Wind Energy: what to expect within the next ten years

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Wind Energy: what to expect within the next ten years

Table of contents:

- Climate change an peak oil
- Energy scenarios & the role of wind
- Wind energy potential in Germany
- How to integrate wind into the grid
- Wind technology – the growth story
- Technology challenges onshore and offshore
- The next steps in technology developments
Global situation and future trends

Global Population Growth,
Energy Demand and CO₂-Concentration

Global Population
Global Energy Demand
CO₂-Concentration in Atmosphere

Global situation and future trends

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How to keep global warming below 2°C

Maximum Amount of Global Emissions 750 Mrd. t CO₂

- Peak in Jahr
- 2011
- 2015
- 2020

<table>
<thead>
<tr>
<th>Maximum Decrease Rate</th>
<th>3.7% per Year</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>5.3% per Year</td>
</tr>
<tr>
<td></td>
<td>9.0% per Year</td>
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</tbody>
</table>

Source: WBGU
Peak oil

OIL AND GAS LIQUIDS
2004 Scenario

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100% Renewables – A historic reality

James Watt
Steam Engine 1764 - 1769

Golden Age of Greece

Biomass
Photovoltaics
Solar Heat
Wind Energy

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<table>
<thead>
<tr>
<th>Global Energy Demand</th>
<th>Potential - Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Energy</td>
<td>DLR / UNDP / Harvard</td>
</tr>
<tr>
<td>Solar Electricity (PV)</td>
<td>Hoogwijk / DLR</td>
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<tr>
<td>Solar Electricity (CSP)</td>
<td>DLR</td>
</tr>
<tr>
<td>Bio Energy</td>
<td>FAO / WBGU</td>
</tr>
<tr>
<td>Hydro Power</td>
<td>UNDP / DLR</td>
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<tr>
<td>Geothermal Energy</td>
<td>UNDP / DLR</td>
</tr>
<tr>
<td>Marine Energy</td>
<td>UNDP</td>
</tr>
</tbody>
</table>

Sources: see picture

Global Renewable Energy potential

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Renewables in Germany between 1990 and 2009

- **hydro power**
- **wind energy**
- **biomass** *
- **photovoltaics**

* feste und flüssige Biomasse, Biogas, Deponie- und Klärgas, biogener Anteil des Abfalls;
Strom aus Geothermie aufgrund geringer Strommengen nicht dargestellt; StromEinspG: Stromeinspeisungsgesetz; BauGB: Baugesetzbuch; EEG: Eneuerbare-Energien-Gesetz;
Quelle: BMU-KI III 1 nach Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat); Bild: BMU / Christoph Edelhoff; Stand: Dezember 2010; Angaben vorläufig

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Mix of Renewables in Germany until 2050

- Gross power generation from renewable energies [GWh/a]


- Renewable energies:
  - Hydro
  - Photovoltaics
  - Biomass/renewable methane
  - Wind
  - Geothermy
  - Renewable power import
  - Gross electricity consumption

- Graph showing the increase in renewable energy production from 2005 to 2050.
Onshore Wind – The potential

The 2 % scenario

- Area without restriction: 77.6%
- Forest without nature reserve: 4.4%
- Usable nature reserve: 10.1%
- Unusable area: 7.9%

Onshore Wind
– The potential

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Based on a new study, onshore wind energy can fulfill 65 percent of the German Energy Demand. But first the declared height restrictions for wind turbines have to be removed in order to use the potential of the turbines to its maximum.
The Renewable Power Plant

Covers 1/10,000 of Germany's load curve at any time – control of real plants

Wind: 12.6 MW
Solar: 5.5 MW
Biogas: 4.0 MW
Hydro: 1.0 MW
Import/Export: 1.0 MW
Storage by Linking Power and Gas Grids

- **Sources**: Wind, Sun, water (H₂O), CO₂, atmosphere, biomass, waste (fossil fuels)
- **Power Grid**
  - Wind
  - Sun
  - Electrolysis (H₂-tank)
  - CO₂
  - Tank
- **Storage Transport**
  - Methanation (CH₄)
- **Compensation**
  - Gasfired power plants
- **Consumption**
  - Power
  - Heat
  - Traffic
- **Gas Grid**
  - Renewable power methane plant
  - Gas storage

Source: Specht et al, 2009
Sterner, 2009
Renewable Power (to) Methane

60-65% methane
35-40% power
50-60% power-heat cogeneration vs. 0% by regulation

Source: Specht et al, 2009
Sterner, 2009
The Wind Energy Growth Story
Wind Energy – State of the art

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Wind Energy – State of the art
# Growth & Scaling Laws

<table>
<thead>
<tr>
<th></th>
<th>Absolute Value</th>
<th>Proportionality</th>
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</thead>
<tbody>
<tr>
<td>Power</td>
<td>$P = \rho/2 ; c_p(\lambda) ; v^3 ; R^2 ; \pi$</td>
<td>$R^2$</td>
</tr>
<tr>
<td>Speed</td>
<td></td>
<td>$R^{-1}$</td>
</tr>
<tr>
<td>Weight</td>
<td></td>
<td>$R^3$</td>
</tr>
<tr>
<td>Thrust</td>
<td>$S = \rho/2 ; c_s(\lambda) ; v^2 ; R^2 ; \pi$</td>
<td>$R^2$</td>
</tr>
<tr>
<td>Weight loading</td>
<td></td>
<td>$R^1$</td>
</tr>
</tbody>
</table>
Going south : wind in forest areas
Old concepts are back again
...or new are being developed.
Integrated turbine design for next generation

Especially offshore requires an integrated design approach

- 6 MW – 126 m rotor
- Down wind turbine
- 2-bladed rotor
- Jacket structure & tower
- DC ionk
- Weight appr. 250 tons
And the Turbine of the 2020s... Floating?
Energy Islands: a concept of future energy supply
...or completely far out ideas instead of turbines?
Thank you for your kind attention!