

# Wind Energy Status and R&D Challenges

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**28 February 2006**

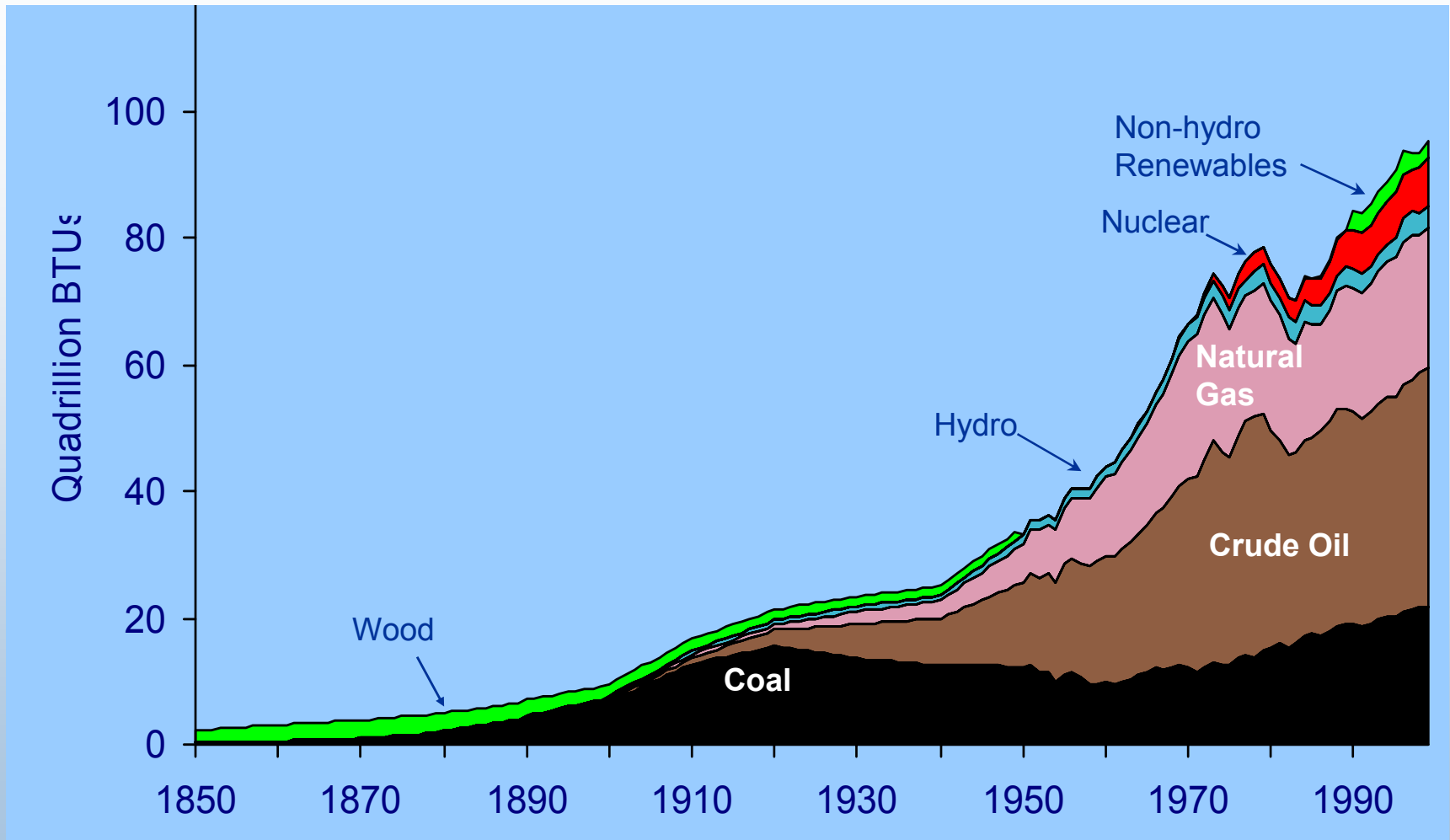


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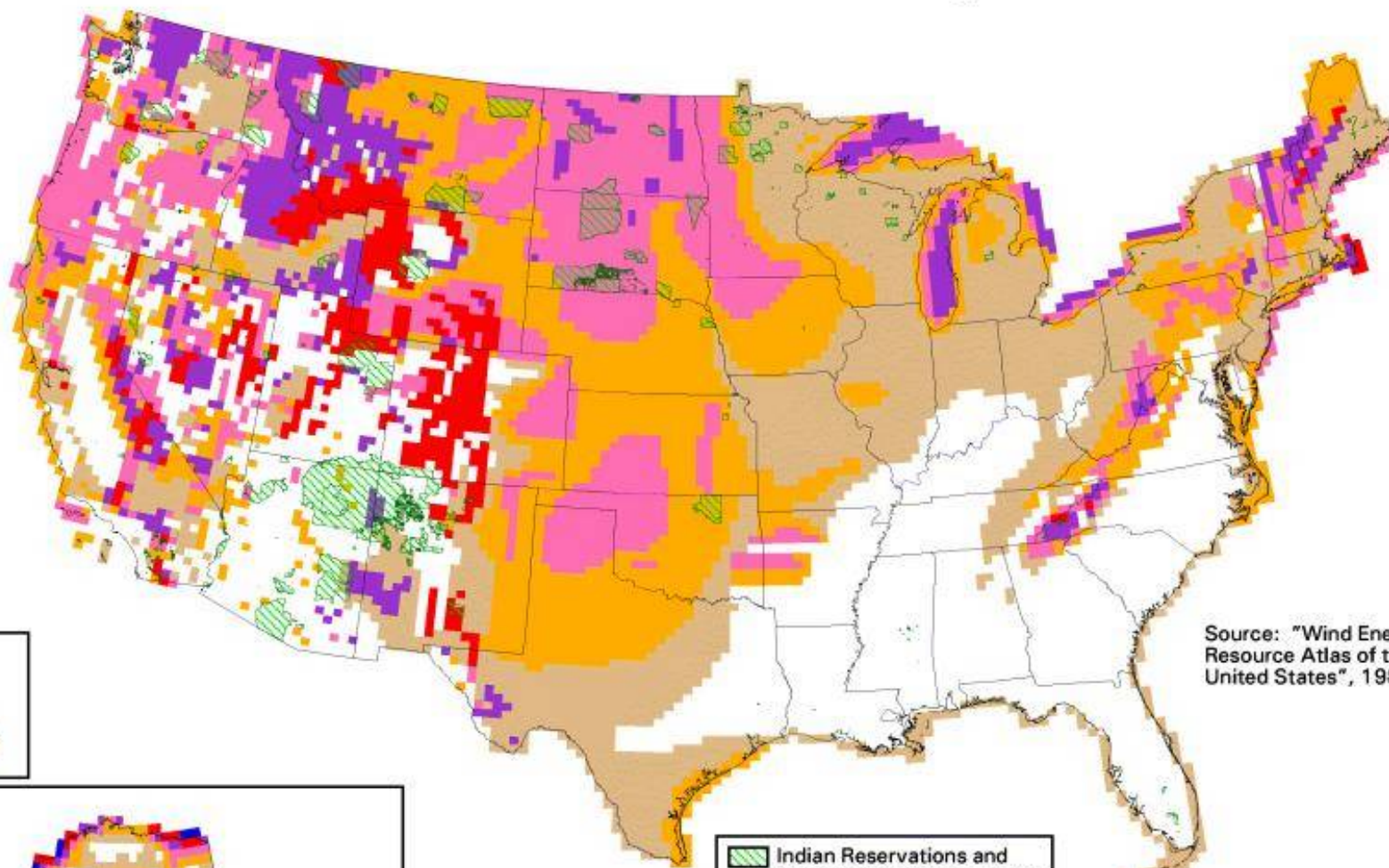
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# The U.S. Energy Picture by source - 1850-1999

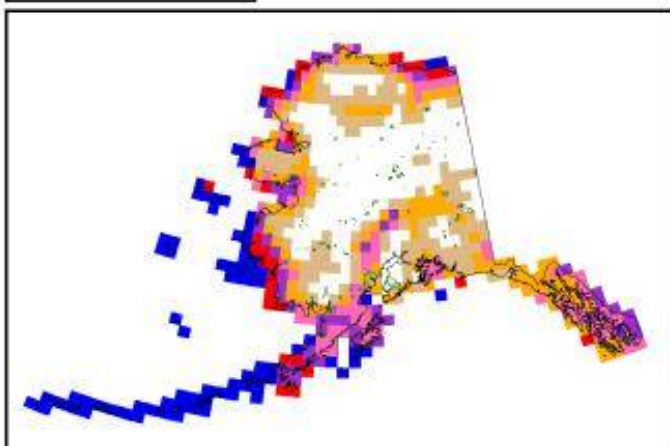


Source: 1850-1949, Energy Perspectives: A Presentation of Major Energy and Energy-Related Data, U.S. Department of the Interior, 1975; 1950-1996, Annual Energy Review 1996, Table 1.3. Note: Between 1950 and 1990, there was no reporting of non-utility use of renewables. 1997-1999, Annual Energy Review 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 <sup>2</sup>	Wind Speed <sup>a</sup> at 50 m m/s	Wind Speed <sup>a</sup> 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

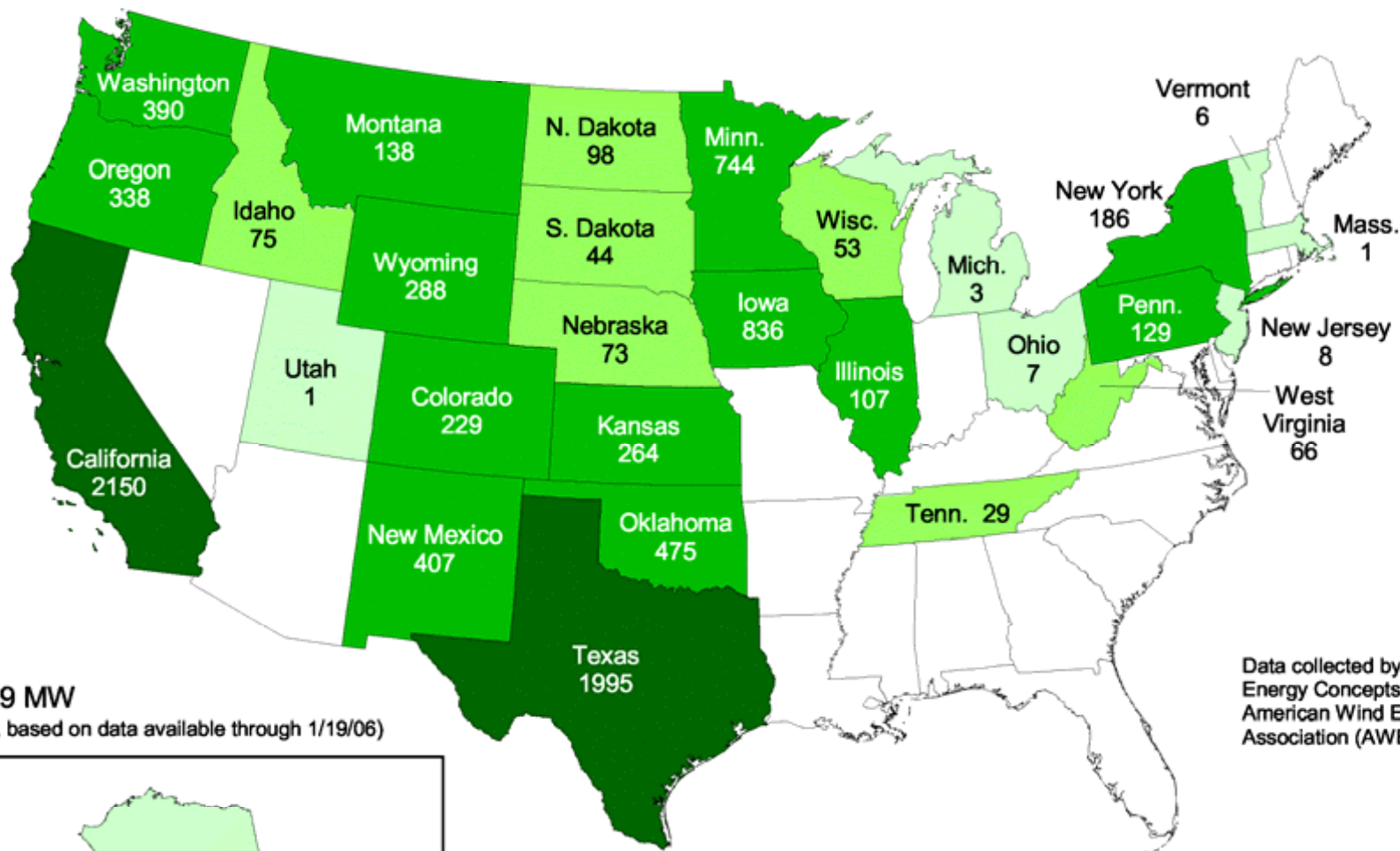
<sup>a</sup> Wind speeds are based on a Weibull k value of 2.0

U.S. Department of Energy  
National Renewable Energy Laboratory



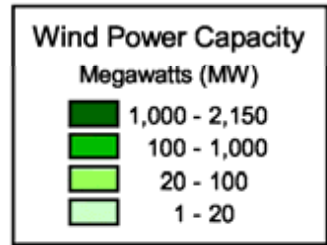


# United States - 2005 Year End Wind Power Capacity (MW)



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

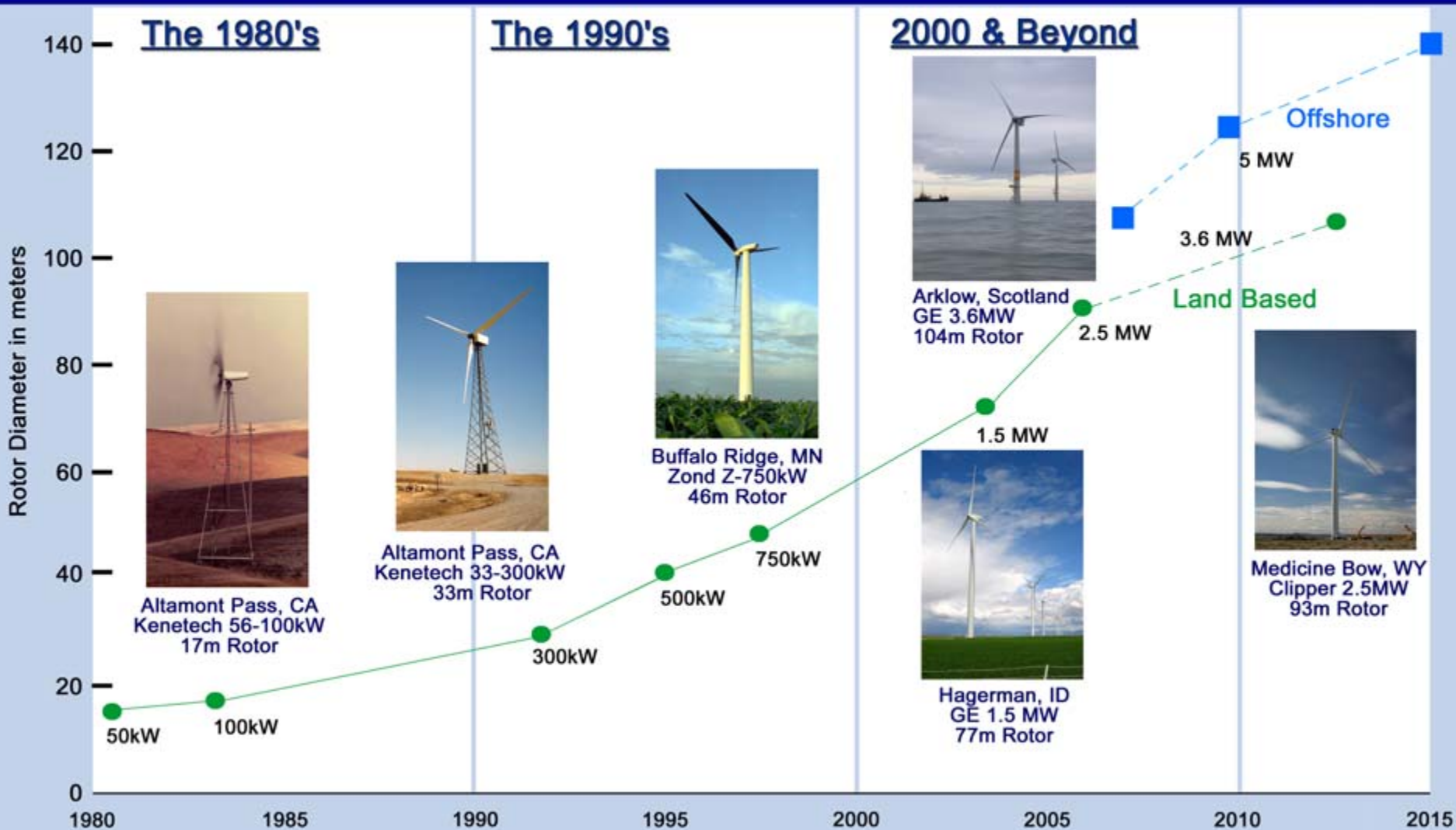
**Total: 9,149 MW**  
(As of 12/31/05, based on data available through 1/19/06)



U.S. Department of Energy  
National Renewable Energy Laboratory



# Evolution of U.S. Commercial Wind Technology



# Cost of Energy Trend

**1981: 40 cents/kWh**

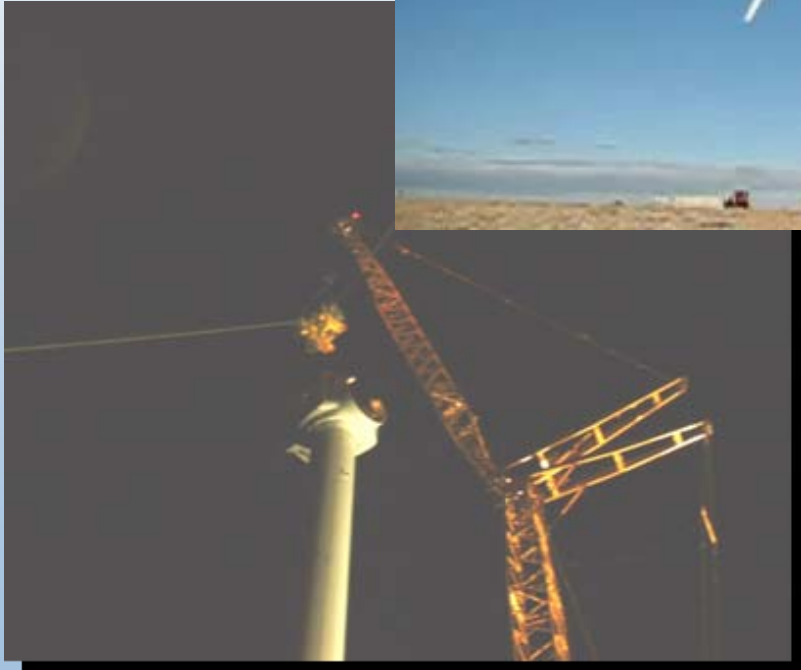
- **Increased Turbine Size**
- **R&D Advances**
- **Manufacturing Improvements**



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

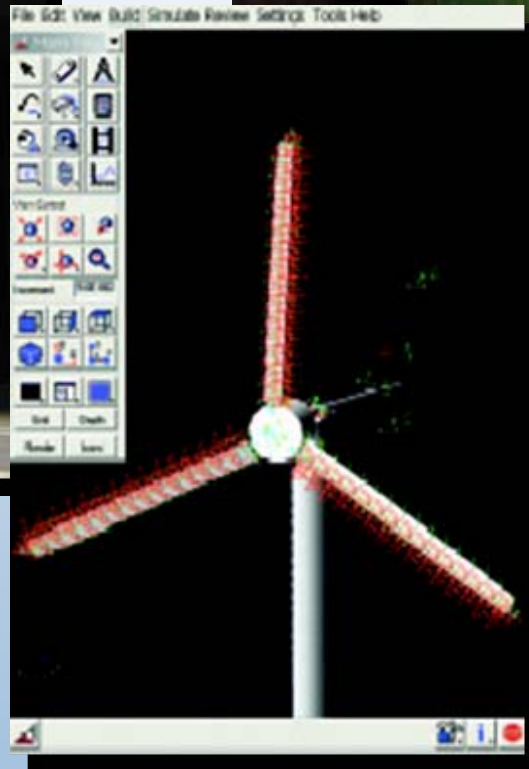
## Supporting Research Activities

- 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

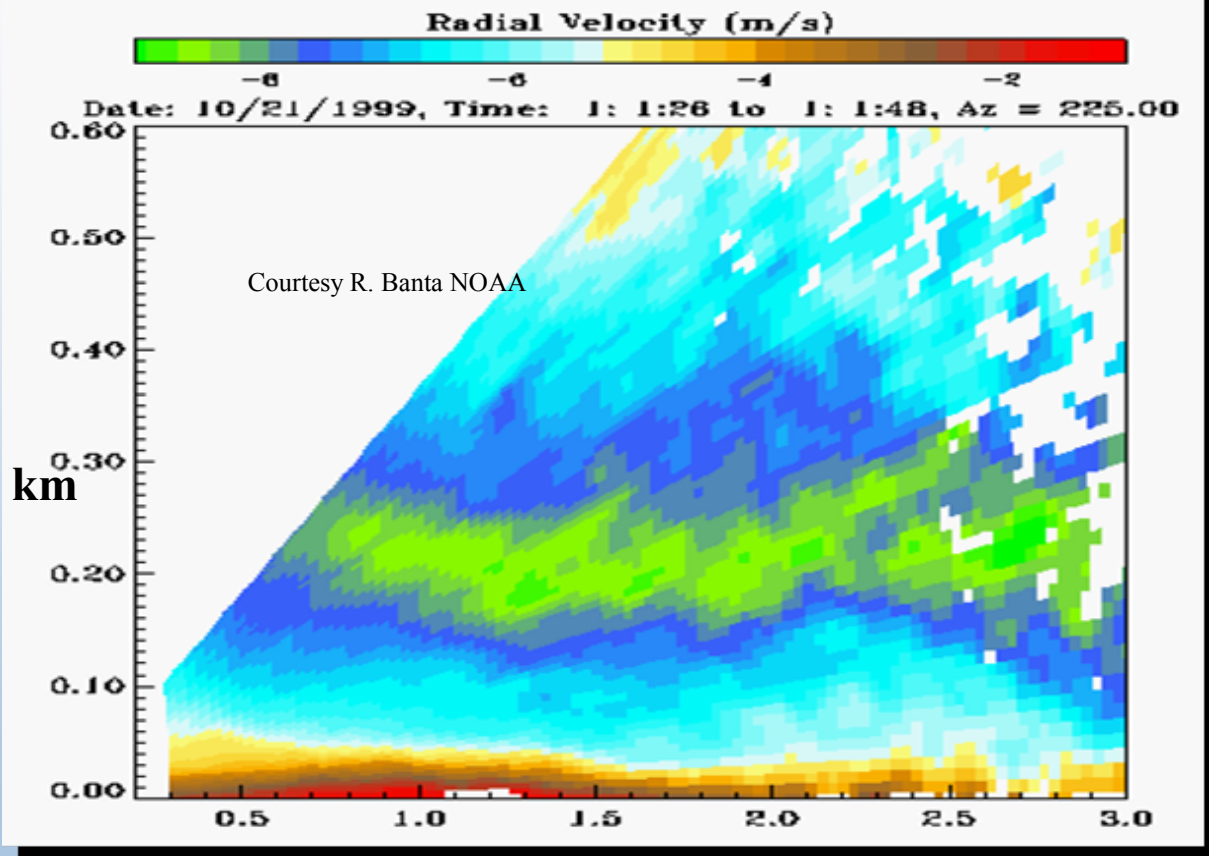


ADAMS Model



Smoke Test

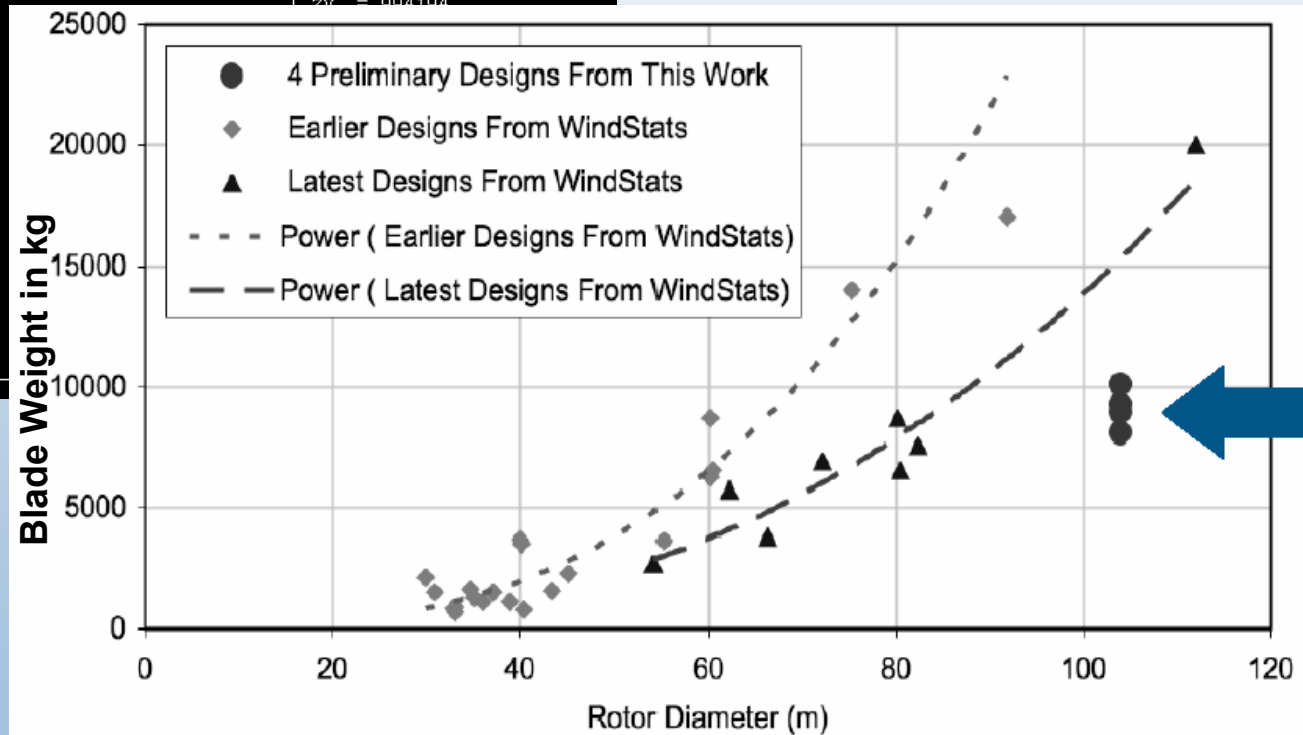
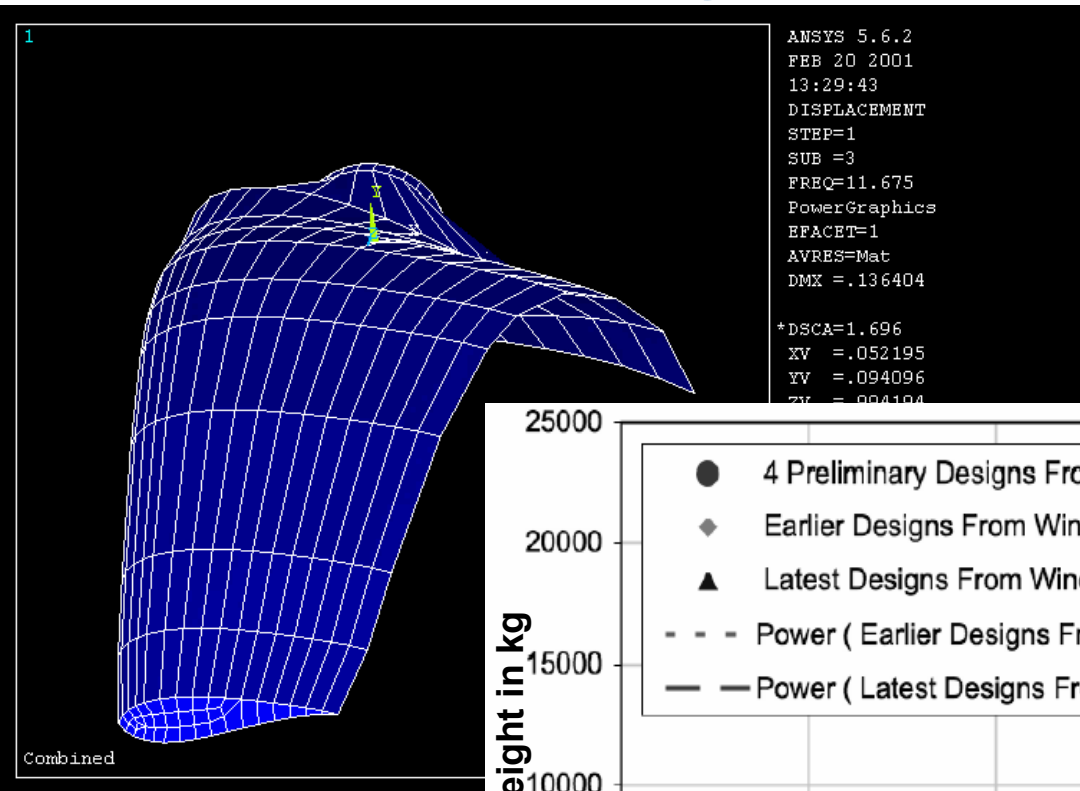
# Measuring and Modeling the Low-Level Nocturnal Jet



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.

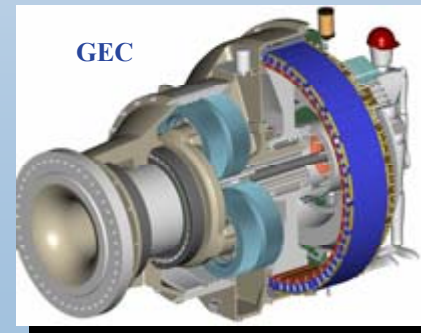


# Advanced Drivetrain R&D

*Tomorrow*  
Prototype Technology

*Today*

1.5 MW Commercial Technology



# What are the Future R&D Needs?

# Offshore Wind – U.S. Rationale

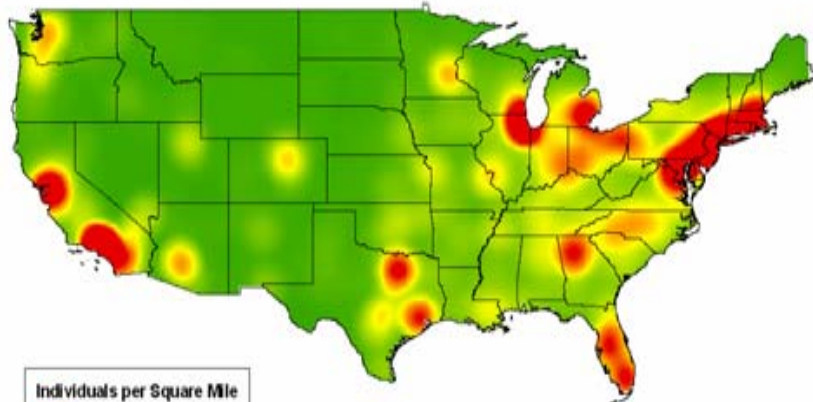
## Why Go Offshore?

*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*

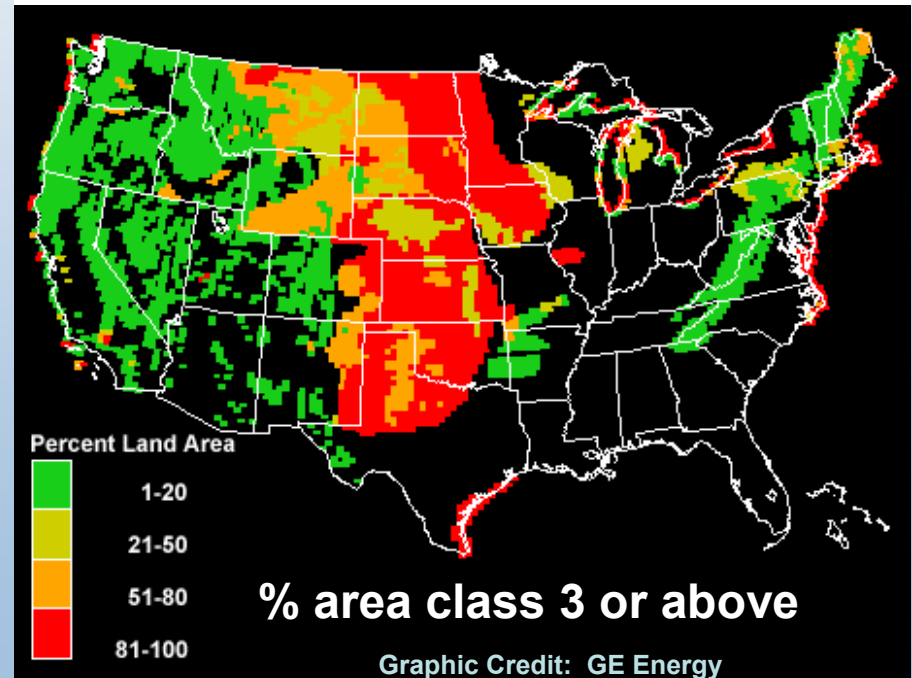
### US Population Concentration



Individuals per Square Mile  
greater than 1,000  
less than 1

Graphic Credit: Bruce Bailey AWS Truewind

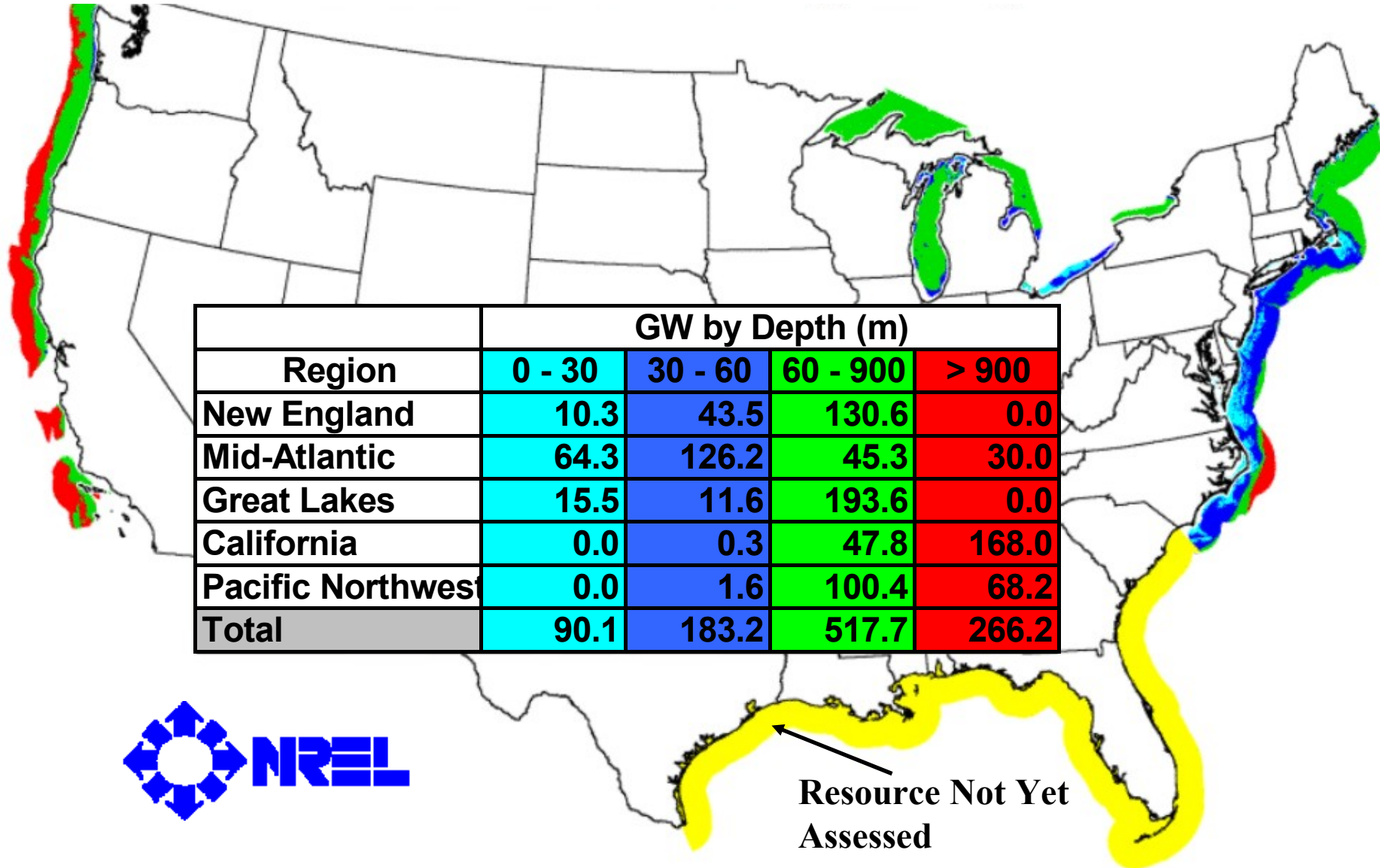
### US Wind Resource



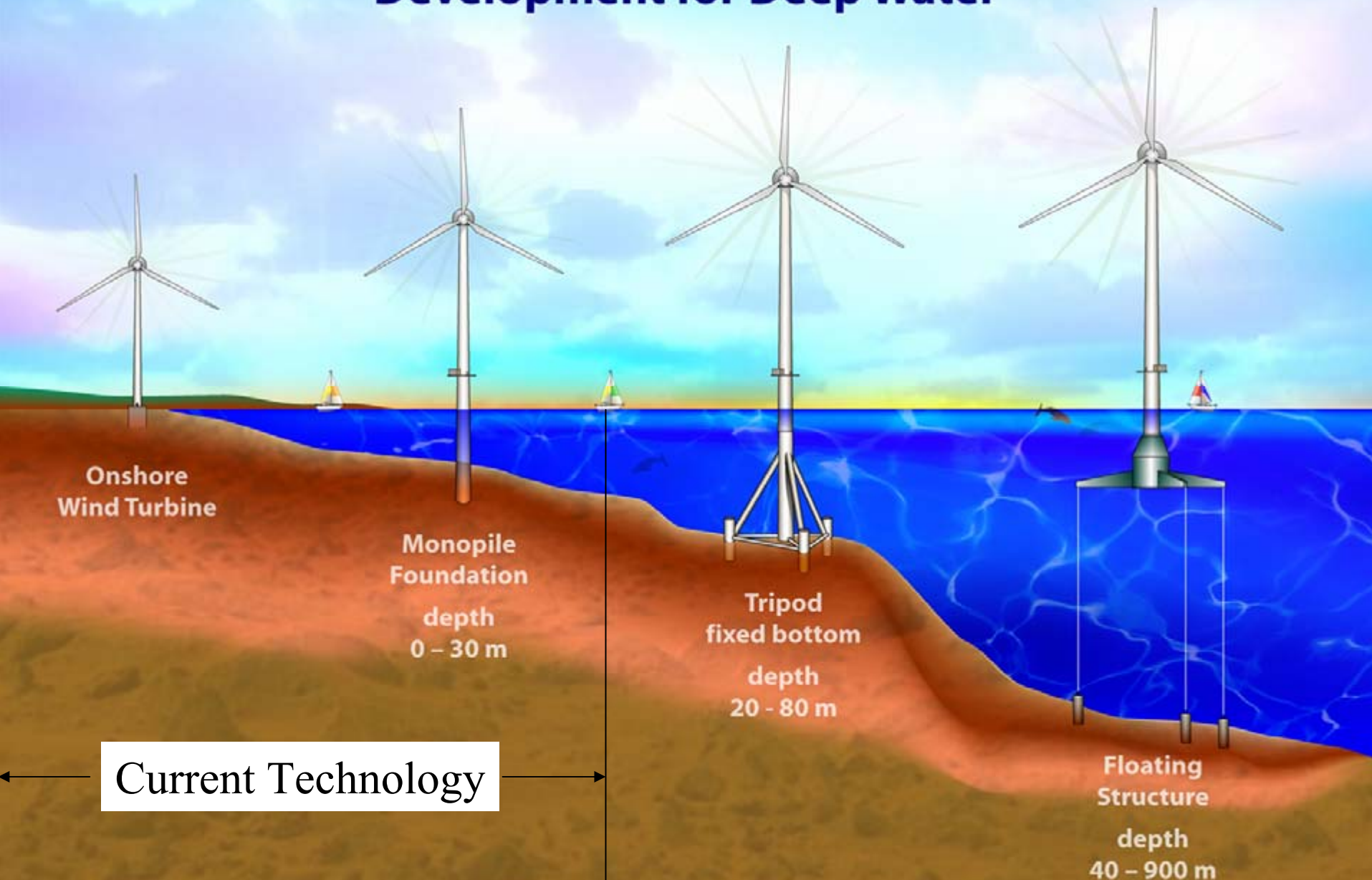
Graphic Credit: GE Energy

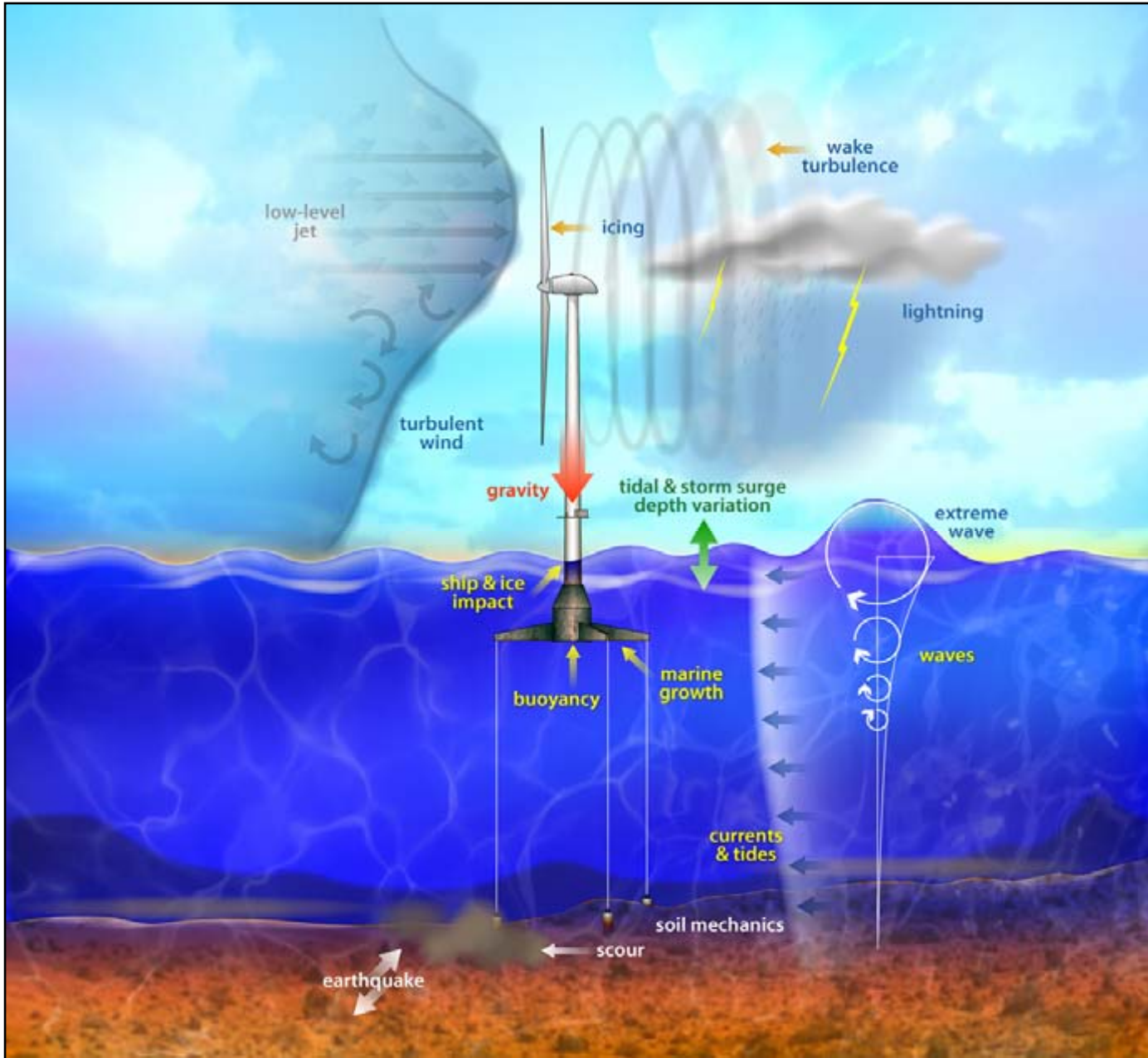


# U.S. Offshore Wind Energy Resource

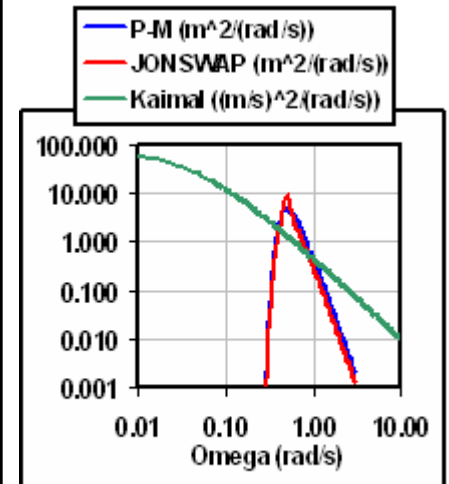


# Offshore Wind Turbine Development for Deep Water



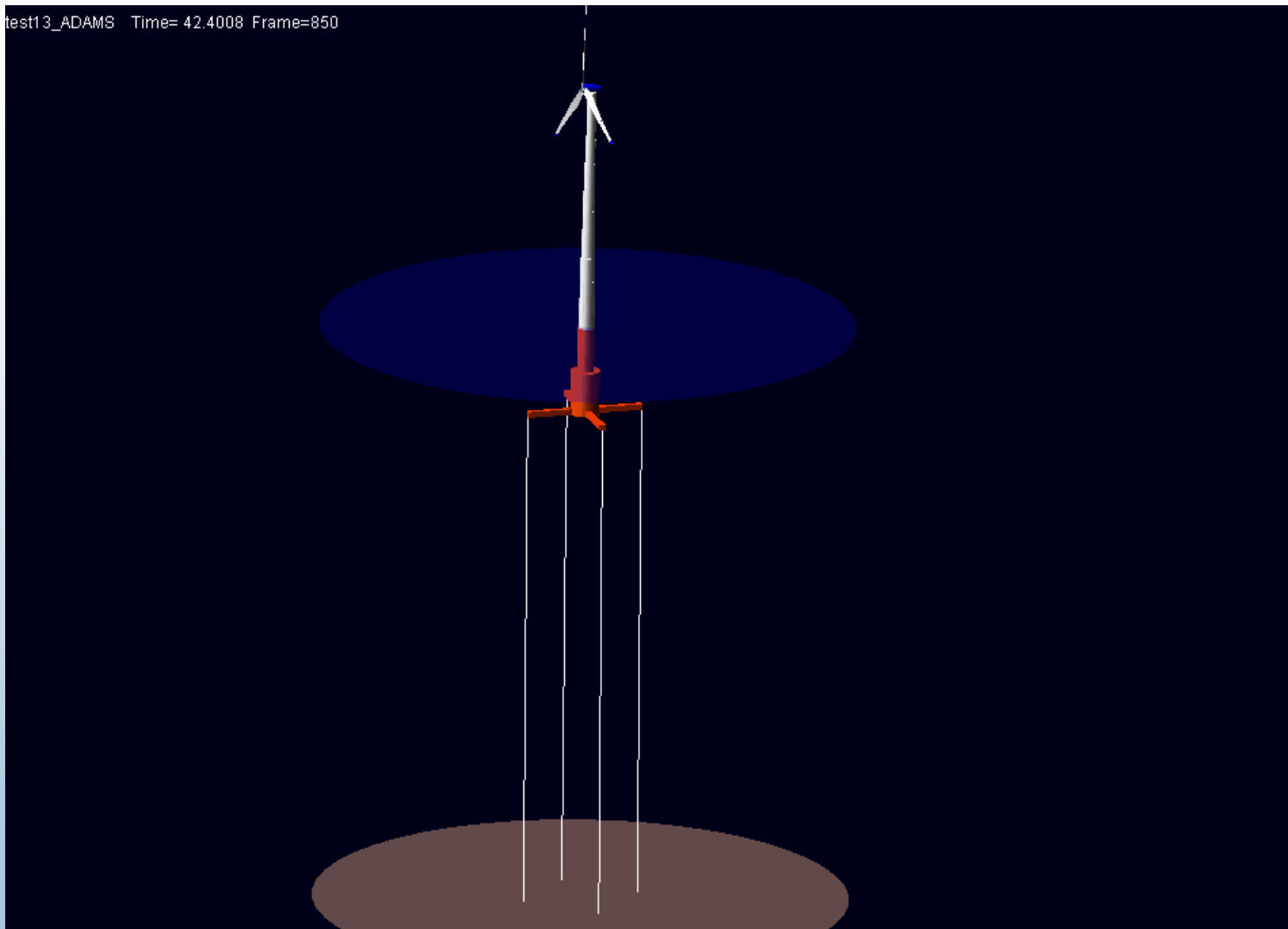


- Turbulent winds
- Irregular waves
- Gravity / inertia
- Aerodynamics:
  - induction
  - skewed wake
  - dynamic stall
- Hydrodynamics:
  - scattering
  - radiation
  - hydrostatics
- Elasticity
- Mooring dynamics
- Control system
- Fully coupled



*Wind and Wave Spectra*

test13\_ADAMS Time= 42.4008 Frame=850





# A Future Vision for Wind Energy Markets

