

Wind Energy Status and R&D Challenges

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28 February 2006



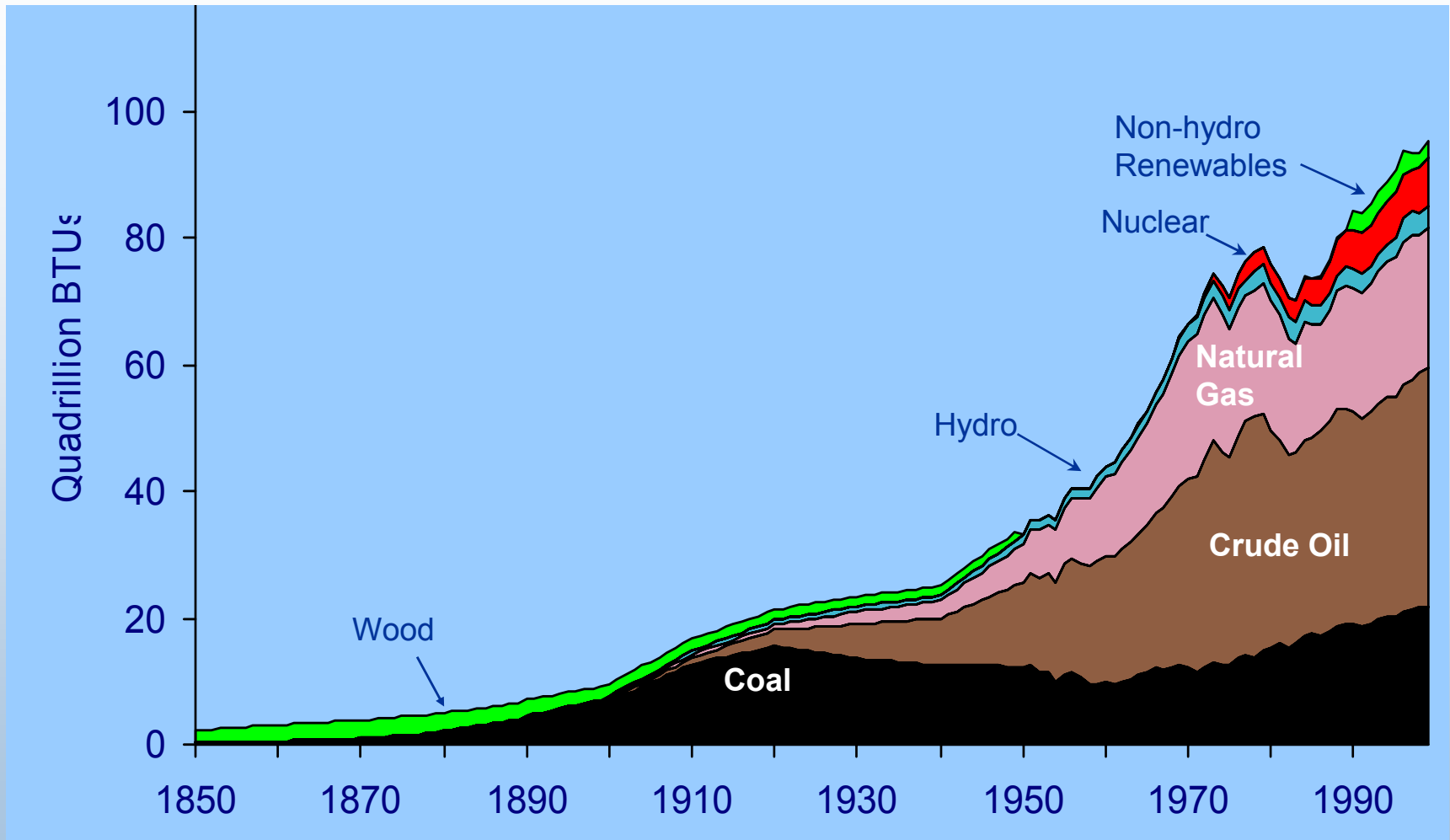
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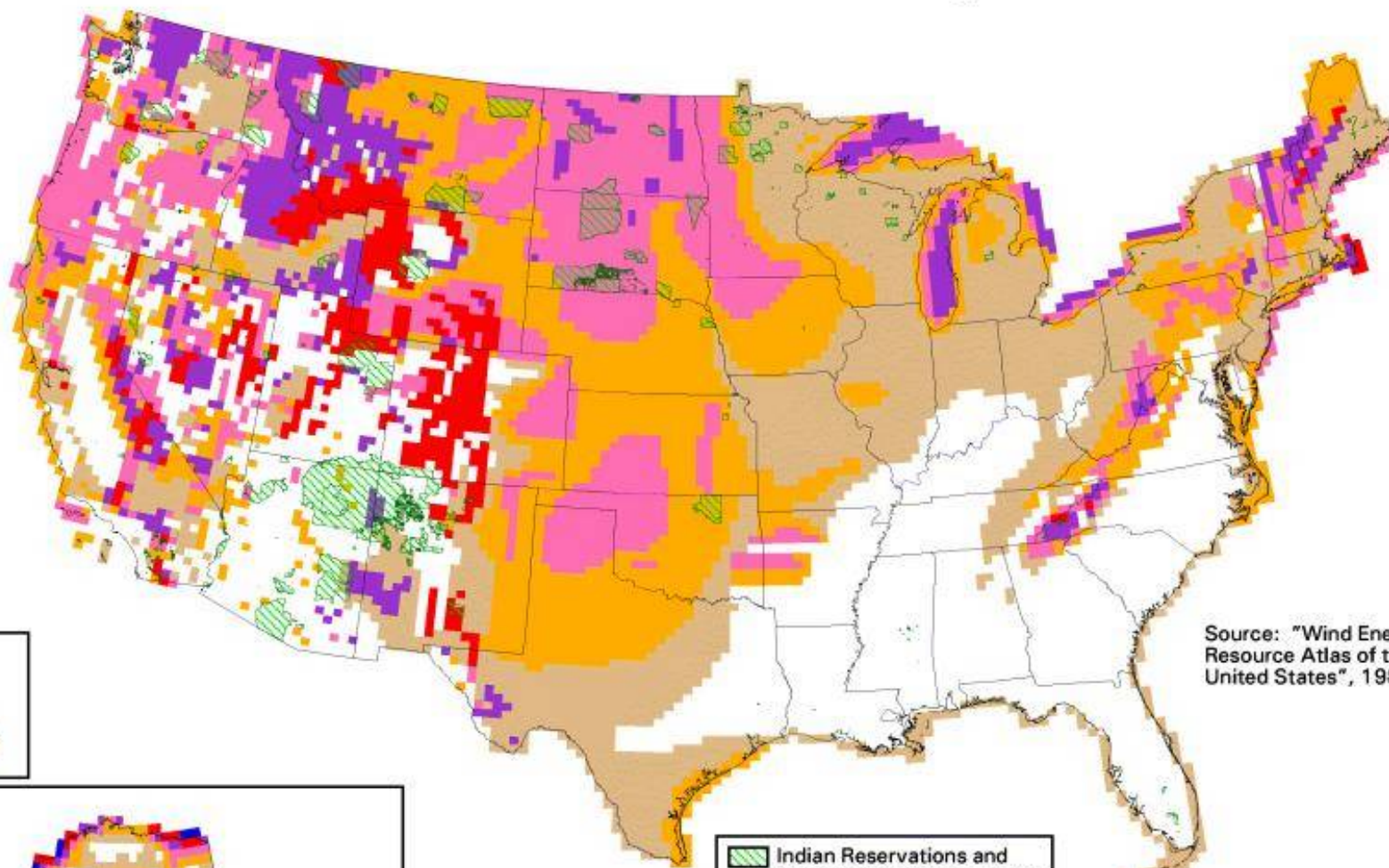
The U.S. Energy Picture

by source - 1850-1999

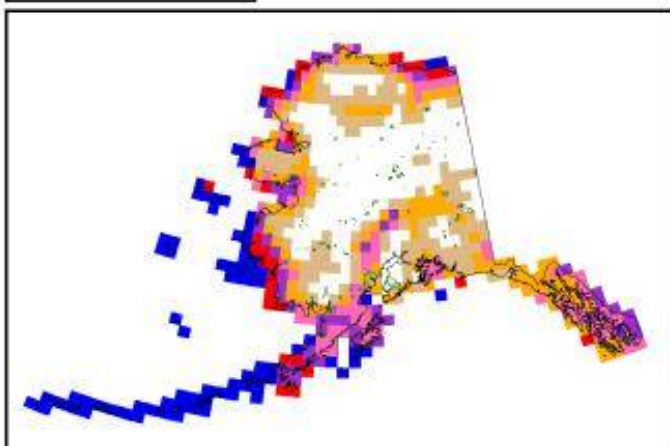


Source: 1850-1949, Energy Perspectives: A Presentation of Major Energy and Energy-Related Data, U.S. Department of the Interior, 1975; 1950-1996, Annual Energy Review 1996, Table 1.3. Note: Between 1950 and 1990, there was no reporting of non-utility use of renewables. 1997-1999, Annual Energy Review 1999, Table F1b.




United States - Wind Resource Map



Source: "Wind Energy Resource Atlas of the United States", 1987



 Indian Reservations and Alaska Native Village Areas

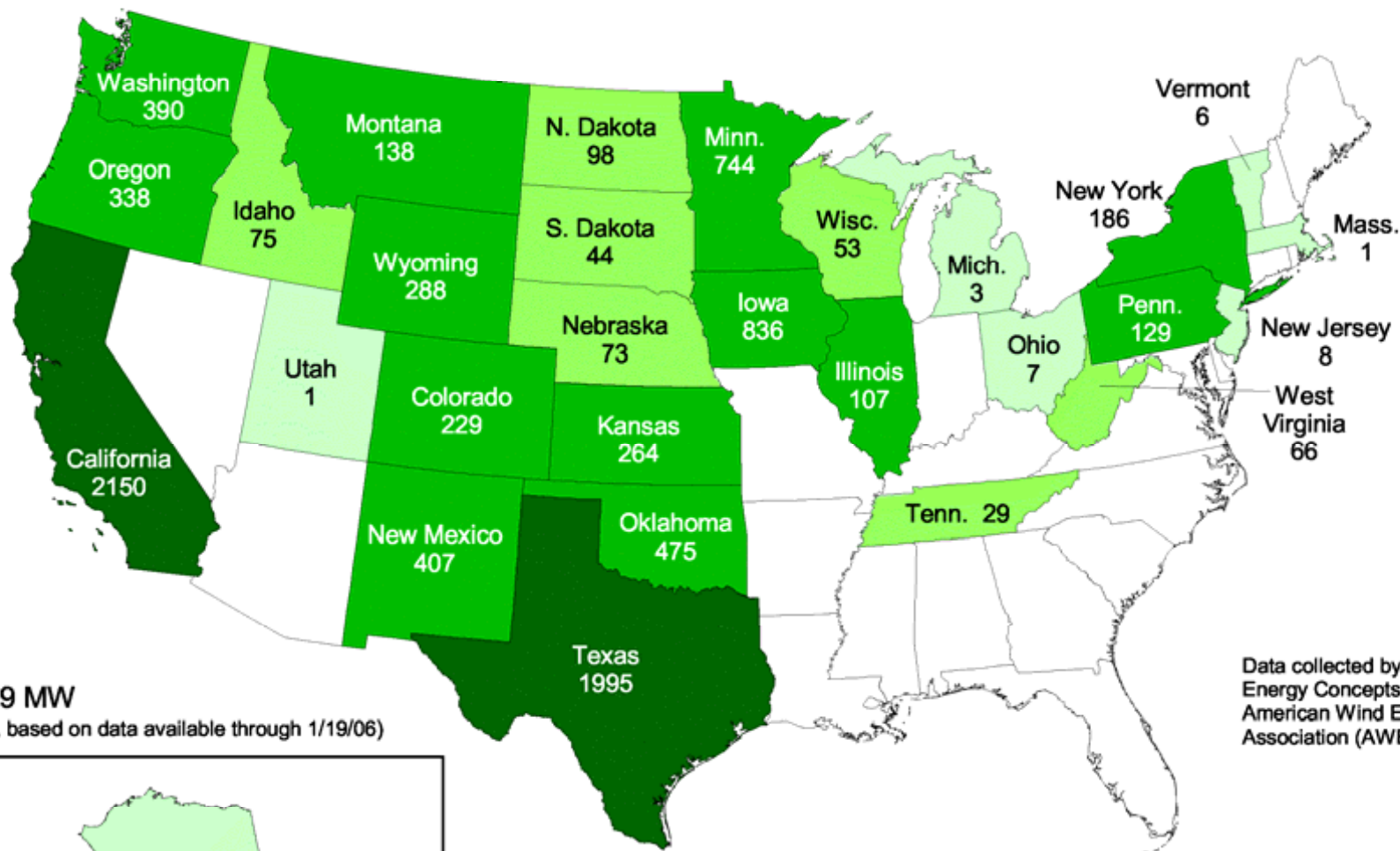
Wind Power Classification				
Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m ²	Wind Speed ^a at 50 m m/s	Wind Speed ^a at 50 m mph
	2 Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
	3 Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
	4 Good	400 - 500	7.0 - 7.5	15.7 - 16.8
	5 Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
	6 Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
	7 Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

^a Wind speeds are based on a Weibull k value of 2.0

U.S. Department of Energy
National Renewable Energy Laboratory

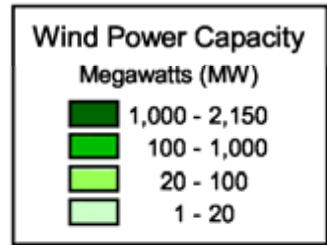


United States - 2005 Year End Wind Power Capacity (MW)



Data collected by Global Energy Concepts and the American Wind Energy Association (AWEA).

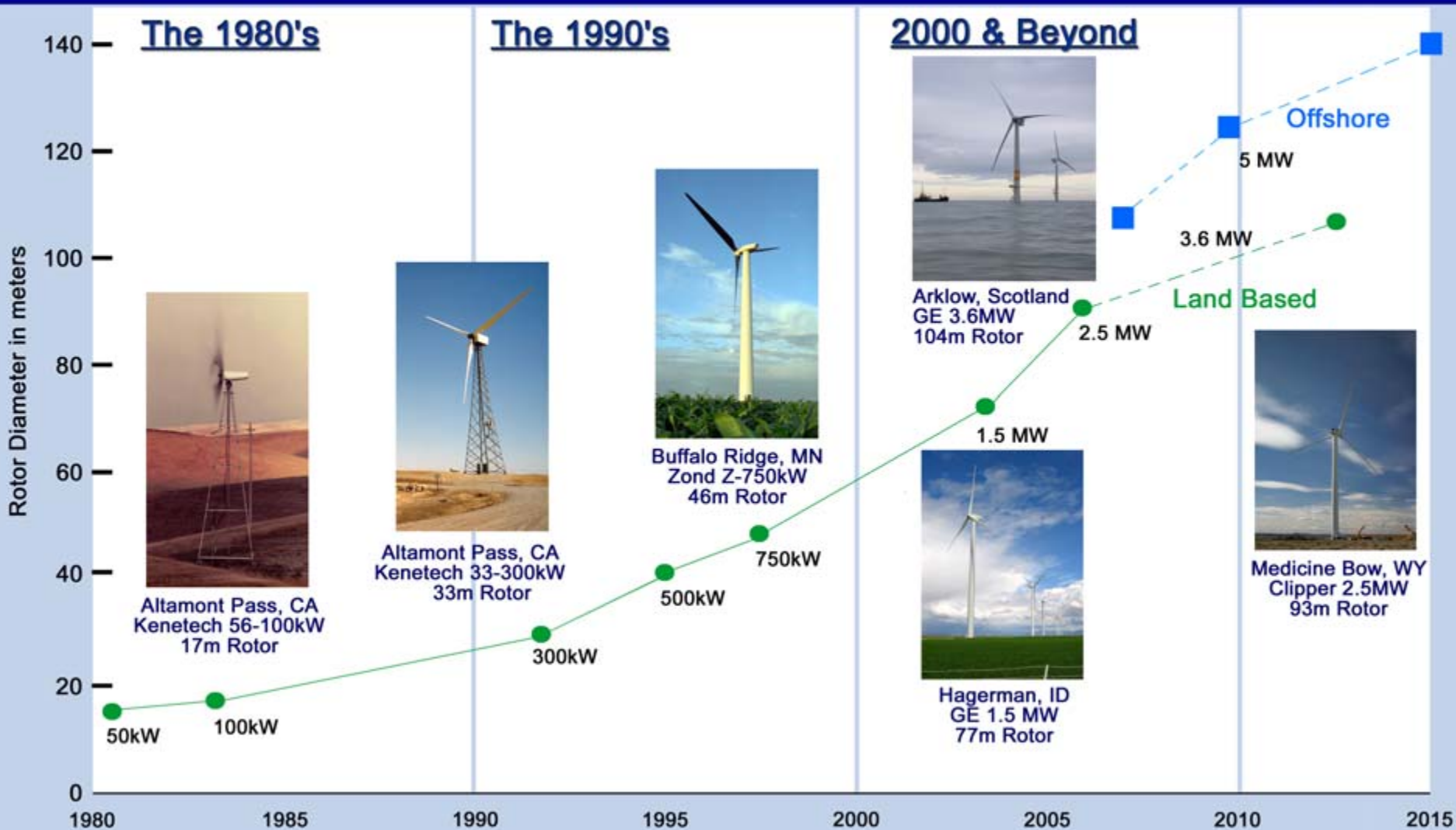
Total: 9,149 MW
(As of 12/31/05, based on data available through 1/19/06)



U.S. Department of Energy
National Renewable Energy Laboratory



Evolution of U.S. Commercial Wind Technology



Cost of Energy Trend

1981: 40 cents/kWh

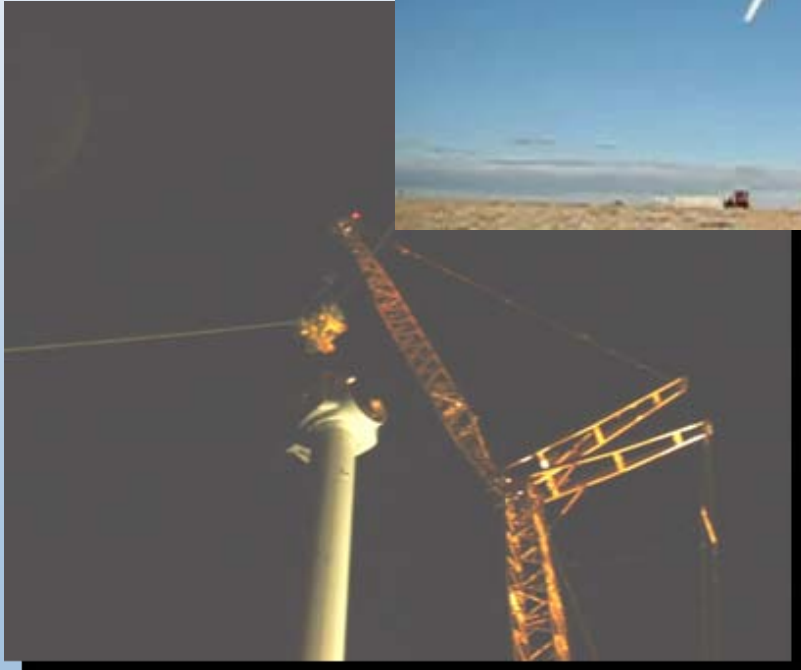
- **Increased Turbine Size**
- **R&D Advances**
- **Manufacturing Improvements**



NSP 107 MW Lake Benton wind farm
4 cents/kWh (unsubsidized)

2006: 3 - 6 cents/kWh with PTC

Clipper LWST Prototype 2.5 MW with 93 m Rotor



Wind Energy Research Activities

Turbine Development Programs

- Low Wind Speed Technology
- Distributed Wind Technology

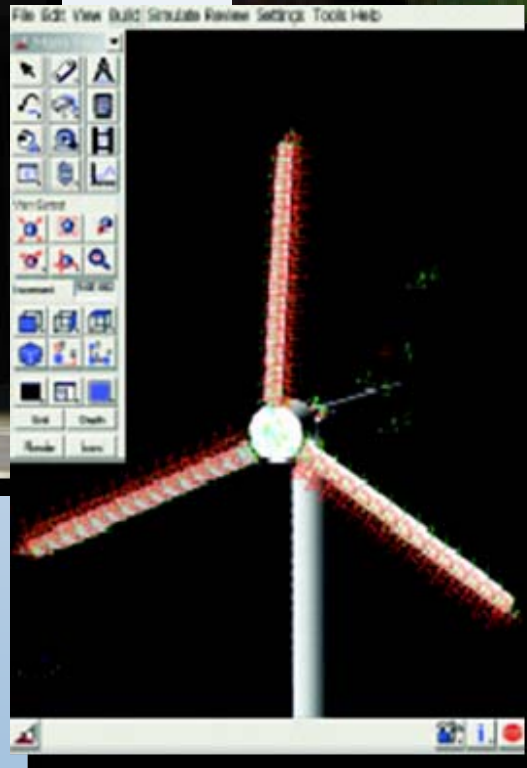
Supporting Research Activities

- Advanced Rotor Development
- Generator, Drivetrain, and Power Electronics
- Systems and Control
- Technology Acceptance
- Utility Grid Integration
- Certification Testing

Measuring and Modeling Dynamic Stall and Unsteady Aerodynamics



NASA Ames 80' by 120'
Wind Tunnel Test

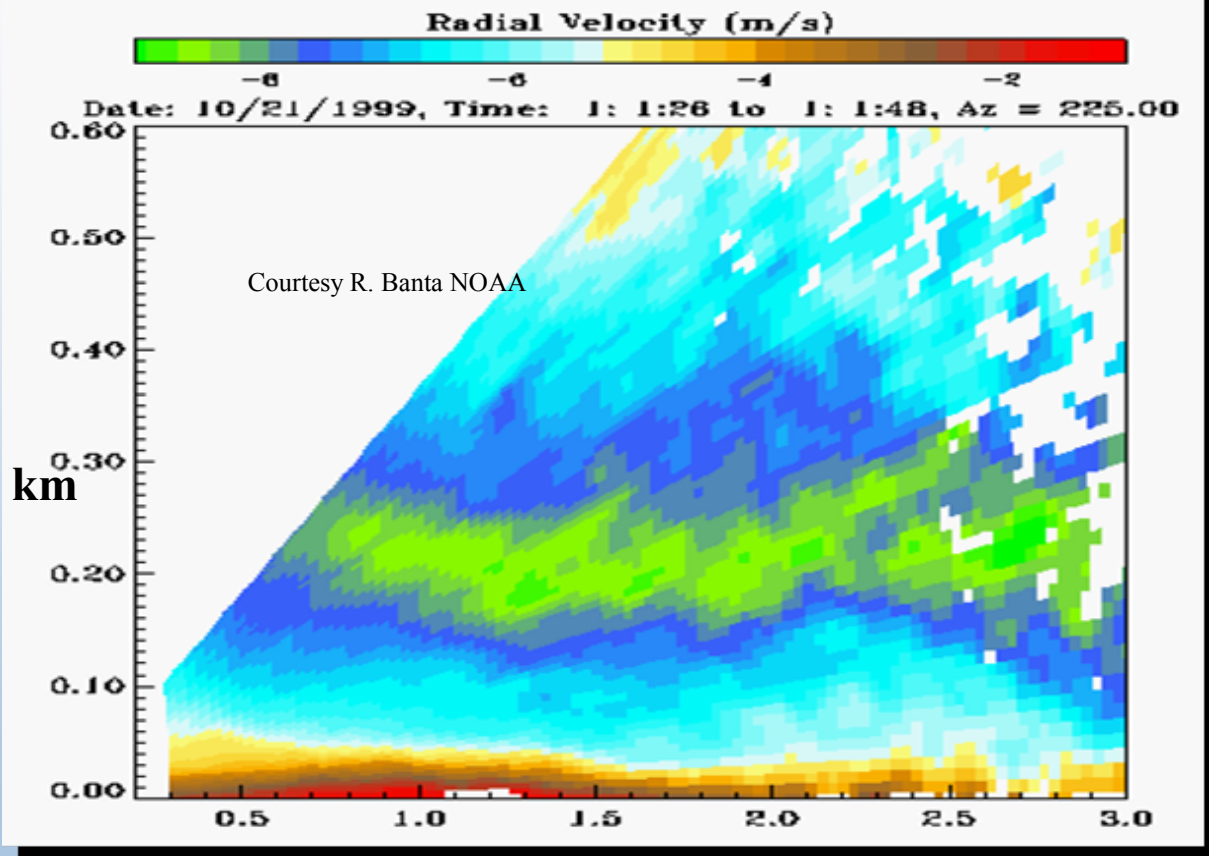


ADAMS Model



Smoke Test

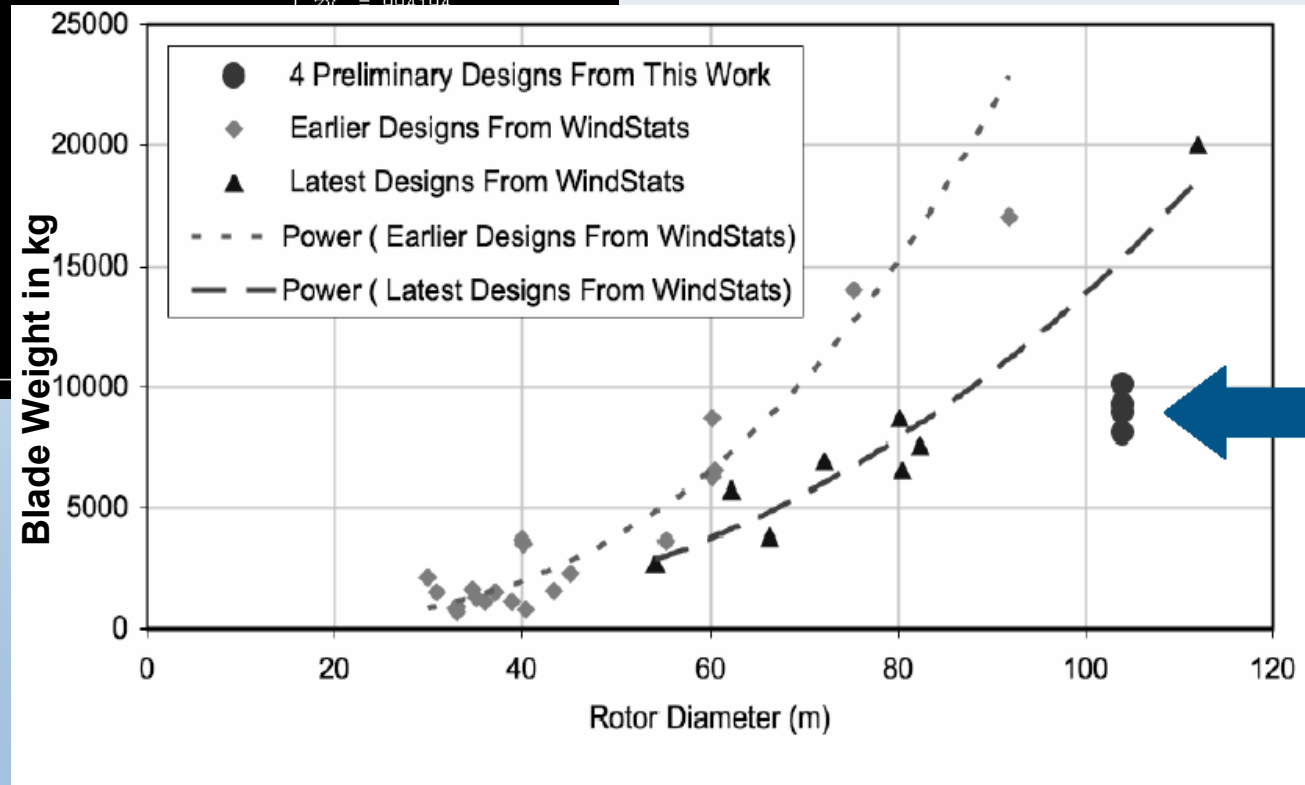
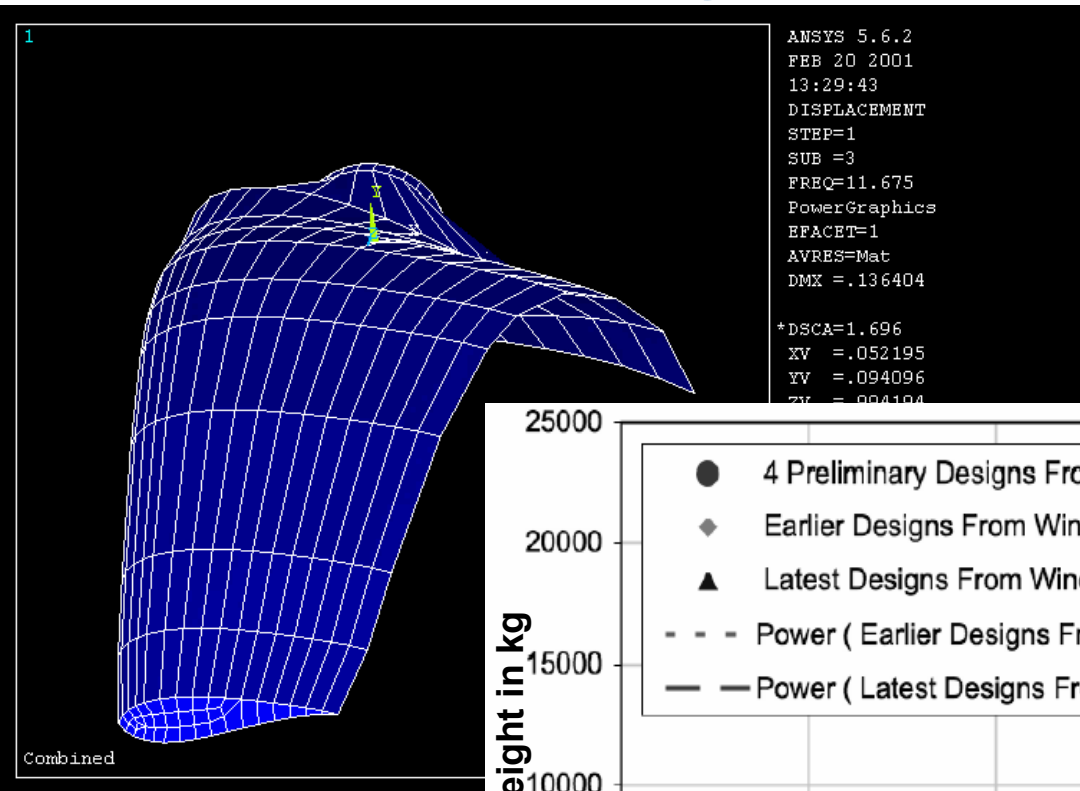
Measuring and Modeling the Low-Level Nocturnal Jet



Met tower and
SODAR at Lamar,
Colorado



Blade Scaling for Multimegawatt Rotors



Industry's Growing Needs



A new 45-meter wind turbine blade was shipped to the NWTC for testing in July 2004.

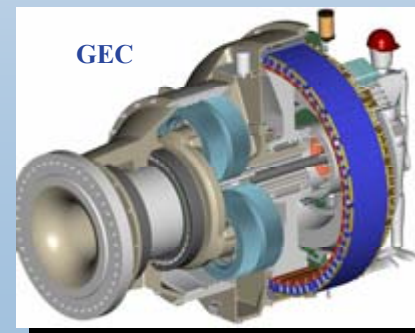


Advanced Drivetrain R&D

Tomorrow
Prototype Technology

Today

1.5 MW Commercial Technology



What are the Future R&D Needs?

Offshore Wind – U.S. Rationale

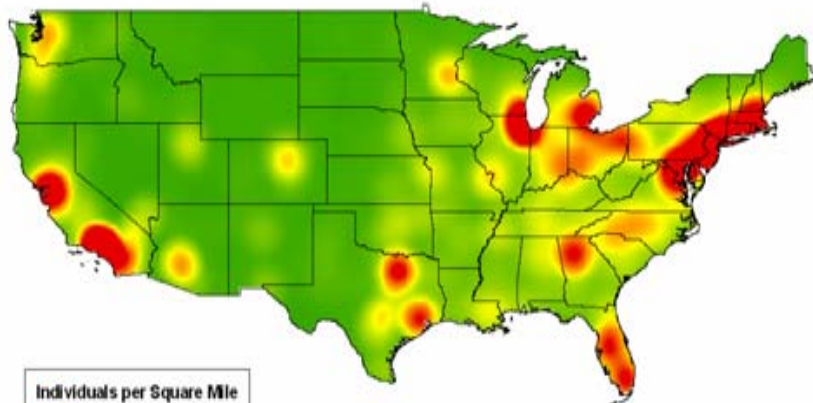
Why Go Offshore?

Windy onshore sites are not close to coastal load centers

The electric utility grid cannot be easily set up for interstate electric transmission

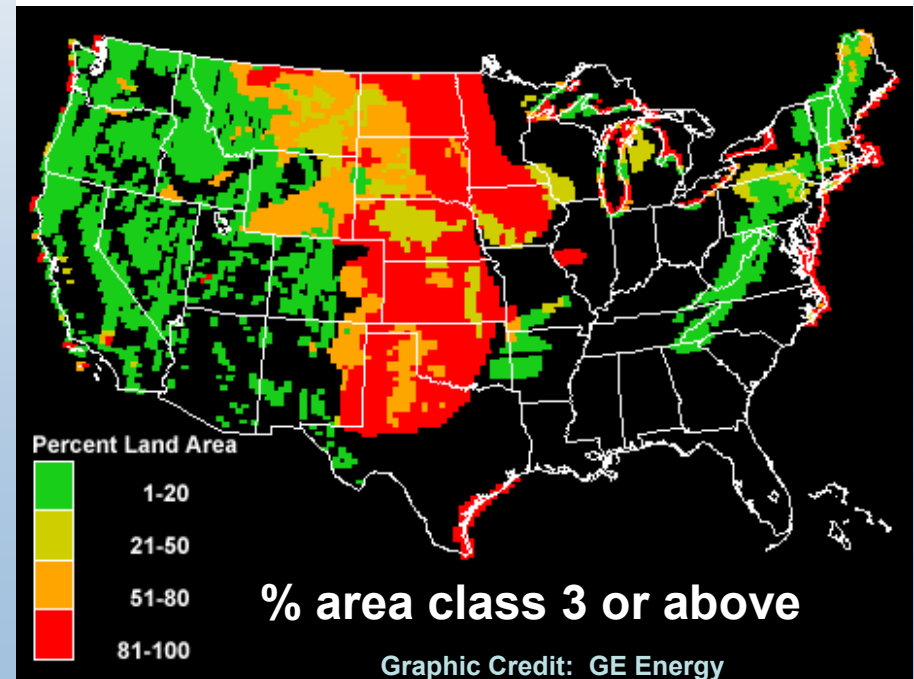
Load centers are close to the offshore wind sites

US Population Concentration

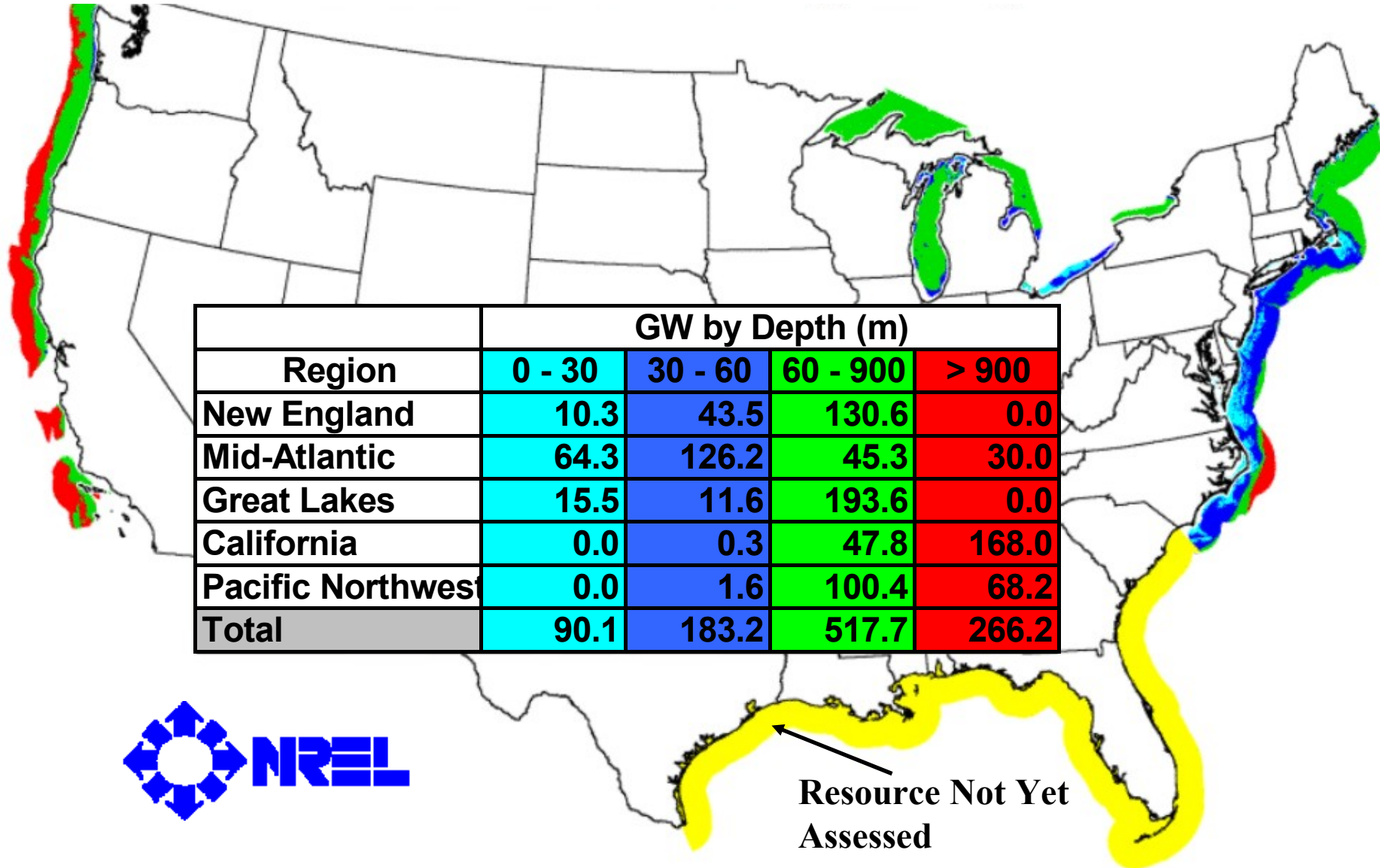


Graphic Credit: Bruce Bailey AWS Truewind

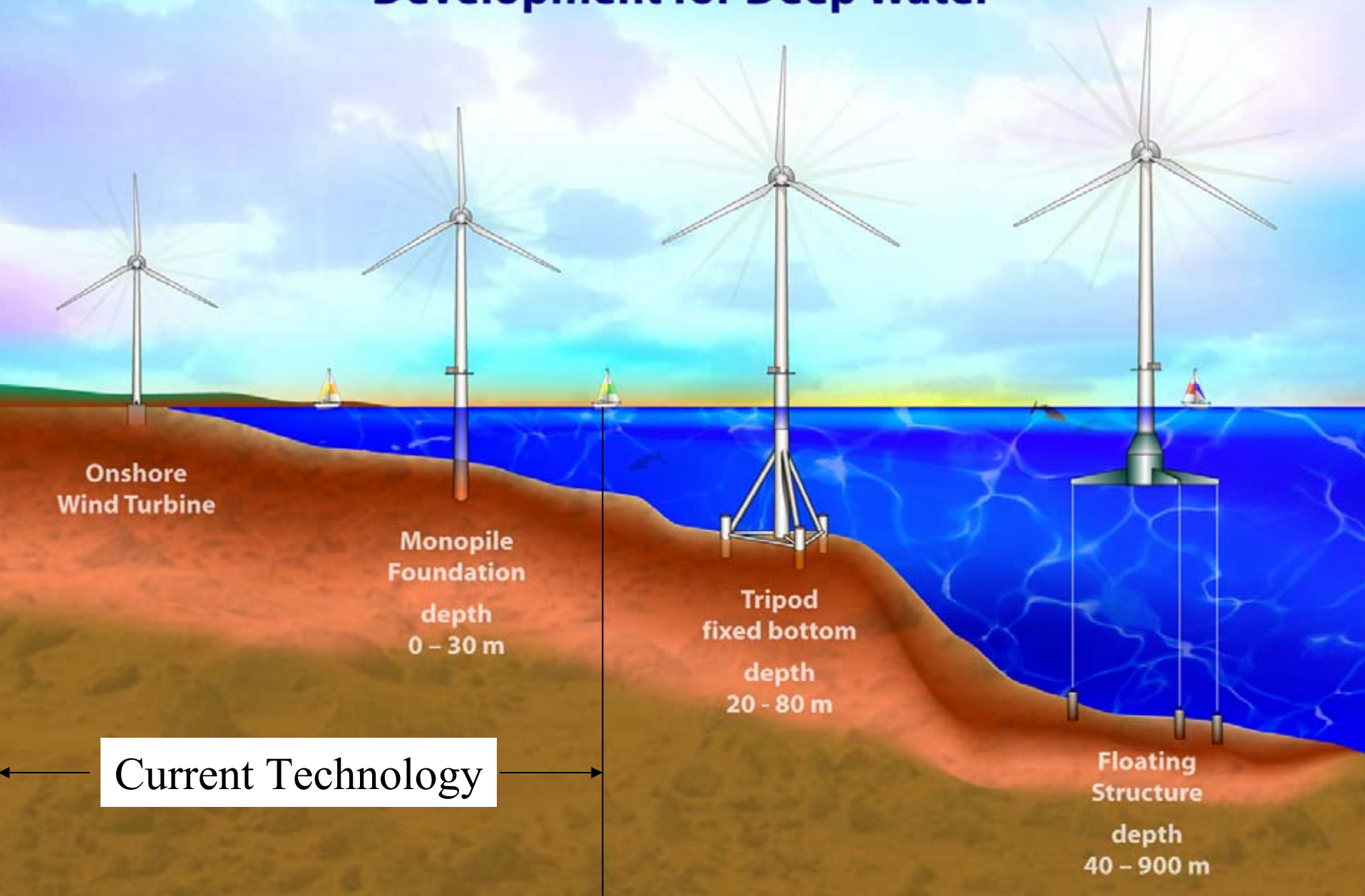
US Wind Resource

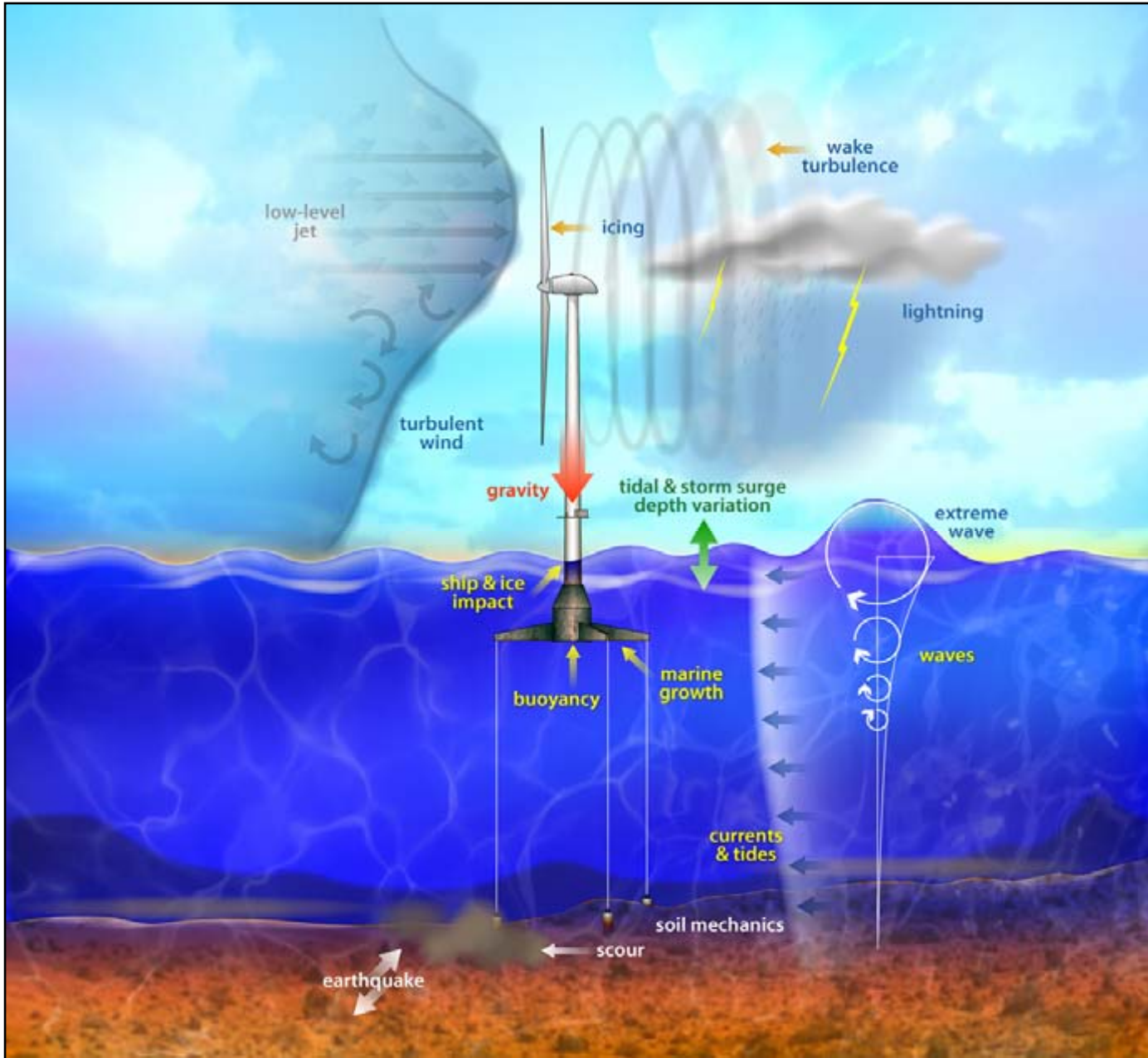


U.S. Offshore Wind Energy Resource

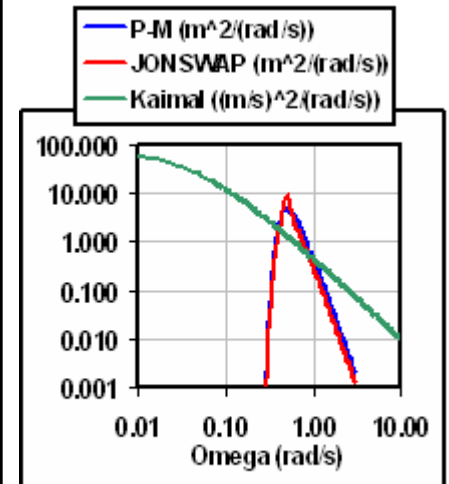


Offshore Wind Turbine Development for Deep Water



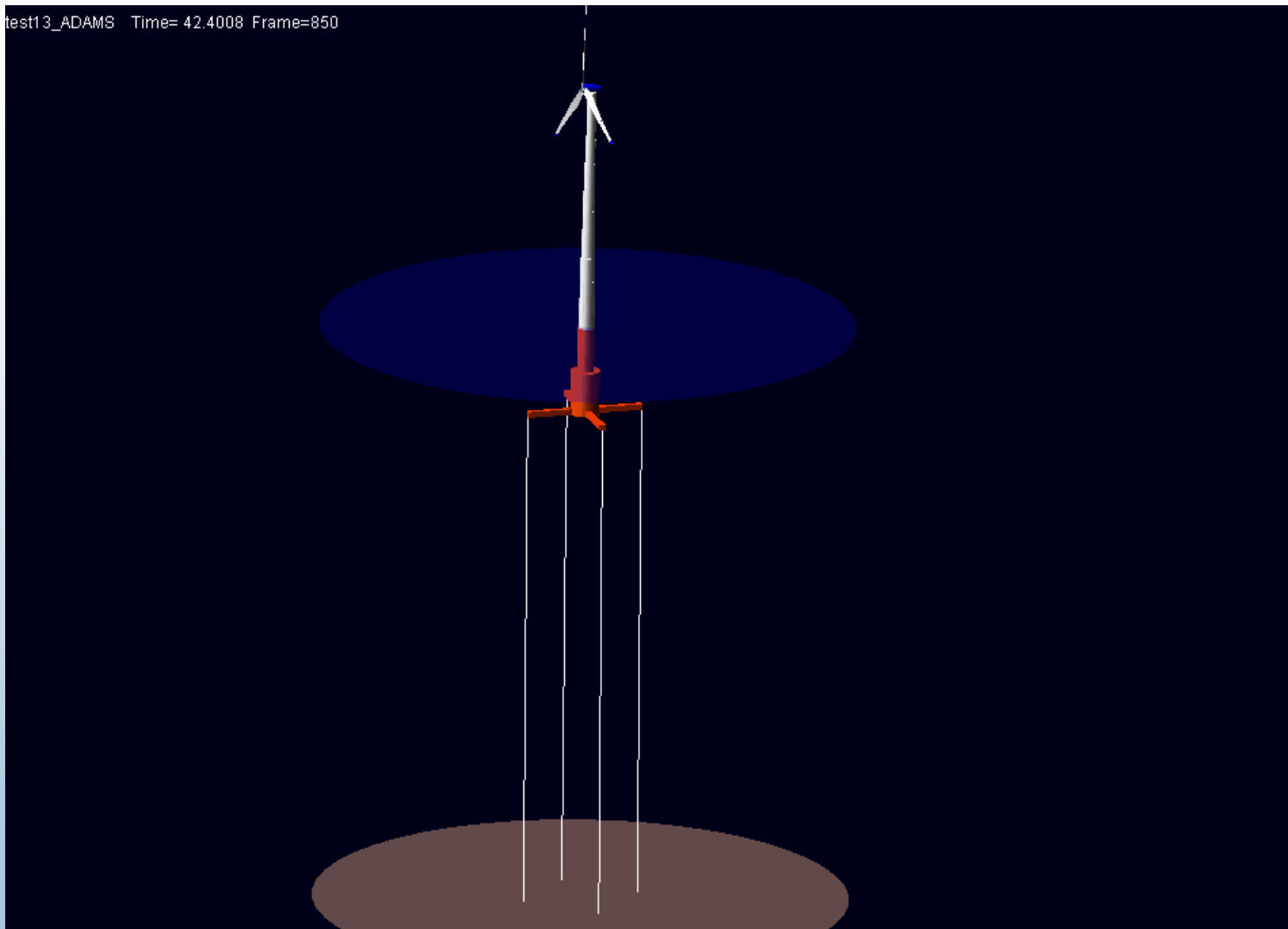


- Turbulent winds
- Irregular waves
- Gravity / inertia
- Aerodynamics:
 - induction
 - skewed wake
 - dynamic stall
- Hydrodynamics:
 - scattering
 - radiation
 - hydrostatics
- Elasticity
- Mooring dynamics
- Control system
- Fully coupled



Wind and Wave Spectra

test13_ADAMS Time= 42.4008 Frame=850



A Future Vision for Wind Energy Markets

