The future of wind power

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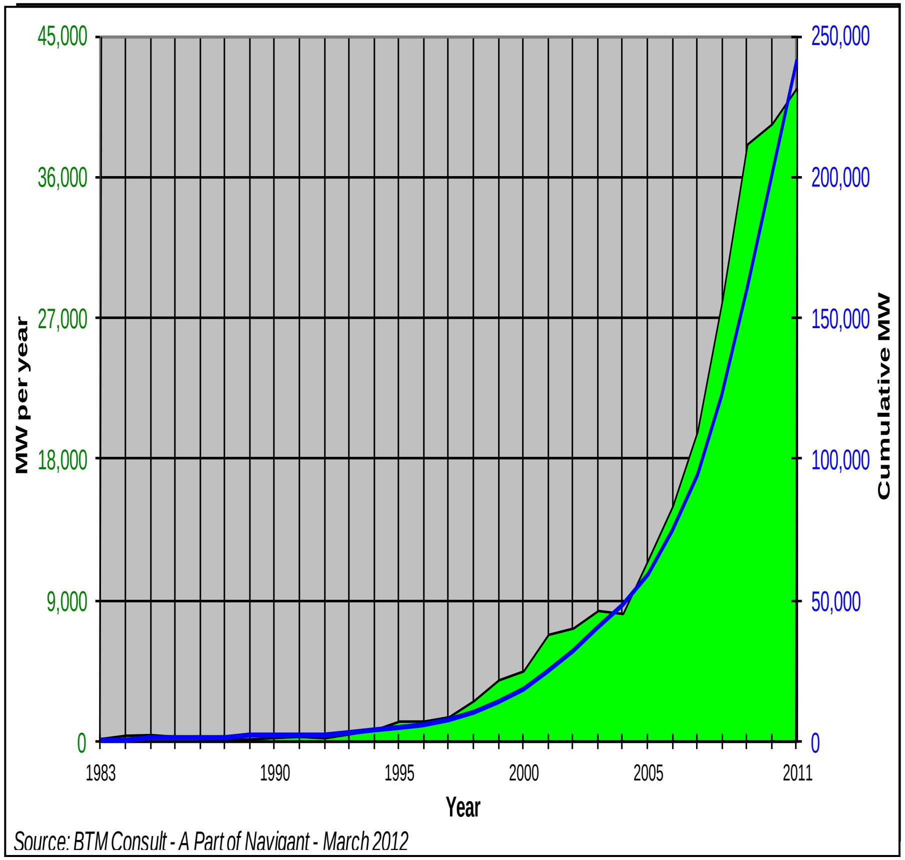
Risø DTU test field for large wind turbines

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

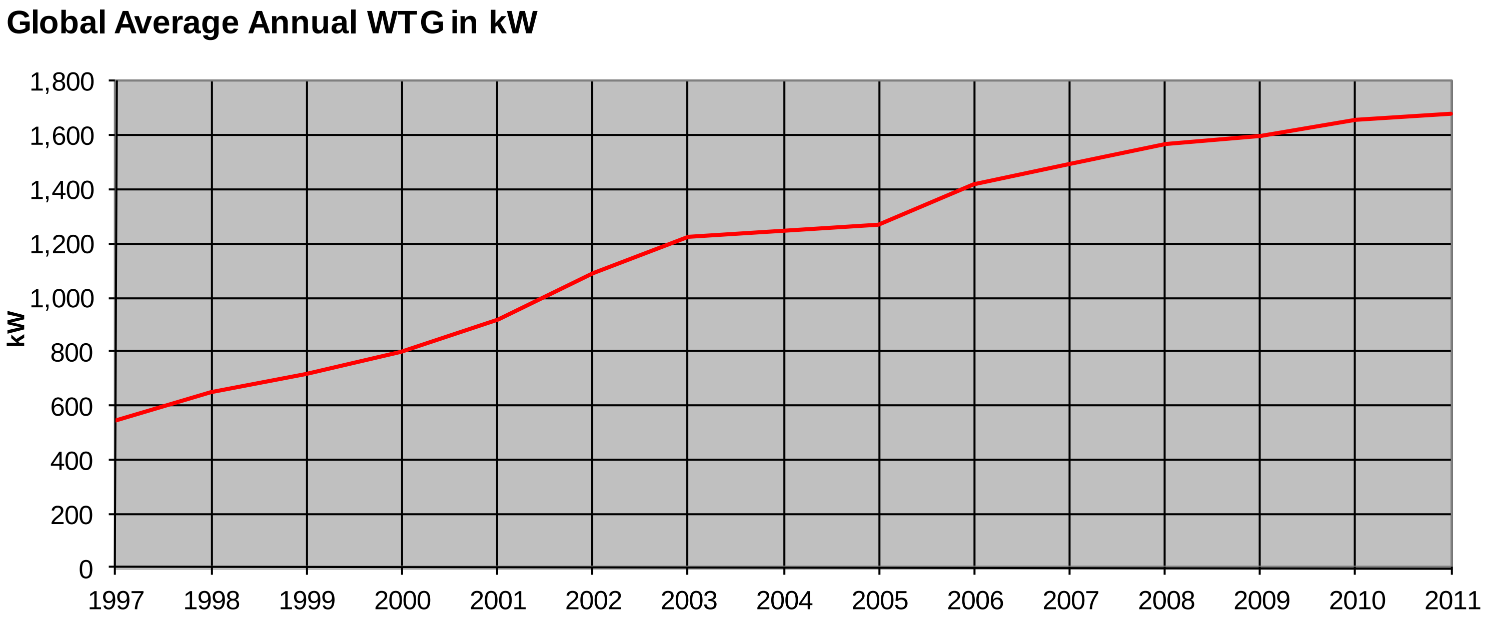


GLOBAL STATUS

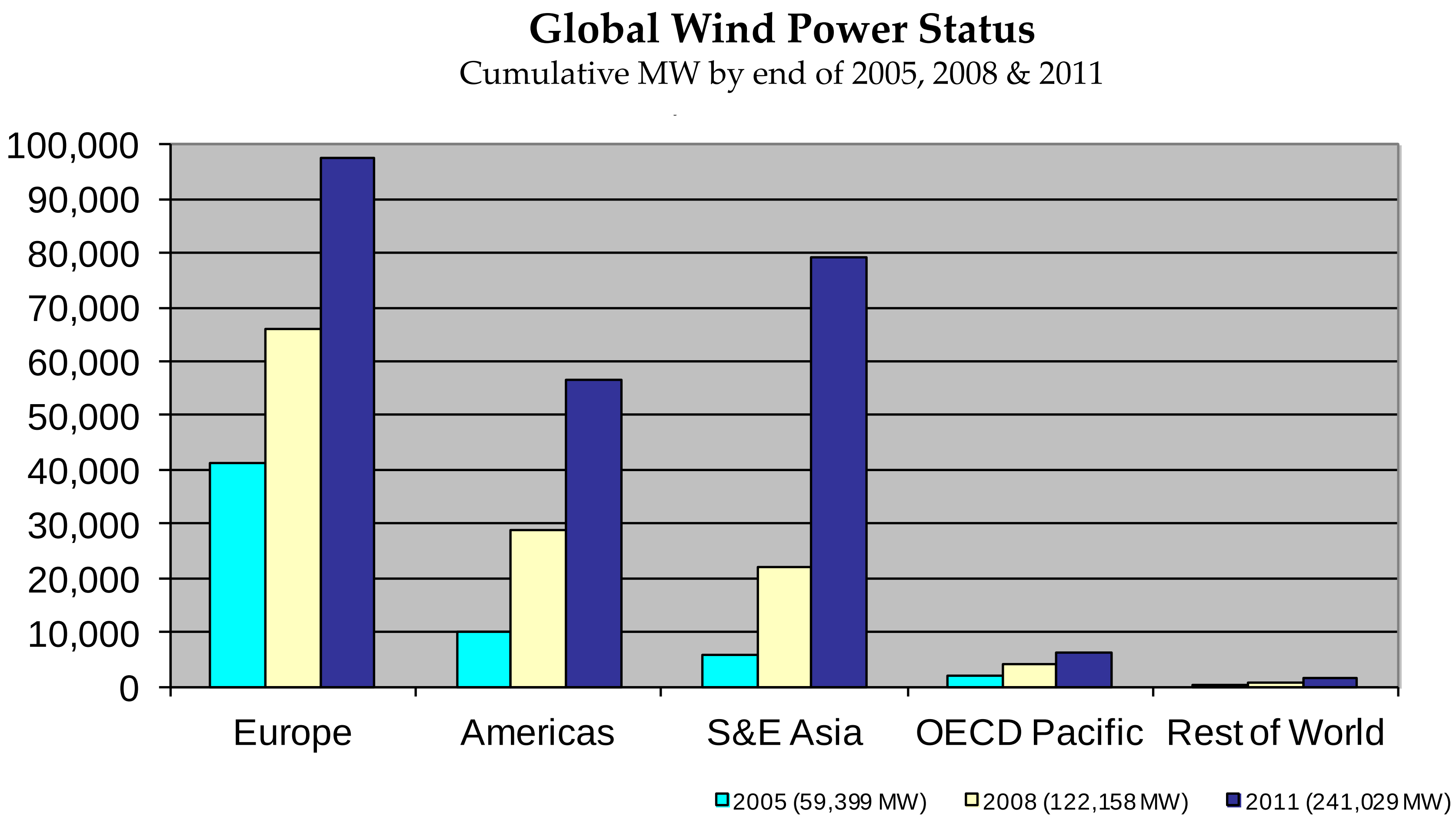
- 41.7 GW installed in 2011
- 241 GW installed in total
- ~1.7% offshore
- 2.3 % of global electricity in 2012
- Wind power growing 22.7% per year (over 5 years)
- Only 6% in 2011
- Cumulative installed power growing 26.5% per year (over 5 year)
- 28% wind power in Denmark in 2011
- 50% wind power in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

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



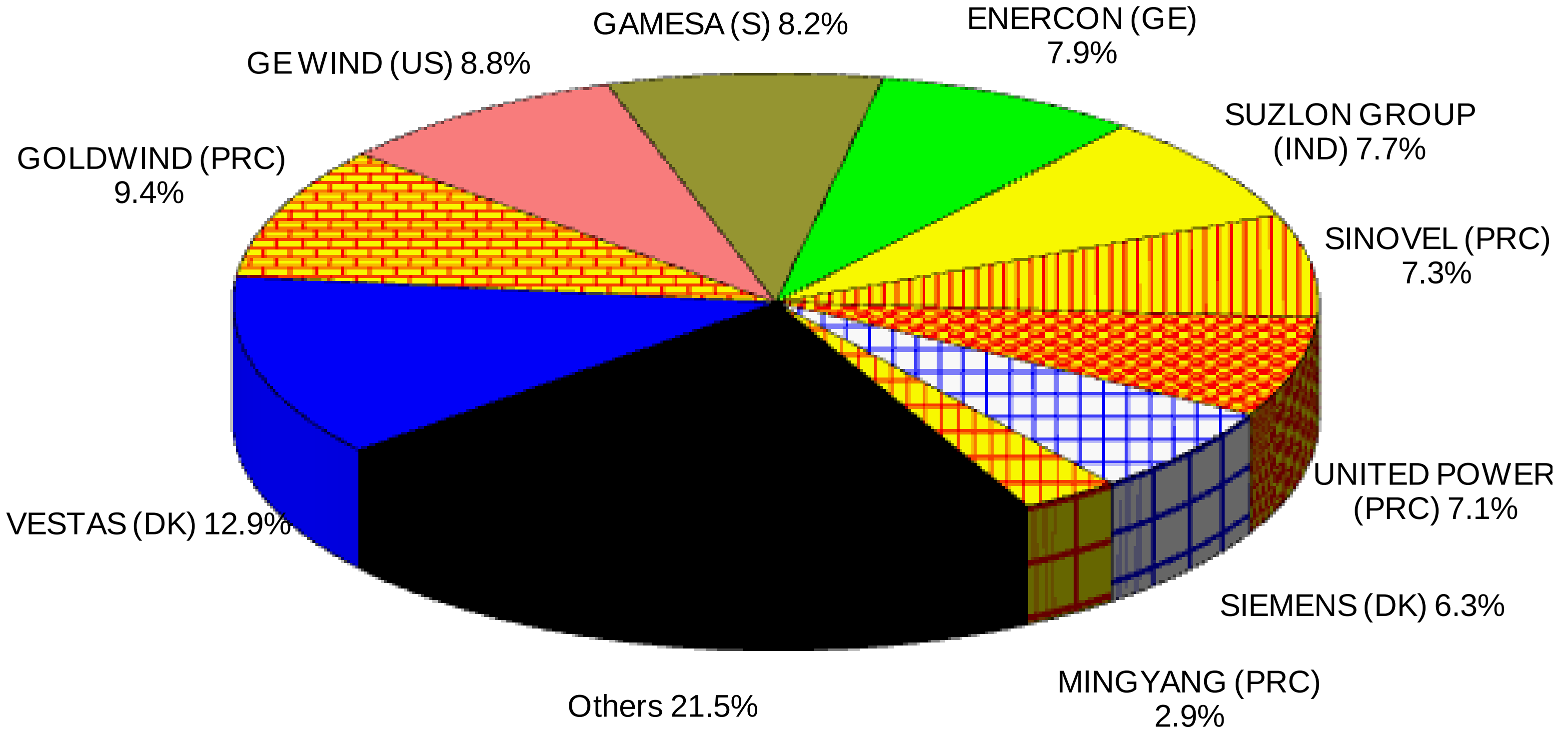
World market status 2011



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

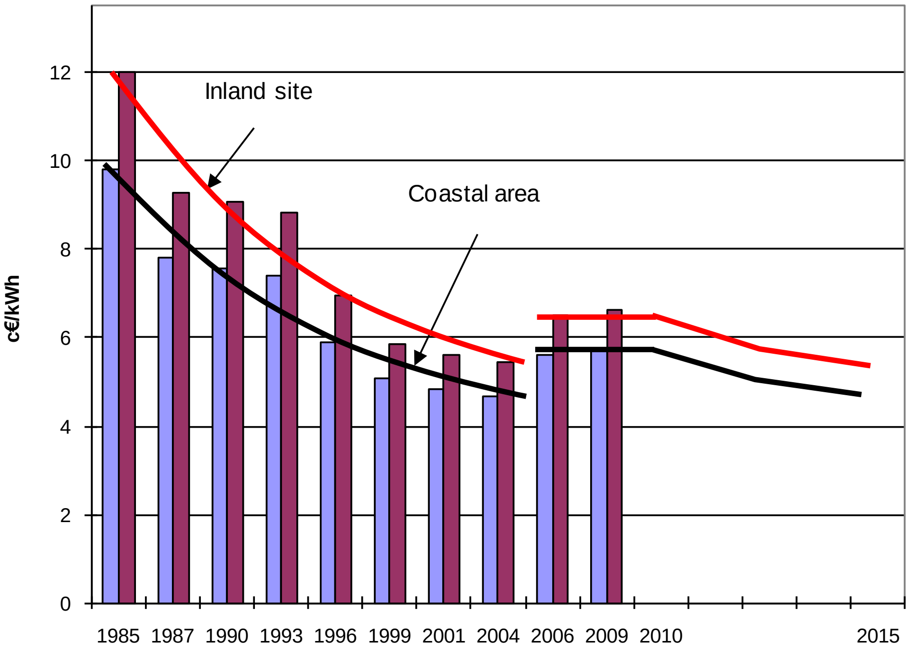
Top-10 Suppliers (Global) in 2011

% of the total market 40,358MW



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

Industry trends and costs



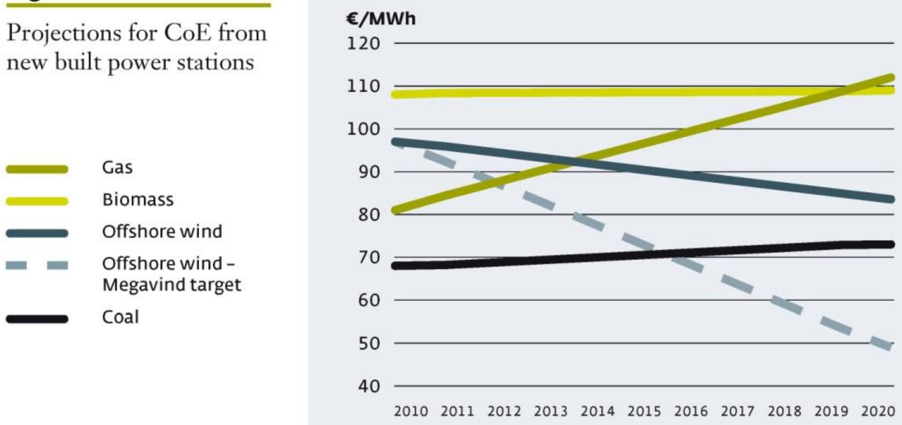
Using experience curves to forecast wind energy economics up to 2015. The costs shown are for an average 2 MW turbine with a present-day production cost of euro ¢6.1/kWh in a medium wind regime (from [Lemming & Morthorst])

- 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 un 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

From Megavind's Strategy for Offshore Wind Research, Development and Demonstration 2010

Figure 3

Projections for CoE from new built power stations



SOURCE: Danish Technology Catalogue, Danish Energy Agency, 2010; Nielsen et al, 2010 and own calculations. CoE is defined as the average CoE measured in €/MWh during the total life span of the electricity production facilities. The calculations for offshore wind power and coal CoE include: Construction costs, discount rate (10%), Operation and maintenance cost, Fuel costs (coal, gas and wood pellets), cost of CO_2 emission quotas, NOx, SOx and other emission taxes. For offshore wind, a life span of 20 years is assumed.

Megavind

Vestas Wind Systems A/S
- Siemens Wind Power A/S
- DONG Energy
- Grontmij I Carl Bro
- The Technical University of Denmark
- Risø DTU - National Laboratory for Sustainable Energy
- Aalborg University
- Energinet.dk (observer)
- Danish Energy Agency (observer)

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**
- ❑ **aeroacostics taken into account in the design**
- ❑ **close contact with universities and labs**

Typical wind turbine 2012

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 throug rotor disc.
- Extracts energy from mass of air corresponding to it’s own total weight in 5 seconds.

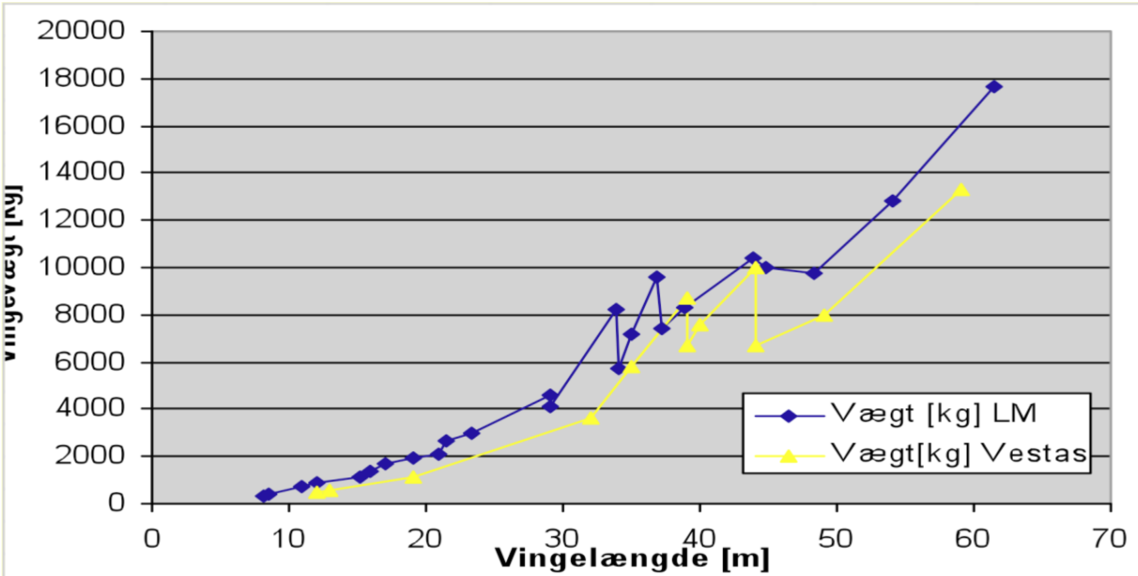
Upscaling has been main driver

Upscaling: ”Square-cube law”

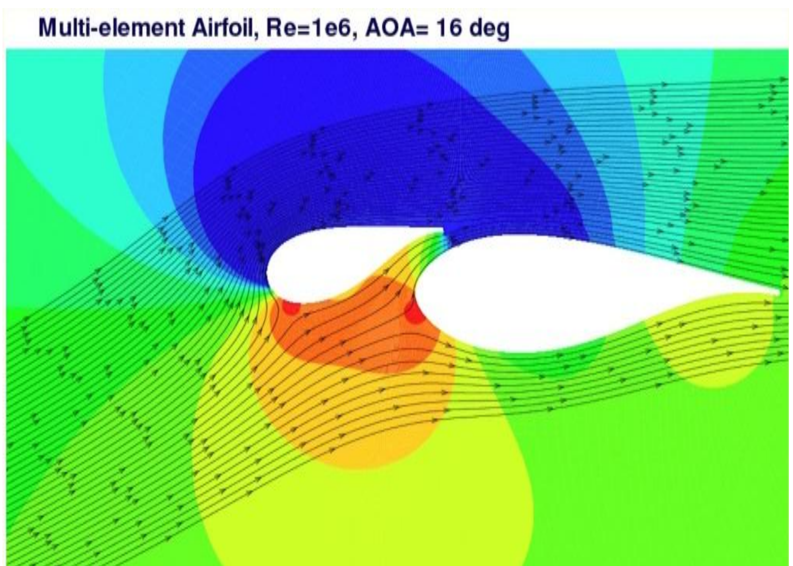
- ❑ Power increases as diameter squared
- ❑ Mass increases as diameter cubed

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 devises to compensate for bad aerodynamic characteristics of thick airfoils

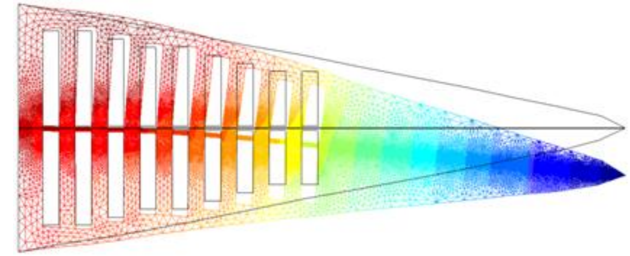
Research and technology trends

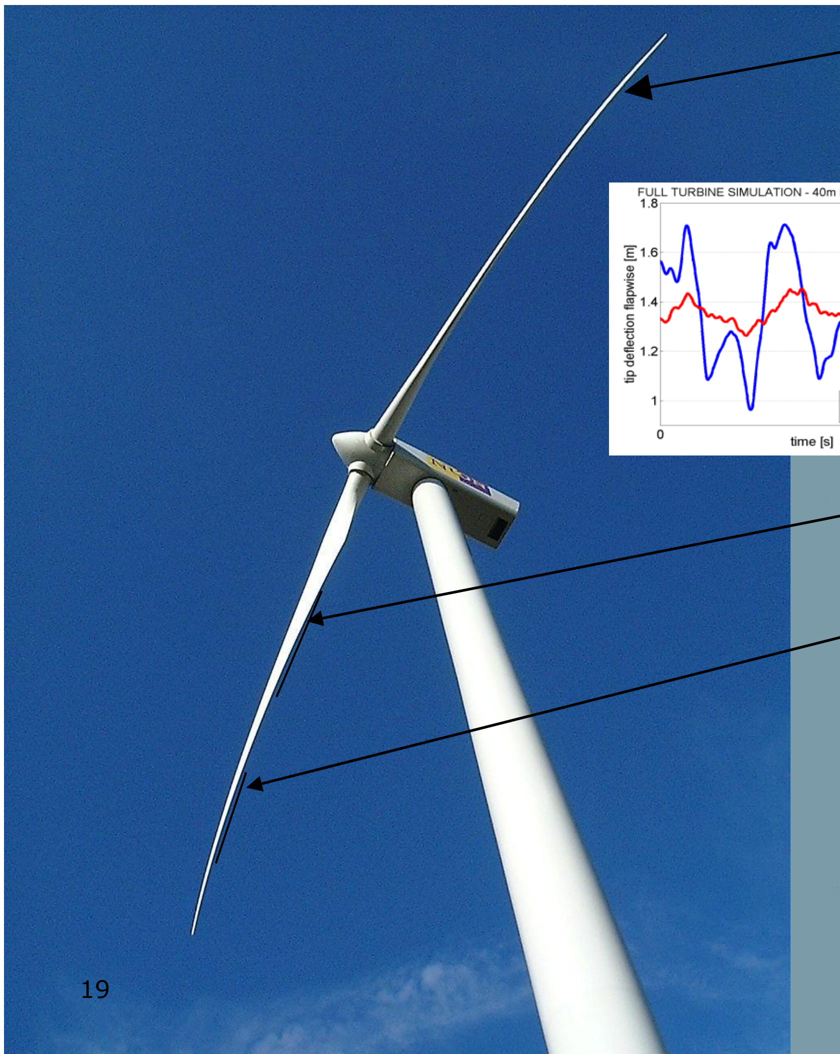
Research areas related to future technology

- ❑ 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

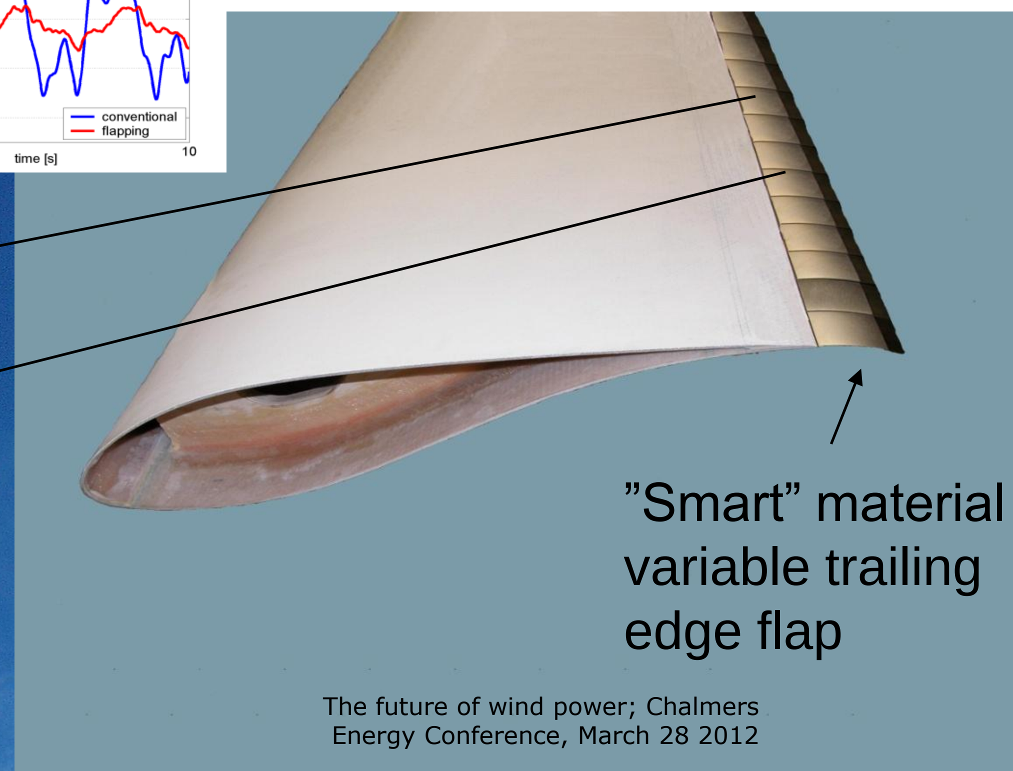
Individual pitch and smart trailing edge control

Elastomeric controllable flap activated by pressure in voids





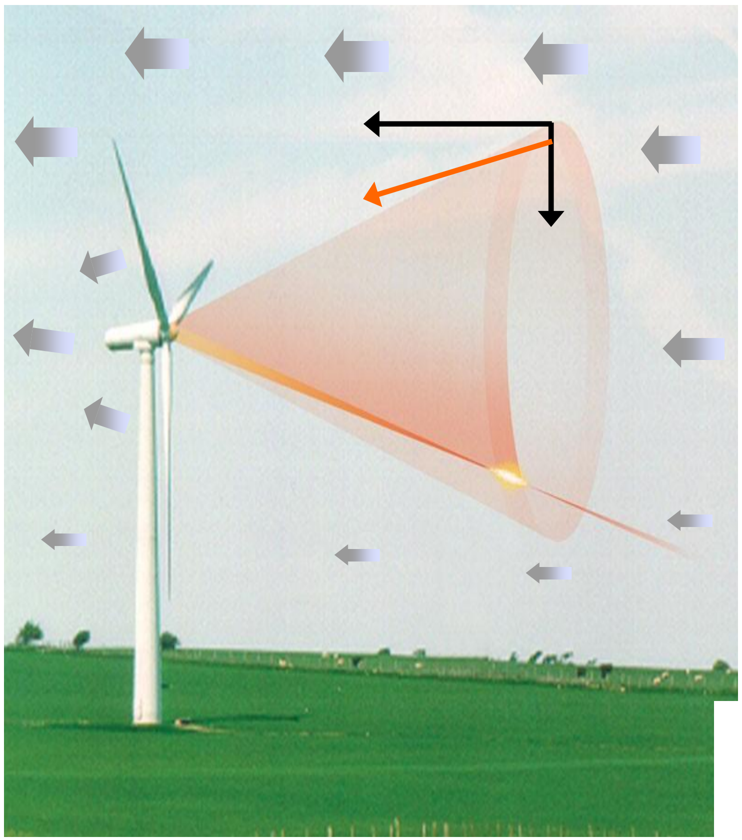
20-40% reduction in blade- and tower fatigue loads



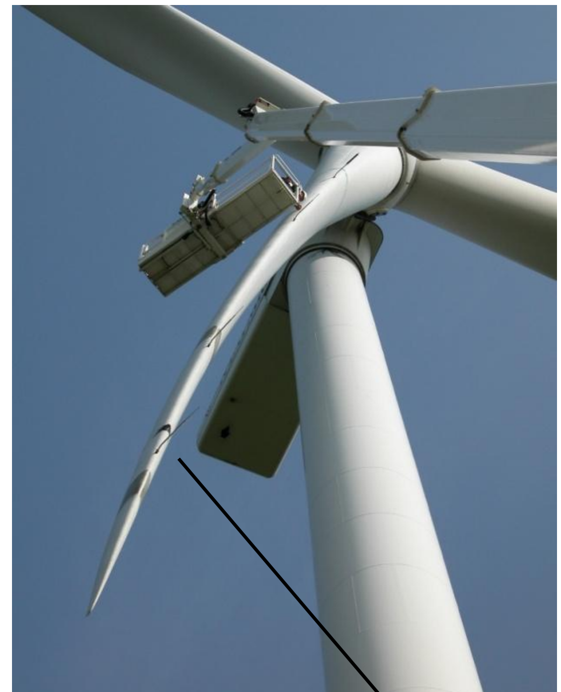
”Smart” material variable trailing edge flap

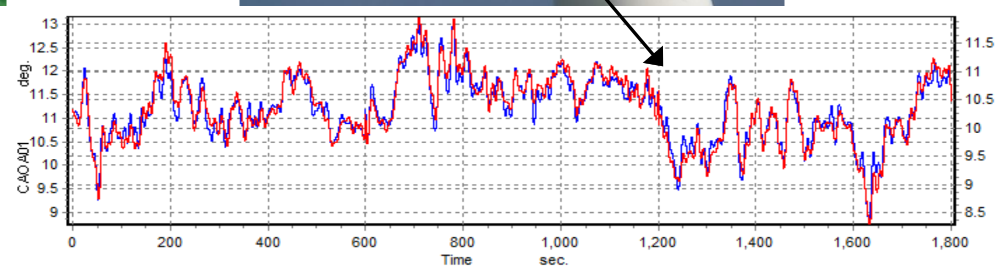
Measuring inflow for pitch or flap control

Lidar technology



Inflow measured with four five hole pitot tubes

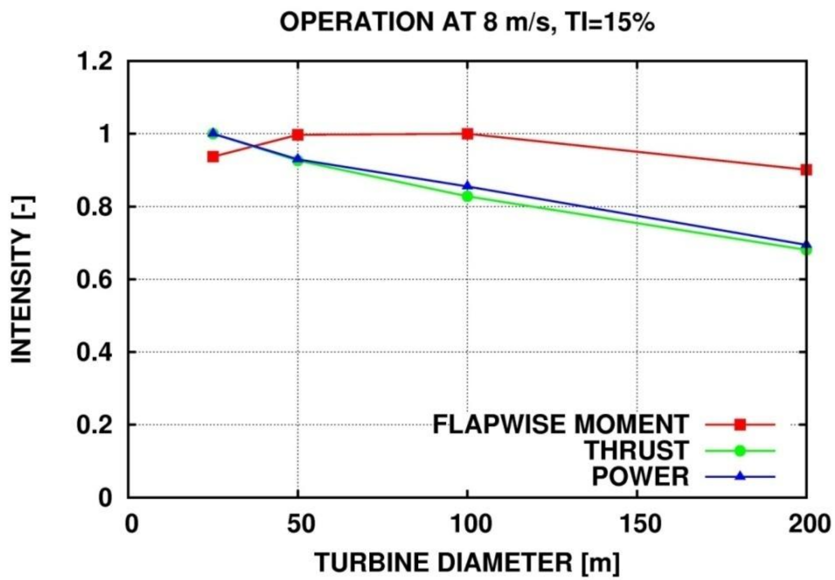




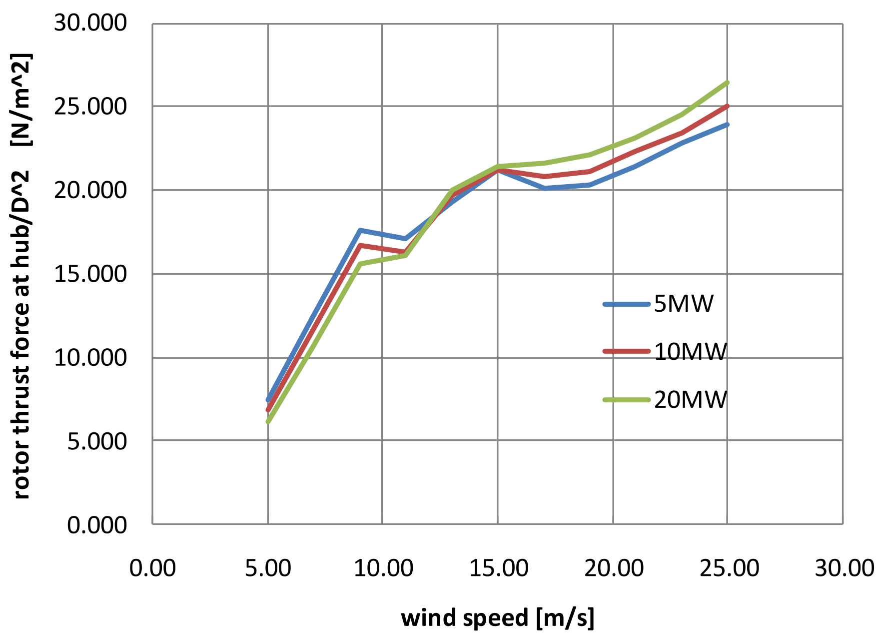
Upscaling effects

- Filtering of turbulence by the rotor increases with size

Results from simplified aerodynamic model with turbulent inflow

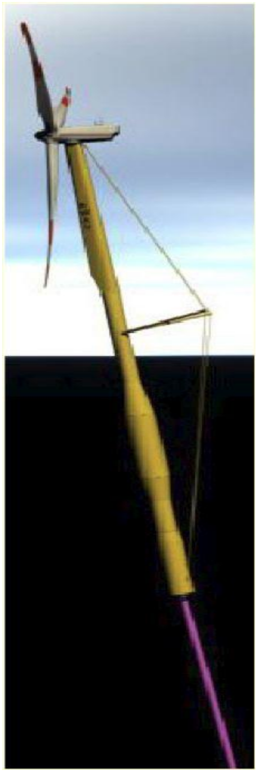


Results based on full aeroelastic model

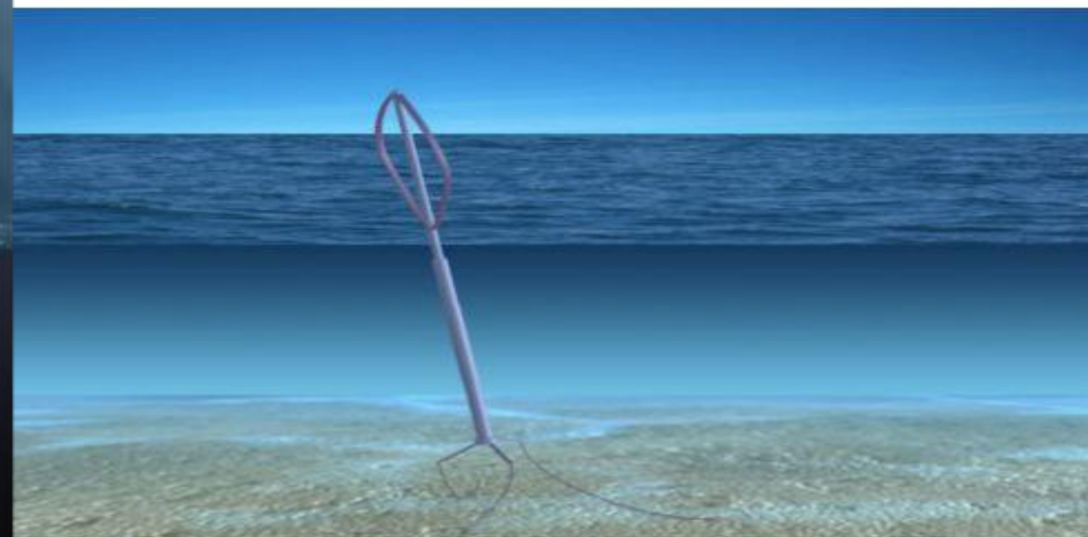


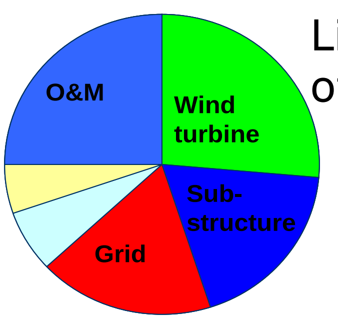
Vasilis et al.: paper to be presented at EWEA 2012

New concepts offshore



Floating turbines



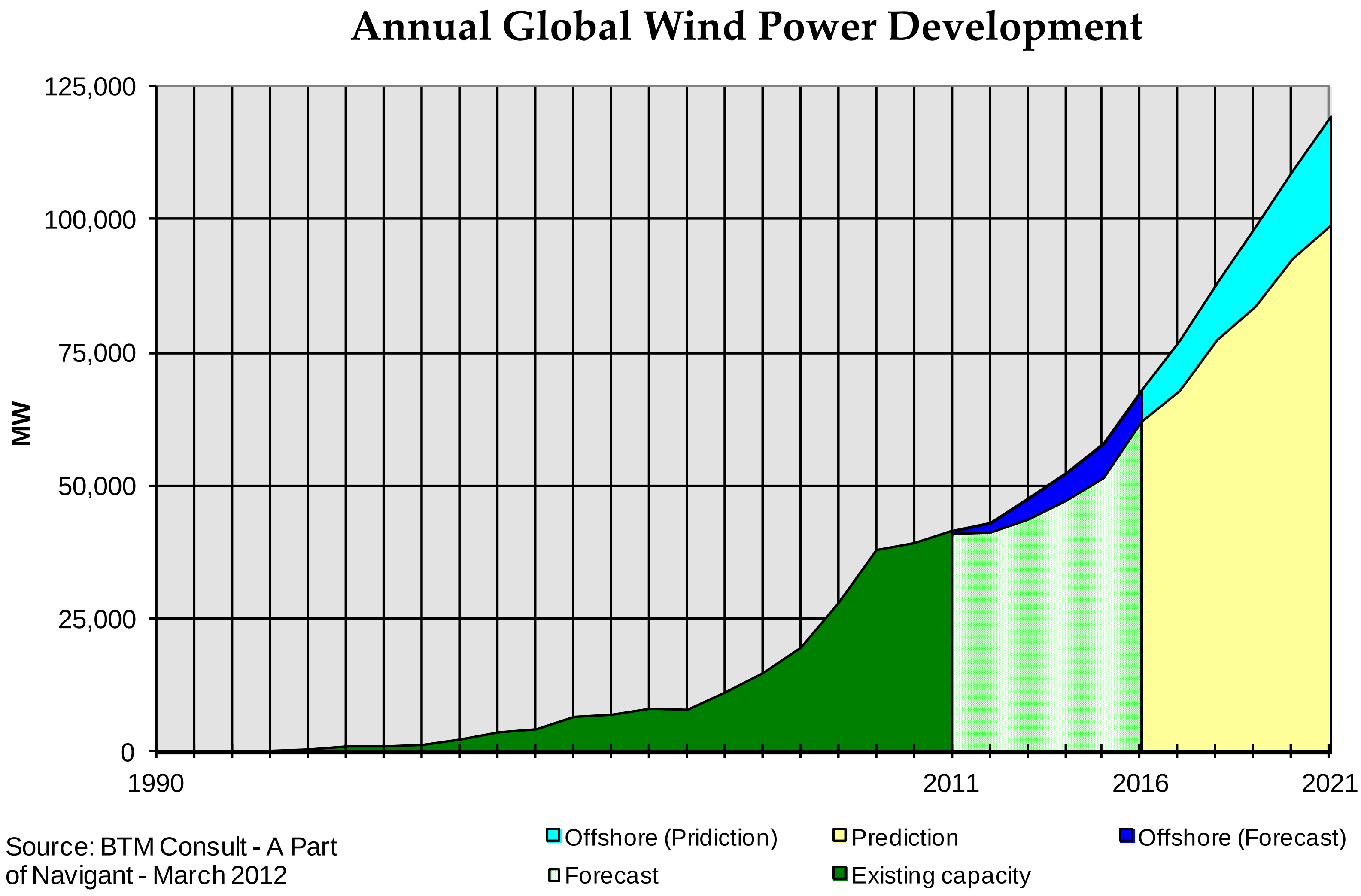


Life cycle costs offshore

Combined wind and wave energy converters

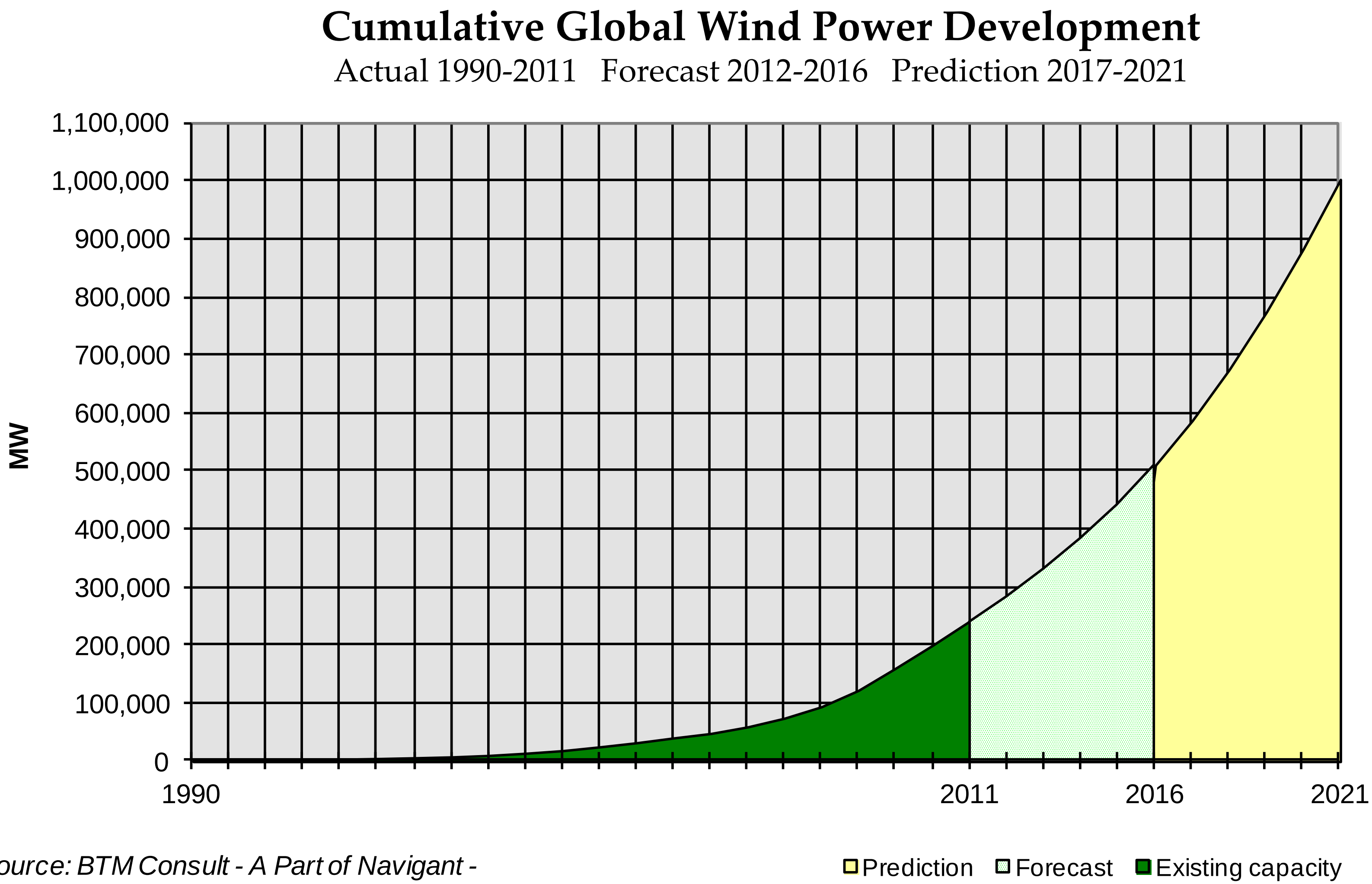
Global wind energy market perspectives

Global wind energy market perspectives



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

Global wind energy market perspectives



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

Global wind energy market perspectives

Contribution of wind power to worldwide electricity generation

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

Source: BTM Consult - A Part of Navigant - March 2012 ; World Figures: IEA World Energy Outlook 2011

World electricity consumption from wind


Energy for the future
Thank you!