Technology Commercialization Showcase 2008
DOE Wind and Water Program

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Agenda

- Market Overview
- Program Objectives
- Technology Commercialization Opportunities
- Unexploited Investment Gaps

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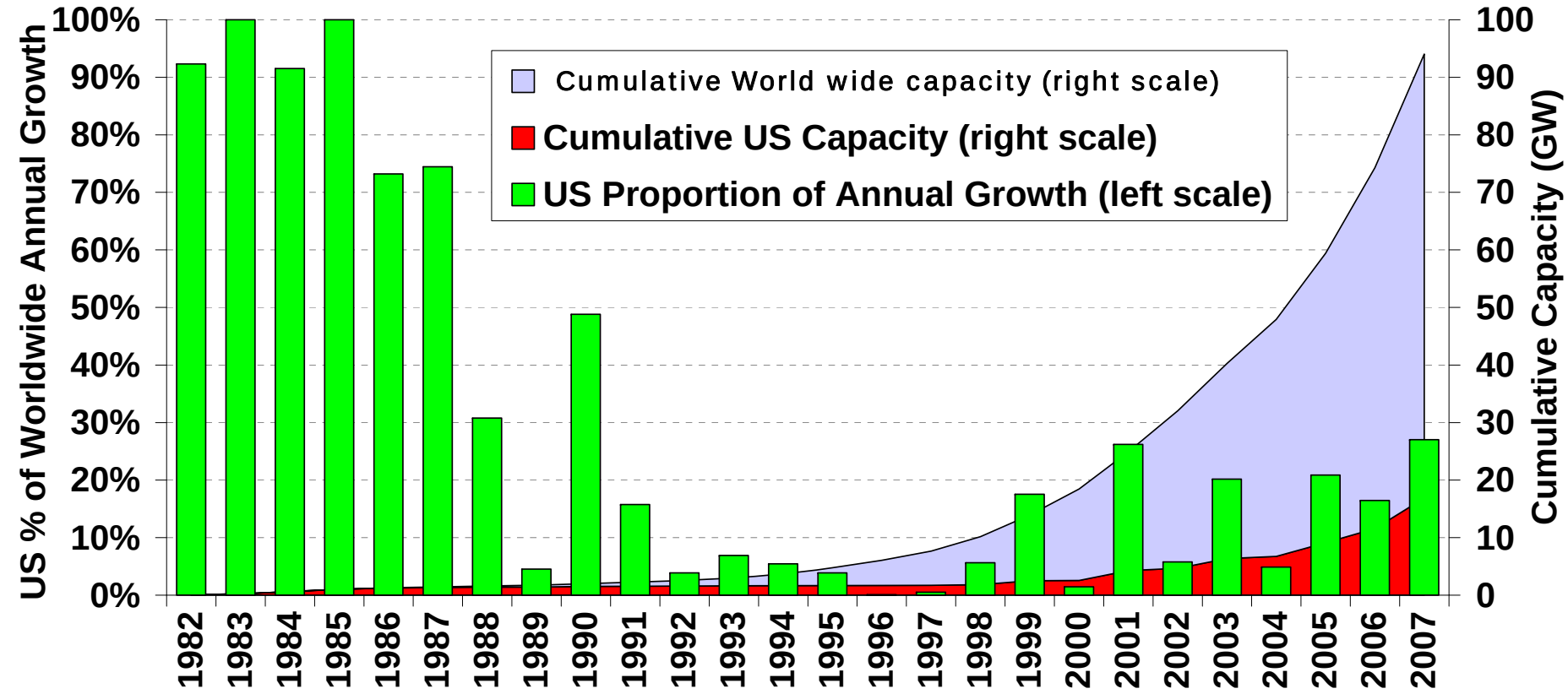
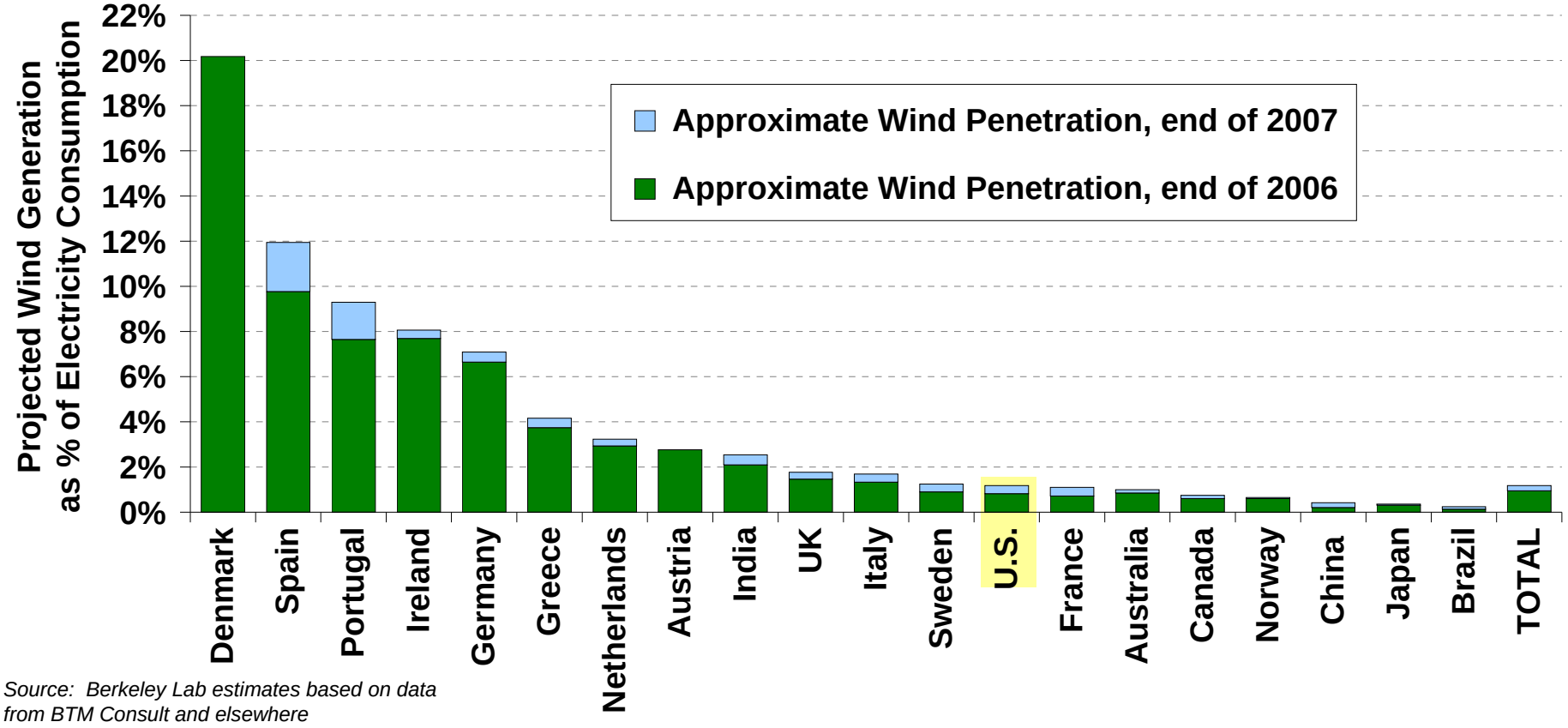
Strong overall growth trends, though U.S. markets highly policy dependent



Source: Earth Policy Institute, BTM Consult, AWEA

U.S. wind compared to international wind – capacity growth in GW

Several countries reaching significant reliance on wind; U.S. now steadily increasing

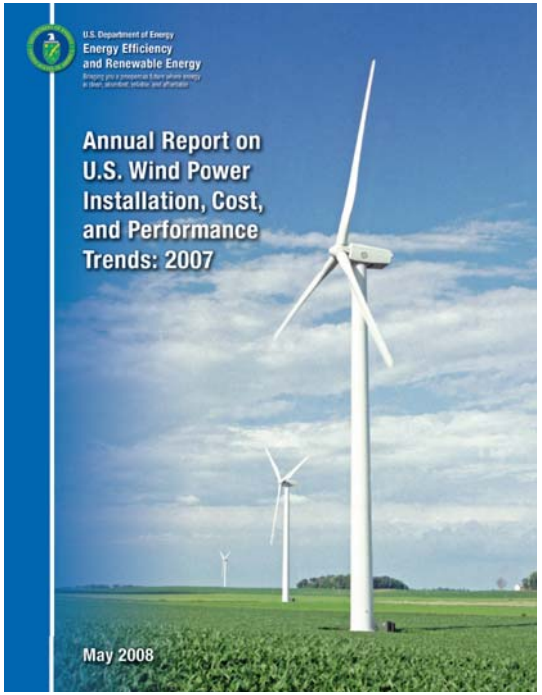


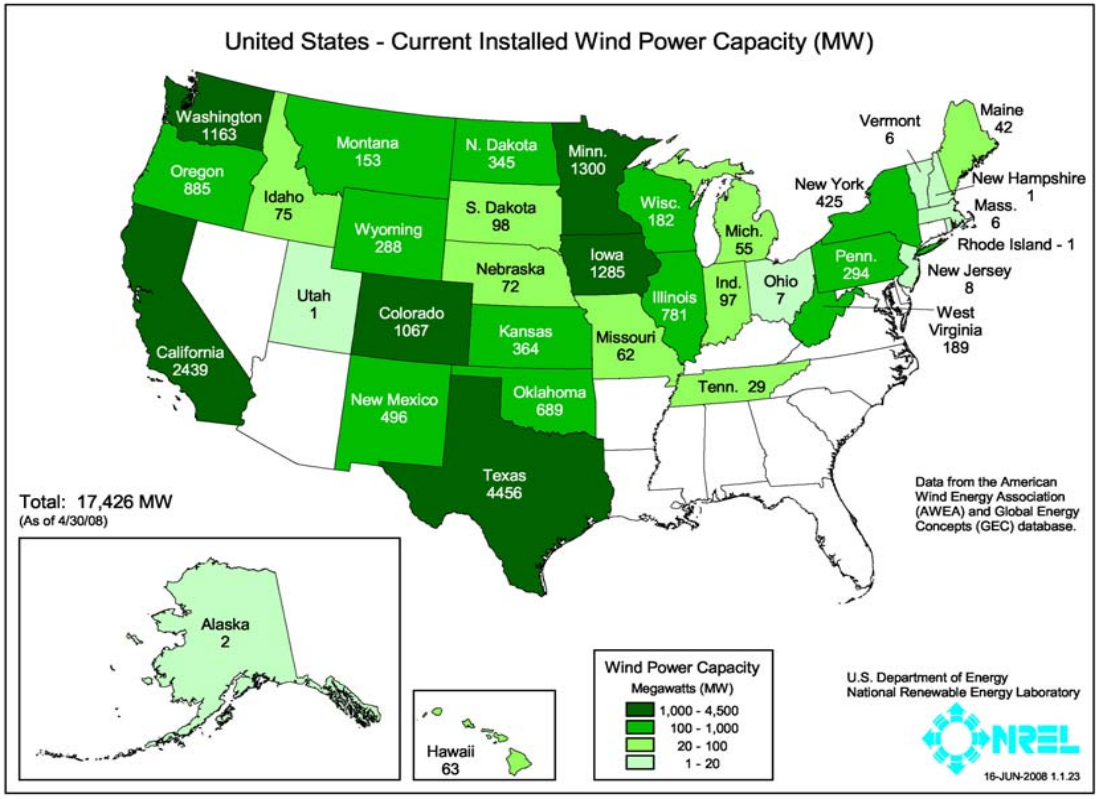
Source: Berkeley Lab estimates based on data from BTM Consult and elsewhere

Wind penetration – *the percentage of wind energy delivered in each country*

Wind power has spread to majority of U.S.

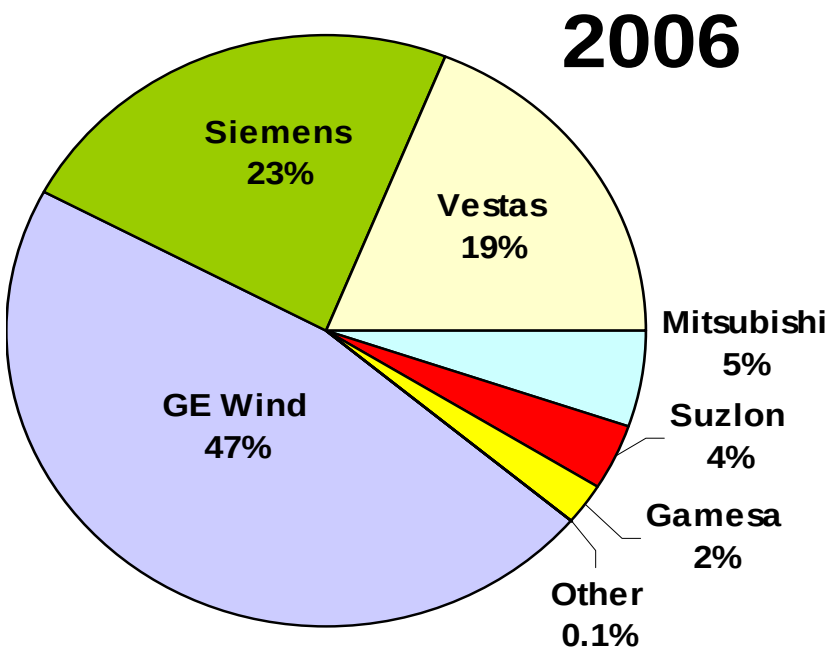
- Over 18,000 MW installed in the U.S. (first quarter of 2008)
- 1% of U.S. energy production
- 100,000 MW installed worldwide
- 38 states now have wind power
- 5700 MW of wind under construction

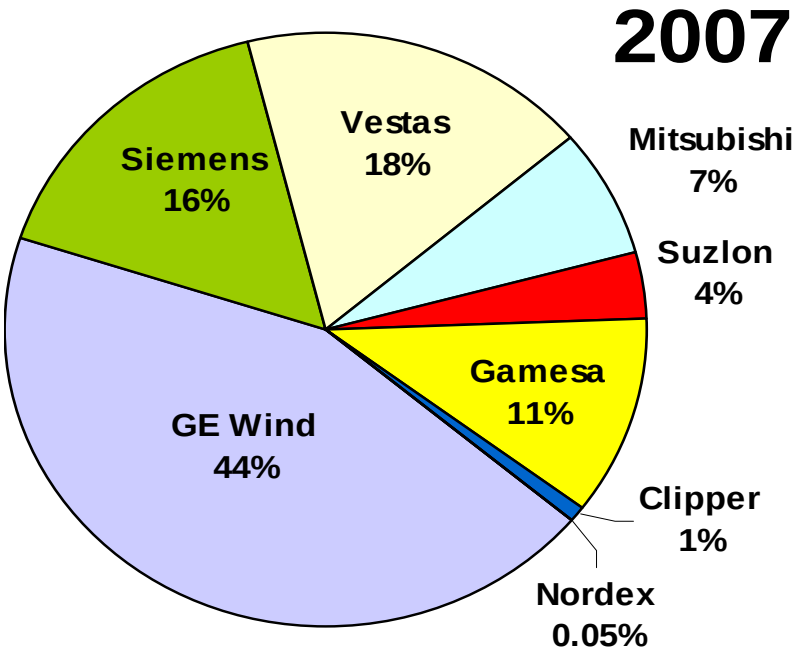




Sources: NREL, AWEA

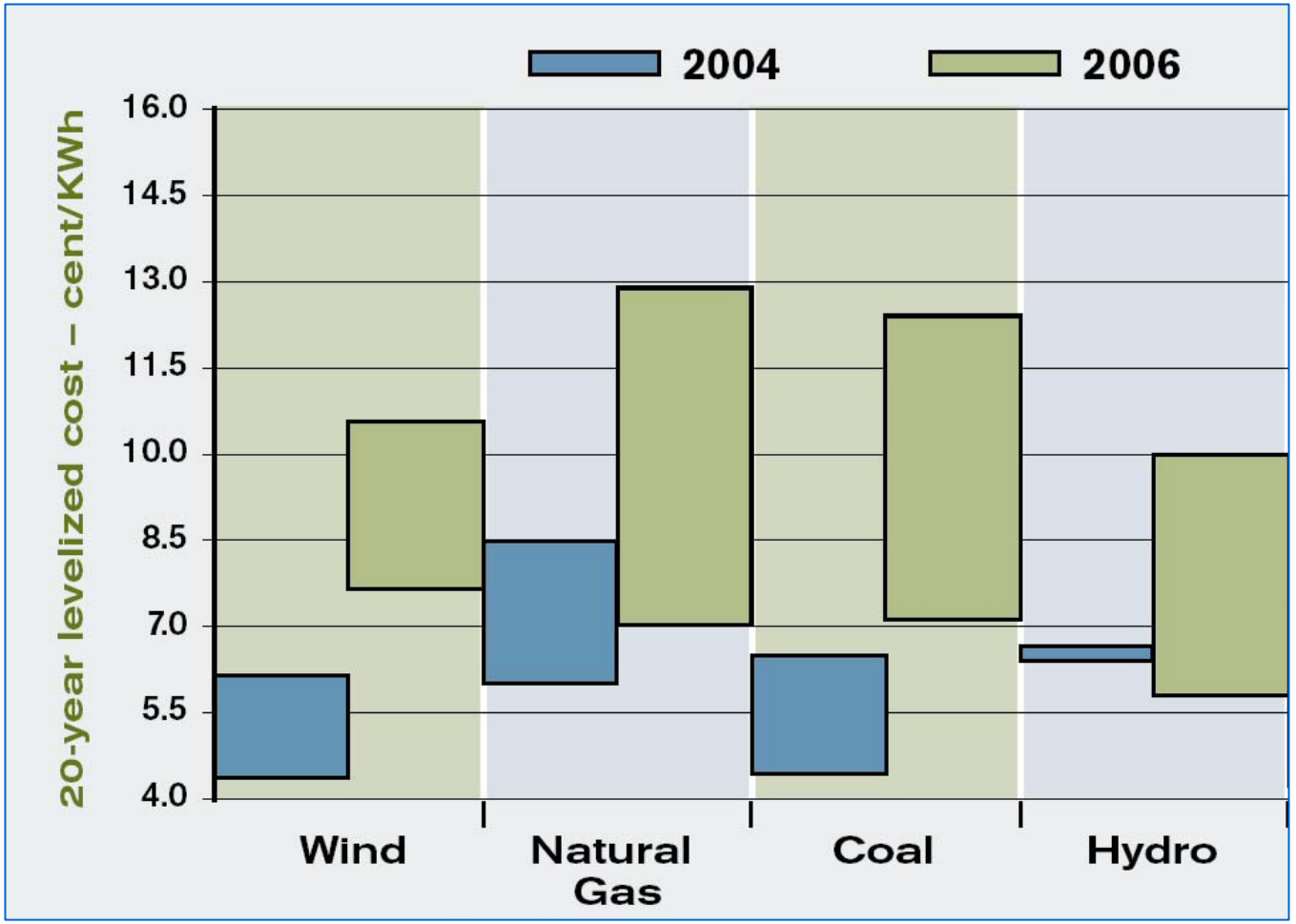
While GE is the dominant turbine vendor in the U.S., new entrants are gaining market share





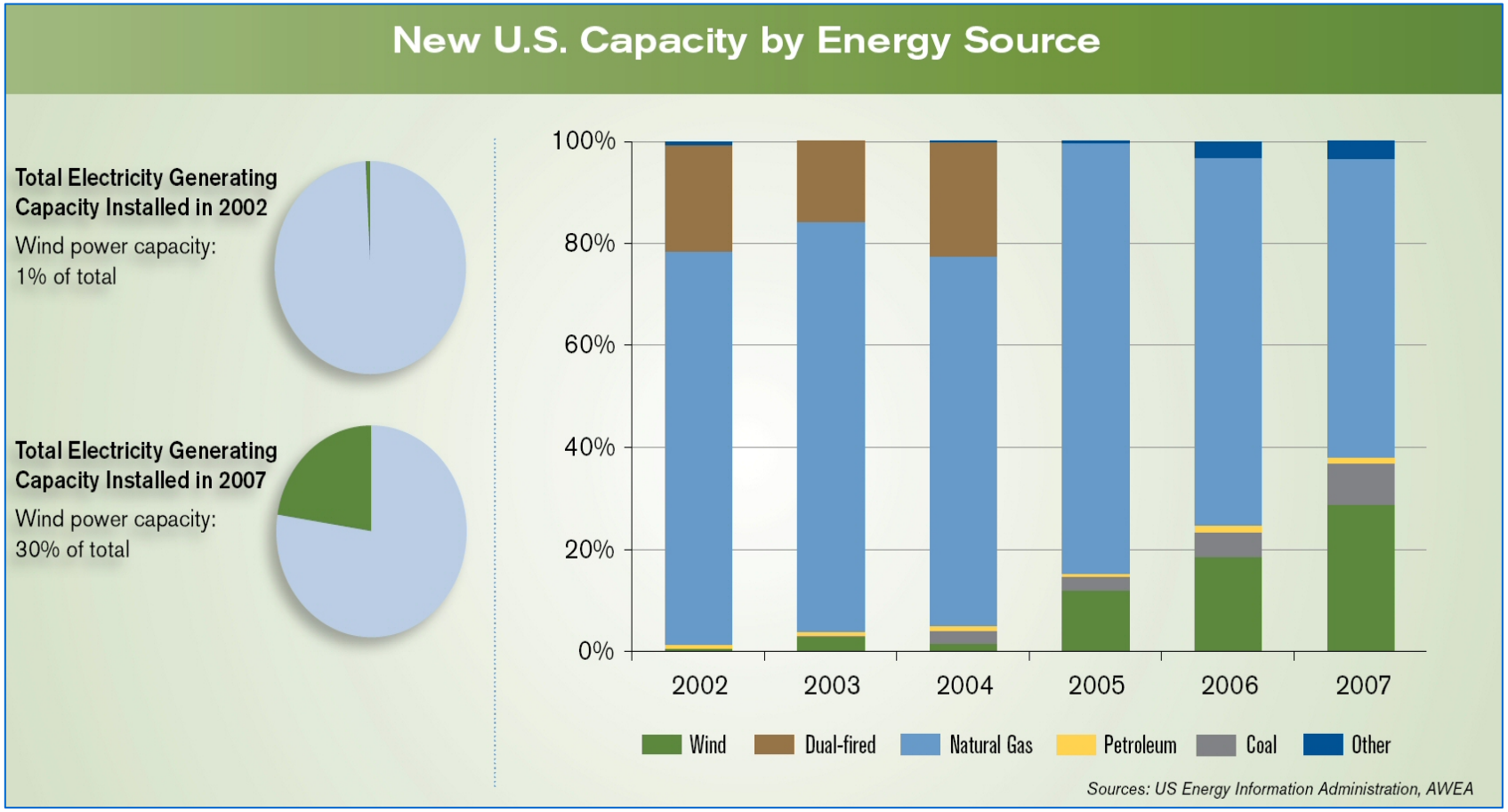
Source: American Wind Energy Association

Wind energy competes well on cost, as recent cost increases have occurred in all forms of generation



Source: Puget Sound Energy

Wind power is second in annual new capacity addition only to natural gas



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DOE Wind Program's mission is to focus on growing the market for wind power in the U.S.

To lead the nation's efforts to improve **wind energy technology** through public/private partnerships that enhance domestic economic benefit from wind power development

and

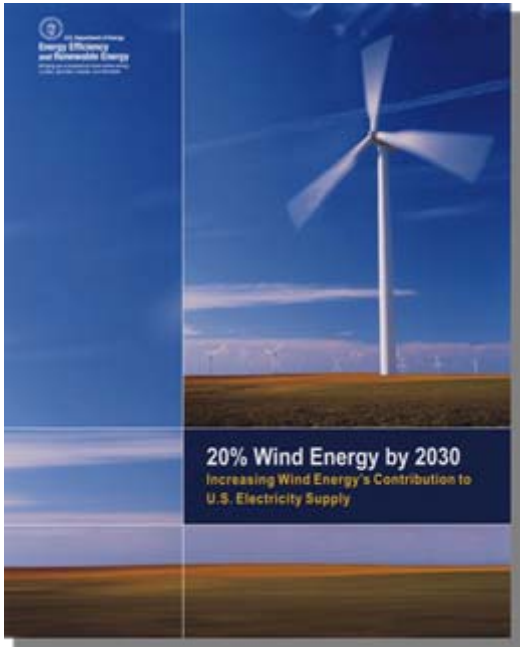
to coordinate with stakeholders on activities that **address barriers to wind energy**

Hallmark report released in May clarifies pathway to major contribution from wind energy in the U.S.

20% U.S. Electricity from Wind by 2030:

Collaborative effort between government, industry and stakeholders provides a detailed assessment of the pathway to greatly expanding wind energy use through:

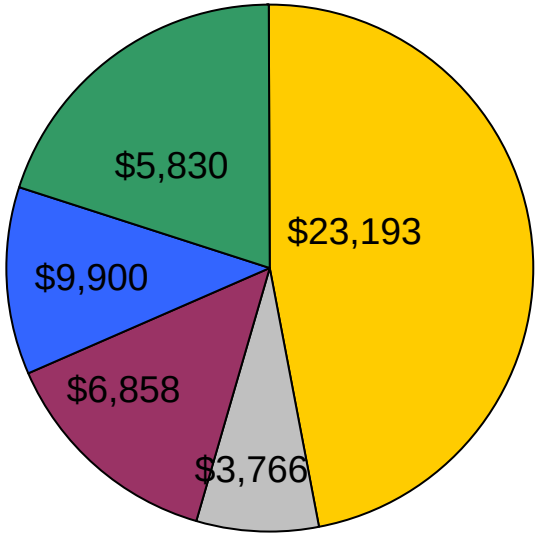
- Technology Improvement
  - Addressing technical and financial risks
- Ramping up Domestic Manufacturing
- Transmission and Integration
  - Transforming utility operations and transmission planning
- Addressing Siting and Environmental Challenges
- Wind Power Market and Application Development



DOE investment to achieve 20% wind penetration

12% Renewable Systems Interconnection

Transmission: Support transmission planning and enable expanded grid integration of variable wind resource



47% Large Wind Technologies

Technology, Manufacturing: Improve reliability and operability, increase capacity factors, and reduce cost of large wind turbine technologies

20% RSI Supplemental

Transmission: Expanded efforts to improve grid analysis, wind forecasting and remove other integration barriers to wind deployment

14% Wind Powering America

Markets, Siting, Environmental: Work with national stakeholders to move wind technology into the power generation market

8% Distributed Wind

Technology: Improve the performance, cost, reliability & availability of small wind and medium scale wind turbines

From inception to generation: DOE's role in wind

DOE Wind is involved in most steps along the way.

Research, testing, prototype design & development by funding national labs and others



Market preparation, siting & environmental work, outreach to utilities and stakeholders





Site assessment, deployment, transmission, technology tracking & improvement, reporting






Track Record of Success: Public-private R&D partnerships bring research advances to market

Breakthrough Products based on DOE Collaboration with Industry

- Improved GE 1.5 MW turbines used for 47 % of 2006 new U.S. capacity
- Clipper Windpower 2.5 MW Liberty turbine — innovative drive train
- Southwest Windpower 1.8 kW Skystream turbine — advanced residential turbine
- Knight & Carver STAR blade – increased energy capture

1.5 MW, 1.5s Series

2.5 MW Liberty

1.8 kW Skystream

"Clipper's Liberty turbine is not only one of the most advanced wind turbines ever produced, it may well be the most efficient wind turbine in the world."

Samuel Bodman - Secretary of Energy August 2, 2006

DOE technology development activities have and continue to play a critical role in today's market.

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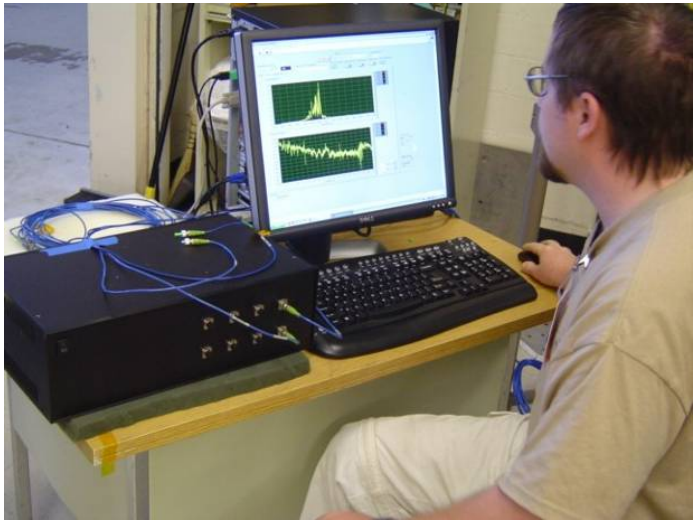
The following technologies are available for commercialization opportunities:

- Low-cost Interrogation System for Fiber Optic Based Sensors
- Wasatch Wind Space-Frame Tower and Lifting System
- Convoloid gears, Genesis Partners LP
- Global Energy Concept Medium-speed Drive Train
- Endurance Windpower, Inc Turbine – 4.25 kW
- Efficient, Variable-Speed Wind Turbine Control

Low-Cost Interrogation System for Fiber Optic Based Sensors

Description

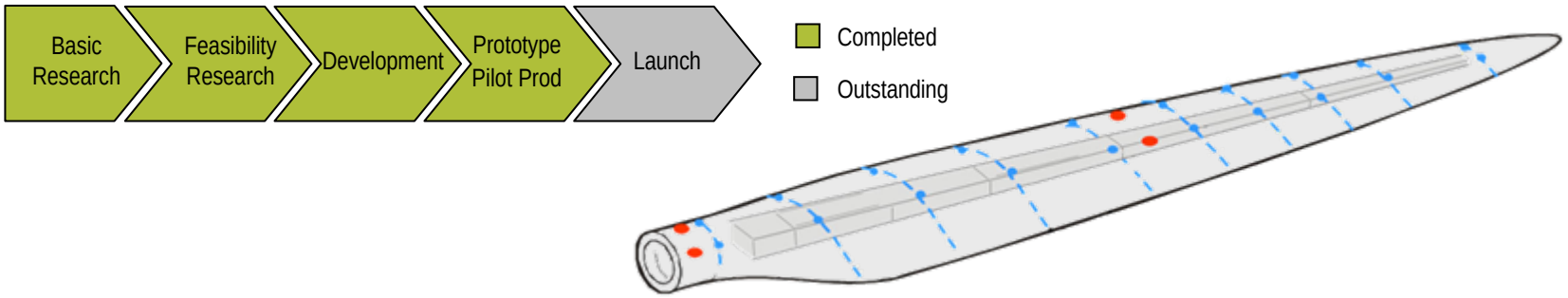
Fiber optic sensors measure critical structural loads on a wind turbine. The interrogator converts the optical signals to electrical signals that can be used by the control system to reduce loads and/or increase energy capture.



Impact

- Fiber optic systems are beginning to be used by industry to monitor structural loading
- Will help expand use of fiber optic monitoring through greatly reduced cost relative to existing interrogators

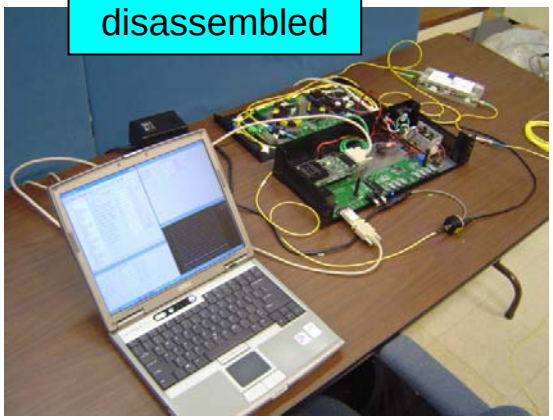
Technology Readiness

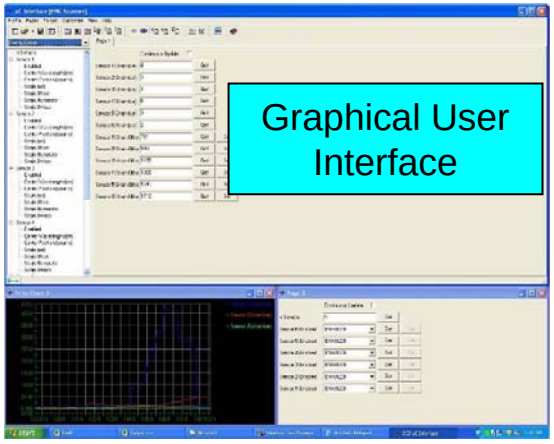


Low-Cost Interrogation System for Fiber Optic Based Sensors

- **Details:** A fiber optic interrogator is a critical component in most fiber optic based sensing systems. These sensors measure critical structural loads on a wind turbine. The interrogator converts optical signals to electrical signals that can be used by the wind turbine control system to reduce loads and/or increase energy capture.
  - Sandia National Labs and UC-Davis developed
  - Currently has no legal protection
  - Many reports and documents have been published
- **Value:** Low-cost solution using COTS (commercial off the shelf) subcomponents. Prototype system <$5,000.
- **Impact:** The capital cost of increasingly larger wind turbines demands increased monitoring of the turbine structure. With the growing need to have blade sensors (fiber optic based sensors have significant advantages in wind turbine blades), a new inexpensive fiber optic interrogation device is needed. Manufacturing currently includes fiber optic strain measurements.
- **Technology Status:** A prototype interrogator has been successfully built and tested.
  - **Invention:** Unique combination of COTS hardware and diagnostic software
  - **Availability:** Currently used in the lab
  - **Improvements:** none to date
  - **Needs:** Needs robust packaging. Should be redesigned to use tunable laser. Several optimizations can be implemented.

Interrogator disassembled





Wasatch Wind Space-Frame Tower and Hi-Jack™ lifting system

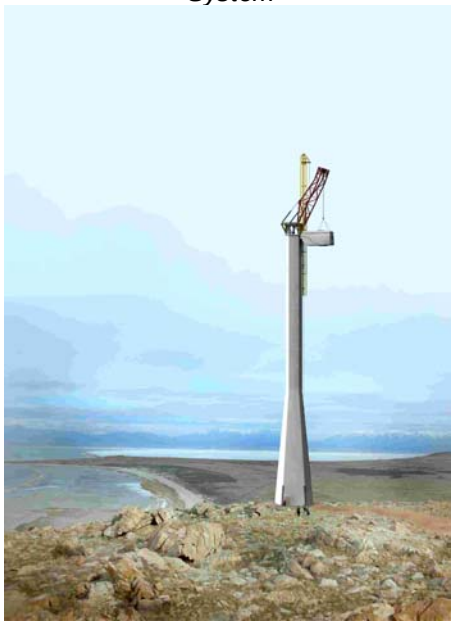
Description

- Damped, space-frame tower with Hi-Jack™ system for 1.0 MW-2.5 MW wind turbines enables installation on rougher terrain, small wind farms, taller towers, and offshore.

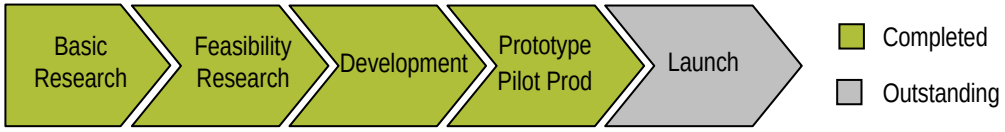
Impact

- Reduces wind cost-of-energy by 5% to 12%
- Tower manufacturing capital expenditures are reduced 65%
- Eliminates need for large track installation crane
- 40% lighter, transports on standard flatbed trucks

Drawing of Space-Frame Tower and Lifting System

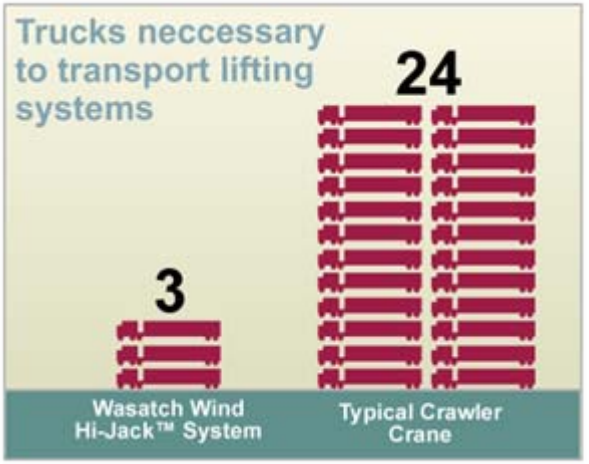


Technology Readiness



Wasatch Wind Space-Frame Tower and Hi-Jack™ lifting system

- **Details:** Founded 2002, received $850,000 DOE SBIR grants to solve utility-scale wind turbine tower limitations that hamper wind power growth.
- **Problem Statement:**
  - Too expensive (weight, transport, erection, foundation)
  - Difficult transport logistics eliminate most good wind sites
  - Ultra-large track cranes required leave large environmental footprint (roads), and high-costs eliminate community & remote wind projects
  - High manufacturing capital expenditures are cited as key problem by industry manufacturers to scaling turbine capacity
  - Do not scale cost-effectively above 80 meters height to better wind resource and resulting higher power outputs/better economics
- **Impact:**
  - Incorporates damping as key technology enabler
  - 40% lighter, transports on standard flatbed trucks
  - Integrated Hi-Jack™ system is cost effective and eliminates requirement for large track cranes
  - Tower manufacturing capital expenditures are reduced 65%
  - Tower scales cost effectively to 100 meters height
  - Tower damping will be advantaged in offshore applications
- **IP:** All IP belongs to Wasatch Wind, Inc.
- **Technology Status:**
  - Towers ordered to date will support 1500 MW
  - DFJ Element/PG&E Series A investment in March '07



Convoloid Gearing by Genesis Partners LP

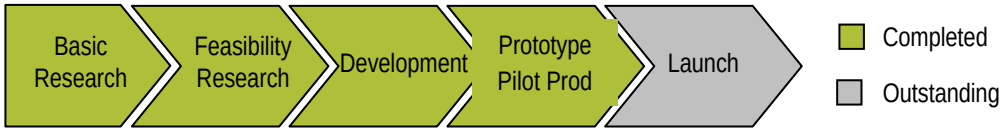
Description

- Convoloid gears take advantage of computer-controlled gear manufacturing with potential to increase load-carrying capacity by 25-40% over conventionally designed units.

Impact

- Increased load carrying capacity would allow use of a smaller gearbox than that for a typical wind turbine which reduces the cost

Technology Readiness



Convoloid gears by Genesis Partners LP

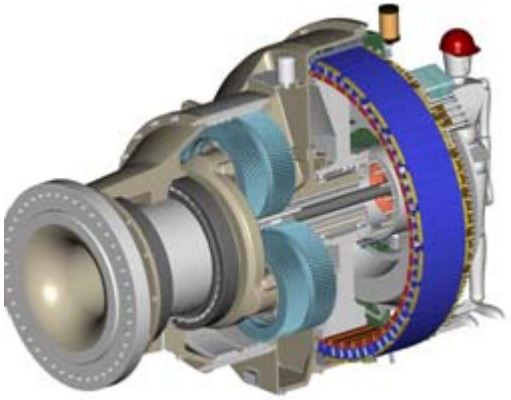
- **Details:**
  - Wind turbine gearbox is critical component that requires frequent maintenance; escalating raw material costs (e.g., steel manufacturing) creates heavy pressures on power density, e.g., more power out of less space.
  - Convoloid gears take advantage of computer-controlled gear manufacturing with potential to increase load-carrying capacity by 25-40% over conventionally designed units.
- **Impact**
  - Increased load carrying capacity would allow use of a smaller gearbox than that for a typical wind turbine which reduces the cost.
- **IP:** patents held by Genesis Partners LP in 63 countries; US: 3 issued, 2 more pending
- **Technology Status**
  - New tooth form analytically shows promise for increasing power density.
  - Laboratory testing to demonstrate effectiveness showing expected successes

GEC medium-speed drive train

Description

- The GEC WindPACT drive train is an integrated main bearing/gearbox/generator unit rated at 1.5 MW.
- Design includes a permanent-magnet generator that operates a 190 rpm.
- Integrated approach results is significantly lower material cost and lower part count.

GE Drive Train

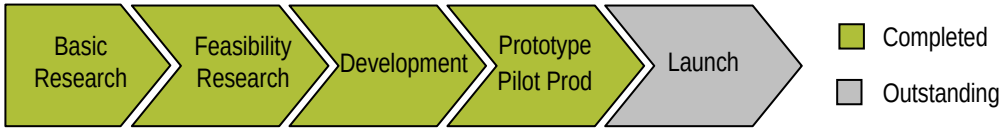


Impact

This cost reduction achieved

- reduction in capital cost (due to size),
- increasing efficiency and
- increasing reliability/reducing repair costs.

Technology Readiness



GEC medium-speed drive train

- **Goal:** to lower the overall cost of wind energy by bringing down drive train costs.
- **Details:** Alternative design study conducted, detailed cost and performance estimates produced to determine relative cost of energy between competing designs. In Phase II, detailed design completed for a single stage drive with a medium speed permanent magnet generator.
- **Impact:** This cost reduction achieved through
  - reduction in capital cost (due to size),
  - increasing efficiency and
  - increasing reliability/reducing repair costs.
- **IP:** Project was paid for by DOE/NREL. Most of the manufacturing drawings are in the public domain, except some generator details that are retained by the generator designer.
- **Technology Status:** This drive train has been tested at NREL's NWTC. During Phase III, now complete, a 1.5 MW prototype drive train has been fabricated per the Phase II detailed design, and has been tested to full-power at the NWTC Dynamometer

Endurance Windpower, Inc.- Endurance 4.25 kW wind turbine

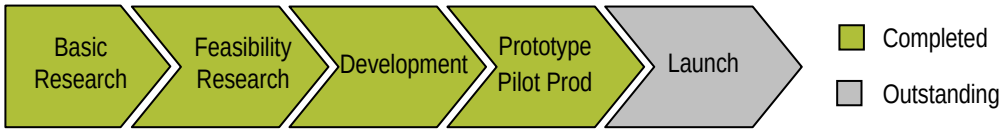
Description

Endurance 4.25 kW turbine provides cost-effective, quiet, reliable wind turbine.

Impact

- induction generator directly connected to grid eliminates power electronics which tend to be unreliable
- off the shelf components manufactured in high volume reduces system cost and improves reliability
- carefully controlled rotor speed quiet under all wind conditions
- Use NREL licensed airfoils designed for residential-scale wind turbines to maximize performance
- Tall tower (108') increases energy capture by raising turbine above trees and buildings (@100' twice available energy in wind compared to 30')

Technology Readiness



Endurance Windpower, Inc.- Endurance 4.25 kW wind turbine

- **Problem:** Residential scale wind turbines tend to be costly, noisy and unreliable, but many homeowners seeking options to produce their own electricity
- **Description:** Endurance 4.25 kW turbine provides cost-effective, quiet, reliable option.
- **Impact:**
  - induction generator directly connected to grid eliminates power electronics which tend to be unreliable
  - off the shelf components manufactured in high volume reduces system cost and improves reliability
  - carefully controlled rotor speed quiet under all wind conditions
  - Use NREL licensed airfoils designed for residential-scale wind turbines to maximize performance
  - Tall tower (108') increases energy capture by raising turbine above trees and buildings (@100' twice available energy in wind compared to 30')
- **IP position**: owned by Windward Engineering (except for off-the-shelf components)
- **Technology Status:**
  - 4 units being beta tested; prototype testing at NWTC since Sep 2006
  - Recently formed new company with new partners and funding through NREL contact

Endurance 4.25 kW turbine

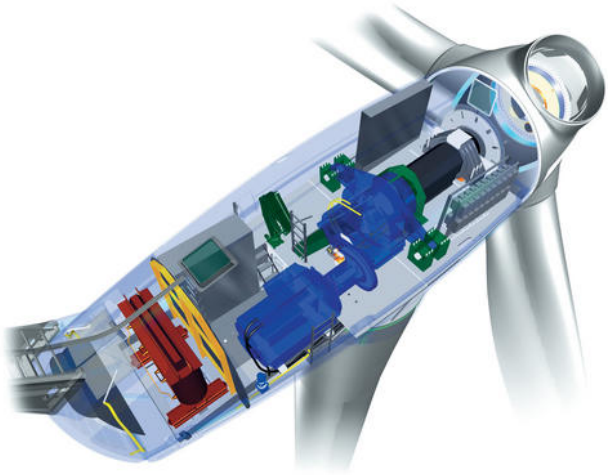
Efficient, variable-speed wind turbine control

Description

Efficient, variable-speed wind turbine control using multilevel matrix converter

Impact

- High efficiency conversion even at low wind speeds
- Scalable for future wind farms requiring medium volta AC



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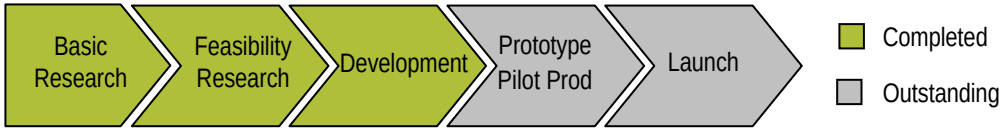

Estimated Time to Market

- 3 to 5 years

Estimated Commercialization Cost

- $5 M

Efficient, Variable-Speed Wind Turbine Control

- **PROBLEM:** Electric generators driven by wind turbines rotate at different speeds, depending on wind conditions, so they produce variable-frequency, variable-voltage, AC electric power. Power converters are used to convert this electric power to fixed-frequency, fixed-voltage AC power to match public utility and similar AC power systems. However, wind turbine power systems spend lots of time operating at light loads or fractions of their rated power capacities, whereas standard, state-of-the-art power converters are designed to operate most efficiently at full-rated power. Also, standard power converters do not work at low voltages. Therefore, when wind turbine-driven generators are operating in low wind, light load conditions, standard power converters are inefficient, or may not even work at all.
- **DESCRIPTION OF INVENTION/TECHNOLOGY:** Space vector modulation is used to control a multilevel matrix converter. This device can then generate multilevel voltage waveforms with a range of magnitudes and frequencies. This allows efficient conversion in a variable-speed generator, even at low speeds.
- **IMPACT:** Potentially very large since this can be used to improve the efficiency of all wind turbines, operating in all wind conditions.
- **IP POSITION**: 1 patent issued, 1 application filed and published.
- **TECHNOLOGY STATUS:** Currently available.
  - **Reduction to practice**: lab prototype built
  - **Special needs to implement**: No special needs.

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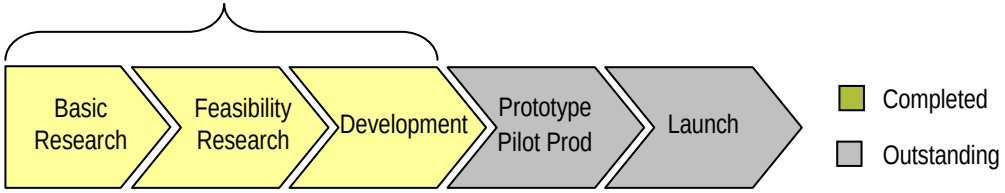
New Territory:

Potential Opportunities for Investment & Projects

Potential project ideas*:

1. More flexible blades for load shedding
2. Innovative rotor design
3. Adaptive controls for active aerodynamic load reduction
4. Blade noise reduction strategies
5. Multi-part blades for low cost shipping and field assembly
6. Improved lightning protection systems for blades
7. High reliability drive trains (direct drive, hybrid drives such as medium speed generators, innovative gear/bearing configurations)
8. Advancements in mid-sized turbine development
9. Low-cost ice detectors for blades
10. Anti-ice and de-icing strategies for wind turbines

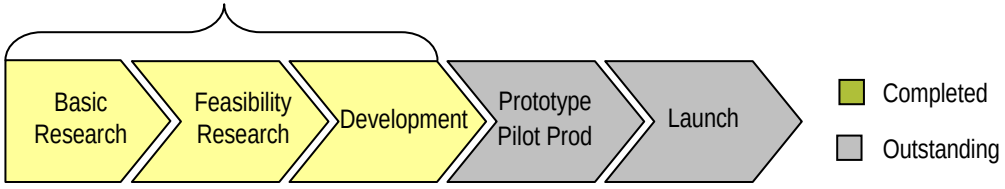


*These ideas and projects are in very early research stages.

New Territory:

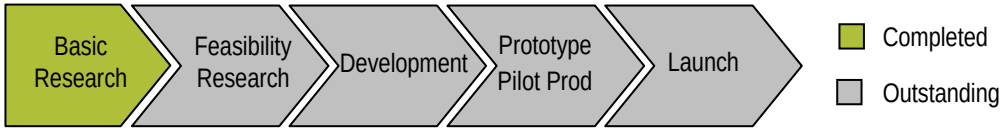
Potential Opportunities for Investment & Projects

11. High reliability generator bearings to accommodate power electronic induced discharge wear
12. High reliability power electronics with switching strategies for reduced bearing discharge wear
13. Wind farm system health management systems that monitor operating conditions and alter high damage rate operation
14. Low cost reliable blade crack growth monitoring systems
15. Durable blade surface coatings for reduced leading edge erosion and improved aerodynamic performance
16. Turbulence inflow sensor technology for feed forward load controls
17. Low cost reliable wind resource instrumentation to replace high met towers such as SODAR and LIDAR
18. Improved accuracy in boundary layer prediction models optimized for 50m – 200m for forecasting



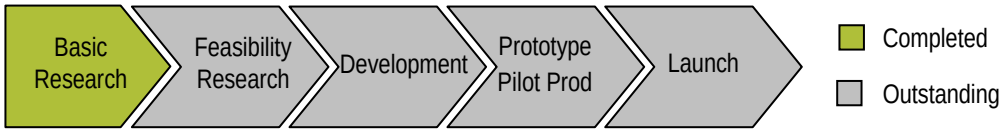
Wind Energy in the Transportation Sector

- Shift from gasoline to electricity to power vehicles
  - Increased demand for electricity implies some additional generation capacity needed and greater utilization
  - Reducing fossil fuel content of transportation sector requires electricity generation from renewable sources like wind
  - Plug-in hybrid electric vehicles could be re-charged overnight with wind and other energy at lower cost to entire system
- Shift from gasoline to hydrogen fuel to power vehicles
  - Production of hydrogen is energy intensive
  - Reducing fossil fuel content of transportation sector requires hydrogen fuel production from renewable sources like wind
  - Electrolyzers that accept varying power input may be improved with power electronics advances



Wind Technology for Dispatchable Generation

- Currently wind farms generate electricity for **energy markets**, usually under Power Purchase Agreements
  - Wind-generated electricity used as it is generated offsetting generation from most costly plants, typically natural gas
  - Integration of up to 20% wind-generated energy is feasible in most electric systems without undue stress to system or large expense
- Coupling wind energy with storage capability creates opportunity for wind technology to participate in **capacity markets**
  - Dispatchable generation required to meet peak loads during peak hours
  - Store wind energy generated during off-peak hours as compressed air, compressed hydrogen, or pumped hydro-power
  - Generate electricity during on-peak hours
    - Provide day-ahead commitment
    - Capacity value contributes to balancing reserve margin calculation
  - Economic studies needed to identify niche where additional value outweighs the additional capital investment for storage



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http://www1.eere.energy.gov/windandhydro/

Appendix

- DOE Wind Program Background

Wind Energy Program Investment Philosophy

The Wind Program's situation is unique – We partner with industry to help them develop and test new wind power ideas. Most DOE-funded Wind IP is owned by companies.

Since the '80s, DOE has used cost-shared partnerships to work with businesses

DOE partnership has encouraged development of high risk technology

- Small businesses entitled to retain intellectual property
- Larger businesses can request advance patent waiver from DOE

Technology transfer process built into the R&D effort

Recently larger companies have entered the wind energy market

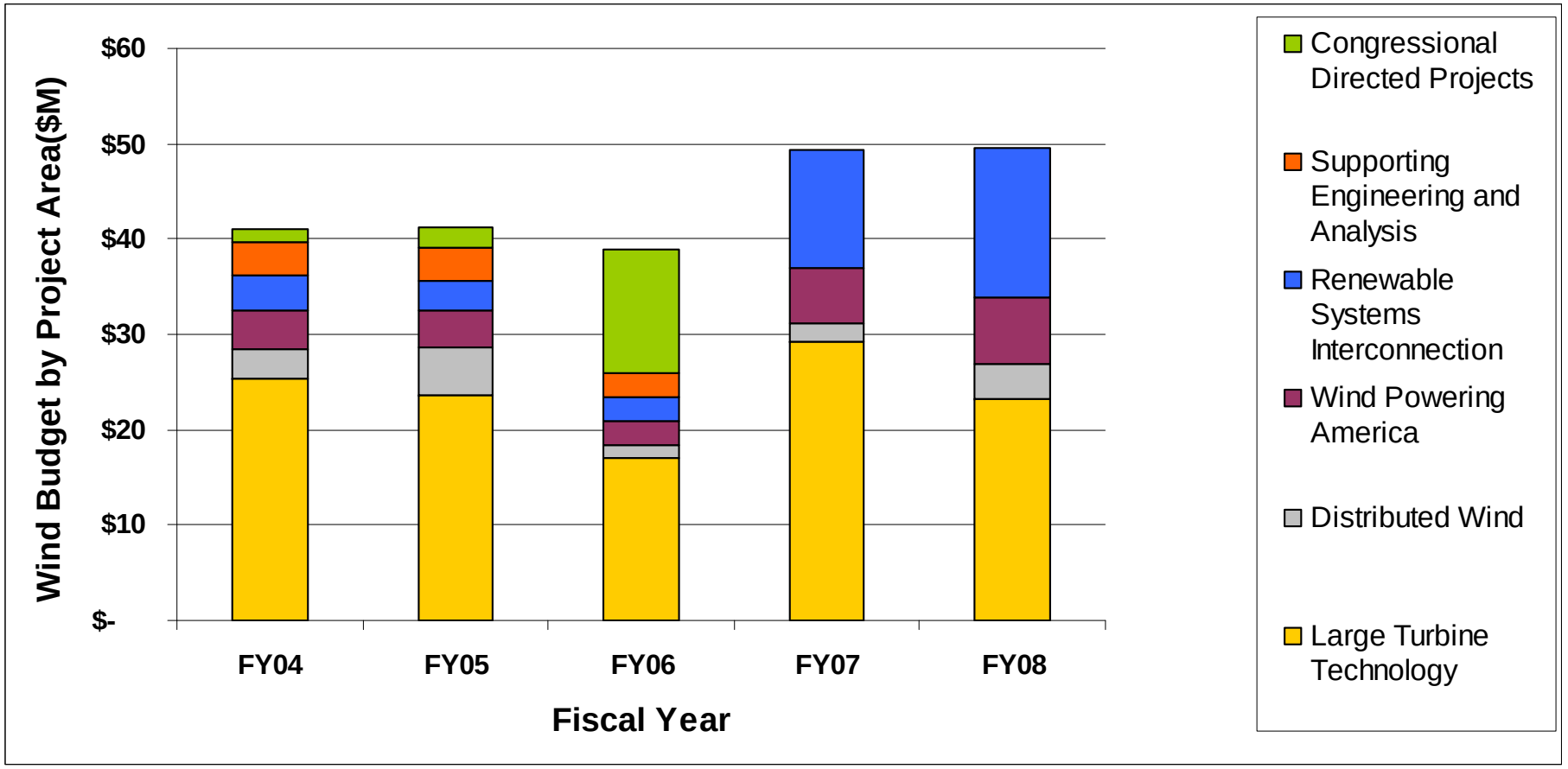
- Increasing use of cooperative agreements wherein IP is negotiated on a case-by-case basis
- DOE Wind has an active program that works with industry to help them develop their ideas. NREL assists industry in providing research and testing
- At both Sandia and NREL, there is innovative work (more basic research) and testing on blades and controls

Result is that today, very little IP is retained by national labs except for innovative testing tools and measurement technologies.

Goals of the Wind Program:

What?	How?	Why?
Today - 2008  - **Over 18,000 MW installed** - Bulk power generation 4-9¢/kWh with no PTC - 10-15¢/kWh at distributed wind site **1% of Electricity Market**		
Large-scale Wind Turbines 2-5 MW	- Advanced Systems to maximize energy capture, reduce stresses and lower costs - Increased reliability - Advanced modeling - Increased power quality	**Tomorrow - 2012** - Mature large land-based market - Increased turbine capacity - Increased performance and reliability
Small & Mid-sized Wind Turbines <100kW & 100kW-1000MW	- Advanced small wind systems - Mid-sized turbine prototypes developed - Activities to expand by five-fold the deployment of distributed wind	- More than 6,000 units installed - Residential and community wind market growth
Systems Integration & Transmission	- Activities to address electric power rules, interconnection impacts, operating strategies, and system planning - Projects to establish new and updated transmission	- Wind serves various markets under fair competition - High efficiency transmission links expanding
Technology Acceptance	- Outreach activities to state-based and Native American organizations - Institution building through utility partnerships - Envirnomental studies - Emerging Applications for Hydrogen and Clean Water	- 30 states will have mature wind energy markets - Custom turbines for multi-markets: Electricity H2 production Water desalination Transportation

Historical Budget



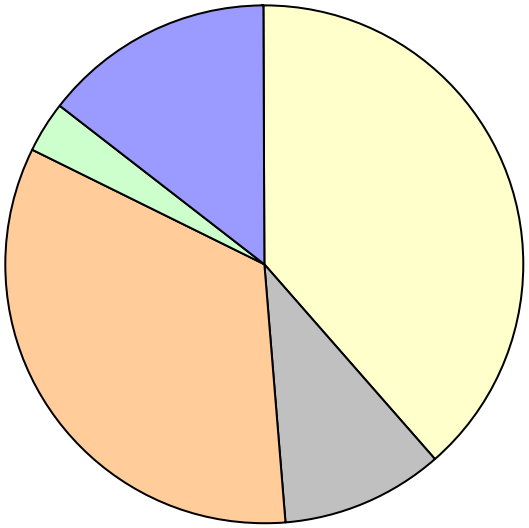
Budget Allocation across Partners

20% DOE Internal Activities & Reserves

Department of Energy conducted product and market analysis and support for deployment activities

3% Other National Labs

Analysis and deployment activities conducted by staff at the INL, ORNL, LBNL and ANL



34% Solicitations & Lab based industry support

Contracts conducted through DOE laboratories to outside entities in addition to specific laboratory based technical and testing support provided directly to industry

39% NREL Based Activities

Research and deployment activities conducted by staff at the National Wind Technology Center including testing, outreach and deployment

10% Sandia Based Activities

Research and deployment activities conducted by staff of Sandia National Laboratory and focuses primarily on manufacturing and wind turbine blade design

Program Objectives:

Program Initiatives

Large Wind Technologies

Wind Powering America

Renewable Systems Interconnection

Distributed Wind

Program Initiatives:

Large Wind Technology

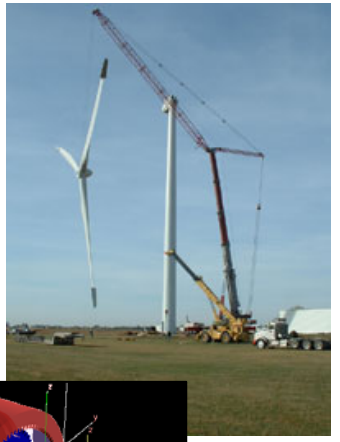
Goal: To support industry partnerships to improve turbine performance and reliability

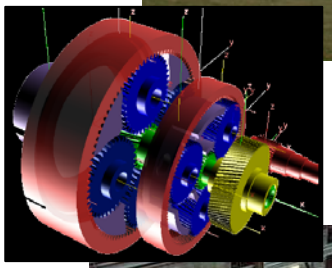
NREL System Reliability-Analysis, Performance & Validation

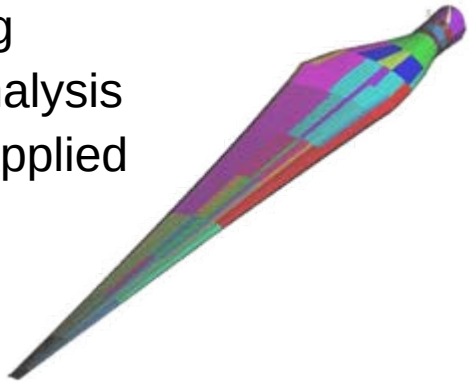
- Field Performance & Reliability Industry Collaboration
- Drive Train & Gearbox Collaborative partnership to address reliability issues
- Blade, Dynamometer & Field Test Support – Partnerships with industry to test wind turbine systems and components
- Collaboration with IEC, IEA & EU

SNL Reliability Database & System Analysis

- System Performance and Blade Testing
- Reliability Collaborative and System Analysis
- Aerodynamic Tools and Applications, Applied Aeroacoustics







Program Initiatives:

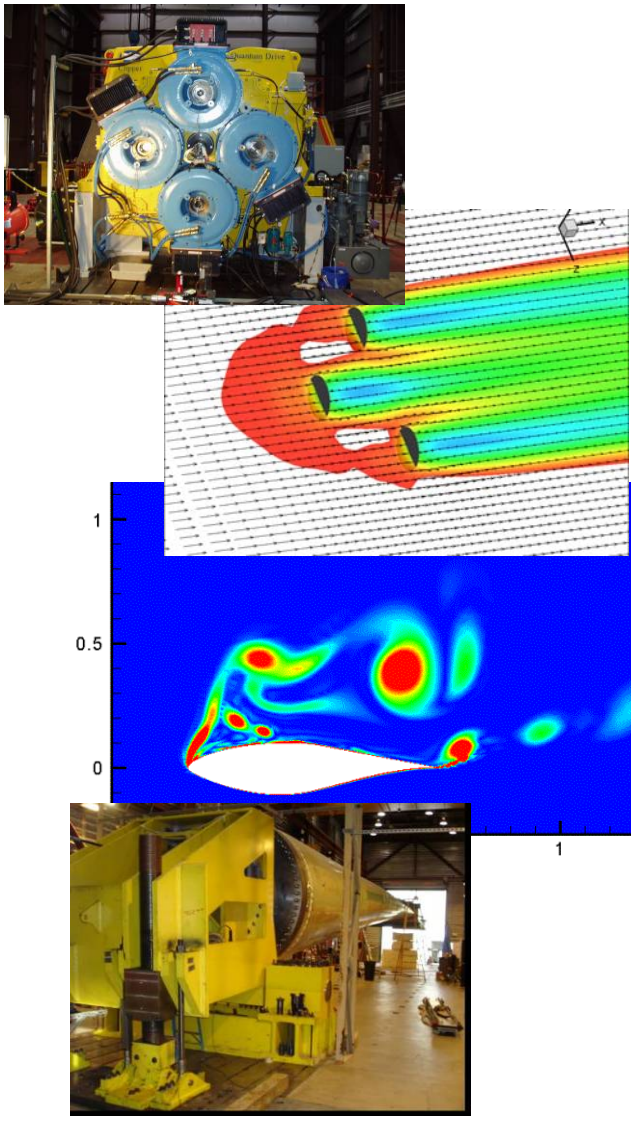
Large Wind Technology

NREL Advanced Concepts, Analysis & Design Tools

- Technology assessment & performance analysis to identify and understanding wind technology potential
- Development of design tools & codes
- Analysis of systems & controls to improve energy capture while reducing turbine loads
- Complex terrain & micro siting to reduce loads and improve power output
- Understanding the inflow characterization of wind resource

SNL Advanced Concepts, Analysis & Design Tools

- Development of design tools & codes
- Array modeling & performance to improve wind farm power output
- Analysis of turbine aeroacoustics to reduce rotor noise



Program Initiatives:

Renewable Systems Interconnection (RSI)

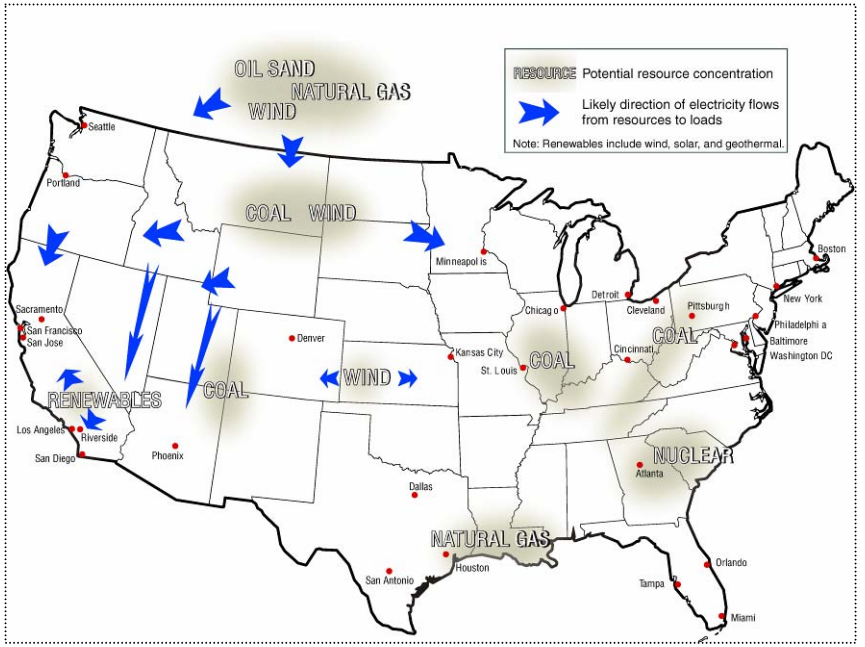
Goal: To enhance critical infrastructure to integrate & diversify the electricity grid

Challenges

- Critical transmission corridors
- Integration of wind into the national energy system
- Fair and equal interconnection policy for wind technologies

Solutions

- Actively supporting the development of major Clean Energy Super Highways
- Collaboration with the DOE Office of Electricity Delivery and Energy Reliability
- Outreach to federal, state and local organizations and utilities
- Research the impact of wind technology on the electricity grid



Transmission will play a key role in the Nation's ability to use its wind resources effectively.

The Program addresses electric power market rules, interconnection impacts, operating strategies, system planning and transmission needed for wind to effectively compete in the Nation's energy markets**.**

Program Initiatives:

Renewable Systems Interconnection

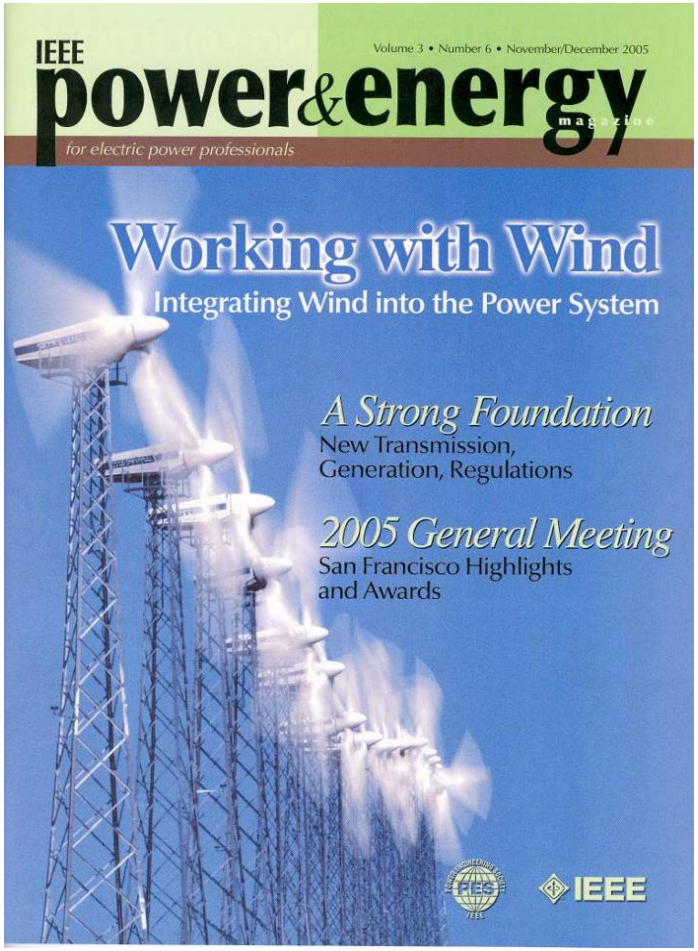
Goal: To enhance critical infrastructure

NREL Grid Integration & Expansion

- Regional meso- model runs – to determine interconnection impacts and allow planning
- Support analysis of new line concepts/Engagement in regional and subregional transmission expansion forums
- Assessment of mitigation measures; creativity vs. storage
- Support development of integration studies (MISO/PJM, WAPA 2606 tribal) which lead into integration efforts (PNM, SMUD, CO and SPP Xcel)
- Hydro integration research and studies

NREL Communication, Policy & Legislative Support

- Support Cooperation between grid operators, stakeholders
- Utility Wind Integration Group – Over 100 stakeholders
- Two IEEE PES wind issues, Nov/Dec 05 & 07
- Expanded stakeholder forum interaction and expert outreach
- Expanded market analysis and reporting
- International information exchange (IEA annexes)



Program Initiatives:

Wind Powering America

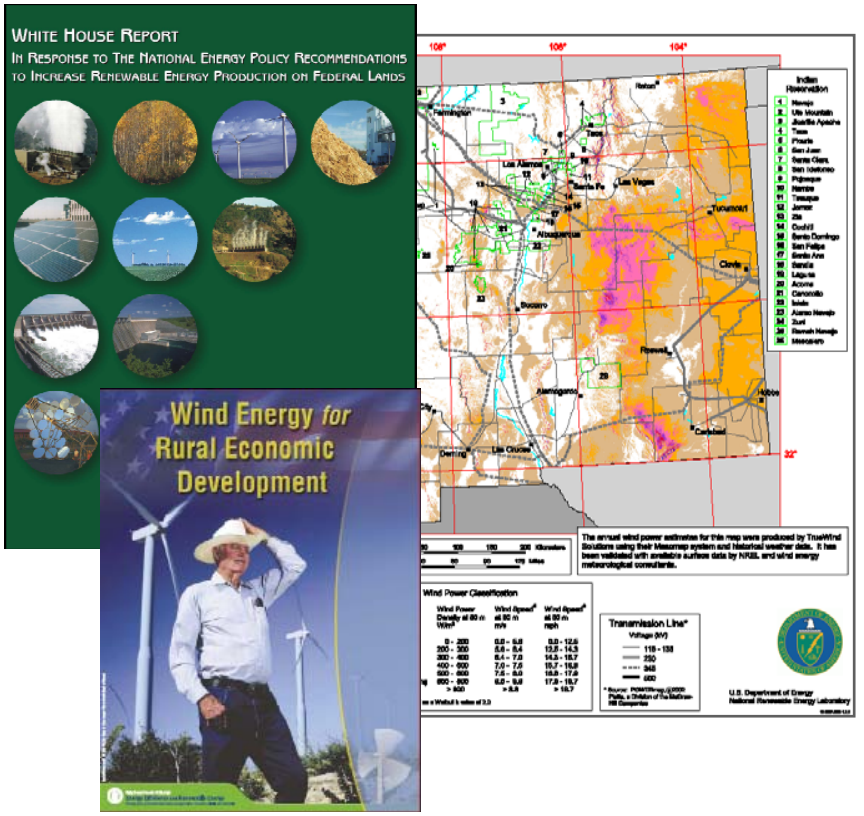
Goal: To reduce barriers to project development accelerates deployment of wind energy

Challenges

- Enhance Public Acceptance
- Promote Supportive Public Policies
- Engage Key Stakeholders
- Address Wind System Siting Issues
- Facilitate Environmental Assessment

Solutions

- Wind Powering America Program (www.windpoweringamerica.gov)
- Interagency Collaboratives
- Targeted Outreach (tribal, utility)
- Facilitation of stakeholder dialog (environmental and siting issues)
- Federal Collaboration – Radar, F&W



The Program builds state-local wind stakeholder networks and engages key decision-makers to promote wind development.

Program Initiative:

Distributed Wind

Goal: To provide reliable, secure energy sources for homes and businesses

Challenges

- Reliable residential turbine technology
- Availability of mid-sized turbine technology (10 to 600 kW) for the farm and industrial sector
- Support for the community wind market

Solutions

- Testing of residential wind turbines
- Technology deployment partnerships with industry
- Applied research: aerodynamics, aero-acoustics, power electronics
- Domestic and international standards development

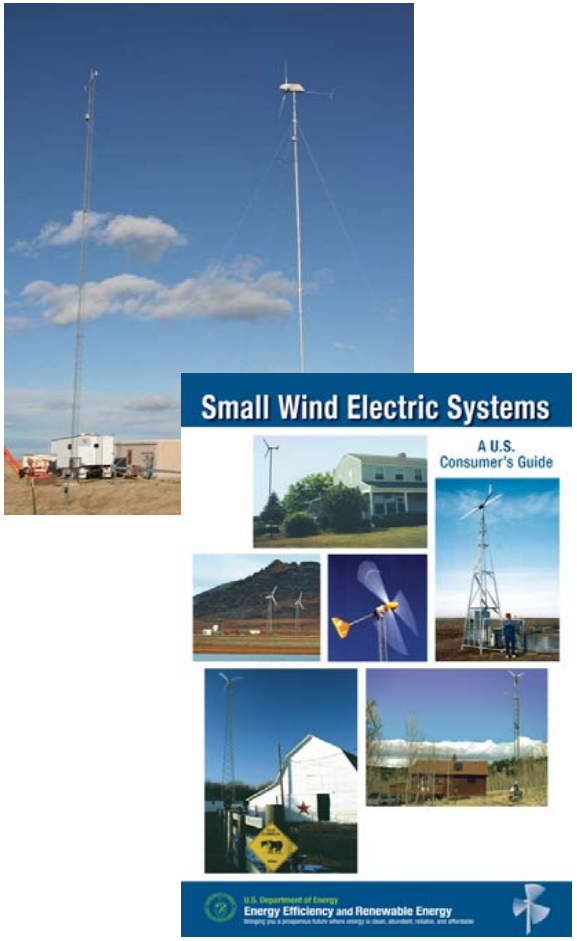
Distributed wind supports public acceptance of wind and enables communities and individuals to play an active role in supporting the Nation's energy future

Program Initiative:
Distributed Wind

Goal: To provide reliable, secure energy sources for homes and businesses

Advanced Distributed Wind Turbines:

- Field test 6 to 8 new small turbines to IEC Standards in support of new turbine commercial deployment
- Provide analysis and testing support to manufacturers to developing small turbines for US grid-connect market (100 kW and less)
- Work with manufacturers to develop advanced components and systems to improve reliability and performance for turbines
- Reduce market barriers for distributed wind systems by analyzing state and local issues such as: zoning, interconnection, understanding of wind resource

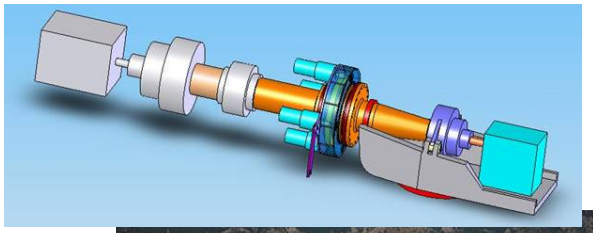


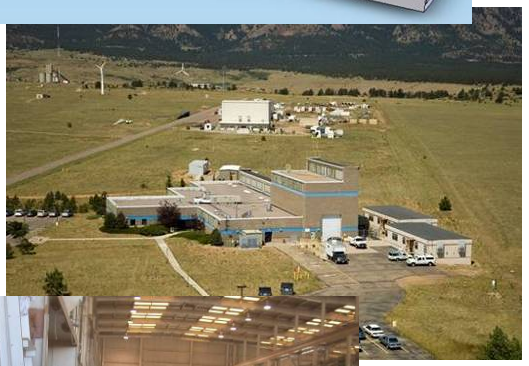
DOE Industry partnership

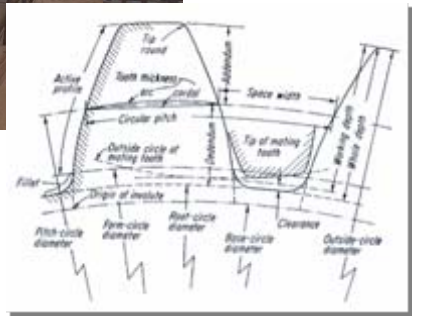
Goal: to support wind technology through improved reliability and performance

NREL/SNL Industry Development & Deployment Support

- Technology development partnerships – Working with industry to develop the next generation of wind technology; Technology Development CRADA's
- Design review and analysis support - Technical support, Parallel research &Review and oversight
- Mitigating deployment barriers – Technology solutions to deployment problems – Noise, grid integration
- WindPACT II - Examine spectrum of current and projected wind technologies to identify/exploit high impact R & D activities for attaining the goal







NREL Capital Equipment/Blade Test Facility Collaborative

- NWTC Utility Scale Wind Turbine Testing Partnership – CRADA Solicitation
- DWT Independent Testing site infrastructure upgrades

Commercialization Opportunities:

Overview of DOE organizations working on Wind Power

Organization	Role of Contributing Organization
NREL	◦ Electrical systems; RE grid interconnect modeling; wind resource characterization ◦ Design tools and code development; integrated control systems development 20% ◦ Wind Scenario Analysis ◦ Technology design review & analysis; turbine reliability and performance ◦ Component and integrated system testing (independent, accredited services) ◦ Technology acceptance, education and outreach ◦ Environmental and wildlife research ◦ Economic, policy, and market analyses; technology characterization
SNL	◦ Advanced blade designs, aerodynamic controls, and structural analysis codes ◦ Improved blade materials and manufacturing techniques; material fatigue analysis ◦ Reliability database; system analysis; non-destructive testing techniques ◦ Wind-radar R&D and mitigation; education and outreach support
GO	◦ Competitive solicitations for industry and universities ◦ Congressionally directed projects (not part of direct Wind Program Budget)
INL	◦ Wind-radar R&D and mitigation; wind siting support
LBNL	◦ Power markets and policy analysis; wind power installation, cost and performance
ORNL	◦ Grid study support; ancillary services analysis; wind/hydro integration
ANL	◦ Technical assistance to evaluate and demonstrate viability of distributed wind energy at Forest City, Hawaii military housing project sites