

Technology Trends - 2012

D. Todd Griffith

**Wind and Water Power
Technologies**

Sandia National Laboratories

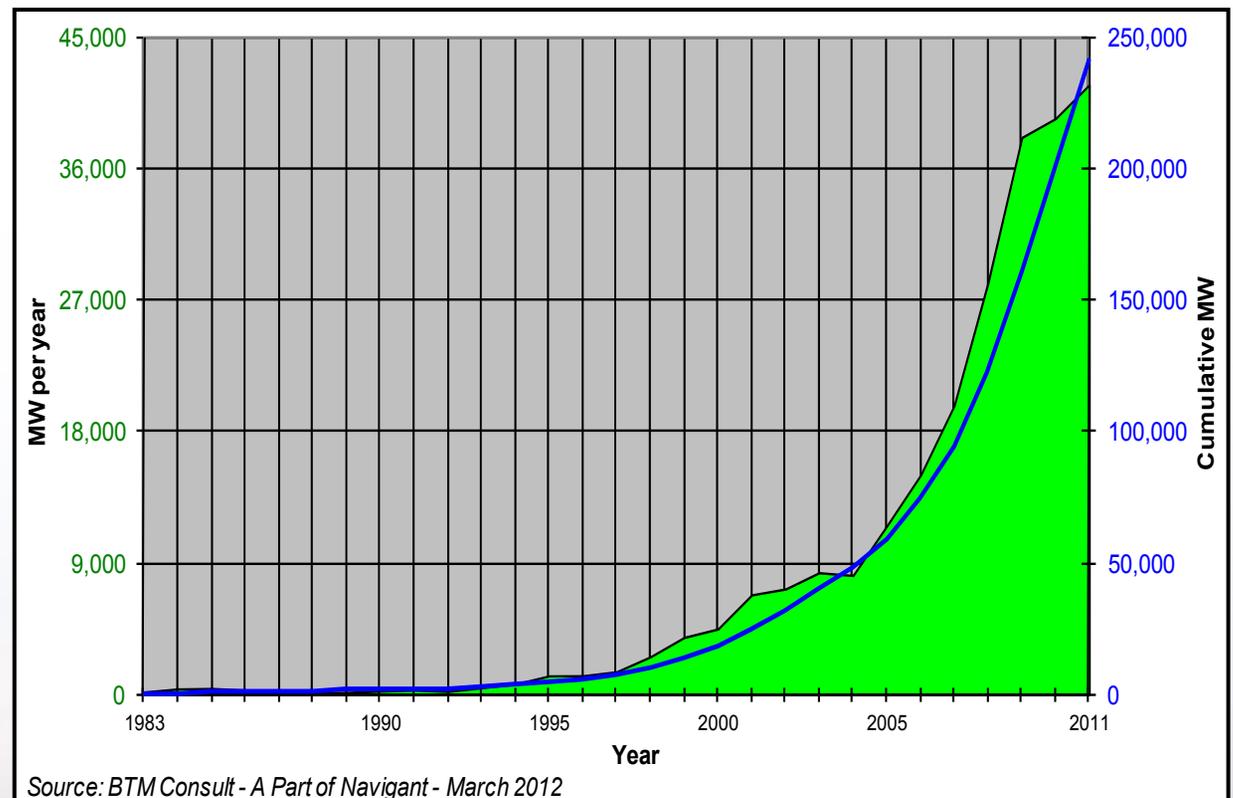
**Fifth Sandia Blade Workshop
May 30, 2012**

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World and U.S. Turbine Trends

- Continued increase in installed wind capacity both world wide and in the U.S.
- China – largest cumulative capacity
- U.S. second in cumulative



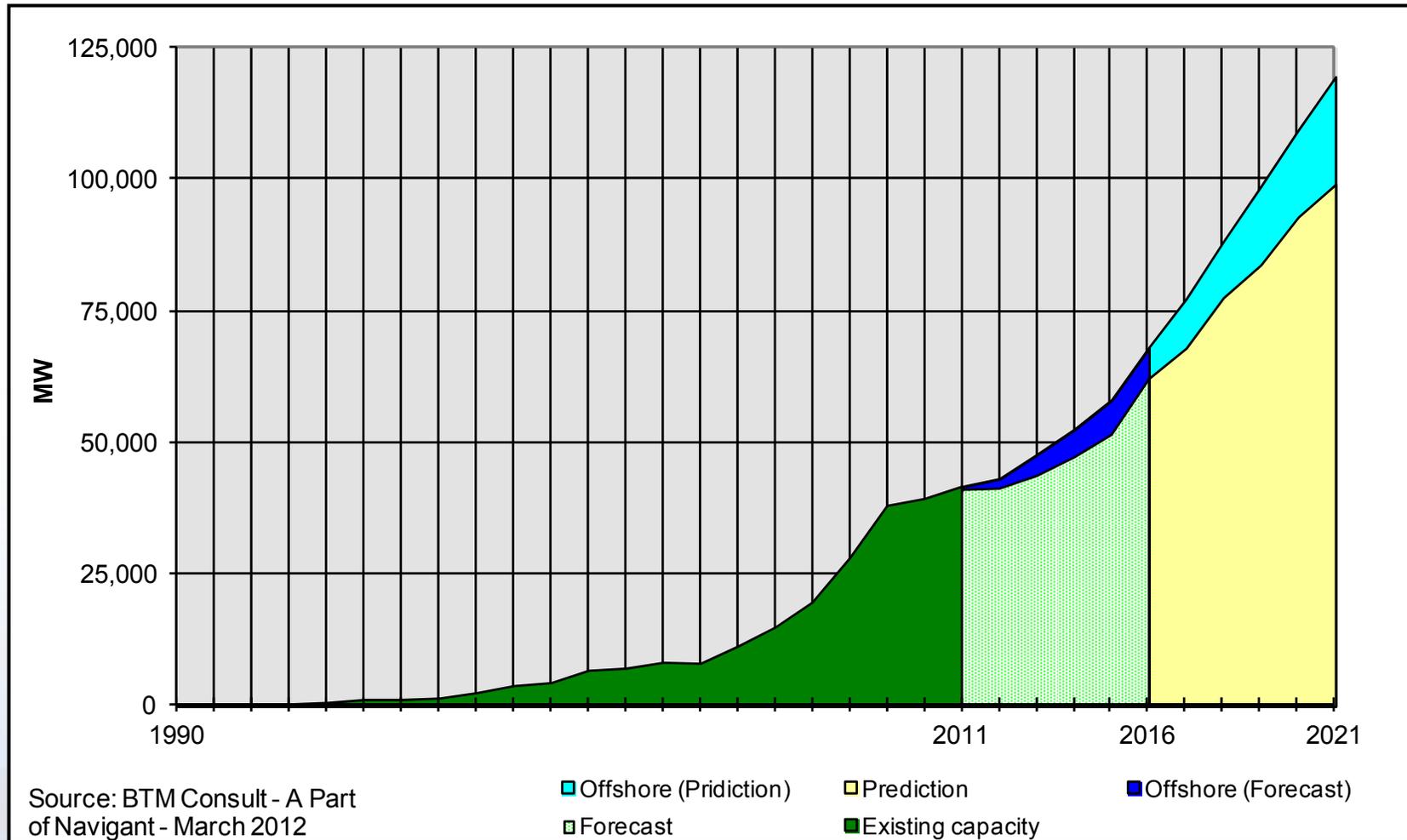
~240 GW Installed Worldwide - Total
~47 GW Installed in U.S. - Total

Large Push to Increase Renewables

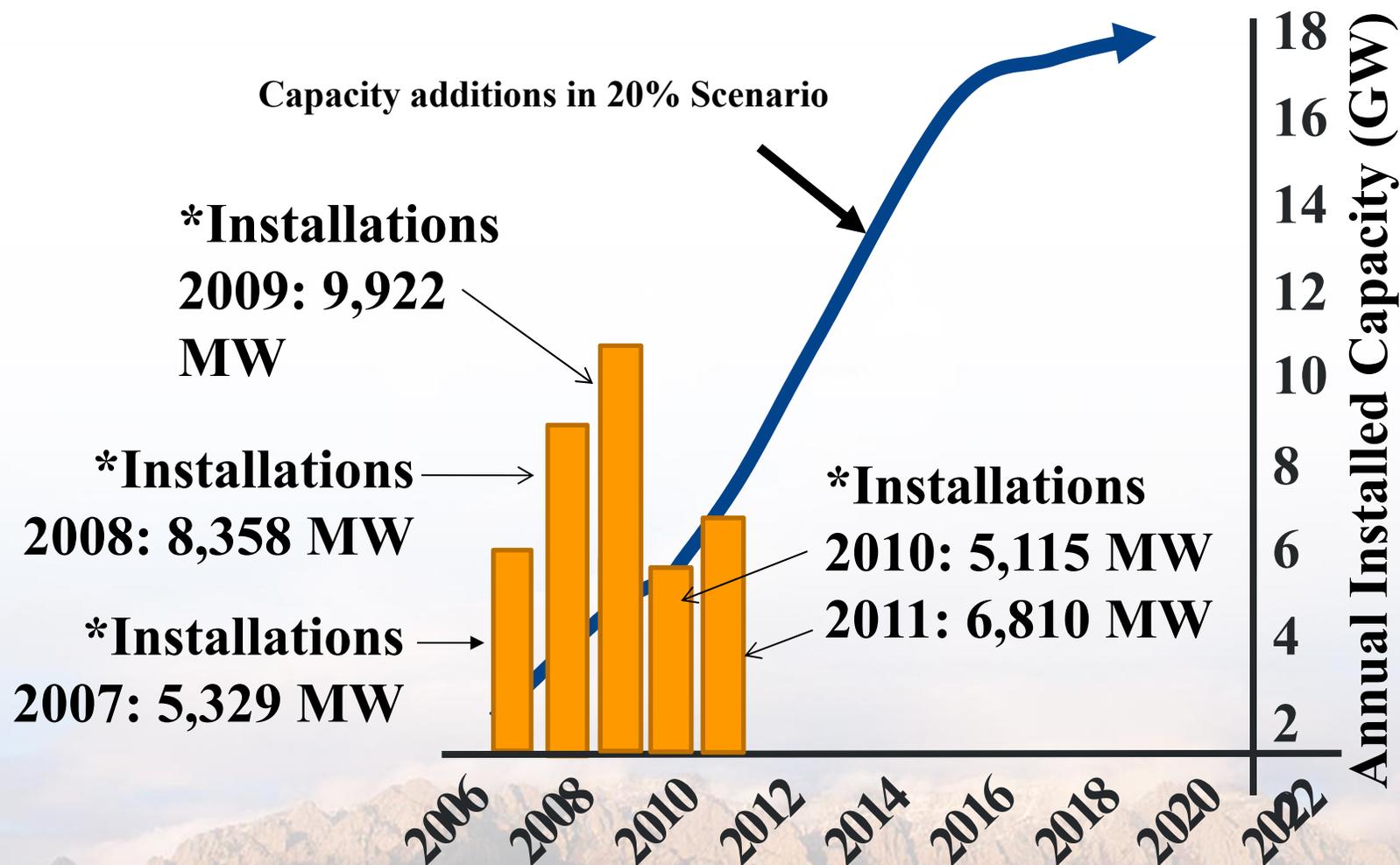
- **U.S. - DOE has proposed the 20% by 2030 scenario**
- **Europe – EU has proposed a 20% renewables by 2020 plan**
- **China committing to much more wind-produced power**
 - Four of 10 top suppliers of utility-grade turbines in 2011 are Chinese
- **UK – significant offshore wind installations**
 - World leader in offshore wind with 2.1 GW installed end of 2011 (53% total world offshore capacity)



Annual Global Wind Power Development



DOE 20% by 2030 Scenario: Installed Capacity – Predicted and Actual



Source*: AWEA, 2010

■ Annual GW Installed



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Wind Industry Trends & Challenges

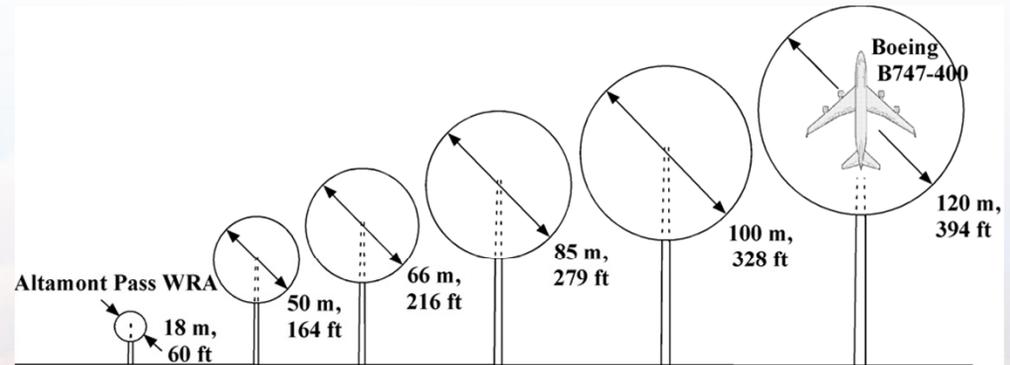
■ Costs (traditional)

- System ~ \$3/lb
- Blades ~ \$6/lb

- High-end Military ~ \$1000/lb
- Aerospace Industry ~ \$100/lb

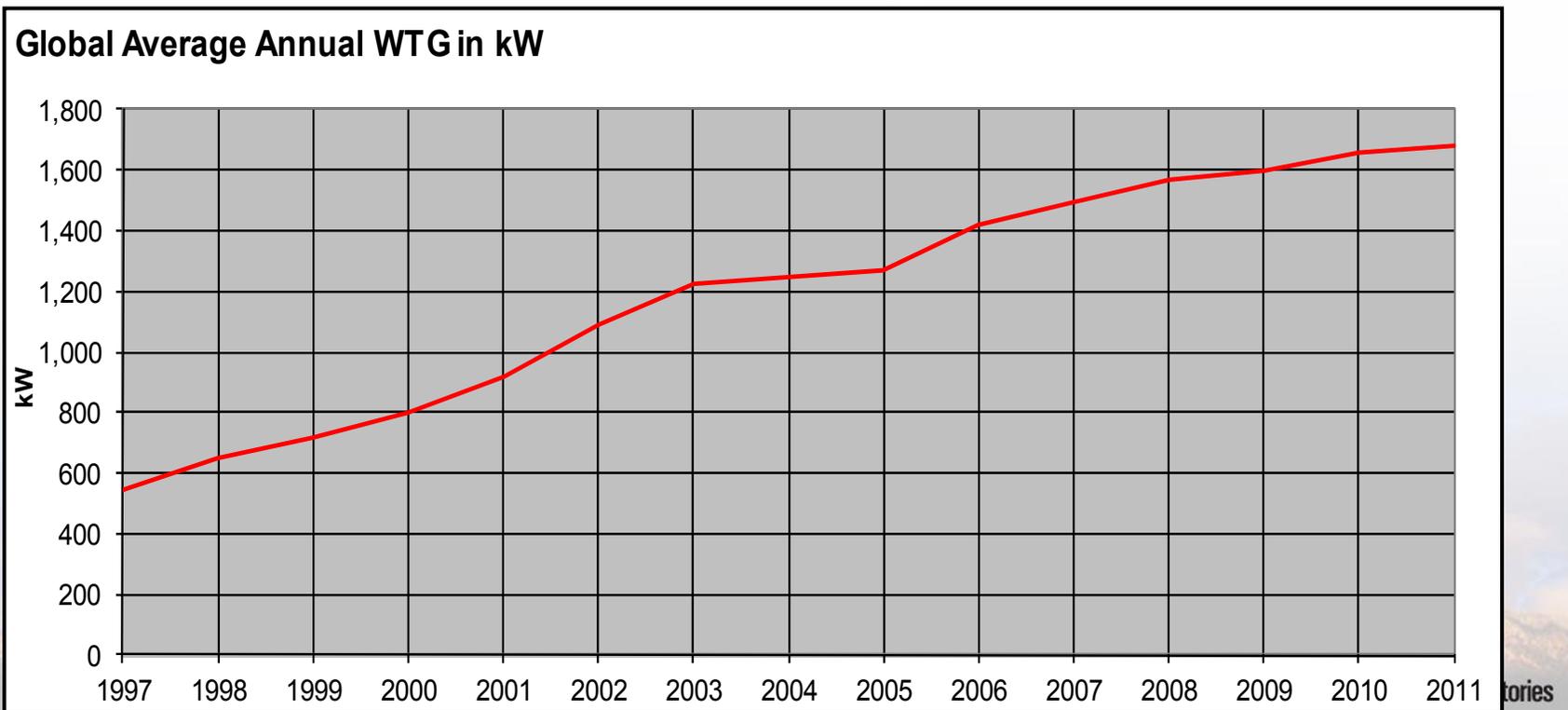
■ Size

- 1.5-5.0 MW
- Towers: 65-100 meters
- Blades: 34-60 meters
- Weight: 150-500 tons

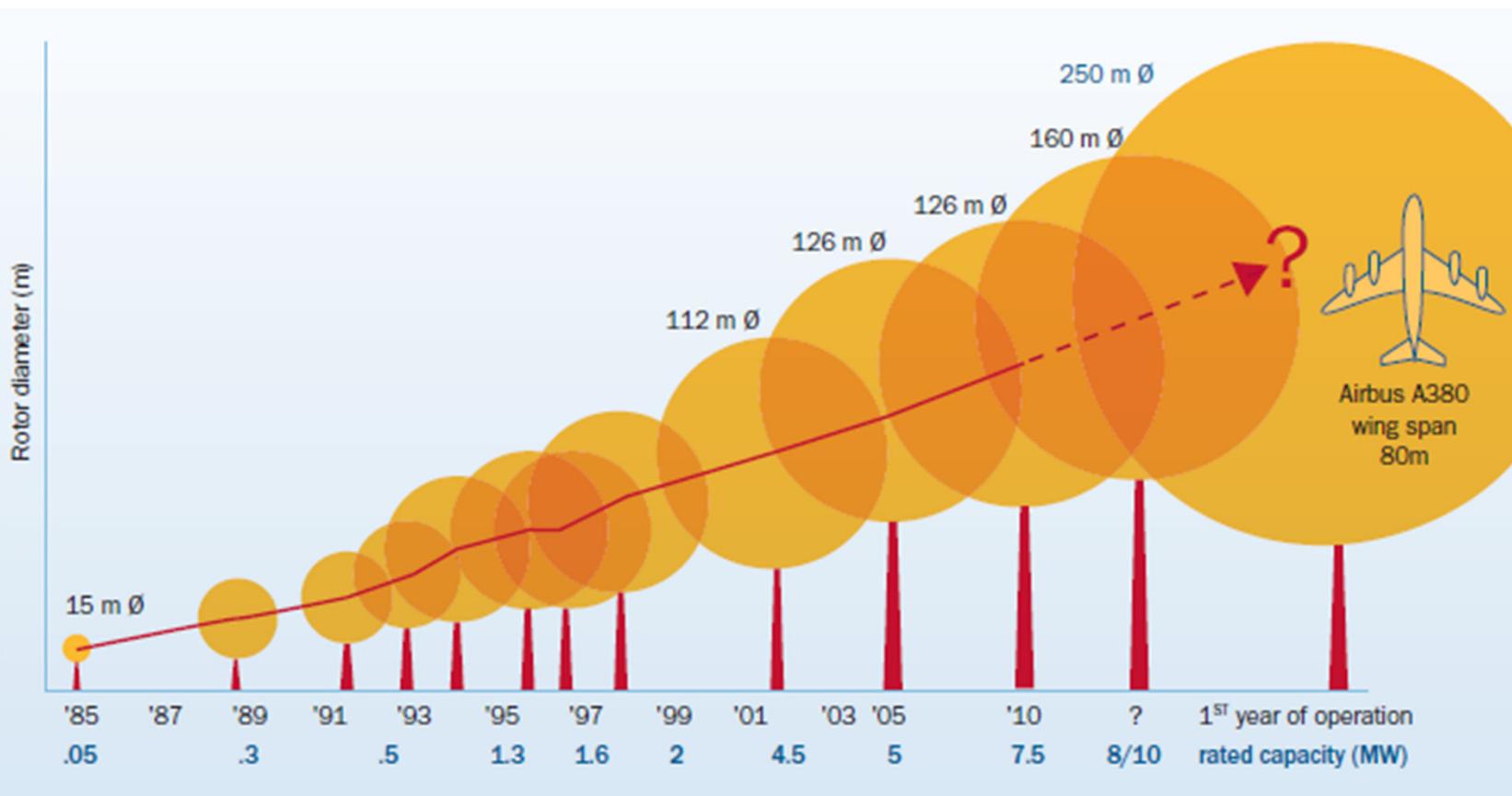


Trends in Turbine & Blade Production

- Small growth of average individual turbine capacity: 1.6 MW
- Mainstream of installed turbines, 1.5-2.5 MW, up to 86% of total capacity delivered in 2011
 - US average size is 1.98 MW

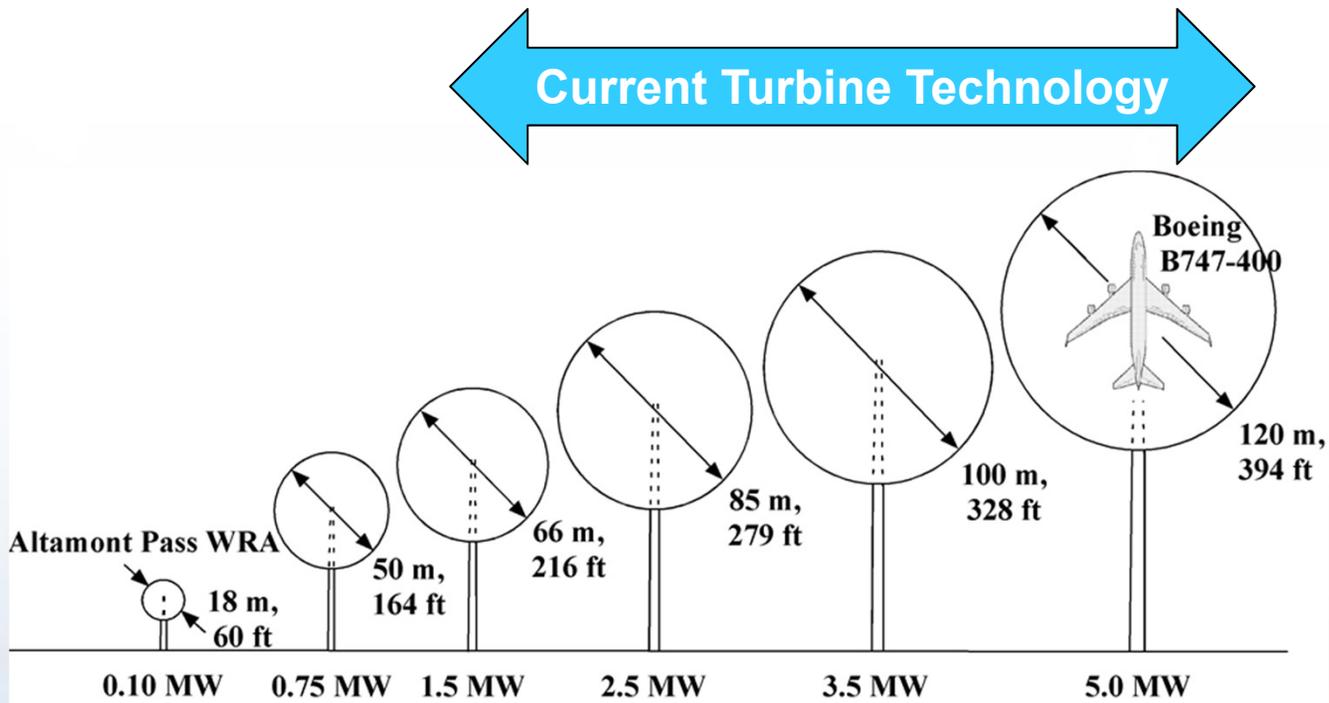


Growth in Rotor Size



Growth in Rotor Size

And, expanded product offerings



Continued rotor growth for offshore (5 MW and above)

Additional offerings for land-based machines 2-3 MW: hub height and rotor size options



Giant Wind Turbines

Currents in Upper Air Form Unfailing Source of Power for "Windmills" of Future

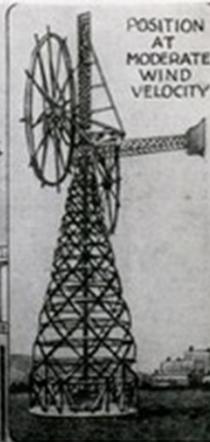


GIANT WIND TURBINE TOWER 1400 FEET

• WIND, at the surface of the earth, is proverbially uncertain; but recent researches show that, a thousand feet or more above the ground, wind is comparatively steady and unfailing. This has given new life to the hope of finding a substantial source of natural power, even more universally available than water power; and the designs illustrated here have been prepared by a German engineer, Honnef, the erector of several huge radio towers. As shown here, the structure carrying the power plant would be higher than any other building man has yet been able to erect.

The surveys which have been made in Germany show that, with little variation, wind velocities of 22 miles an hour are quite constant at the height illustrated. To utilize this most effectively, instead of small wheels, it is proposed to erect on each wind-turbine tower three power wheels, each 530 feet in (Continued on page 683)

EMPIRE STATE BUILDING 1248 FEET



POSITION AT MODERATE WIND VELOCITY

Large Turbines: Old idea?

1932 Article
1400 foot tower

Article inset:
Currents in Upper Air Form
Unfailing Source of Power for
"Windmills of Future"

Offshore Growth

- Significant installations in the UK in recent years
- Many offshore projects also in pipeline particularly in Germany and China
- 1.1% of 2011 installations were offshore (slight drop)
- Forecasting 9% for next five years (2012-2016)



Offshore Growth (cont'd)

- **Until recent years, two prime suppliers of offshore turbines (Siemens, Vestas) – new entrants recently**
- **Offshore is test bed for large turbine technology**
- **At least five turbines with rating of 5 MW or more are commercialized**
 - 5.0 MW (Areva, Bard, RePower), 6.15 MW (RePower), 7.5 MW (Enercon)
- **New large machines in development for offshore**
 - 6 MW Alstom (150-meter diameter)
 - 6 MW Siemens (120-meter diameter)
 - 7 MW Vestas (164-meter diameter)
 - 7 MW Mitsubishi (165-meter diameter)
 - 4.5 MW Gamesa (134-meter diameter)





Additional Turbine Trends

- **Direct drive concept continues to increase in its application**
 - Direct drive account for 21% of world's supply of wind power capacity in 2011 (up from 14% in 2009)
 - Simpler mechanism with no gear box maintenance and likely to be competitive with traditional drive train machines
- **Concern about supply chain of permanent magnet materials**



Issues, Supporting Technologies & Innovations for Blade Technology



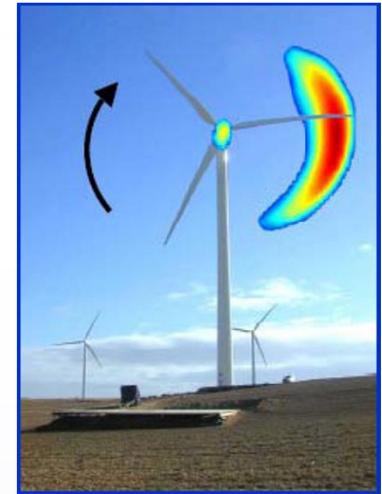
LM 61.5 m blade

Solving issues, improving codes and standards, and developing innovations all lead to lower COE – either lower capital costs, lower O&M, or increased energy capture.

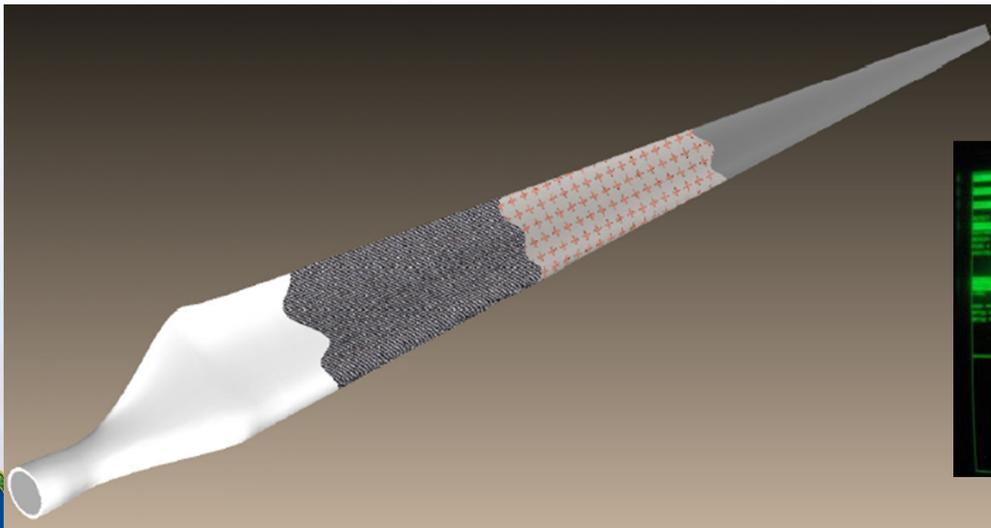


Issues

- Radar
- Noise
- Transportation
- Field Service & Repair
- Lightning
- Reliability of blade design & manufacturing



Acoustic
Research

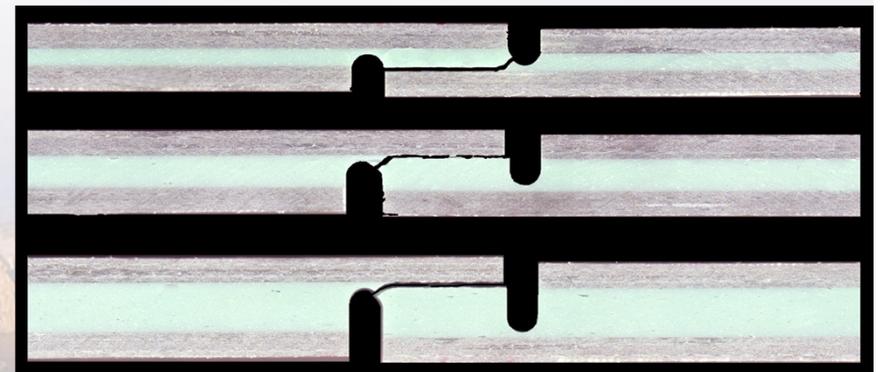
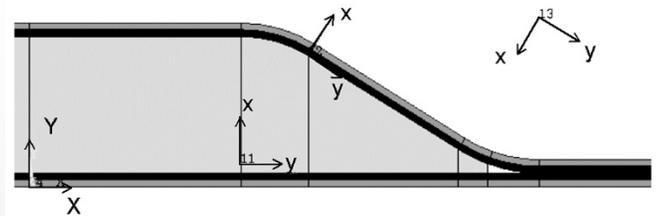


Effects of
Turbines on
Radar



Supporting Technologies

- Standards
- Codes and design methods
- Testing
- Sensors & inspection
- Material performance in fatigue
- Small & mid-size wind



Innovations

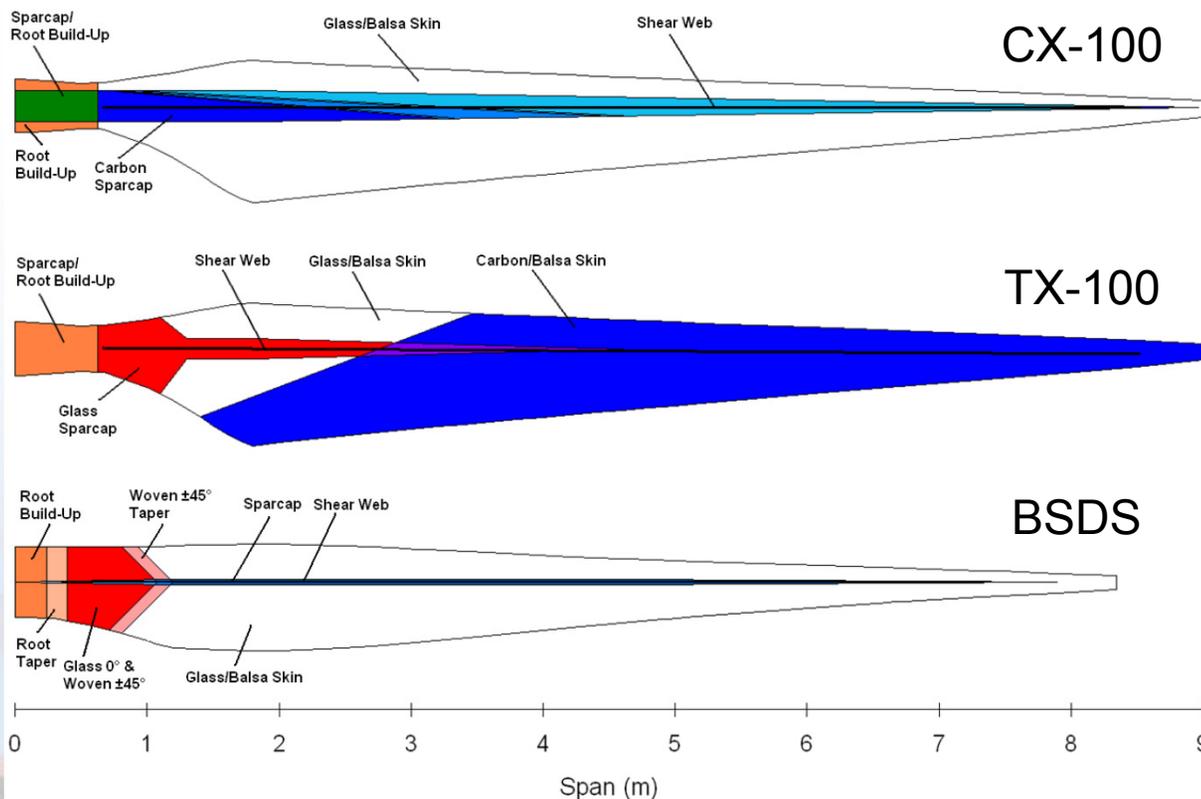
- Blade manufacturing improvements – improve quality, reduce labor (automation)
- Aerodynamic performance enhancement devices
- Segmented blades - For 4.5 MW, Gamesa has 62.5 m long blades with joints at 30 m of span



Innovations (cont'd)

■ Innovations appearing in commercialized products

- New materials, more use of carbon for large blades
- Flatback variants
- Geometric sweep



STAR Blade



Innovations (cont'd)

■ Innovations in research communities – labs, universities, industry

- Passive load control
- Large blade development
- Active load and performance control
- Vertical Axis Wind Turbine (VAWT designs)
- New materials characterizations
- Sensor development for SHM and active load control
- Increased tip speeds
- Coatings for radar, lightning

60 meters = 196'

100 meters = 328'

150 meters = 492'

 6' human scale



Materials Needs in Future

	% of Blade Wt.	2009 U.S. Needs (kg x 10 ⁶)	2009 World Needs (kg x 10 ⁶)	2020 U.S. Needs (kg x 10 ⁶)	2020 World Needs (kg x 10 ⁶)
Fiberglass	51	69	276	138	900
Resin	33	44	176	88	572
Sandwich Core	4	5.4	22	11	70
Adhesive	7.5	10	40	20	130
Bolts & lightning protection	4.5	6	24	12	78





Thanks to speakers,
sponsors of evening mixers
and attendees!!

Support staff: Lenore Boulton, Sam
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Leading Manufacturer's Model Sizes

Turbine Size	200-350 kW	600-750kW	800-900 kW	1.0-1.2MW	1.3-1.65 MW	1.8-2.0 MW	2.1.-2.5 MW	3.0 MW & >
Vestas			52,60		82	80,90,100		3.0(90,90Off112, 112(Off))
GE					1.5 (77,82.5)		100	3.0-4.0Off (90,110)
Sinovel					1.5 (60,70,77,83)			
Enercon	33		44,48,53			82	71	6.0-7.5
Goldwind		43,48,50		62	1.5 (70,77,82)			
Gamesa			52,58			80,87,90		4.5 (128)
Dong Fang					70,77		X (2009)	5.0 (2012)
Suzlon		52			64,66,82		88	
Siemens							82,93,101	3.0,3.6 (101,107)
RePower						82,92		~3.2 (104,114) 5.0 (126) 6.15 (126)
Nordex					70,77,82		80,90,100	
United Power					X			
Clipper							2.5 (89,93,96,99)	
Mitsubishi				X57,62			92,100,102	
Mingyang					X			3.0 (developing)



Sources: Company Web Sites (July 2010)