WIND ENERGY PROGRAM

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VENTURE CAPITAL TECHNOLOGY SHOWCASE
AUG 21 AND 22, 2007

Wind Energy Program Investment Philosophy

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

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

→ **Most DOE-funded Wind IP is owned by companies**

The Wind Program supports both Utility- and Distributed-Scale Turbine Development Projects

- There are many pathways to R&D partnership with the DOE:

Typical values	Utility Scale	Distributed Scale
Concept design studies	**$200K** **6-12 months**	**$100K** **9-12 months**
Component development	**$2M** **2-3 years**	**$0.5 – $1.5M** **2-3 years**
Prototype development	**$8M** **3-4 years**	**$1.5M** **2-3 years**

- Under Federal procurement law, all IP is retained by the small business

The Wind Program supports both Utility- and Distributed-Scale Turbine Development Projects

DOE worked with Clipper Windpower to develop the Liberty 2.5 MW prototype

Multiple generator technology tested in NREL dynamometer

Light-weight nacelle that can be lifted with same size crane as 1.5 MW turbine

Clipper listed on the London Stock Exchange in 2005

The Wind Program supports both Utility- and Distributed-Scale Turbine Development Projects

DOE worked with Southwest Windpower to develop the Skystream 1.8 kW Prototype

Designed especially for residential grid connection with integrated controls and inverter

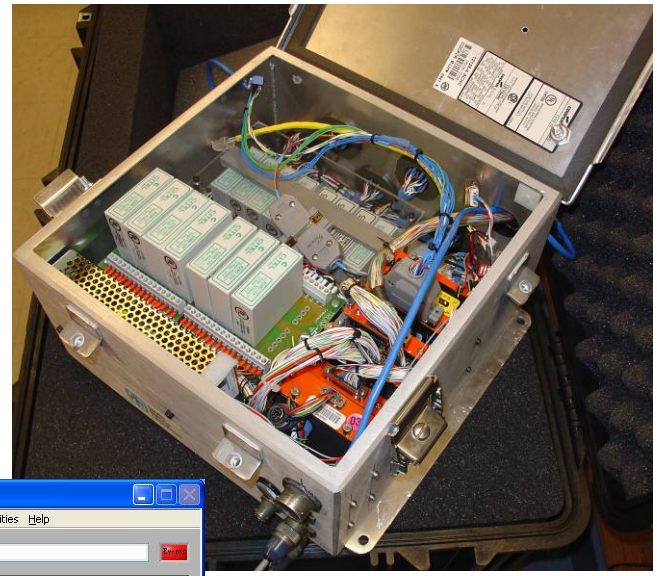
Low-noise, swept fiberglass blades using NREL airfoils

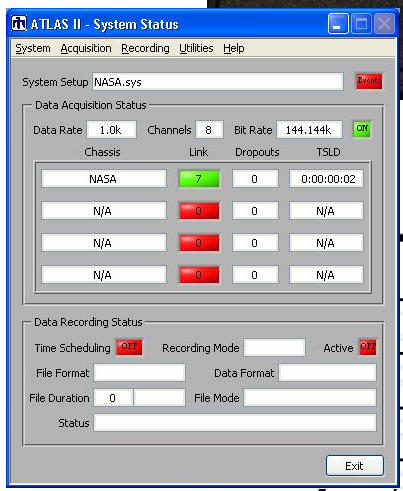
Southwest received VC investment in 2006 and 2007

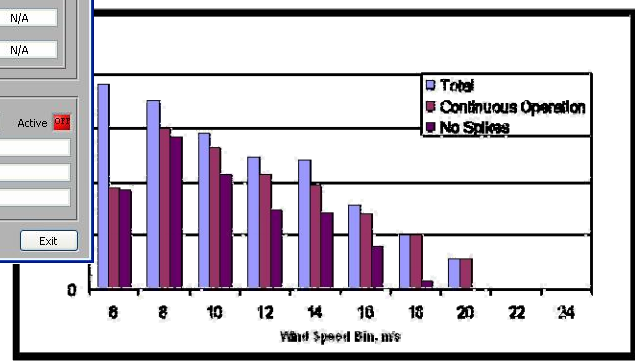
Wind Turbine Continuous Data Acquisition System – ATLAS II

(Accurate Time-Linked data Acquisition System)

- **Problem:** Current wind turbines require long-term data to analyze performance and reliability of current systems. The ATLAS-II system provides a means to collect data that will lead to more reliable turbine technology and lower O&M costs over a turbine's lifetime.
- **Description:** Environmentally protected, military grade data acquisition system. Flexible configuration provides reliable continuous data acquisition (24/7/365), with error-proof design and installation.
- **Impact:** Continuous long-term data on wind farm performance can be turned into increased performance and less cost through turbine evaluation and certification, technology improvements, and site characterization.
- **IP position:** Currently has no legal protection
- **Status:** Technology has been demonstrated in both research and collaborative experiments with industry.
  - **Invention:** Unique software for data acquisition and post-processing
  - **Availability:** Currently in use
  - **Improvements:** Development for volume manufacturability. Several optimizations can be implemented.
  - **Needs:** Funding for optimization







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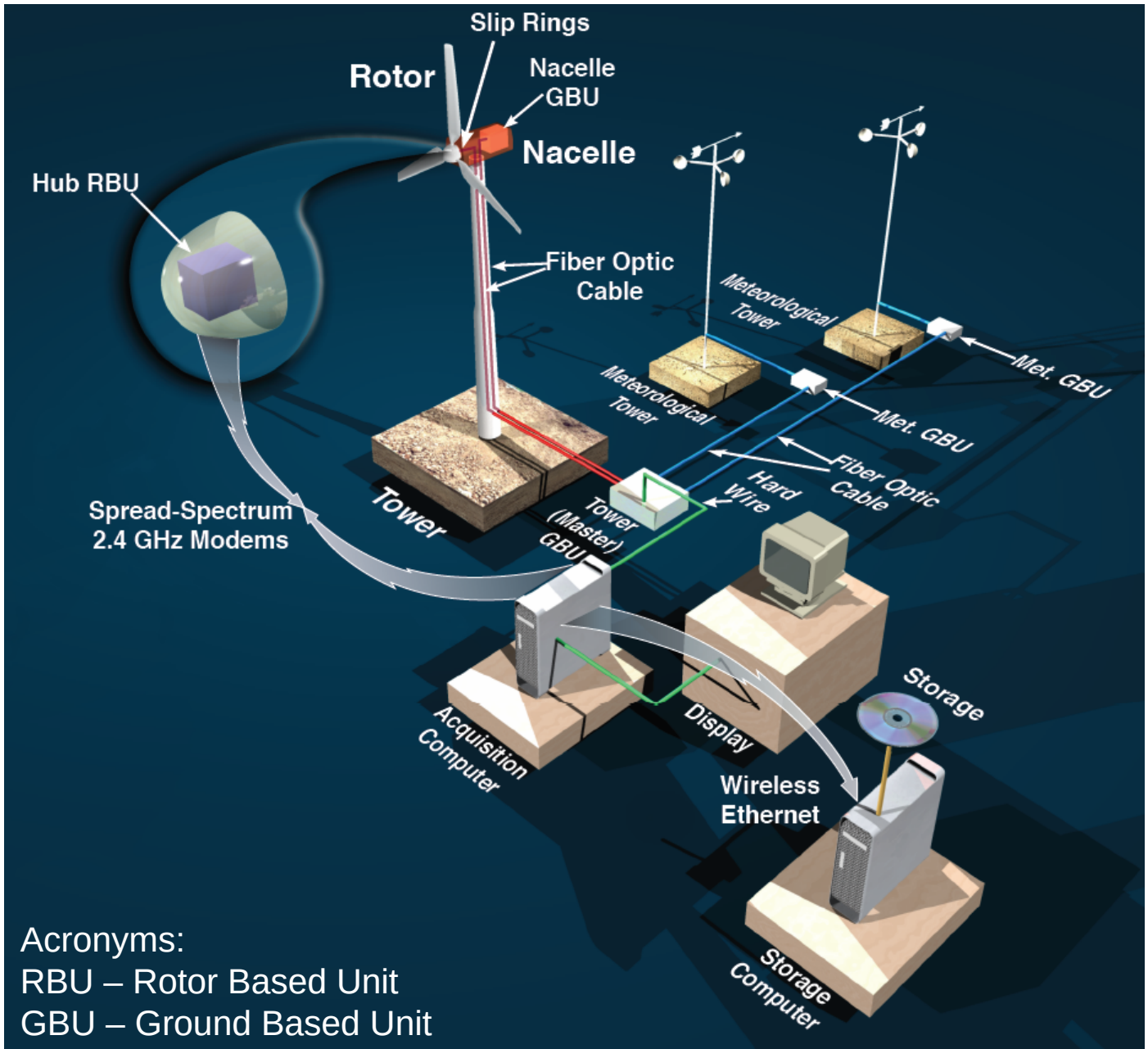
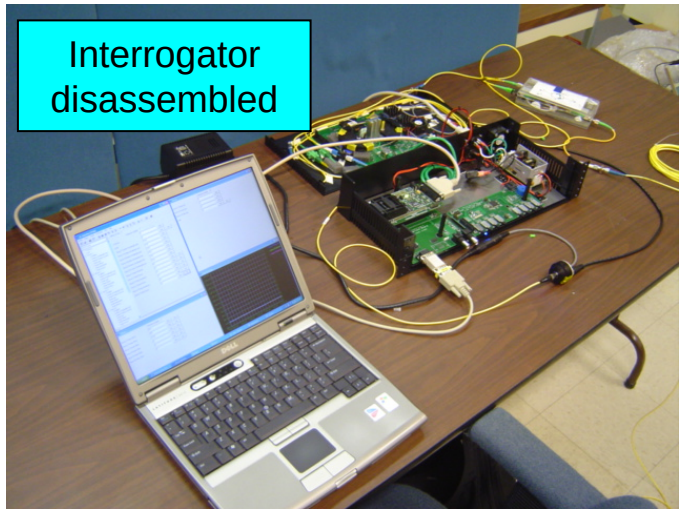
ATLAS II – Typical Field Deployment Schematic

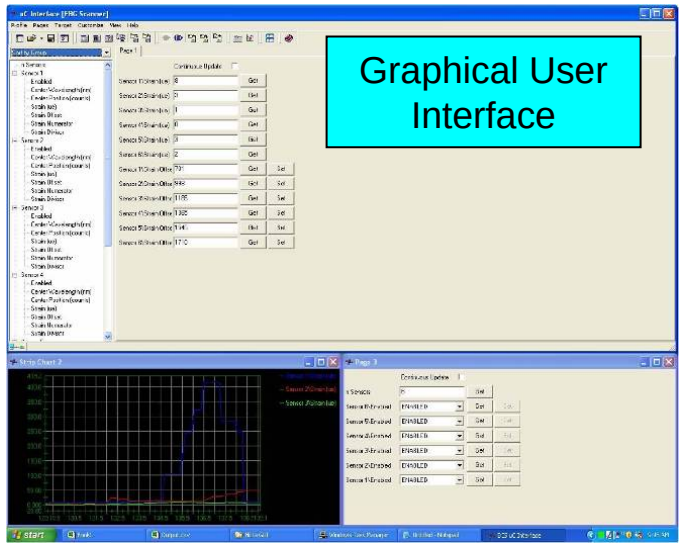


Acronyms:
RBU – Rotor Based Unit
GBU – Ground Based Unit

Low-Cost Interrogation System for Fiber Optic Based Sensors

- **Problem:** The capital cost of increasingly larger wind turbines demands increased monitoring of the turbine structure. Fiber optic based sensors have significant advantages in wind turbine blades, and measure critical structural loads on a wind turbine. A fiber optic interrogator is a critical component in fiber optic based sensing systems, yet current fiber optic interrogation devices cost between $30k and $40k.
- **Description:** The interrogator converts the optical signals to electrical signals that can be used by the wind turbine control system to reduce loads and/or increase energy capture. This system is designed specifically for wind turbines, rather than a generic interrogator application.
- **Impact:** Low-cost solution (~$4k) using COTS (commercial off the shelf) subcomponents.
- **IP position:** Currently has no legal protection
- **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.





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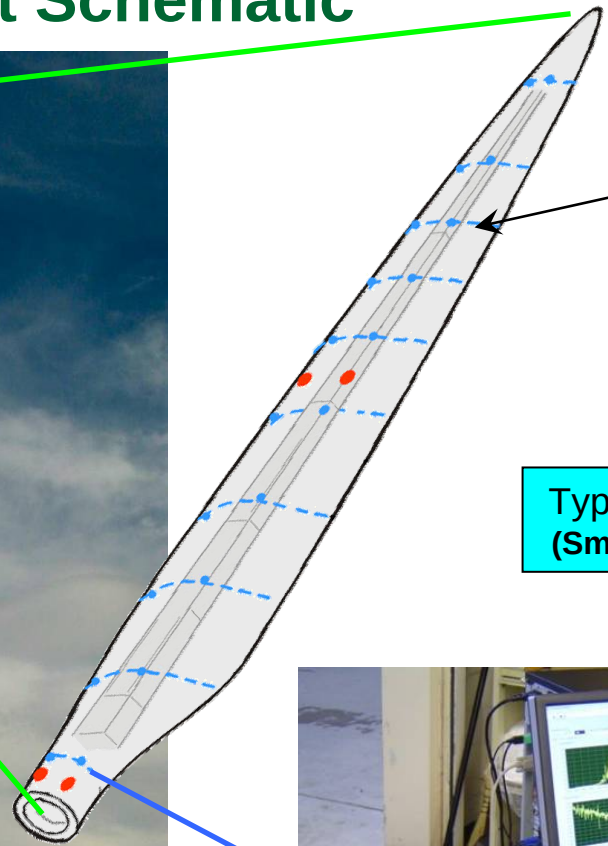
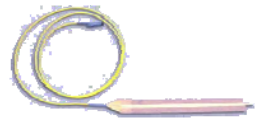
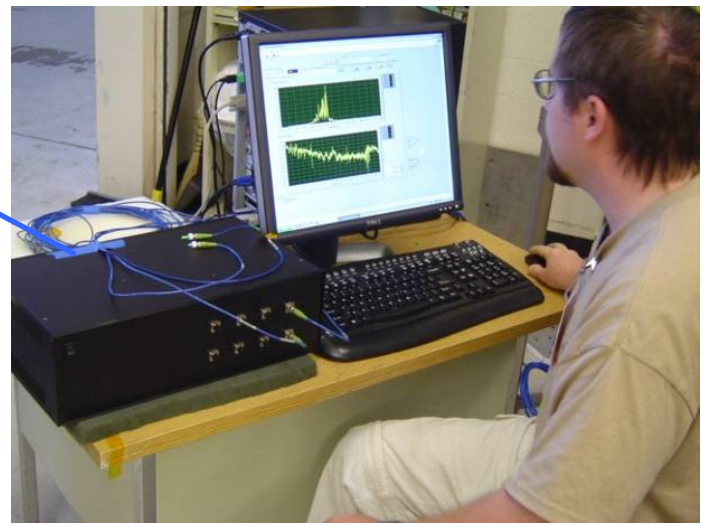
Typical Field Deployment Schematic



fiber optic cable and integrated sensors

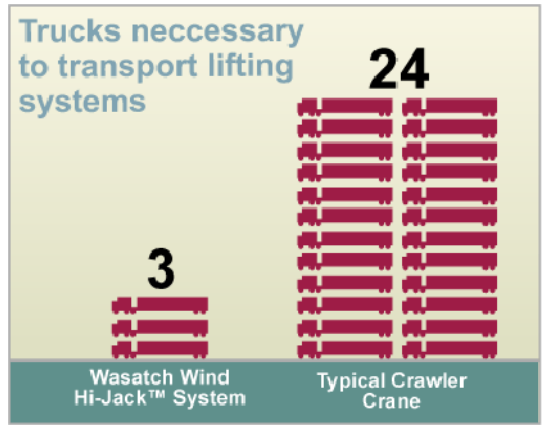


Typical fiber optic sensor
(Smart Fibres SmartTape®)



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

- **Problem:** Current industry-standard tubular towers:
  - Are very expensive due to weight: costs of raw material, transportation, foundation, and erection
  - Require ultra-large track cranes which are high-cost and leave large environmental footprints (roads), eliminating many otherwise attractive remote wind projects
  - Have high manufacturing capital expenditures, cited as a key problem by industry manufacturers to scaling turbine capacity
  - Don't scale cost-effectively above 80 meters tall, and thus don't capture better wind resource, resulting in lower power outputs and overall poorer economics
- **Description:** Damped, space-frame tower with Hi-Jack™ lifting system for 1.0 MW-2.5 MW wind turbines enables installation on rougher terrain, small wind farms, taller towers, and offshore.
- **Impact:**
  - Incorporates damping as key technology enabler, which is advantageous in offshore applications
  - 40% lighter, transports on standard flatbed trucks
  - Integrated Hi-Jack™ system is cost-effective and eliminates requirement for large track cranes
  - Reduces tower manufacturing capital expense by 65%
  - Scales cost-effectively to 100 meters tall



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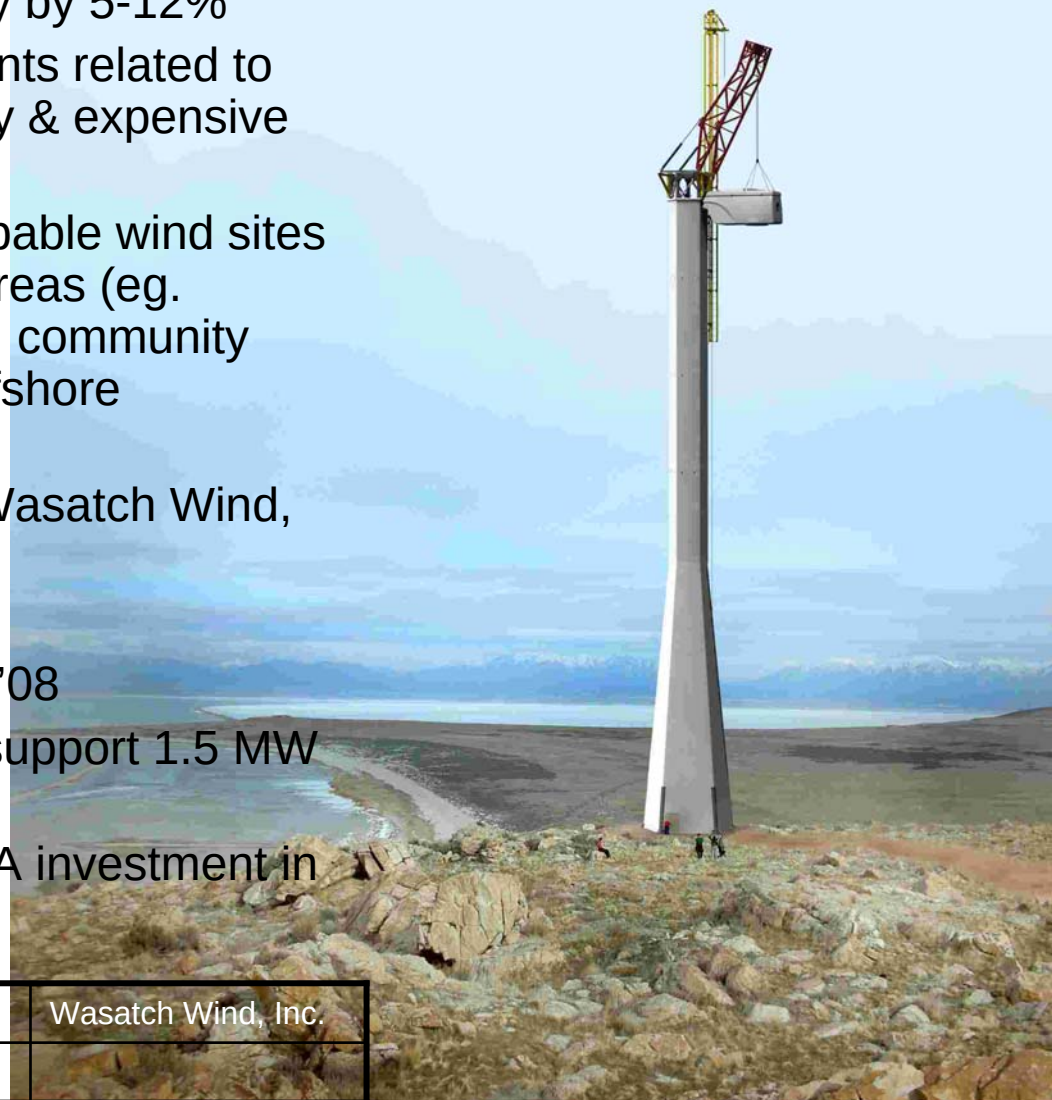
Wasatch Wind Space-Frame Tower and Hi-Jack™ lifting system

- **Impact:**
  - Reduces wind cost-of-energy by 5-12%
  - Removes industry choke-points related to tower manufacturing capacity & expensive crawler crane availability
  - Enables currently un-developable wind sites in remote, difficult to reach areas (eg. ridgelines, islands & Alaska), community (small) wind projects, and offshore installations.
- **IP position:** All IP belongs to Wasatch Wind, Inc.
- **Status:**
  - Production slated for Spring ’08
  - Towers ordered to date will support 1.5 MW turbines
  - DFJ Element/ PG&E Series A investment in March ‘07



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Genesis Partners LP – Convoloid gears

- **Problem:** A wind turbine's gearbox is a critical component that requires frequent maintenance; standard involute gears use the same design first used in the 18th Century.
- **Description:** Revolutionary convoloid gears that take advantage of computer-controlled precision milling.
- **Impact:**
  - Potential to increase load-carrying capacity of traditional gearbox designs by 25-40% over similar-sized units with traditional gearing.
  - Increased load carrying capacity would allow use of a smaller gearbox than that for a typical wind turbine which reduces the cost.
- **IP position:** Patents held in 63 countries; US: 3 issued, 1 pending.
- **Status:**
  - New tooth form analytically shows promise for increasing power density.
  - Laboratory testing to demonstrate effectiveness nearly completed.

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Distributed Energy Systems – NW100B

- **Problem:** Lack of availability of turbines in the 50-500 kW range. Large agricultural entities, schools, manufacturing facilities have very limited product selection.
- **Description:** Value-engineered 100 kW turbine based on a design for withstanding harsh climates.
- **Impact:**
  - Re-engineered and proven design built for arctic climates to be cost-competitive throughout the US.
  - Larger rotor increases energy capture.
  - Low-speed direct drive generator minimizes moving parts, reducing servicing requirements
  - Power electronics integrated into nacelle to provide factory assembly and testing of the entire drive-train, simplifying installation
  - Remote monitoring capability reduces down-time and minimizes unnecessary service calls.
- **IP position:** Owned by Distributed Energy Systems.
- **Status:**
  - Prototype testing conducted at NREL's National Wind Technology Center in April 07
  - Near-term market identified for the NW100B in New York, Vermont and Massachusetts

NW100B 100-kW wind turbine

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Endurance Wind Power S-250 Wind Turbine

- **Problem:** Previous generation residential-scale wind turbines tended to be costly, noisy and unreliable, with few products sized to offset a modern home's electrical consumption.
- **Description:** Endurance 4.25 kW turbine provides a cost-effective, quiet, reliable option for the on-grid residential, small business and government markets.
- **Impact:**
  - Induction generator directly connects to grid, eliminating power electronics which tend to be costly & unreliable
  - Off-the-shelf components manufactured in high volume reduce system cost and improve reliability
  - Constant rotor speed results in quiet operation under all wind conditions.
  - Use of NREL-licensed airfoils designed specifically for stall controlled wind turbines maximizes performance and safety.
  - Tall tower (105') increases energy capture by raising turbine above trees and buildings (wind at 105' holds almost twice the available energy of winds at 30')
- **IP position:** Owned by Endurance Wind Power, Inc.
- **Status:**
  - 5 units currently being beta tested; IEC testing at NWTC since November 2006.
  - 1.5 years of nearly continuous operation on original prototype (class 4+ wind resource); over 4.25 years total run time on all beta units.
  - Currently in small production runs with new manufacturing facility opening in Bellingham, WA in September 2007.

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Wind Technology for Dispatchable Generation

- Currently wind farms generate electricity for **energy markets**, usually under Power Purchase Agreements
  - Wind-generated electricity is used as it is generated, offsetting generation from balancing plants which are typically natural gas-fired.
  - Integration of up to 20% wind-generated energy is feasible in most electric systems without large expense or undue stress to the system

- 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
  - Wind energy generated during off-peak hours is stored as compressed air, compressed hydrogen, or pumped hydro-power
  - Electricity is then generated during on-peak hours
    - Provide day-ahead commitment
    - Capacity contributes to balancing reserve margin calculation
  - Economic studies needed to identify niche where additional value outweighs the additional capital investment for storage.