The future of wind power

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The future of wind power

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Risø DTU test field for large wind turbines
Outline

• Global wind energy market status
• Technology status
• Research and Technology trends
• Global wind energy market perspectives
Global wind energy market status
World market for wind energy - 2011

GLOBAL STATUS

- 41.7 GW installed in 2011
- 241 GW installed in total
- ~1.7% offshore
- 2.3% of global electricity in 2012
- Wind power growing 22.7% per year (over 5 years)
- Only 6% in 2011
- Cumulative installed power growing 26.5% per year (over 5 years)
- 28% wind power in Denmark in 2011
- 50% wind power in Denmark in 2020

Source: BTM Consult - A Part of Navigant - March 2012
World market status 2011

- 17.6 GW (nearly 42%) of World market in China
- Global average installed size is 1.68 MW
- Direct drive account for 21.2% of production
- Seven Chinese manufacturers among top 15

Global Average Annual WTG in kW

![Global Average Annual WTG in kW chart](chart.png)
Global Wind Power Status
Cumulative MW by end of 2005, 2008 & 2011

Source: BTM Consult - A Part of Navigant - March 2012

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Top-10 Suppliers (Global) in 2011
% of the total market 40,358MW

Source: BTM Consult - A Part of Navigant - March 2012
Industry trends and costs

• WT technology developed by small companies in Europe and USA in close corporation with research organisations.
• Taken over by multi-national energy companies (GE, Siemens) or merged (Vestas)
• Asian development based on licensed technology from Europe
• Learning rates up to 2005 of 0.09-0.17.
• By 2005 increasing costs, focus on increasing production capacity and improving reliability

Using experience curves to forecast wind energy economics up to 2015. The costs shown are for an average 2 MW turbine with a present-day production cost of euro €6.1/kWh in a medium wind regime (from [Lemming & Morthorst])
Target to be met by:

- improved optimized design (larger rotors), optimizing operation of the farm and exploring potentials within delivery of system benefits
- “operation and maintenance” is expected to contribute to the 50% reduction of CoE
Technology status
Industrial design process

- advanced design tools used by industry
  - 2D and 3D CFD codes for rotor and blade design
  - 3D CFD codes for terrain simulations
  - integrated aero/servo/hydro simulation tools

- integrated design process
- tailored airfoil designs
- aeroacoustics taken into account in the design
- close contact with universities and labs
Typical wind turbine 2012

- Three bladed upwind
- Pitch-controlled
- Variable speed
- Grid connected
- 18% with direct drive
- Average size 1.7 MW
- 7-10 MW being developed
A material-efficient machine

10 m/s:

- 80 tons/sec: Mass of air through rotor disc.
- Extracts energy from mass of air corresponding to its own total weight in 5 seconds.
Upscaling has been main driver

Upscaling: "Square-cube law"

- Power increases as diameter squared
- Mass increases as diameter cubed

Limit in size?
Lightweight blades

Blade mass increases only close to the diameter squared (exponent 2.2-2.3) due to optimised and thick airfoils and due to optimized structural design.

Lift enhancing devices to compensate for bad aerodynamic characteristics of thick airfoils.
Research and technology trends
Research areas related to future technology

- distributed control with flaps along the blades (e.g. 100 m long) to alleviate loads

- optimized aeroelastic coupling effects for passive load alleviation

- simulating real inflow with turbulence and shear to the turbine in the CFD rotor codes

- detailed monitoring of inflow to the turbine for control

- integrated design process considering the turbine as a component of a wind power plant

- upscaling effects
Individual pitch and smart trailing edge control

Elastomeric controllable flap activated by pressure in voids

20-40% reduction in blade- and tower fatigue loads

"Smart" material variable trailing edge flap

The future of wind power; Chalmers Energy Conference, March 28 2012
Measuring inflow for pitch or flap control

Lidar technology

Inflow measured with four five hole pitot tubes
Upscaling effects

- Filtering of turbulence by the rotor increases with size

Results from simplified aerodynamic model with turbulent inflow

Results based on full aeroelastic model

Vasilis et al.: paper to be presented at EWEA 2012
New concepts offshore

Floating turbines

Life cycle costs offshore

Combined wind and wave energy converters
Global wind energy market perspectives
Global wind energy market perspectives

Annual Global Wind Power Development

Source: BTM Consult - A Part of Navigant - March 2012

- Offshore (Prediction)
- Prediction
- Forecast
- Existing capacity

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Global wind energy market perspectives

Cumulative Global Wind Power Development
Actual 1990-2011  Forecast 2012-2016  Prediction 2017-2021

Source: BTM Consult - A Part of Navigant - March 2012

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Global wind energy market perspectives

Contribution of wind power to worldwide electricity generation

<table>
<thead>
<tr>
<th>Year</th>
<th>Electricity gen. by Wind Power (BTM-C) TWh</th>
<th>Electricity from all gen. sources (incl. Wind) IEA TWh</th>
<th>Wind Power's share of the world's electricity generation: %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>12.23</td>
<td>13,613</td>
<td>0.09%</td>
</tr>
<tr>
<td>1997</td>
<td>15.39</td>
<td>13,949</td>
<td>0.11%</td>
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<tr>
<td>1998</td>
<td>21.25</td>
<td>14,340</td>
<td>0.15%</td>
</tr>
<tr>
<td>1999</td>
<td>23.18</td>
<td>14,741</td>
<td>0.16%</td>
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<tr>
<td>2000</td>
<td>37.30</td>
<td>15,153</td>
<td>0.25%</td>
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<tr>
<td>2001</td>
<td>50.27</td>
<td>15,577</td>
<td>0.32%</td>
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<tr>
<td>2002</td>
<td>64.81</td>
<td>16,233</td>
<td>0.40%</td>
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<tr>
<td>2003</td>
<td>82.24</td>
<td>16,671</td>
<td>0.49%</td>
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<tr>
<td>2004</td>
<td>96.50</td>
<td>17,408</td>
<td>0.55%</td>
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<tr>
<td>2005</td>
<td>120.72</td>
<td>17,982</td>
<td>0.67%</td>
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<tr>
<td>2006</td>
<td>152.35</td>
<td>18,576</td>
<td>0.82%</td>
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<tr>
<td>2007</td>
<td>194.16</td>
<td>19,756</td>
<td>1.01%</td>
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<td>2008</td>
<td>254.13</td>
<td>20,230</td>
<td>1.30%</td>
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<tr>
<td>2009</td>
<td>331.91</td>
<td>20,750</td>
<td>1.60%</td>
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<tr>
<td>2010</td>
<td>409.91</td>
<td>21,333</td>
<td>1.92%</td>
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<tr>
<td>2011</td>
<td>473.88</td>
<td>20,976</td>
<td>2.26%</td>
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<td>2016 (forecast)</td>
<td>1074.1</td>
<td>24,529</td>
<td>4.38%</td>
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<td>2021 (est.)</td>
<td>2,286.1</td>
<td>28,522</td>
<td>8.02%</td>
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World electricity consumption from wind
Energy for the future

Thank you!