



## The future of wind power

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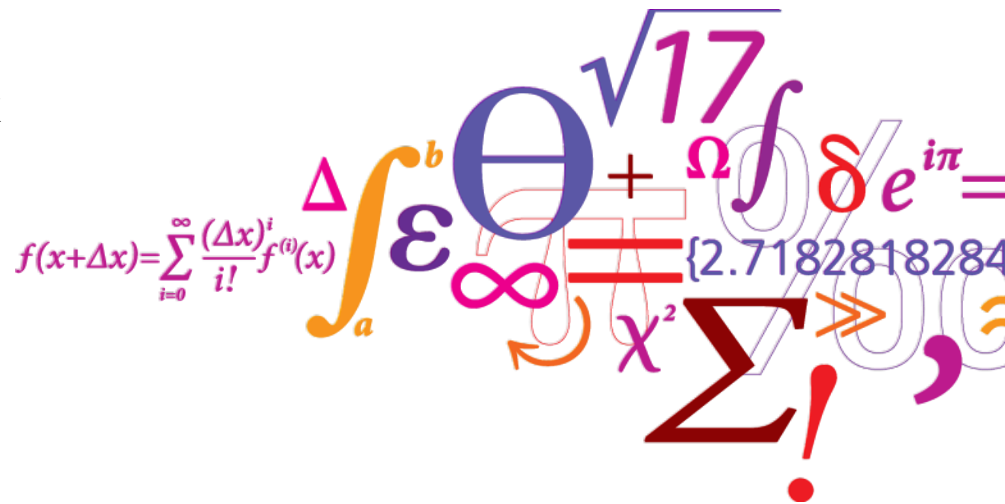
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# The future of wind power

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# Risø DTU test field for large wind turbines



Høvsøre 2007



Risø 1979

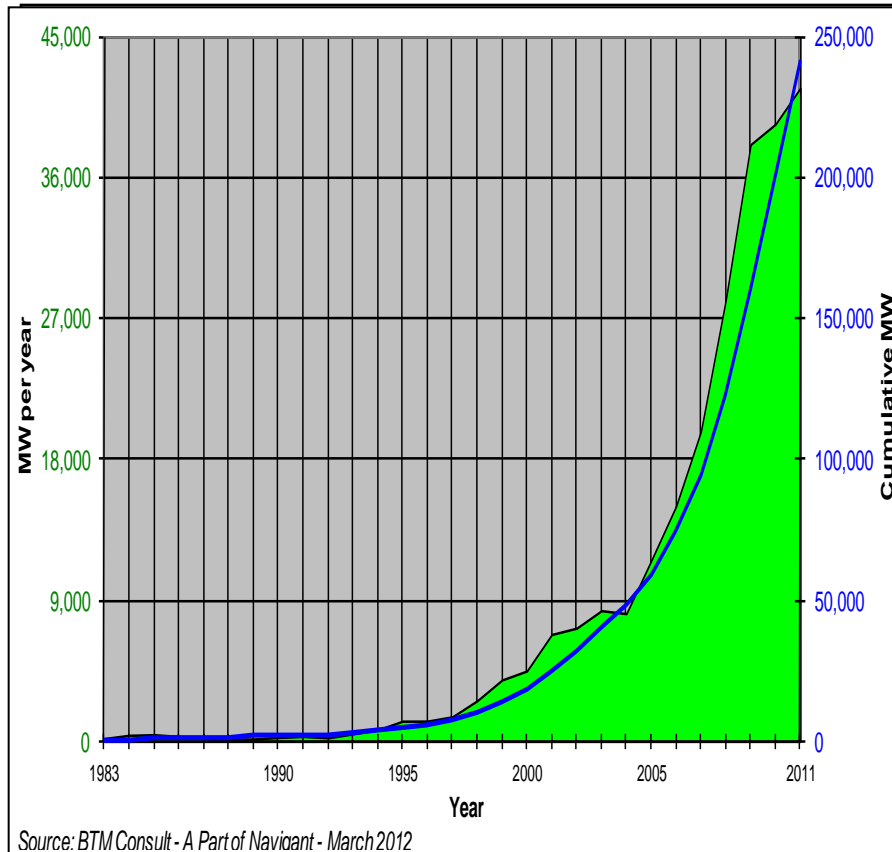


# Outline

- 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



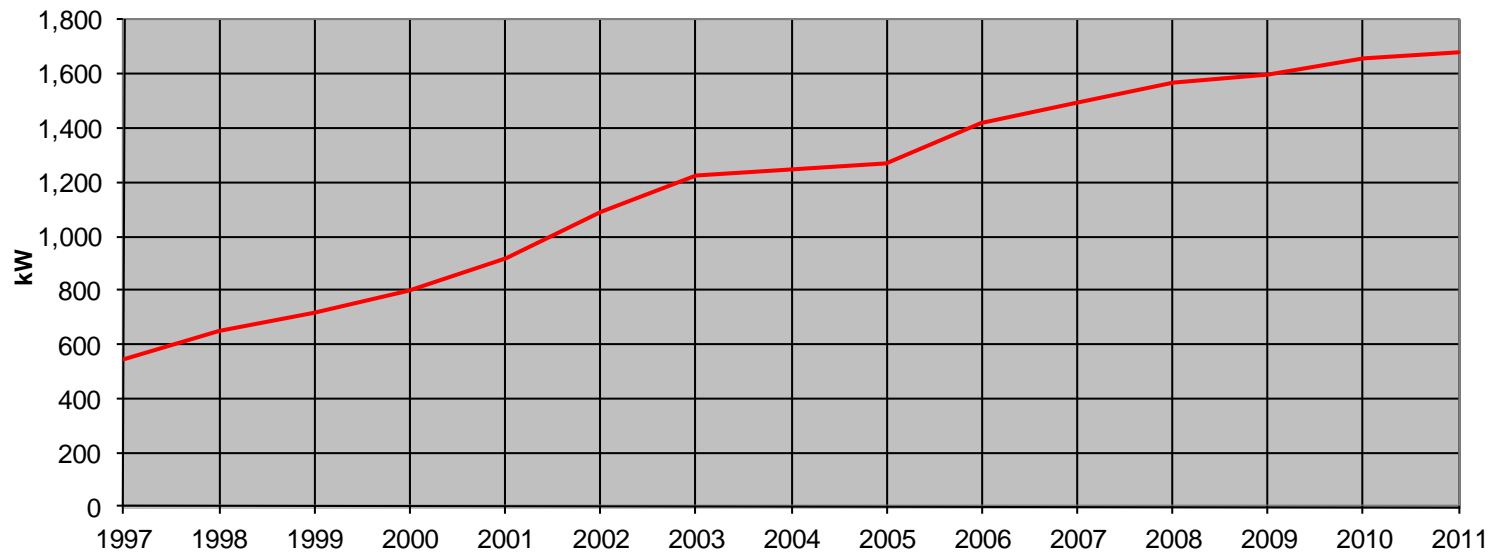
## GLOBAL STATUS

- 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

**Global Average Annual WTG in kW**

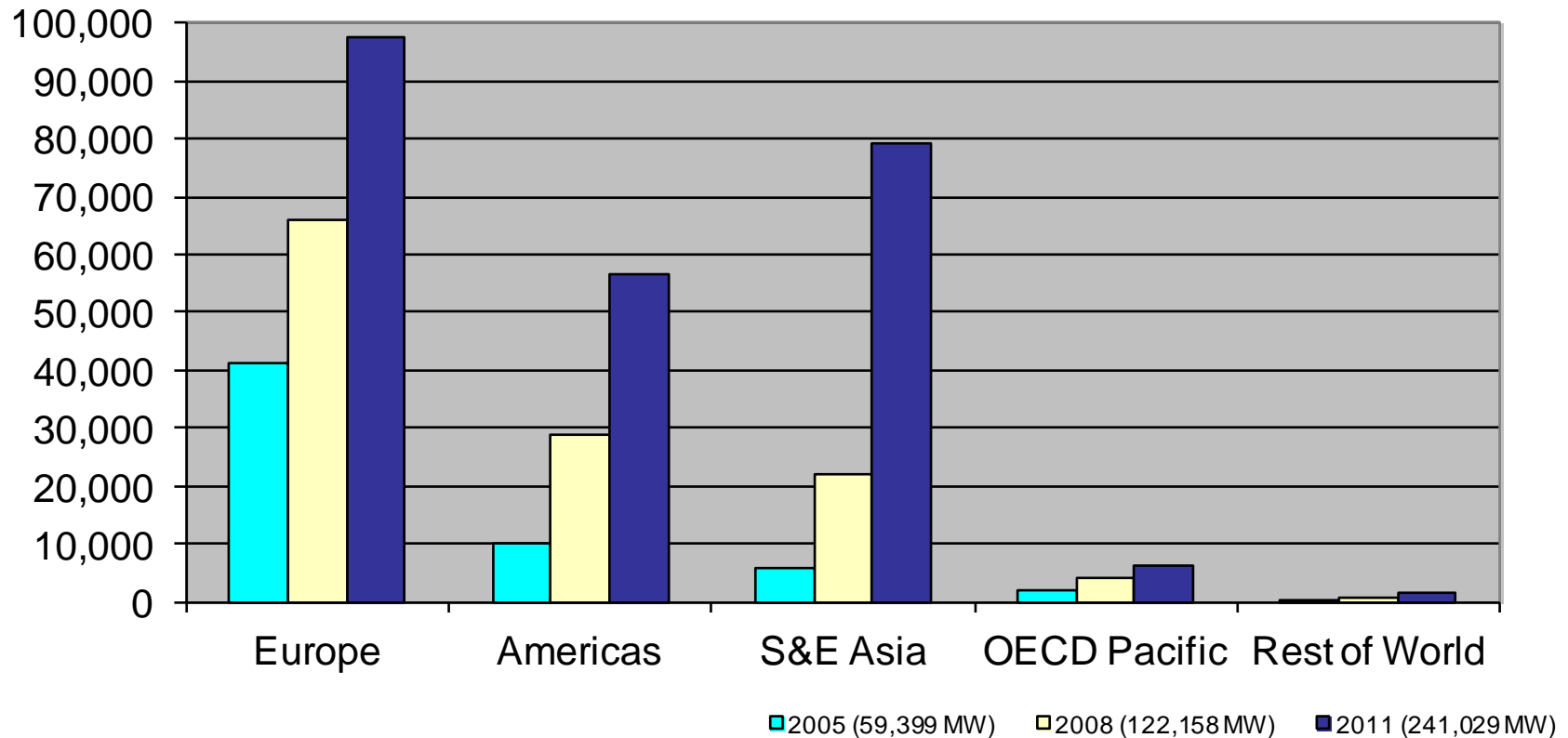


# World market status 2011



## Global Wind Power Status

Cumulative MW by end of 2005, 2008 & 2011

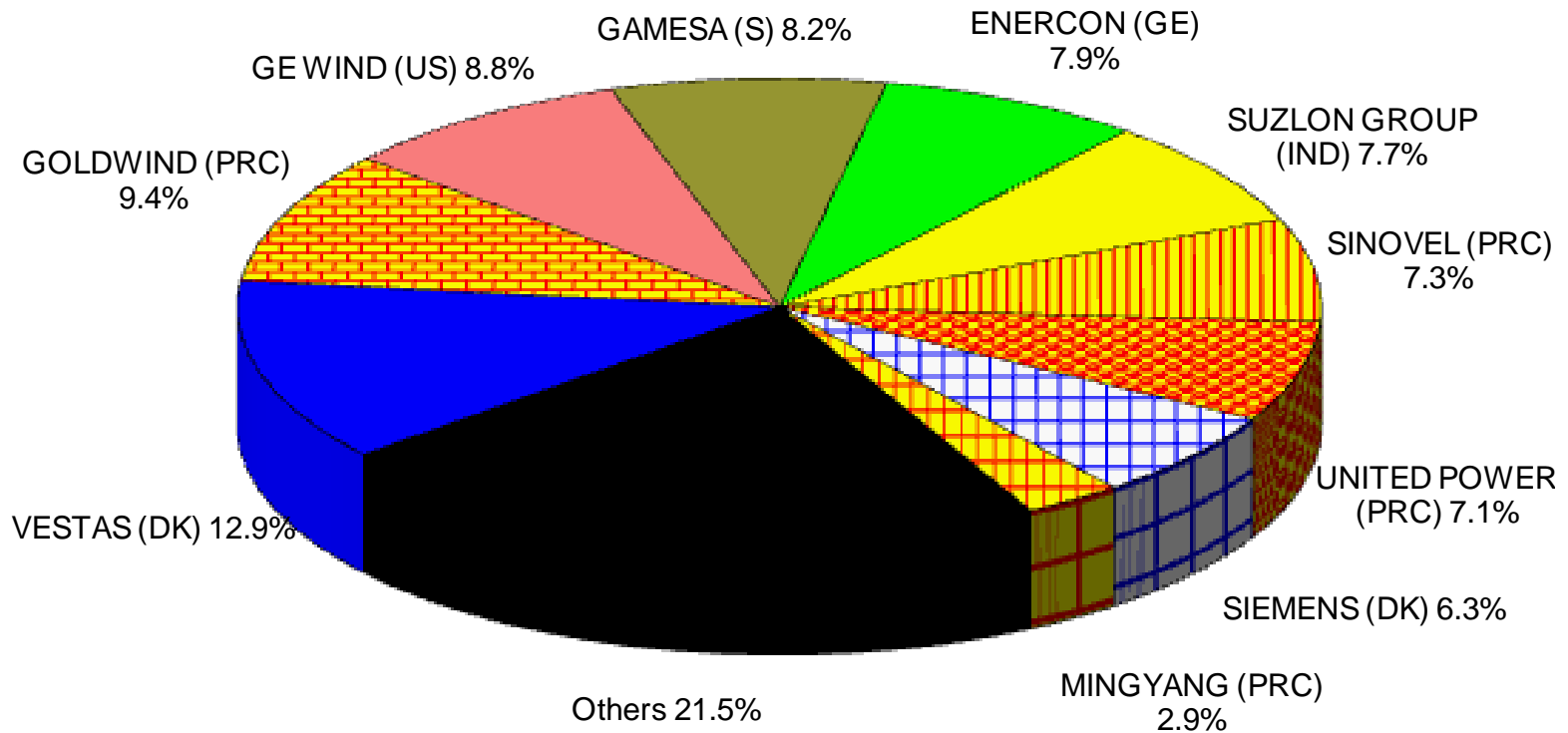


Source: BTM Consult - A Part of Navigant - March 2012



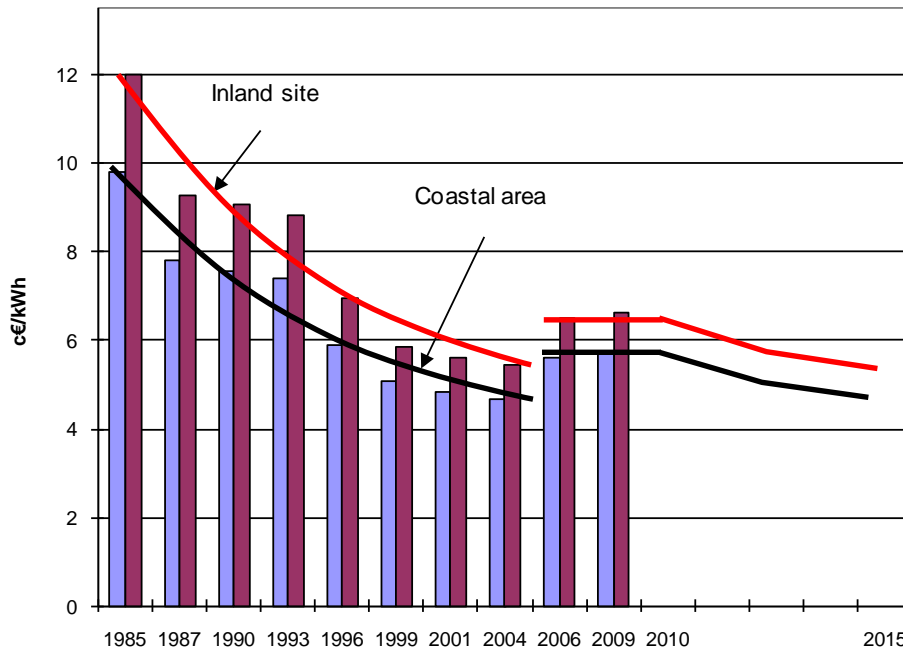
# Top-10 Suppliers (Global) in 2011

% of the total market 40,358MW



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

# Industry trends and costs



- 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

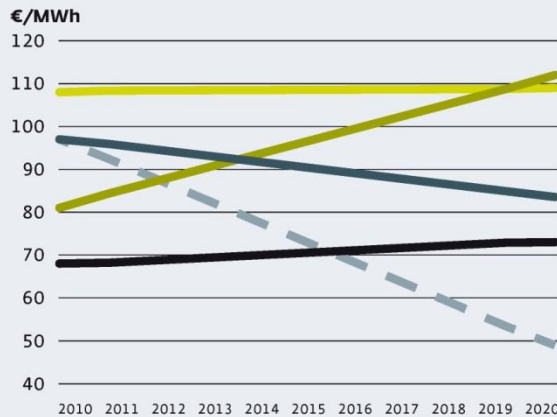
*Using experience curves to forecast wind energy economics up to 2015. The costs shown are for an average 2 MW turbine with a present-day production cost of euro €6.1/kWh in a medium wind regime (from [Lemming & Morthorst])*

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

**Figure 3**

Projections for CoE from new built power stations

- Gas
- Biomass
- Offshore wind
- - - Offshore wind - Megavind target
- Coal



**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<sub>2</sub> emission quotas, NO<sub>x</sub>, SO<sub>x</sub> 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**
- ❑ **aeroacoustics 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 through rotor disc.
- Extracts energy from mass of air corresponding to its own total weight in 5 seconds.

# Upscaling has been main driver



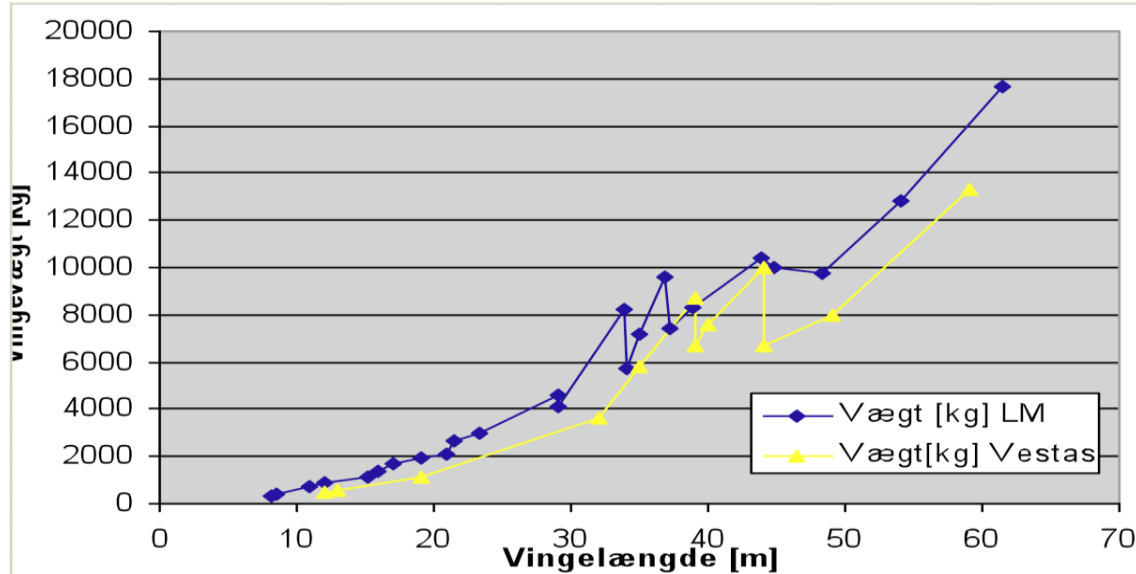
## Upscaling: "Square-cube law"

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

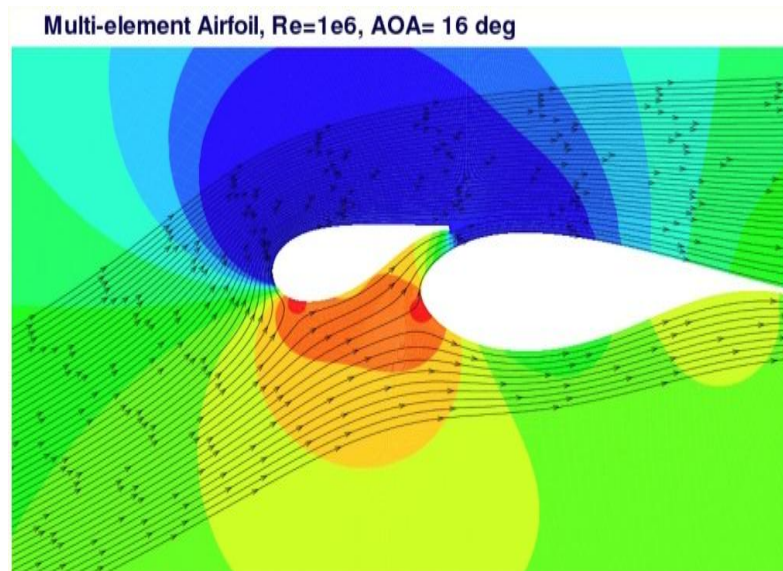
Limit in size ?



# 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

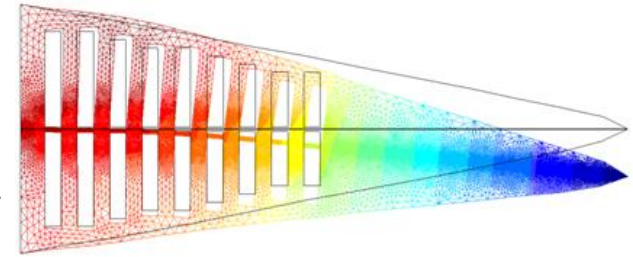
# Research and technology trends

# Research areas related to future technology

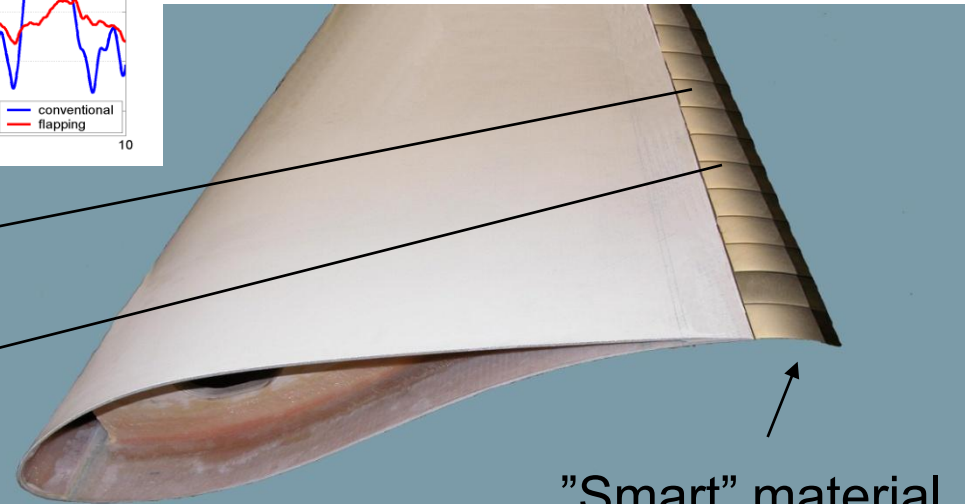
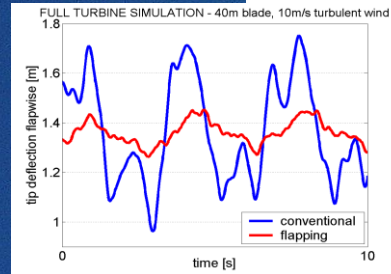
- ❑ distributed control with flaps along the blades (e.g. 100 m long) to alleviate loads
- ❑ optimized aeroelastic coupling effects for passive load alleviation
- ❑ simulating real inflow with turbulence and shear to the turbine in the CFD rotor codes
- ❑ detailed monitoring of inflow to the turbine 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



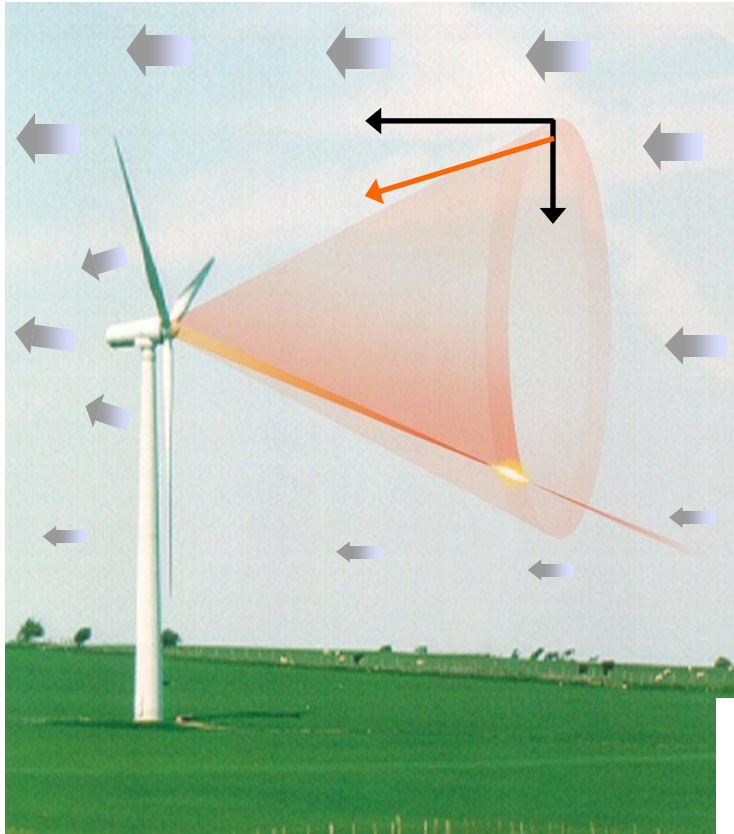
20-40% reduction in blade- and tower fatigue loads



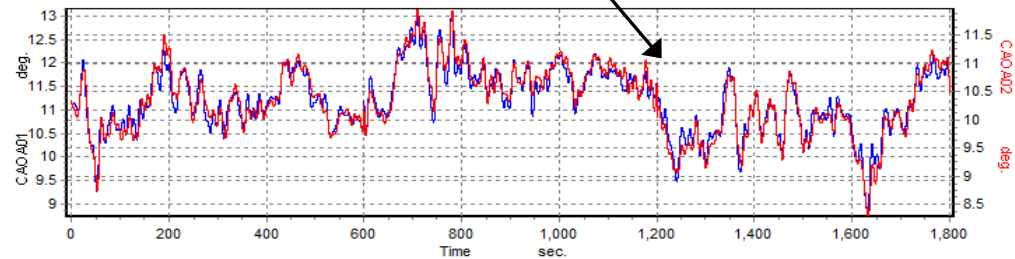
"Smart" material variable trailing edge flap

# Measuring inflow for pitch or flap control

Lidar technology



Inflow measured with four five hole pitot tubes

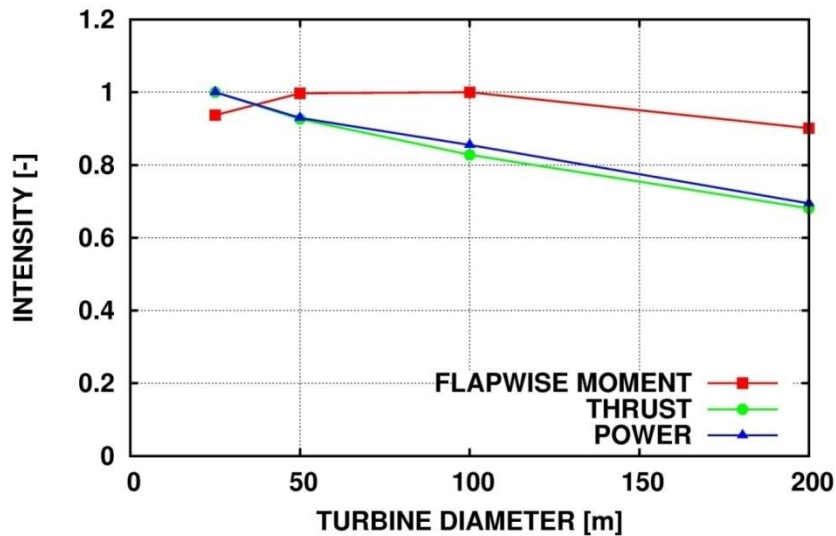


# Upscaling effects

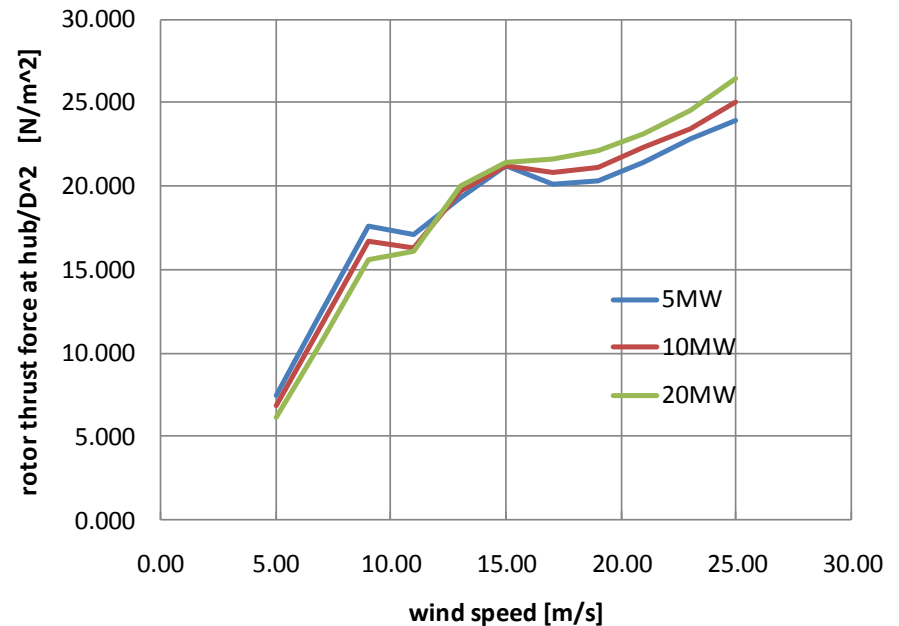
- Filtering of turbulence by the rotor increases with size

Results from simplified aerodynamic model with turbulent inflow

OPERATION AT 8 m/s, TI=15%

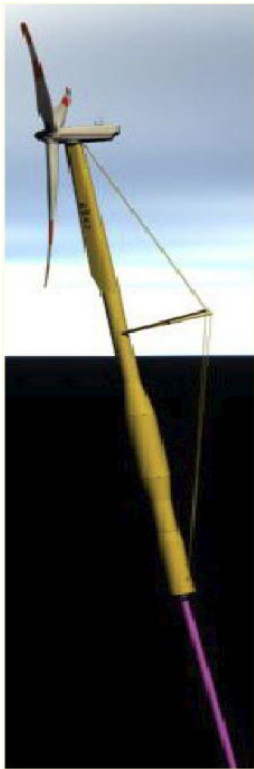


Results based on full aeroelastic model

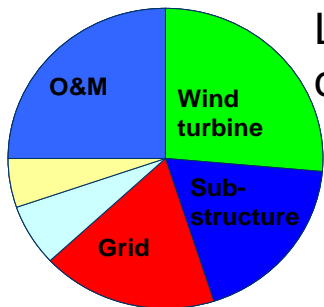
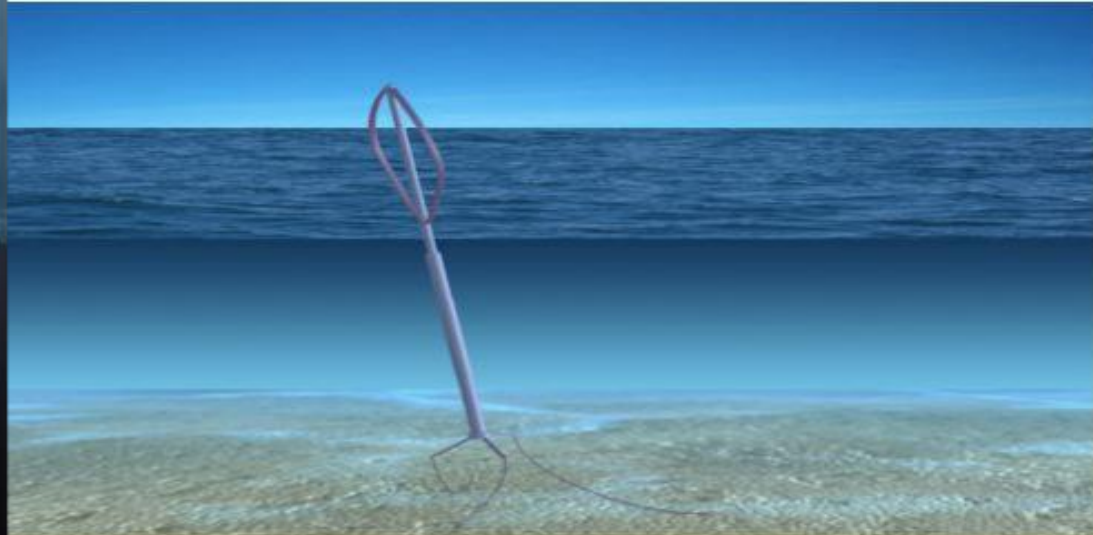


Vasilis et al.: paper to be presented at EWEA 2012

# New concepts offshore



Floating turbines



Life cycle costs offshore

Combined wind and wave energy converters

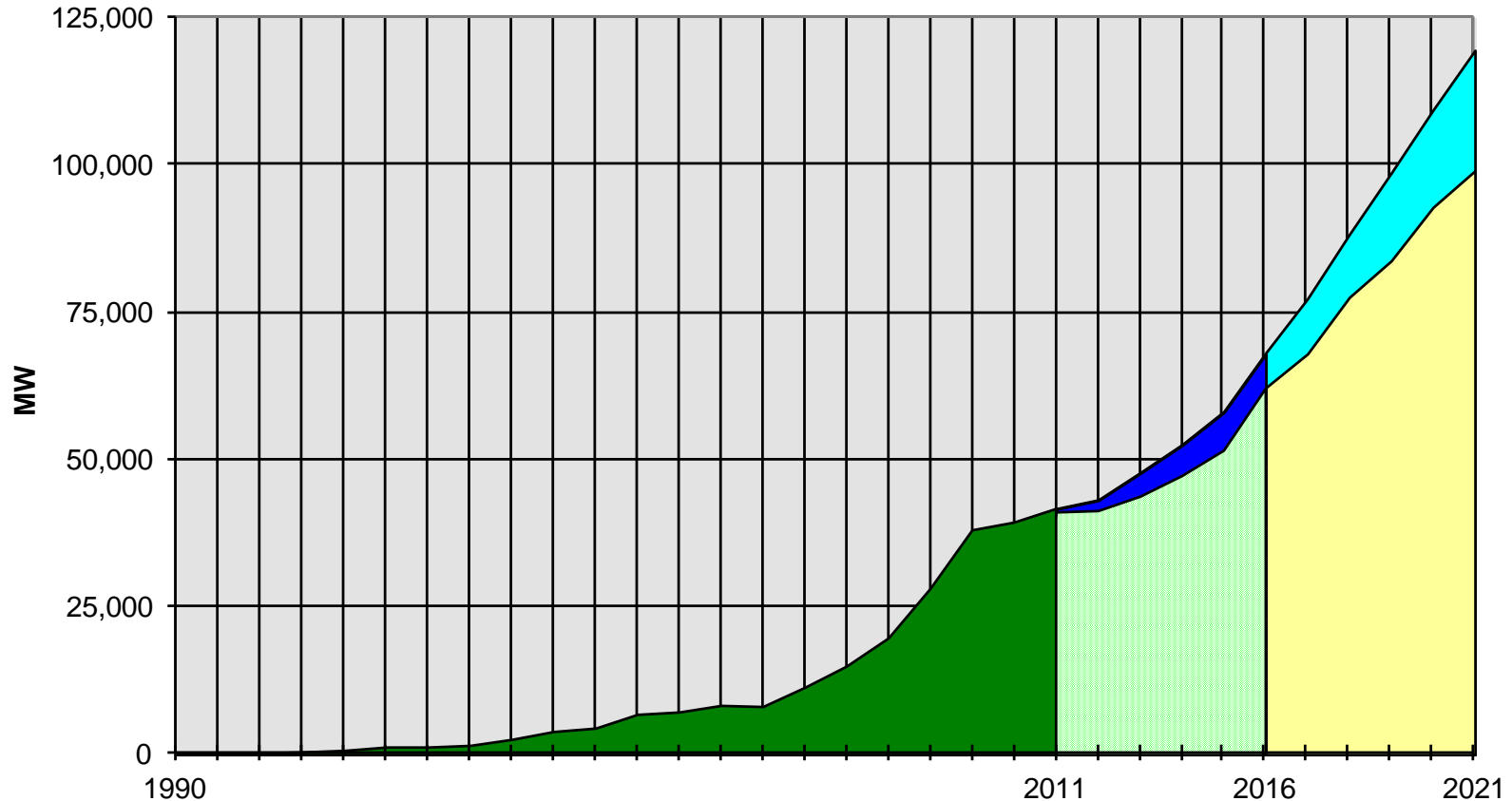


# **Global wind energy market perspectives**



# Global wind energy market perspectives

## Annual Global Wind Power Development



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

Offshore (Prediction)  
Forecast

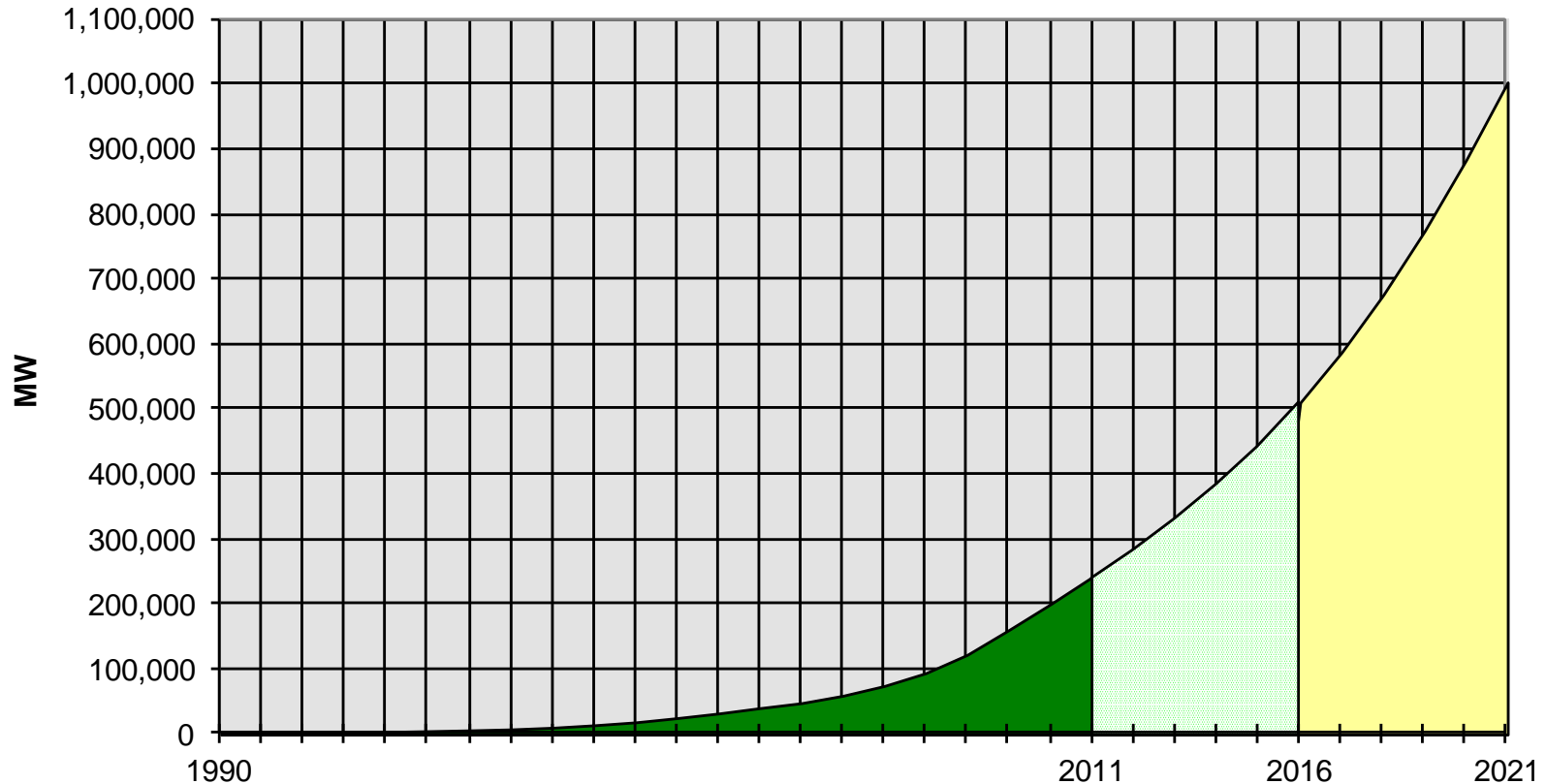
Prediction  
Existing capacity

Offshore (Forecast)

# 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

■ Prediction 
 ■ Forecast 
 ■ Existing capacity

# Global wind energy market perspectives

## Contribution of wind power to worldwide electricity generation

Generation Technology	Electricity gen. by Wind Power (BTM-C)	Electricity from all gen. sources (incl. Wind) IEA	Wind Power's share of the world's electricity generation:
Year:	TWh	TWh	%
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%
<b>2011</b>	<b>473.88</b>	<b>20,976</b>	<b>2.26%</b>
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!**