



Trends in Turbine & Blade Technology - 2010

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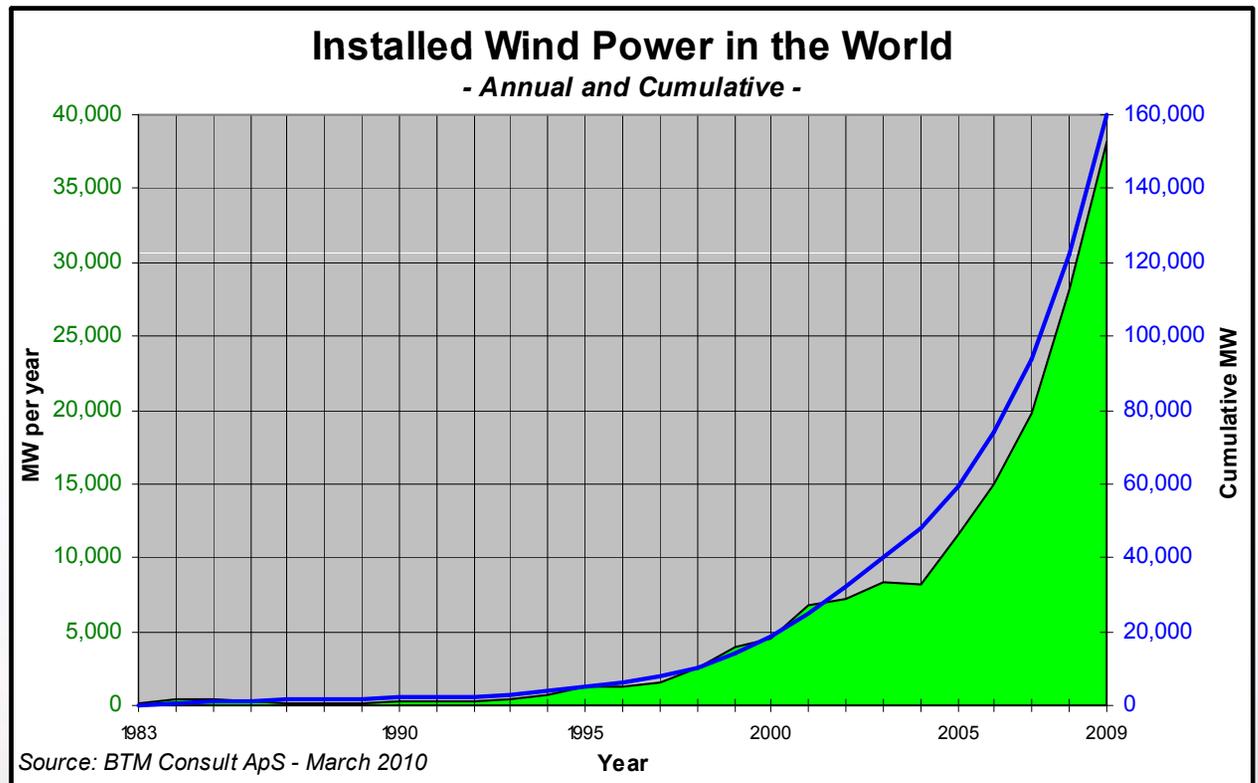
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World and U. S. Turbine Trends

- Continued increase in installed wind capacity both world wide and in the U.S.
- U.S. – largest cumulative capacity
- China second in cumulative and 1st in 2009 installed capacity



~160 GW Installed Worldwide - Total
~40 GW Installed in U.S. - Total



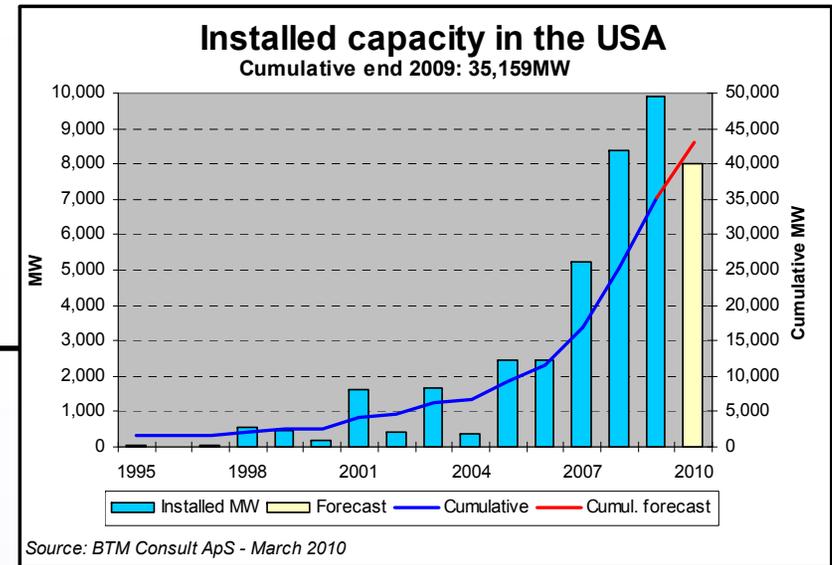
Large Push to Increase Renewables

- **Increasing desire to reduce dependence on fossil-based fuels**
 - Geopolitical and environmental groups
 - Government commitments
- **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**
 - Five of 15 top suppliers of utility-grade turbines in 2009 are Chinese



08-09 Financial Crises Effects

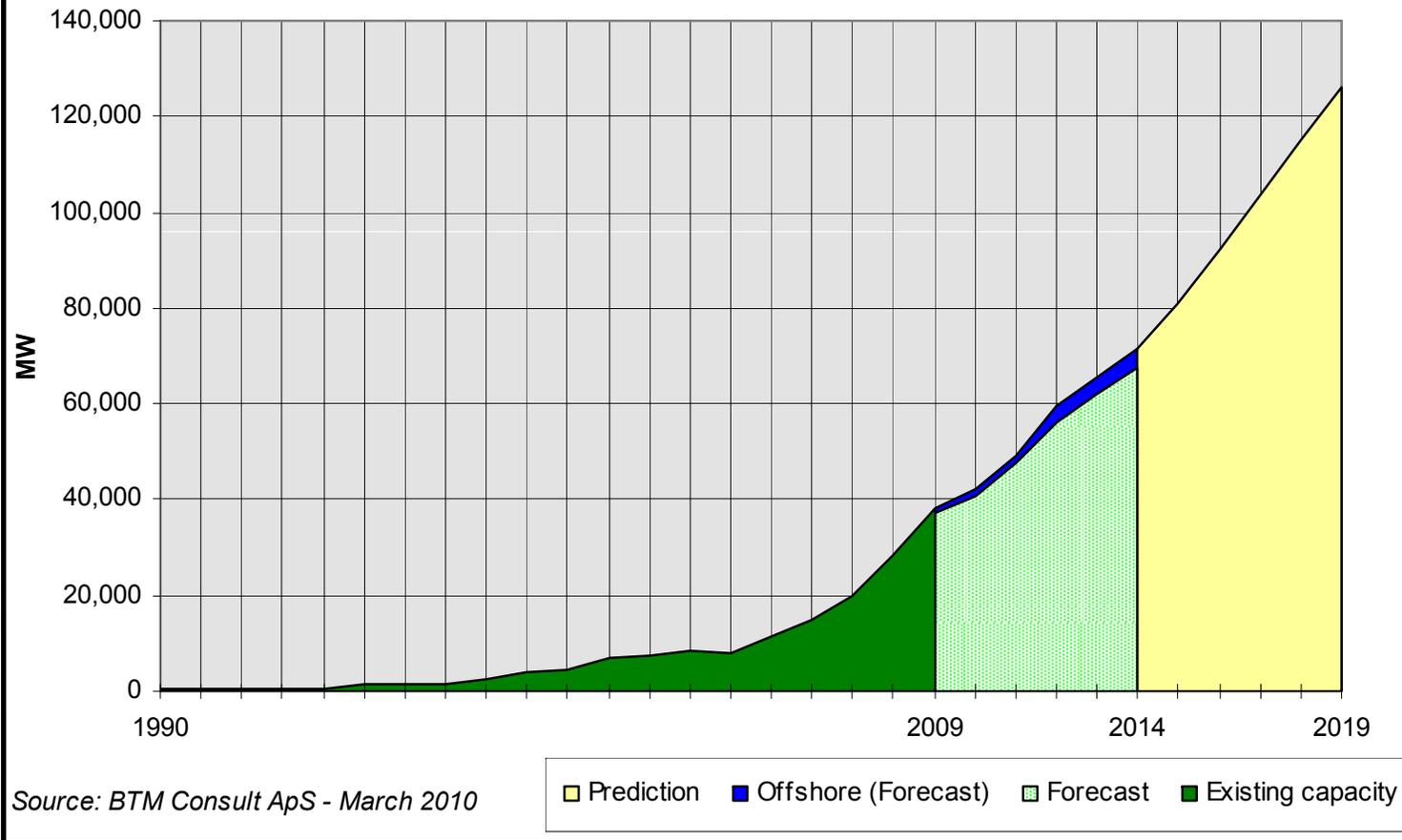
- Urgent enthusiasm changed to one of caution
- Less and more expensive capital
 - Fall in price of fossil fuels made wind less competitive
- Slow down in flow of asset-based finance – more mergers and acquisitions
- Investors (institutional) are more rigorous in evaluation of profitability
- Flight to quality
- Smaller transactions
- More turbines available and at cheaper prices



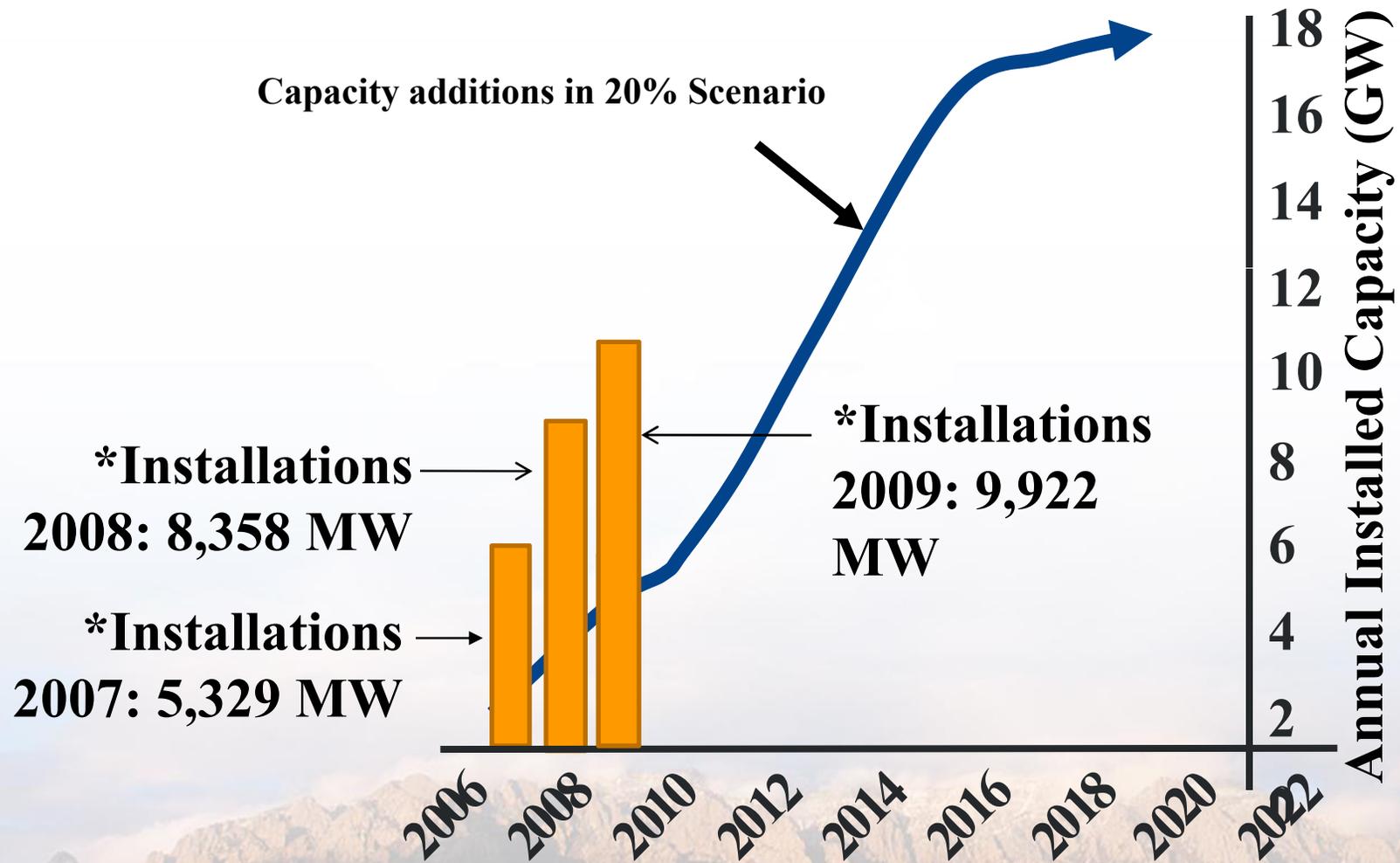
Source: BTM ConsultAPs – 3-2009

Annual Global Wind Power Development

Actual 1990-2009 Forecast 2010-2014 Prediction 2015-2019



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



Source*: AWEA, 2010

■ Annual GW Installed



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Renewable energy targets for EU member states to meet the “20% by 2020” policy.

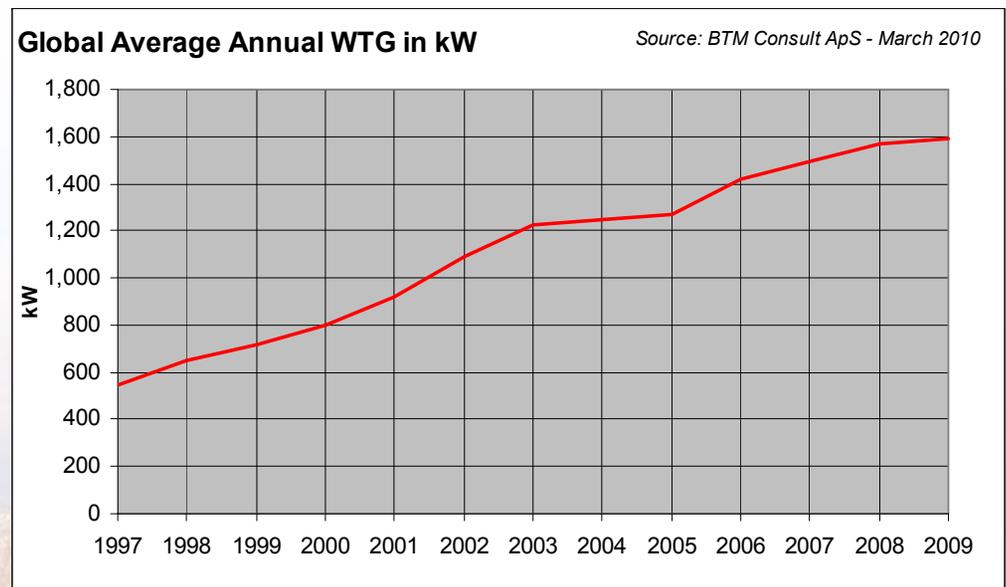
	Share of energy from renewable sources in final consumption of energy, 2005	Target for share of energy from renewable sources in final consumption of energy, 2020
Belgium	2.20%	13%
Bulgaria	9.40%	16%
Czech Republic	6.10%	13%
Denmark	17.00%	30%
Germany	5.80%	18%
Estonia	18.00%	25%
Ireland	3.10%	16%
Greece	6.90%	18%
Spain	8.70%	20%
France	10.30%	23%
Italy	5.20%	17%
Cyprus	2.90%	13%
Latvia	34.90%	40%
Lithuania	15.00%	23%
Luxembourg	0.90%	11%
Hungary	4.30%	13%
Malta	0.00%	10%
Netherlands	2.40%	14%
Austria	23.30%	34%
Poland	7.20%	15%
Portugal	20.50%	31%
Romania	17.80%	24%
Slovenia	16.00%	25%
Slovak Republic	6.70%	14%
Finland	28.50%	38%
Sweden	39.80%	49%
United Kingdom	1.30%	15%

Source: European Commission – COM (2008) 19 final, Brussels Jan. 21, 2008



Trends in Turbine & Blade Production

- Continued growth of individual turbine capacity slowed down, reached 1.6 MW
- Mainstream of turbines, 1.5-2.5 MW, 82% of total capacity delivered in 2009
 - China average size is 1.36 MW
 - US dominated by GE 1.5 MW
 - Europe dominated by 2-3 MW



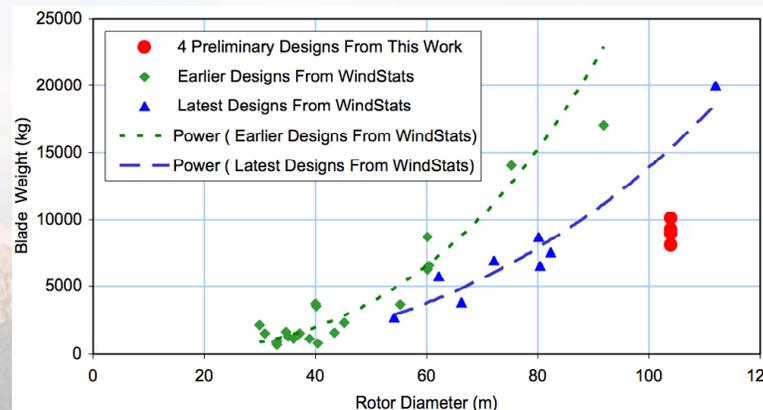
Turbine and Blade Trends (cont'd)

- **Direct drive concept increasing in its application**
 - Direct drive account for 14% of world's supply of wind power capacity
 - Simpler mechanism with no gear box maintenance and likely to be competitive with traditional drive train machines
 - Some concern about operations offshore
 - Enercon used to be only supplier – Goldwind supplied 1200 of its 1.5 MW direct drive with a PMG
- **Concern about supply chain of permanent magnet materials, only sourced in China and Canada**



Offshore

- Many projects in pipeline particularly UK and Germany
- 1.8% of 2009 installations were offshore
- Forecasting 13.5% for next five years
- Until recently three prime suppliers of offshore turbines – Siemens, Vestas, Repower
- New emergents
- Three turbines with rating of 5 MW or more are commercialized
- Enercon E-126 is a 6 MW machine but can operate to 7.5 MW
- Clipper developing a 10 MW offshore turbine



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

Issues, Supporting Technologies & Innovations for Blade Technology



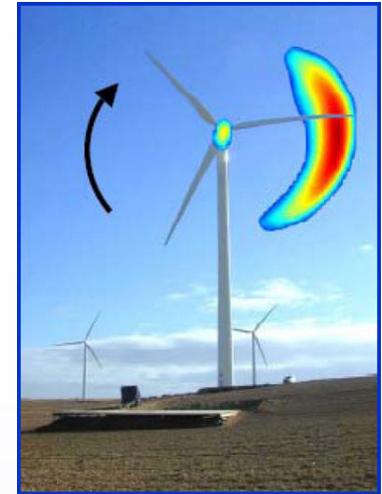
LM 62.5 m
blade

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.

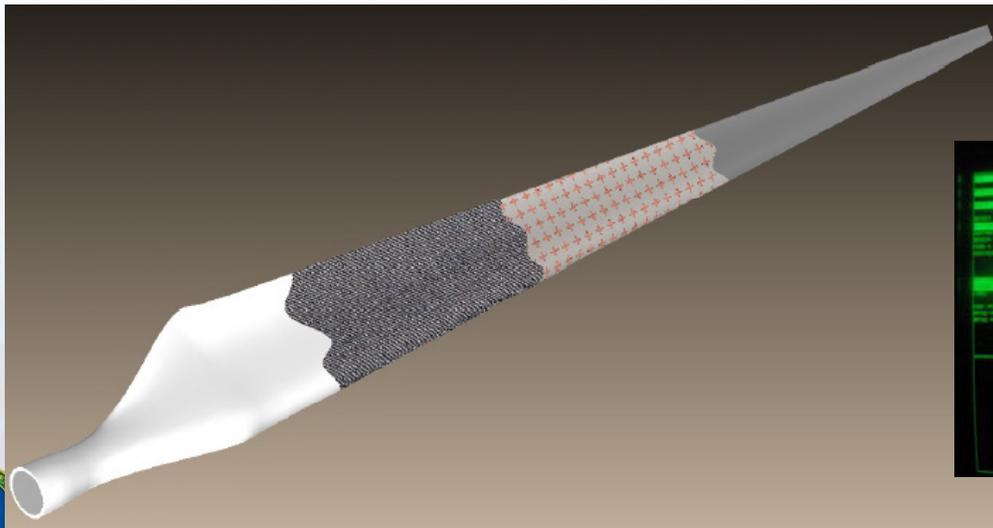


Issues

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



Acoustic
Research

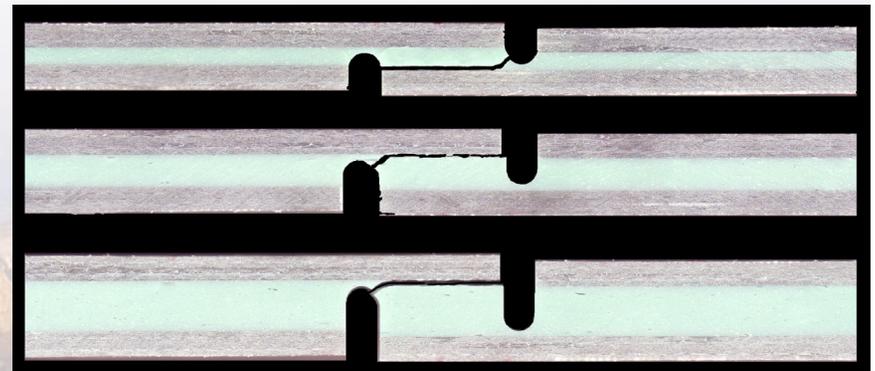
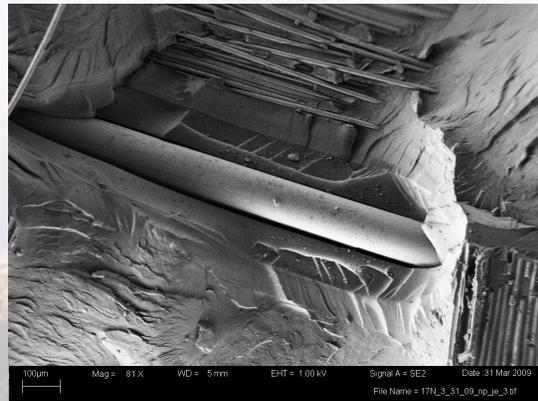
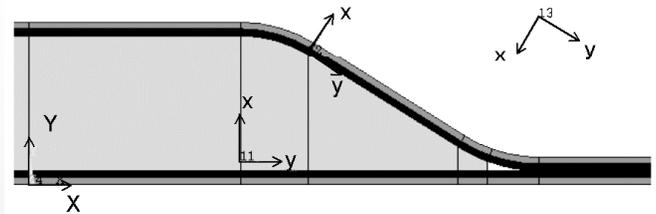


Effects of
Turbines on
Radar



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)**
- **Offshore**
- **Innovations appearing in commercialized products**
 - New materials and material forms
 - More use of carbon for large blades



Industry Technology & Innovations (cont'd)



- Performance enhancement devices
- Load alleviation – sweep
- Flatback variants
- Segmented blades - For 4.5 MW, Gamesa has 62.5 m long blades with joints at 30 m of span



Innovations (cont'd)

■ Innovations in research communities – labs, universities, industry

- Passive load control
- Large blade development
- Active load and performance control
- 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 10⁶)	2009 World Needs (kg x 10⁶)	2020 U.S. Needs (kg x 10⁶)	2020 World Needs (kg x 10⁶)
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





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