Global wind energy development from a European R&D Perspective

Jos Beurskens

SET Analysis

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Jos Beurskens

WinterWind 2012, February 7, 2012
Skellefteå (S)

This presentation

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- Putting Cold Climate issues in a wider perspective
- Mainstream developments; review
- Similarities between CC and Offshore issues
- Towards a universal (= IEA, EU) Research Agenda

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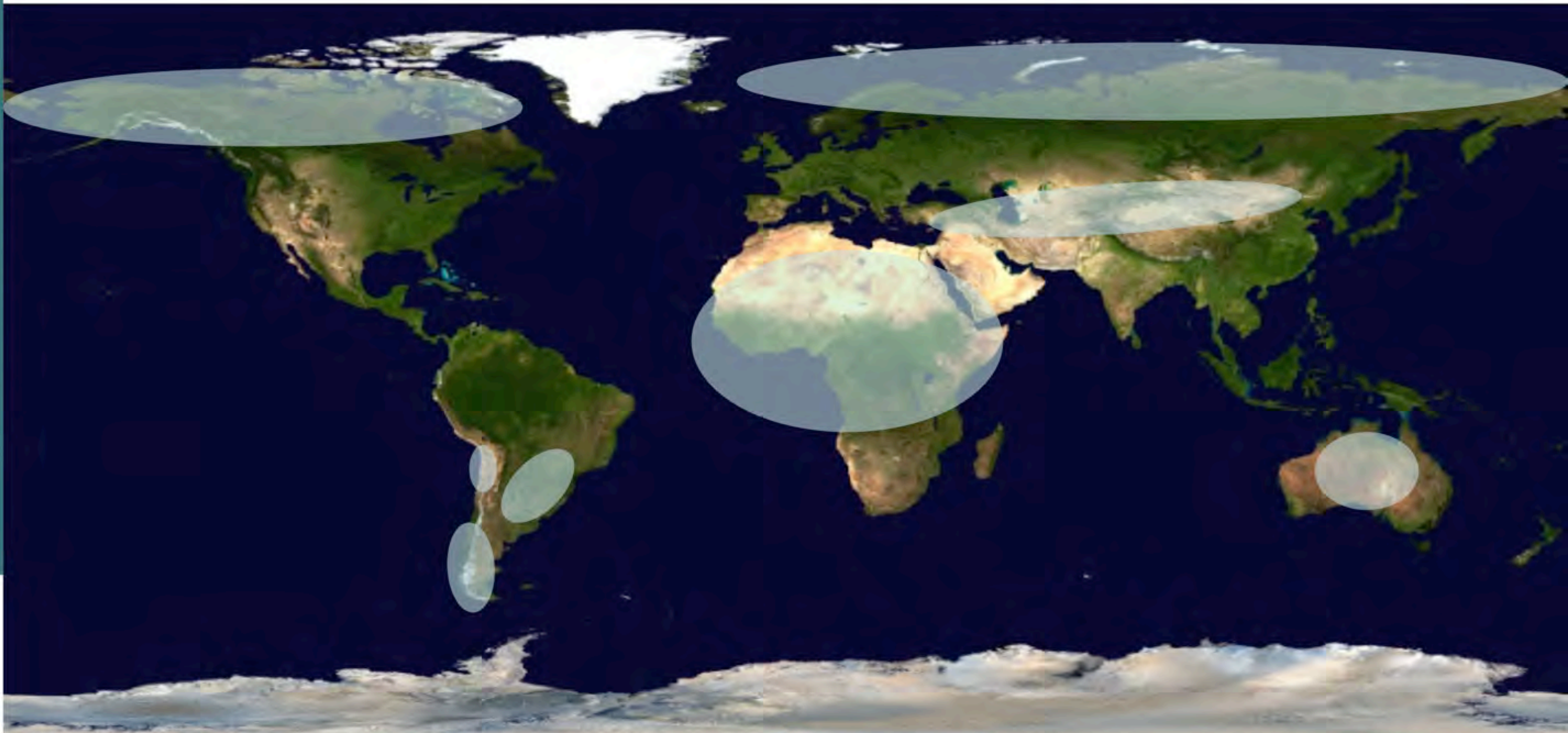
Why is it necessary to put CC issues in a wider perspective?

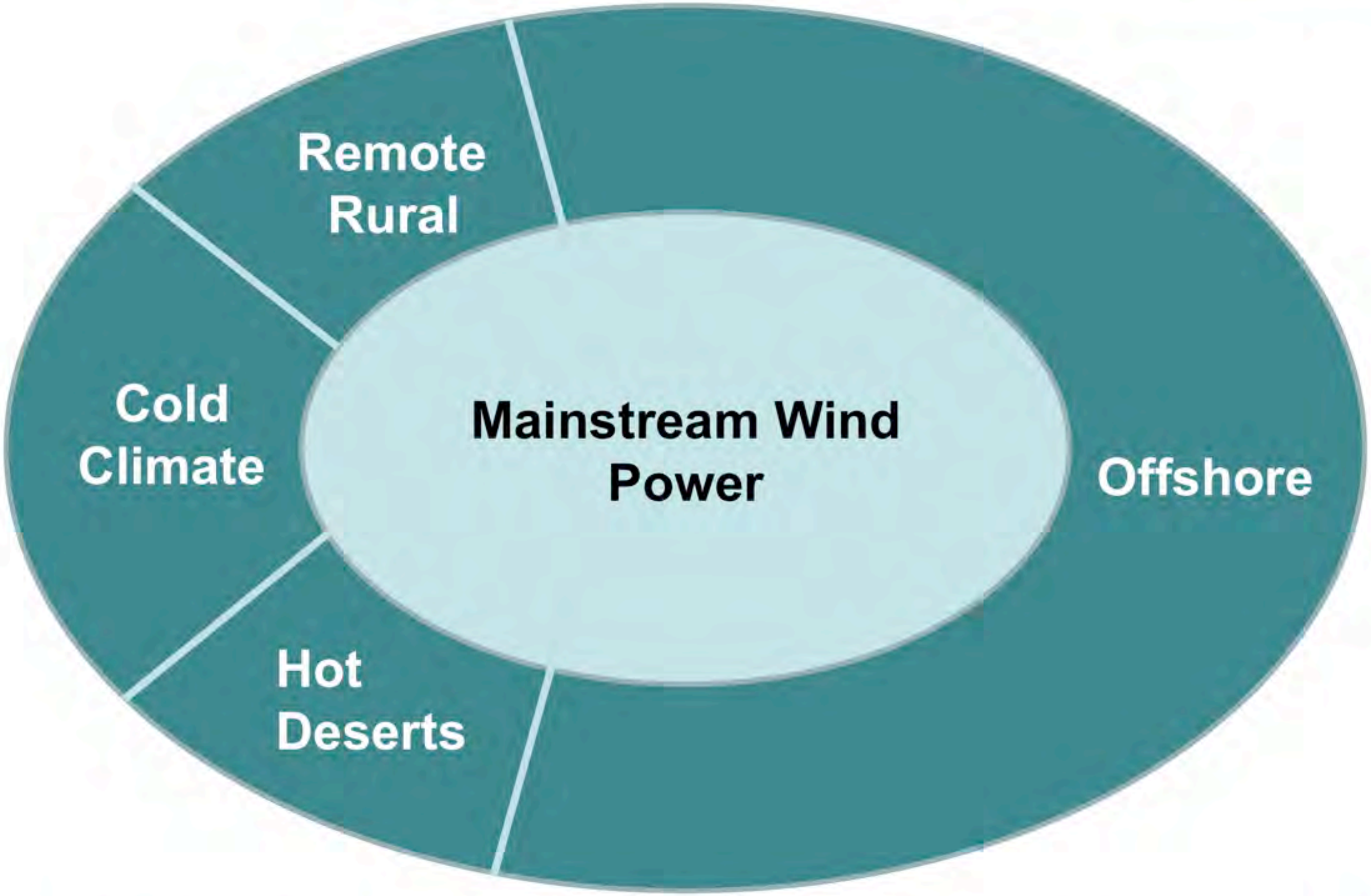
Because:

- Mainstream Politics and Industry is only impressed by GW's and size
- Instead, the number of people served should be accounted for

External Conditions

- The vast majority of wind turbines have been installed in ‘moderate’ climates
- Remote and extreme areas are under explored and exploited





The present Research Agenda is incomplete !

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- Claim x % of offshore R&D resources for CC, hot deserts, remote& rural areas

- Claim y% of this part for CC

Various types of electricity producing wind turbines

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Grid connected turbines; small scale

Grid connected turbines; wind farms on land

Grid connected turbines; wind farms offshore

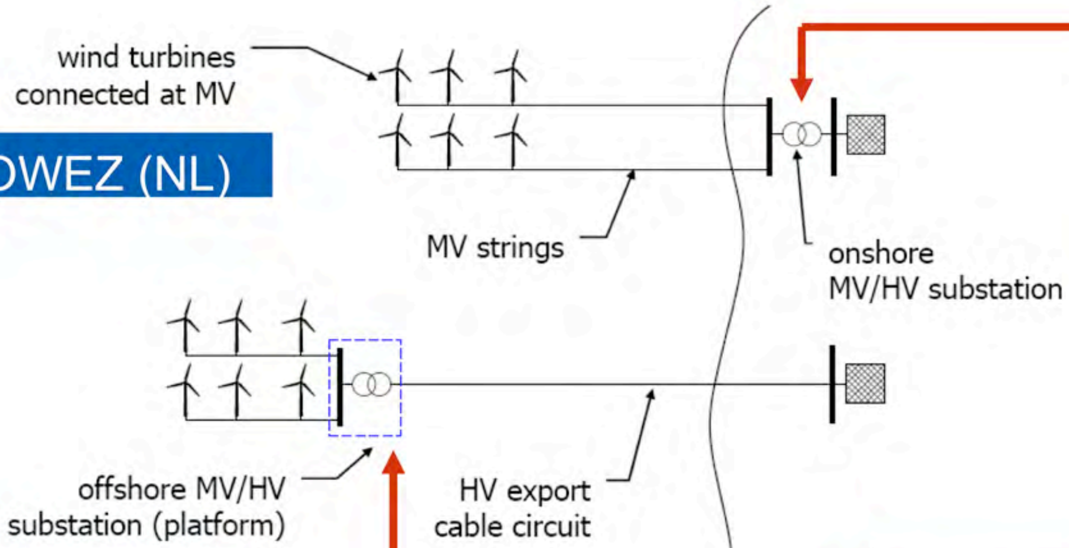
Autonomous

Hybrid systems (AWDS)

Hybrid systems (W-PV)

Grid connection of offshore wind farms

E.g.: OWEZ (NL)

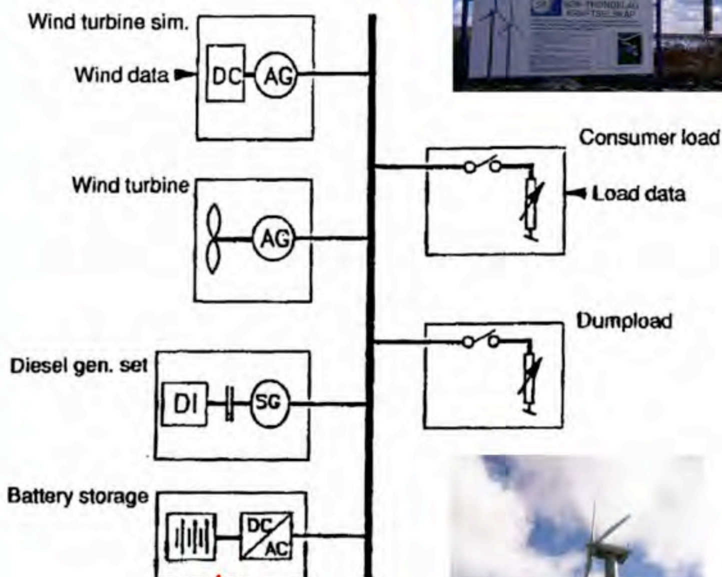


E.g.: Q7 (NL)

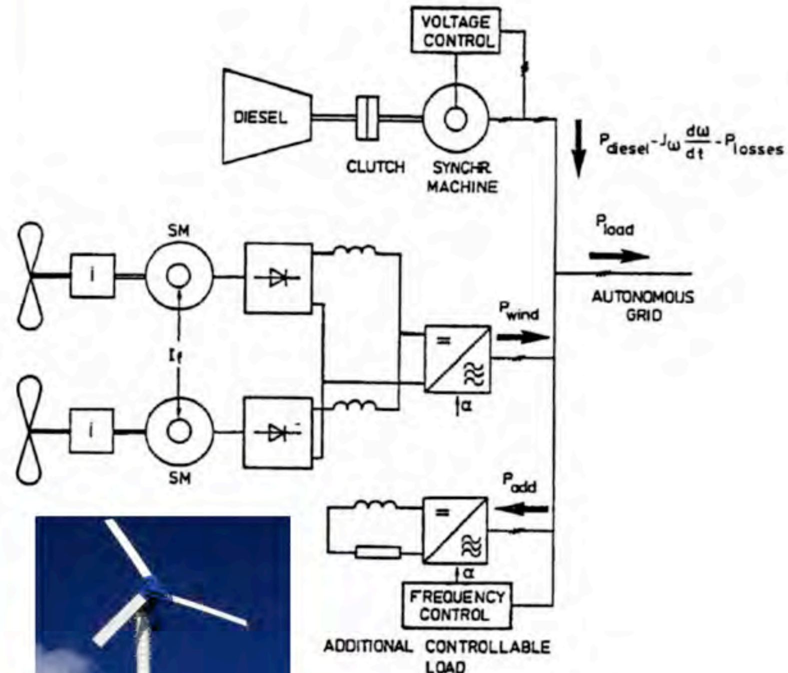
Bron: Arjen van der Meer, TUDelft

Electrical lay-out of autonomous wind diesel systems (AWDS)

Frøya. 50 kW + 50 kW



AWDS developed by TUEindhoven and ECN

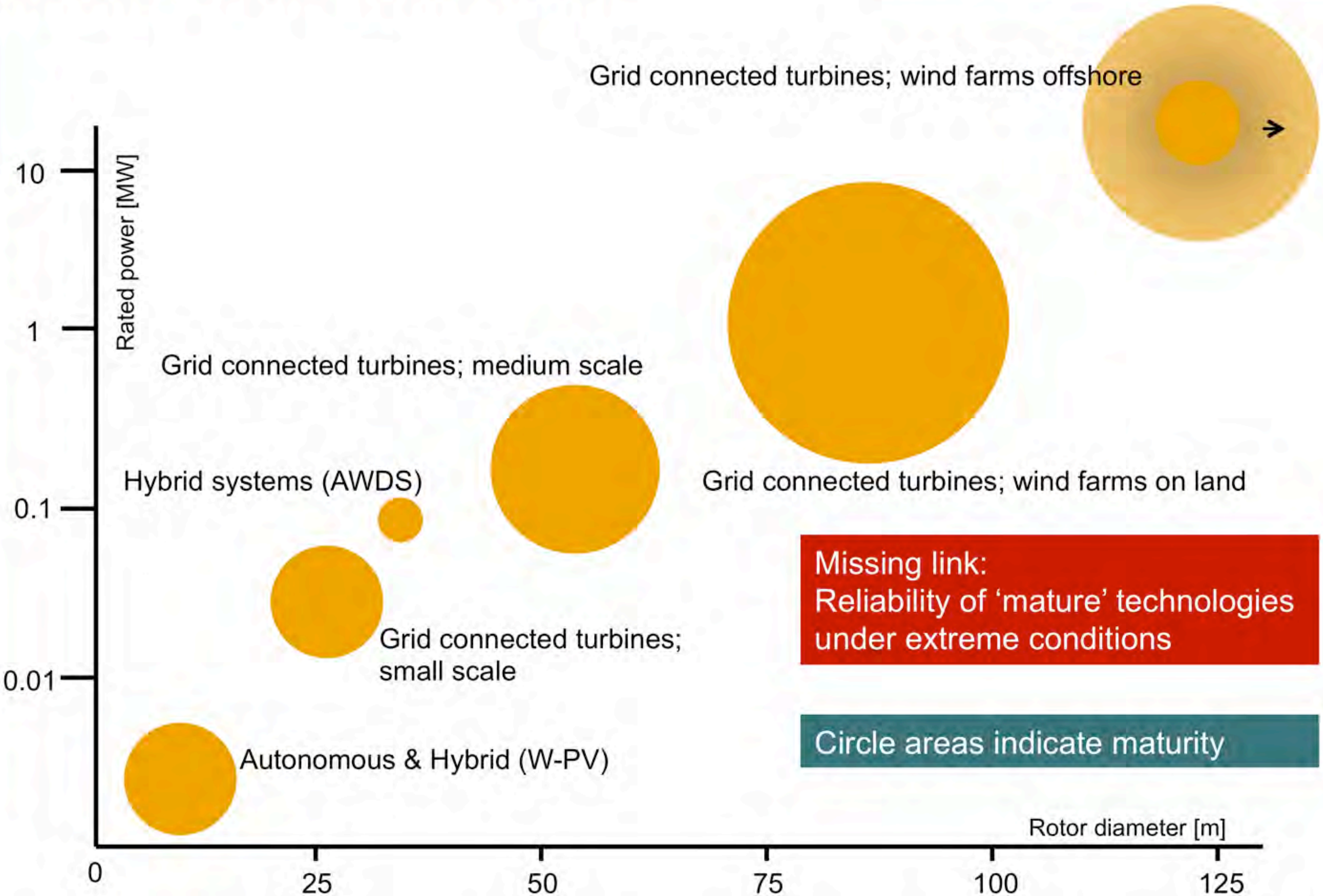


Autonomous wind turbines

March 14, 1895: Nansen and Johansen (second and seventh from left) prepare to leave the *Fram* with three sleds, 28 dogs, and three Norwegian flags. Their goal: the North Pole.

Copied from National Geographic Magazine

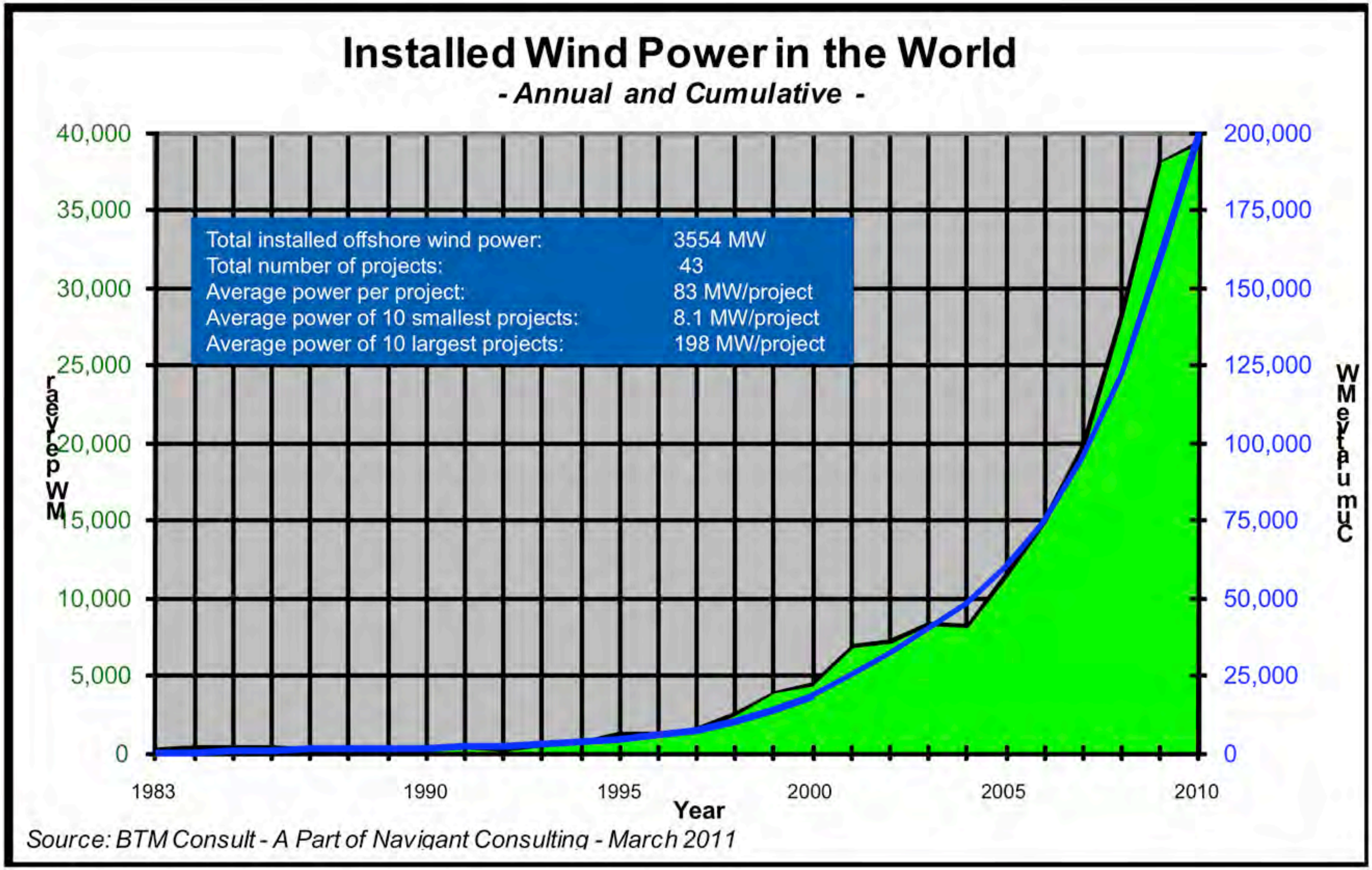
Maturity of the technologies



Missing link:
Reliability of 'mature' technologies under extreme conditions

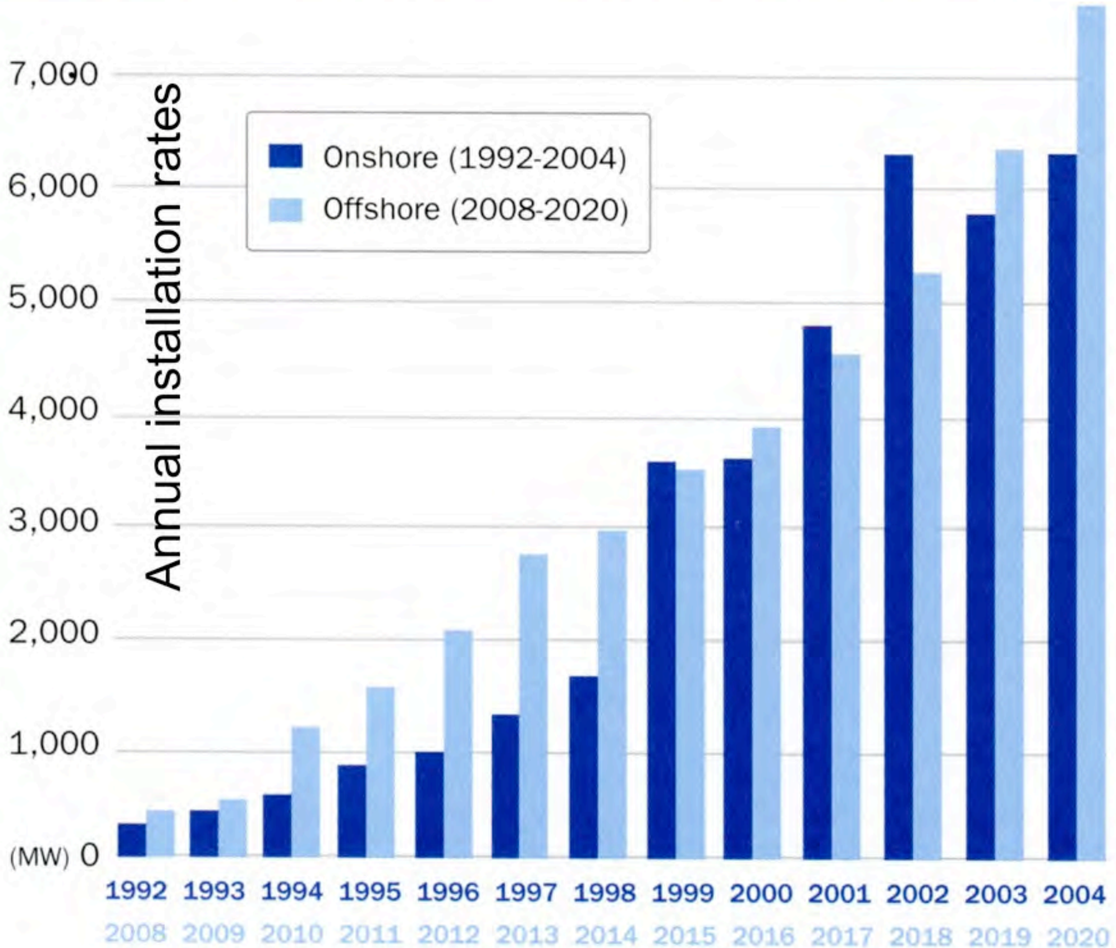
Circle areas indicate maturity

Market (31-12-2010)



EWEA's wind power scenarios (in GW)

FIGURE 1: Historical onshore growth 1992-2004 compared to EWEA's offshore projection 2008-2020 (MW)

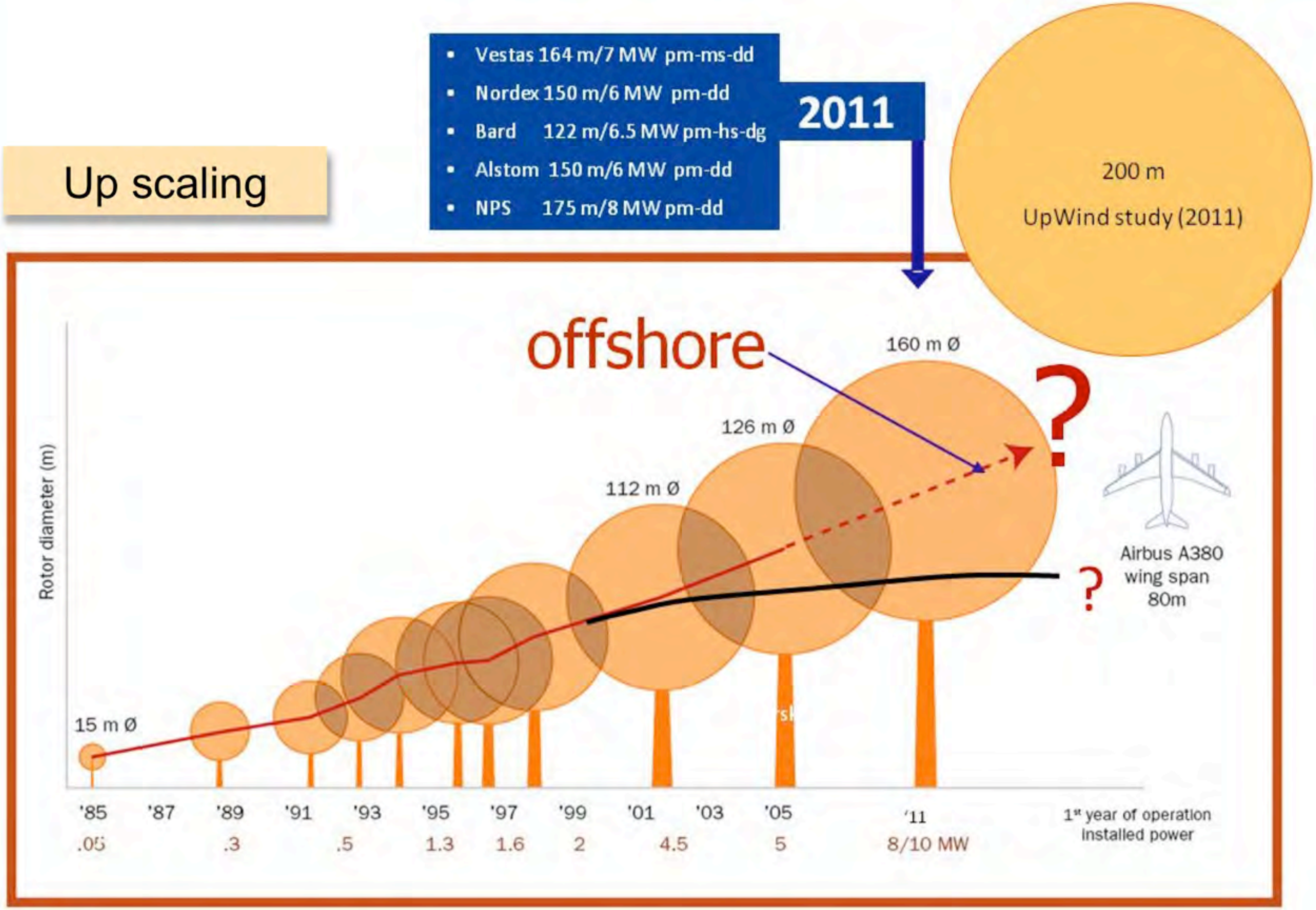


Offshore is the driver !

Time lines displaced by 16 years !

Source: EWEA
Oceans of Opportunity

The evolution of wind turbines



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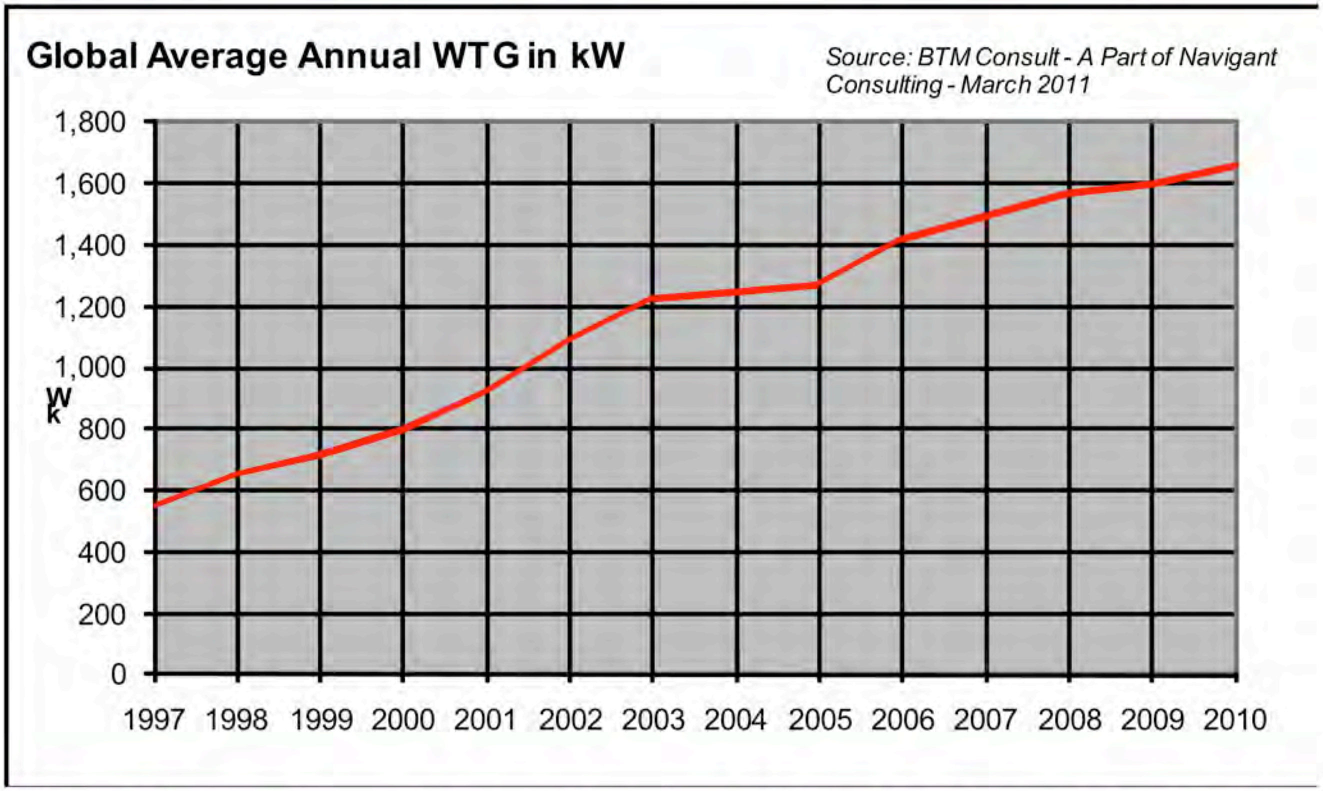
The evolution of wind turbines

Average size Wind turbine (kW), installed each year

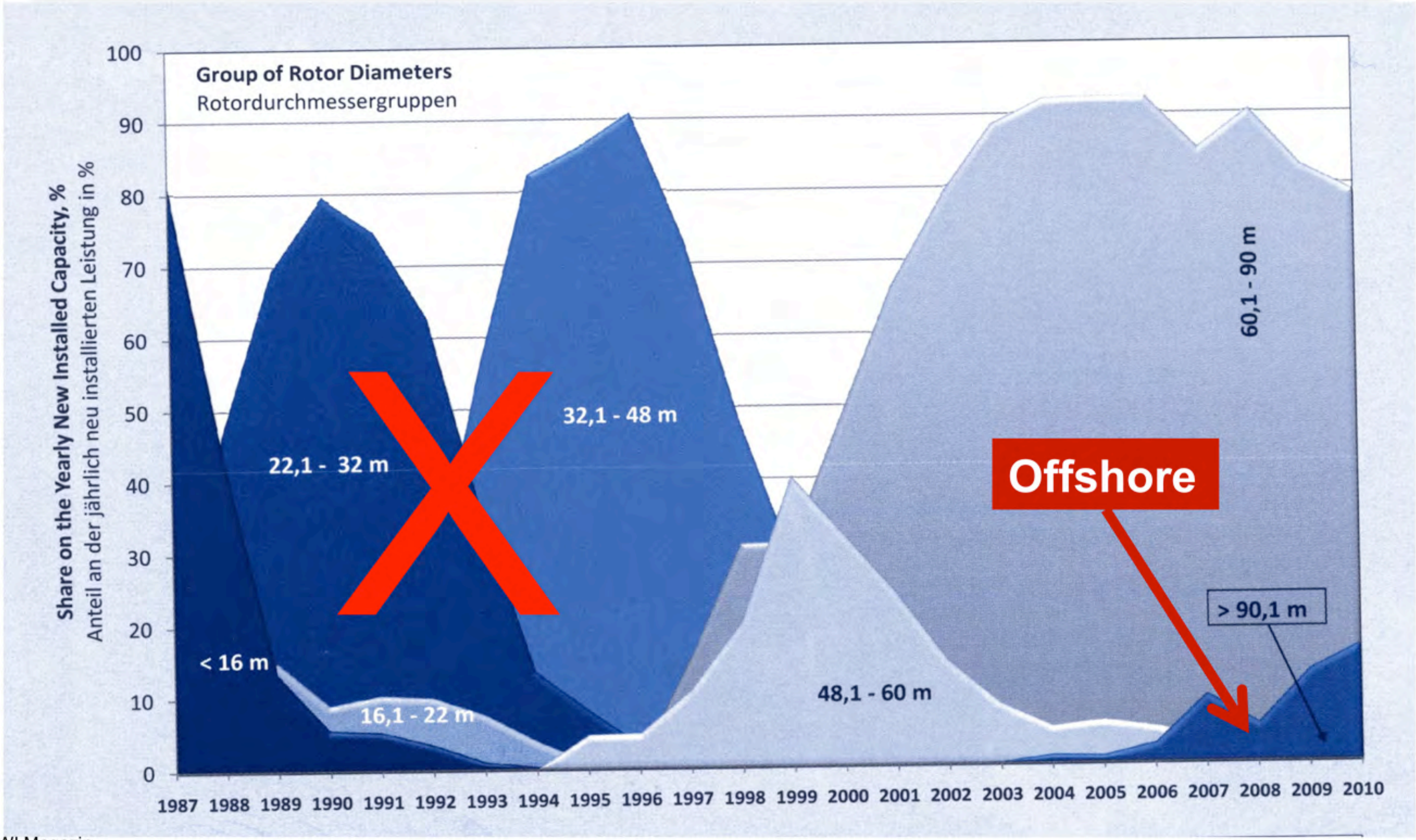


Year	China	Denmark	Germany	India	Spain	Sweden	UK	USA
2005	897	1381	1634	780	1105	1126	2172	1466
2006	931	1875	1848	926	1469	1138	1953	1667
2007	1079	850	1879	986	1648	1670	2049	1669
2008	1220	2277	1916	999	1837	1738	2256	1677
2009	1360	2368	1976	1117	1904	1974	2241	1731
2010	*1,469*	*2,514*	*2,047*	*1,293*	*1,929*	*1,995*	*2,568*	*1,875*

Source: BTM Consult - A Part of Navigant Consulting - March 2011

The evolution of wind turbines

Wind turbine capacity product cycle



Source: DEWI Magazin

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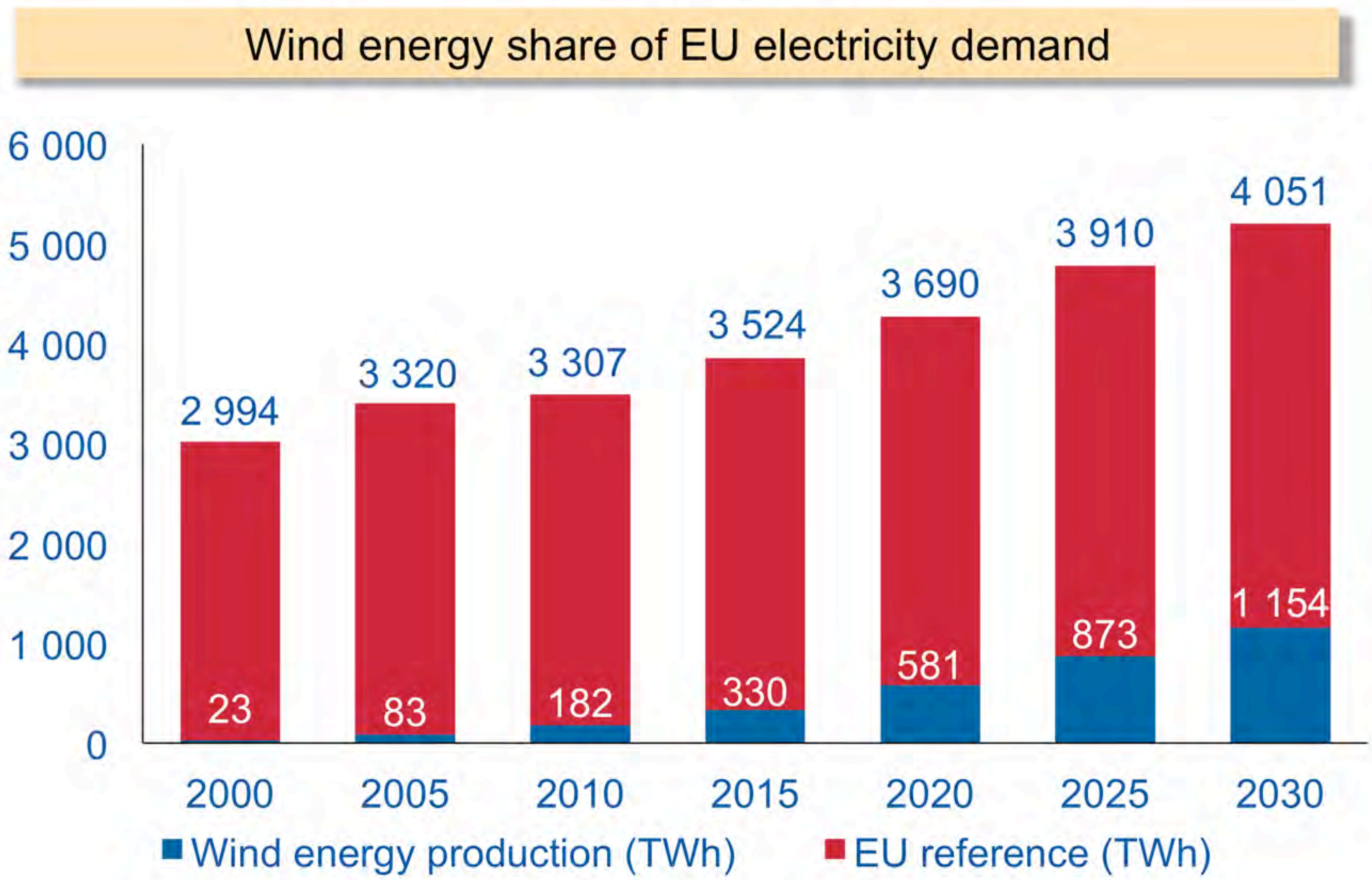

Source: EWEA and EC 2010

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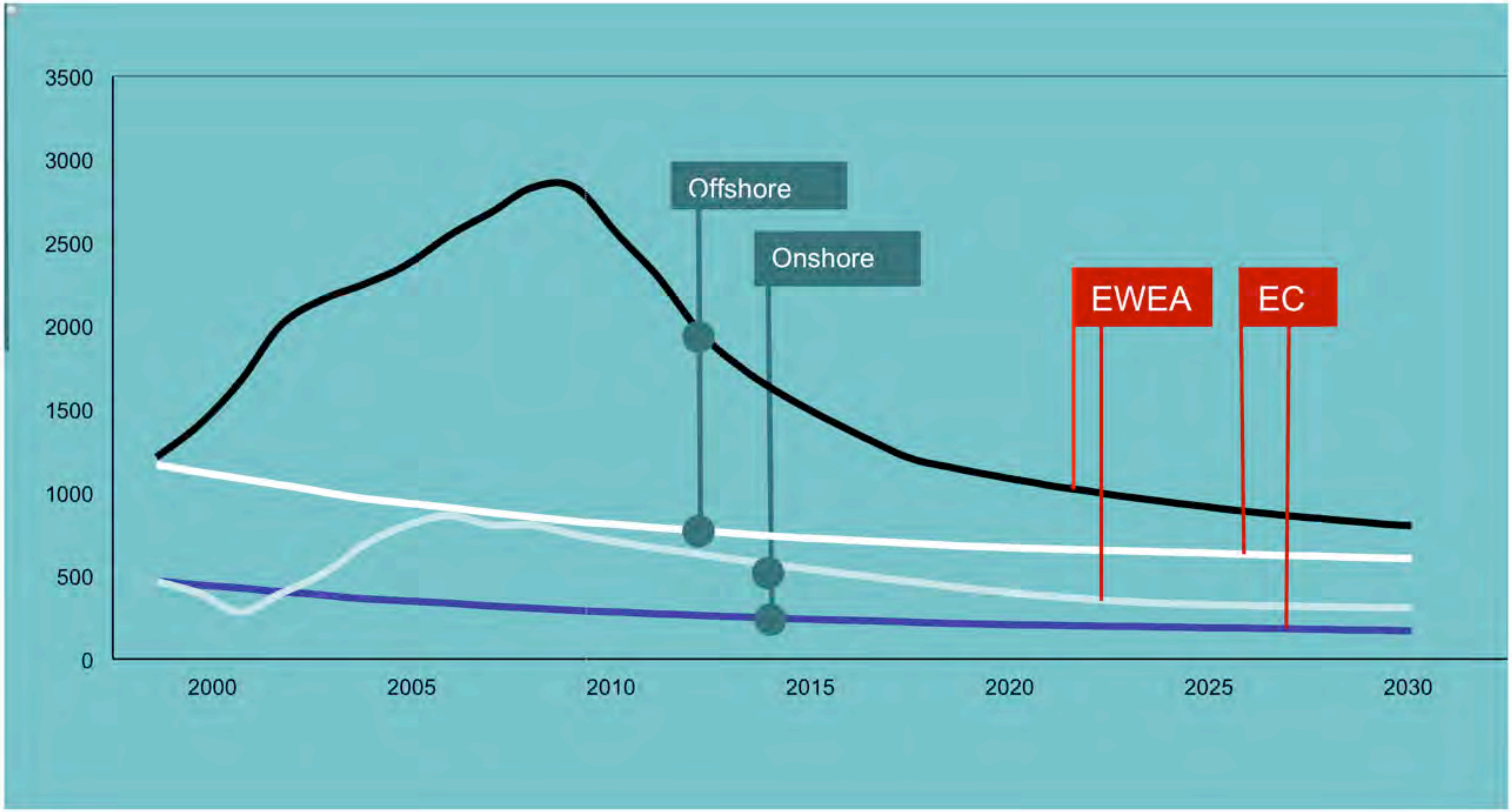
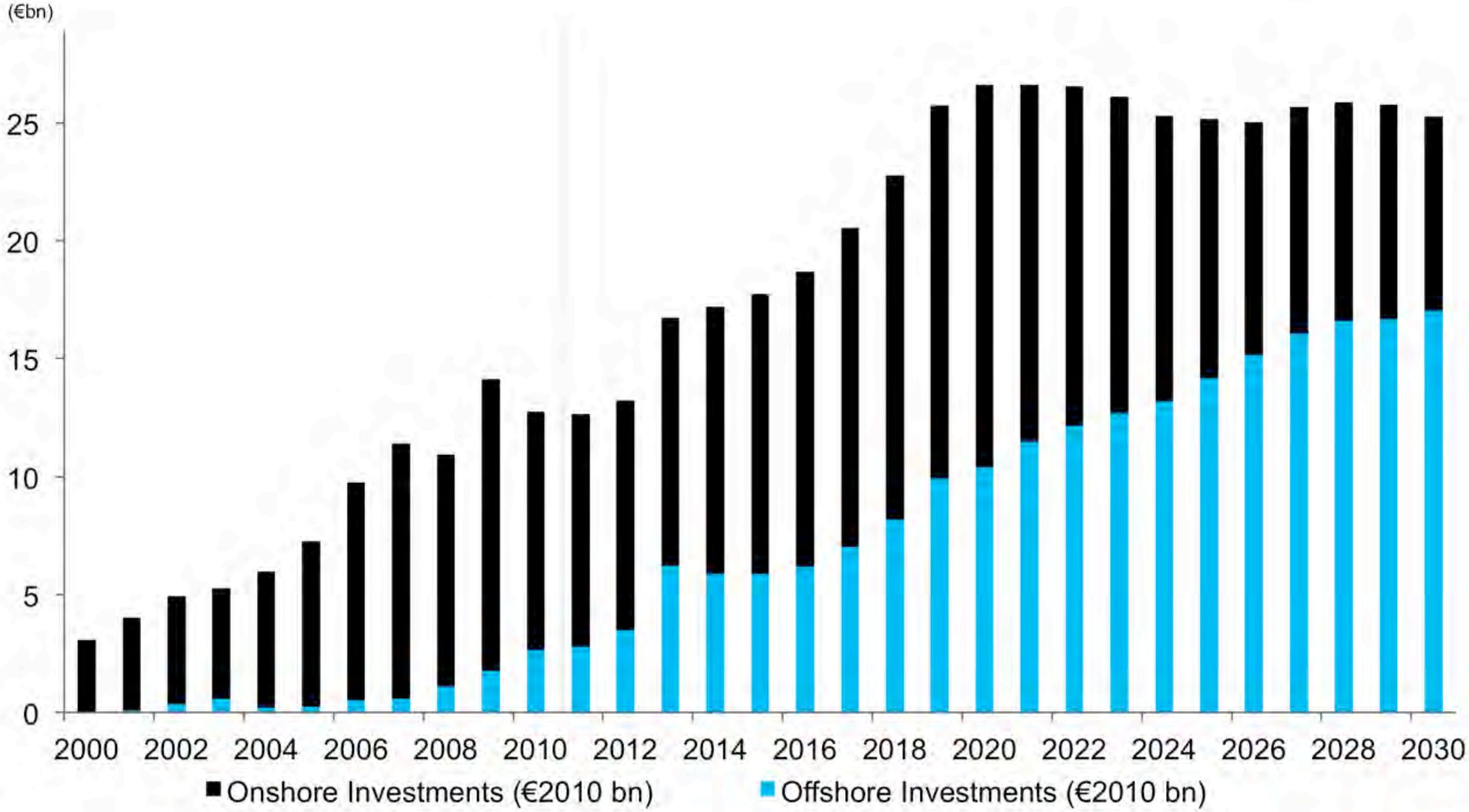
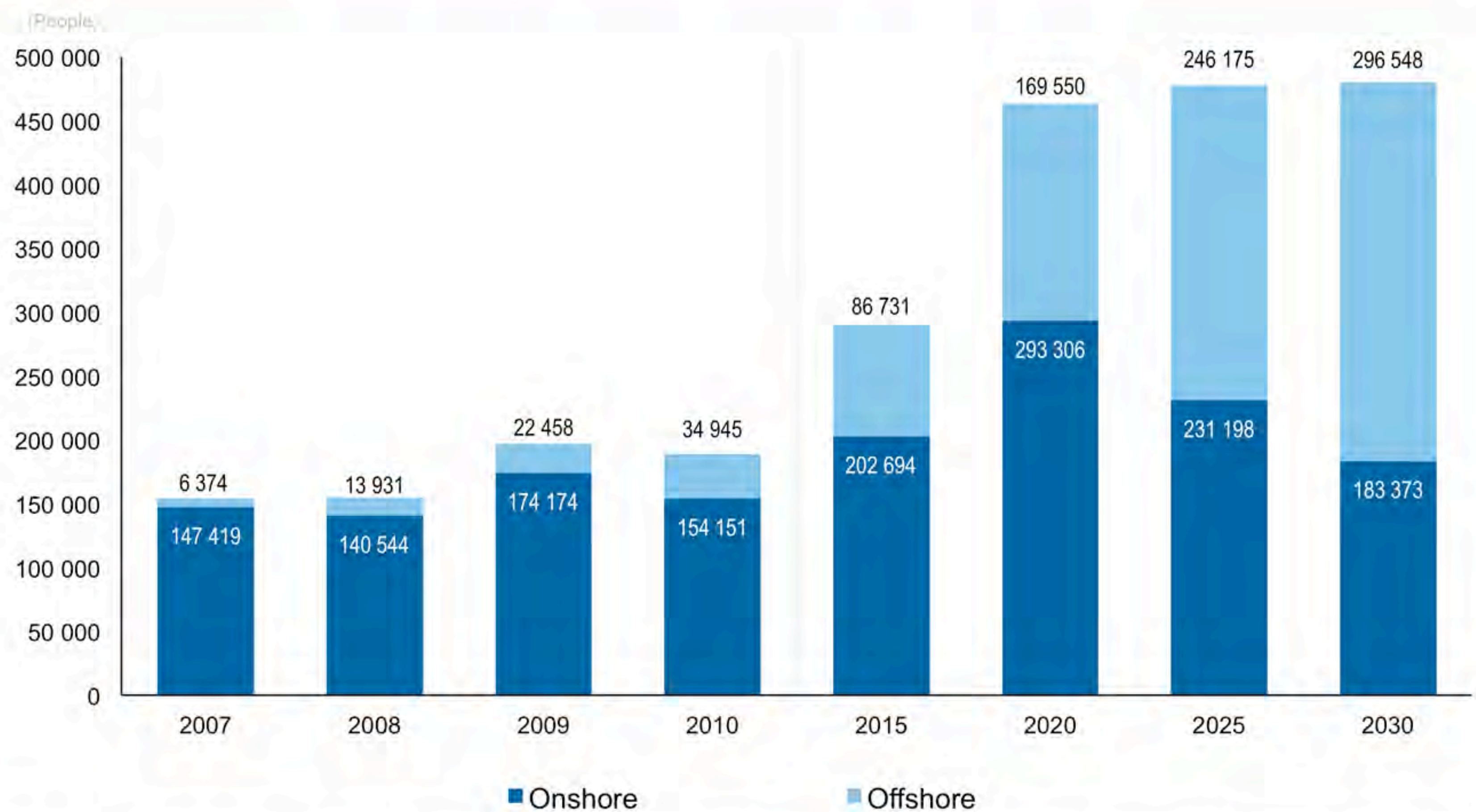
Capital cost of on- and offshore wind power



Wind power investments



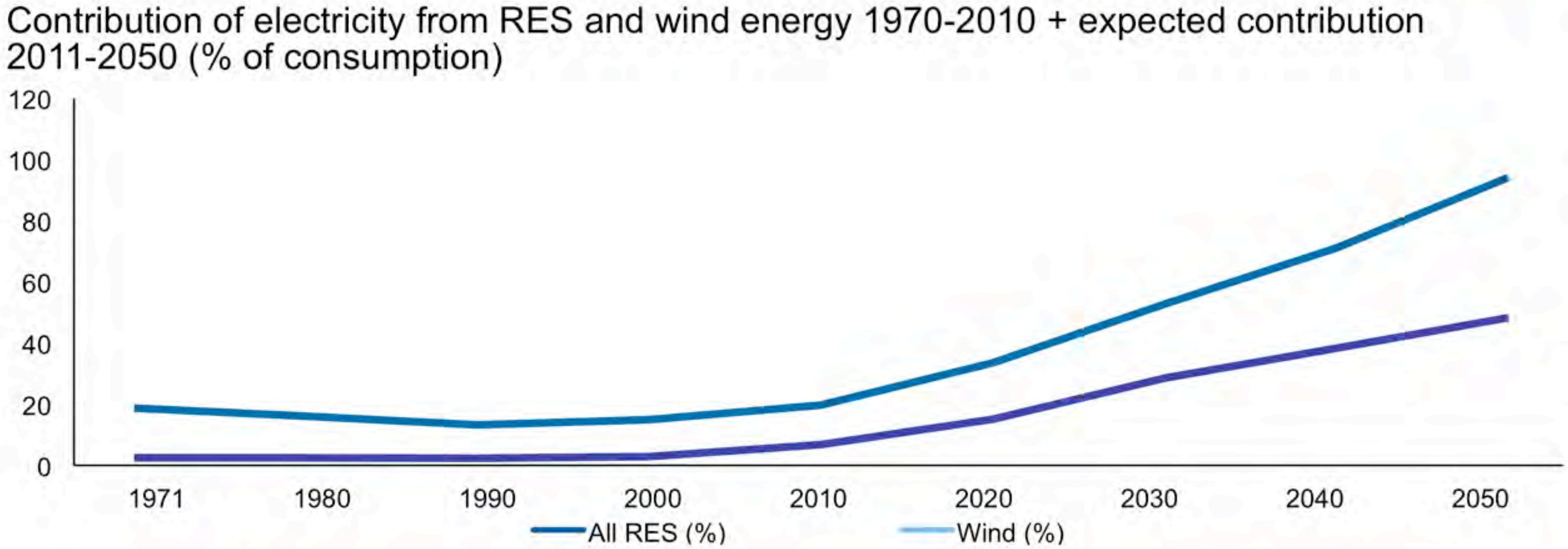
Wind power energy sector employment



	2007	2008	2009	2010	2015	2020	2025	2030
Total	153,793	154,476	196,632	189,096	289,425	462,856	477,373	479,921

Source: EWEA and EC 2010

Installed capacity, electricity productionand share in EU demand



	Onshore wind (GW)	Offshore wind (GW)	Total wind energy capacity (GW)	Average capacity factor onshore	Average capacity factor offshore	TWh onshore	TWh offshore	TWh total	EU-27 gross electricity consumption	Wind power's share of electricity demand
2020	190	40	230	26%	42.30%	433	148	581	3,690	16%
2030	250	150	400	27%	42.80%	591	562	1,154	4,051	29%
2050	275	460	735	29%	45%	699	1,813	2,512	5,000	50%

Sources: 1971-1989 3E/EWEA assumption: 1990-2008 Eurostat: 2009
EWEA assumption: 2010-2020 NREAPs: 2020-2030 EWEA (based on PRIMES consumption 2030: 2031-2050 EWEA).

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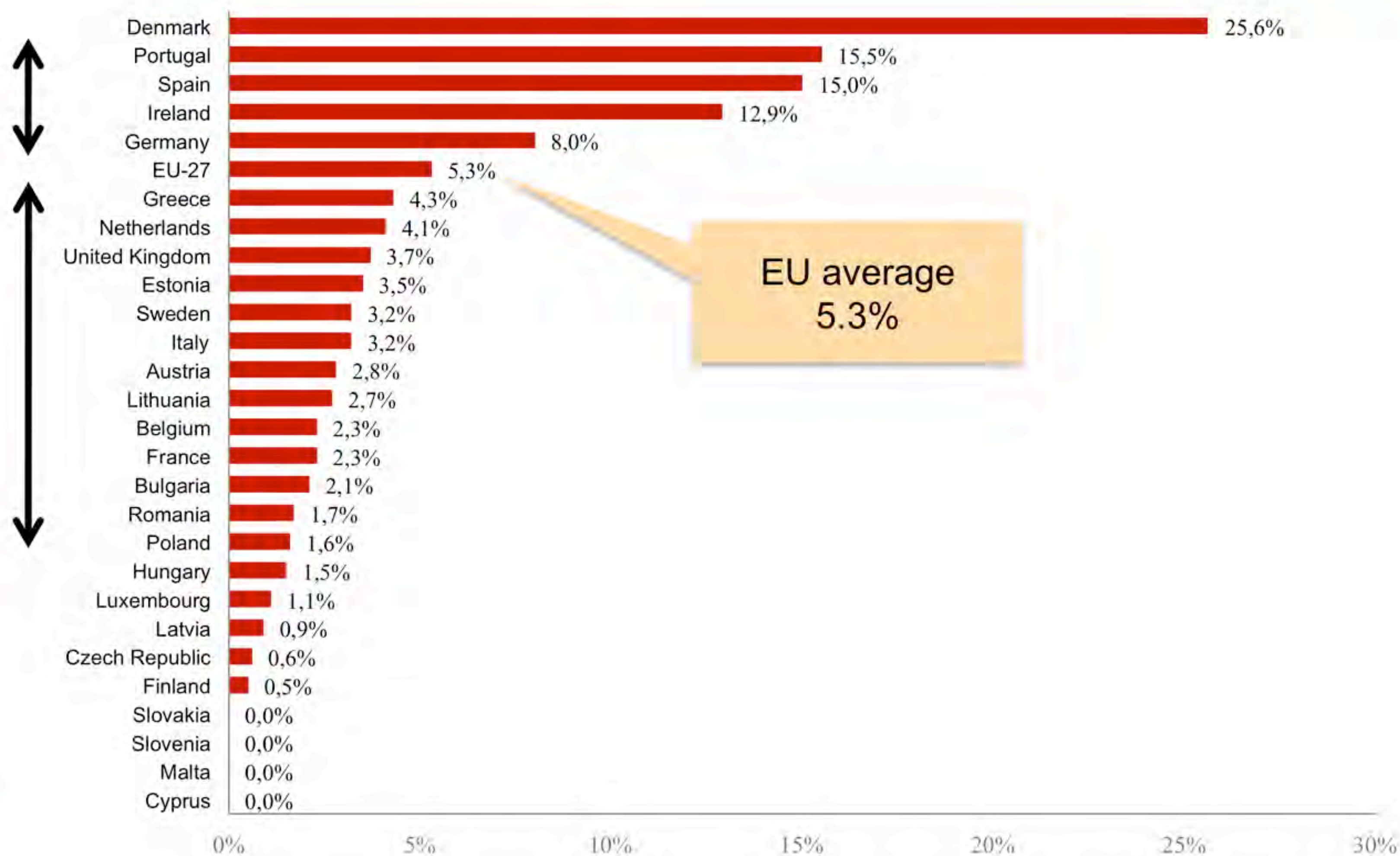
Wind energy in 2030 – EWEA targets

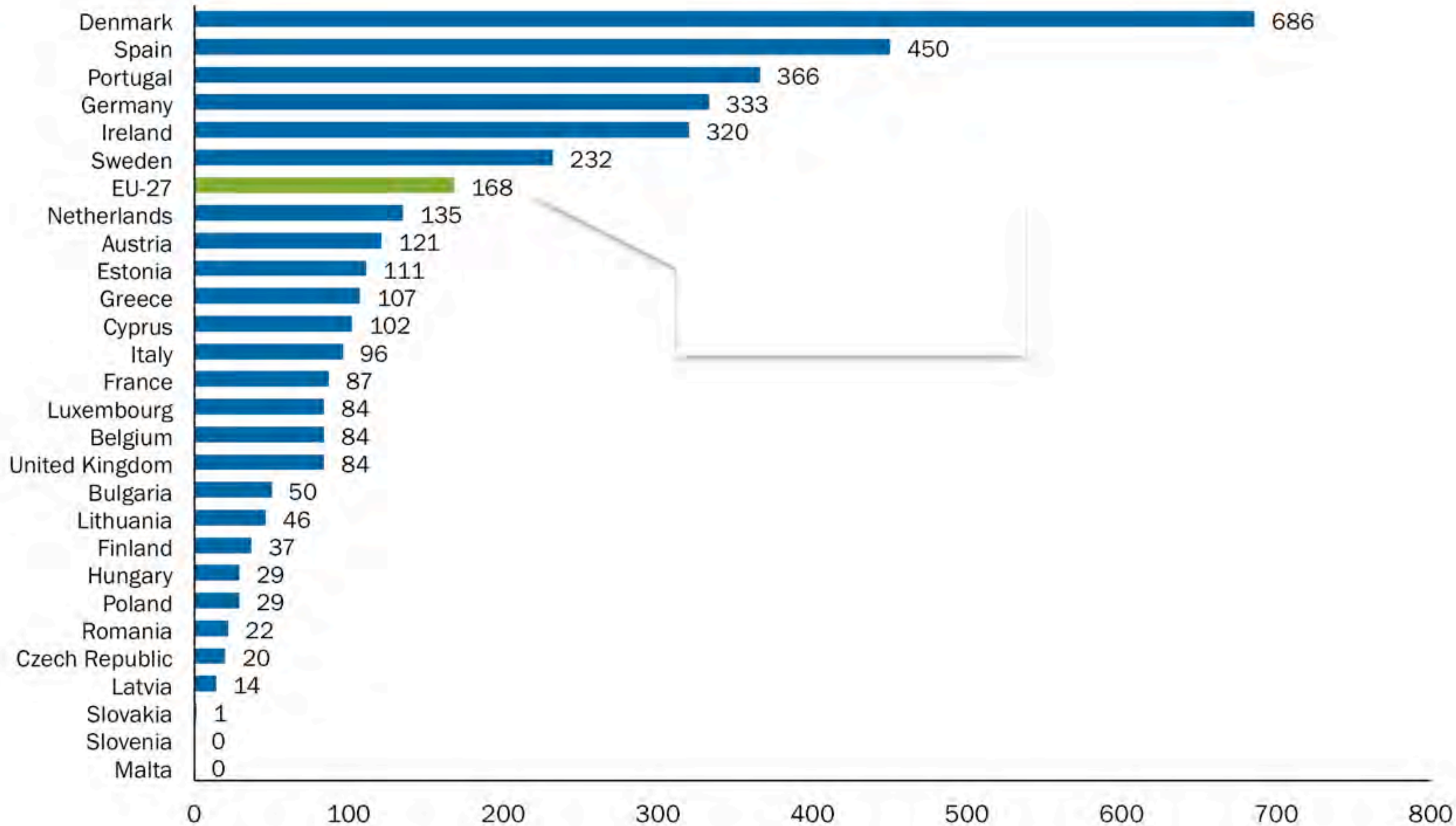
	Onshore	Offshore	Total
Installed capacity (GW)	250	150	400
Annual installations (GW)	10	13.7	23.7
Annual investments (bn€)	8.2	17.1	25.3
Electricity production (TWh)	591	562	1,154

Wind energy's share of national electricity demand, end 2010



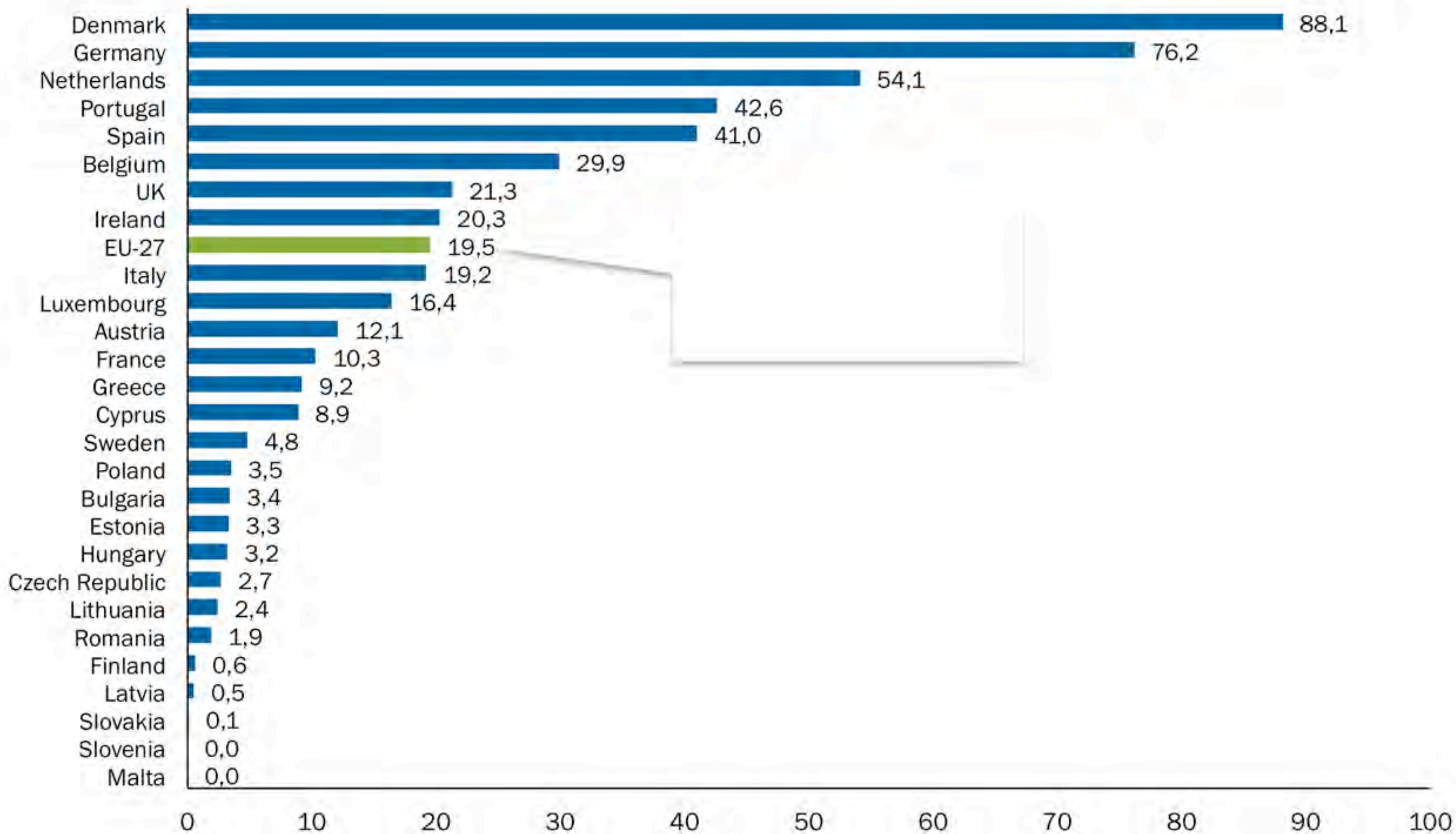
Source: EWEA, GWEC and International Atomic Energy Agency (IAEA)

Wind energy capacity [kW] per 1000 citizens, end 2010



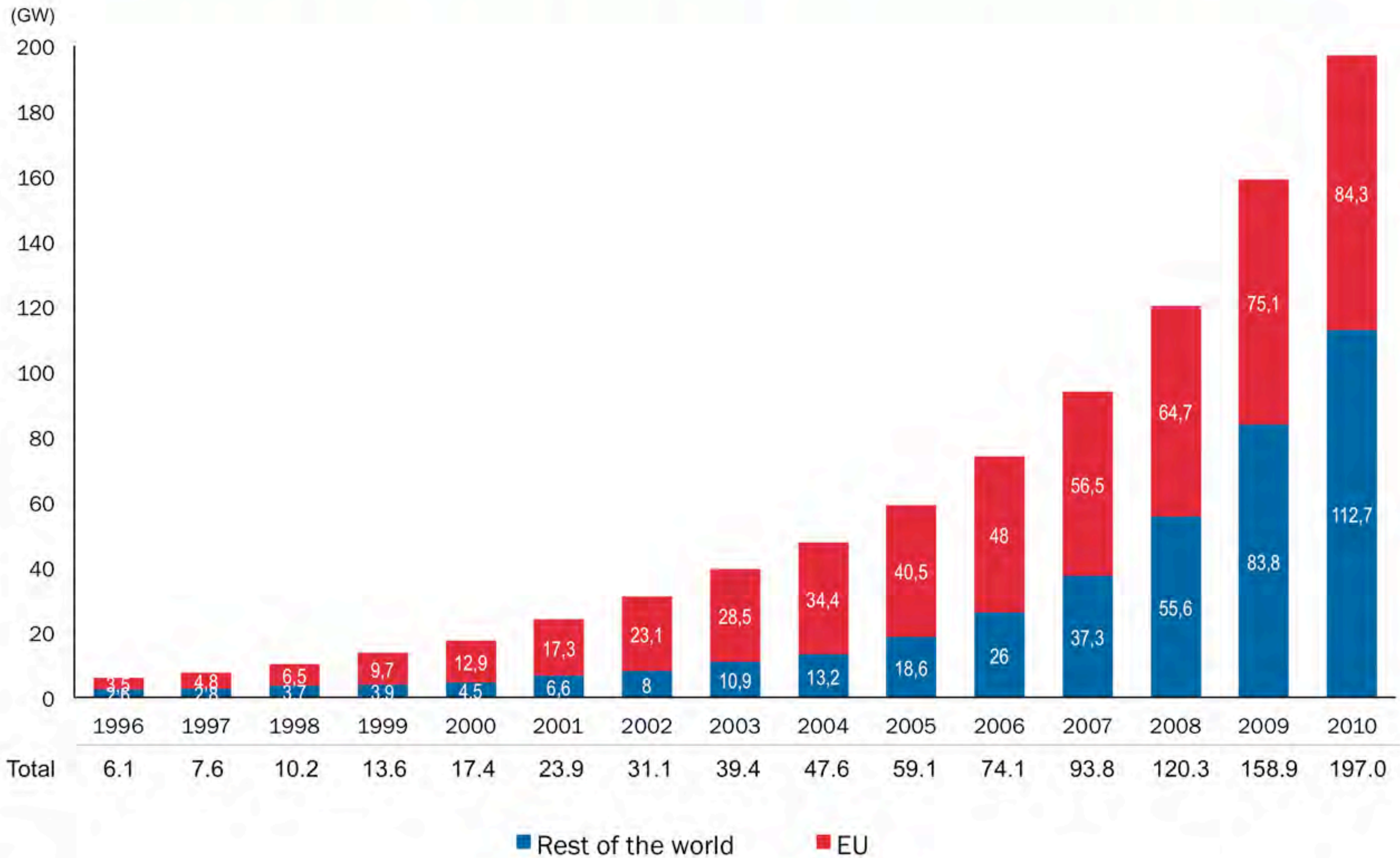
Source: EWEA, GWEC and International Atomic Energy Agency (IAEA)

Installed wind power per 1000 km², end 2010



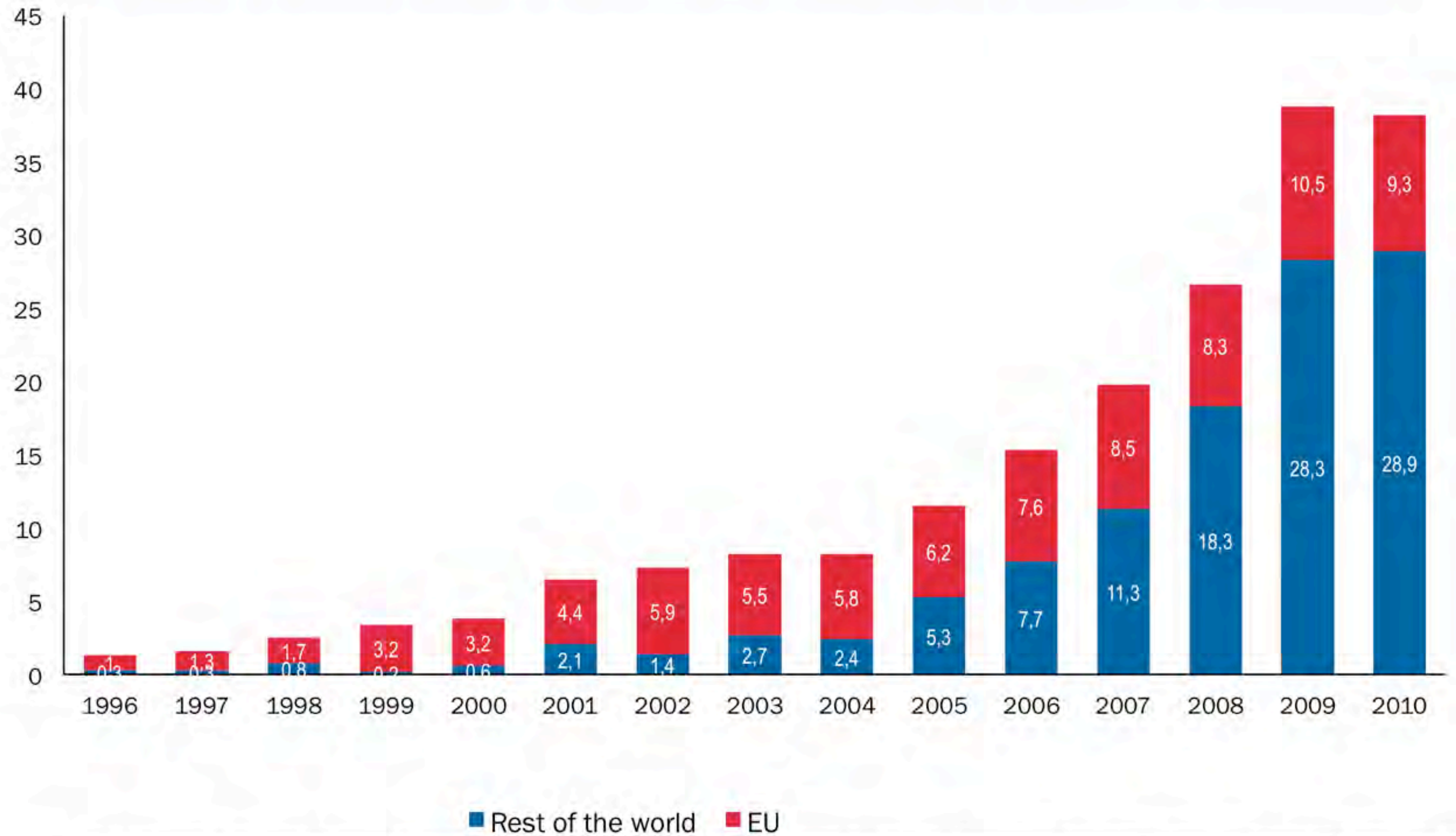
Source: EWEA, GWEC and International Atomic Energy Agency (IAEA)

Global Cumulative wind power capacity (1996-2010)



Source: "Global wind report – annual market update 2010" – GWEC 2011; EWEA 2011

Global annual wind power capacity (1996-2010)



Total	1.3	1.6	2.5	3.4	3.8	6.5	7.3	8.2	8.2	11.5	15.3	19.8	26.6	38.8	38.2

Source: "Global wind report – annual market update 2010" – GWEC 2011; EWEA 2011

Similarities Offshore & Cold Climate issues

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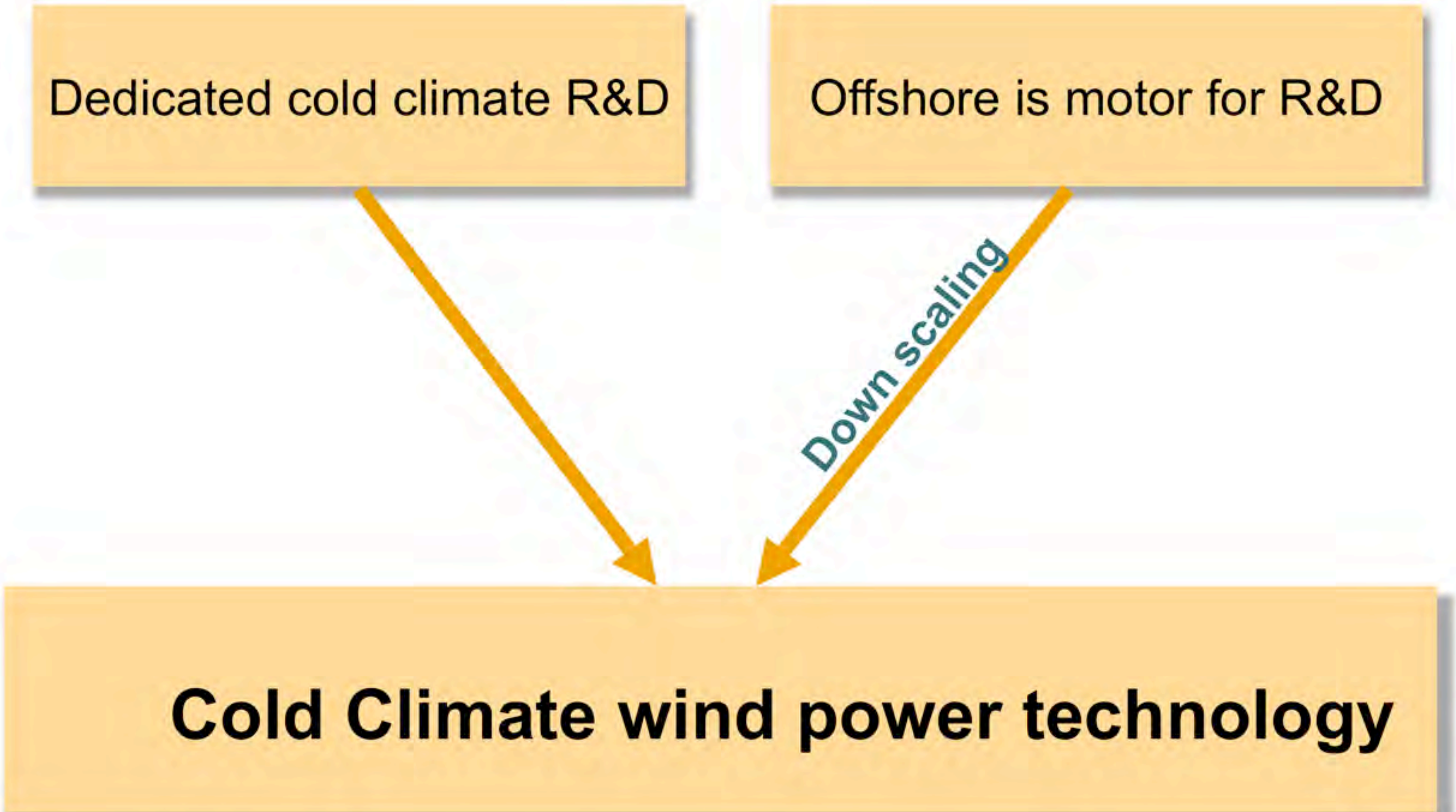
R&D drivers for offshore and remote and extreme climate applications of WE

Offshore	Issue
Foundation, grid	Cost breakdown
Waves, saline atm, turbulence, sea bottom, eaxtreme winds	External conditions
RAMS, dedicated wind turbines	Wind turbne concept
3 media (soil, water, air)	Support structure
Marine weather windows	Transport & assembly
Marine weather windows	Accessibility for O&M
No electrical infrastruture; large scale integration on HV level	Grid connection & integration
Large scale operations	Scale and risks
Marine eco-systems, shipping, oil and gas safety	Nature & safety
Wind farm interaction, alternative use of oceans	Spatial planning


Dedicated cold climate R&D
Offshore is motor for R&D
Down scaling
Cold Climate wind power technology

Offshore wind turbines

Cost of support structures are dominant and are relatively insensitive to load carrying capacity

↓

The wind turbines should be as big as possible !

Up scaling wind turbines

For the engineer:

mass ~ (D^3)
cross section ~ (D^2)
stress (= mass/cross section) ~ D

For the economist:

investment cost ~ (D^3)
energy output ~ (D^2)
COE (= inv. cost/energy output) ~ D

Development of advanced materials with a higher strenth to mass ratio

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Three important consequences of extreme up scaling

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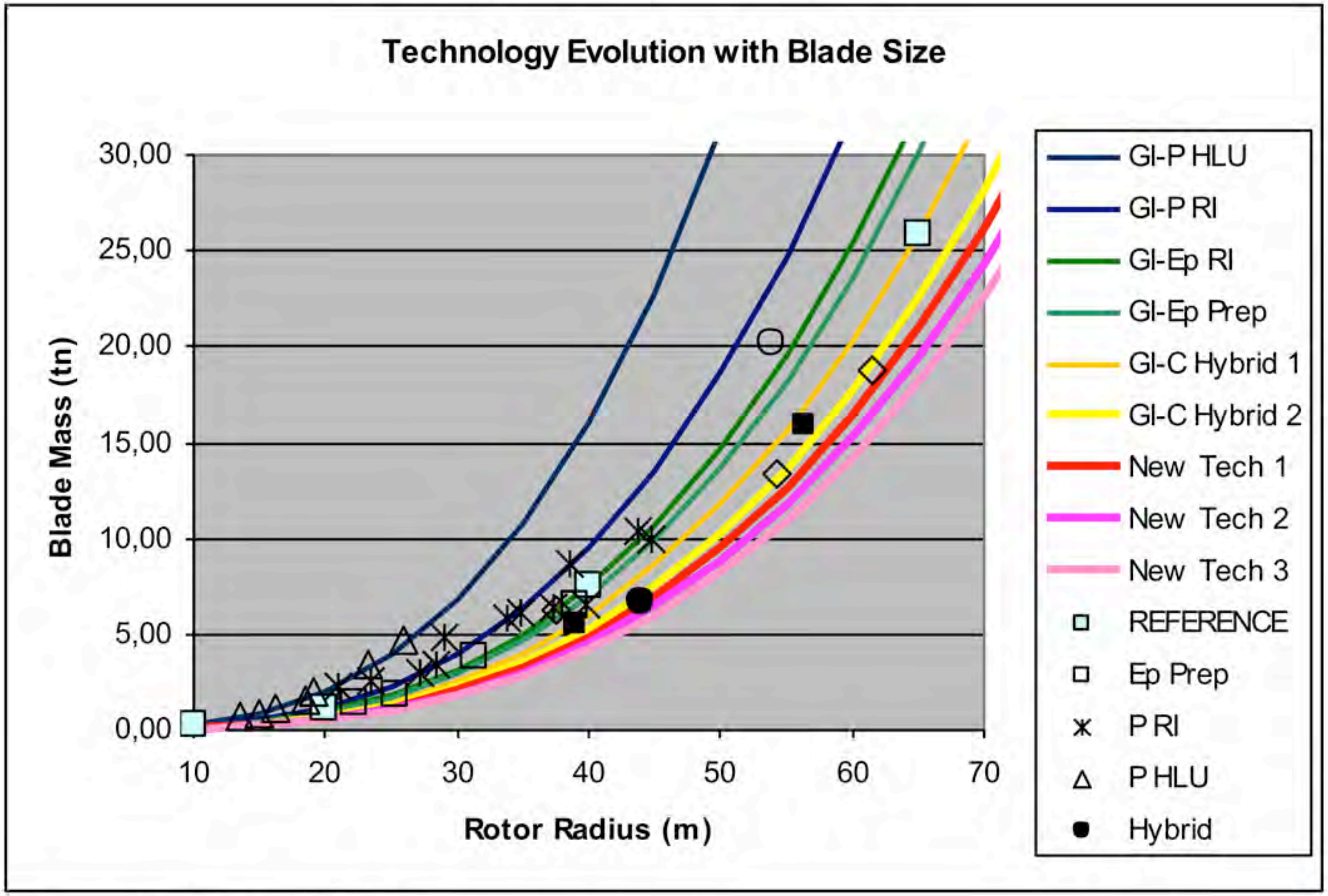
- Extreme up scaling only possible if materials with low mass to strength ratio become available
- Distributed aerodynamic control needed
- *More flexibility in structure to cope with (dynamic) fatigue loads*

Up scaling: weight requirements for blades



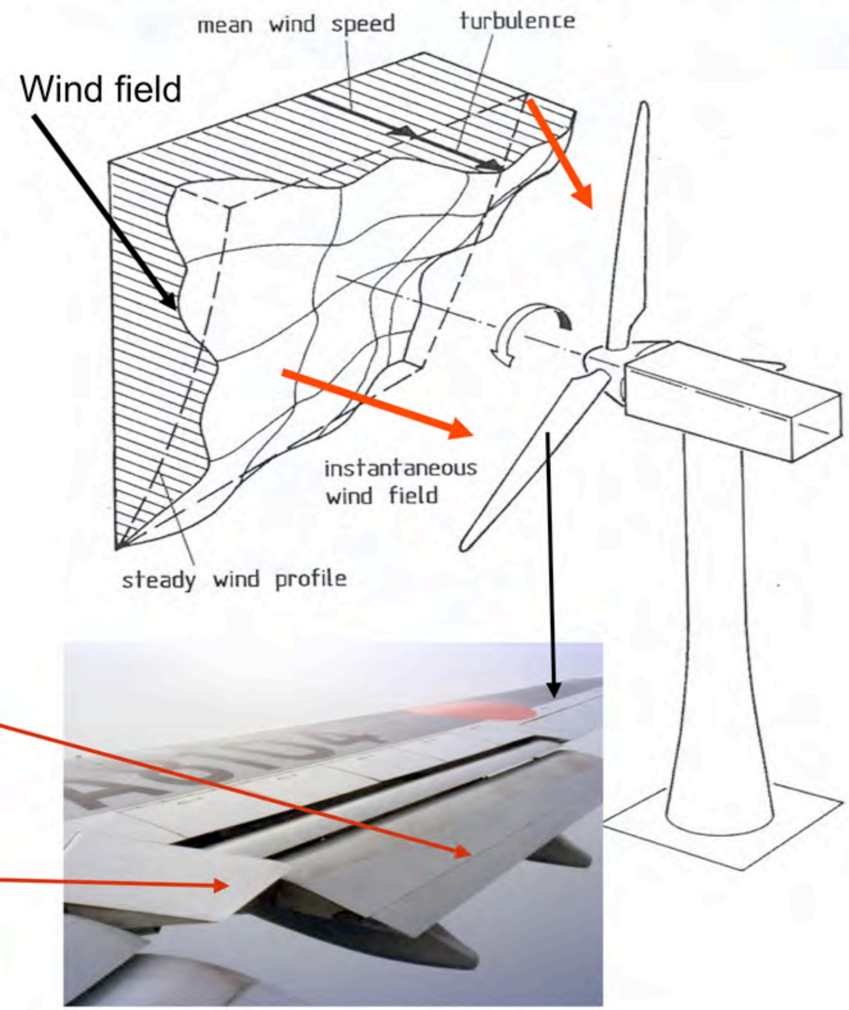
Source: UpWind; CRES, GR

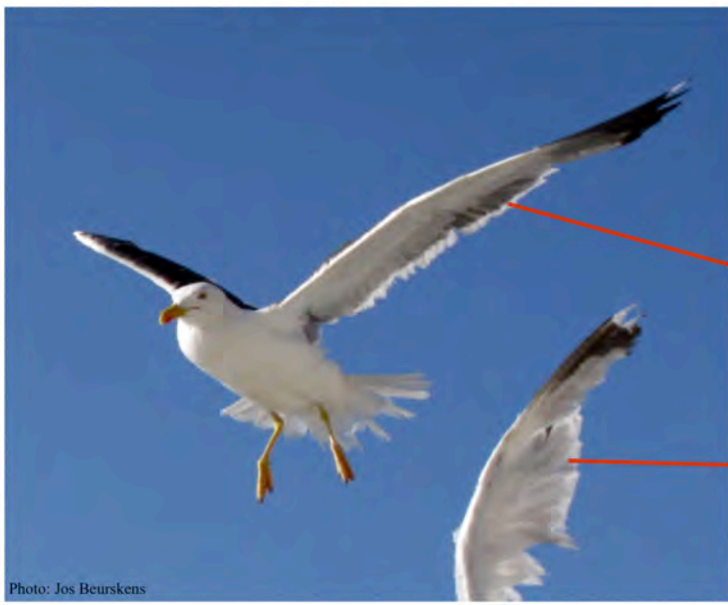
UpWind

Wind turbines

UpWind

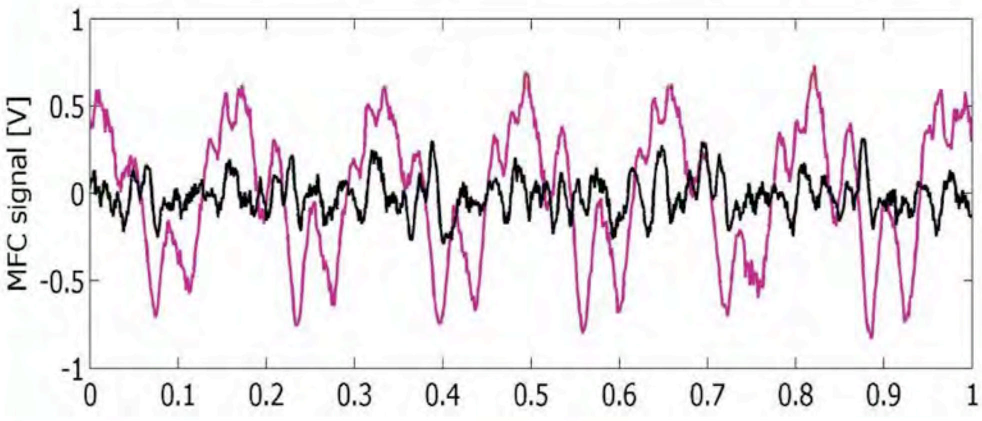
Distributed blade control necessary





Faigue load reduction by distributed blade control

Wind tunnel tests on a scaled smart rotor – flapwise root bending moment <u>with</u> and <u>without</u> flap activation



Comparison with Individual Pitch Control:

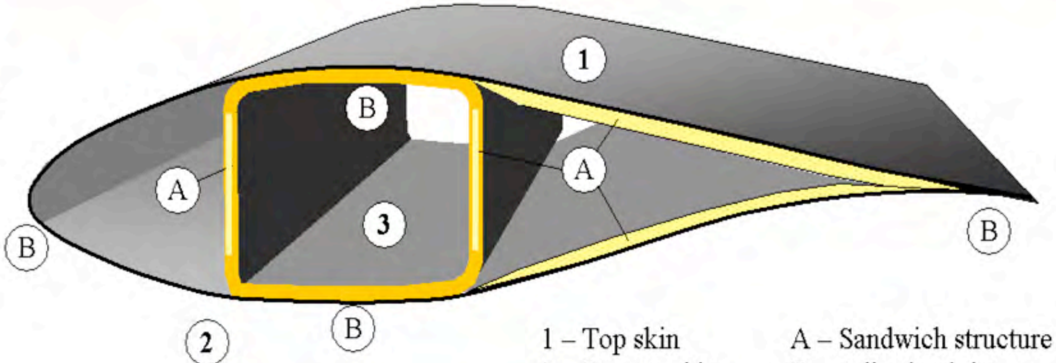
- 15-25% reduction of fatigue damage equivalent load, depending on load case
- Can add up to 30%

TUDelft
Delft University of Technology

Wind turbines

UpWind

Thermoplastic blades



Operation and Maintenance

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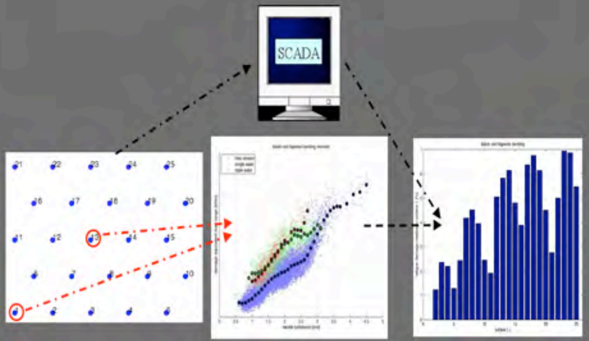
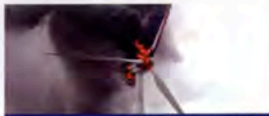
Photo: Jos Beurskens

Ampelmann

Harbour at sea

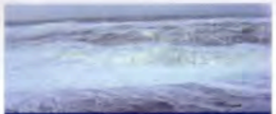


Flight Leader concept



Failure behaviour and maintainability

Characterisation of access and hoisting systems

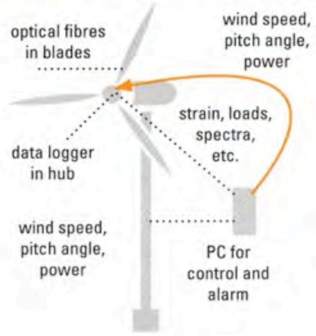


Characterisation of weather conditions (wind, waves, lighting and visibility)

Corrective maintenance

Preventive maintenance

Condition monitoring



feed back

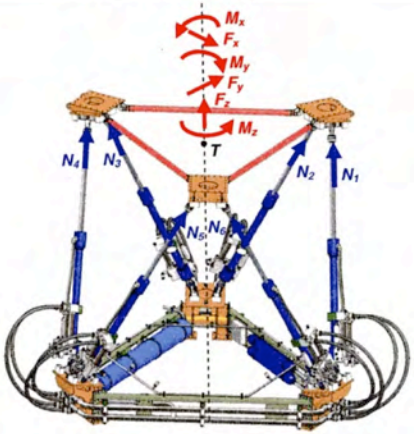
Results:

- High availability
- low price per kWh
- waiting times
- identification of cost drivers
- recommendations for improvement

ECN

HEDEN

Operation and Maintenance; Access



Ampelmann concept

Access

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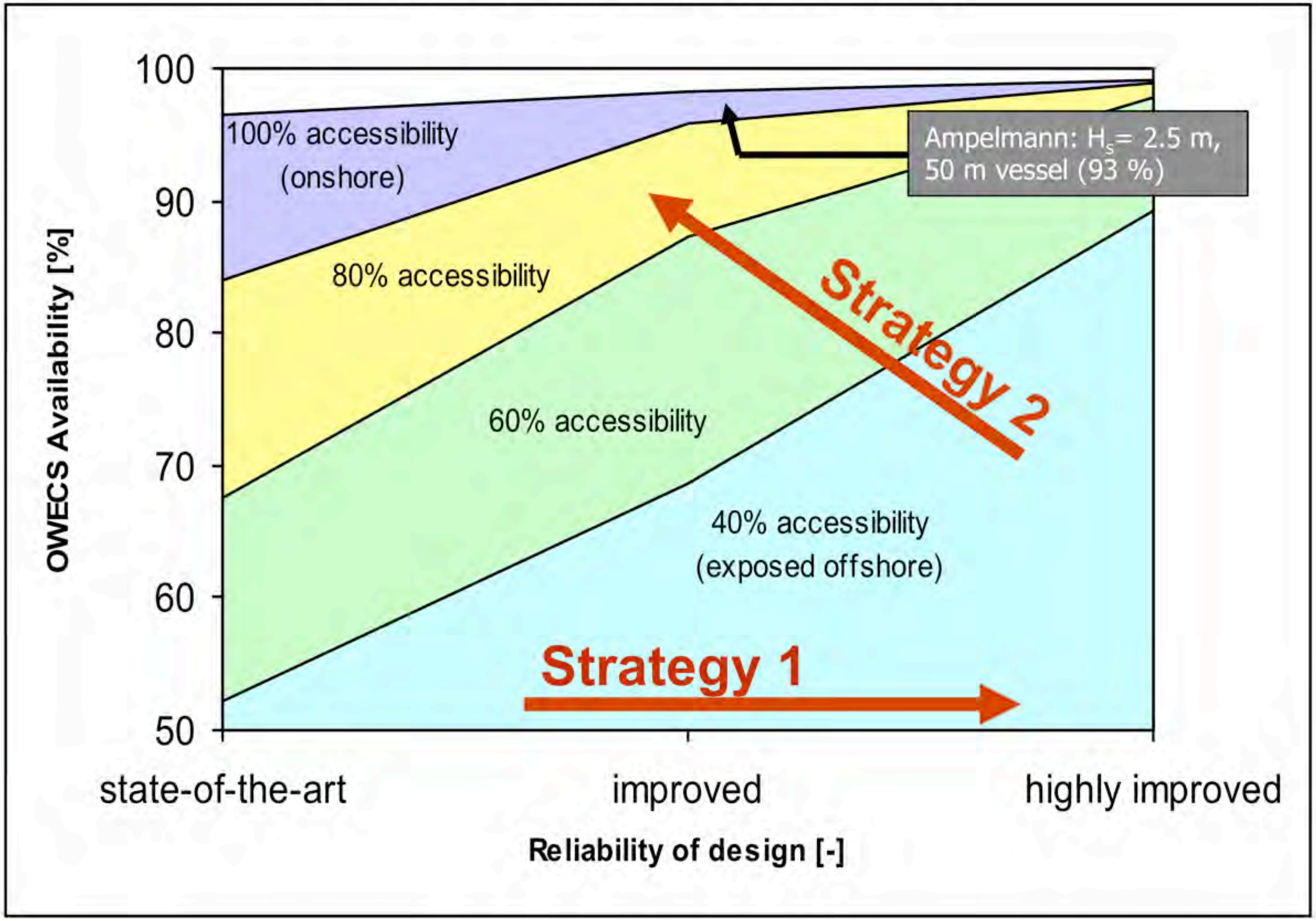
Availability = *f* (reliability, accessibility)



Lessons learned of small turbines in extreme climates

- Turbines do require ongoing maintenance
- Many locations are remote and lack onsite or accessible technical
- Support and spare parts
- Potential for small faults or maintenance
- Items lead to long downtimes
- Therefore, Staging of spare parts and
- Technical knowledge at central
- Critical to long term success

Source: EAPC

Towards a universal CC Research (& Implementation) Agenda

- Physics of icing (accretion of ice; types of icing)
- Atlas of icing probability
- Impact on wind turbines; energy output, loads, acoustic noise emission)
- Anti-icing and De-icing
- Safety

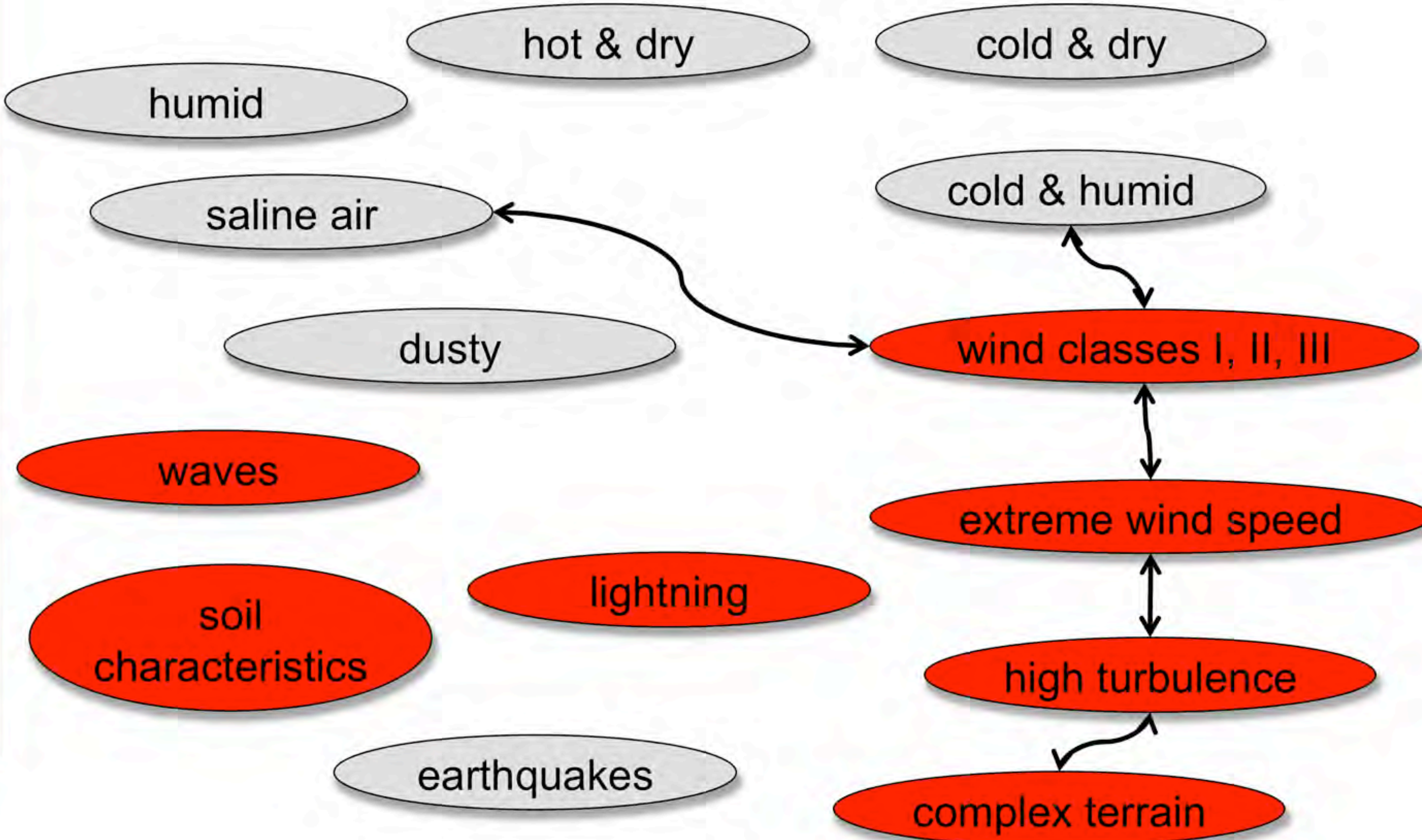
And:

Dedicated Cold Climate wind turbines

Identification of systems

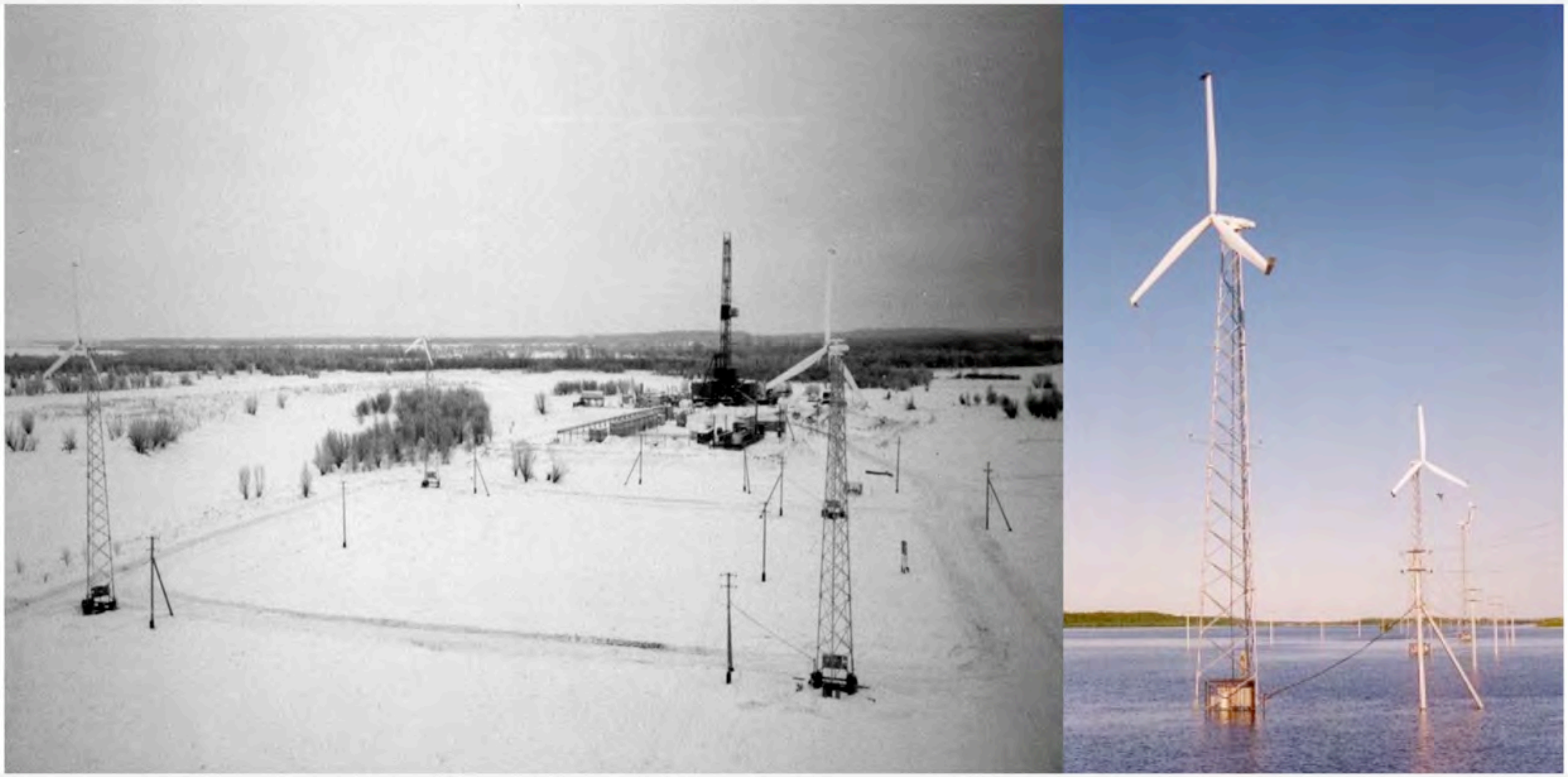
- Grid connected
- Autonomous
- Hybrid (AWDS)
- Size and capacity
- External conditions (standards)

External Conditions



External Conditions

Surprises remain showing up !!

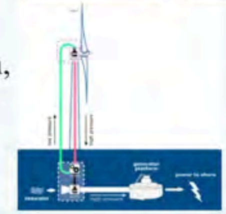
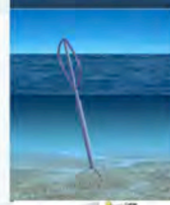
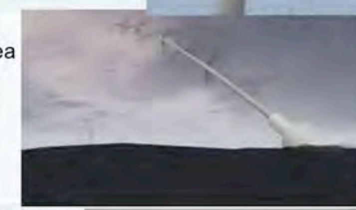
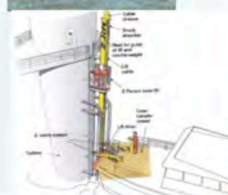
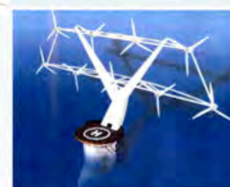
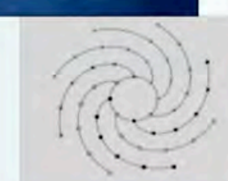


Russia

Source: EAPC

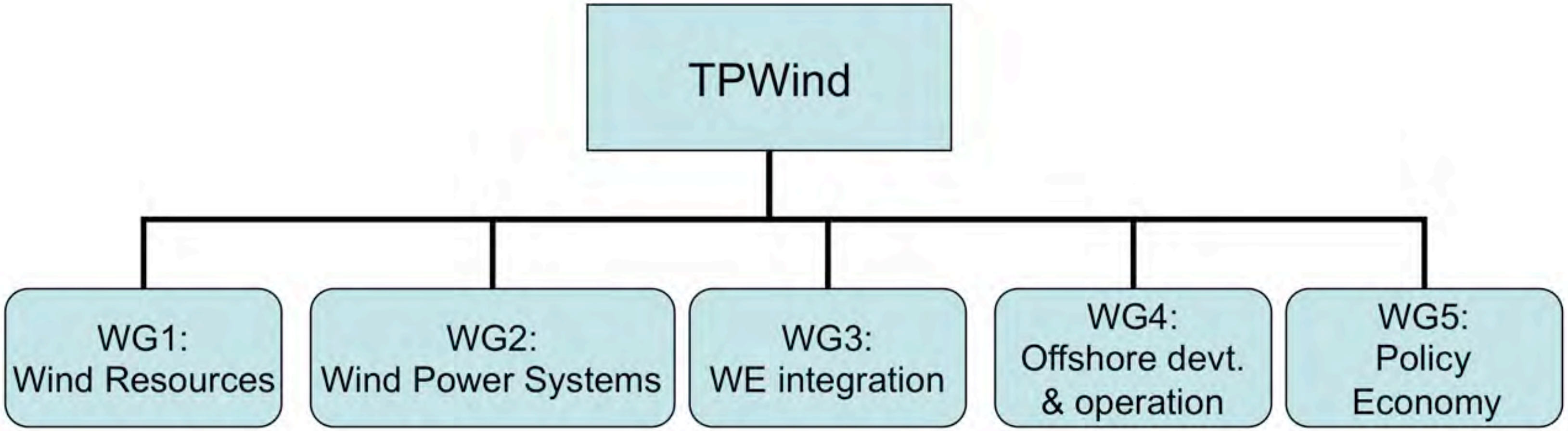
Full integration of requirements into design

- Transport & Installation
- RAMS
- O&M (Accessibility)
- Anti- & De- icing
- Foundations & Support structures
- Decommissioning

Requirement	Solution	Concepts
Up scaling (Full blade pitch becomes ineffective due to large variations in the wind field in the rotor plane)	Distributed blade control with advanced (LIDAR based) control systems	 
Reliability	Reduced number of components (central conversion unit in wind farm, direct drive generators, passive yawing)	 DOT Hydraulic conversion; Lagerwey   Stork Ultimate turbine
Weight reduction	Two bladed rotor (reduces rotor weight and increases rotor speed, which leeds to reduced drive train weight)	 2B-Energy
Integrated operations and design	Transport of floating components. Self erecting and installing systems	 Deep Wind  Sway; Selsam-Sea 
Servicebility	Access technology	 Z Technologies; Ampelmann 
Maintainability	Floating cantilever structures	  Lagerwey
Wind farm efficiency	Movable foundations Non conventional wind farm lay outs	 Ideol (movable foundations)  Topfarm

Concluding remarks

- Measuring EU targets in [MW's] only, denies potential of wind energy in areas with extreme climates and low population density
- An adopted strategic R&D and implementation Agenda, similar to Offshore issues is needed, among others as an input for:



Thank you very much for your attention !

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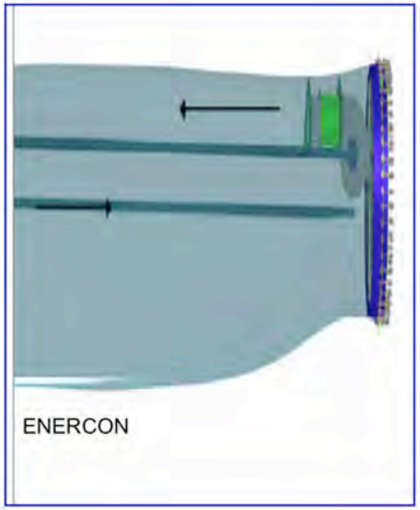
Priorities (1)

Dedicated cold weather wind turbine concepts

- Anti icing & de-icing:

  Innovations, integrated blade design
  (priority number 1)

  Intensification innovation and using know- how from other disciplines and technologies (aircraft, material science, physics, …)

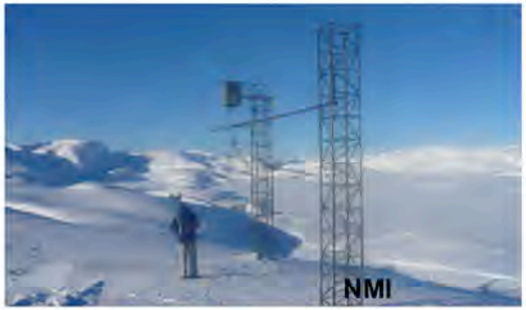


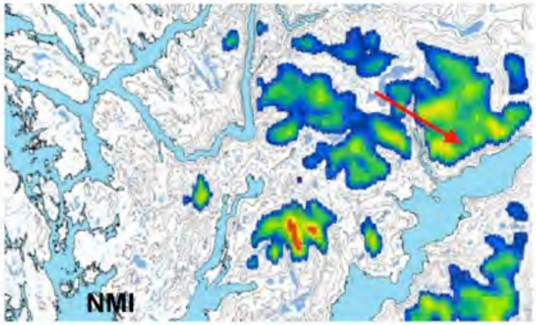
From: Conclusions from WinterWind 2011, Umeå (S), February 9, 2011 by Jos Beurskens

Priorities (2)

External conditions

- Conditions for icing (super cooling, sublimation, (T, Humidity, V))
- Combination of icing conditions with other aspects: water spray (offshore), wind speed, altitude.
- Icing probability mapping of areas with high wind potential ('iso icing days/annum' contours)
- Cold climate resistant measuring instruments and associated power supply units (performance, resource assessment, ice detection, loads, heating system control





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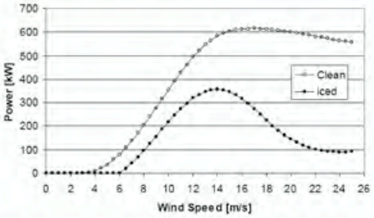
Priorities (3)

Wind turbine concepts, assembly, O&M

- Impact on performance (how big are ‘hidden’ energy losses?)
- Impact on loading (aerodynamically and mechanical/aerodynamically induced loads, scale effects
- Transport and assembly, because of poor access
- Operation and maintenance/access
- Safety, standards

Effect of ice on the basis of theories



Result of WT-perf calculation when 100% increase in drag, -2 degree stall angle reduction, 15% decrease in maximum lift of profiles are assumed.

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Priorities (4)

General issues

- Field test facilities for problem definition and verification of models
- Feed back of operational experiences to designers
- Bridging gap between meteorological aspects and wt technology impacts

From: Conclusions from WinterWind 2011, Umeå (S), February 9, 2011 by Jos Beurskens

Priorities (5)

- Continuous up-dating market potential based upon Mapping, Performance losses, Market developments
- The grid !!!!


VTT

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