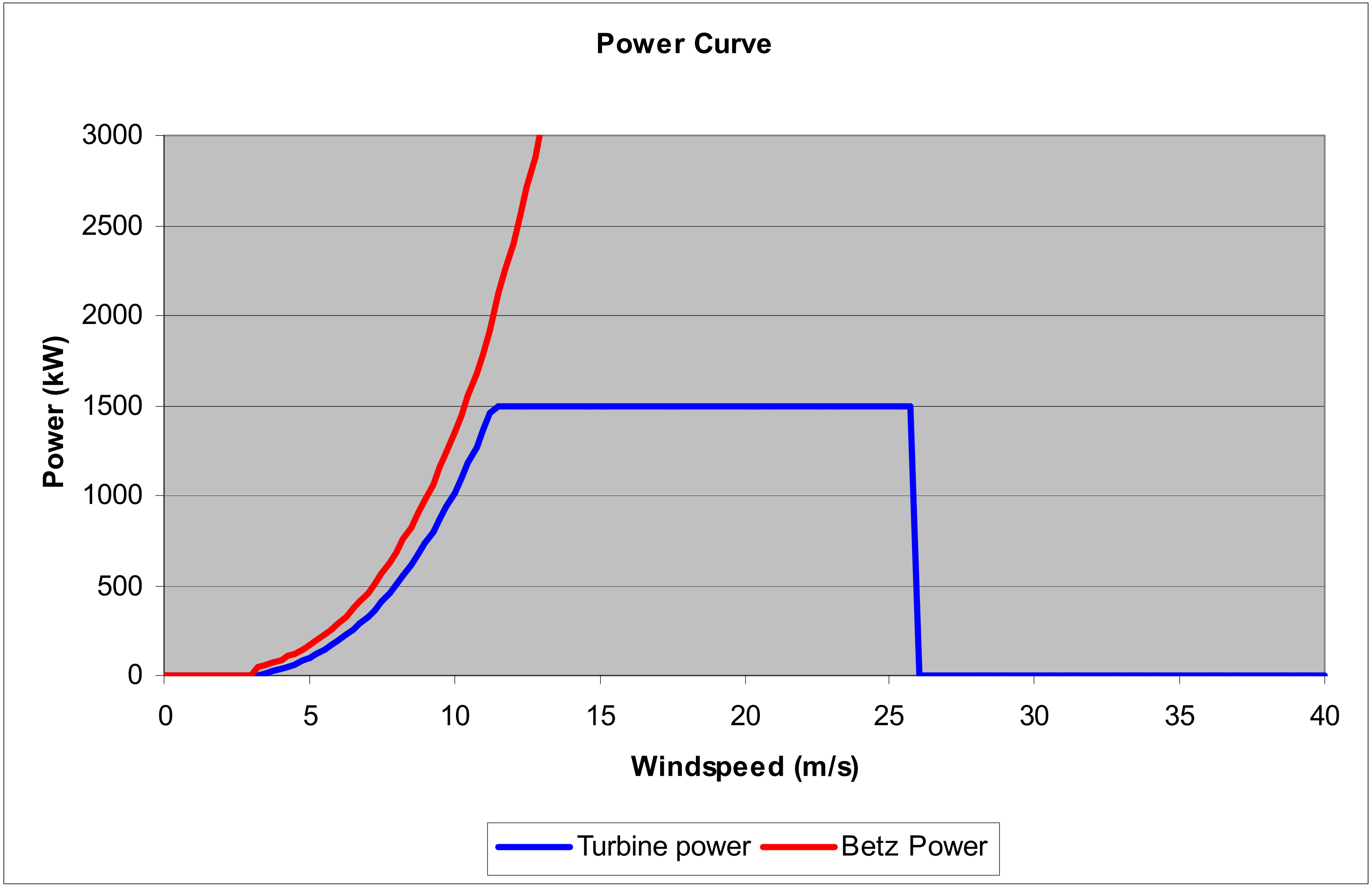
$$WindPower = \frac{1}{2}\rho A V^3$$

Wind Power output is proportional to wind speed cubed.

ρ = Air Density
A = Area swept by blades
V = Wind speed

Wind Power Basics

Power vs. Wind Speed



Wind Power Basics

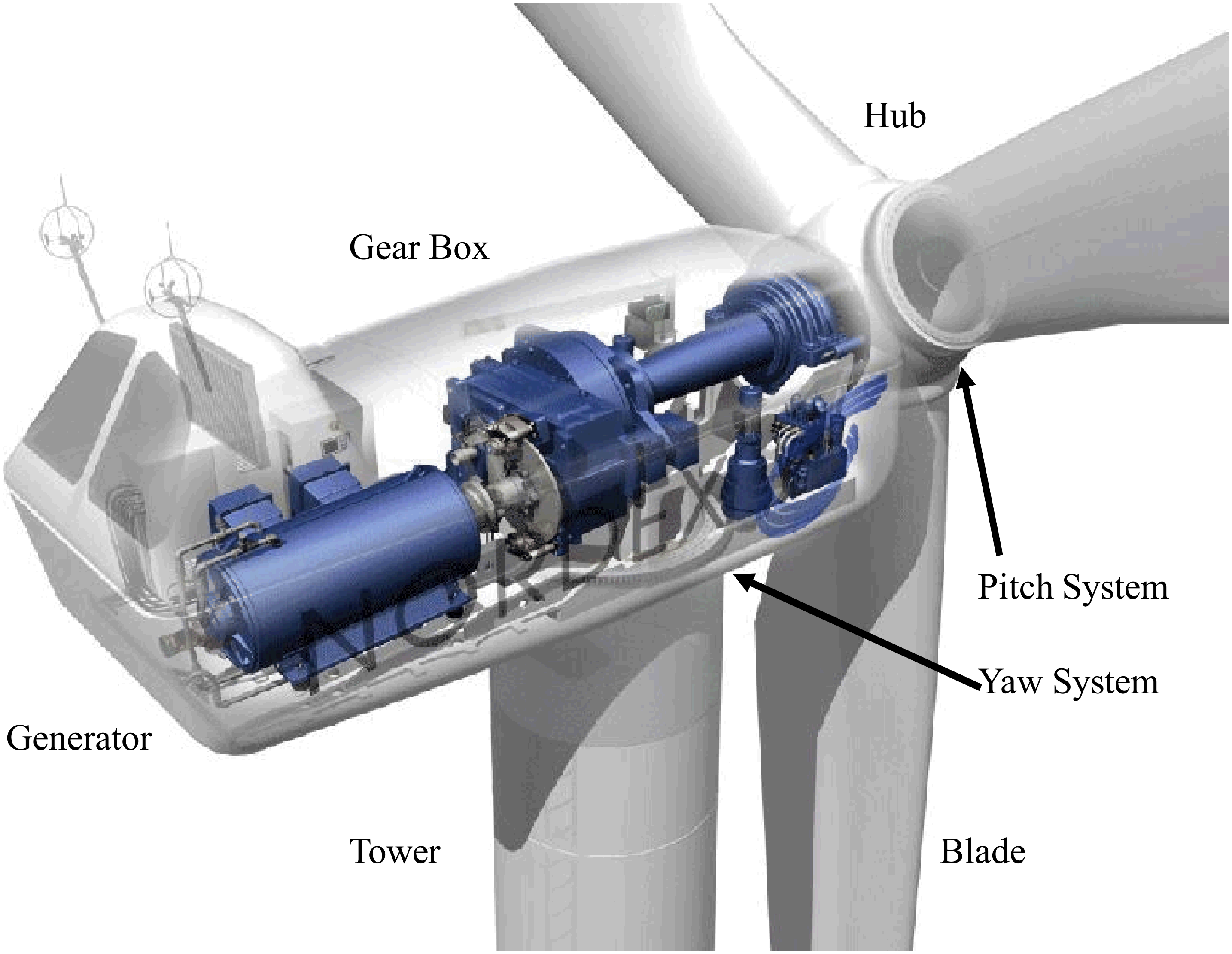
small wind

(1-10 kW)

1 www.bergey.com
2 www.skystreamenergy.com

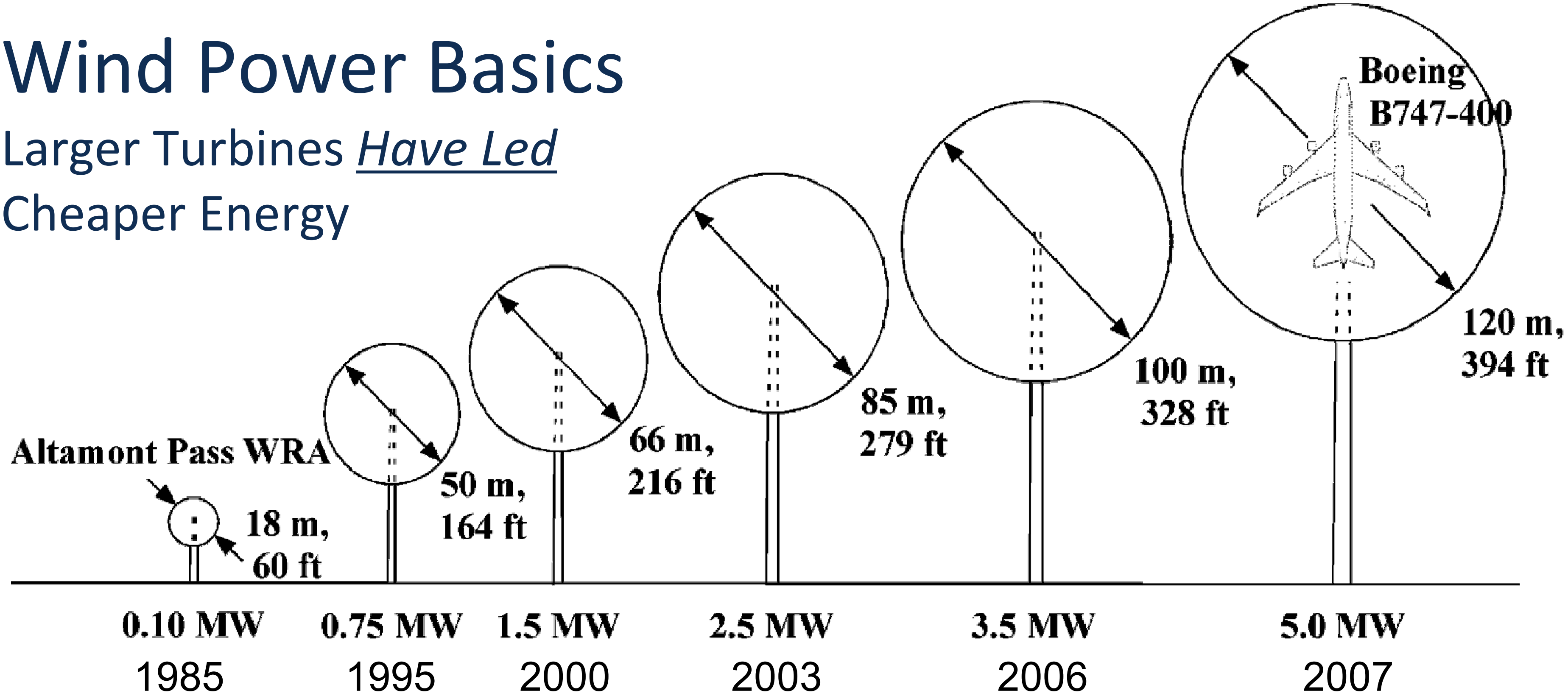
Wind Power Basics

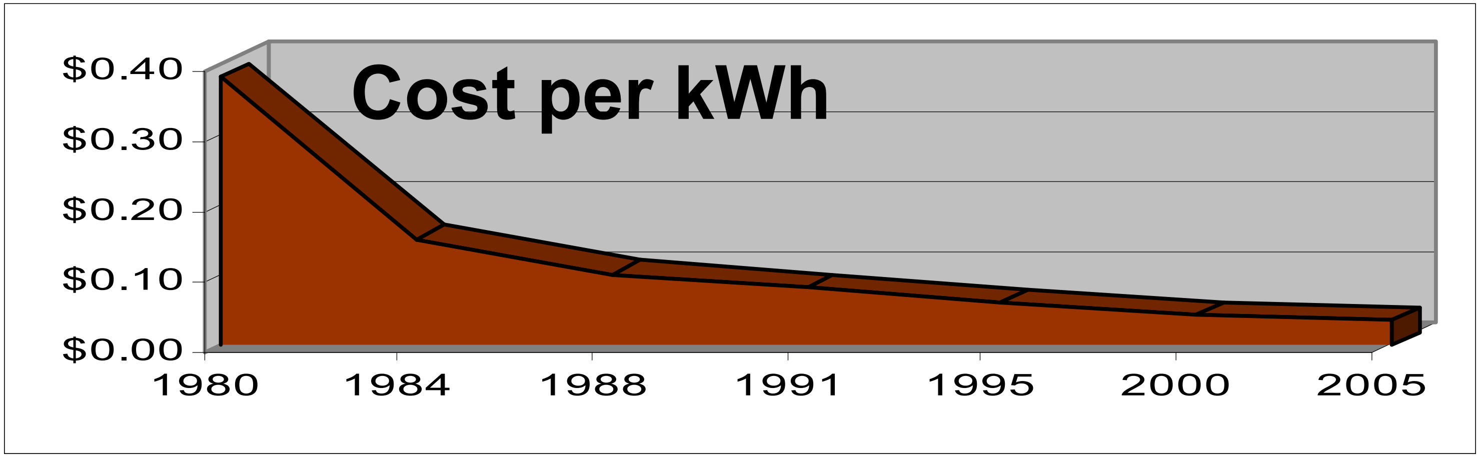
Typical Turbine Design



Wind Power Basics

Larger Turbines *Have Led* Cheaper Energy





Wind Power Basics

Leading Turbine Manufacturers

GE (US)

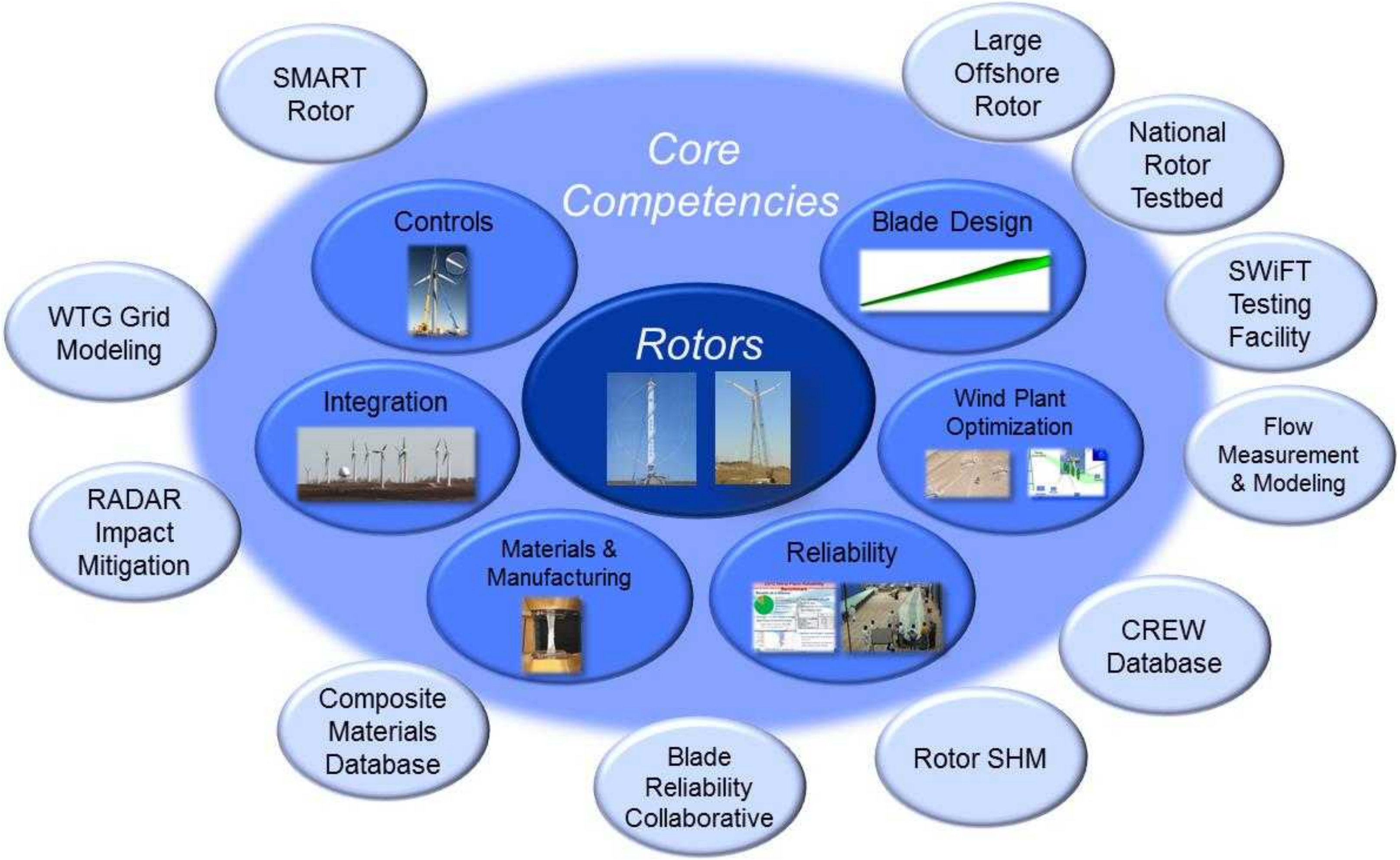
Gamesa
(Spain)

These four suppliers account for 60% of the world market

Enercon
(Germany)

Vestas
(Denmark)

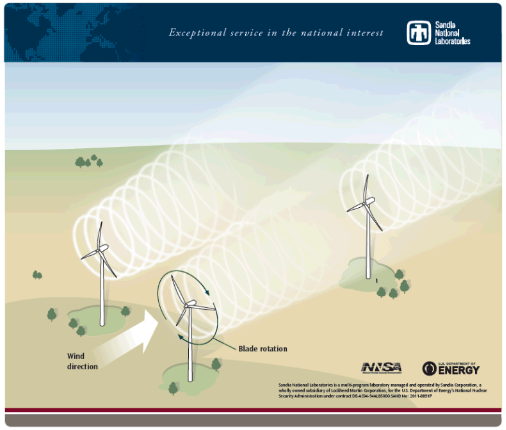
Sandia Wind Energy Department



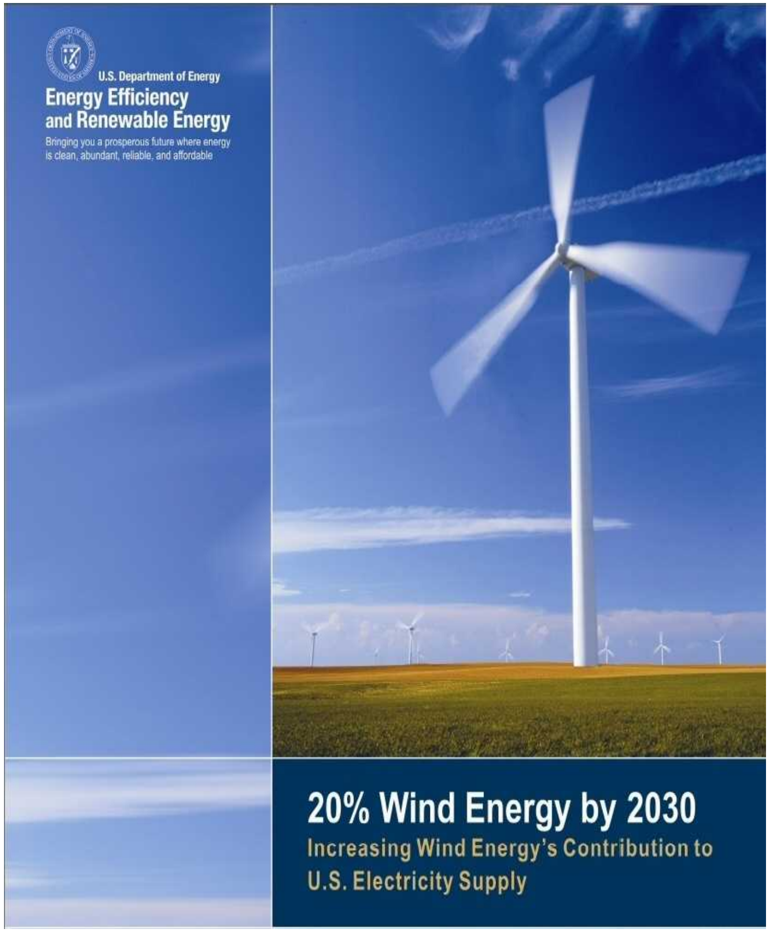
Sandia Capabilities

Scaled WInd Farm Technology (SWIFT) Center TTU – Lubbock, TX

- Unique Capabilities
  - 1st facility in the world to specifically study wind farm wakes and their effects on downwind turbines
  - Highest category wind class, with average winds of 17 mph
  - Scaled research turbines (Vestas model V27) allow for rapid technology development at 5% of the full size experiment cost
- National Value
  - Reduce performance losses and maintenance costs from turbine-turbine interaction
  - Develop advanced wind turbine rotors for increased energy capture and improved reliability
  - Turbine models and data are an open-source research asset to aid the entire wind energy community
- Significant Partners
  - Vestas, the world's largest wind turbine manufacturer, is installing its own V27 turbine to perform both cooperative and proprietary research.
  - TTU has partnered to develop the test facility, which will be used to foster academic research and wind energy education.
  - Finalizing NDA's to perform research testing at the facility for GE, Gamesa, and Alstom.



Wind Energy – Opportunities and Challenges



U.S. DOE Goal:

20% Wind Energy
by 2030

Wind Energy – Opportunities and Challenges

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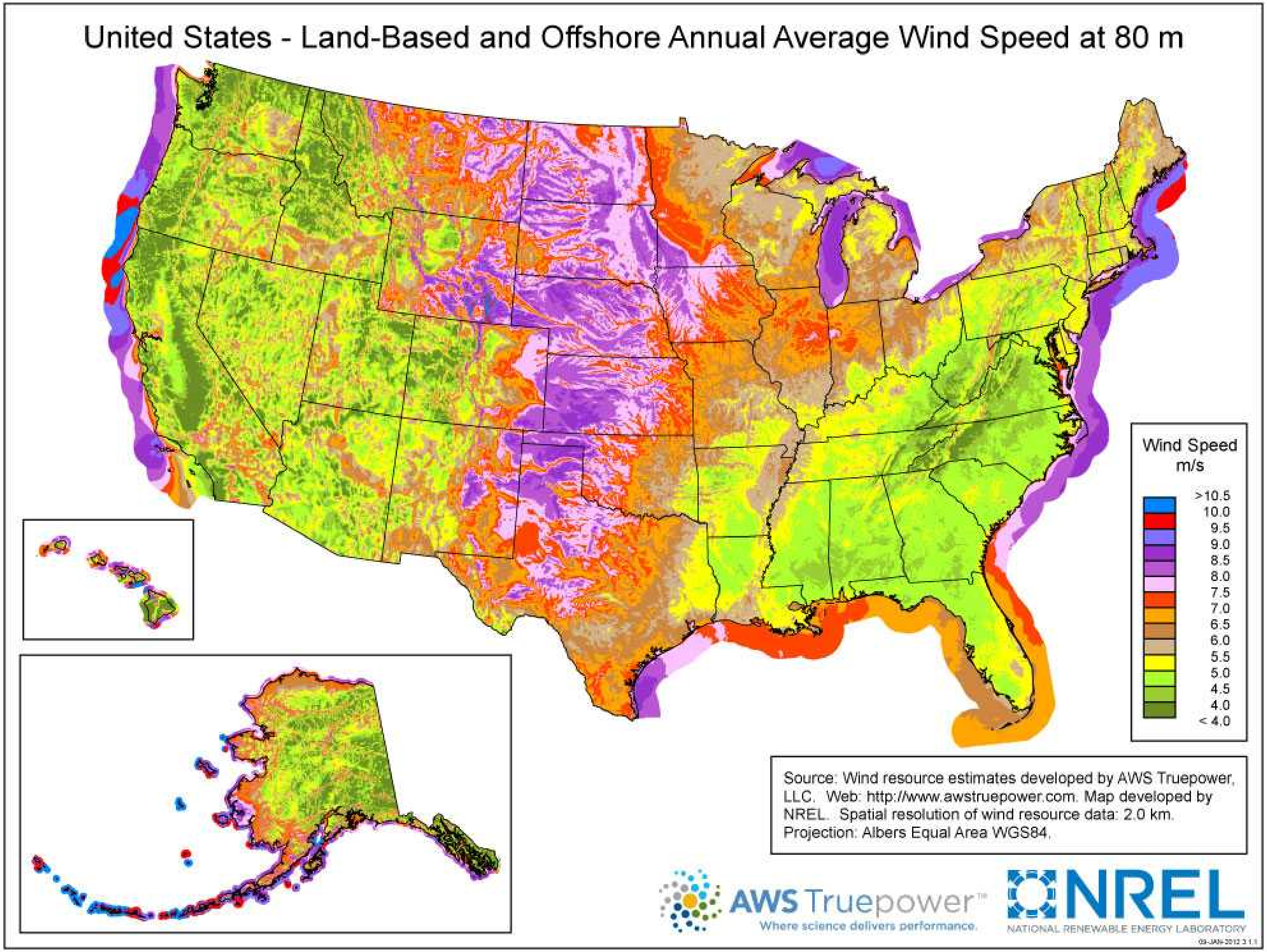
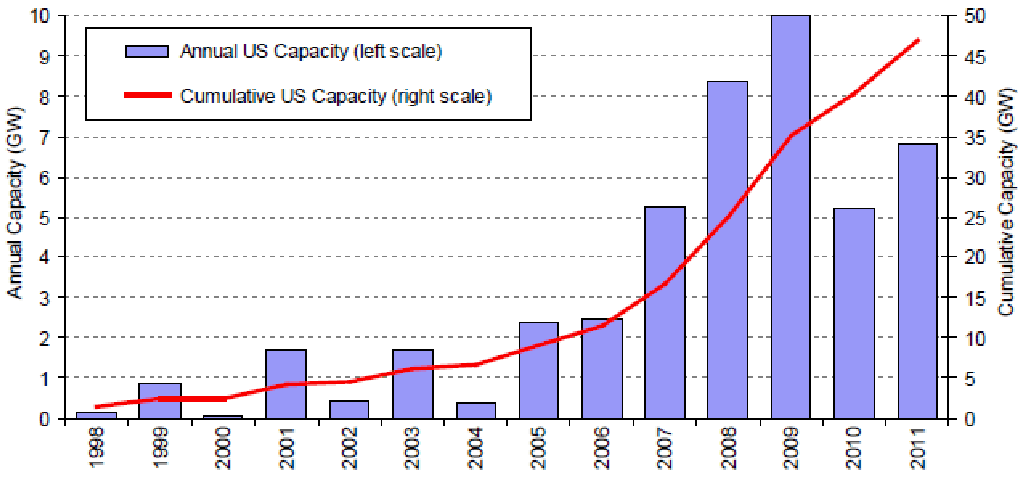
How much wind is there?



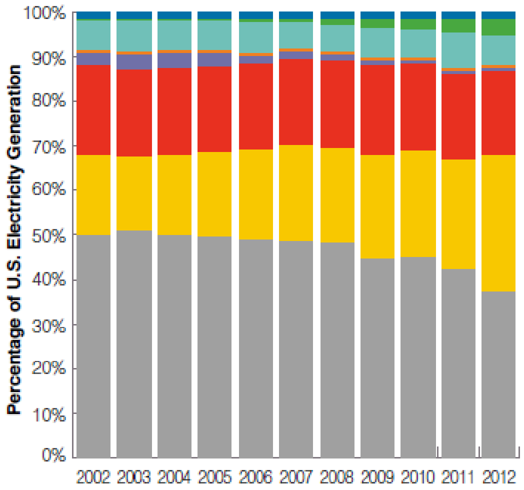
Source: DOE

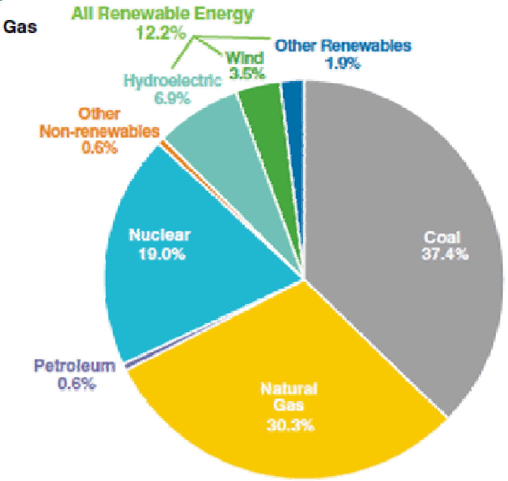
Wind Energy – Opportunities and Challenges

How much does wind contribute?

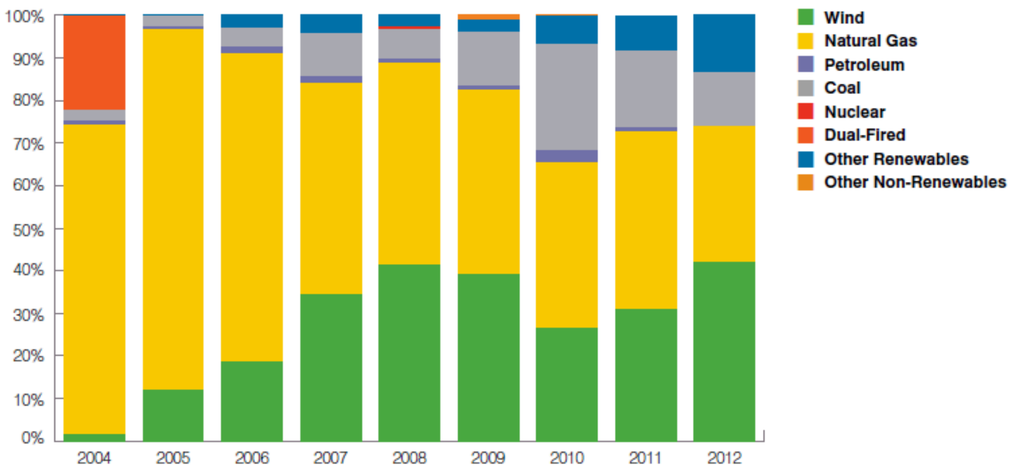


US Installed Capacity





Generation Mix

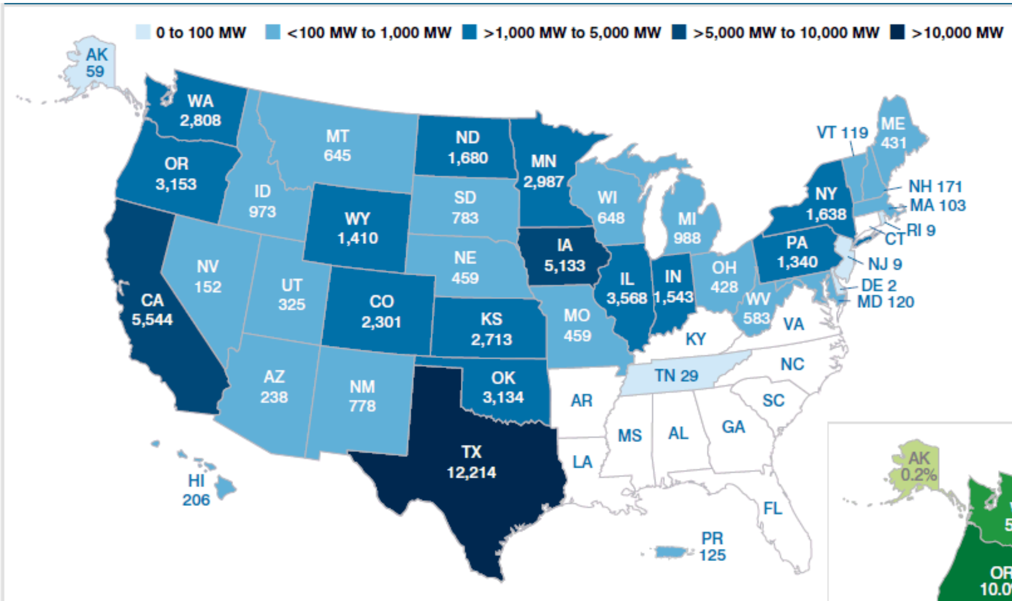


U.S. Recent Capacity Additions

Source: DOE/AWEA

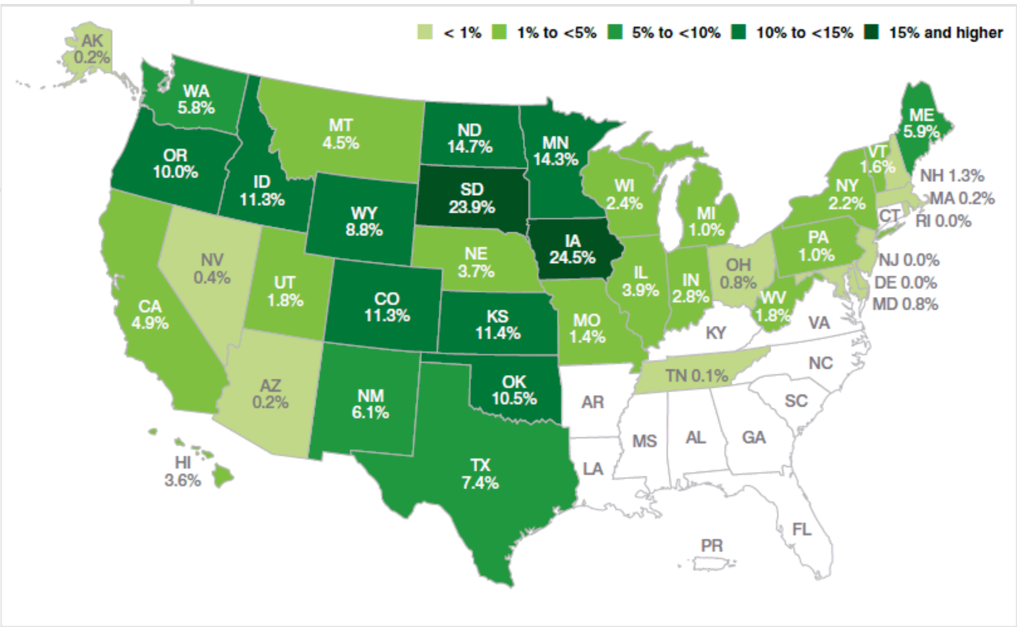
Wind Energy – Opportunities and Challenges

Where are wind farms installed?



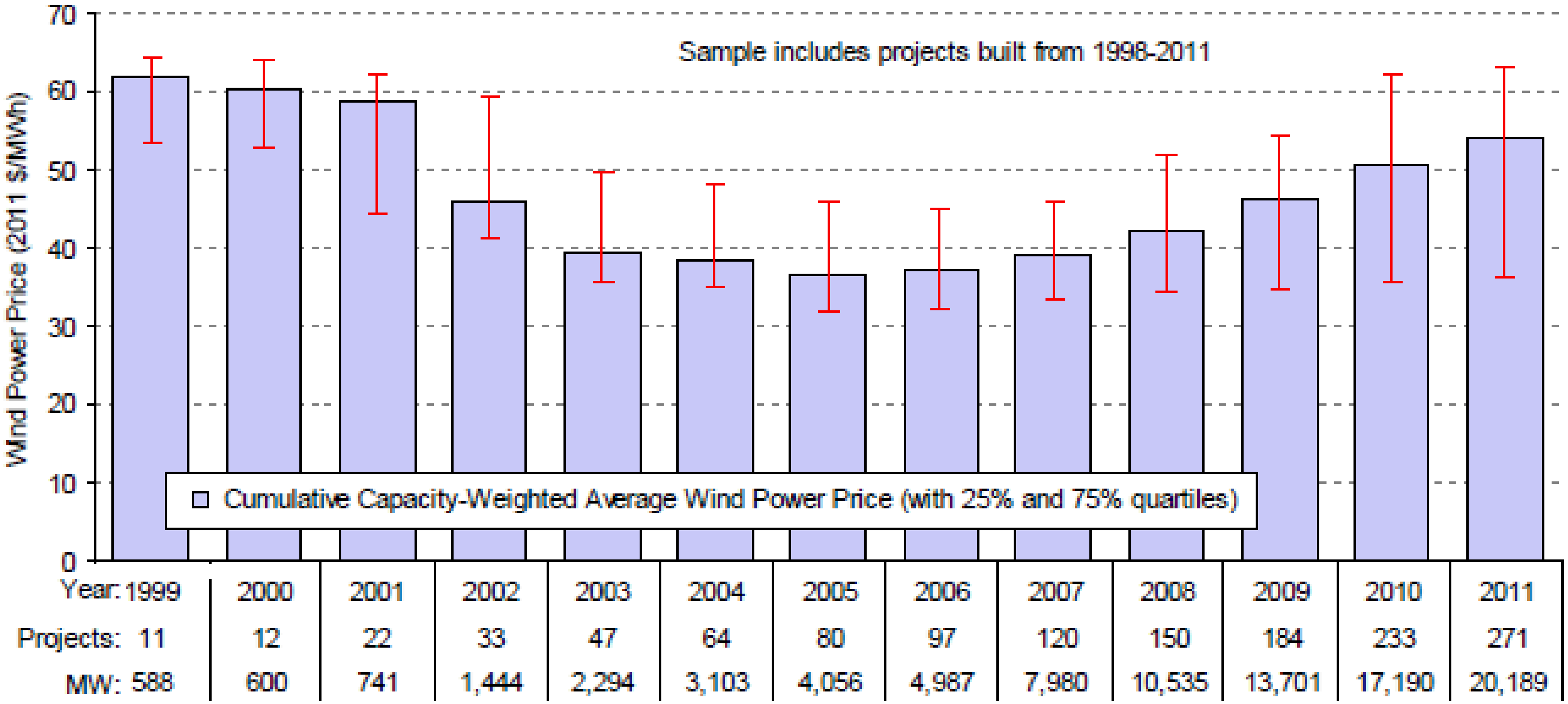
Installed Capacity by State

Share of Production by State



Wind Energy – Opportunities and Challenges

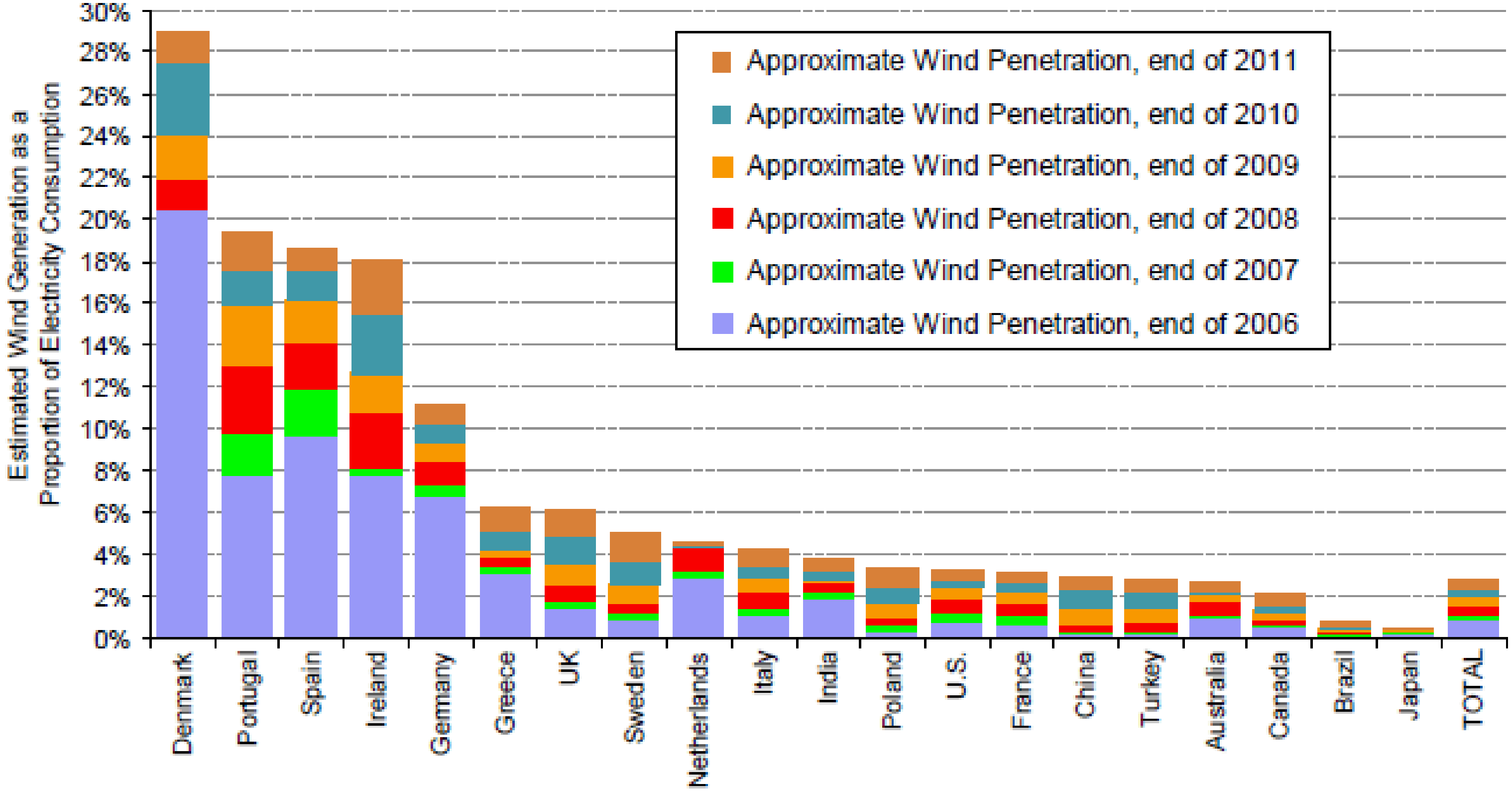
How much does is cost?



Source: DOE

Wind Energy – Opportunities and Challenges

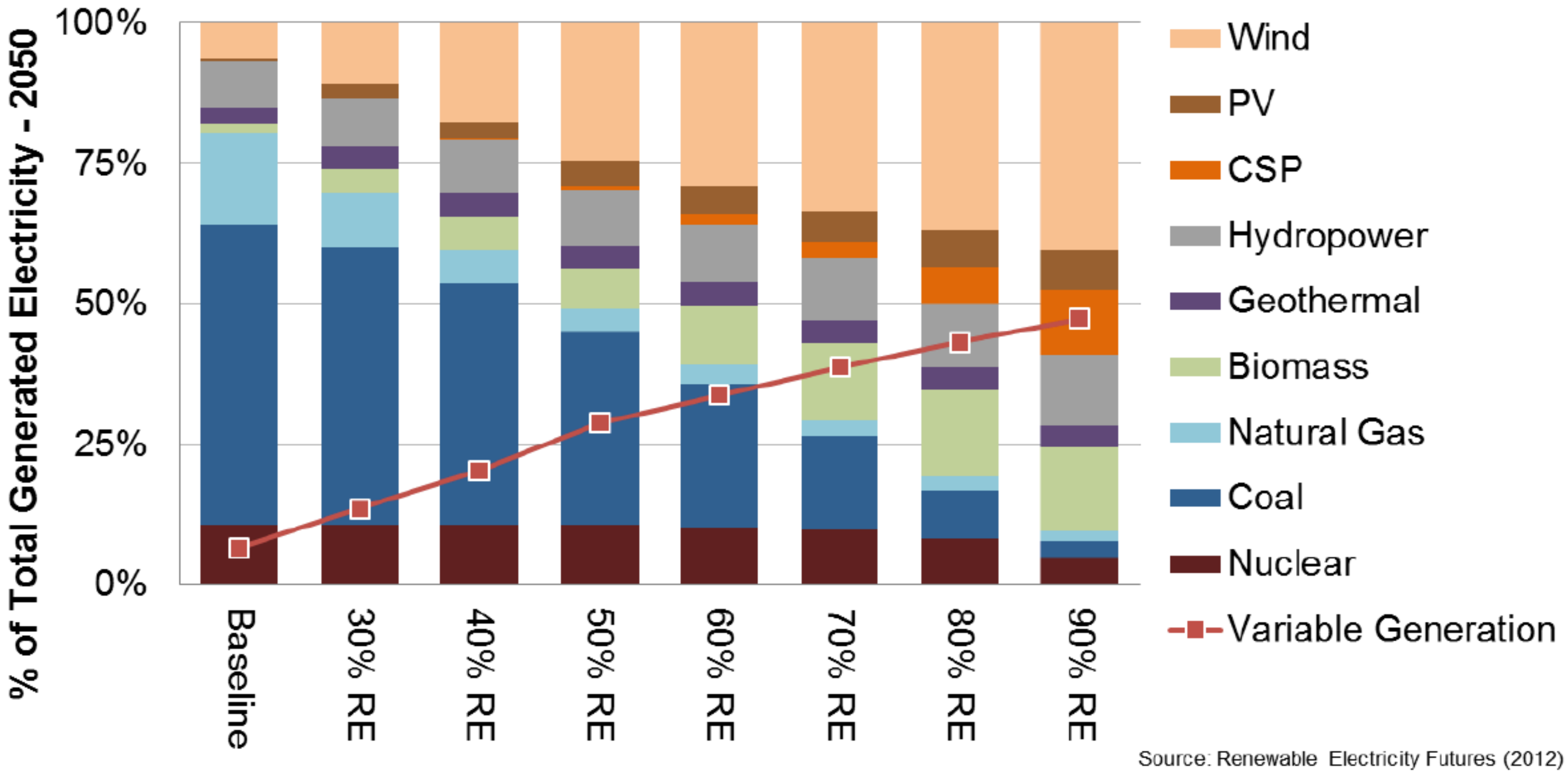
How does the US compare to other countries?



Source: DOE

Wind Energy – Opportunities and Challenges

What does the future hold for wind?

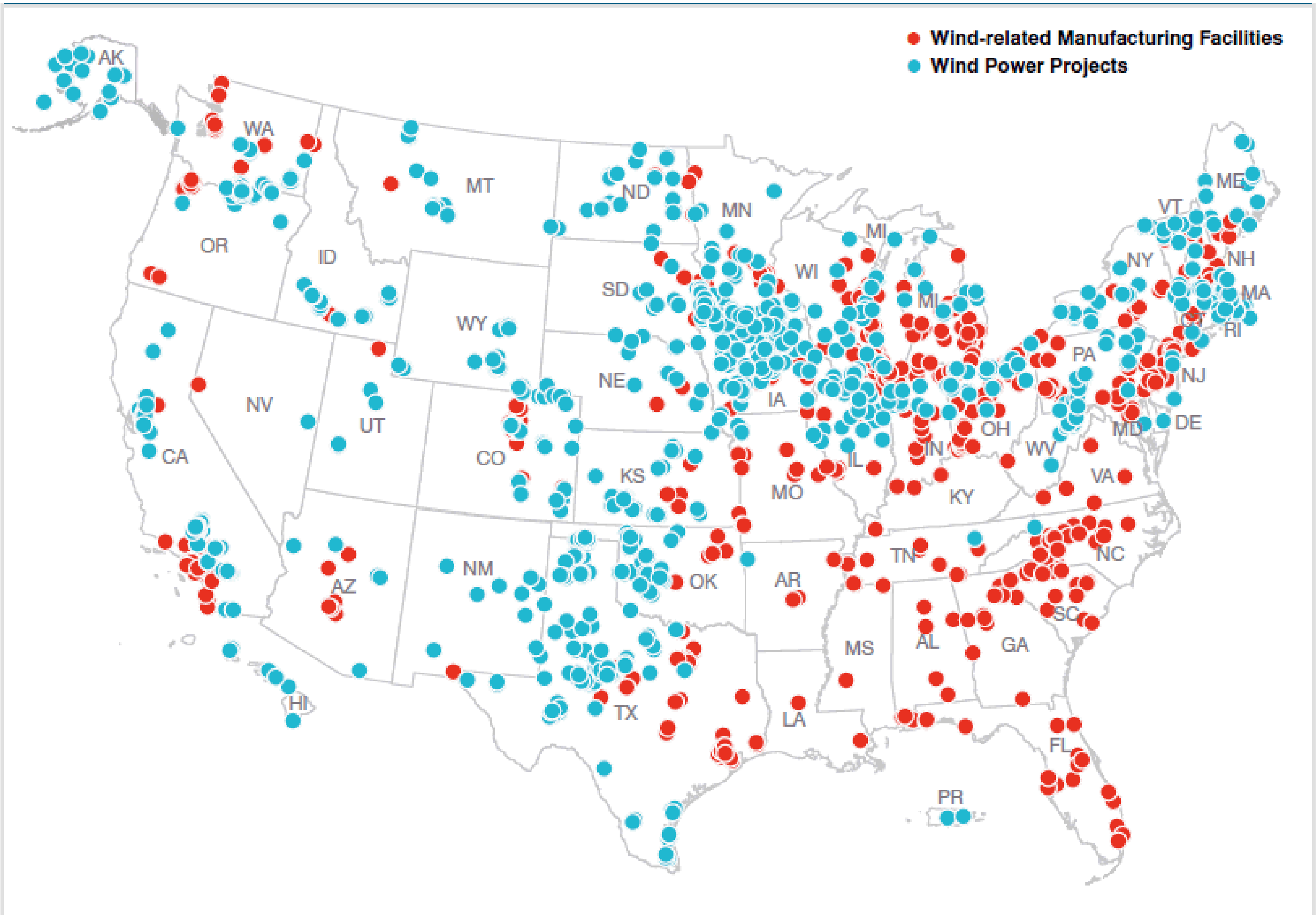


Renewable Electricity Future Report: Feasibility study of achieving 80% renewable penetration rate in the U.S. by 2050

Source: DOE

Wind Energy – Opportunities and Challenges

Economic Considerations



Source: AWEA

Wind Energy – Opportunities and Challenges

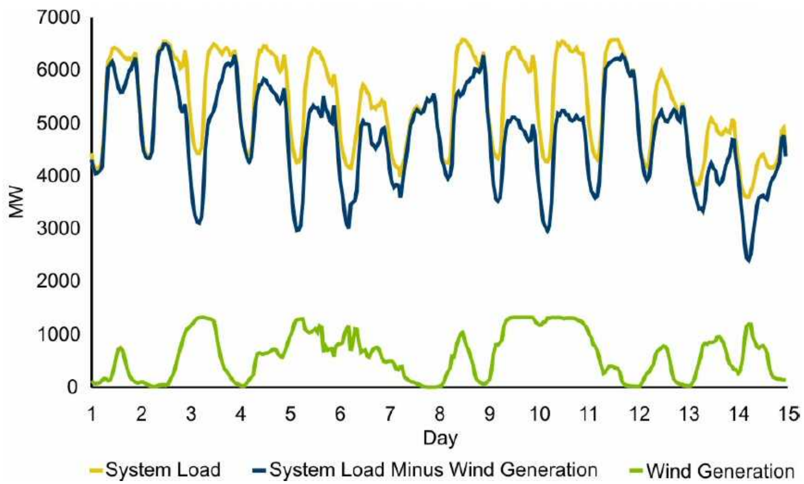
Benefits of Wind Power

- **Economic Development**
  - **Land leases, tax revenue, green jobs**
- **Cost Stability**
- **Resource Availability**
  - **Domestic, inexhaustible, low risk**
- **Environmental**
  - **No CO_2, SO_2, NO_x, mercury**
  - **No mining or drilling**
  - **No significant waste**
  - **No water use**
  - **Little impact on land use**

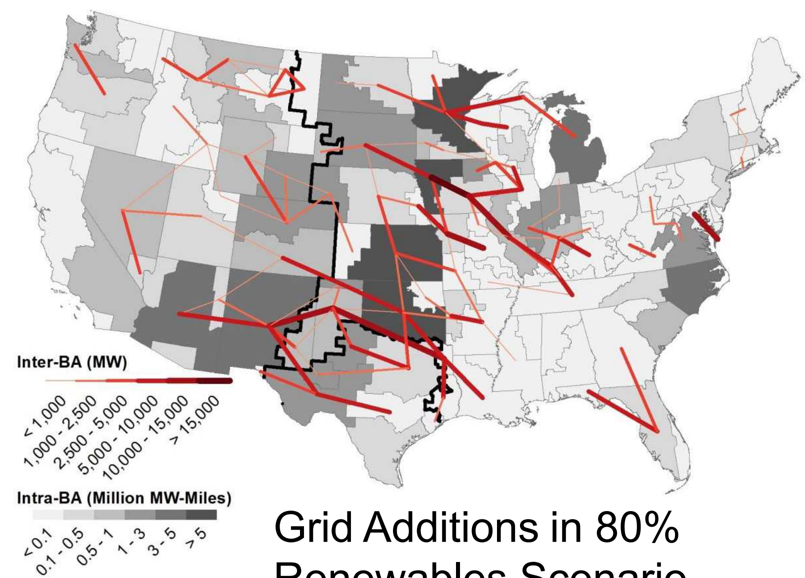
Wind Energy – Opportunities and Challenges

Power Variability

- Production and load both fluctuate significantly
  - All plants have limitations on their ramp rates to follow load
  - Storage is great…but it's great for the grid in general
  - Long term storage is currently expensive when compared to buffering capacity afforded by natural gas
  - The current grid can handle moderate amounts of variability
- What about high levels wind/renewables?
  - 2012 Renewable Electricity Futures Report found 110-190 million MW miles of transmission would be added for 80% renewable penetration
  - Annual investments of $5.7-8.4B/year, within range of recent expenditure rates



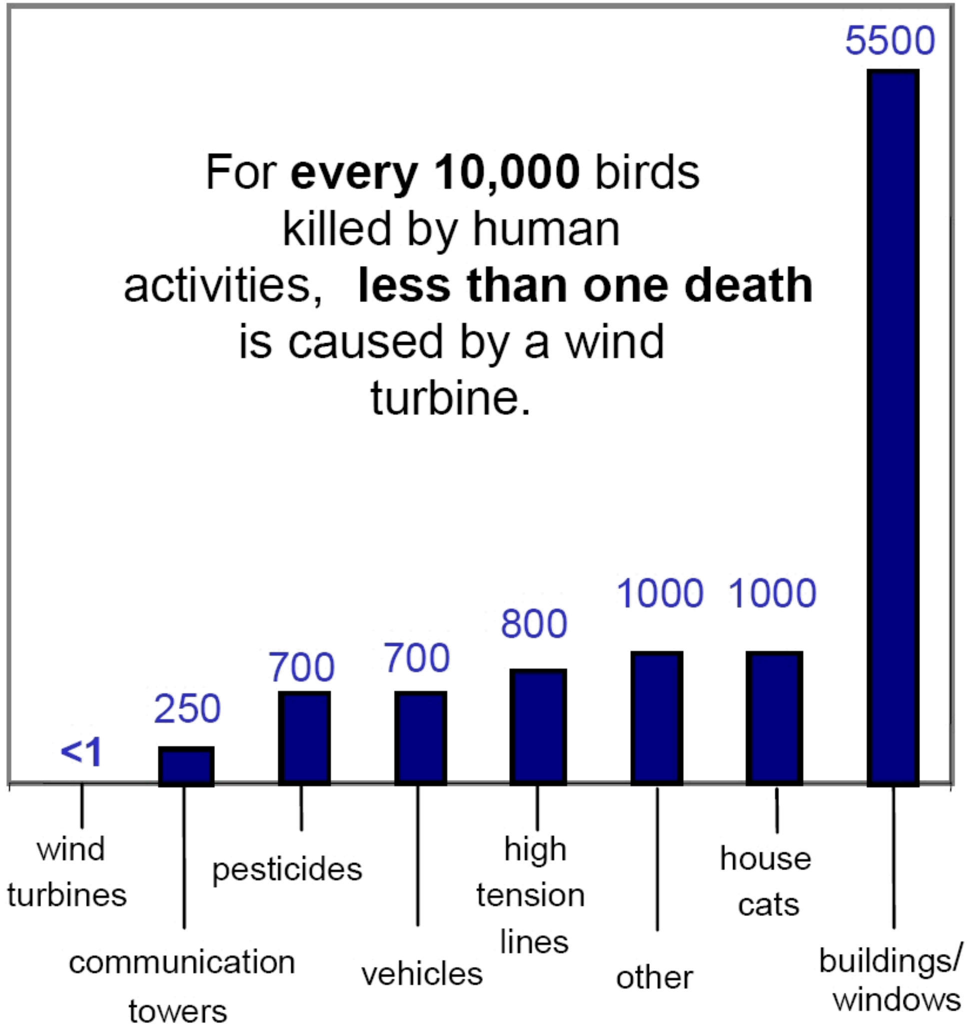
System Load Impact from Wind



Grid Additions in 80% Renewables Scenario

Wind Energy – Opportunities and Challenges

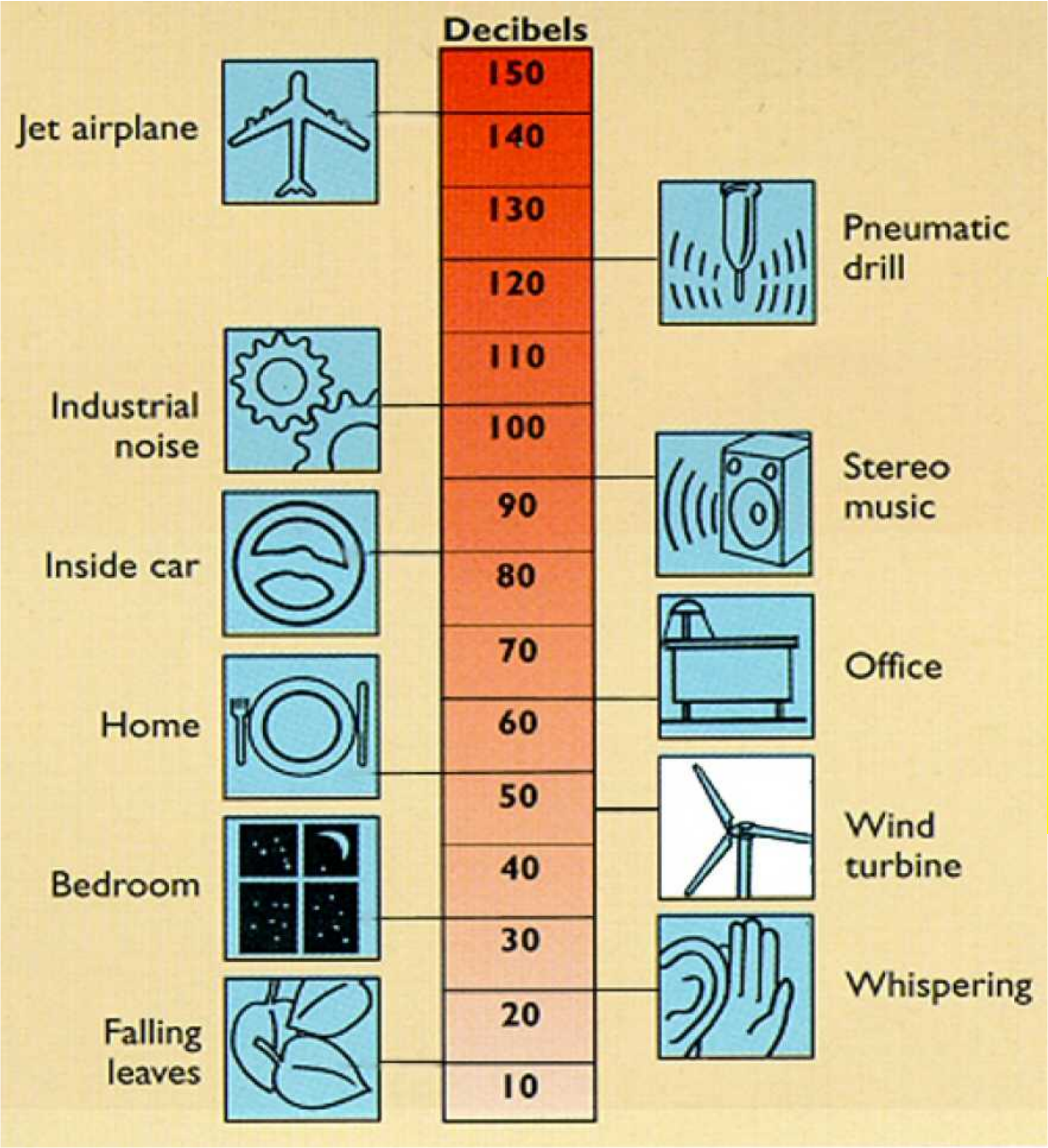
Bird Mortality is a Public Relations Concern



Problem documented in Altamont Pass, CA which is one of the nation's largest concentrations of federally-protected raptors

Erickson et al., 2002, Summary of Anthropogenic Causes of Bird Mortality

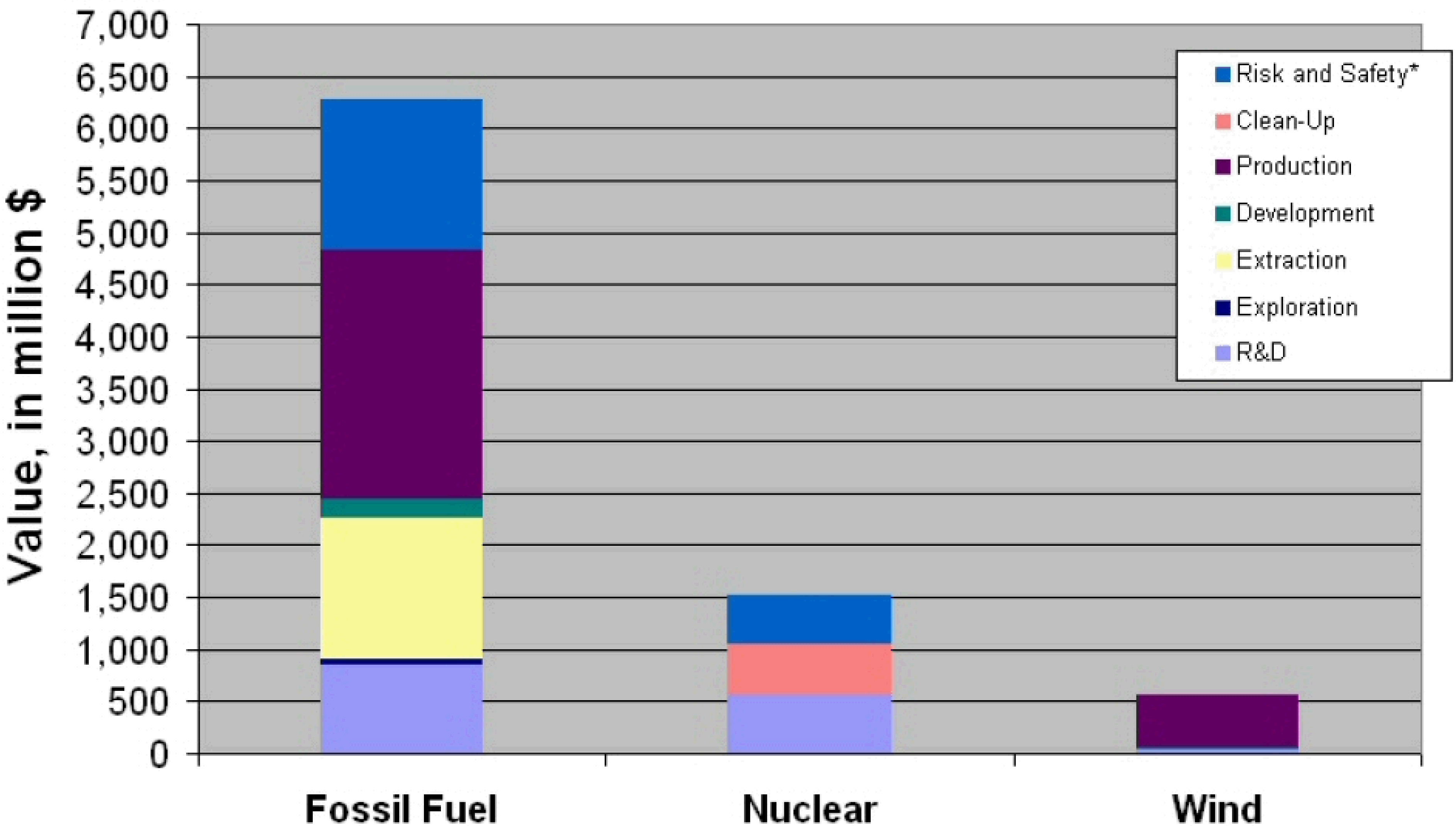
Wind Energy – Opportunities and Challenges
Wind Turbine Noise



The level of noise created by wind turbines is halfway between that in your bedroom at night and your office in the daytime.

Wind Energy – Opportunities and Challenges

U.S. Federal Energy Subsidies (2006) are small but necessary.



☺ THANK YOU! ☺

QUESTION & ANSWER SESSION

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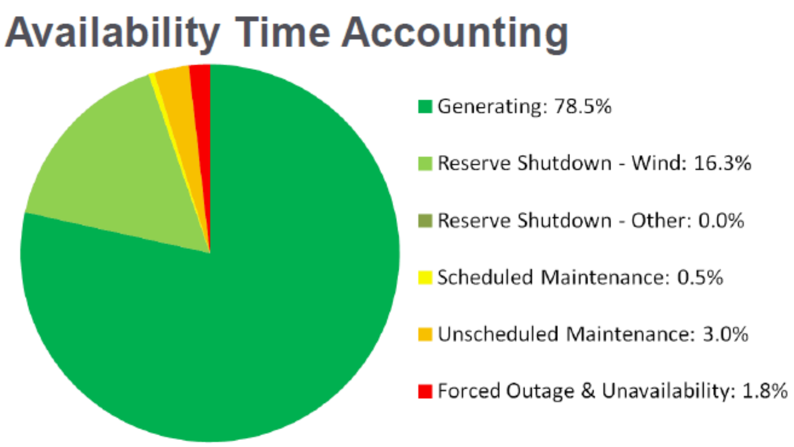
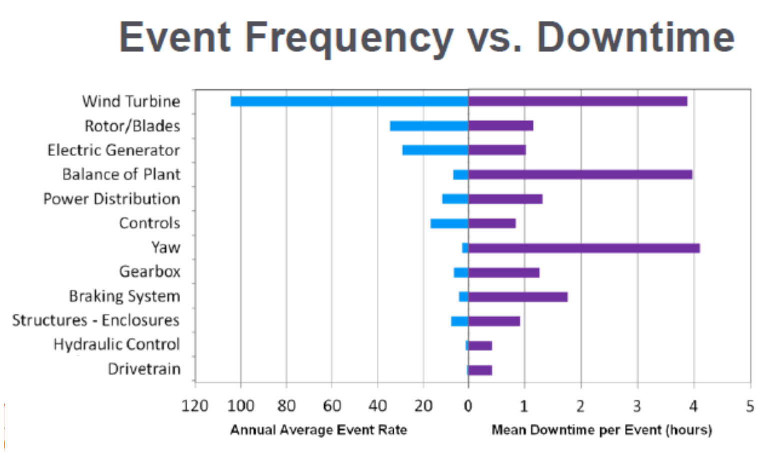
CREW Database and Analysis Program

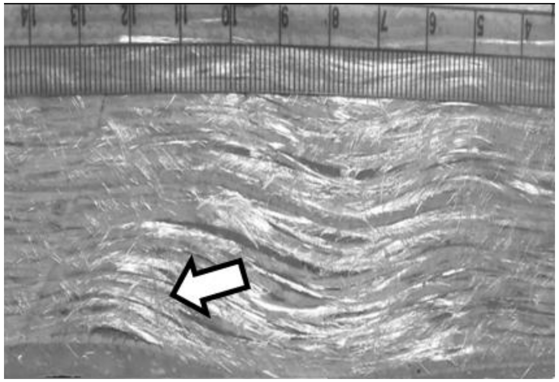
- Problem:
  - No baseline within wind industry to characterize operation and maintenance (O&M) practices
  - Ineffective collection, storage and analysis of O&M data that contribute to reduced availability and higher than expected O&M costs
  - Lower than expected reliability of components
- Goal: Advanced capability in wind industry that focuses on the use of data to create actionable knowledge that decreases the O&M costs and increase availability





Blade Reliability Collaborative

- Problem: Blade reliability issues related to manufacturing, transportation, installation, and operation can have large effects on COE as blade failures can cause extensive down time and lead to expensive repairs.
- Goal: Improve the reliability of blades delivered to the field so that remediation work before operation can be eliminated and the service lifetimes can achieve the 20 year targets that are expected by wind plant operators and financiers.



DOE/SNL/TTU SWIFT Test Site

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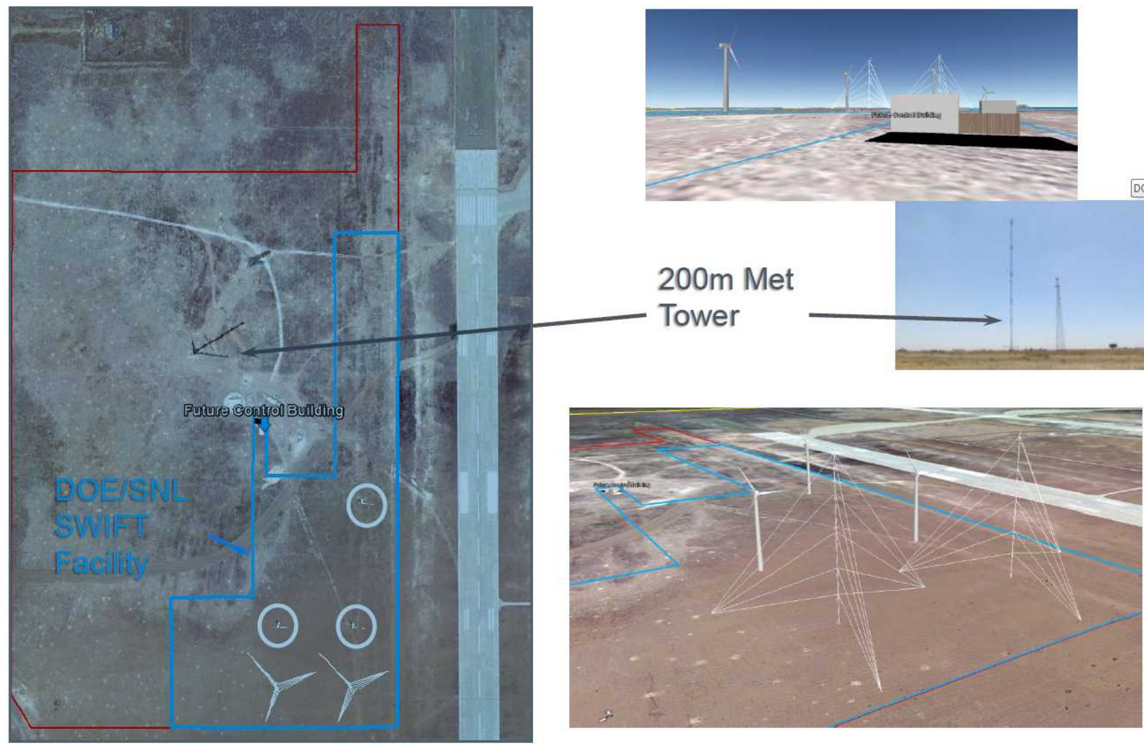
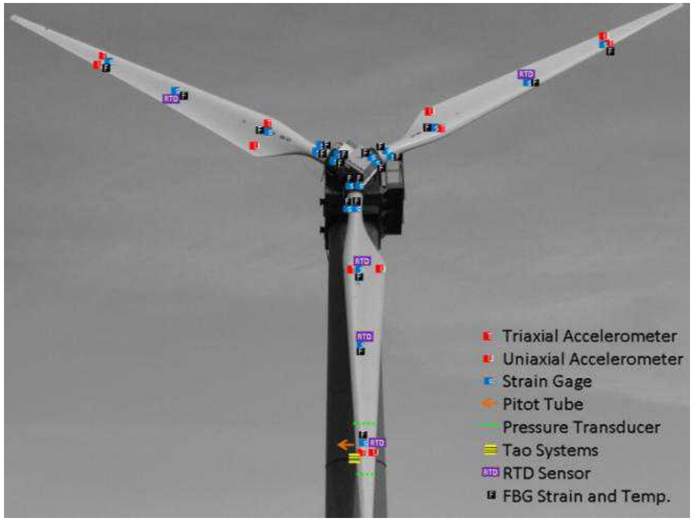
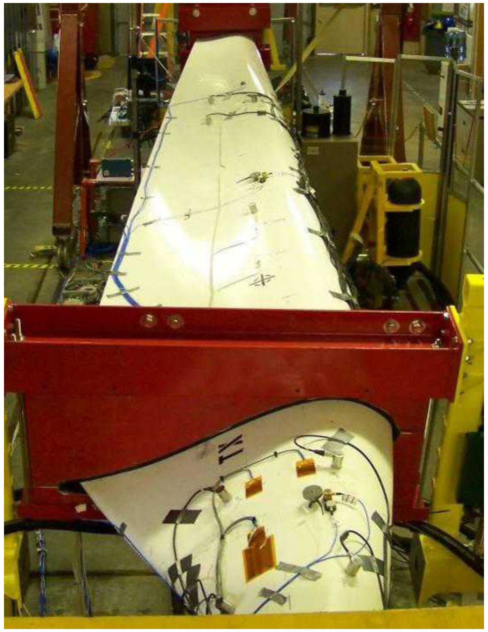
- Problem: World-class testing facilities are required to transition early-stage high-risk disruptive technology from basic research up to commercialization.
- Goal: Lower cost of energy with innovative advancements to wind energy, developed in the most rapid and cost-efficient process possible.



Sensor Blades 1 and 2

- Problem: Advanced sensing systems are required to actively control rotor loads, increase turbine energy capture and optimize wind farm performance.
- Goal: Fabricate and test blades to develop sensing technologies and evaluate
  - Manufacturing integration
  - Field performance
  - Fatigue resistance



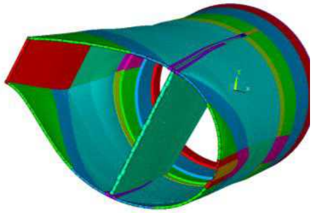


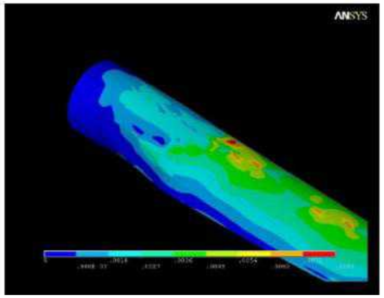
Active Aerodynamic Load Control

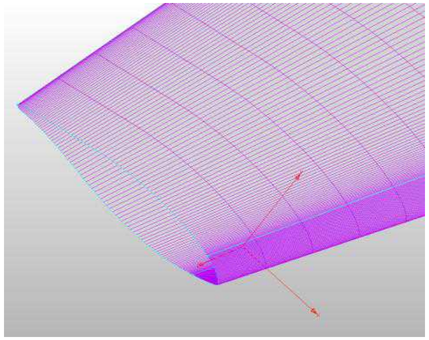
- Problem: To achieve higher energy capture and lower COE, wind turbine rotors must increase in size while maintaining or reducing system loads.
- Goal: Demonstrate Active Aerodynamic Load Control technology (flaps) on a research scale turbine and use the test results to improve simulation capabilities and to guide the future direction of active load control research.

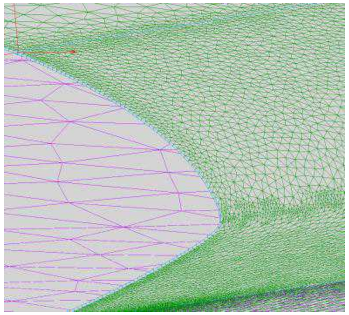
Blade Design Tools and System Modeling

- Problem: Simulation and analysis demands constantly push the limits of the state of the art in wind turbine blade structural and full system aeroelastic simulation
- Goal: Utilize and develop design codes to analyze:
  - Structures
  - Aerodynamics
  - Control
  - Aero-servo-elastic stability



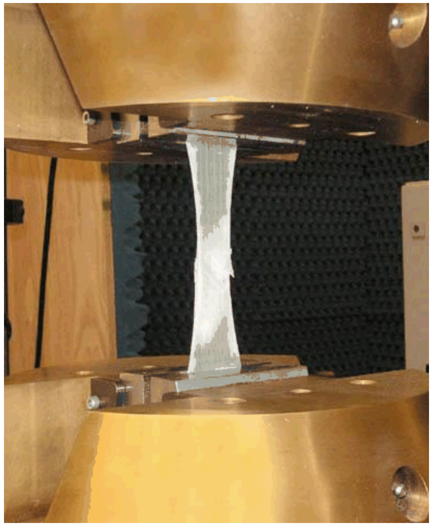


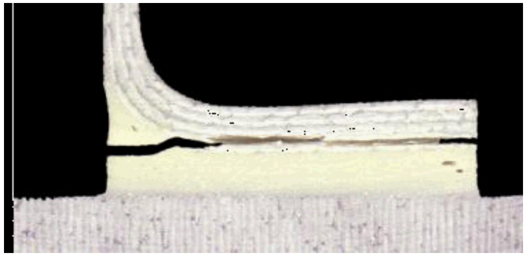


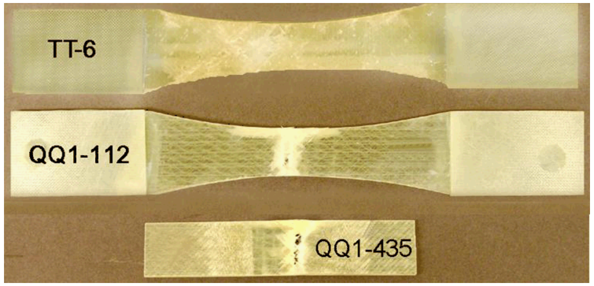


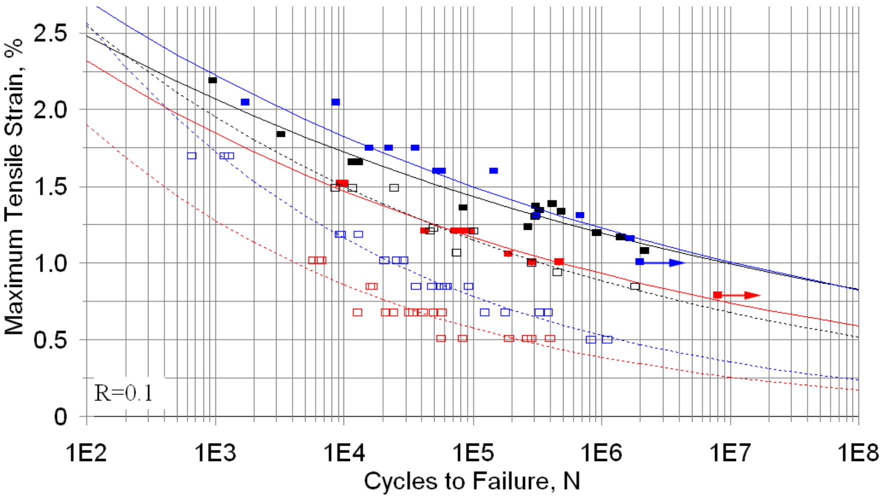
Materials Research

- Problem: Wind turbine blades face dual drivers of performance and cost un-paralleled in composite design and manufacturing.
- Goal: Characterization of new and existing wind blade materials directly effects blade design and reliability, and feeds through to the entire turbine system.







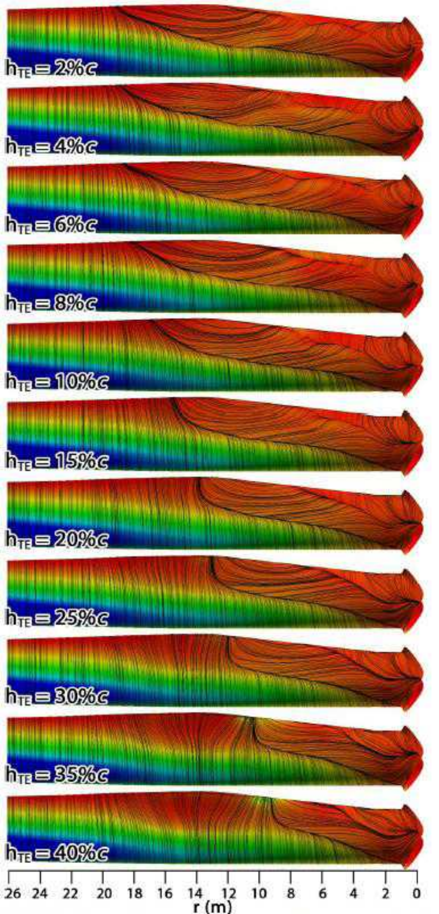


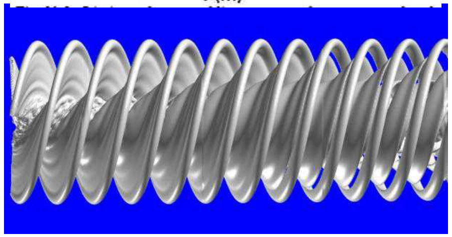
Advanced Manufacturing Initiative

- Problem: High labor rates make U.S.-based blade fabrication uncompetitive compared to blade fabrication in low cost-of-labor nations – even for the U.S. market
- Goal: Increase labor productivity by 35% and reduce cycle time by 35% while maintaining or improving part quality

Aerodynamics and Aeroacoustics

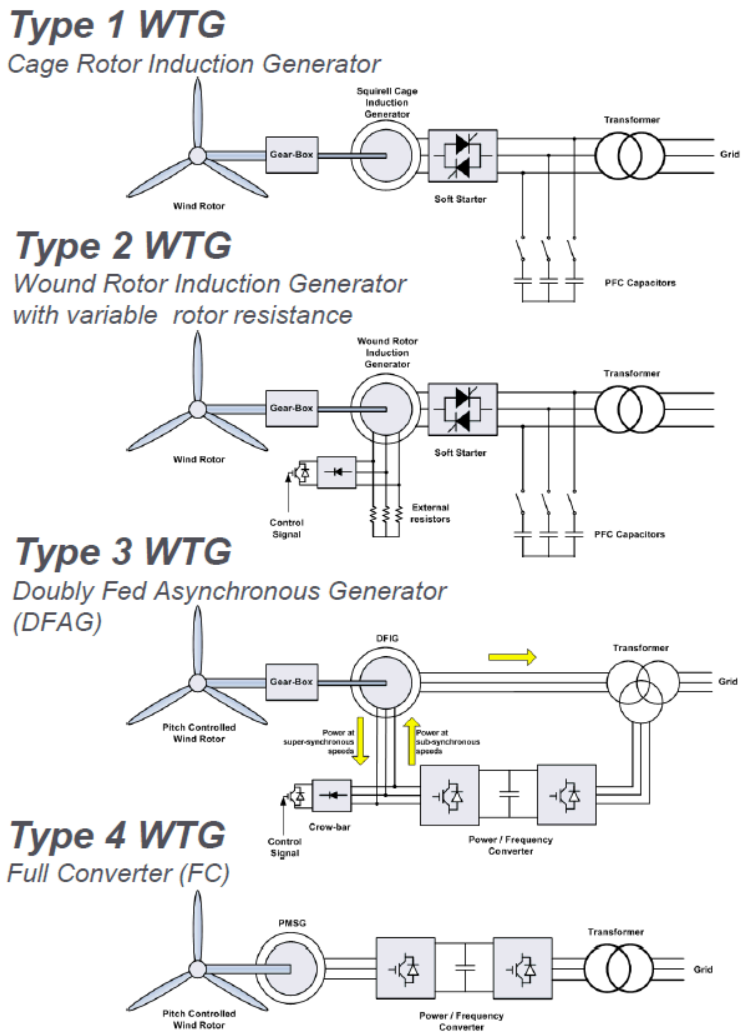
- Problem:
  - Inboard blade designs do not maximize energy capture
  - Uncertainty in extreme load predictions leads to sub-optimal turbine design
  - Current field measurements of aeroacoustic noise are inadequate
- Goal:
  - Validate design concepts for the next generation of aerodynamically efficient wind turbine blades.
  - Improve wind turbine design standards based on massive amounts of loads simulation.
  - Develop microphone array measurement technique for wind turbine noise characterization.





Wind Power Plant Modeling

- Problem: Generic, standard and publicly available power flow and dynamic models have not been readily available to the regional reliability organizations and grid operators who are responsible for maintaining the grid.
- Goal: Collaborate in industry wide efforts to develop and validate WTG models.



Wind Radar Interagency Field Test & Evaluation

- Problem: Wind turbines impact radars:
  - Decrease sensitivity
  - Increase false alarms
  - Corrupt track quality
- Goal: This project will reduce barriers to wind project deployments by:
  - Guiding FAA, DHS, and DOD radar investments.
  - Supporting development of algorithms, tools, models, designs, and processes that expand wind development options