

# Design for X

- perspectives for future blade and turbine technologies

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- **State-of-the-art analysis** of wind energy systems, wind turbine technologies and materials and components written by leading DTU Wind Energy researchers in cooperation with leading Danish and international experts
- **17 short chapters** targeted towards colleagues and collaborating partners in the wind energy sector at large, funding organizations, institutional investors, ministries and authorities and international organizations such as the EU, IEA, UN and the World Bank.
- To be published **25 October 2021**

# Outline

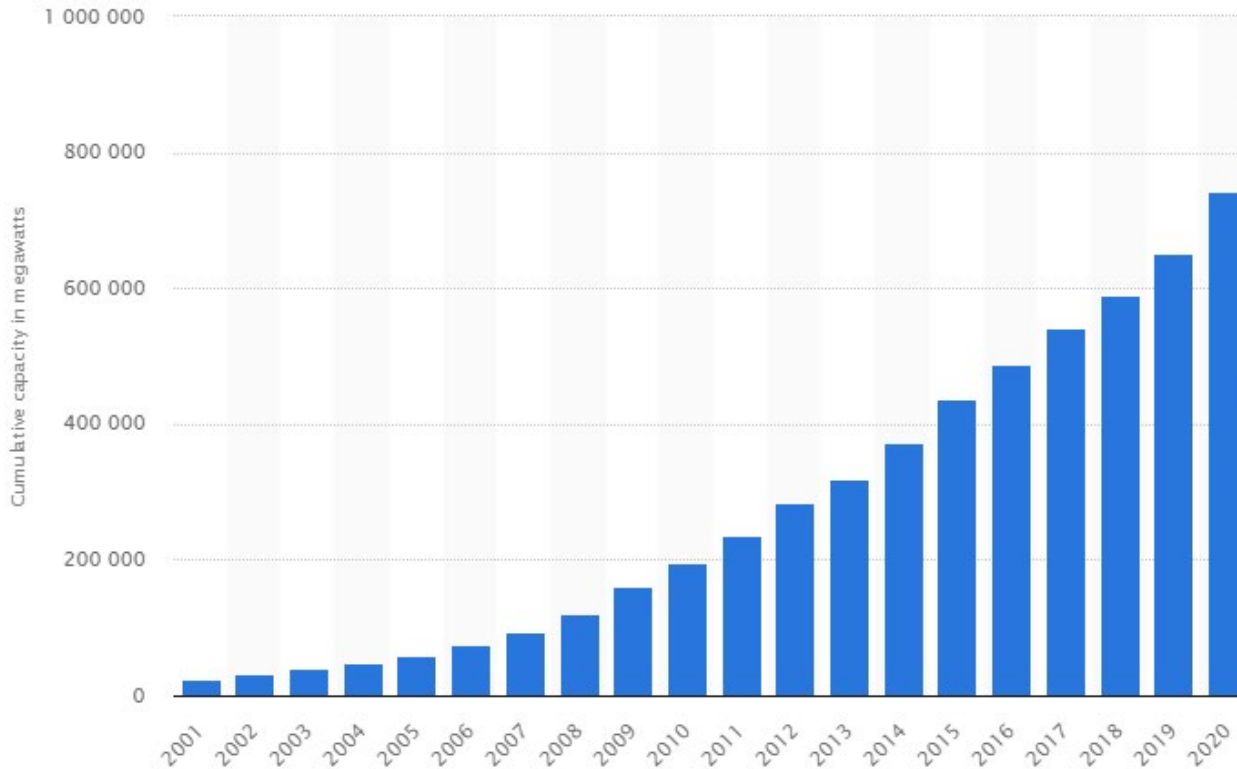
- Status on global market and technology development
- Perspectives for the next 30 years
- The need for Design for X
- New common visions and aligned roadmaps

## Challenge:

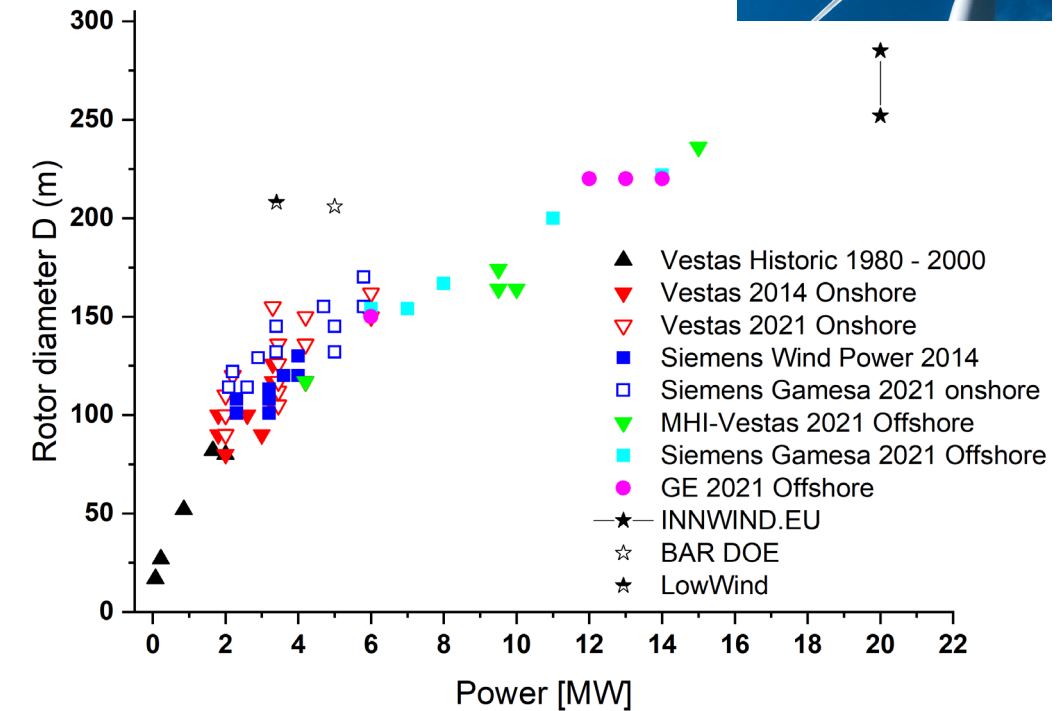
- Indications of a general perception that wind turbine technology is fully mature and has reached the point of diminishing returns (concerning research effort)
- I will try to convince you about the opposite

# Impressive achievements during the last 20 years

Market: 740 GW Wind installed



Technology: 12-15 MW



• [Global installed wind energy capacity 2020 | Statista](#) © Statista 2021

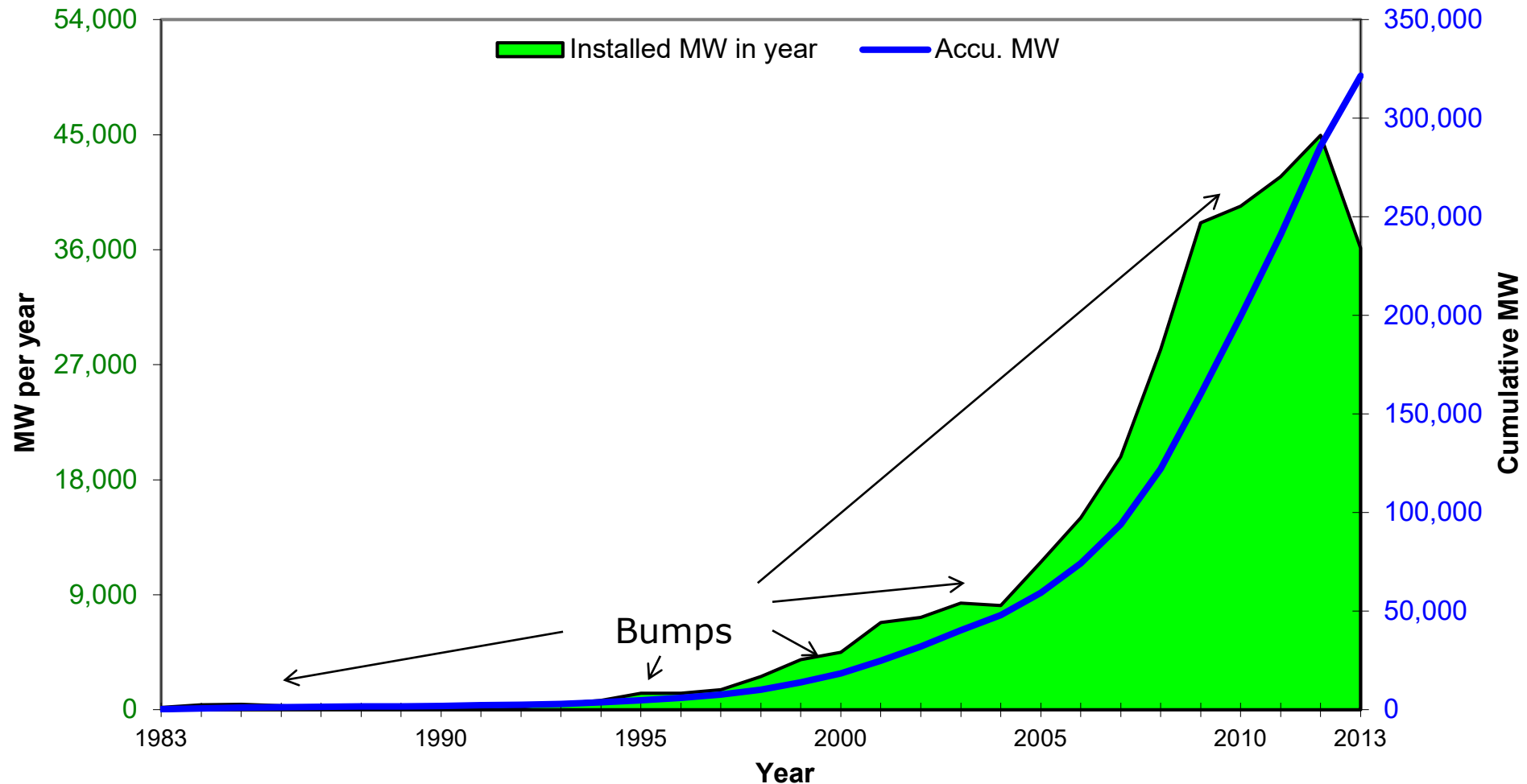
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A.B. Abrahamsen, DTU Wind Energy, July 2021

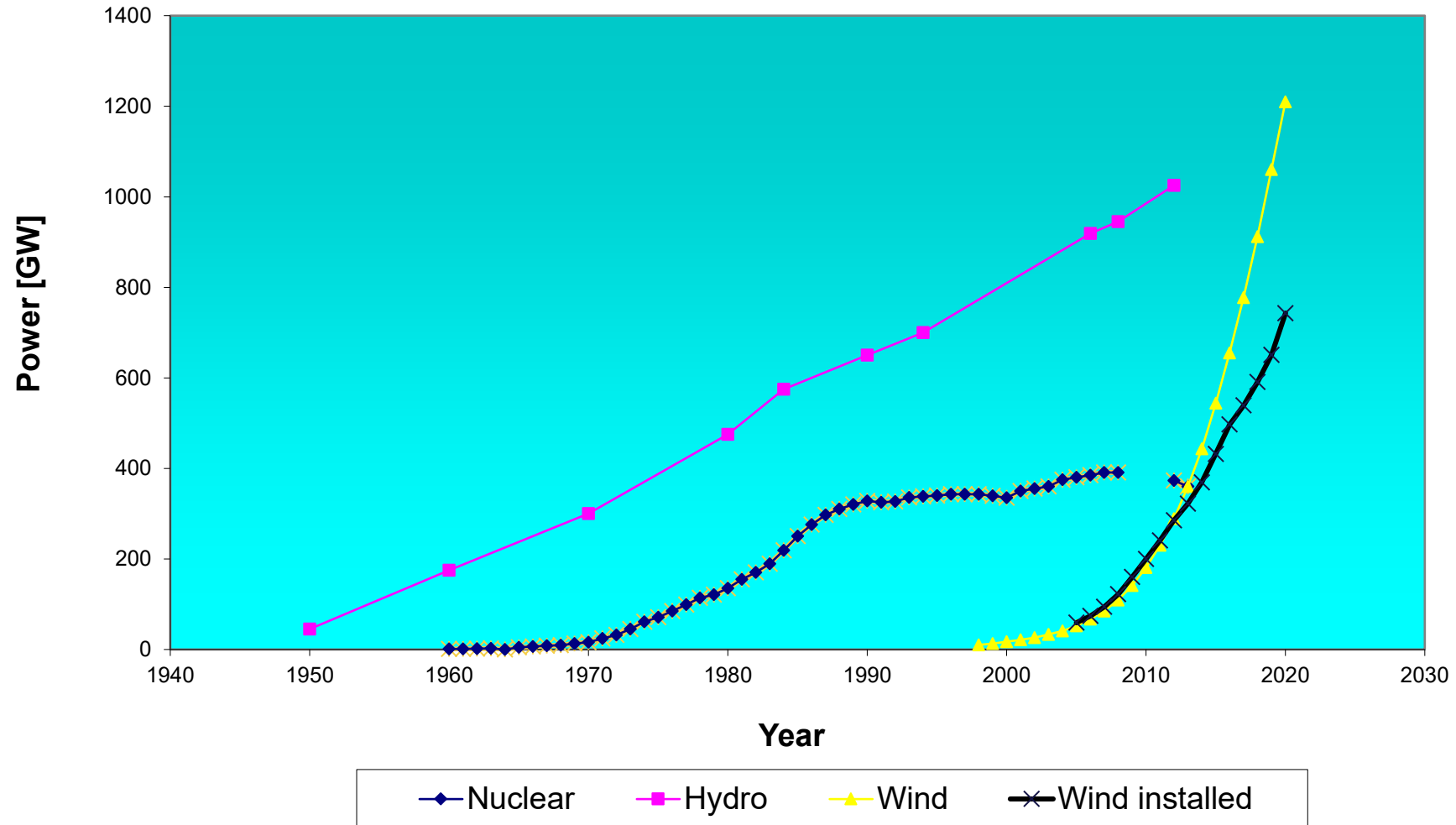
# Global market development 1983 - 2014

## Installed Wind Power in the World - Annual and Cumulative -



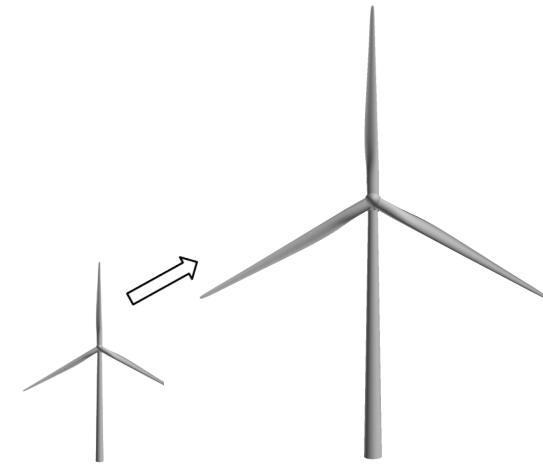
# World generation capacity and Wind Force 10 - 10% wind energy scenario from 1998

by BTM-Consult



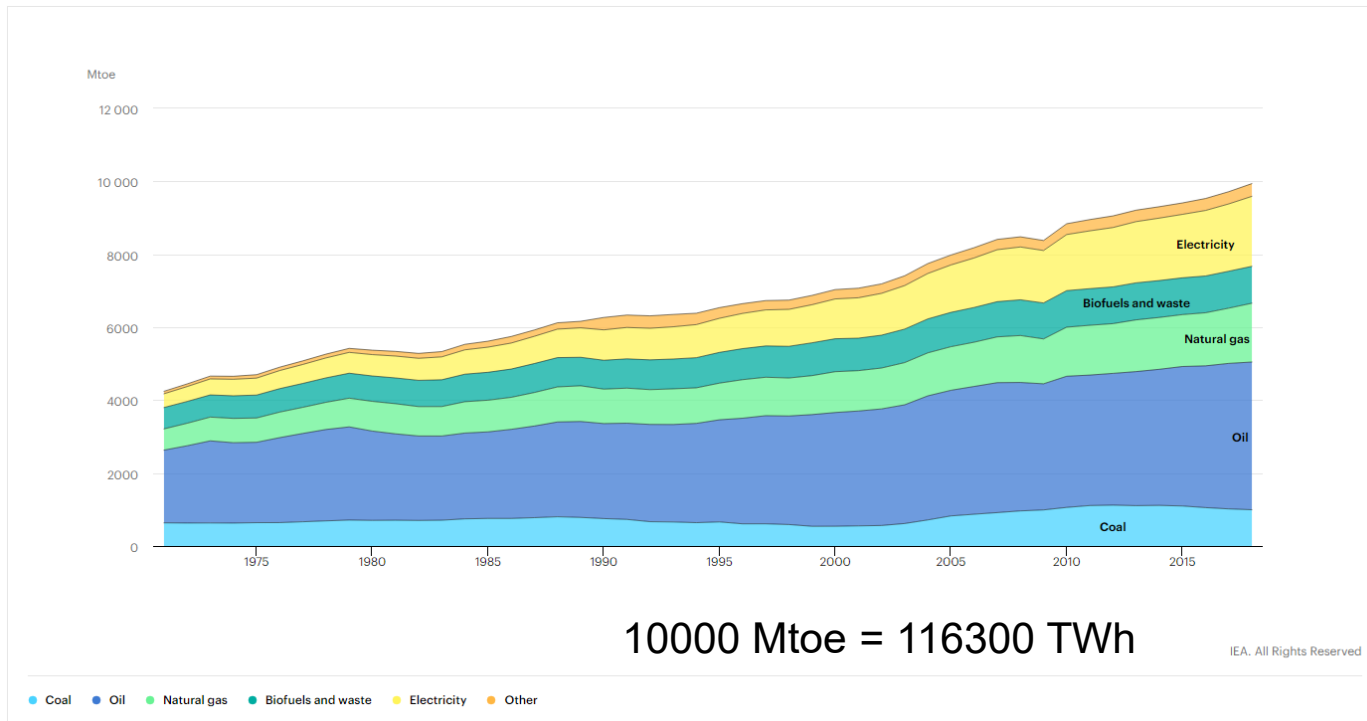
# Upscaling the technology

- 2002 EU application 'Wind Power Plant 2020 – the Size, the Concept the System', aim of envisioning 20-MW turbines being developed by 2020, with wind generating 10 % electricity and establishing research road-maps to actually get there.
- 2006 -2018 EU UPWIND and INNWIND: 20 MW turbines with 240 m rotors
- 2021 Vestas announced their new offshore turbine of 15 MW with a rotor diameter of 236 m
- Illustrates importance of establishing a common vision and framework, which to a large extent has been the case for the wind-energy community, and that the research status, needs and potentials should be seen in that context.



# World total energy consumption

- Global consumption: 116.300 TWh
- Electricity: 27.000 TWh



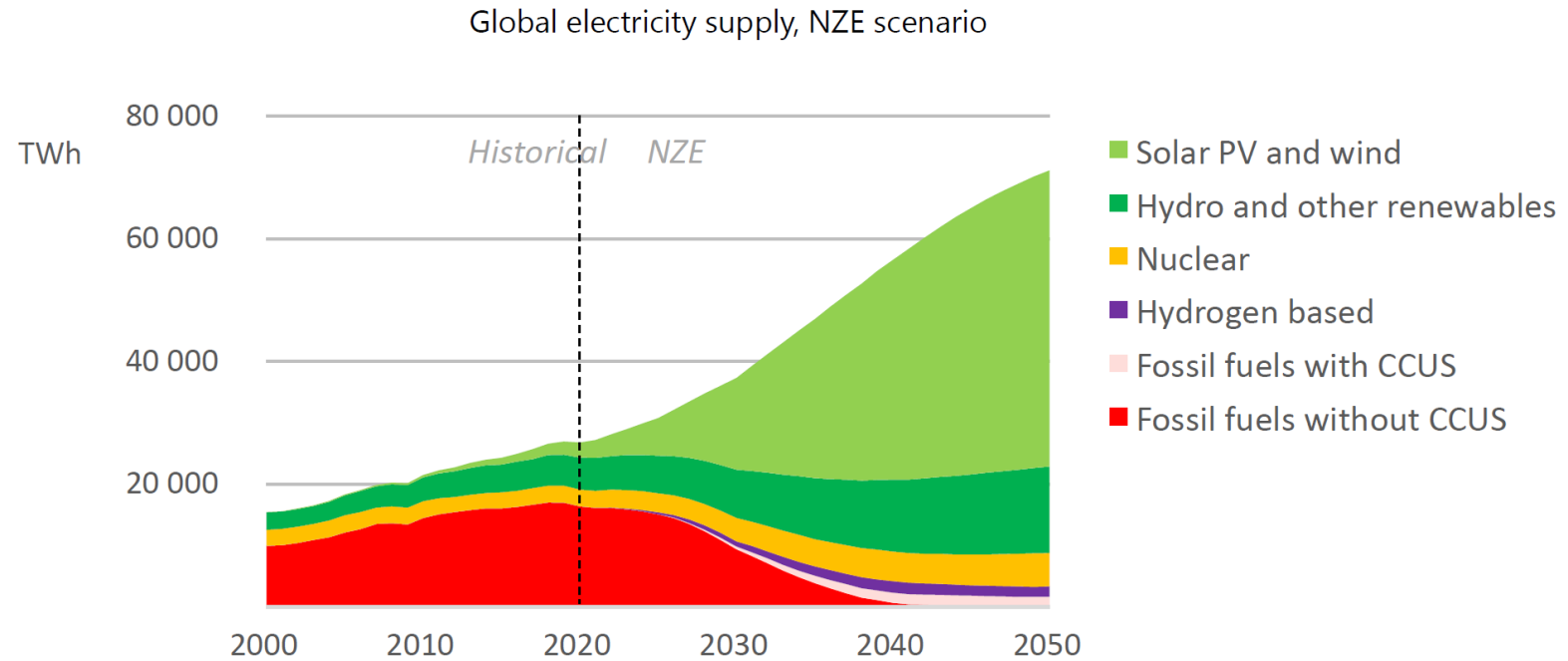
- Wind and PV: 2700 TWh = 10 % of electricity, but only 2.3% of Global consumption
- Wind: 2/3, PV: 1/3
- Wind: 7 % by 2020

[World total final consumption by source, 1973-2018 – Charts – Data & Statistics - IEA](#)



# Net zero emission scenario

## Electricity leads the way to net zero

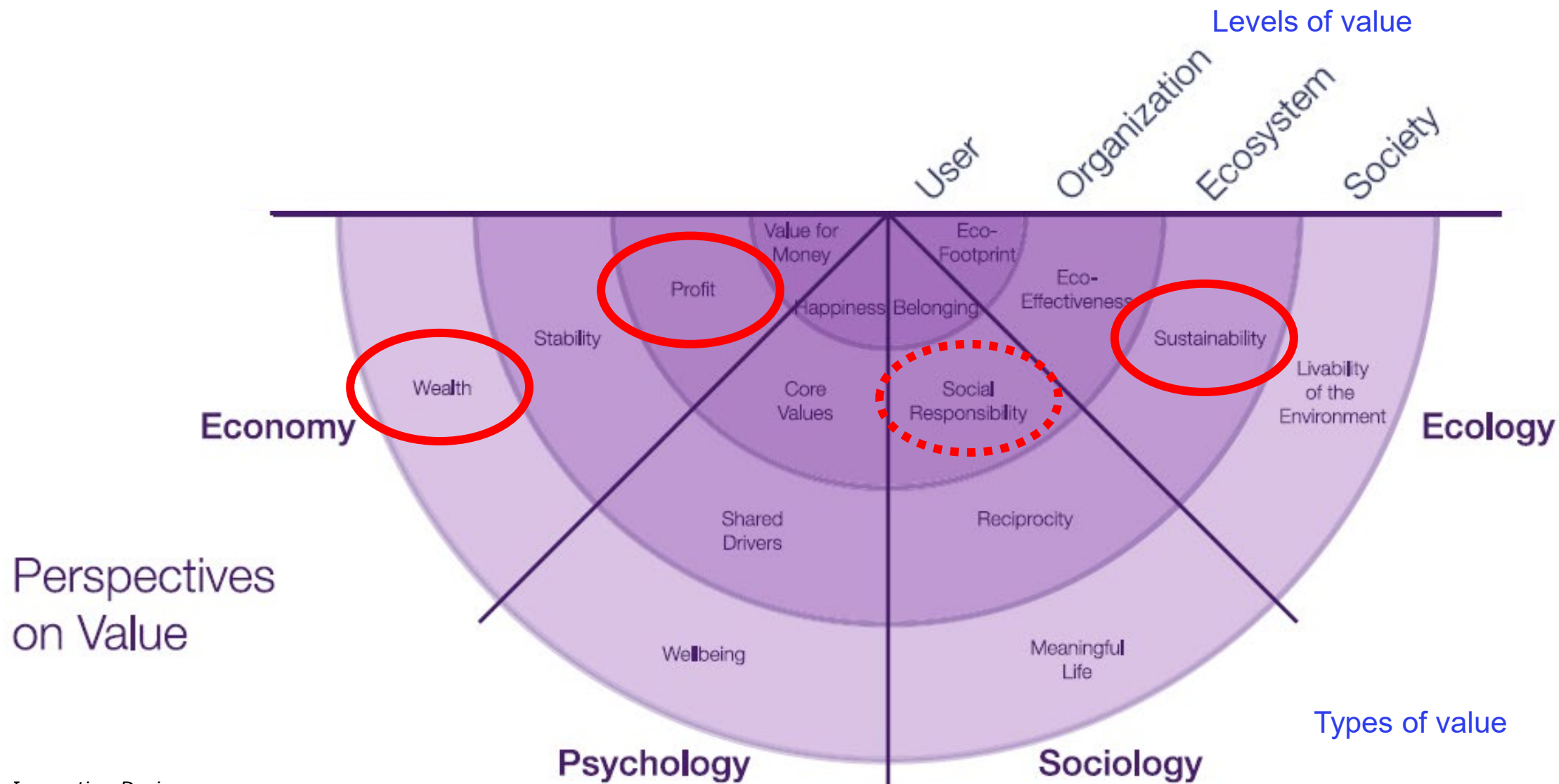


**In IEA net zero pathway, renewables make up nearly 90% of electricity generation in 2050, propelled largely by solar PV and wind.**

# New visions and scenarios

- Time to set new ambitious scenarios and goals that could include and turbines optimized for improved energy-system operation and sustainability, and possibly 'lighthouse' turbines of up to 40 MW and 200 m blades by 2040-2050.
- From cost to value by inclusion of more variables, long term perspectives, sustainability, innovation, disruption and research in the design loop.
- Need to focus on both the integration of wind (P2X) and the wind turbine technology development.
- Extend Wind Power Hub and Value Concepts

# Value concepts from different perspectives



# Article in Politiken

MOGENS LYKKETOFT  
ANDERS ELDRUP

Griber vi chancen, kan  
brint blive det nye  
danske bæredygtige  
energieventyr. Ligesom  
vindmøllerne i sin tid.  
Men der skal handles nu.

# Wind turbine design to facilitate integration

## Design for X (D4X)

Design for:

- Cost
- Value (e.g. LowWind, Power plant characteristics, ....)
- Sustainability
- Energy efficiency
- Lifetime
- O&M, Service
- Modularization
- Recycling
- Power 2 X
- Scalability, upscaling
- Siting
- Manufacturing
- Price-optimization
- Public Acceptance
- .....with varying weight in a system engineering optimization

Examples for illustration

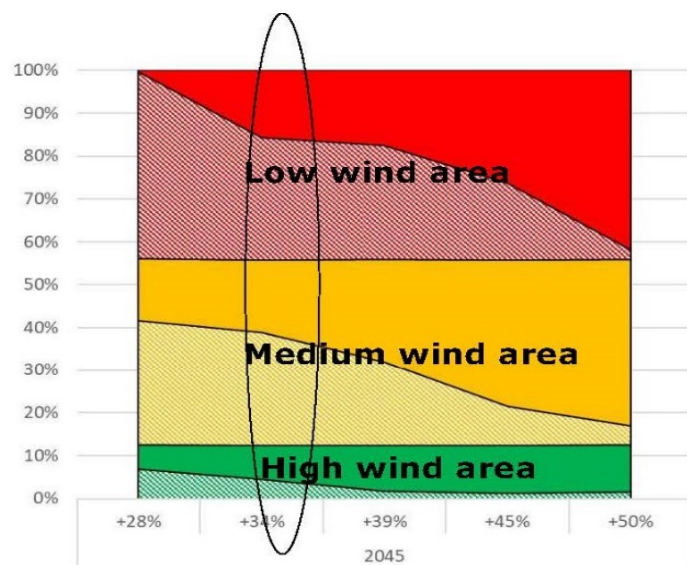


# Design for value: The LowWind turbine – technology innovations

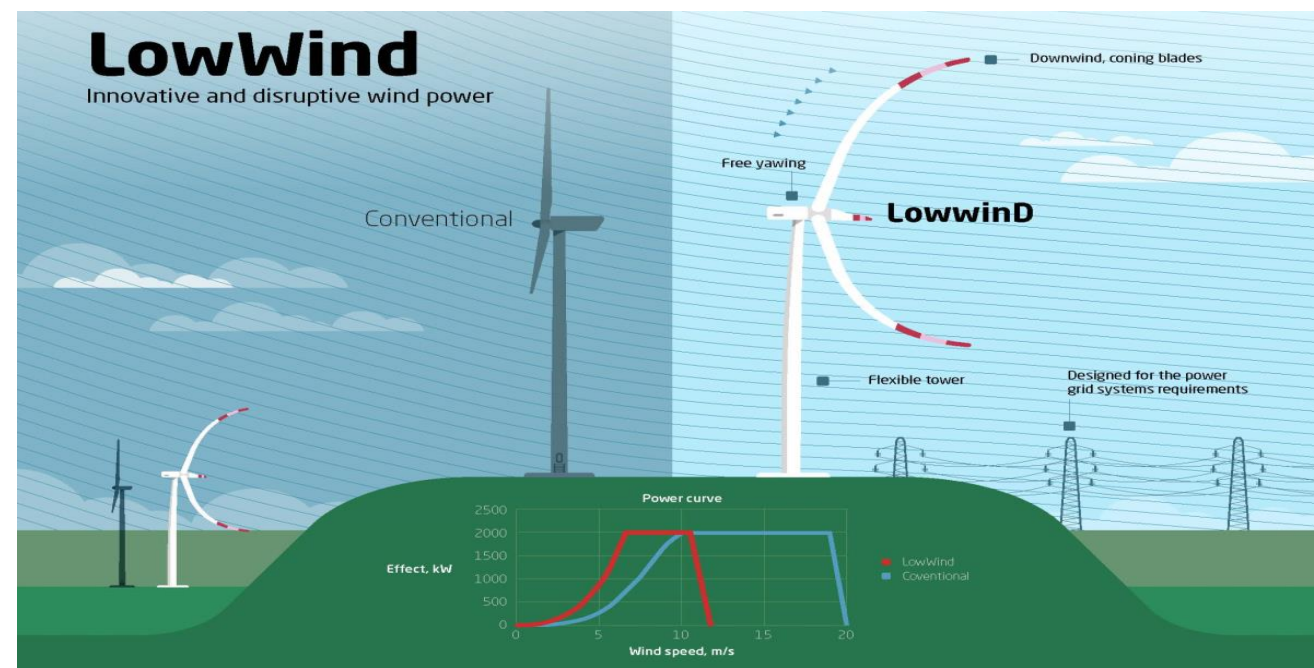
## 3.4 MW IEA RWT



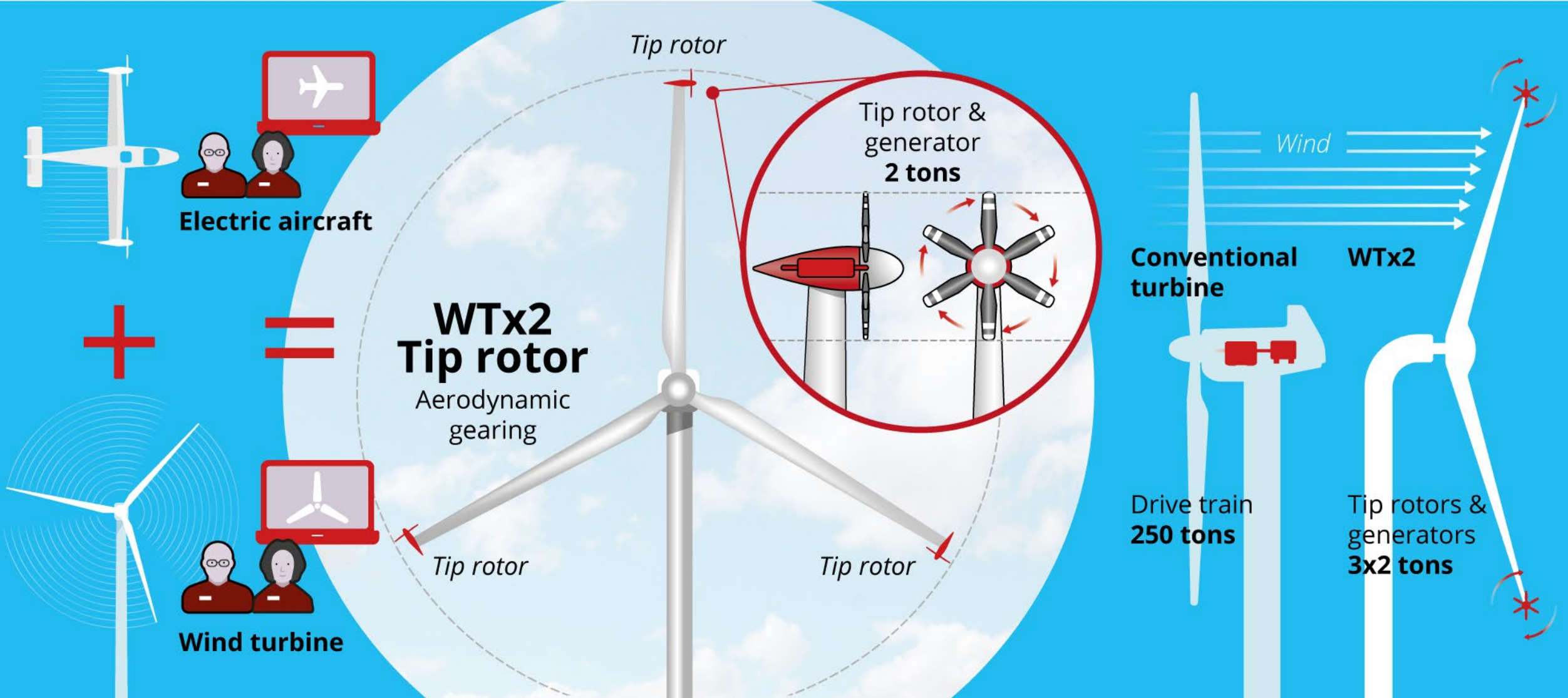
## 3.4 MW LowWind turbine with 208 m rotor



Shaded areas show the predicted share of LowWind technology of the wind-turbine market in 2045 as a function of increased CapEx relative to the cost of conventional turbine technology.



# Design for energy efficiency, weight and O&M



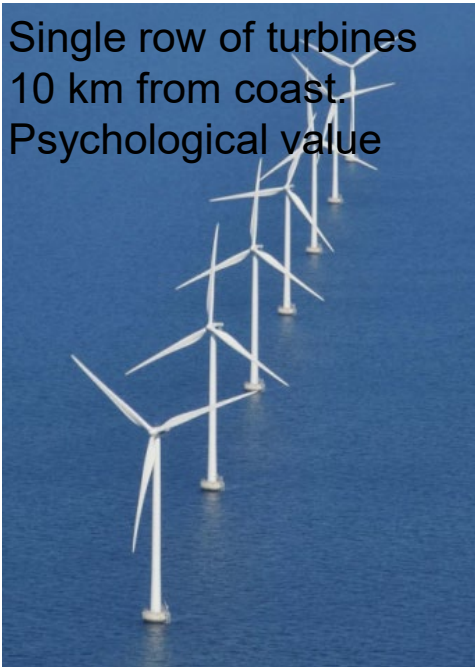
# Considerations on Design for X

Lightweight, 10 years design lifetime in a sustainable context of saving fossile fuels

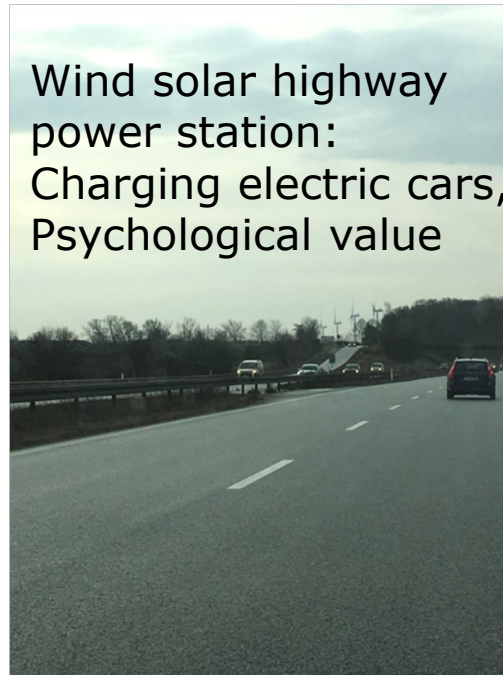
Sound design > < noise

Modularisation, recycling:  
Building value into decommissioned turbine.  
Storing of valuable components or materials for end release.

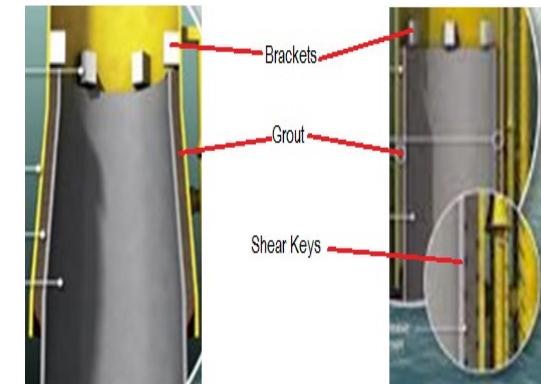
Single row of turbines  
10 km from coast.  
Psychological value



Wind solar highway  
power station:  
Charging electric cars,  
Psychological value

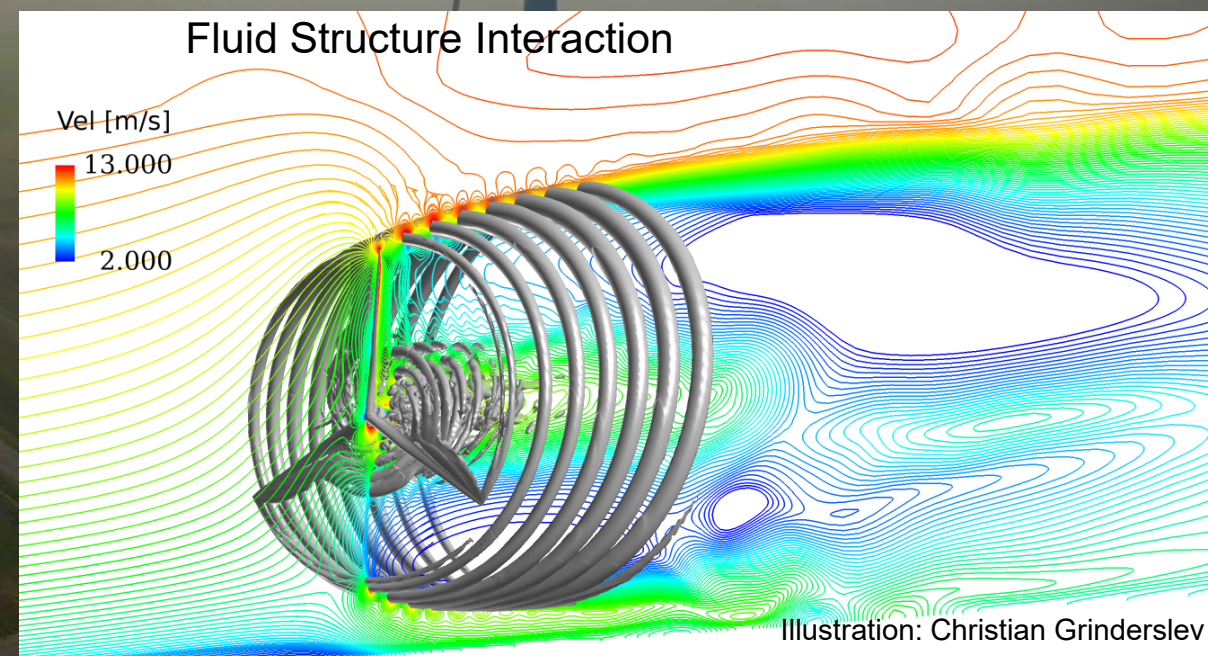
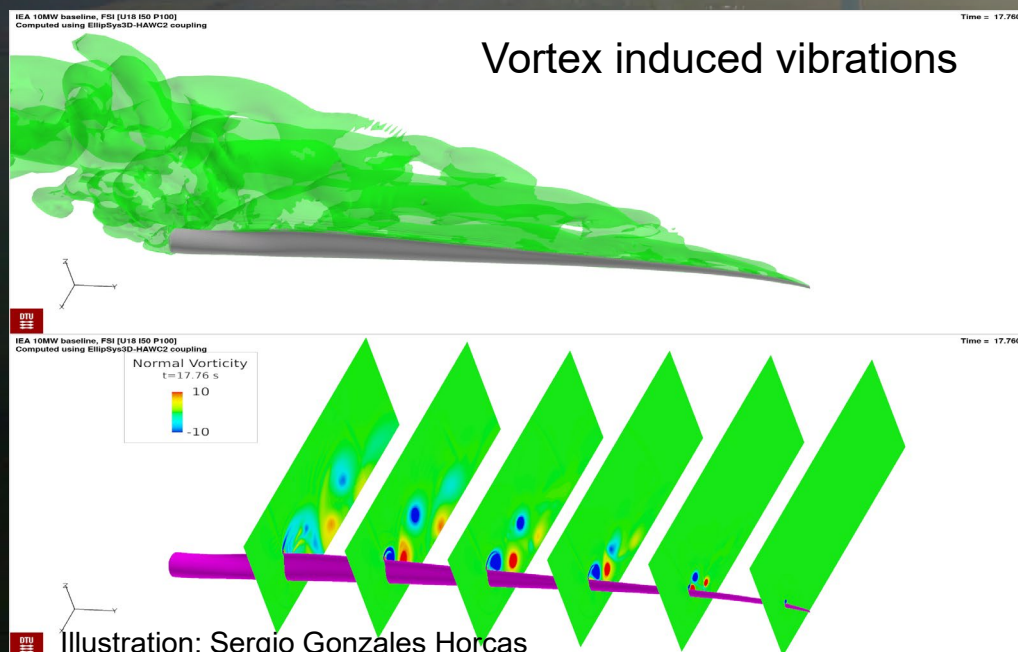
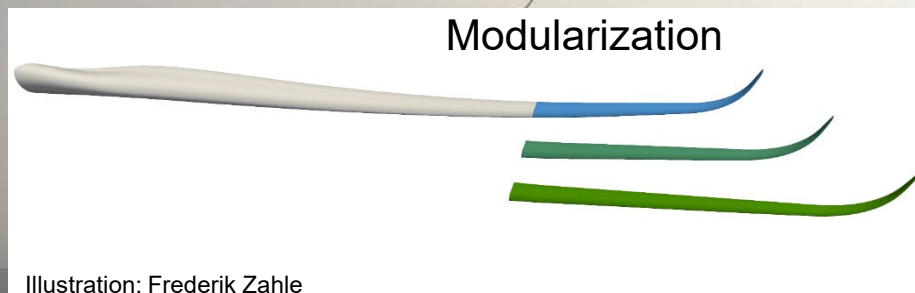


Blades and  
monopile to be  
fully recycled





# Multi fidelity tools and New technologies



# Long-term development trends for turbine design

**Much bigger turbines**

**More floating**

**More control**

**Different use cases**

**Life cycle perspective**

**Risk reduction  
in design**

**New  
technologies**

**New design  
solution and  
approach**

**Detailed and  
comprehensive  
validation**

**Integration of  
solutions**

**Integration of  
design and  
operations**



# Conclusion

- Huge perspectives in turbine technology and Design 4 X, but it requires constant upgrading of the design methods.
- Not far from what we have been doing, and is building upon our strongholds.
- We can afford it now.
- Our goal is cost efficiency, value and sustainable development. Not the same as the cheapest turbine right now.
- System engineering, AI, Digital twins and virtual validation to unlock the potentials and help develop new insight and maintain knowledge. Increase crowd intelligence.

An aerial photograph of a wind farm during the 'golden hour' of sunrise or sunset. The sky is a mix of soft orange, yellow, and pale blue. A thick layer of fog or low-lying clouds covers the ground, partially obscuring the forest and the bases of the wind turbines. Several wind turbines are visible in the distance, their silhouettes softened by the haze. In the center-right, a large construction crane stands on the ground. On the far right, a single wind turbine is in sharp focus, showing its three blades and tower. The overall mood is serene and atmospheric.

# Thank you!

Photo: Poul Falk Nielsen

S9