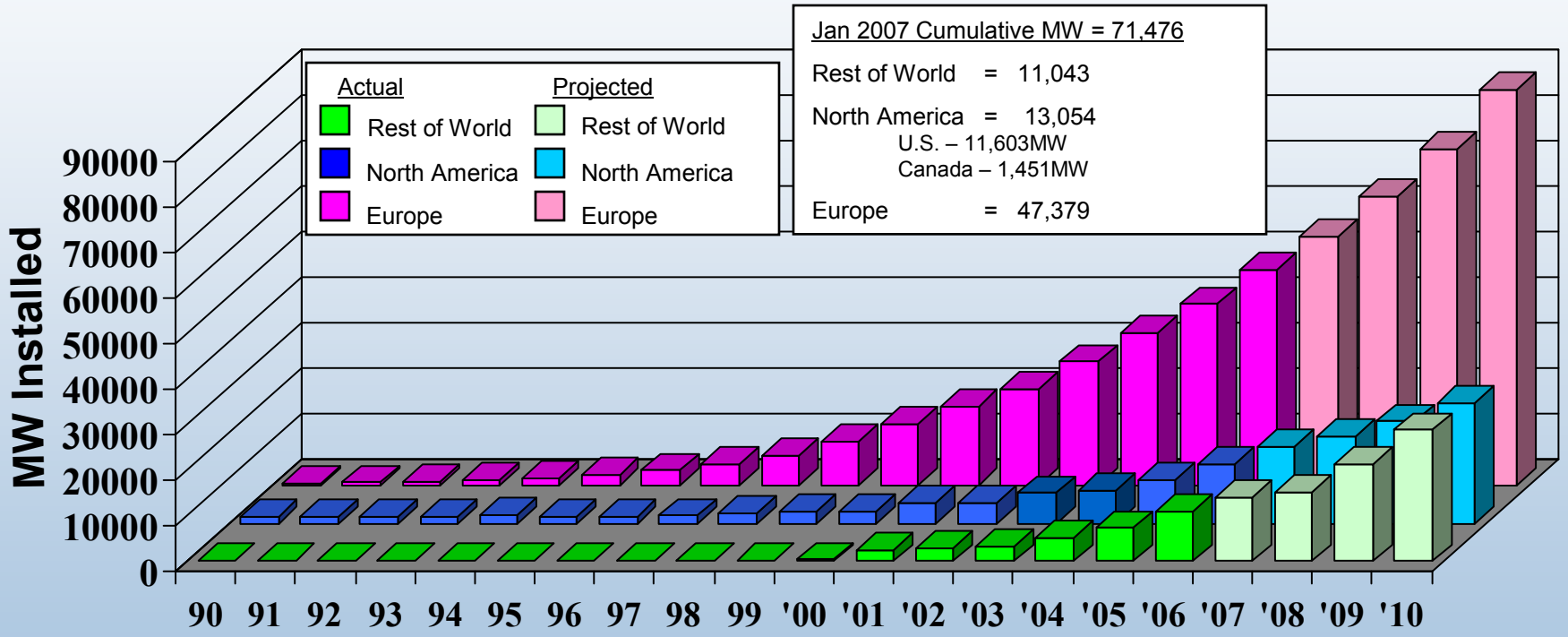
Wind Energy Technology and Application

National Wind Technology Center
Golden, Colorado

Ian Baring-Gould

September 13, 2007

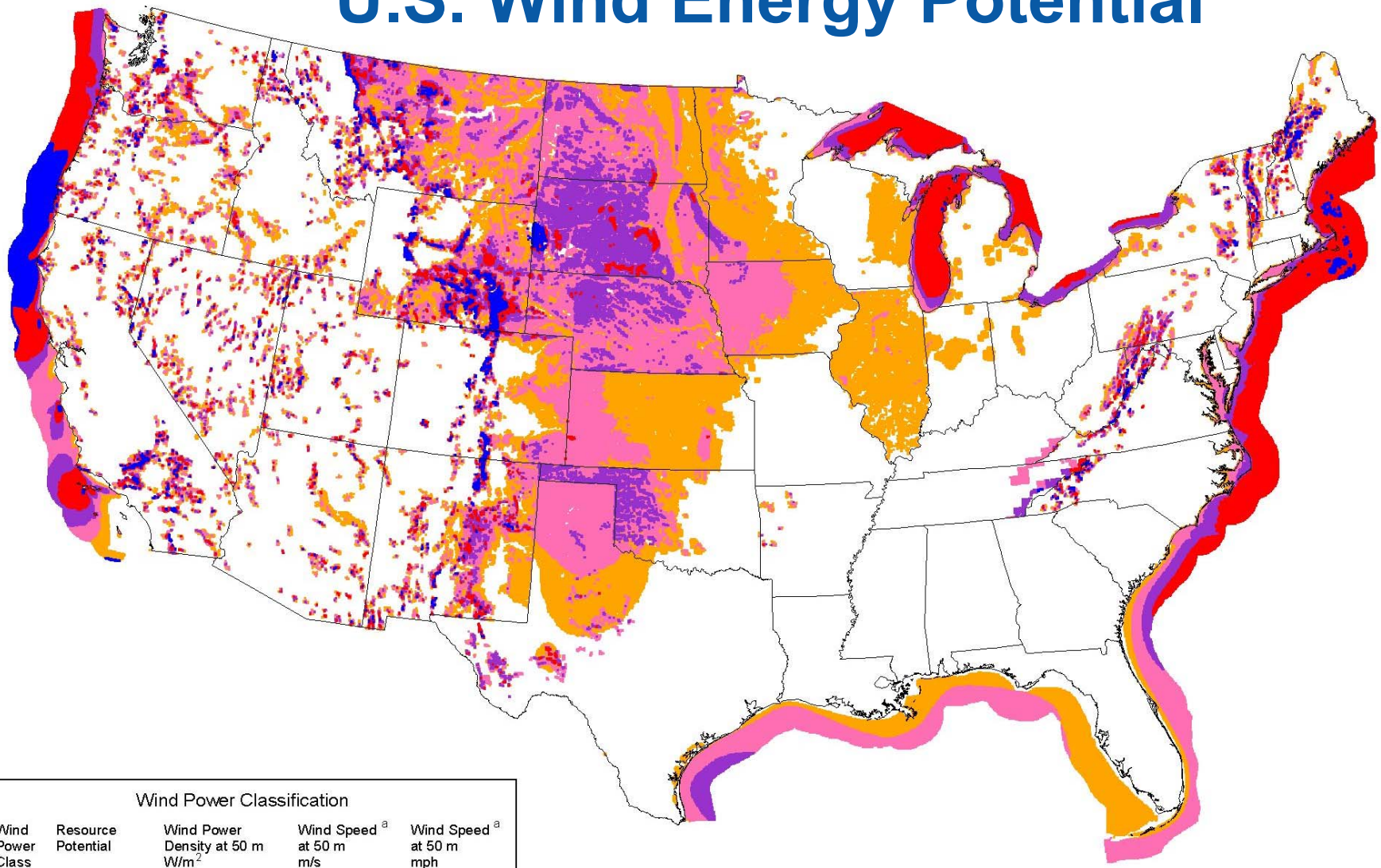
Growth of Wind Energy Capacity Worldwide



Sources: BTM Consult Aps, March 2005
Windpower Monthly, January 2007
*NREL Estimate for 2007

NREL National Renewable Energy Laboratory

U.S. Wind Energy Potential



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
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

This map shows the wind resource data used by the WinDS model in Oct. 2006. It is a combination of high resolution and low resolution datasets produced by NREL and other organizations. The data has been screened to eliminate areas unlikely to be developed onshore.

U.S. Department of Energy
National Renewable Energy Laboratory

NREL

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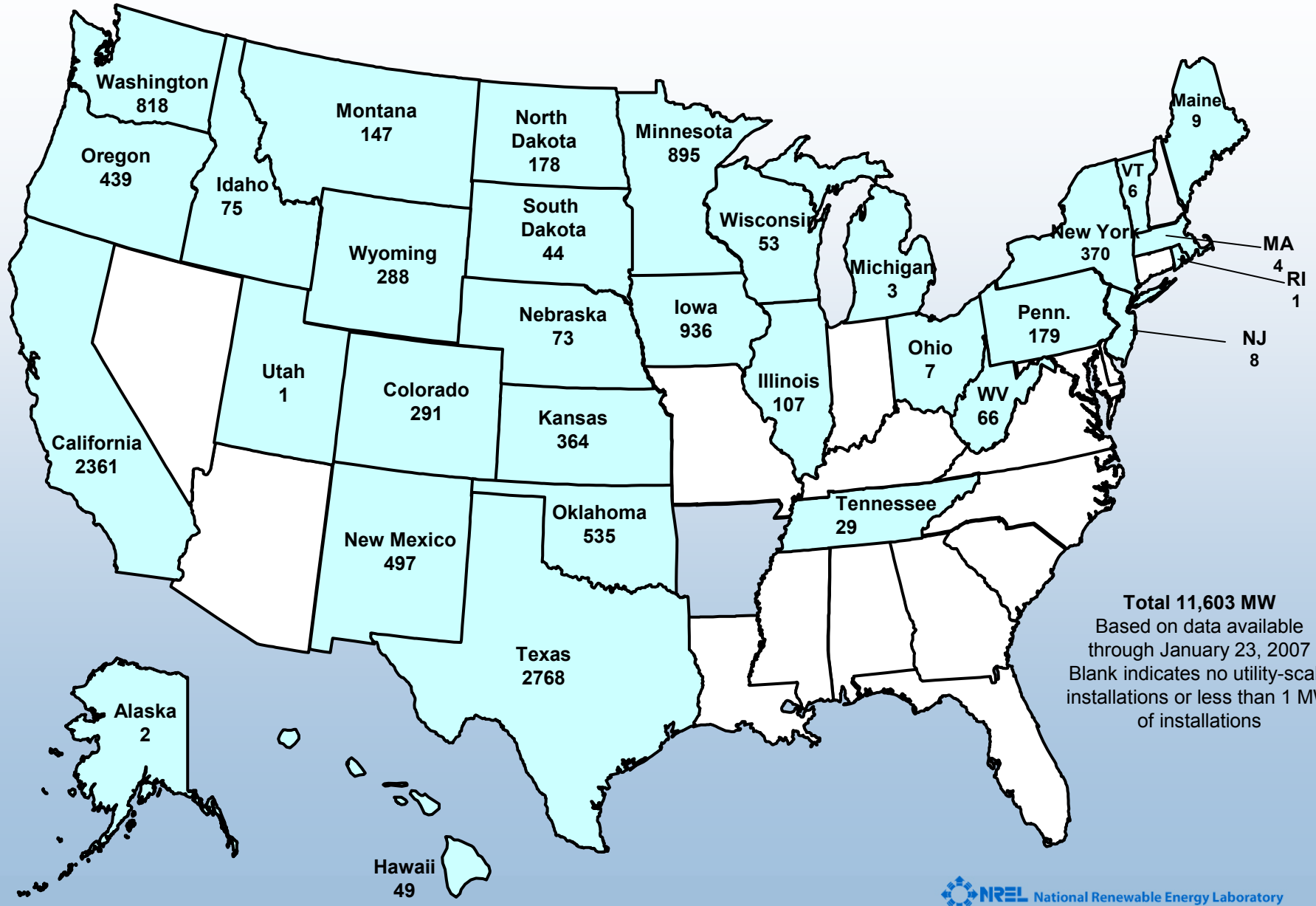
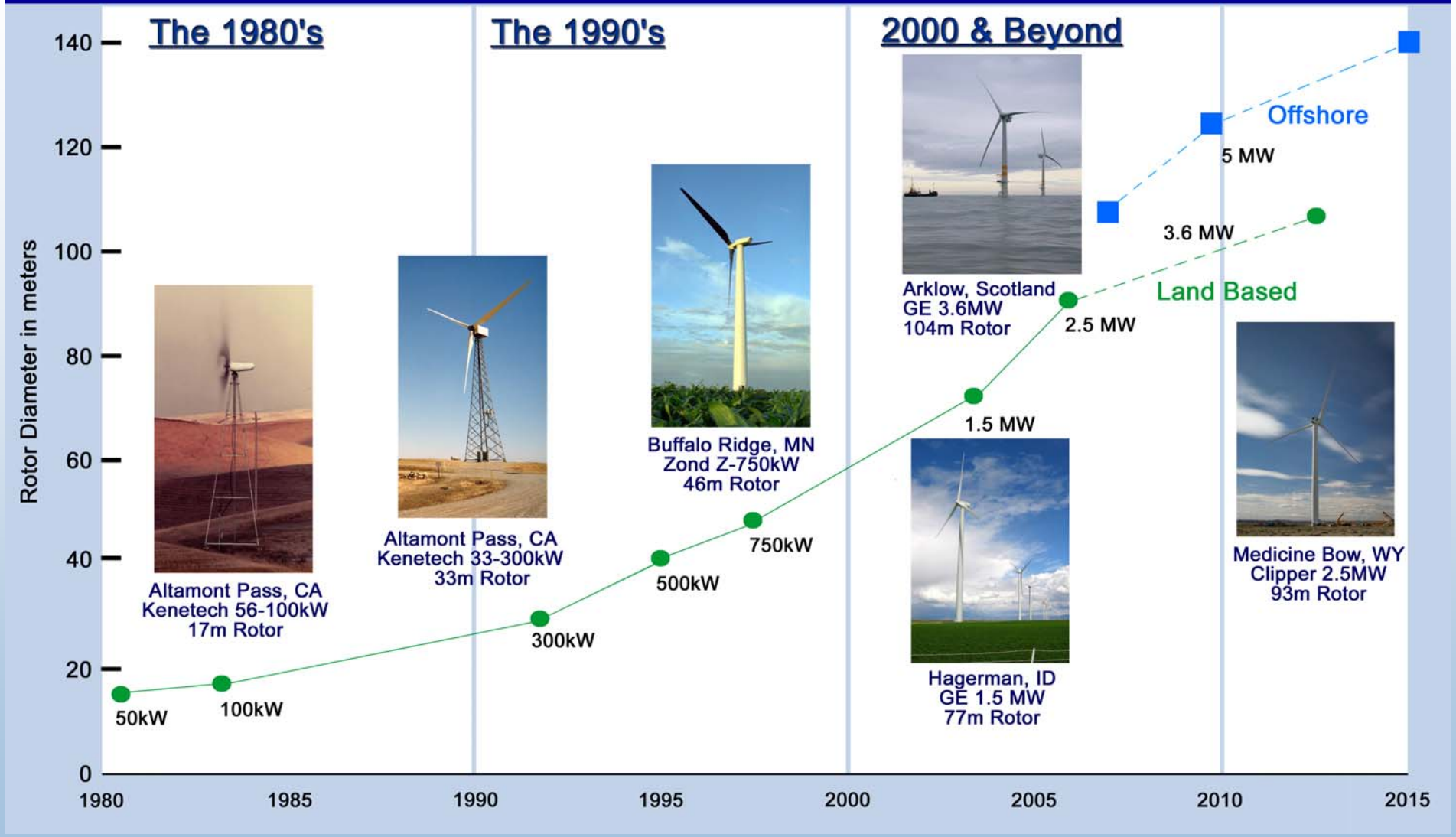
Megawatts of Installed Utility-Scale Wind Power at December 31, 2006



NREL National Renewable Energy Laboratory

Evolution of U.S. Commercial Wind Technology



Cost of Energy Trend

1981: 40 cents/kWh

Decreasing Cost Due to:

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

NSP 107 MW Lake Benton, MN wind farm

2006: 5-8 cents/kWh with no PTC for a 13mph wind speed at 10m (18mph at 100m hub)

Recent cost increases are due to:

- **Price increases in steel & copper**
- **Turbines sold out for 2 years**

Note: These energy costs are average for the US and costs in many locations with lower winds at hub height, higher insurance, permitting, and land cost, such as in California can increase energy cost by up to 20%.

Goal : To make wind competitive with no subsidies

Sizes and Applications

Small (≤10 kW)

- Homes (Grid connected)
- Farms
- Remote Applications

(e.g. battery changing, water pumping, telecom sites, icemaking)

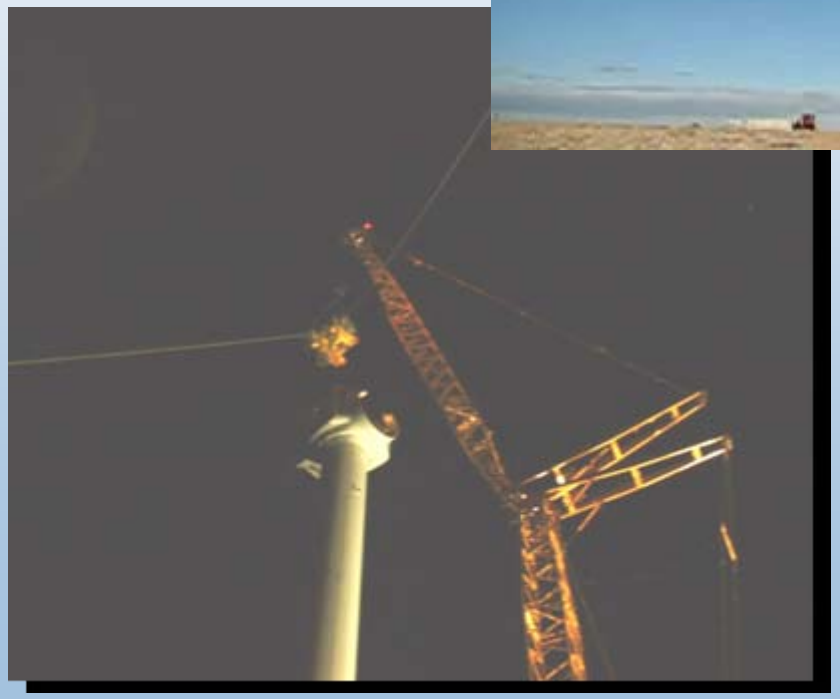
Intermediate (10-500 kW)

- Village Power
- Hybrid Systems
- Distributed Power

Large (500 kW – 6 MW)

- Central Station Wind Farms
- Distributed Power
- Offshore Wind Generation Stations

Clipper LWST Prototype
2.5 MW with 93 m Rotor

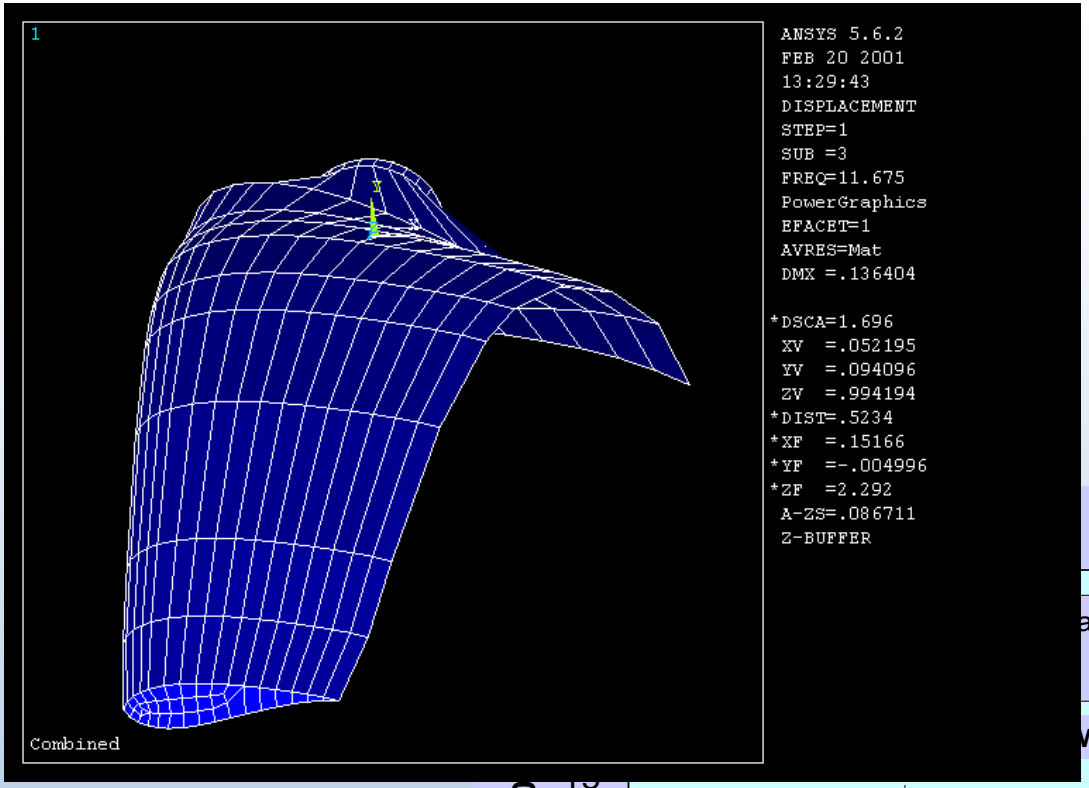


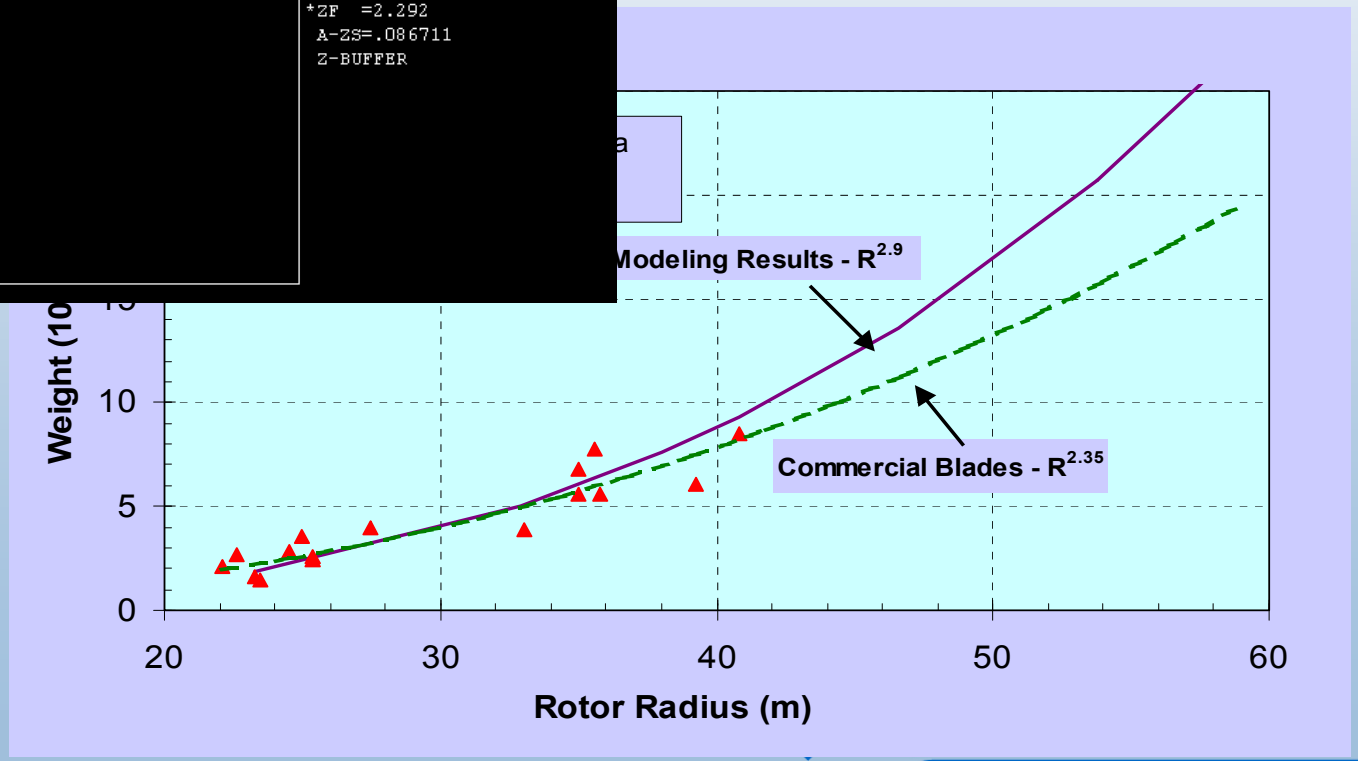
SWWP DWT Prototype 1.8kW under test at the NWTC

High Wind Operation

Installation

Blade Scaling for Multi-megawatt Rotors



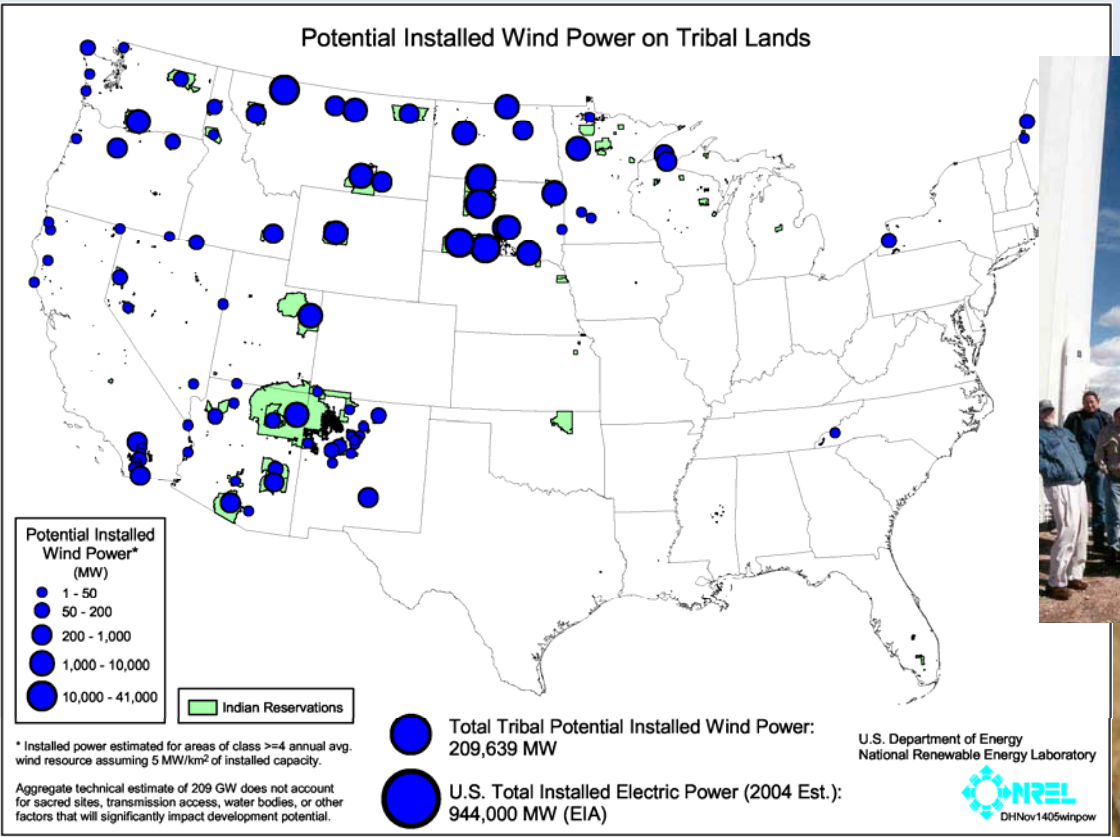


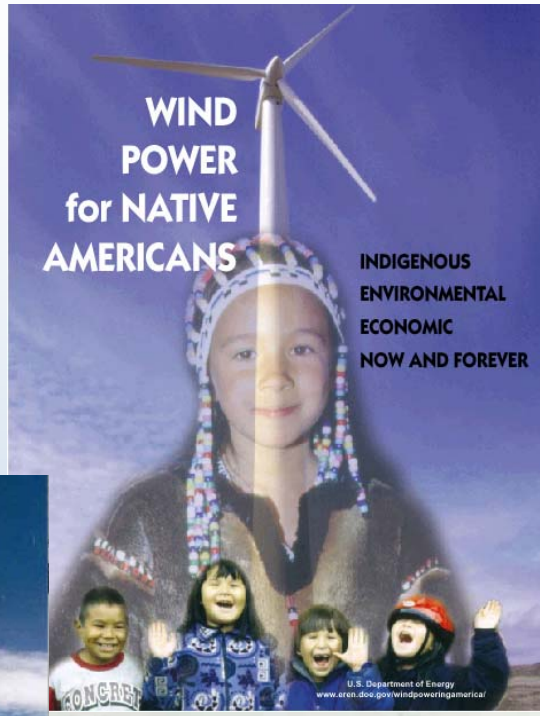
Industry's Growing Needs

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

WPA Native American Outreach

- Anemometer loan program
- Native American Wind Interest Group outreach
- U.S. DOE/Tribal Energy Program wind projects technical assistance
- Annual Wind Energy Applications and Training Symposium
- Wind Powering Native America video
- Analysis and Technical Assistance to tribes

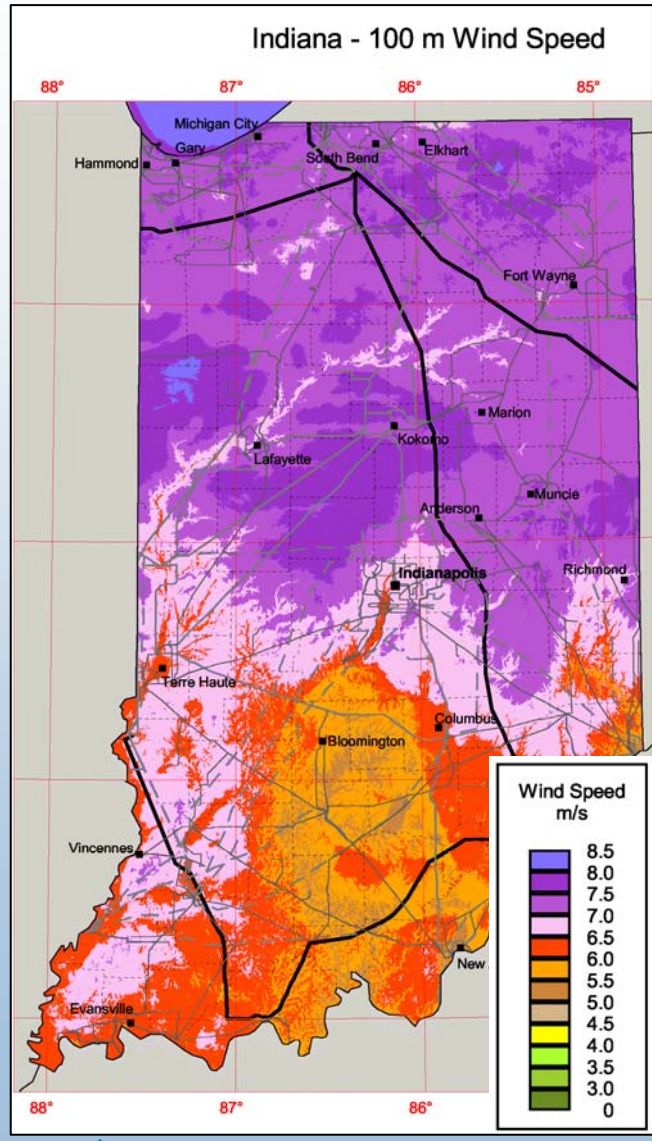




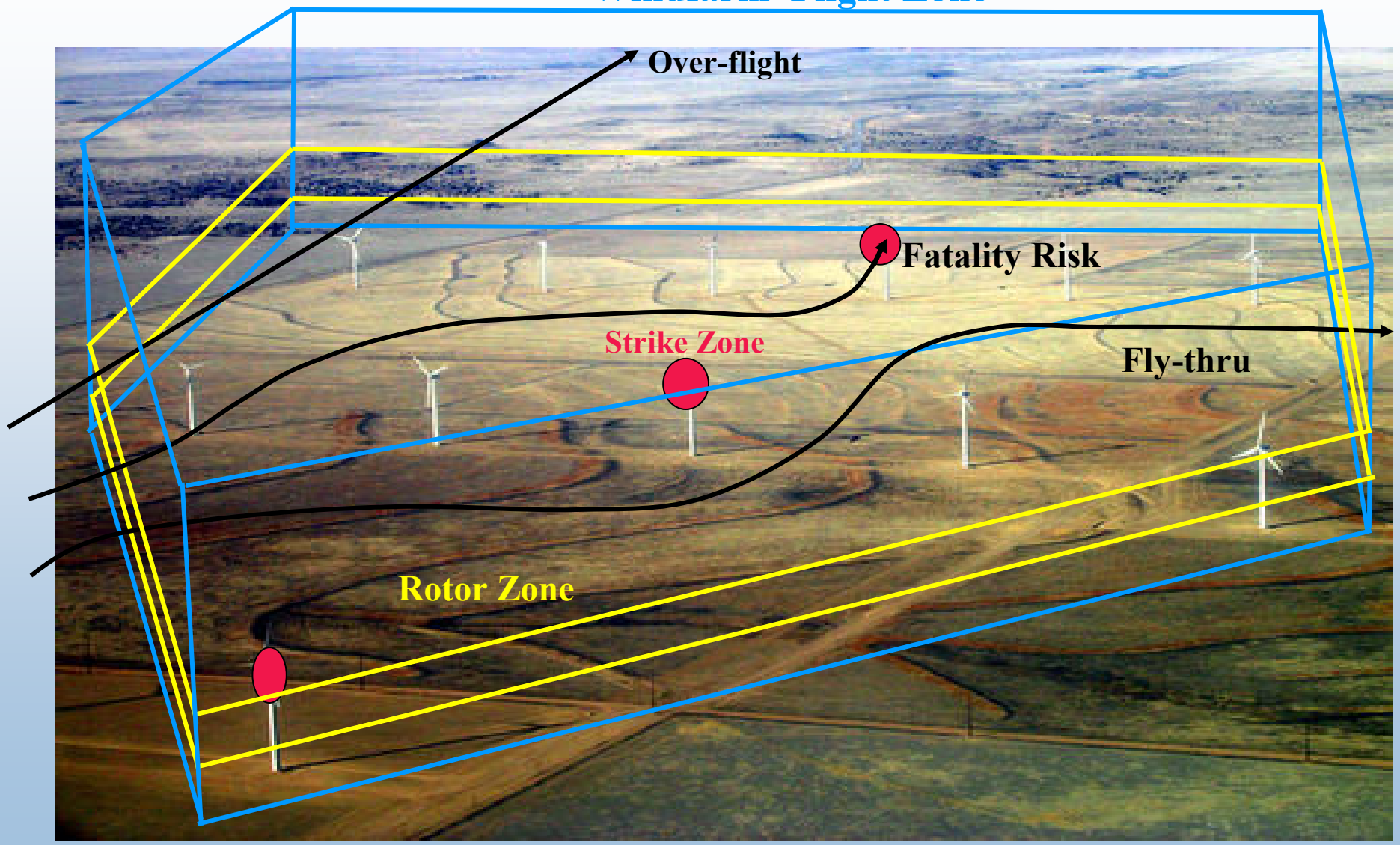
Direction for 2007and beyond: Reducing Barriers to Wind Developers

Wind Powering America Focus Areas:

- State Outreach and Policy through State Working Groups
  - Deliberative Polling
  - Comparative generation benefits analysis
  - Ag Outreach and regulatory and legislative briefings
- **Wind For Schools**
  - Expand Wind For Schools to 4-5 new states each year
  - Develop Wind Applications Centers at State Engineering Universities
- **Initiate Regional Wind Energy Institutes**
  - Establish collaborations to initiate virtual Regional Wind Energy Institutes in support of regional issues and information needs
- **Ag Sector Outreach**
  - Enhance Ag Sector support and communications
- **Public Power Partnerships**
  - Enhance education activities in partnership with UWIG and NRECA
- **Native American Outreach**
  - Support wind project development on Native American Lands
- **Radar Laboratory Team Participation** to develop solutions
- **Wind Resource Mapping**
  - Initiate enhanced remapping of priority States at the 100m level



Visualization of Avian Interaction Zones



Infrared Image of a Bat Flying Through a Wind Turbine Rotor

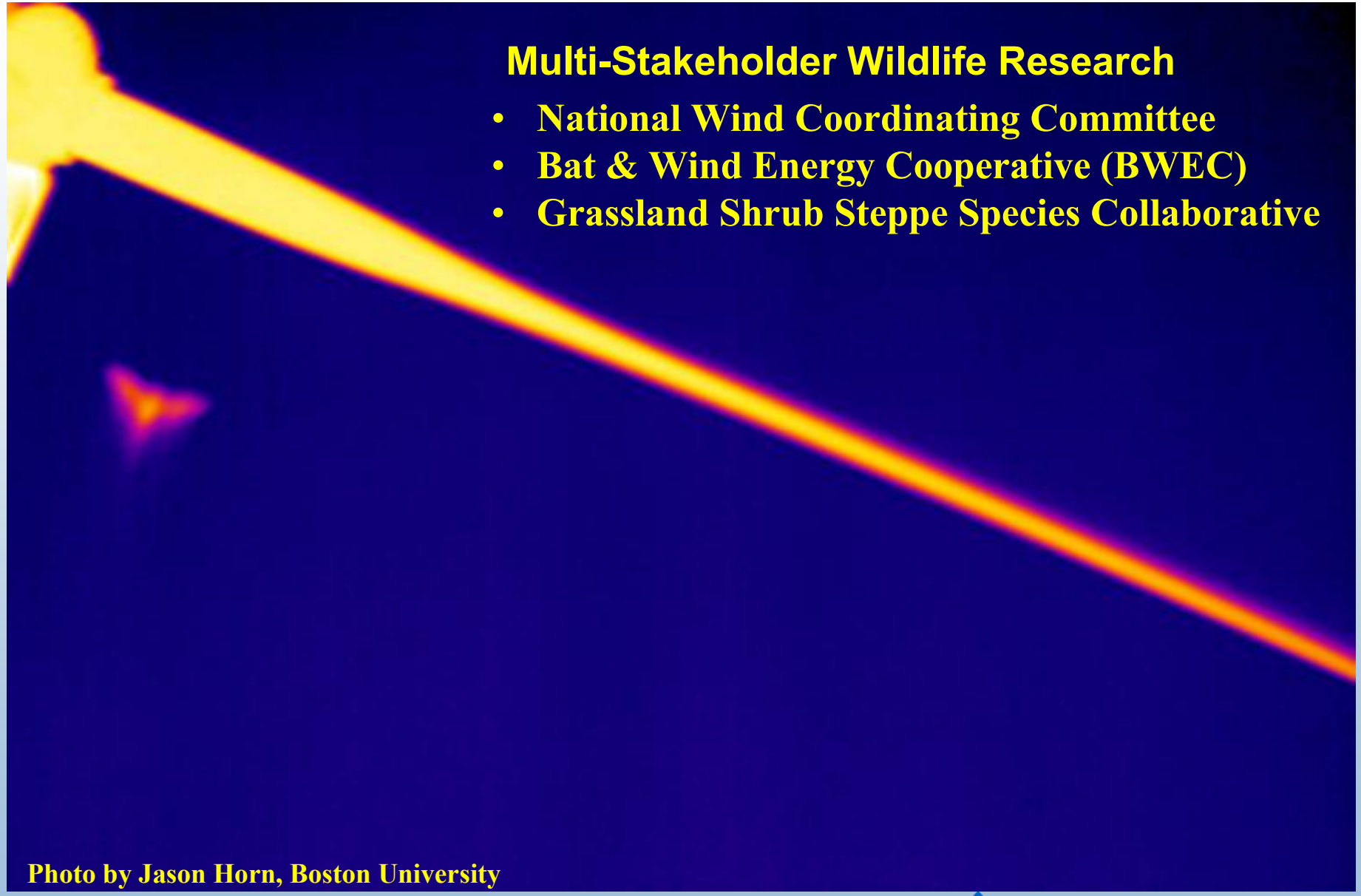


Photo by Jason Horn, Boston University

A Future Vision for Wind Energy Markets

Today 2006

Bulk Power Generator
5-8¢ at 13mph* With No PTC

- Land Based
- Bulk Electricity
- Wind Farms

Less than 1% of Electricity Market

Tomorrow

Land Based Electricity Path

Land Based LWST 2–5 MW

Transmission Barriers

LWST Turbines:
- 20% Cost Reduction 2015
- 20% Increase in Energy 2015
- 20% of Electricity Market by 2030

Offshore Electricity Path

Offshore Turbines 5 MW and Larger

Cost & Regulatory Barriers

Offshore LWST Turbine:
- Higher Wind Sites
- Shallow/***Deep*** *water*
- Coastal Cities
- 35% Cost Reduction
- Commercial by 2015

New Applications Path

- **Hydrogen**
- **Clean Water**
- **Plug Hybrids**

Cost & Infrastructure Barriers

Custom Turbines for Multi-markets:
- Electricity
- H2 production
- Desalinate water

2020 and Beyond

* Note: The site wind speed is measured at 10m and assumes a 1/7 power law wind shear giving a hub height wind speed of 18mph, while the siting, land and related project costs are assumed to be average for the US.