R&D as a prerequisite for successfully utilising the cold climate wind energy market oppotunities

Jos Beurskens
SET Analysis
(Former ECN)

Winterwind 2015
Piteå (S)
3 February 2015

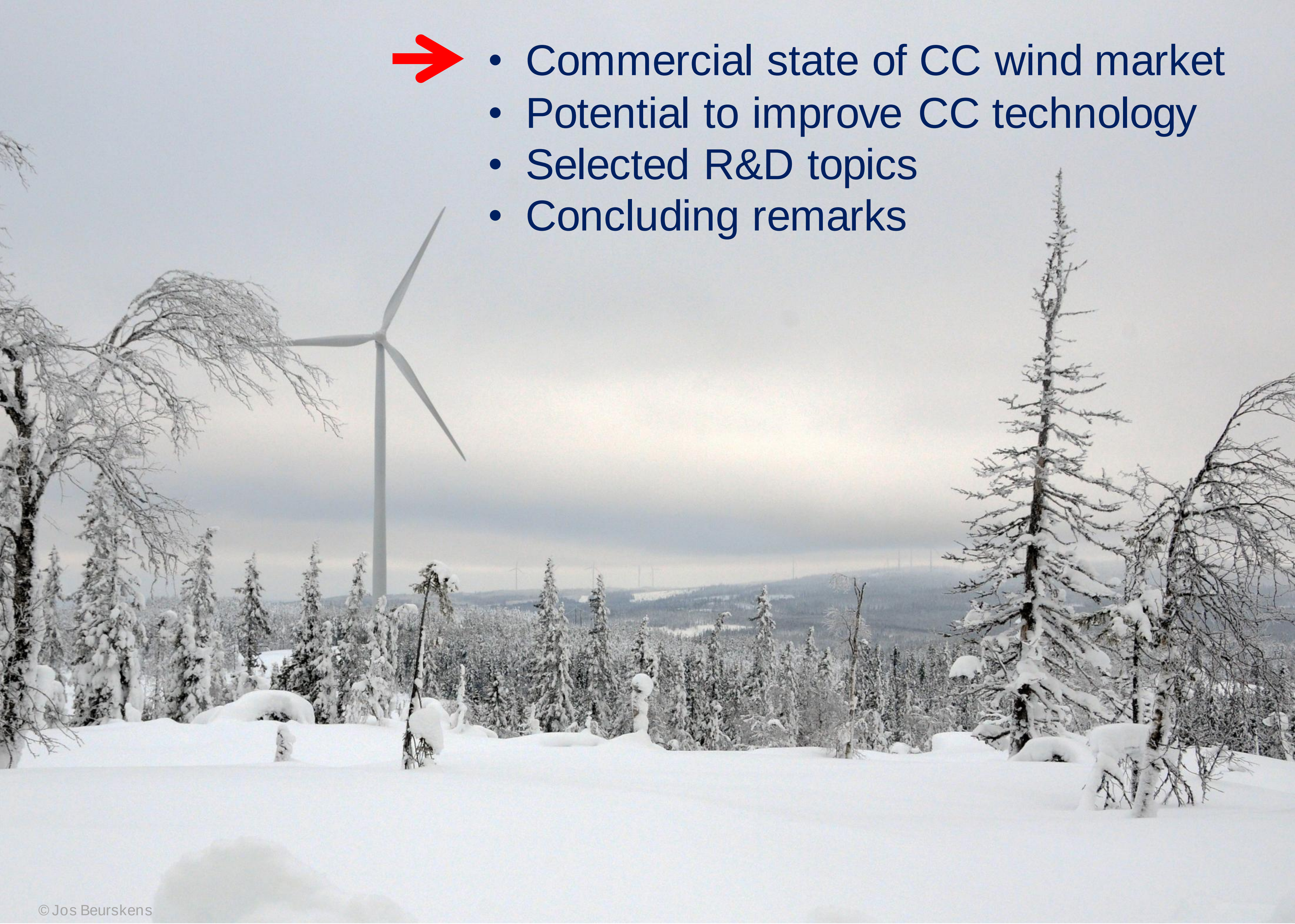
This presentation

- Commercial state of CC wind market
- Potential to improve CC wind energy technology
- Selected R&D topics
- Concluding remarks

Conclusions

- Increase budgets for CC R&D considerably

- Commercial state of CC wind market
- Potential to improve CC technology
- Selected R&D topics
- Concluding remarks

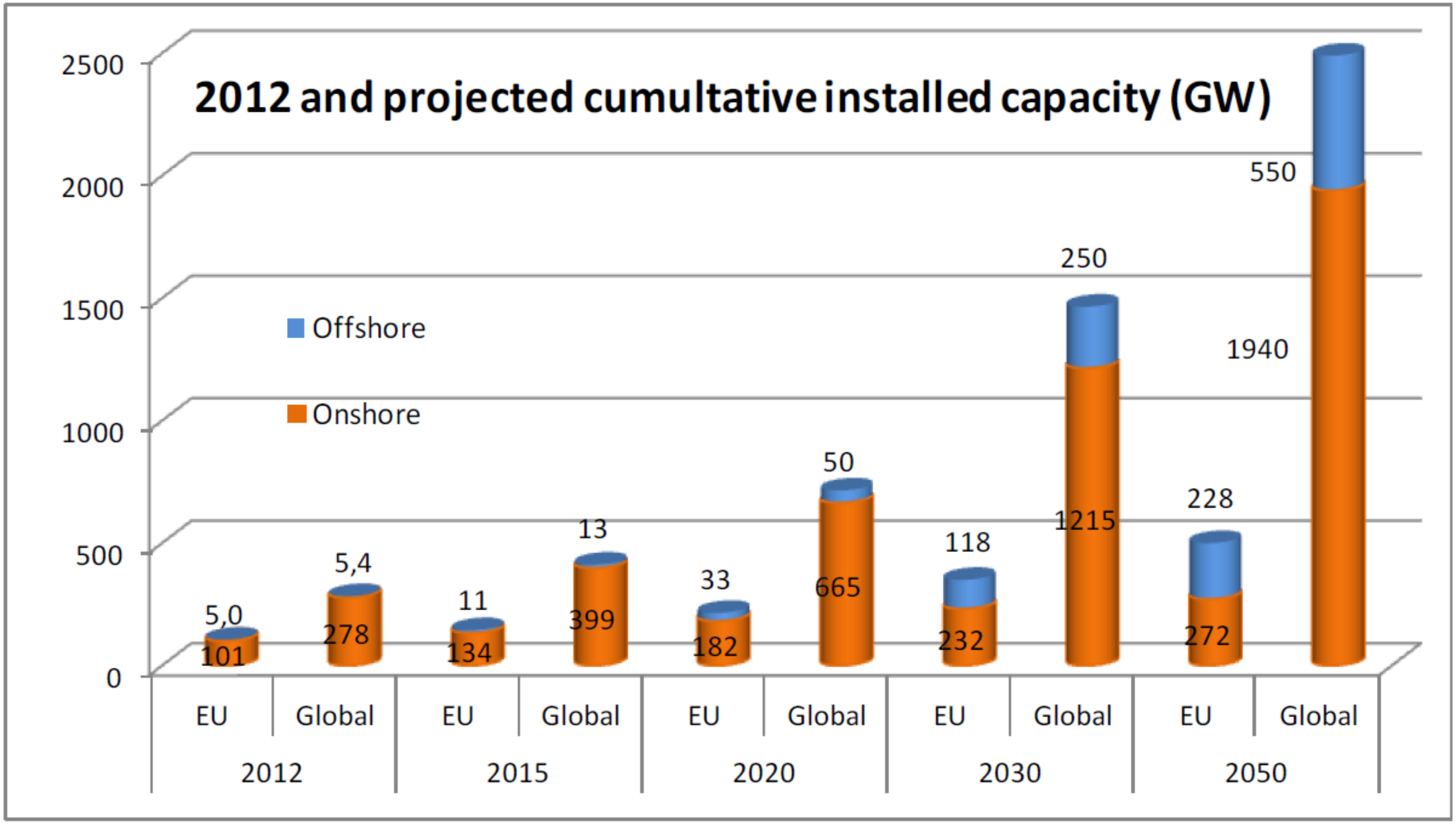


Market state

Application area	Rated power	Relative contribution	Potential by 2017	R&D intensity
Globally installed (end 2014)	365 GW	100 %	530	
In areas prone to CC issues (all categories)	90 GW	25 %	120 (22.6%) (Δ=10GW/a)	!
Offshore	7 GW	2 %	9.2 (1.7%)	!!!
Desert	?	?	?	0

Estimates derived from IEA Task 19 data and Navigant/BTM World market Update 2012 and 2013, EWEA and GWEC data.

Forecast of wind energy byond 2017



: Projected cumulative installed capacity (GW). Source: JRC

Market state

Cold Climate wind energy about 25% of global wind power, but growth potential is similar to world growth rate:

Good track records for investors

&

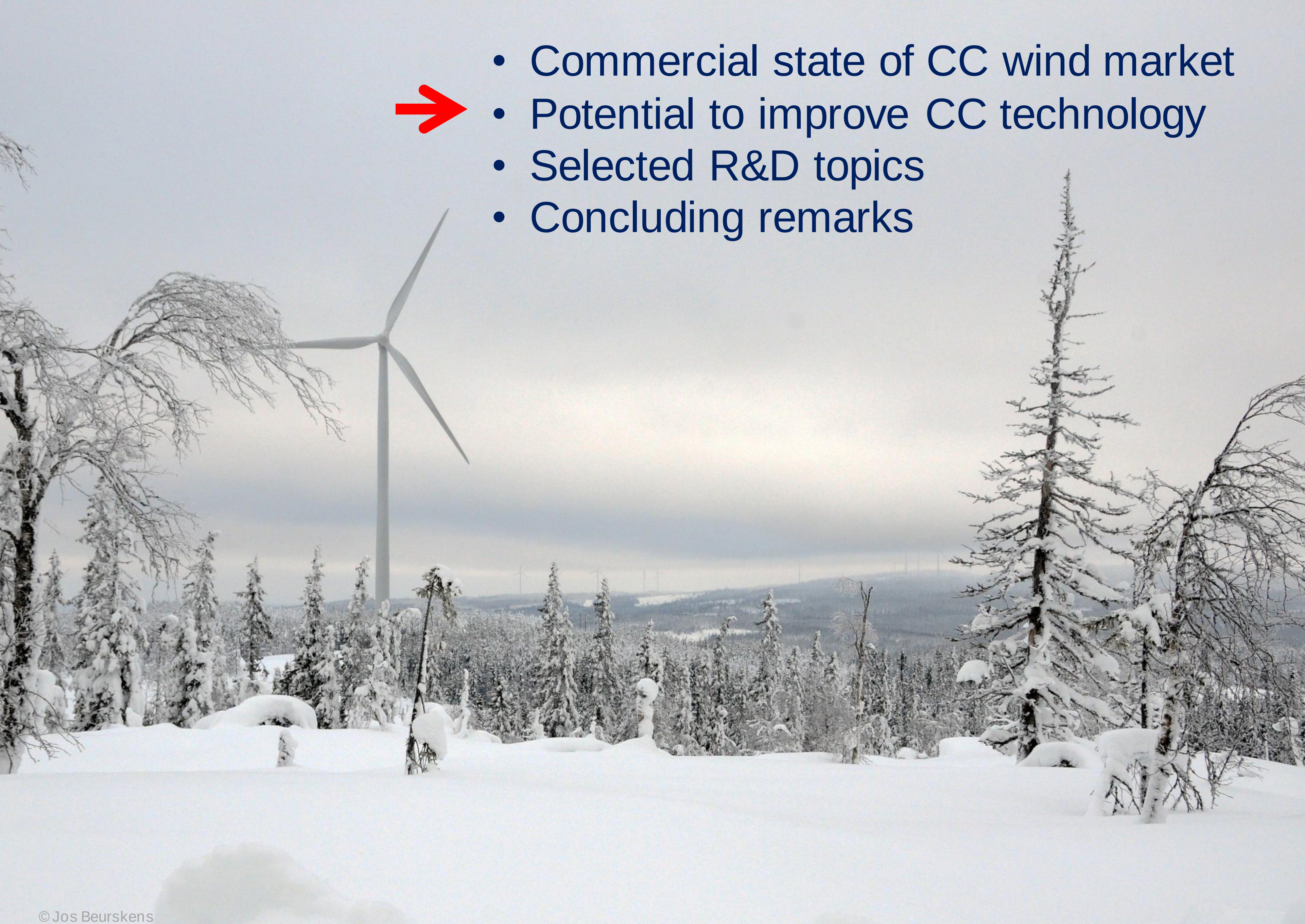
Enormous room for application of innovations for cost reduction

Designing a project, a puzzle

- Permits
- Contracts
- Insurance
- Planning
- Financing

- Project developer
- Site exploration
- Foundations/support structures provider
- Logistics planner
- Wind turbine provider
- Operators (transport & installation & O&M)
- CC protection
- Cable provider
- Transformer/invertor platform provider
- Certification

How to implement innovations as each non tested innovation drives (risk based) financing cost up ?



- Commercial state of CC wind market
- Potential to improve CC technology
- Selected R&D topics
- Concluding remarks

Cost reduction strategies

- Loads
- Scale
- Concept

- Inspection
- Maintenance
- Repairs
- Condition based Maintenance

* $LCoE = \frac{CAPEX + OPEX}{E}$

- Efficiency
  (rotor, transmission, control, el. Conversion)
- Availability
  (icing, failures, accessibility, etc.)

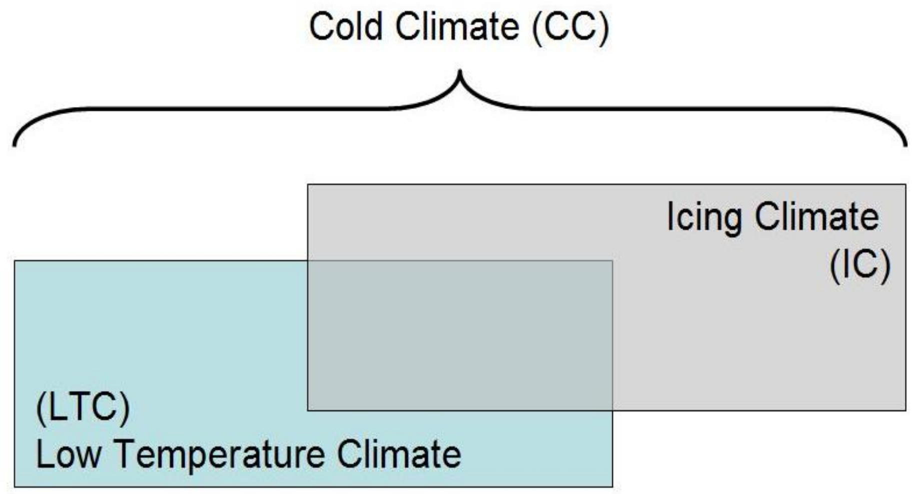
* Learning by doing
* Financing
* Consenting, planning, integral design
* Cost of grid connection and integration

Maximise penetration degree of WE $\neq$ Maximising wind farm output

Cost reduction potential

Annual Energy production (P90)	100%
No operation during icing	72%
Maximum Icing protection	99%

VTT, Winterwind 2013



Source: Expert Group Study on Recommended Practices for Wind Energy Projects in Cold Climates. IEA Wind Recommended practices no. 13. 2012.

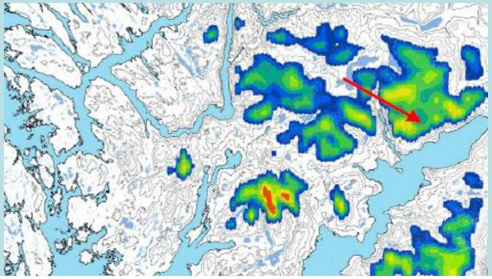
R&D Focal Points

	Energy output		CAPEX / Loads	CAPEX / Scale	Grid integration
	Maximise availability	Maximise efficiency			
Moderate	!	0	!!	0	!
Offshore	!!	0	!!!	!!!	!!!
CC	!!!	!	!!	!	!!!
Desert	?	0	!	!	!!!

Typical CC additional cost & risks

(CAPEX related)

- Mapping of icing probability
- Instruments and measuring or resource assessment and load prediction
- De-icing add-ons
- Anti-icing technology
- Foundations
- Environment, safety and warning systems
- Limited weather windows for installation



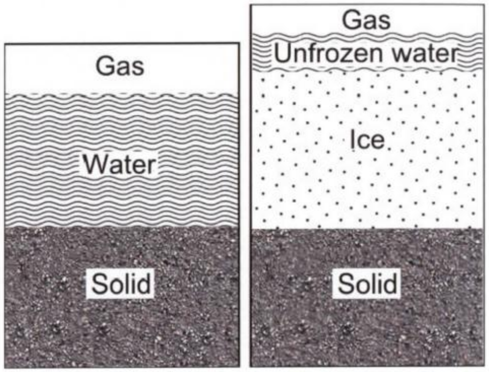
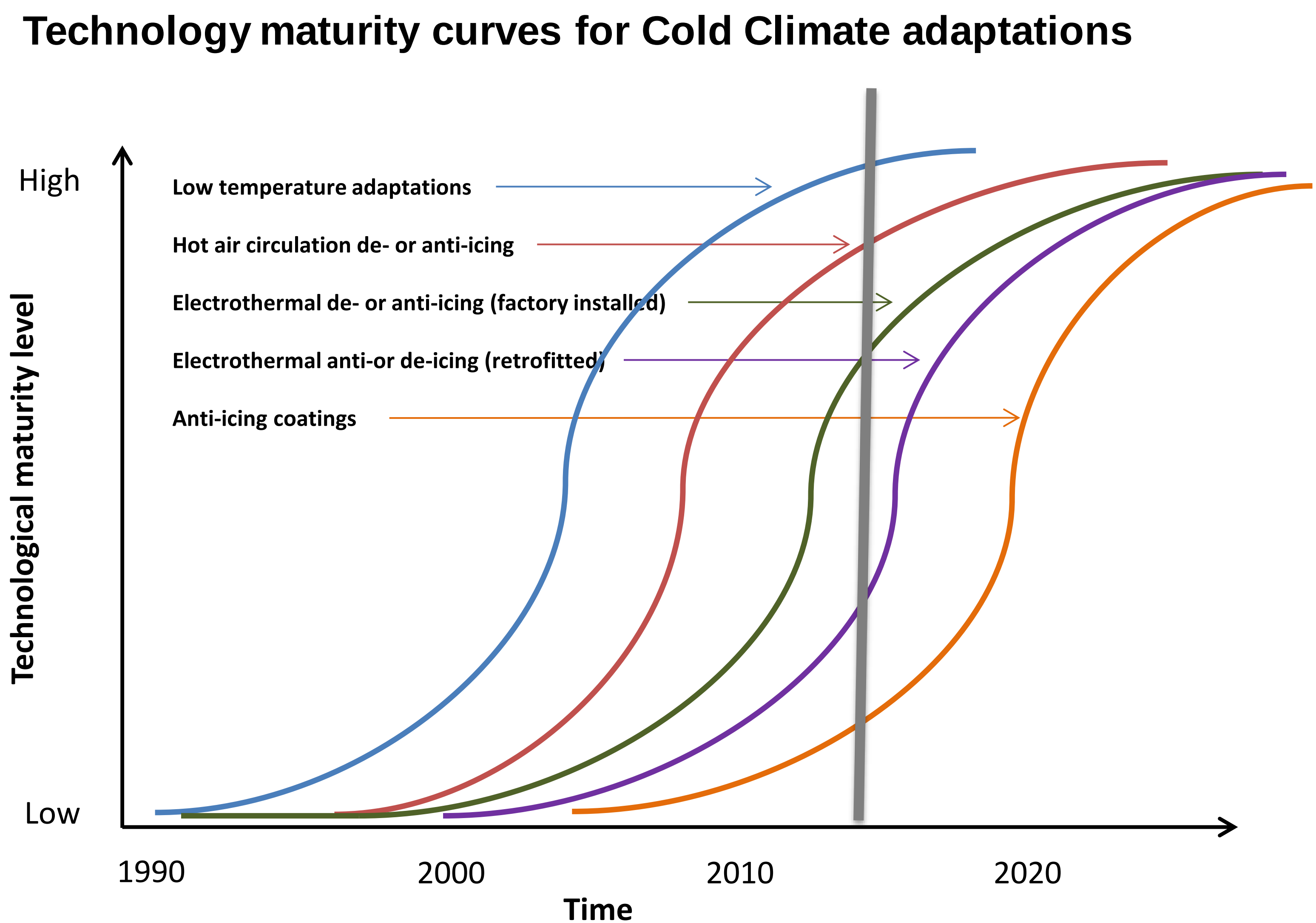


Figure 4. Illustration of components in unfrozen (three phase system) and frozen soil (four phase system).

Adaptation to Cold Climate conditions



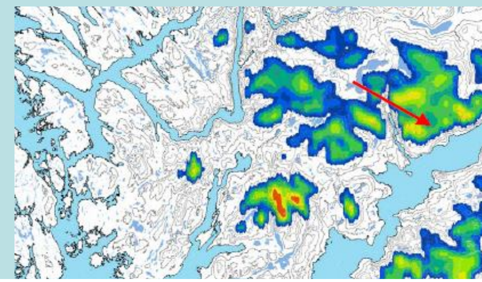
From: Navigant/BTM Consult

SET Analysis

Typical CC additional cost & risks

(CAPEX related)

- Mapping of icing probability
- Instruments and measuring or resource assessment and load prediction
- De-icing add-ons
- Anti-icing technology
- Foundations
- Environment, safety and warning systems
- Limited weather windows for installation



These issues will be addressed during this conference.

But there is more!

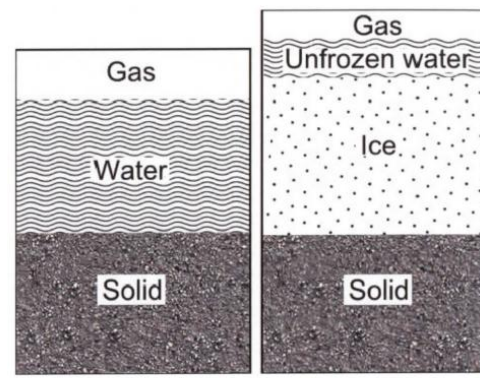


Figure 4. Illustration of components in unfrozen (three phase system) and frozen soil (four phase system).

Selected topics

Cost reduction strategies

$$* \quad LCoE = \frac{CAPEX + OPEX}{E}$$

- Efficiency
  (rotor, transmission, control, el. Conversion)
- Availability
  (icing, failures, accessibility, etc.)

Materials for higher reliability and thus Availability

Material properties

(Initial) S**tructural condition**

Usage (monitoring)

Load spectrum (monitoring)

Environmental factors (monitoring)

Damage degradation modes for metals and composites (hidden damages due to manufacturing & inherent in materials)

Physics needed !!

- Water and salt ingress
- Freezing and thaw cycles
- Wear and Fretting
- Long term effects of UV Light exposure
- Heat & LT damage
- Lightning Strike
- Bird Impact
- Erosion (blade leading edges)

Structural Health Monitoring

Condition Based Maintenance

Based on: Martinez, TUDelft

2. Cost reduction strategies

- Loads
- Scale
- Concept

$$* \quad LCoE = \frac{CAPEX + OPEX}{E}$$

Why up scaling ?

For the engineer:

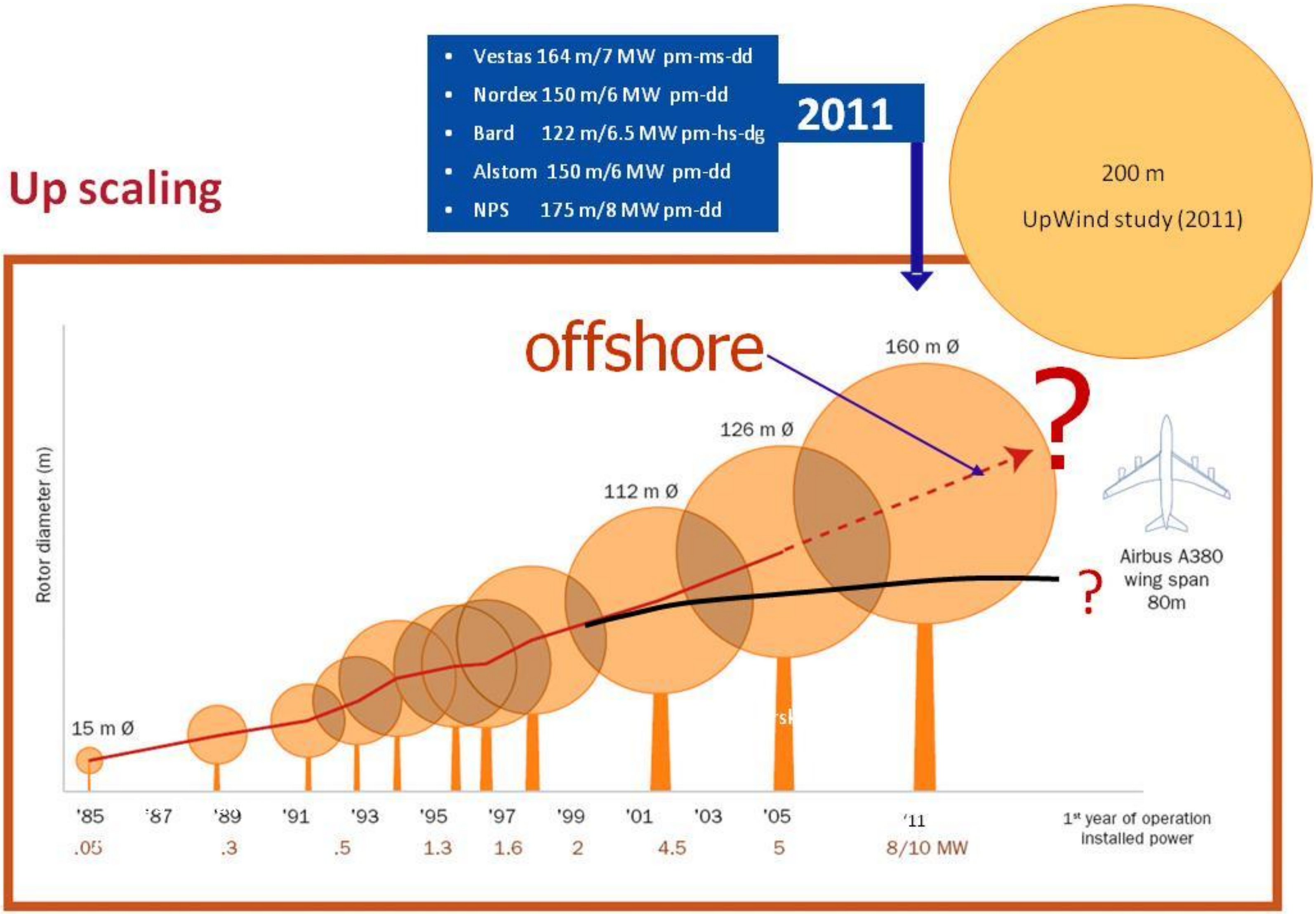
mass ~ (D^3)
cross section ~ (D^2)
stress (= mass/cross section) ~ D

For the economist:

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

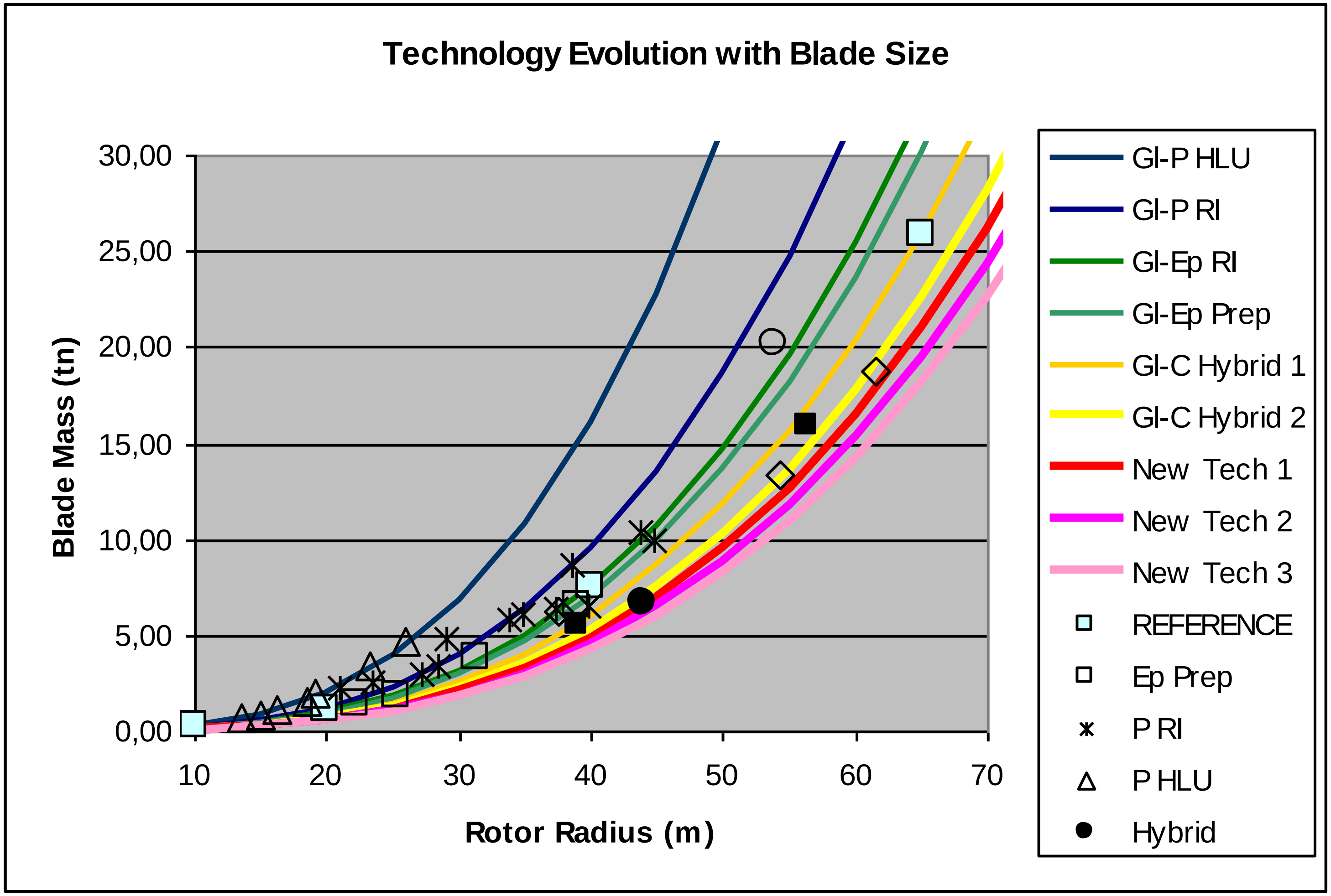
Development of advanced materials with a higher strenth to mass ratio

Up scaling



Jos Beurskens

Blade materials

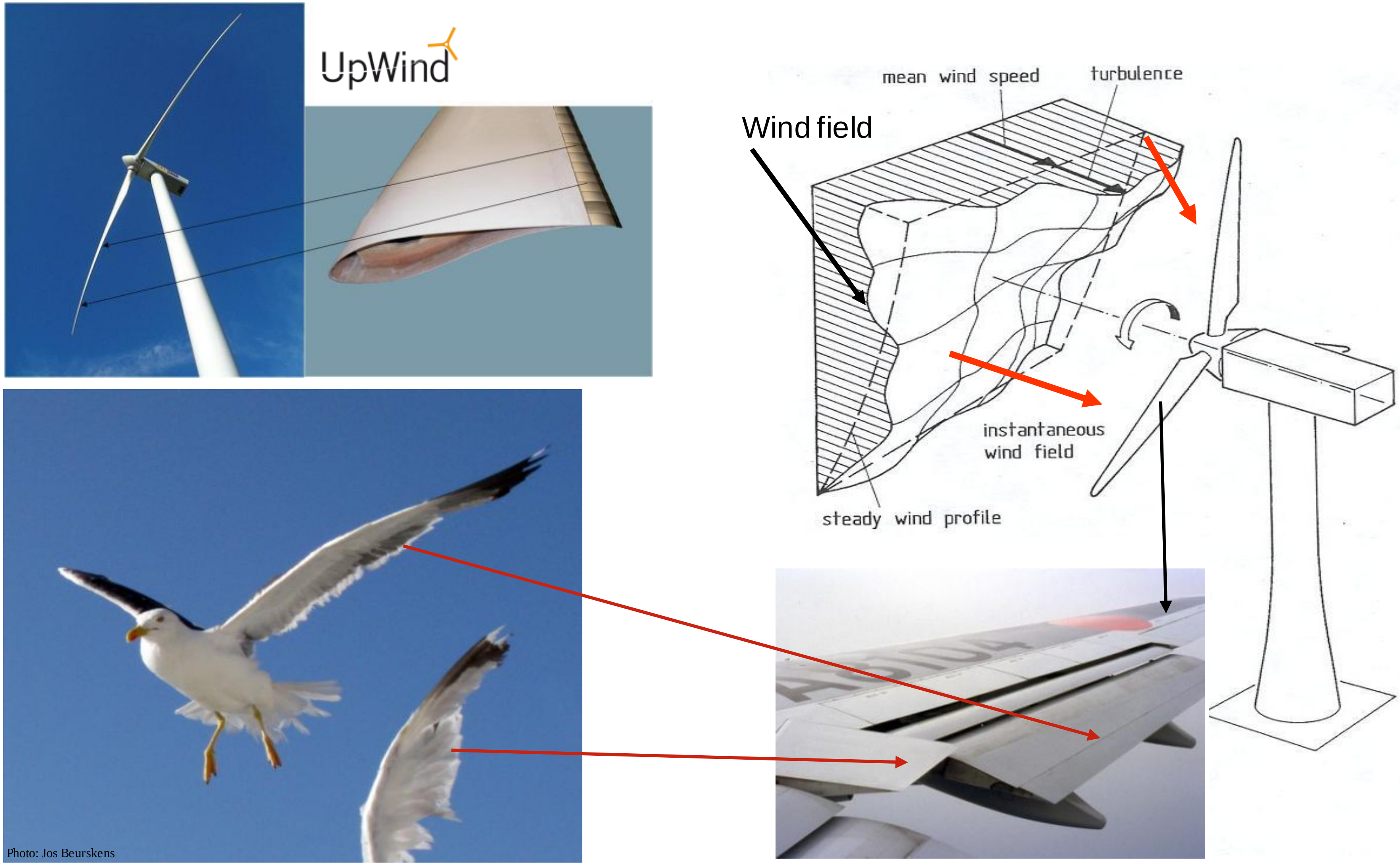


Source: UpWind; CRES, GR

Transport limits dimensions of land based wind turbines

Frankfurt 20-11-2013

Up scaling; distributed blade control reduces fatigue loads

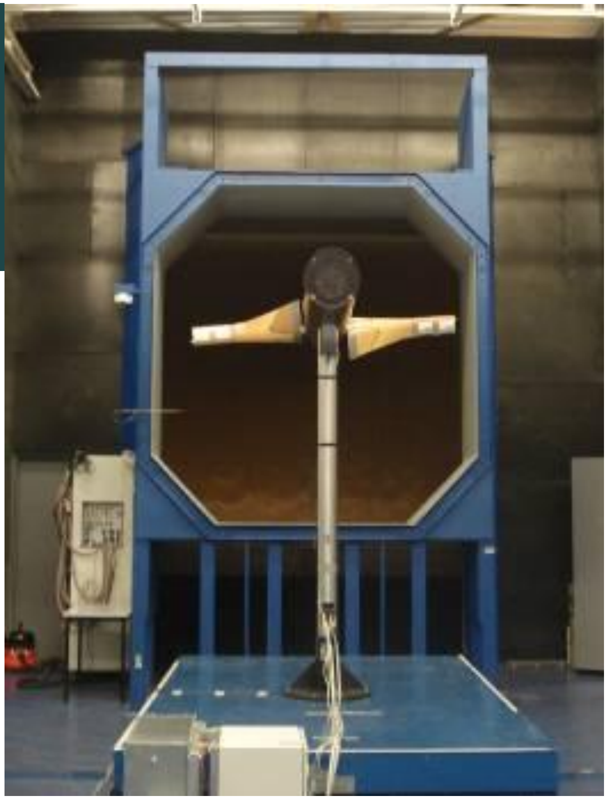


Up scaling; distributed blade control reduces fatigue loads

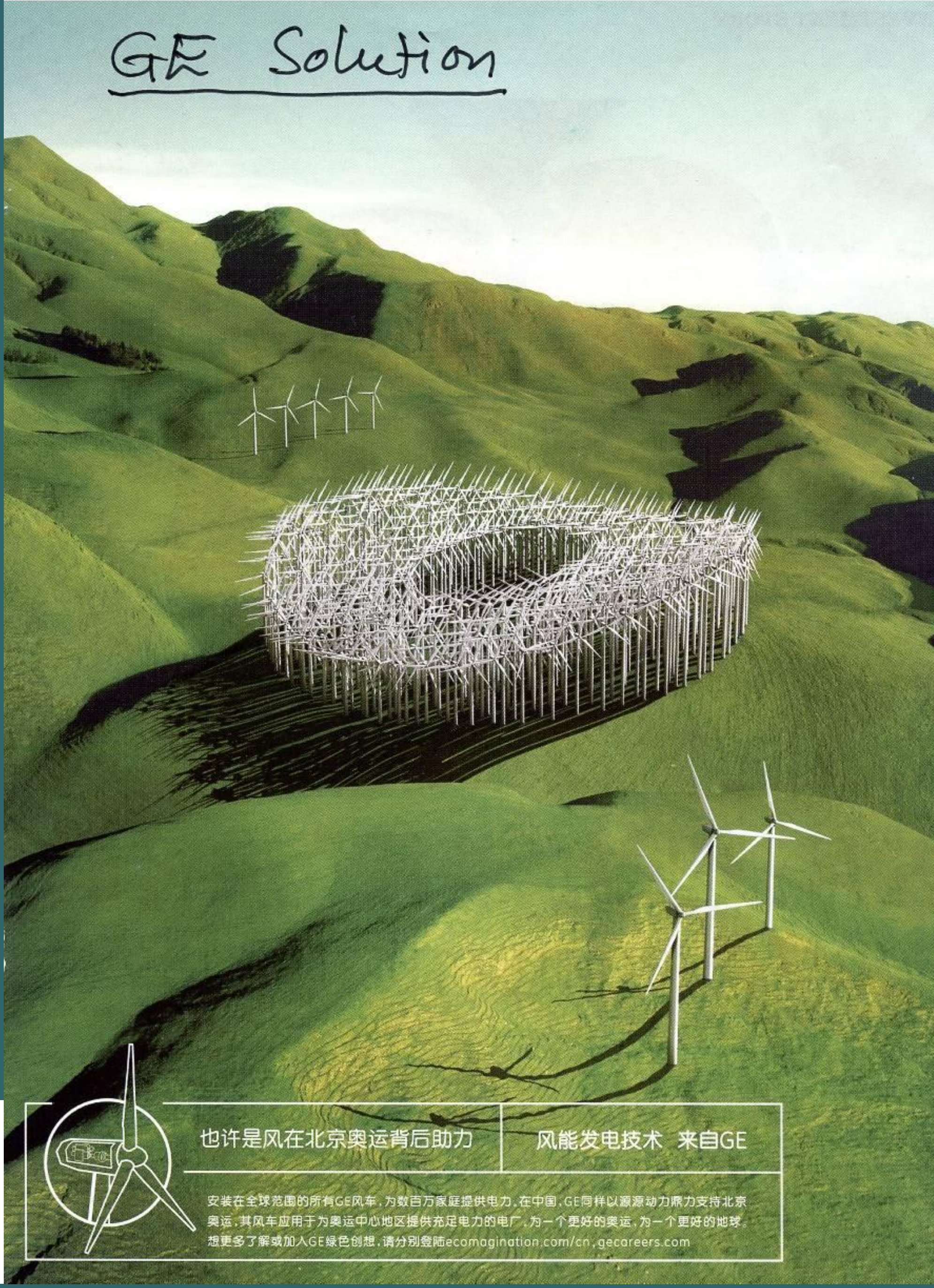
Distributed blade control reduces fatigue loads

Comparison with Individual Pitch Control:

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



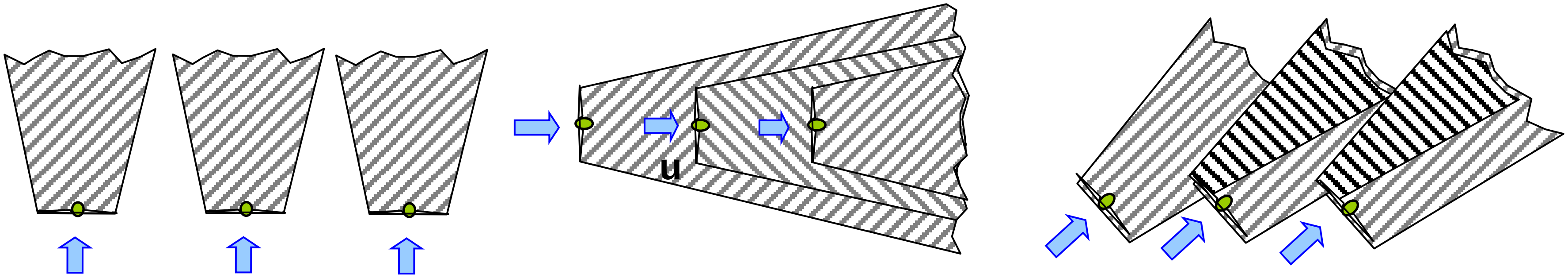
Concepts: Wind farm design

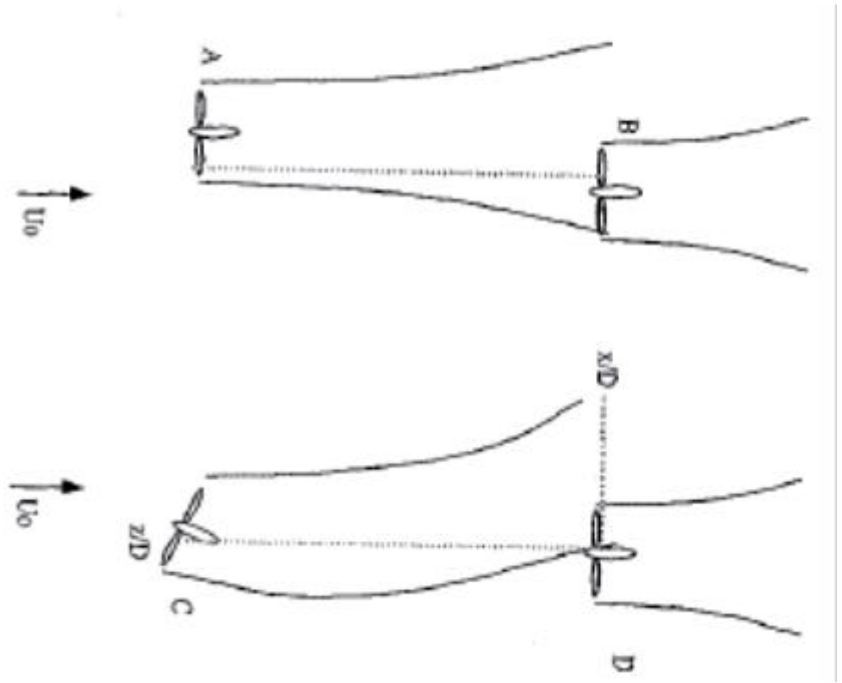


More energy at same investment level

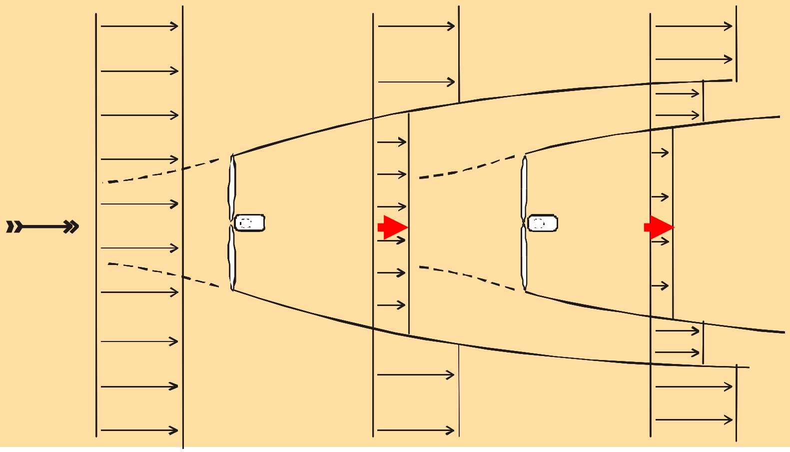
(optimising lay-out & wake control)

Wake control (1)

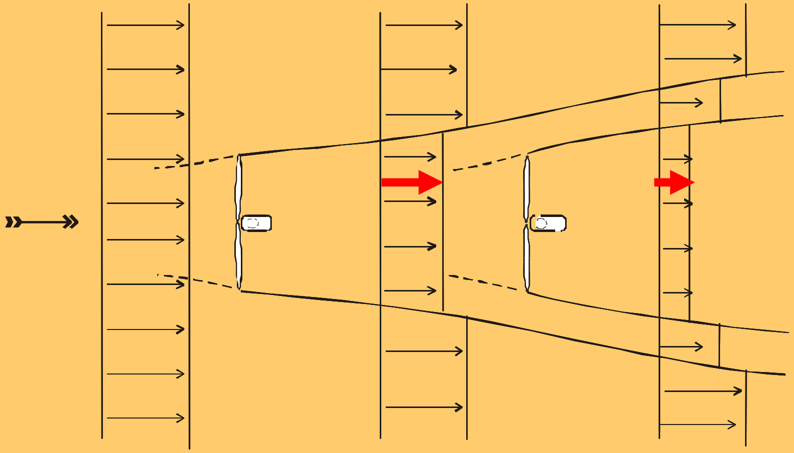




Wake control (2)

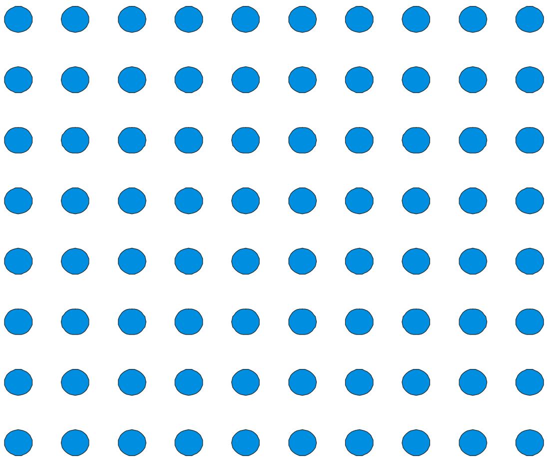


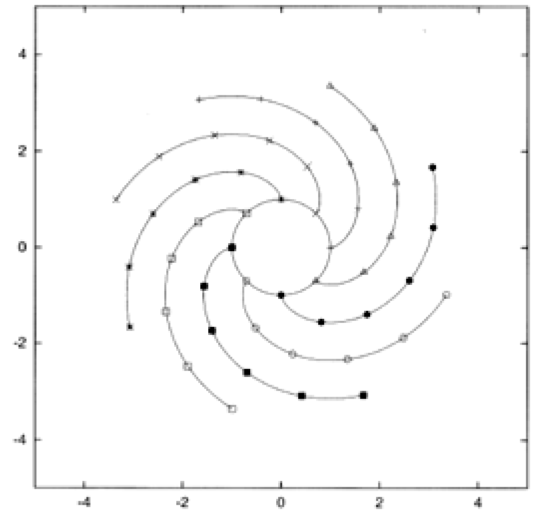
First row(s) more ‘transparant’ for flow’

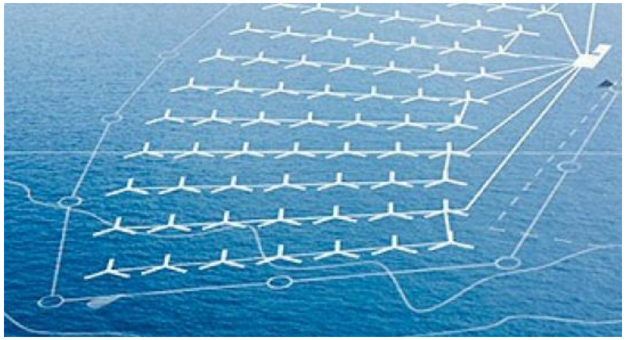


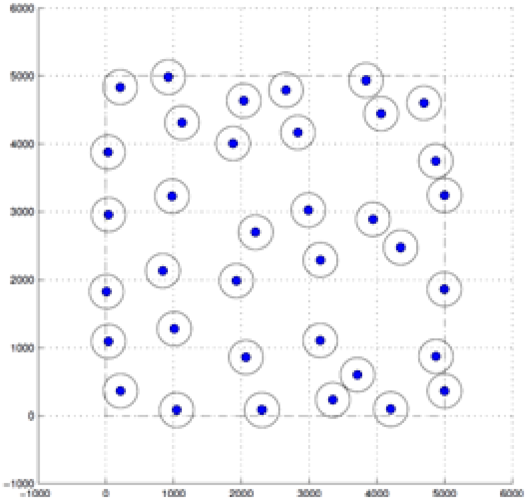
Source: ECN

Lay-out for high turbulence areas irrelevant





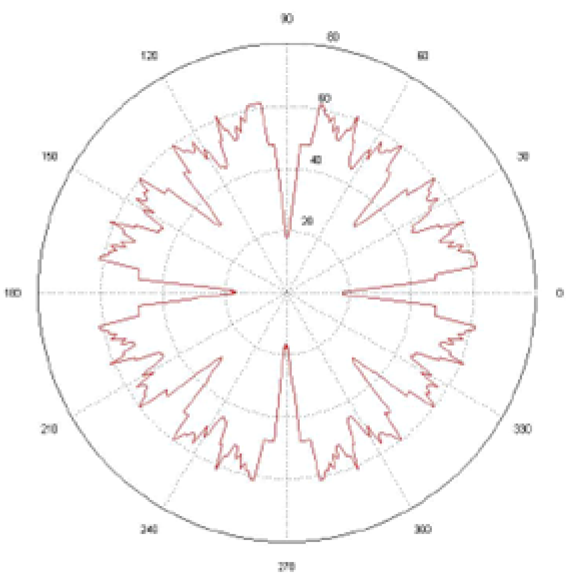




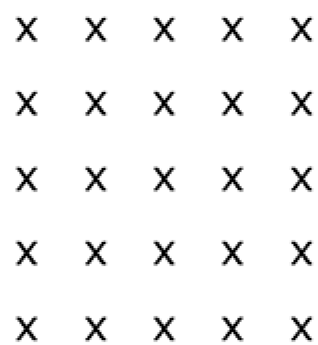
Power quality of wind farms; variability of power output

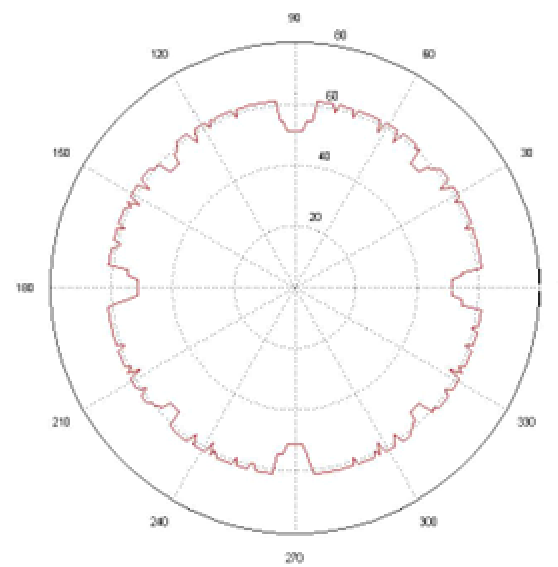
Wind farm lay-out, effect of wind direction variations

Never place wind turbine offshore in straight rows !!



1% ambient t.int





10% ambient t.int

Torben J. Larsen, DTU-Risø

3. Cost reduction strategies

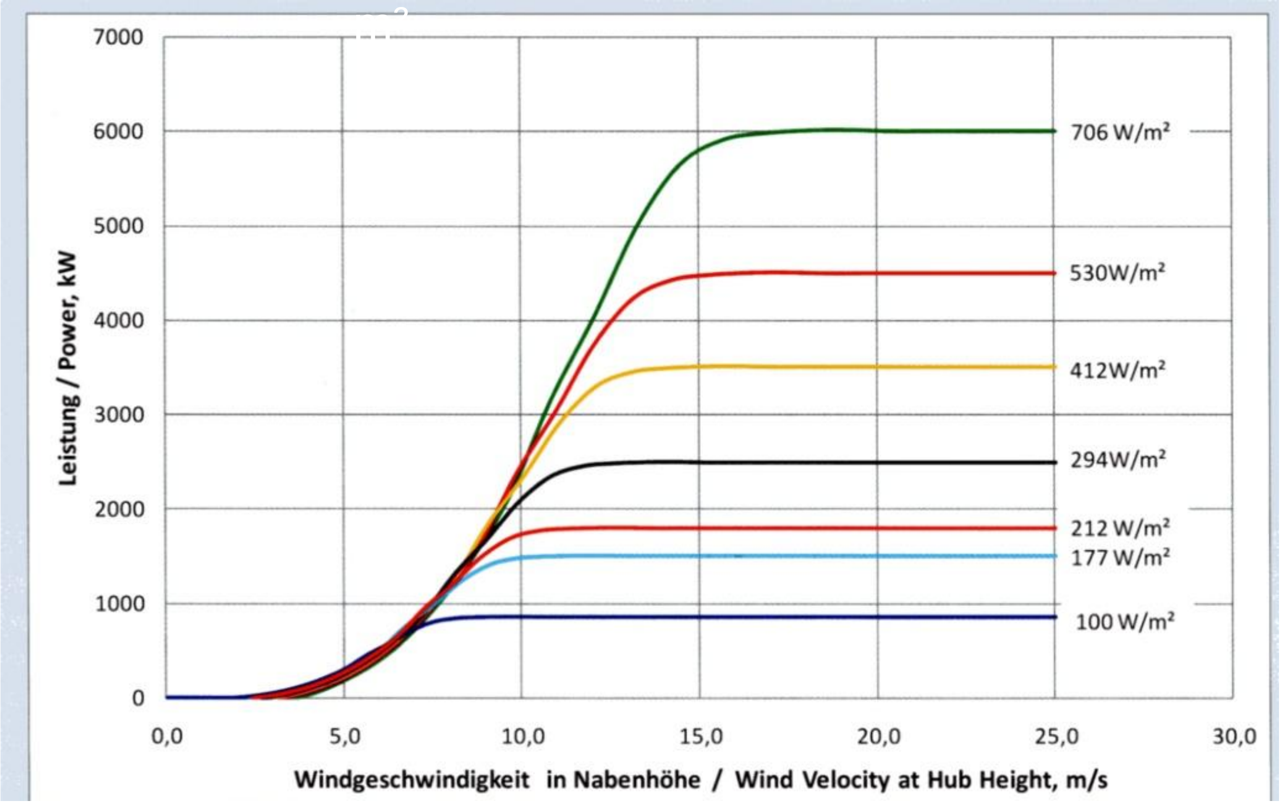
* $LCoE = \frac{CAPEX + OPEX}{E}$

* Cost of grid connection and integration

* Maximise penetration degree of WE

  $\neq$ Maximising wind farm output

Wind turbine power rating

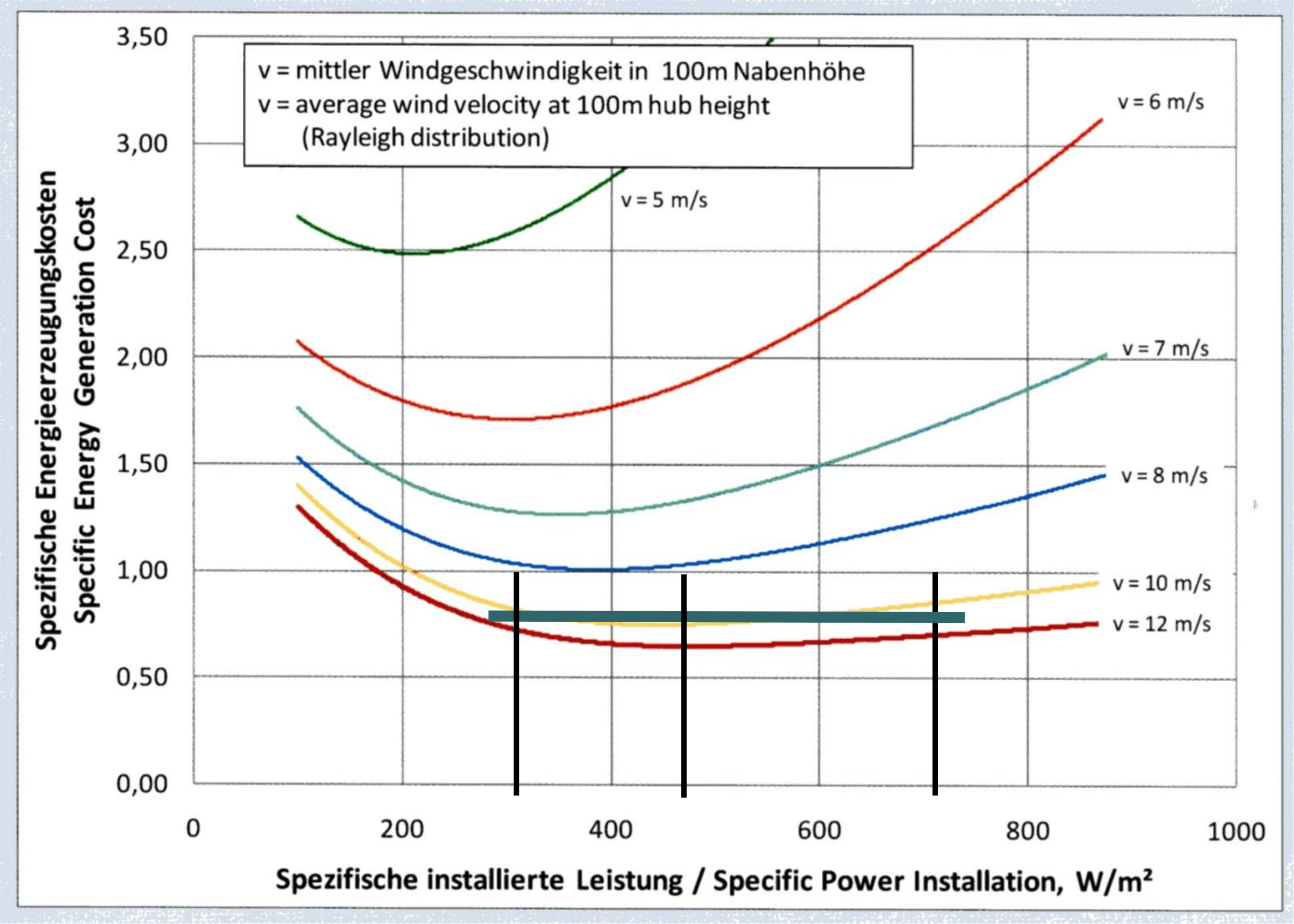


$$p = \frac{P_R}{A_{rotor}} \quad [W/m^2]$$

Source: J.P. Molly, DEWI

SET Analysis

Cost of de-rating wind turbines

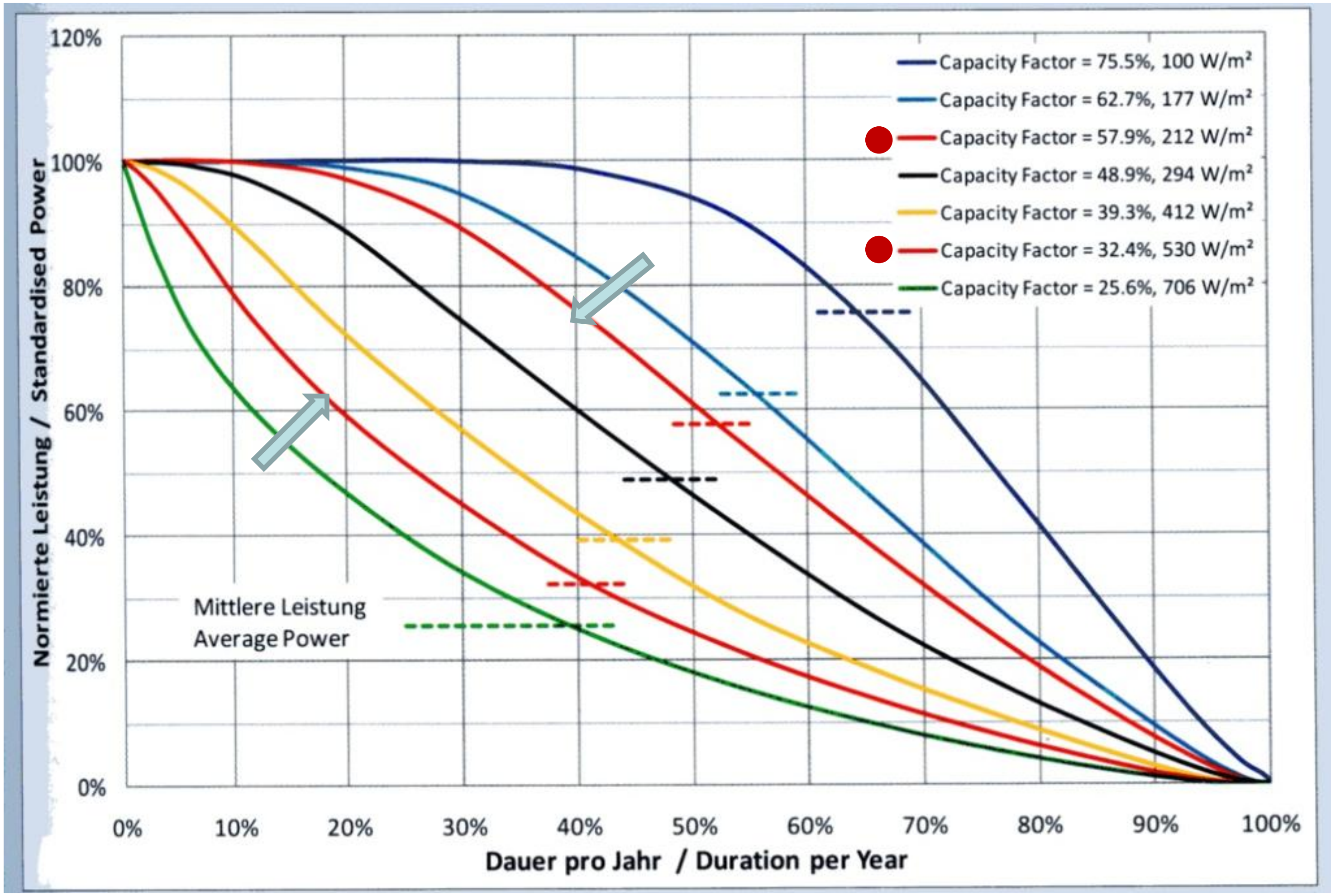


Source: J.P. Molly, DEWI

System rating: Low wind regime rating
Mechanical design: High wind speed regime

Lower p-values > higher capacity factors

Wind turbine power rating and capacity factor



Source: J.P. Molly, DEWI

Advantages of low value of p, or high capacity factor

- Cost reduction of all electrical components, which outweighs slight decrease of output per m² swept rotor area.
- Higher penetration degree of WE
- Improved output predictability of wind farm output (< 24 hours ahead)
- Lower balancing cost
- Lower storage cost

Conclusions

- Resource assessment, icing probabilities
- Focus research on anti-icing equipment and de-icing
- Standardised Monitoring and Testing
- Develop low-p [W/m²] wind turbines for better grid integration
- Increase budgets for CC R&D considerably (SF, S, CND, …….., Manufacturers, Developers/Owner-Operators)

Thank you for your attention !

Photo: Jos Beurskens