Developing the Future

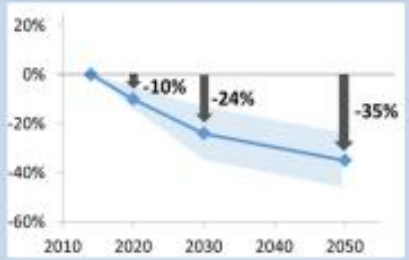
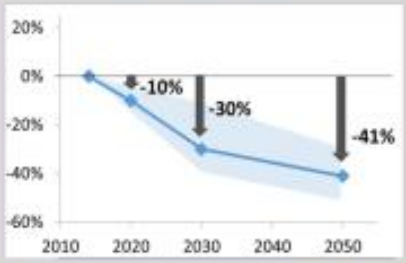
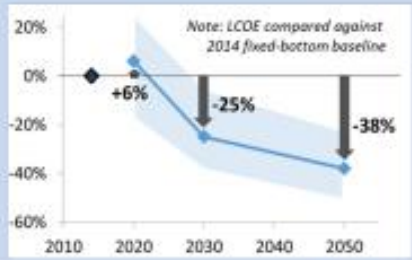
from Vision to Reality

SkyWind

Forecasting Wind Energy Costs and Cost Drivers

SkyWind

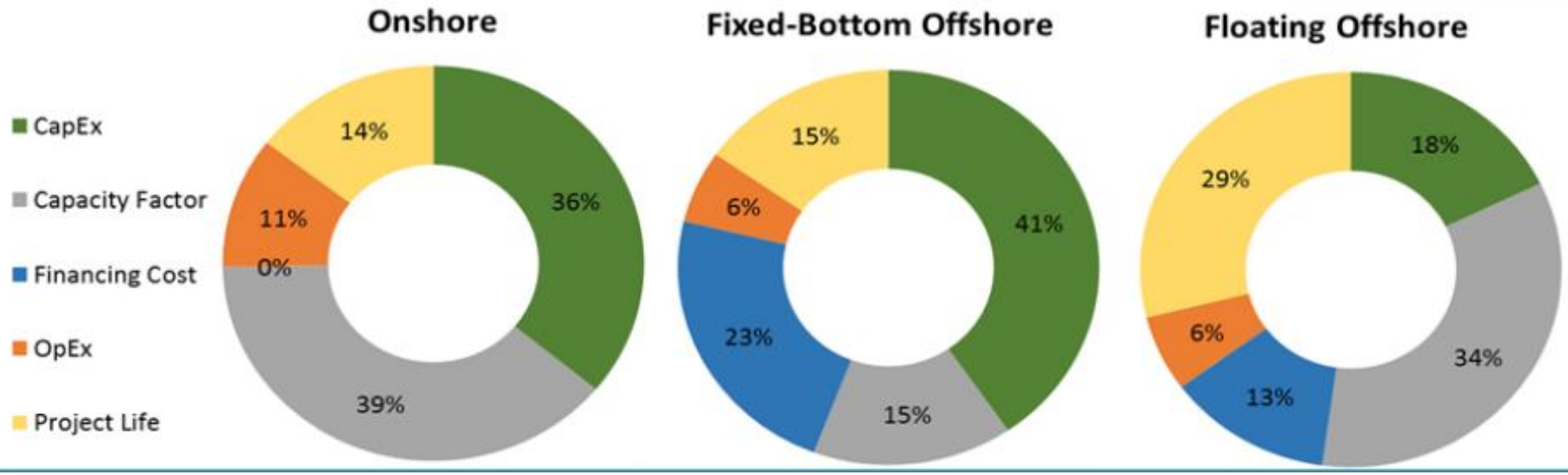
The Views of the World's Leading Experts

	ONSHORE (LAND-BASED)	FIXED-BOTTOM OFFSHORE	FLOATING OFFSHORE
LEVELIZED COST OF ENERGY (median estimates for median scenario & 1st-3rd quartile range)			
DRIVERS FOR COST REDUCTION IN 2030 (median estimates; median scenario)	Capacity factor: +10% Project life: +10% CapEx: -12% OpEx: -9% WACC: no Δ	Capacity factor: +4% Project life: +15% CapEx: -14% OpEx: -9% WACC: -10%	Capacity factor: +9% Project life: +25% CapEx: -5% OpEx: -8% WACC: -5%
TURBINE SIZE IN 2030 (typical projects)	 3.25 MW 115 m hub height 135 m rotor diameter	 11 MW 125 m hub height 190 m rotor diameter	 9 MW 125 m hub height 190 m rotor diameter
TOP-FIVE IMPACT CATEGORIES	• Larger rotors, reduced specific power • Rotor design advancements • Taller towers • Reduced financing costs • Component durability / reliability	• Larger turbine capacity • Foundation / support structure design • Reduced financing costs • Economies of scale via project size • Component durability / reliability	• Foundation / support structure design • Installation process efficiencies • Foundation / support manufacturing • Economies of scale via project size • Installation / transport equipment

Berkeley Lab · NREL · iea wind

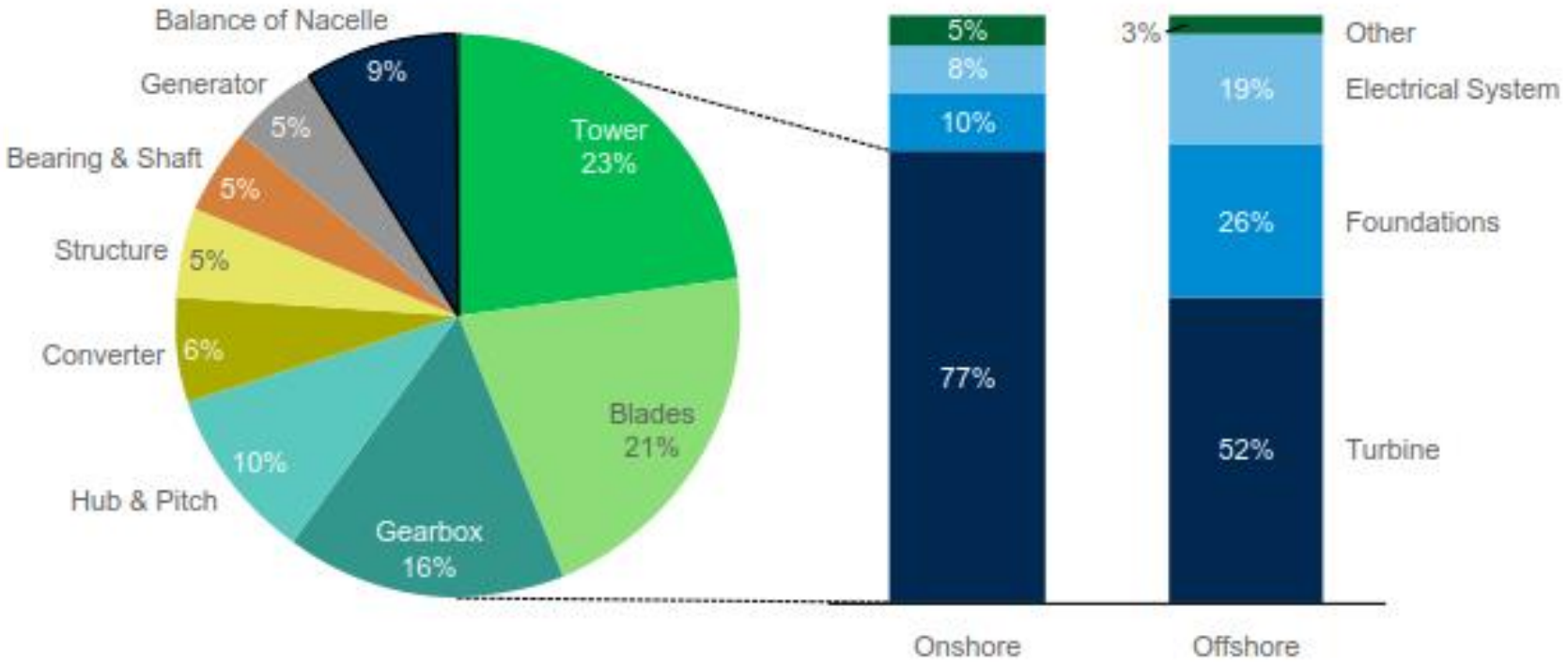
2016

Relative Impact of Drivers for LCOE Reduction in 2030



2016

CAPEX and turbine components' contribution



Source: MAKE

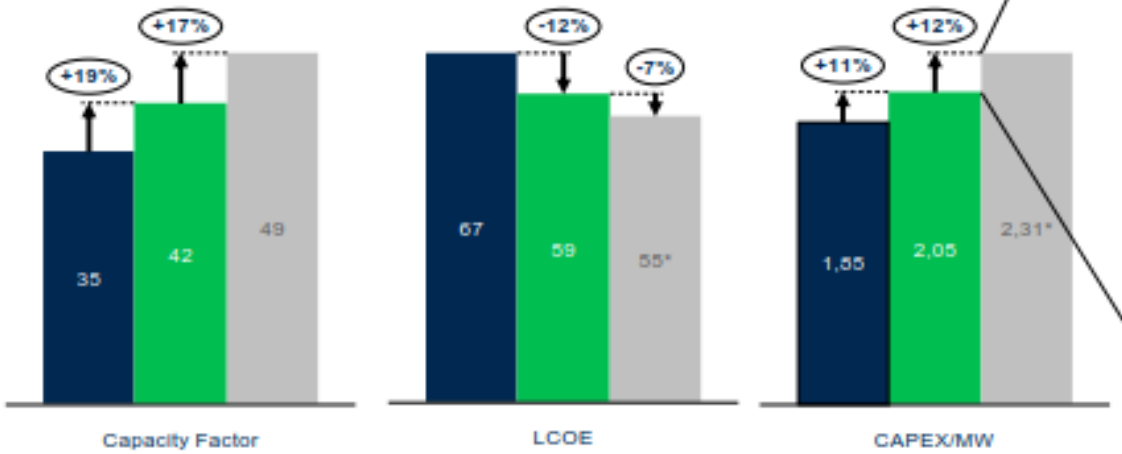
Note: Baseline Turbine: 2-2.5MW, 90-110m rotor glass blades, DFIG electrical system, 80m steel tubular tower

Onshore wind plant: 100MW, flat terrain, 33 kV interarray, 220 kV collector. Wind turbine = 2.0MW, 80m towers

Offshore wind plant: 396MW, 50m depth, 30km from shore, 33kV interarray, 2x 220 kV collector, 1 substation. Wind turbine = 6.0MW, quadrapod foundation

Cost barriers for larger rotor MW-scale turbines

	Units	<2010 Turbine	>2010 Turbine	Next Gen 1.X
Color Code				
Turbine Rating	(MW)	1.8	1.8	1.8
Rotor Diameter	(meters)	82	100	124
Specific Rating	(W/m^2)	340	230	**150***



Added Cost components

Blades
- 12 meters longer
- Adds ~5 tons per blade

Tower
- 10-12 meters taller
- 80m → 90/95m
- Adds ~35 tons of steel

Machine structure
- Weight increase
- Gearbox redesign
- Main shaft redesign
- Hub redesign
- Bedplate redesign

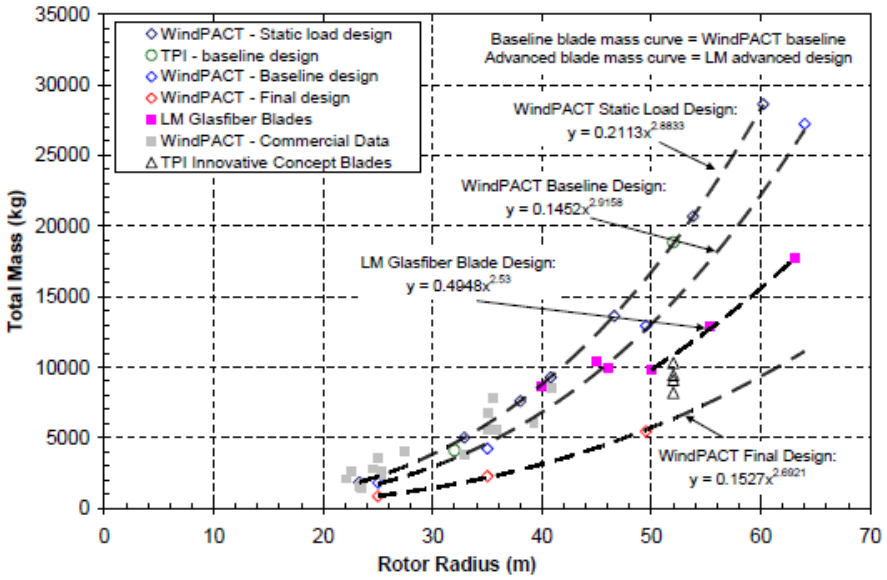
Foundations
- Weight increase ~30%

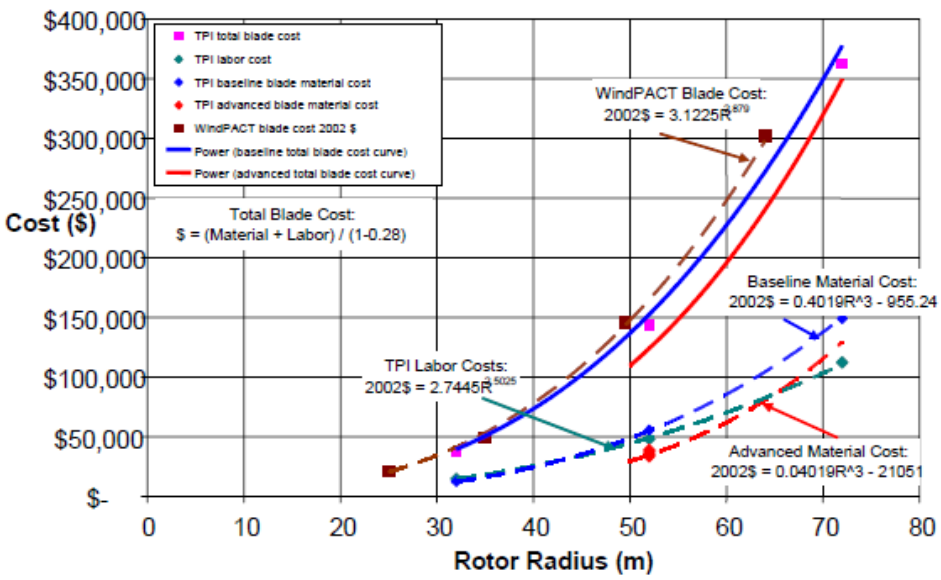
Roads
- Road length increase by ~7.5km

Interarray cabling
- Cables increase by ~10km

Source: MAKE
Note: * Indicates target values
100MW U.S. wind plant, PTC
OPEX cost = USD 60K/Turbine/year Full Service Agreement
Finance: 20-year life, WACC = 8%, 70/30 Debt/Equity, Debt Rate = 5%, 10 year tenor

Turbine Weight and Cost „Scaling Laws“

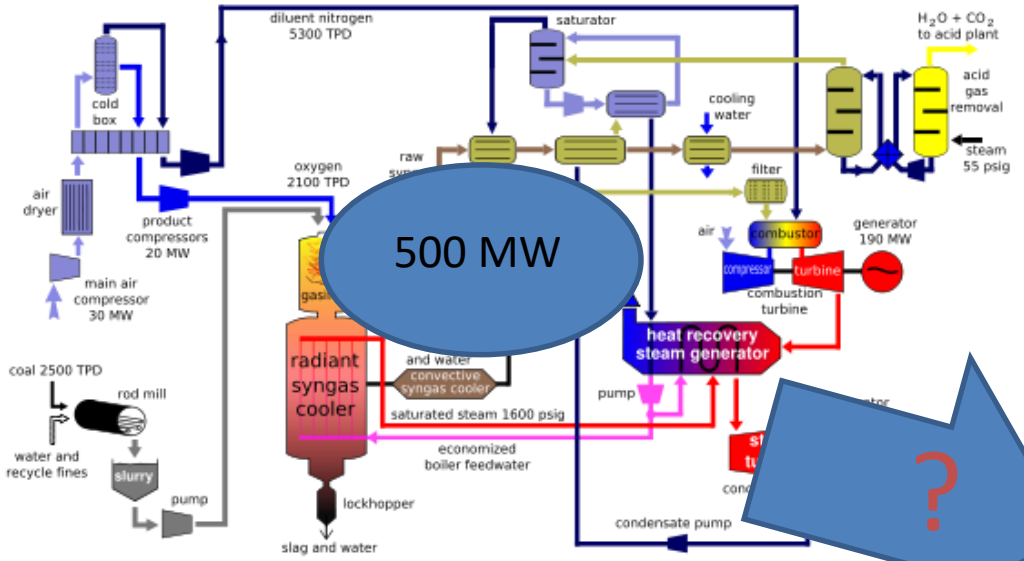




U.S. Department of Energy's (DoE's) Wind Partnership for Advanced Component Technologies (WindPACT)

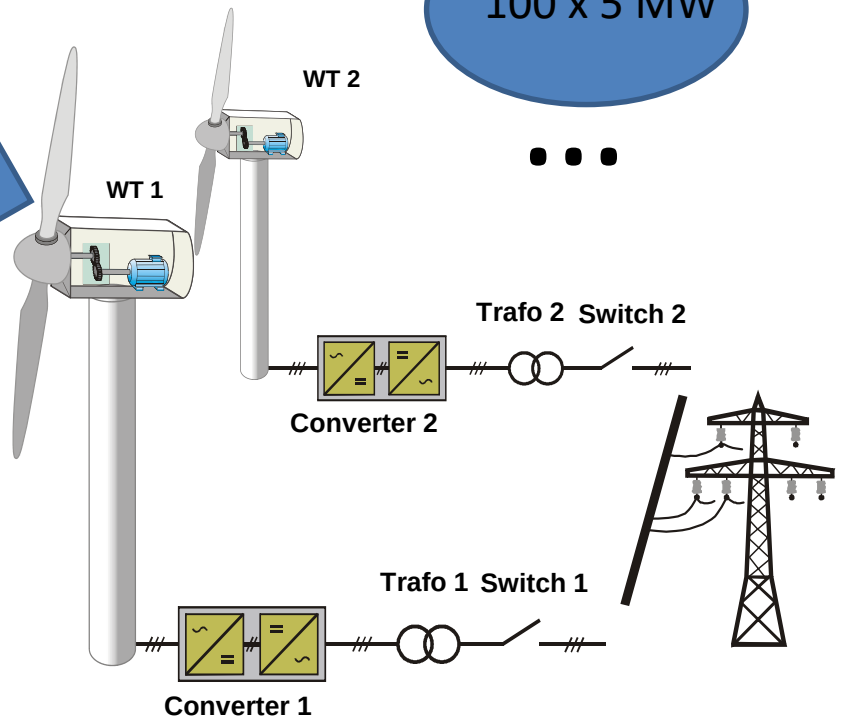
Scaling means:
Extending existing systems and technology

We talk about Power Plants!



500 MW

?



Conventional power plants consists out of several generators, which work together with specific devices for grid connection, whereas each wind turbine has its own grid connection system.

Is this a setup for a economic (wind) power plant?

Background of SkyWind

20 Years Experience

- Planning, realization and operation of wind farms (250 turbines, all types, all manufactures)
- Design, service, education and training

Development Approach

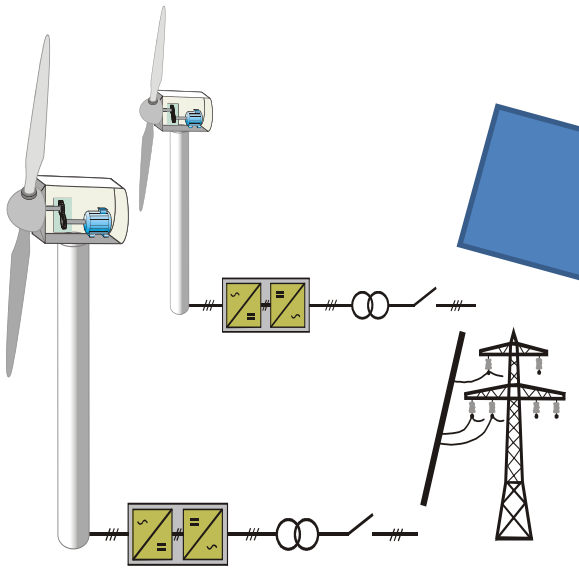
- Born from experience (eliminate / improve failure areas)
- Change point of view (supplier-> operator, manufacturer -> user)

Aim of the development

- Minimize the Life Cycle Costs of Energy of wind turbines
- Bundling of wind turbines to Wind Power Plant (WPP/RPP)

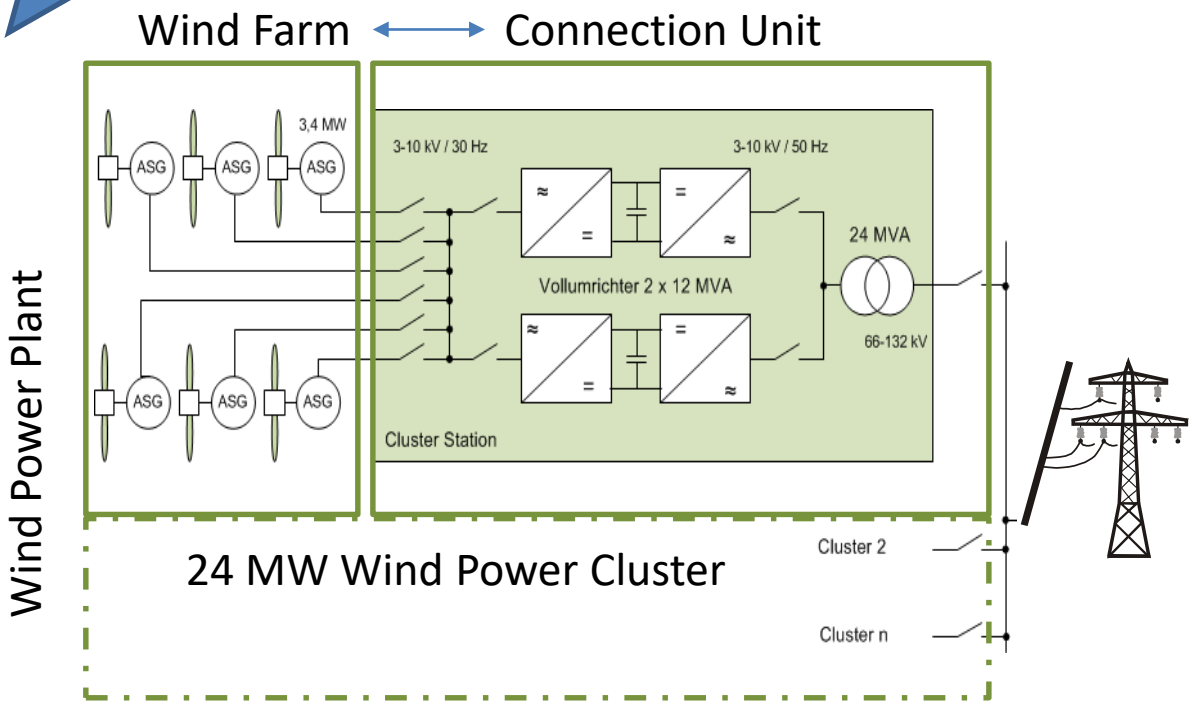
Wind Power Plant with Grid Connection Unit

Single Wind Turbines

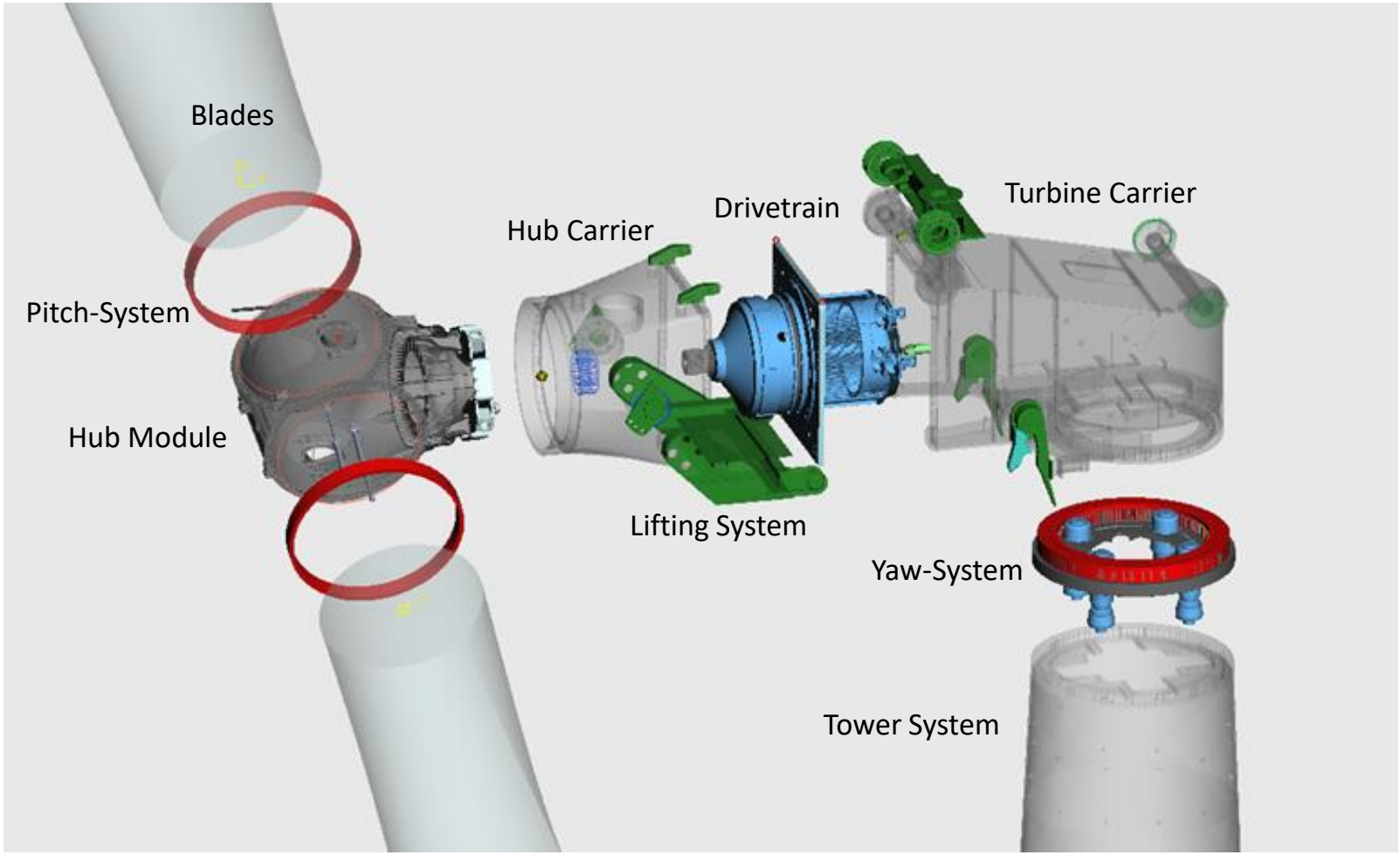


Distance between
Turbines usually
5 X RD -> 500 m

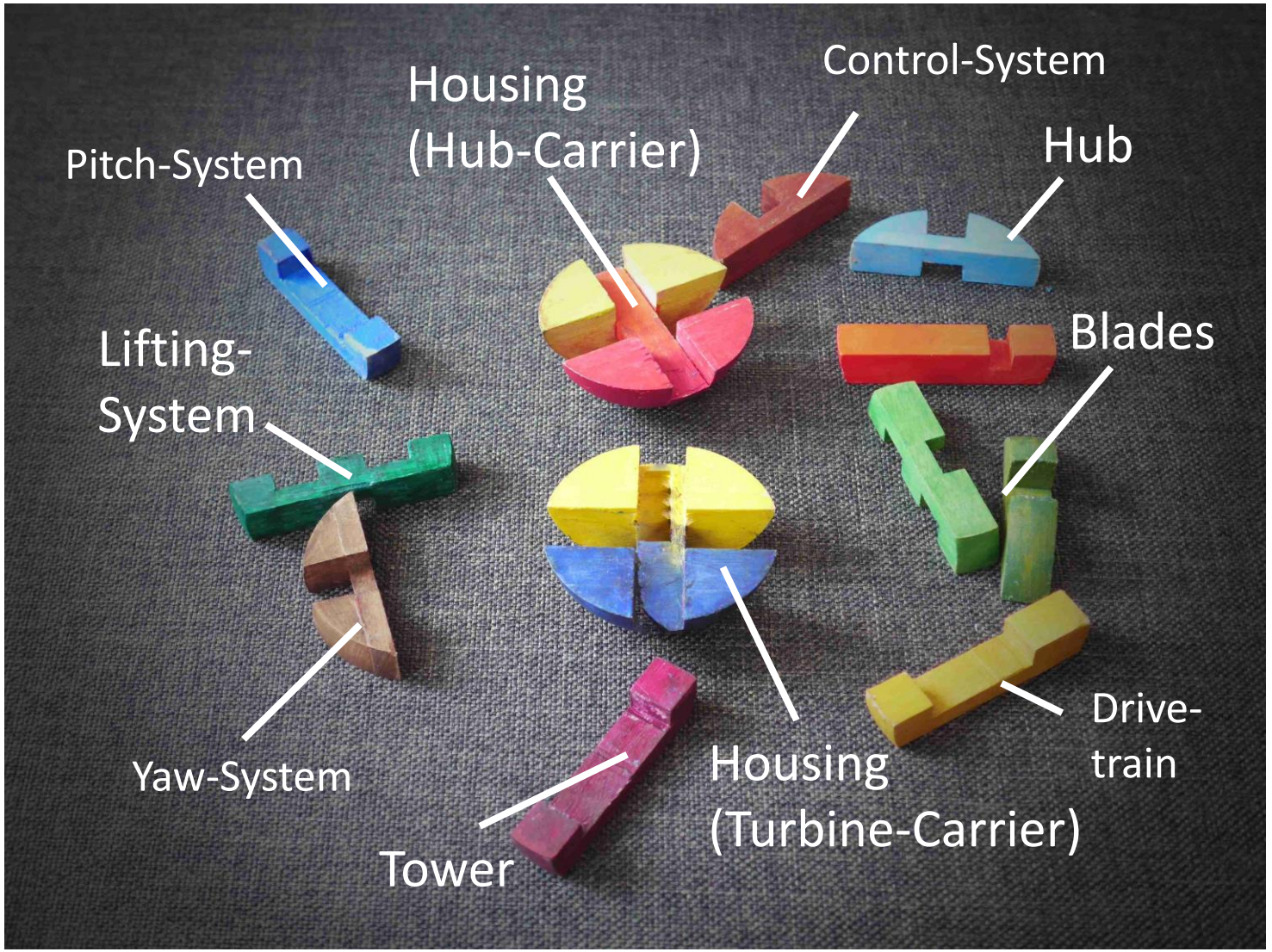
Distance between
WindFrame and Connection Unit
up 10 km



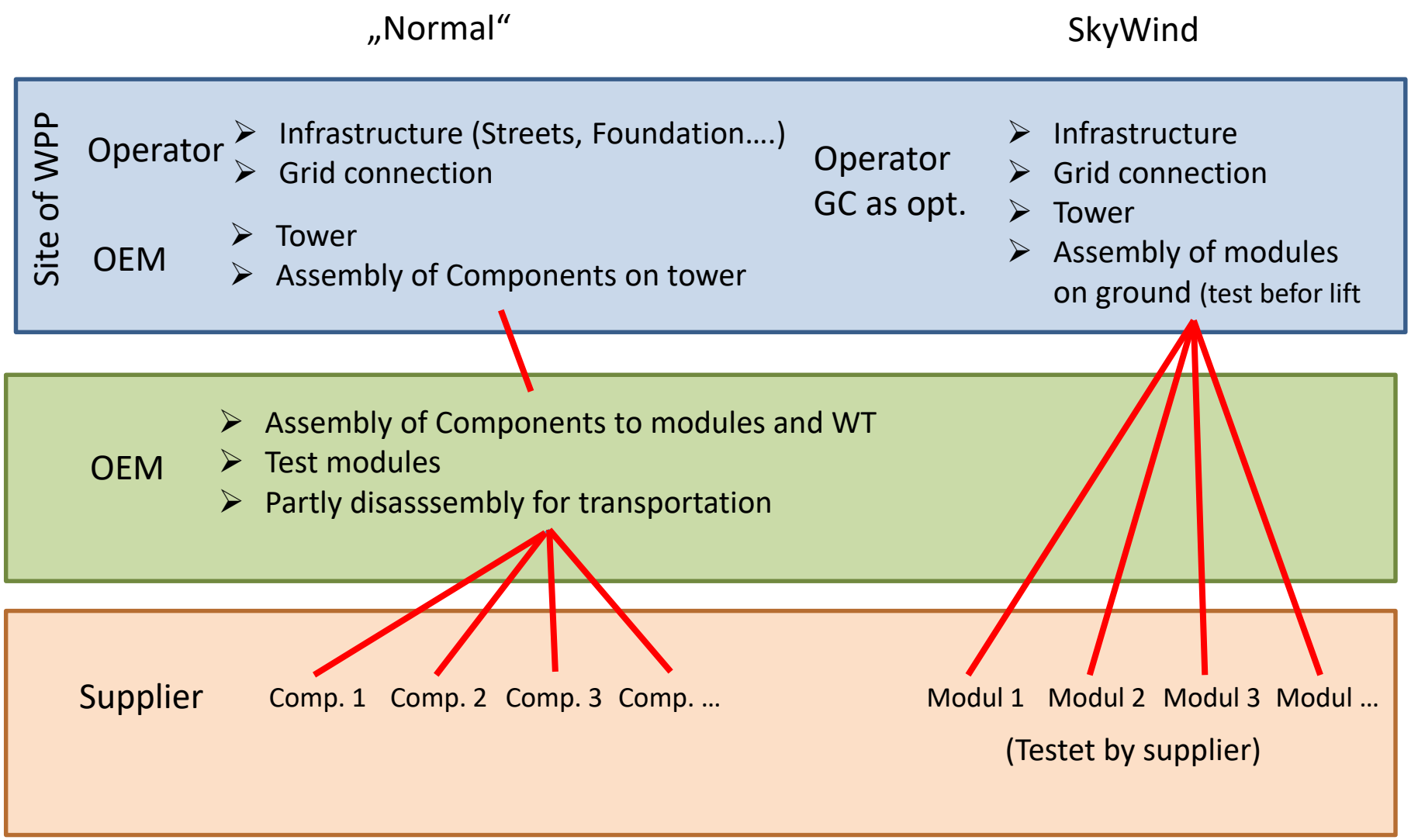
Built in separate modules



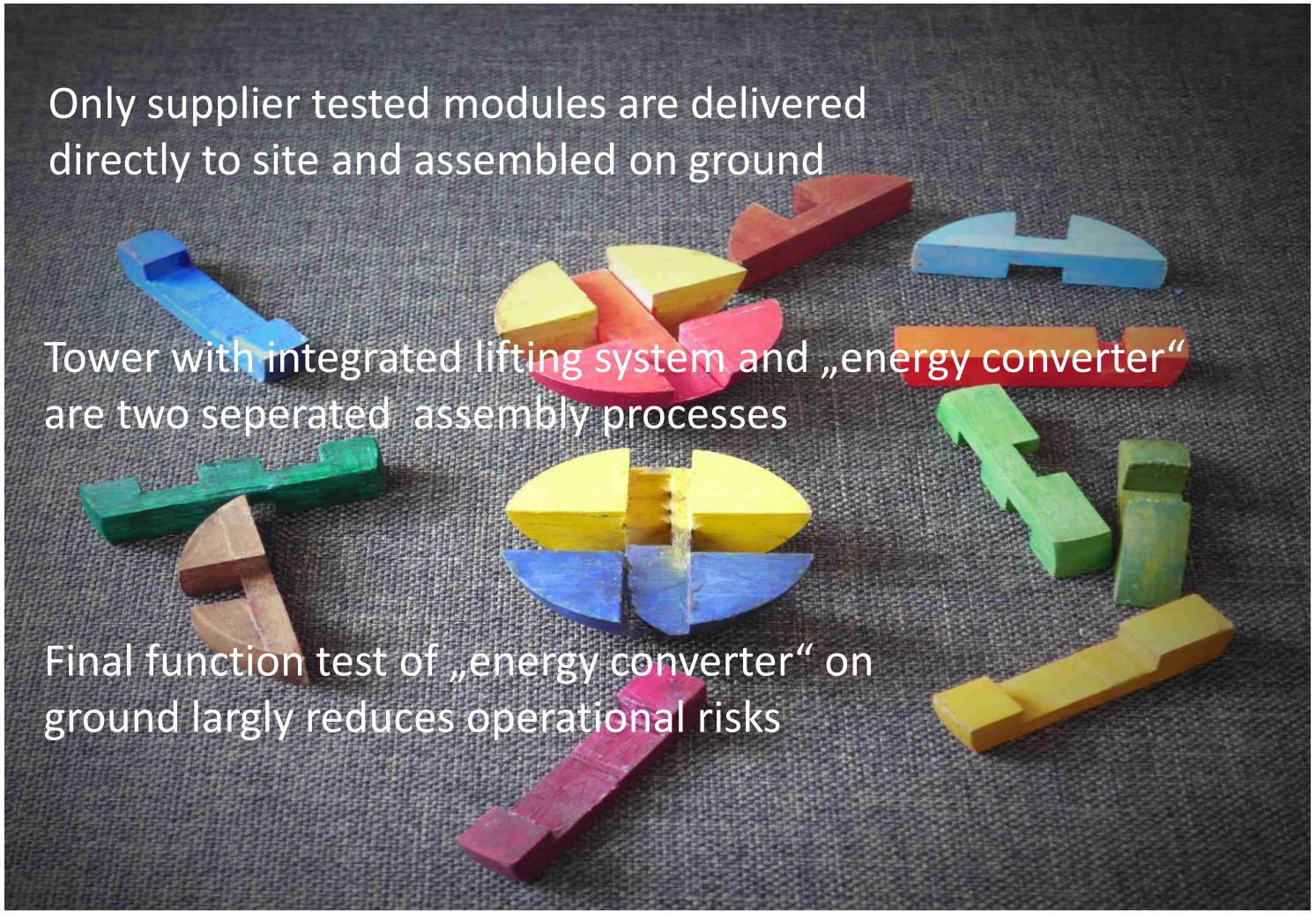
Built in Modules



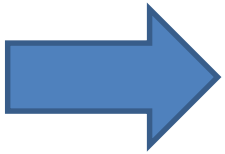
Prozess WindPowerPlant



Assembly



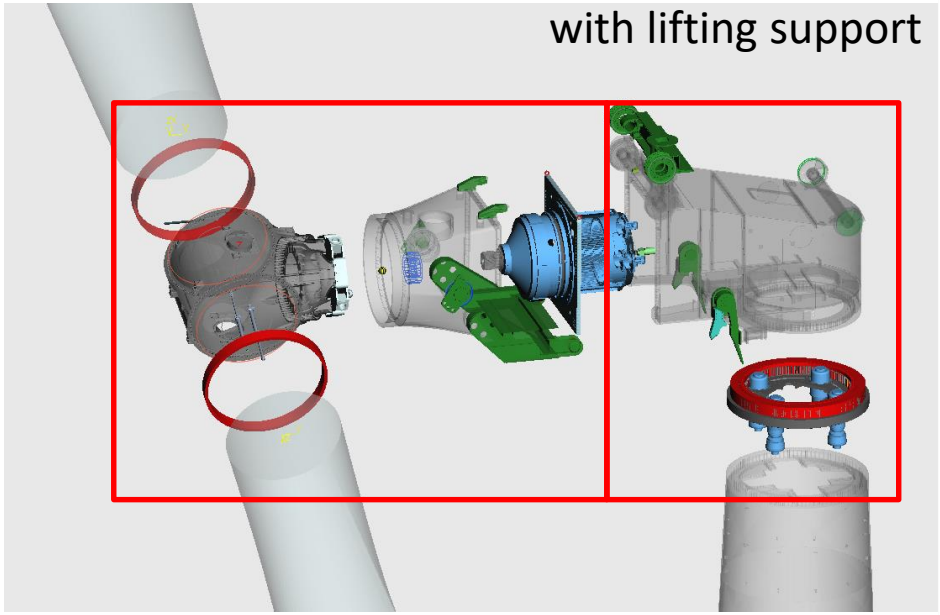
Installation



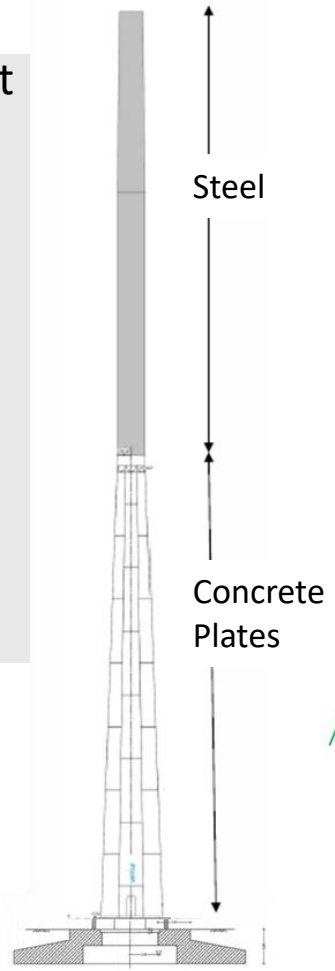
Installation (onshore)

„Turbine“

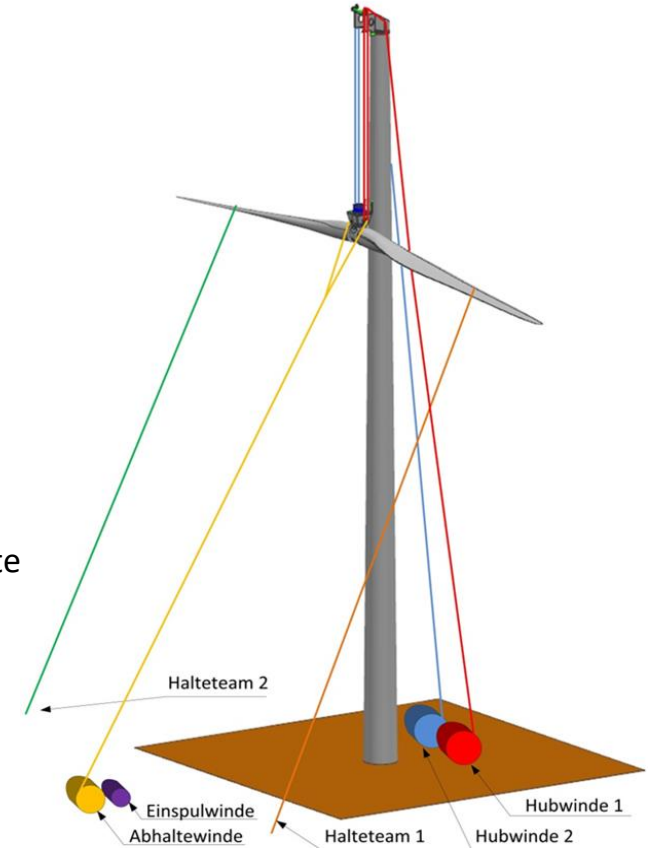
Turbine Carrier
with lifting support



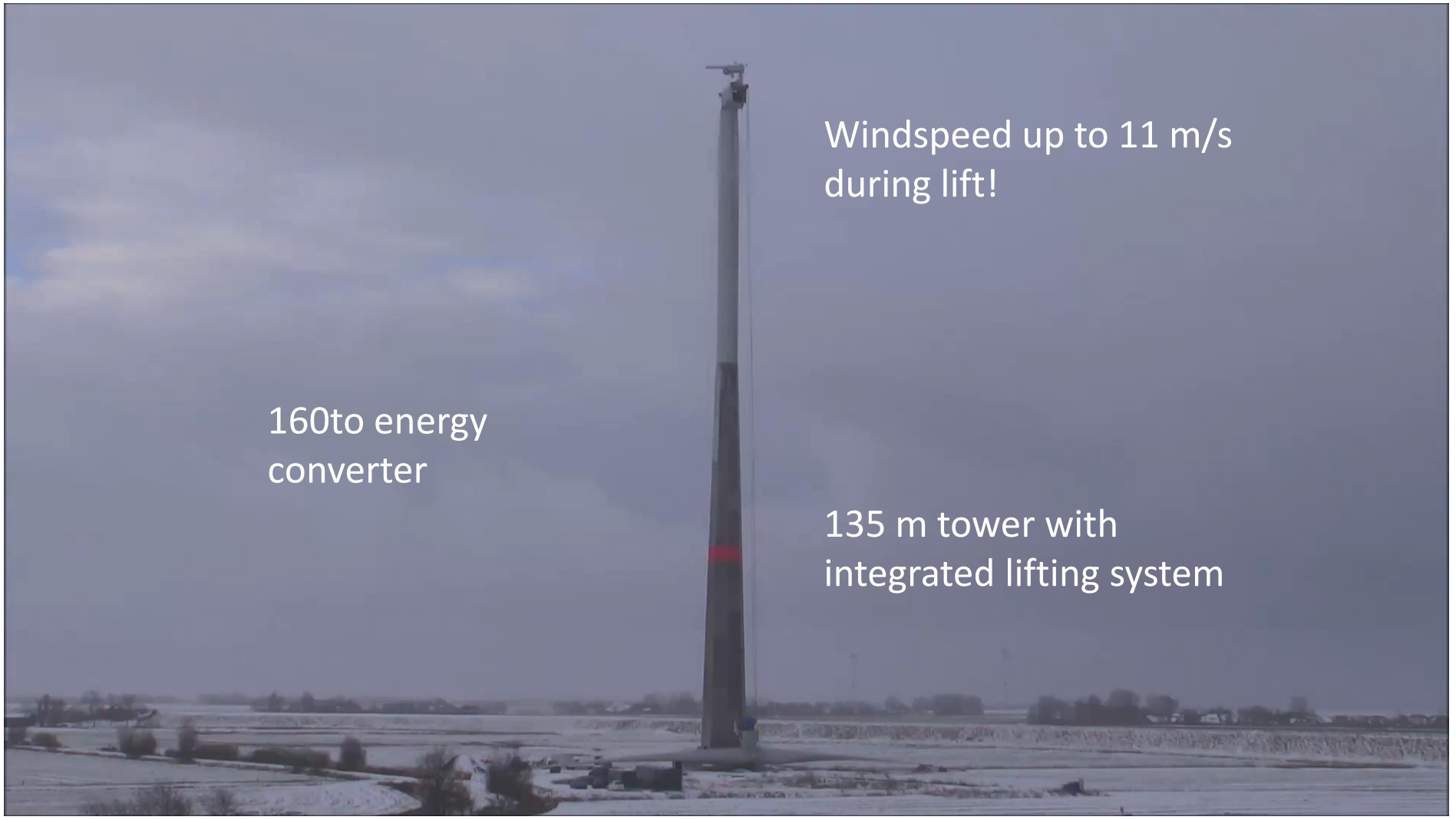
Hybrid tower



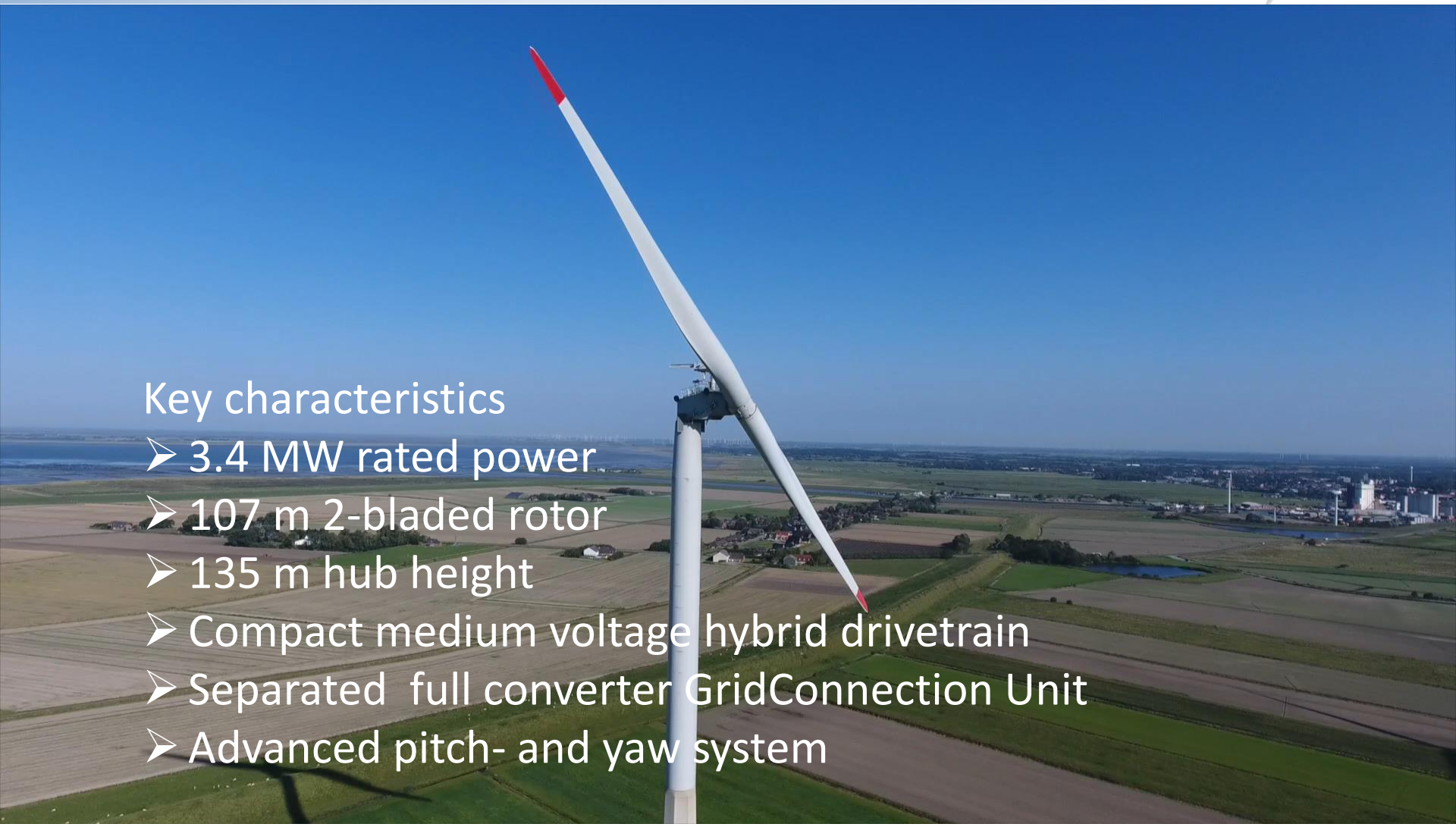
„Craneless“ Lifting



WETEC Lifting



WETEC Operation



Key characteristics

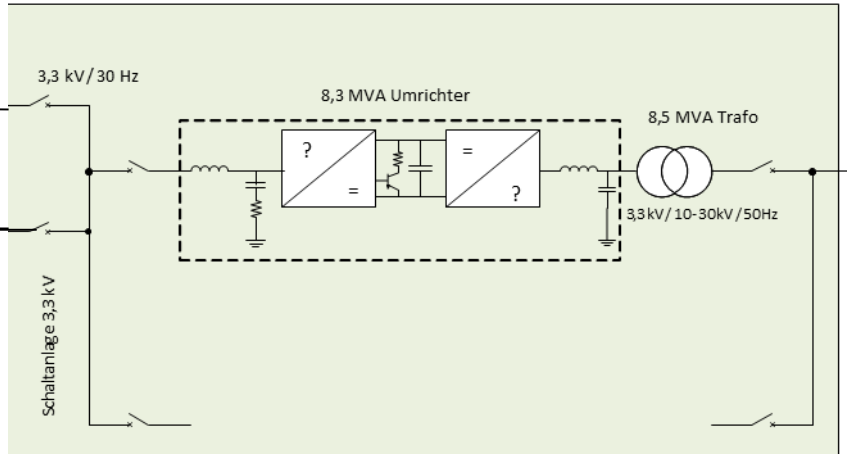
- 3.4 MW rated power
- 107 m 2-bladed rotor
- 135 m hub height
- Compact medium voltage hybrid drivetrain
- Separated full converter GridConnection Unit
- Advanced pitch- and yaw system

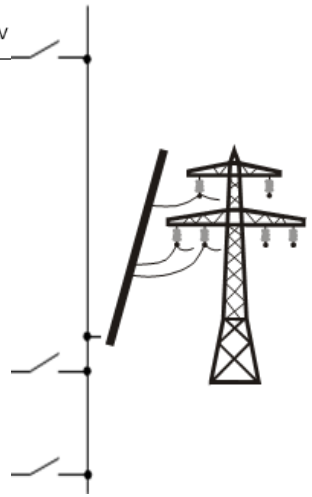
Scaling up ?

Scaling up: Twin Rotor

Adapted to
7-8 MW offshore

Proven 8.3 MVA Grid connection Unit



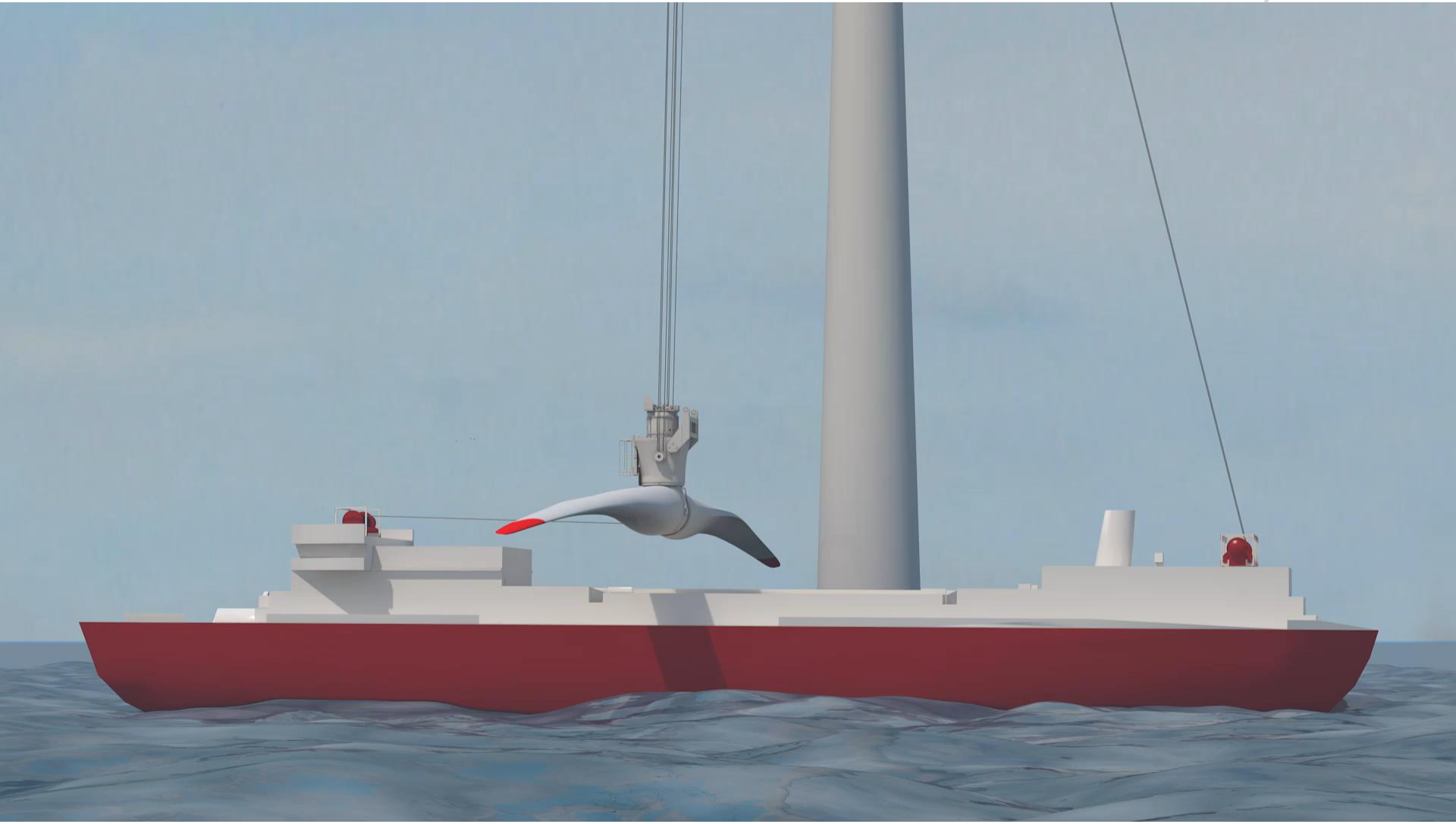


Multirotor

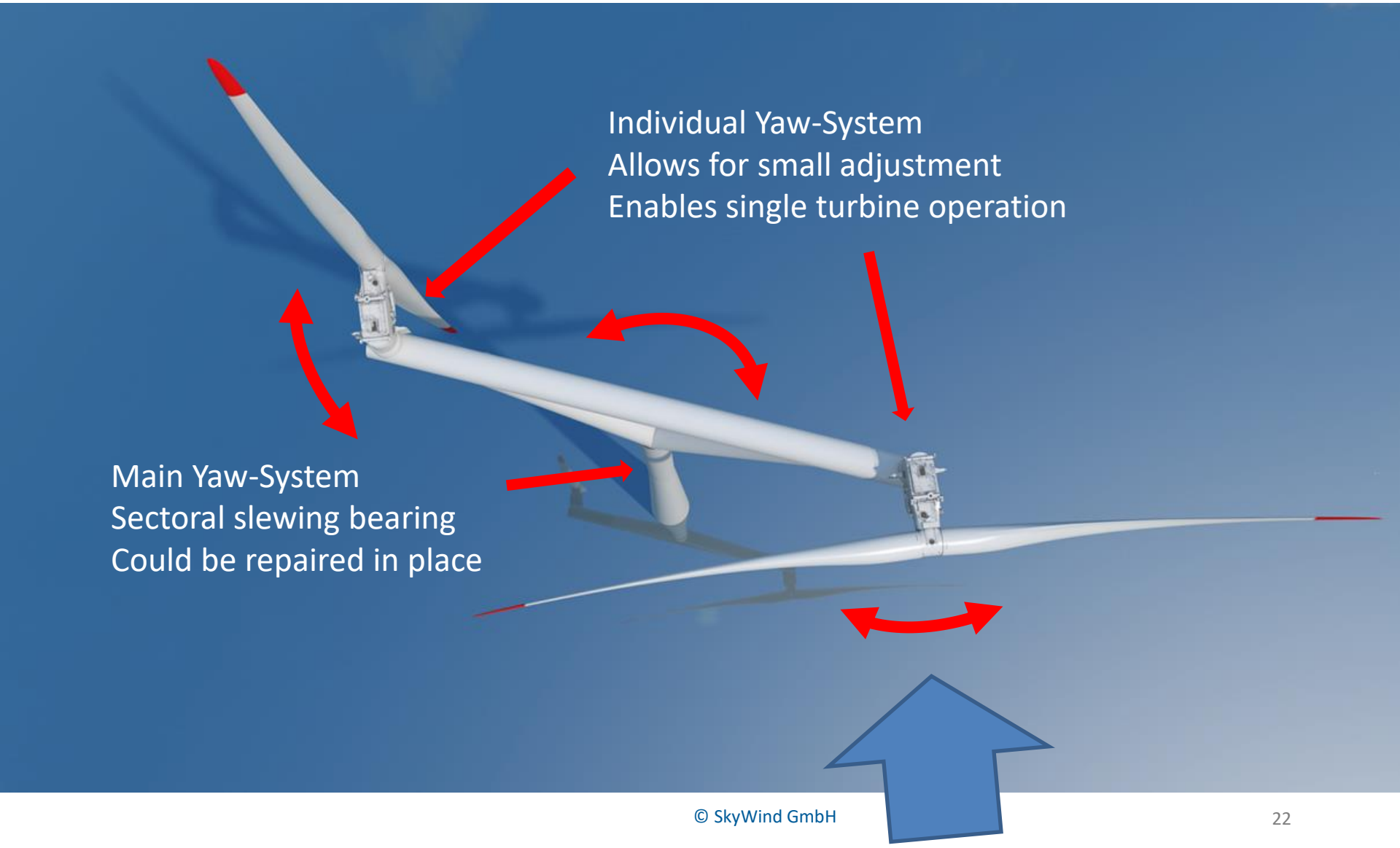
4 X 100 kW Lagerwey 1976

4 X 225 kW Vestas 2016

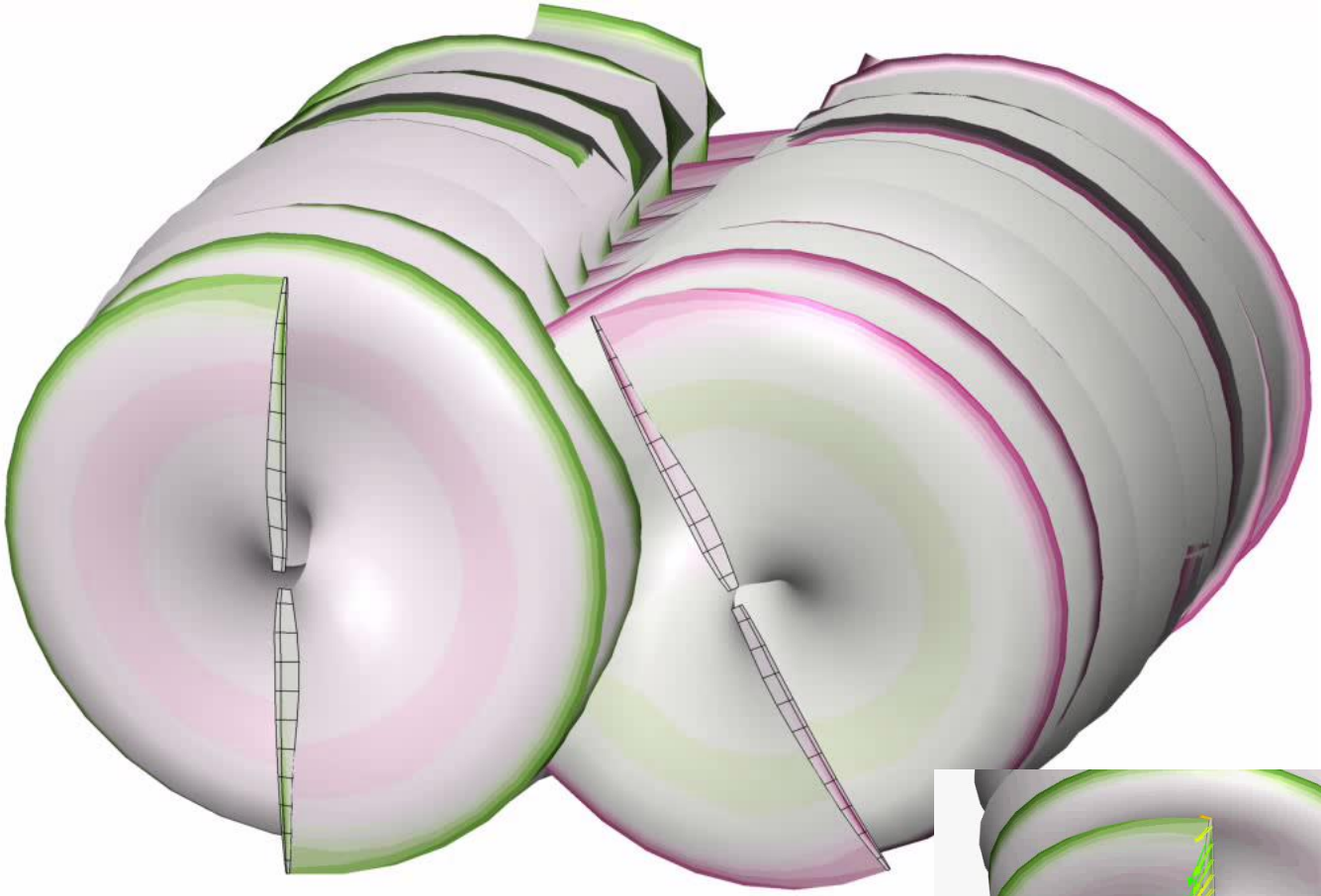
Adapt onshore to offshore

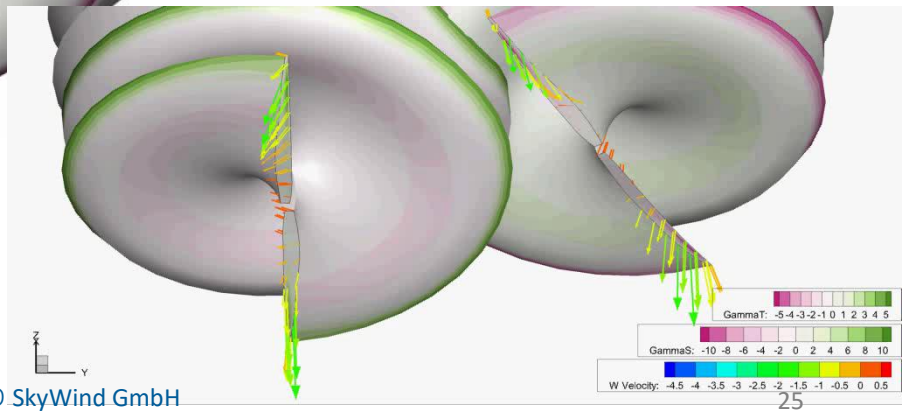


Yaw Issue



Performance and dynamic behaviour



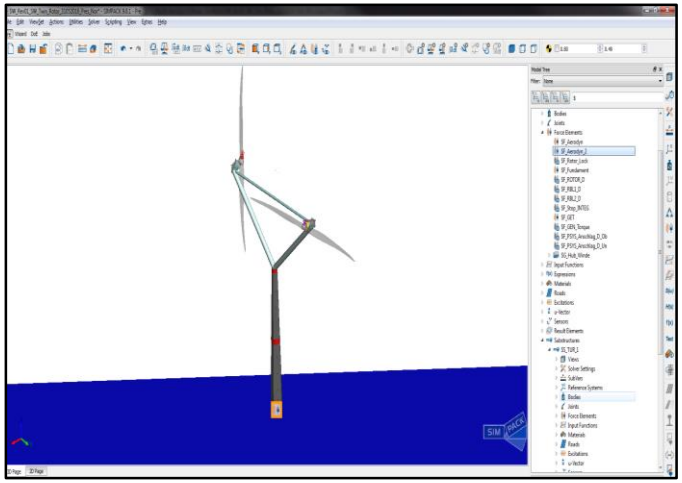


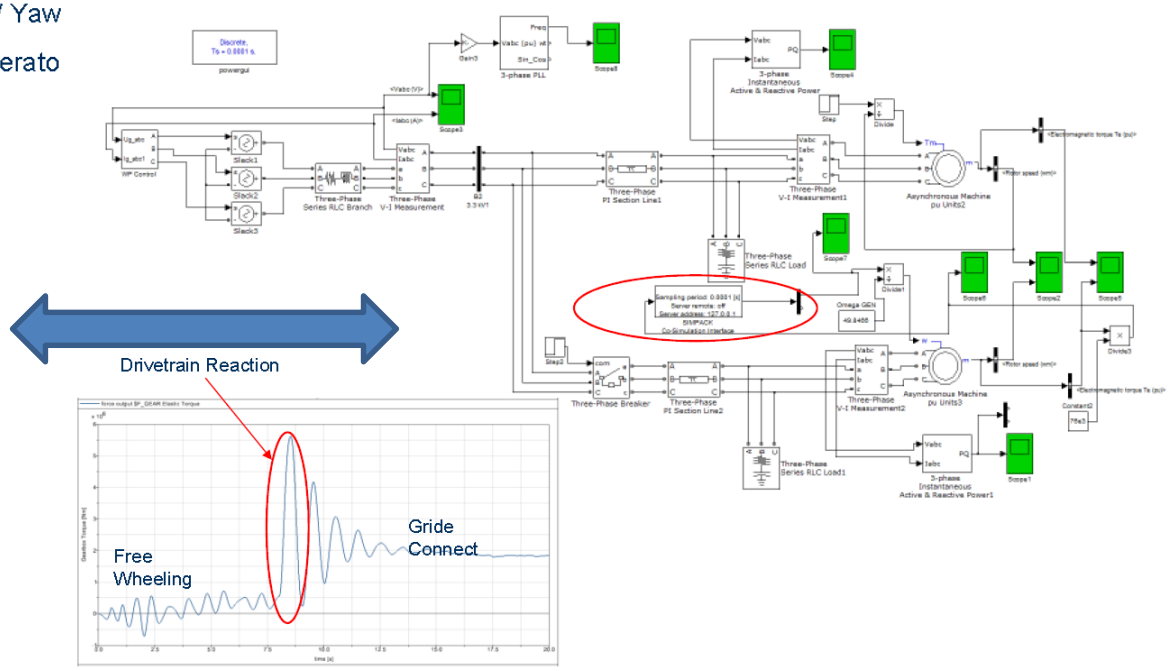
Twin Rotor Simulation

SkyWind System Simulation Controller

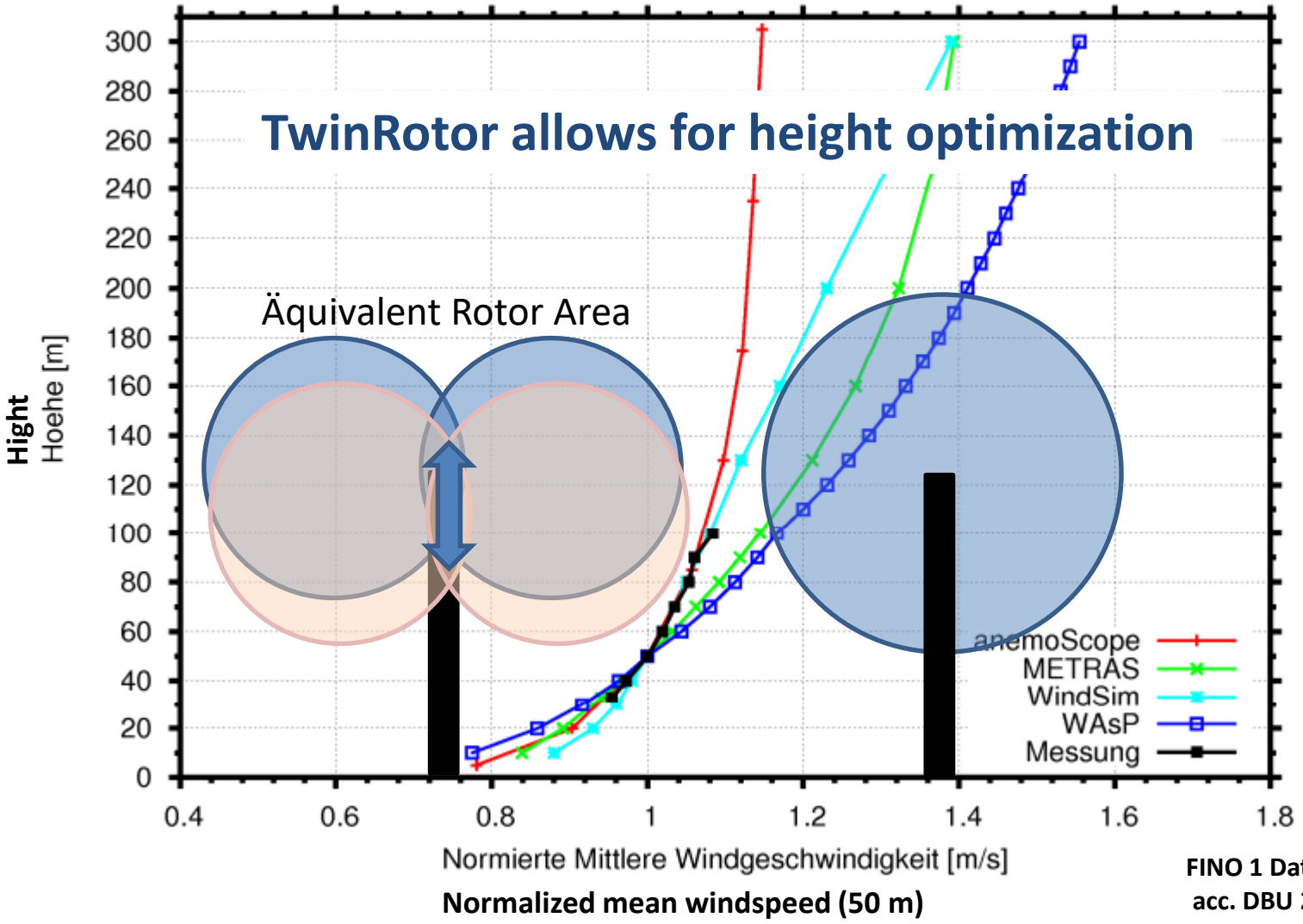
- **Blade Pitch Controller**
- **Generator Torque Controller**
- **Nacelle Yaw Controller**

- **Use detail Model for DLC**
- **Define Pitch Actuator for connection between Pitch Controller and Rotor blade**
- Using details MATLAB with Simulink Model as Pitch/ Yaw
- **Using details** MATLAB with Simulink Model as Generato





Windprofile and Rotorsize

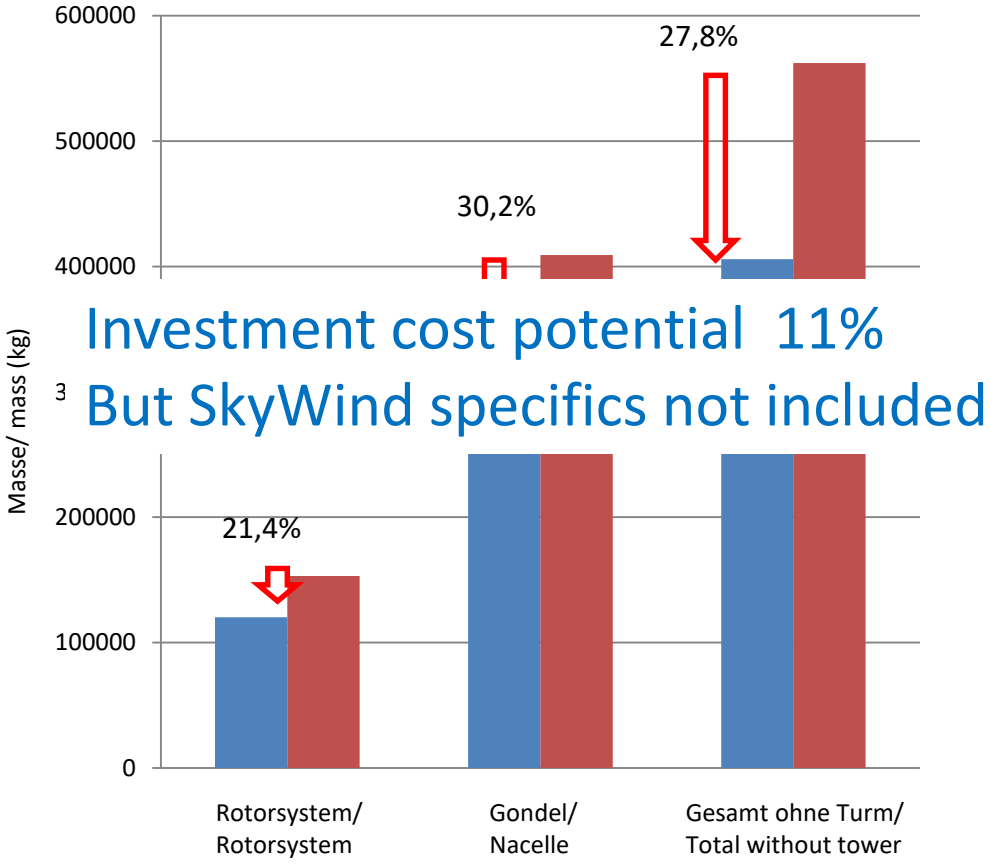


Normalized mean windspeed (50 m)

FINO 1 Data, extrapolation acc. DBU 24780 R&D project

Mass- and Cost Potential

According to WindPACT und Jamieson scaling laws



Investment cost potential 11%

But SkyWind specifics not included

Further cost reduction potential

- Supply Process
- 20 m lower tower
- Installation method (also for maintenance !)
- Same turbine on- and offshore
  - Serial production
  - Stuff education
  - Common SCADA
  - Spare parts

Target: 30 %

Summary- SkyWind for offshore wind farms

- Scaling up with two “known” turbines per foundation
- Installation is controlled with winches on DP vessel - no large cranes needed
- Substructure / foundation needs to be developed and total system to be optimized (eg. controller)

⇨ Invitation for Norwegian R&D

Pilot options Karmøy Metcentre (or onshore)

Potential that turbine(s)
with lowest CoE
could be manufactured
in Norway!!

Thank You

SkyWind

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