Universität Rostock

Traditio et Innovatio

Windparks in tiefem Wasser: wie schwimmende Unterstrukturen das Potential von Offshore-Windenergieanlagen vervielfachen können

Bad Honnef 19th of April 2018

Dr.-Ing. Frank Adam

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Personal introduction

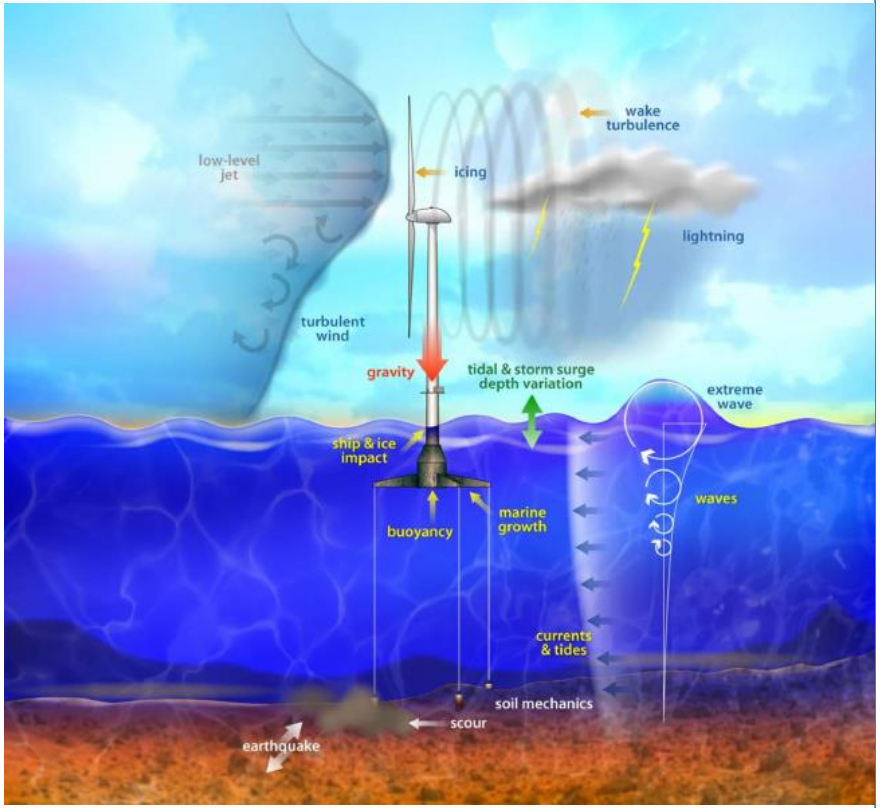
Dr.-Ing. Frank ADAM (married, 3 children)

- 2009 – Diploma at the excellent Technical University of Dresden
- 2015 – PhD (summa cum laude) at the Technical University Bergakademie Freiberg (Topic: System dynamic of floating offshore wind)
- Since 2015 – group leader offshore wind at the University of Rostock
- Reviewer for several Journals within the field of Renewable Energy
- Member of: ISSC V.4 committee, IEC61400-3-2 standard committee, ISOPE and ReNew conference technical committee
- Observer: DNV-GL JIP Floating offshore wind simulation, Friends of floating wind

Publications:

Content of the presentation

- Motivation
- Introduction & wording
- Calcuation methodes
- Selected examples
- R&D work at the Endowed Chair of Wind Energy Technology



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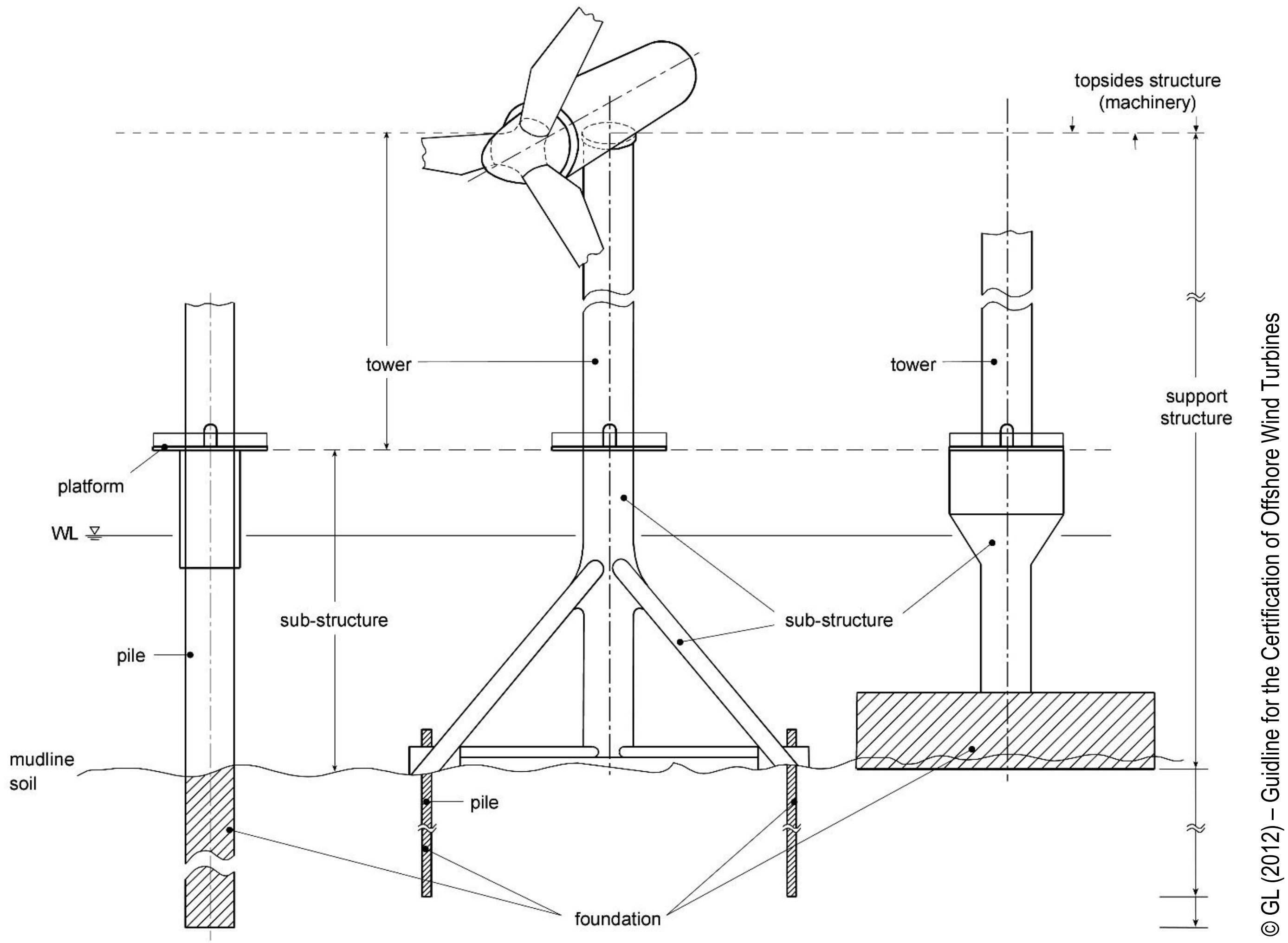
Motivation

MOTIVATION - Floating offshore wind vision

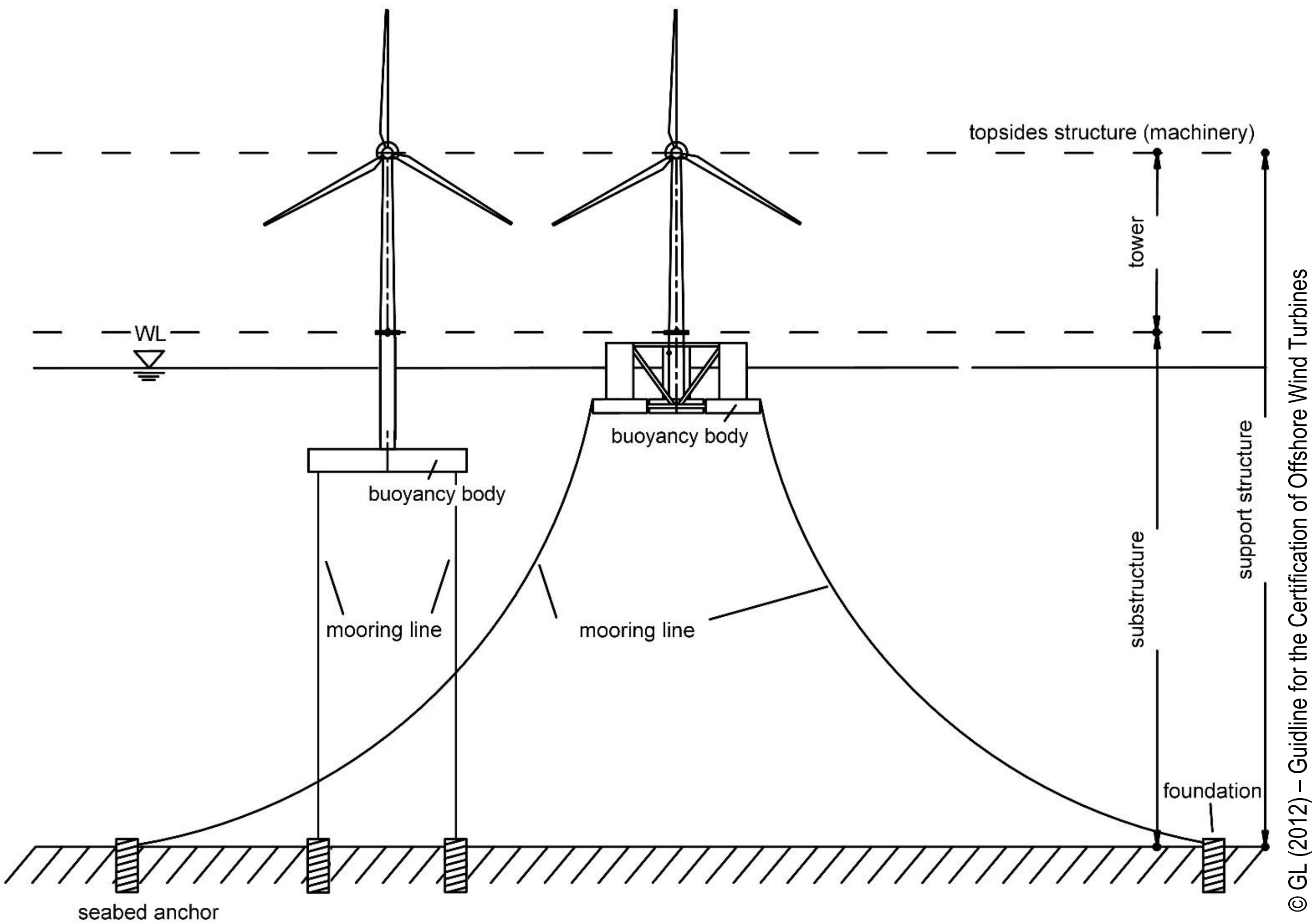
DNV·GL

Introduction & wording

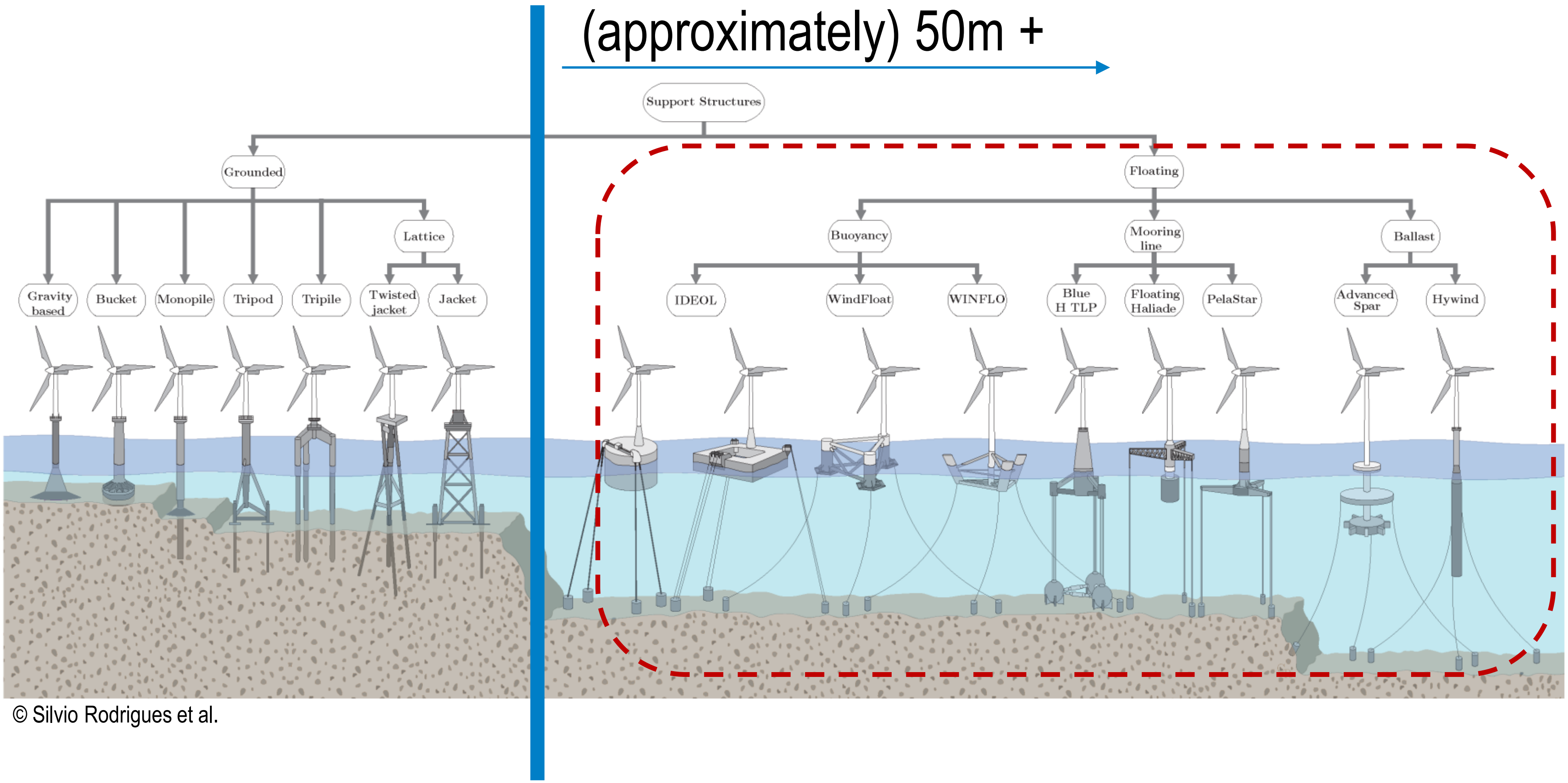
Introduction - Definition



Introduction - Definition



Introduction - Substructures

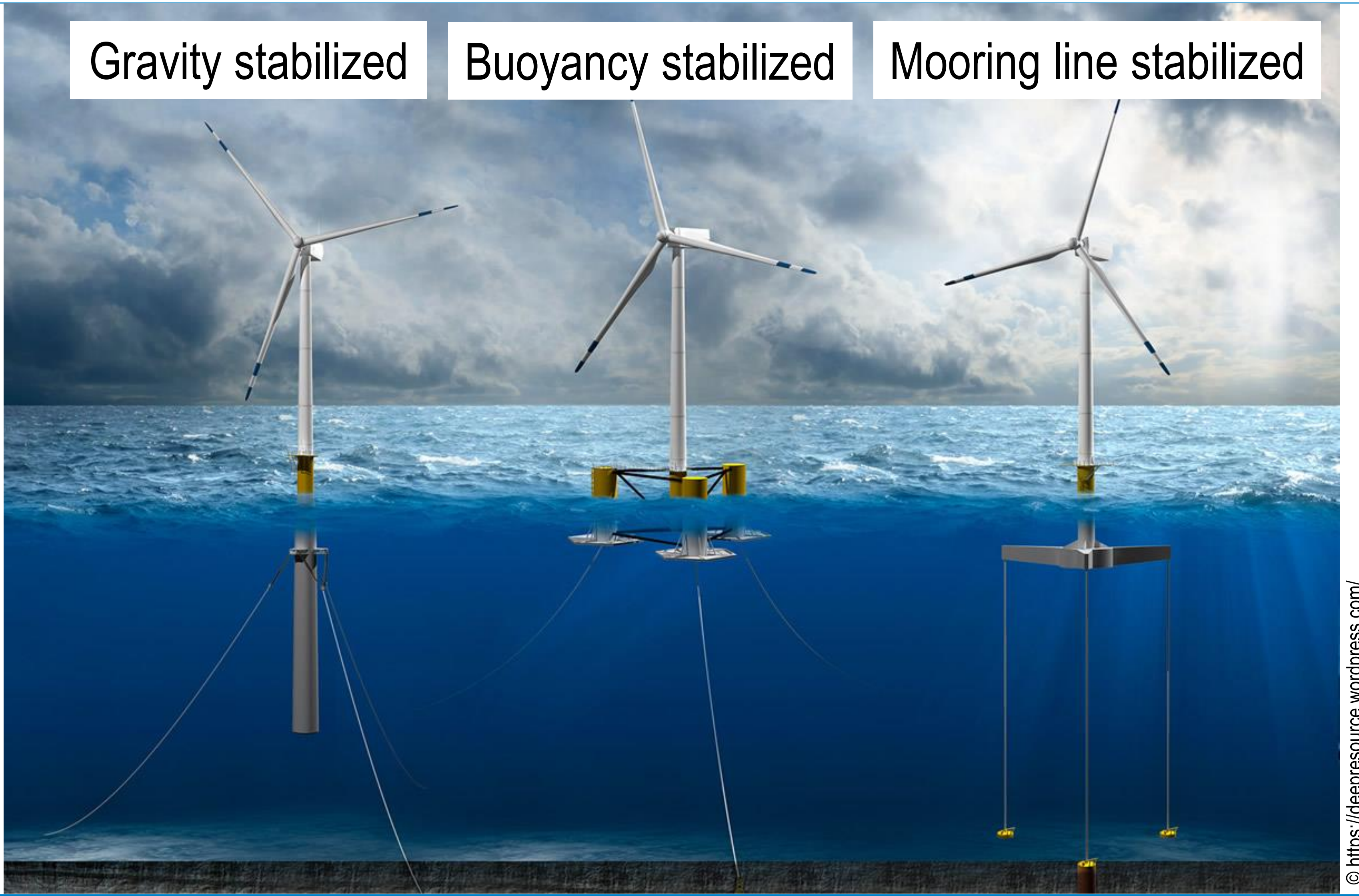


© Silvio Rodrigues et al.

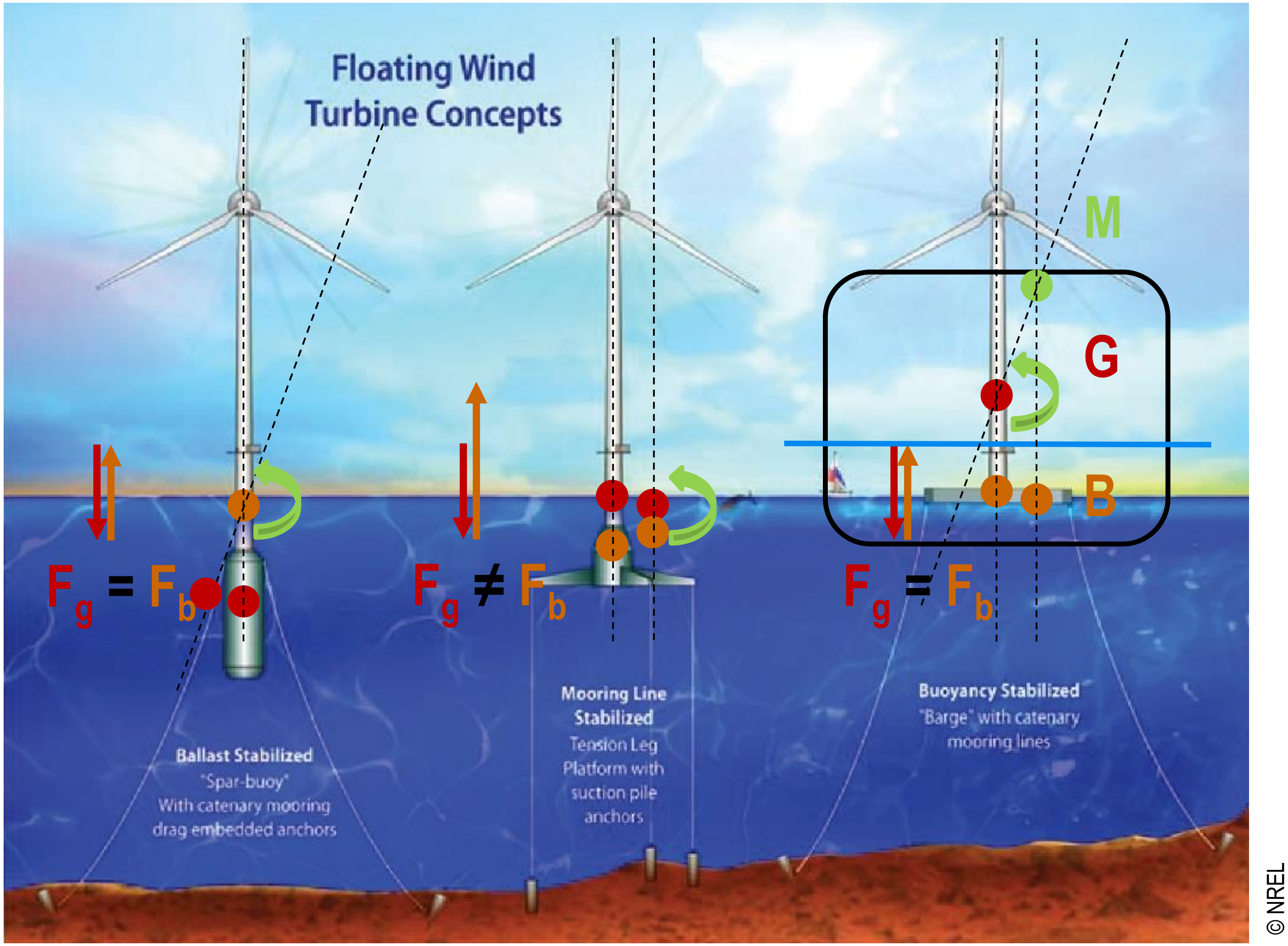
Introduction - Substructures

	Fixed	Floating
Water depth	0 – 50 m Design depending on the water depth	50 – x m Design independent from the water depth
Installation	Hugh and expensive transport & installation vessels needed	Transport & installation with the wind turbine on top; only small tug boats needed
Certification	Each support-structure need it´s own certification	Type certification is possible
Costs	Cost competitive for specific boundary conditions (water depth, distance to shore)	On the way to be cost competitive
Environmental impact	Noisy pile driving, decommissioning issues	No pile driving and nearly fully decommission

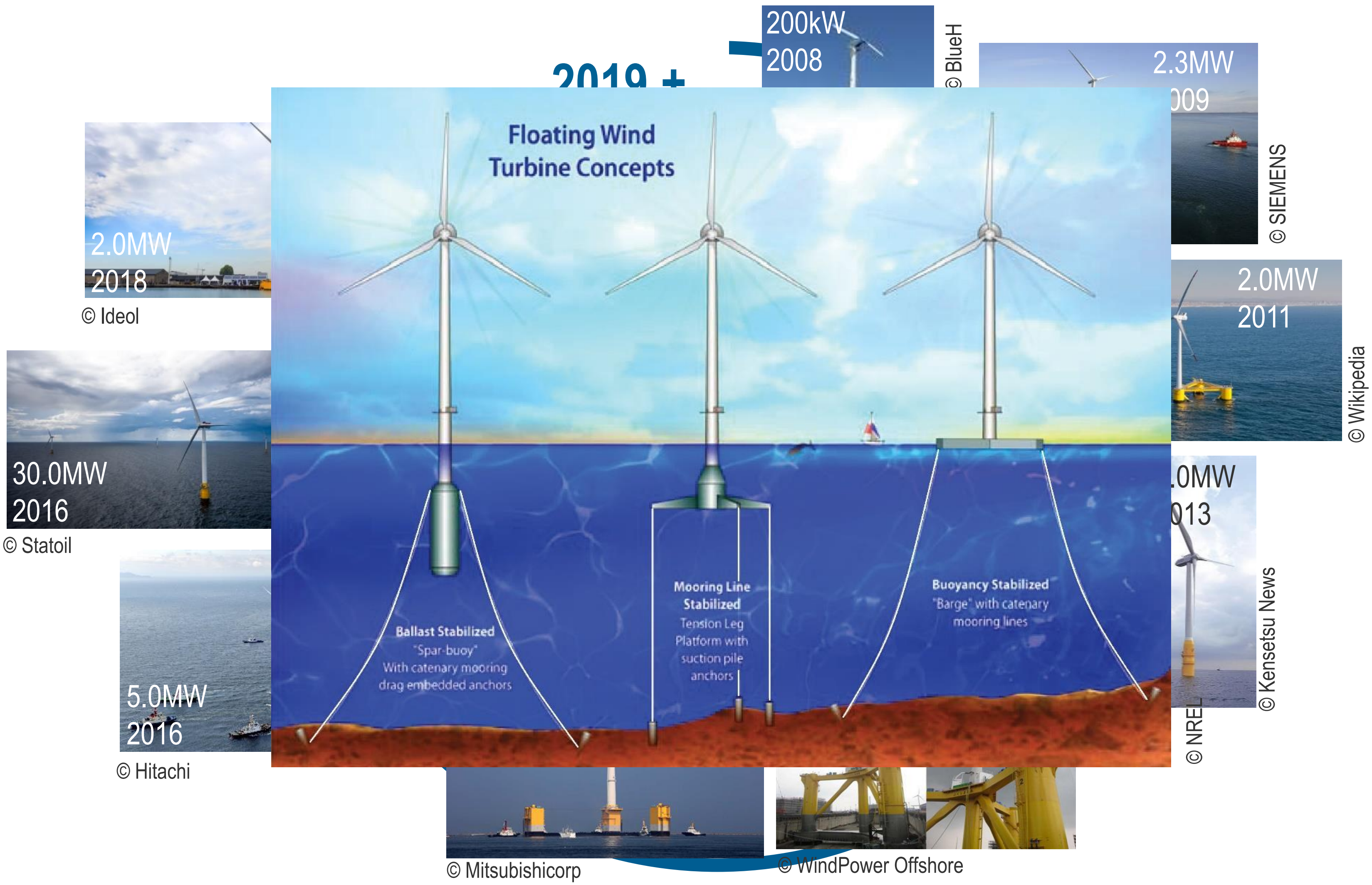
Introduction - Kind of floating solutions



Introduction - Floating stability



Introduction - Floating solutions pilot plants



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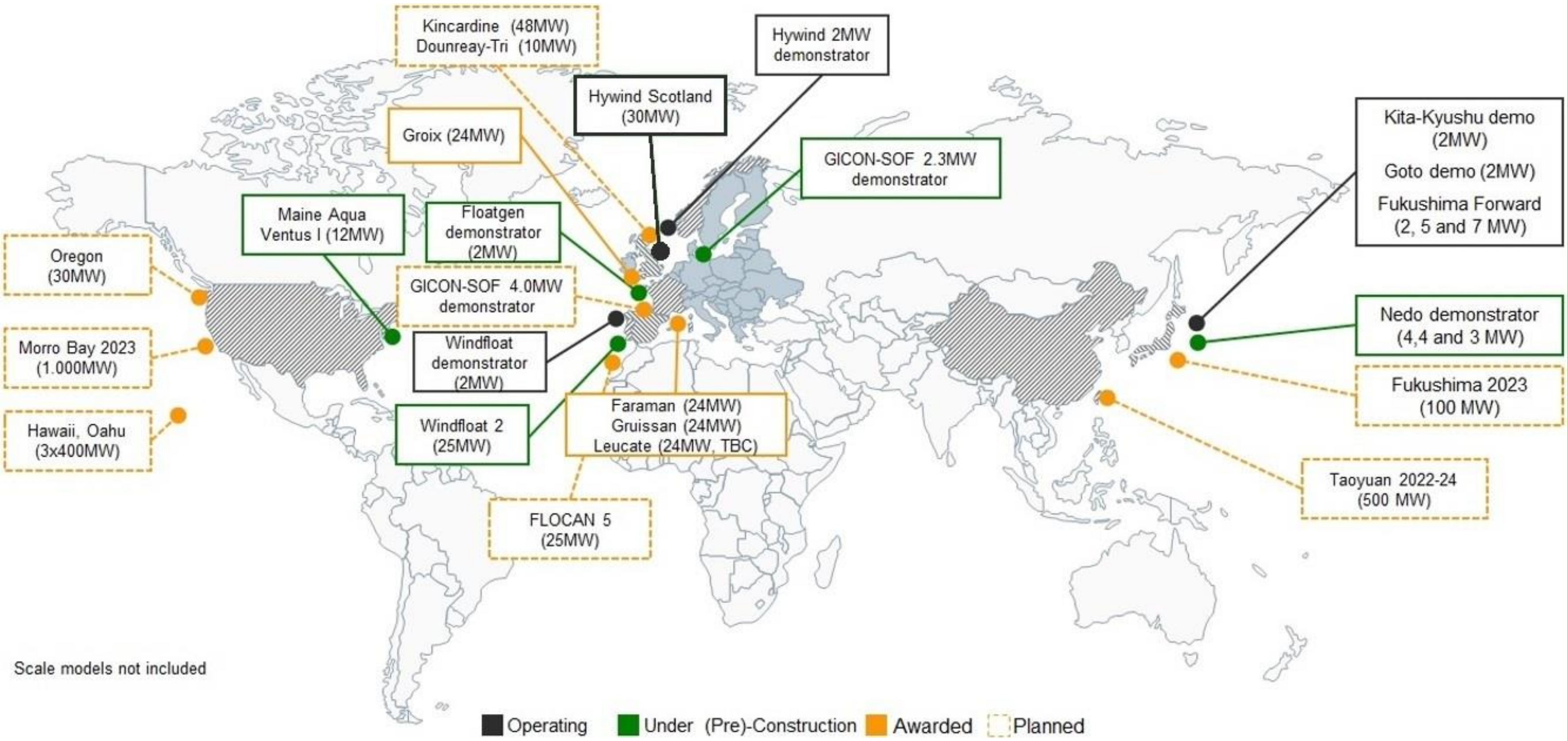
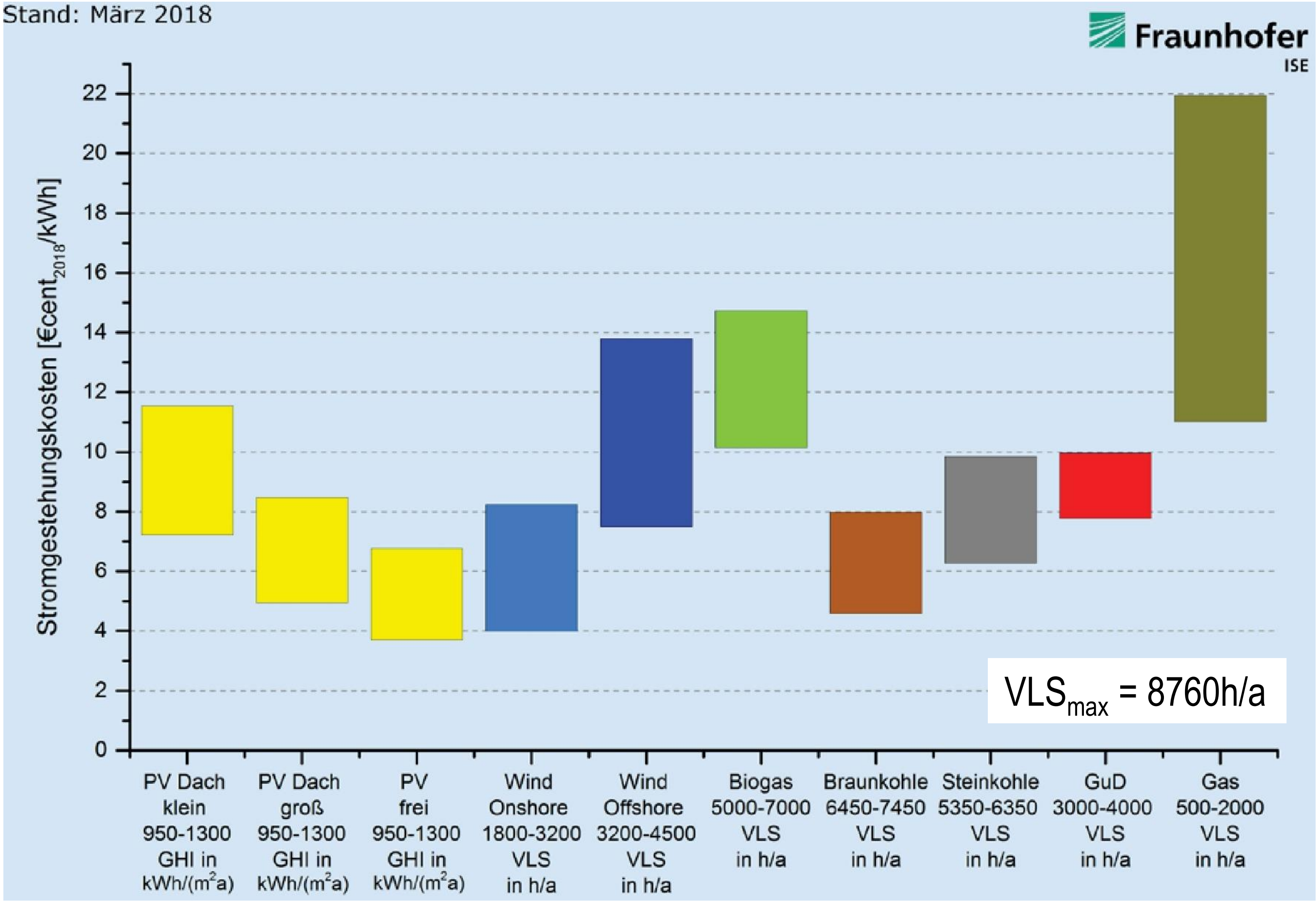
Introduction - Floating wind marketed analysis

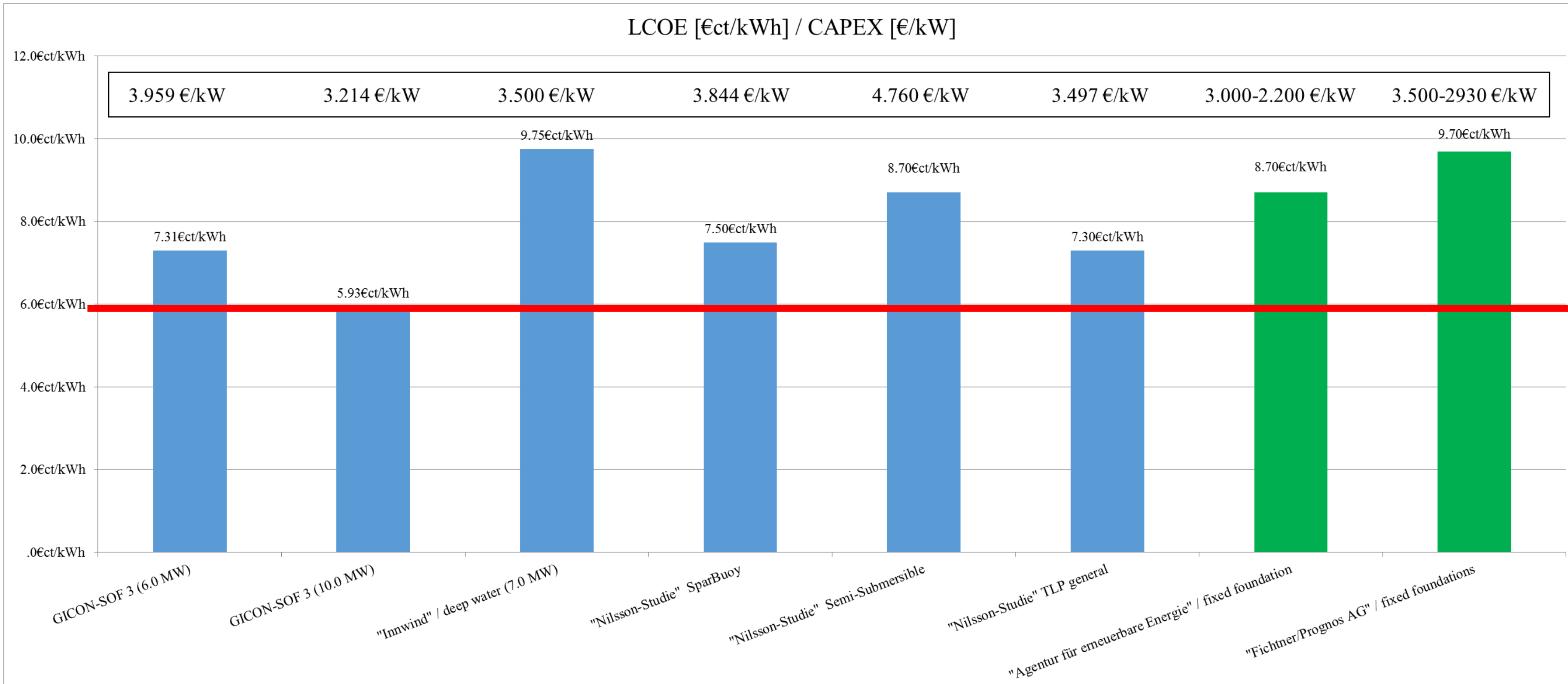


© J. Møller (SIEMENS) – Offshore Wind Conference June 2017 London

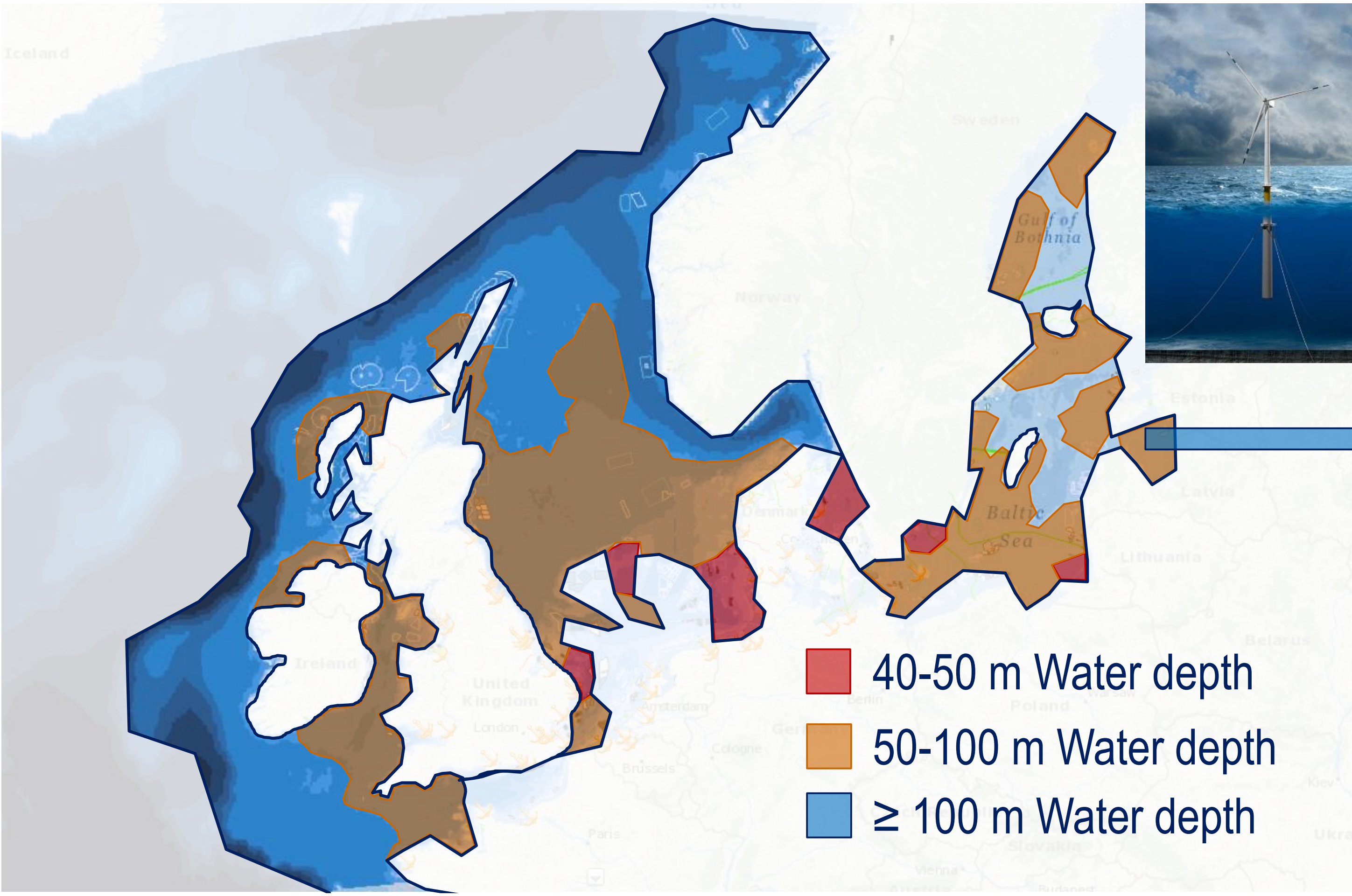
Introduction - **Reduced LCOE**

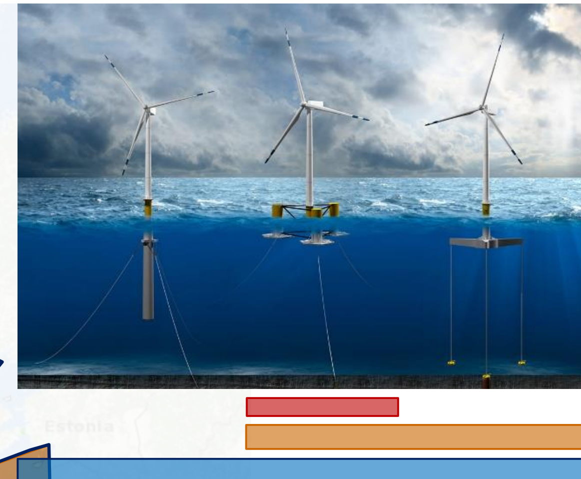


Introduction - **Reduced LCOE**



Introduction - Bathymetry north sea





Introduction - Floating wind marketed analysis

Source: J. Møller (SIEMENS) – Offshore Wind Conference June 2017 London

2009

First demo

- **Site:** Hywind
- **Size:** 2,3 MW
- **Turbine:** SWT-2.3-93
- **Foundation: Spar buoy**
- Demonstration project off the coast of Norway

2017

First wind farm

- **Site:** Hywind Scotland
- **Size:** 30 MW
- **Turbine:** SWT-6.0-154
- World's first floating windfarm, all turbines installed, start of operation late 2017

2020

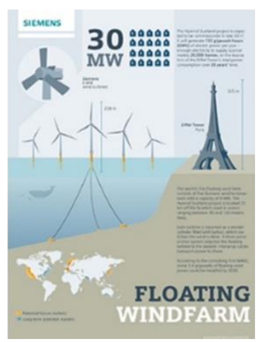
Demo in France

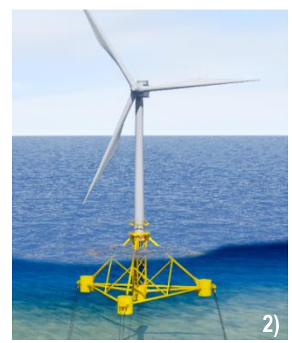
- **Site:** Provence Grand Large
- **Size:** 24 MW
- **Turbine:** SWT-8.0-154
- **Foundation:** SBM

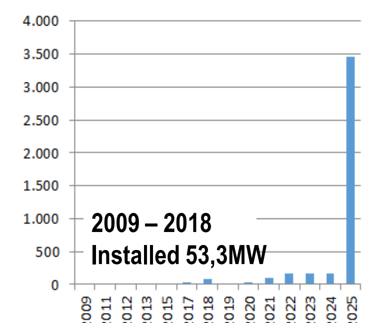
2025

Future markets

- Future markets for floating wind farms are seen in Japan, Taiwan and the US
- Full scale installations expected starting in 2025







1) Hywind wind farm illustration, Source: Statoil; 2) SBM offshore floater, Source: SBM

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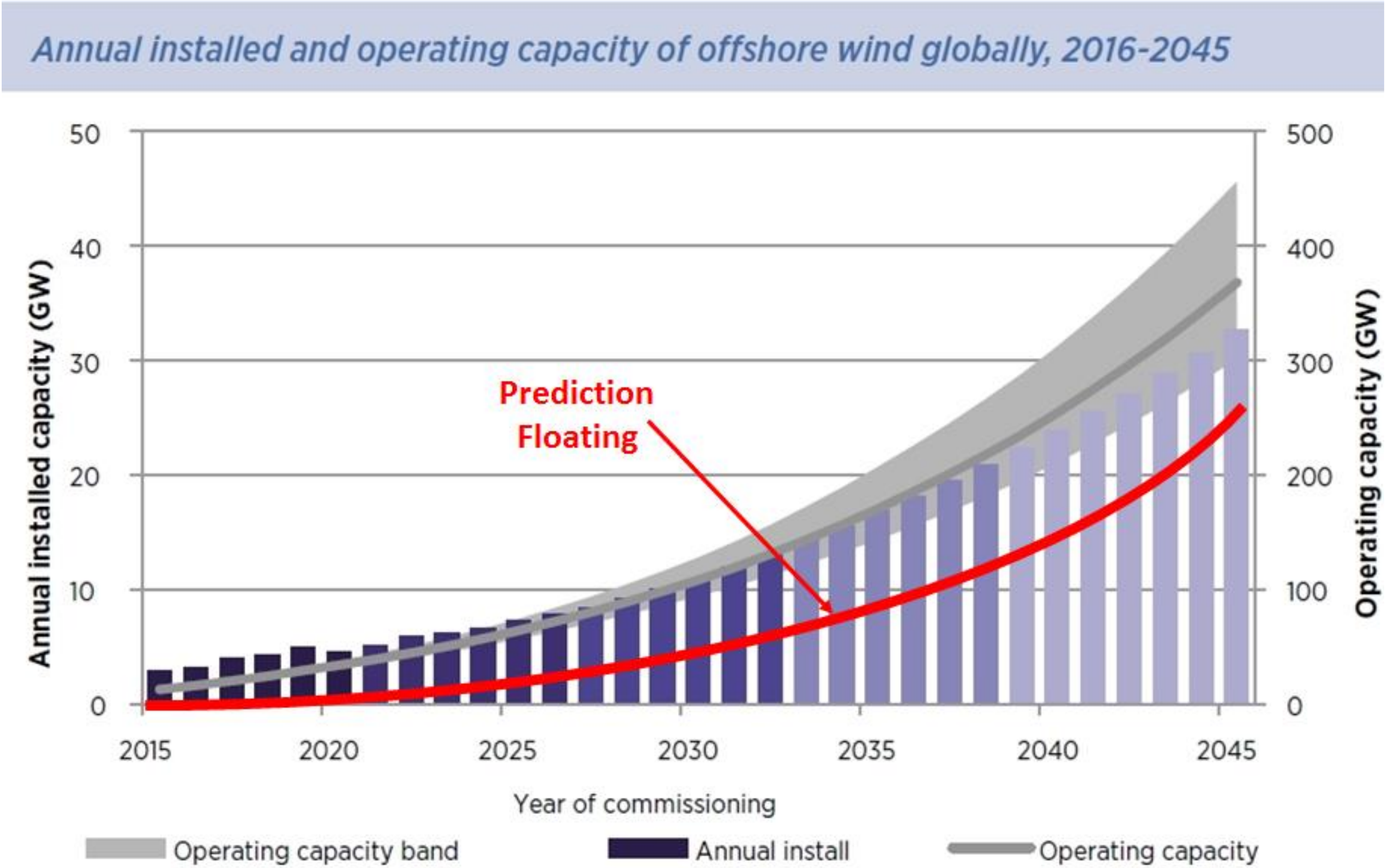
Introduction - Floating wind marketed analysis

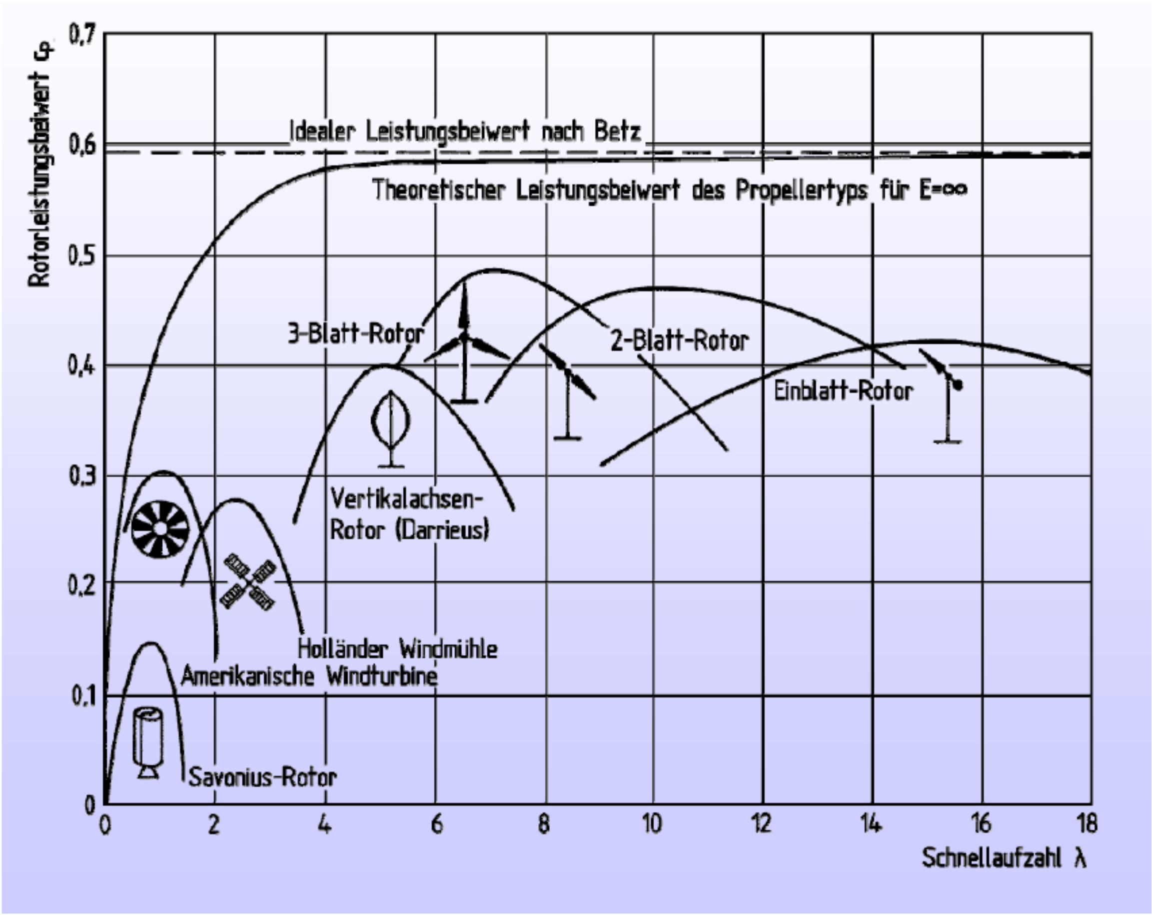


Basis: IRENA, Innovation Outlook Offshore Wind, 2016

Calcuation methodes

Power coefficient

c_p



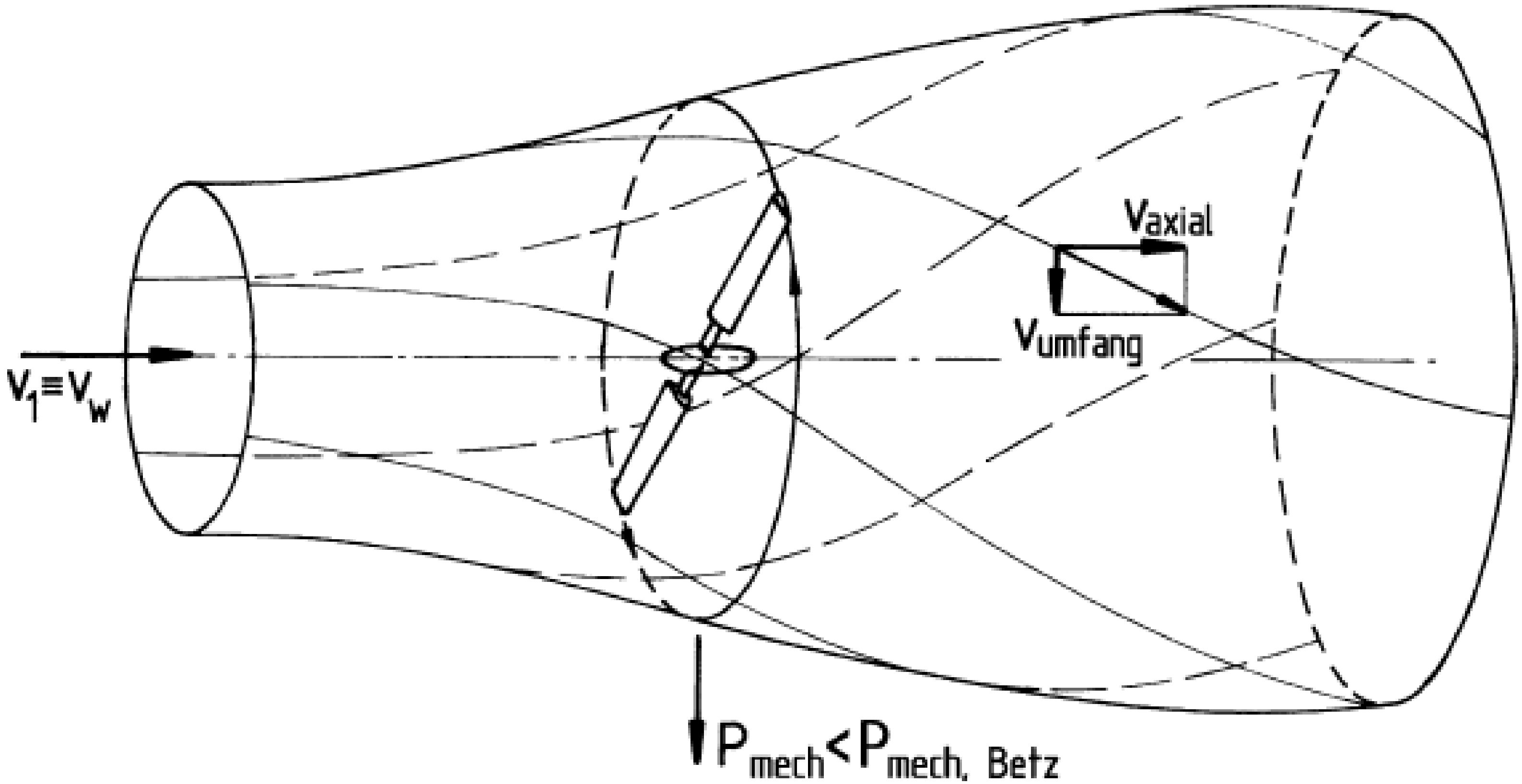
© E. Hau: Windkraftanlagen: Grundlagen, Technik, Einsatz, Wirtschaftlichkeit

v_u … tip speed

v_w … wind speed

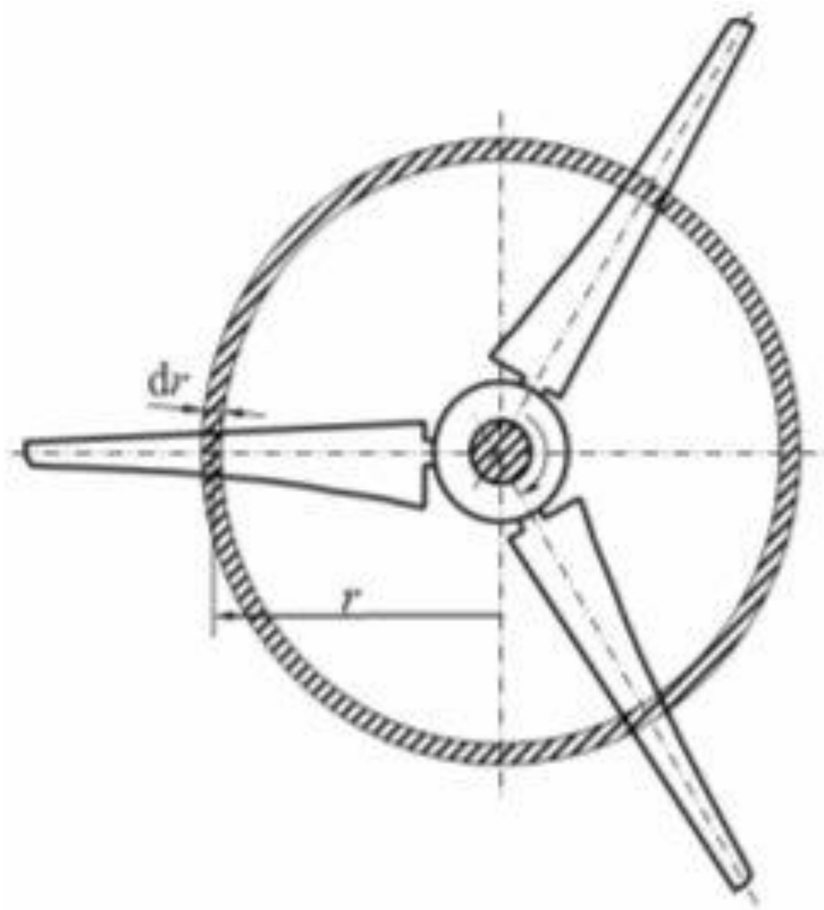
$$\lambda = v_u / v_w$$

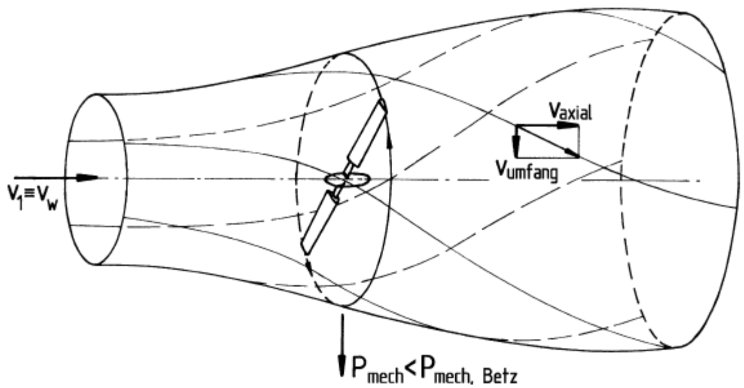
Betz

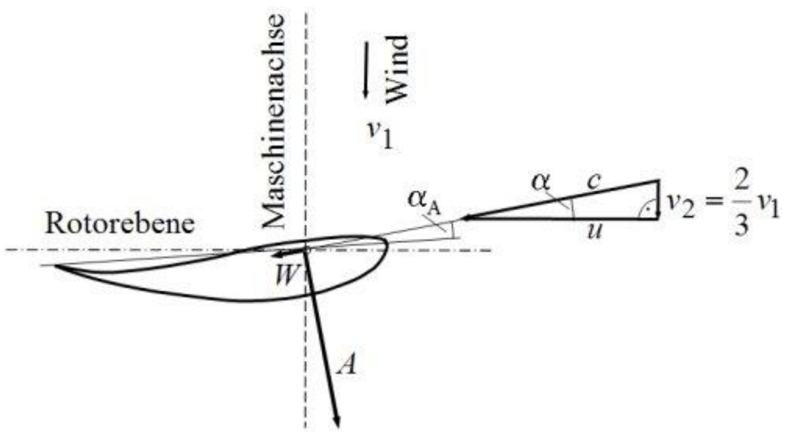


© R. Gasch: Windkraftanlagen

Loads at profile







Blatt-Elemente-Theorie BE

Bezug zu Impuls und Drehimpulsänderung im Luftstrom

BEM Theorie (M für "Momentum")

Impuls $p = m \cdot v$ (p: Impuls)

Luftstrom (stationär)

$$\dot{m} \cdot v = (\rho \cdot A \cdot v) \cdot v$$

Impulsänderung = Kraft

$$T = \rho \cdot A_2 \cdot v_2(v_1 - v_3)$$

Loads at profile

Schub

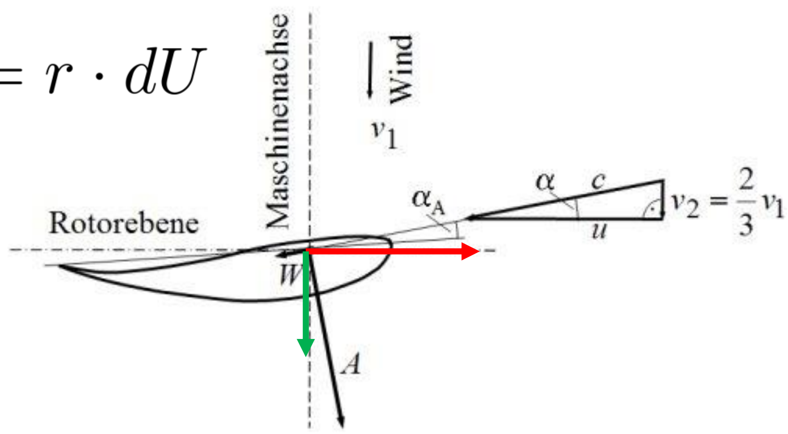
$$dT = \frac{1}{2} \cdot \rho \cdot c^2 \cdot (c_L \cdot \cos\alpha + c_D \cdot \sin\alpha) \cdot t(r) \cdot dr$$

Vortrieb

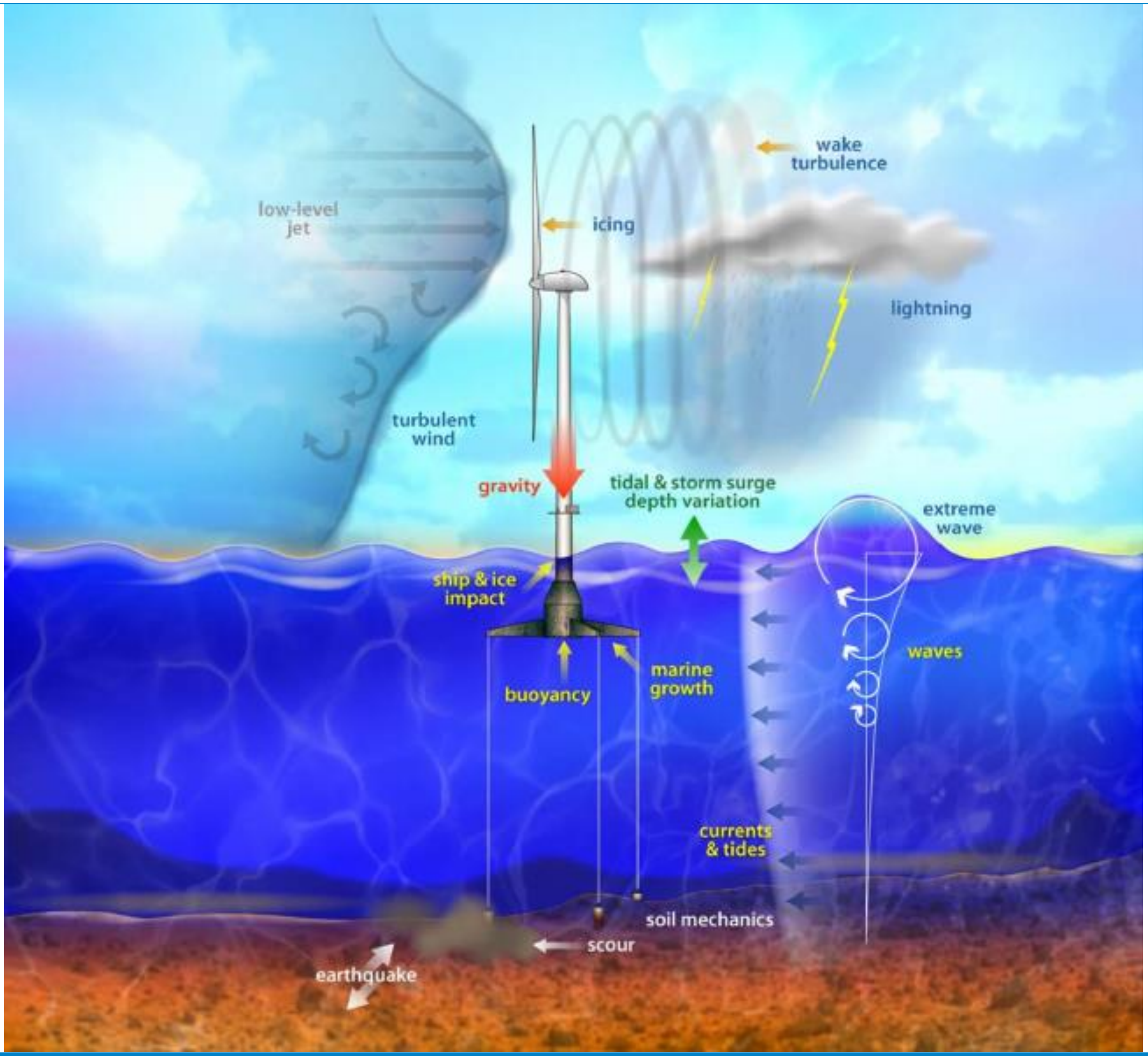
$$dU = \frac{1}{2} \cdot \rho \cdot c^2 \cdot (c_L \cdot \sin\alpha - c_D \cdot \cos\alpha) \cdot t(r) \cdot dr$$

Drehmoment

$$dM = r \cdot dU$$



Loads



low-level jet
icing
wake turbulence
lightning
turbulent wind
gravity
tidal & storm surge depth variation
extreme wave
ship & ice impact
buoyancy
marine growth
waves
currents & tides
soil mechanics
scour
earthquake

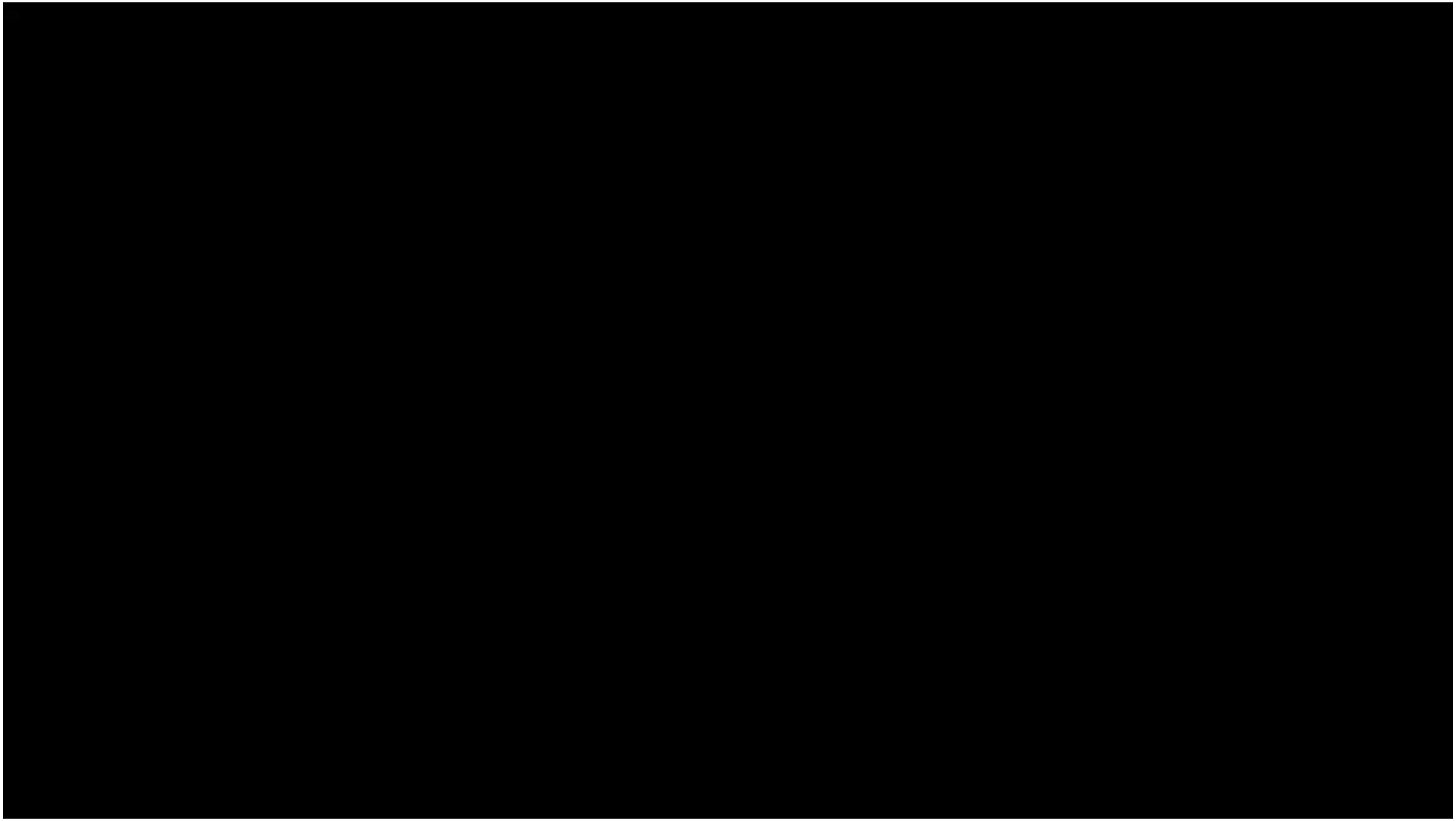
Selected examples

Principle Powers´s buoyancy stabilized system

WindFloat

by Principle Power

Statoils´s gravity stabilized system



GICON´s mooring line stabilized system

R&D work at the Endowed Chair of Wind Energy Technology

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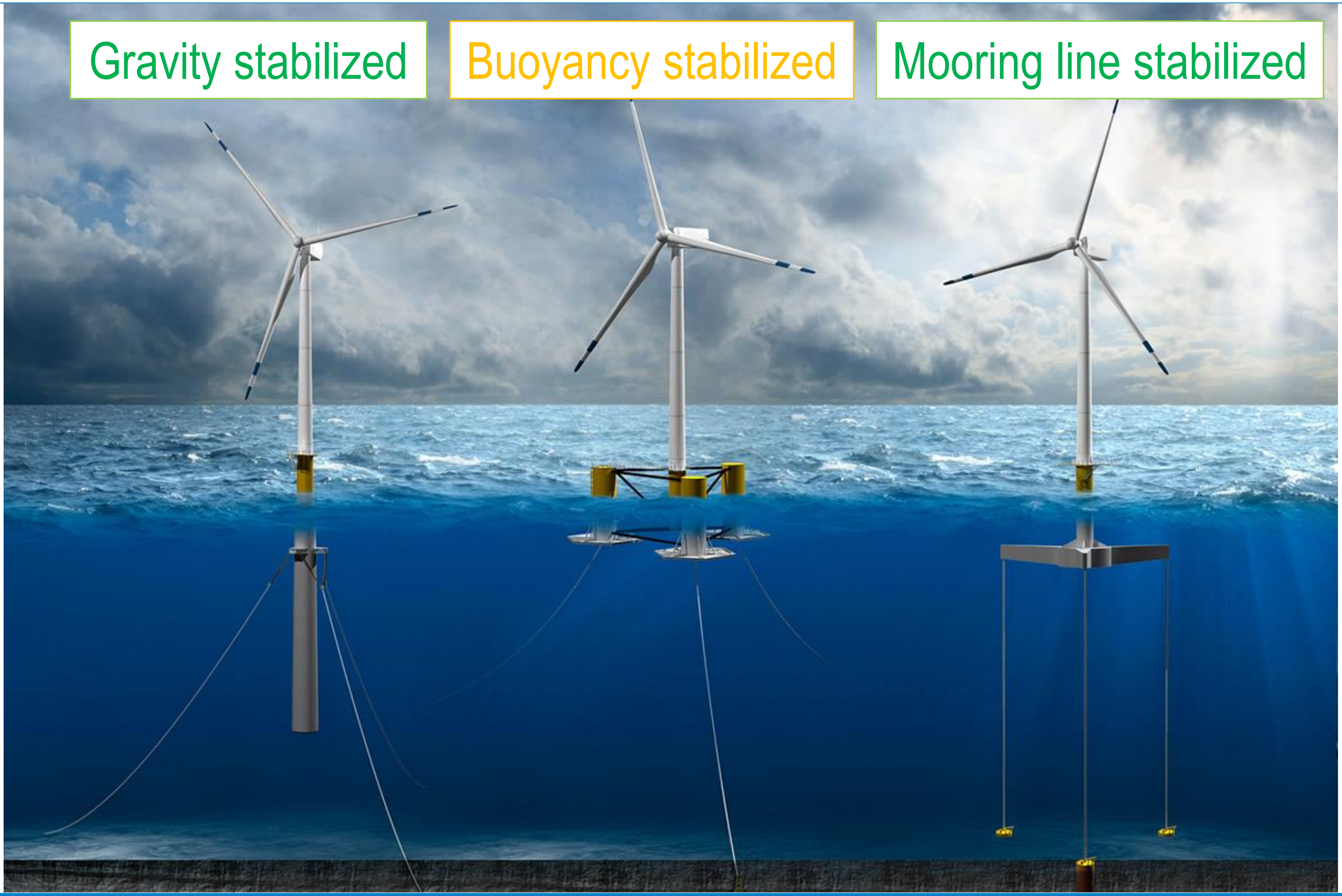
R&D work at the Chair with regard to floating wind



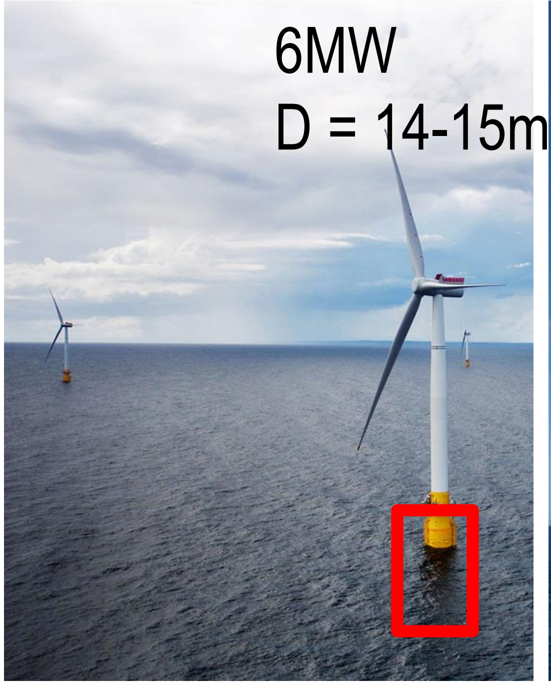
R&D work at the Chair with regard to floating wind

Gravity stabilized	Buoyancy stabilized	Mooring line stabilized
• Structural basis design • Active controlled Spar-Buoy concept • Transport and Installation process design etc. • Reduce costs for fabrication via a structural optimization tool • Tank tests & validation	• Code comparison (OC5&OC6) • Simulation Code Verification	• Structural basis & detail design • One-Step installation process • Using composite materials • Modularity design to get a flexible supply chain • Reduce costs for fabrication via a structural optimization tool and flexible supply chain • Tank tests & validation

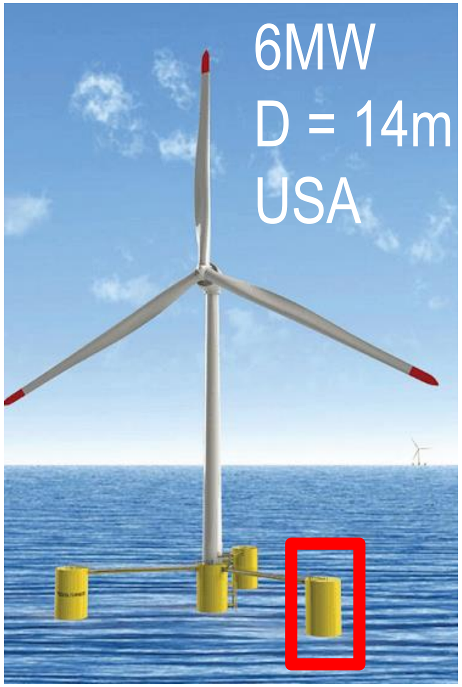
- Design of inter array cableing for floating offshore wind farms
- Floating O&M platforms for offshore wind
- In collaboration with Windrad Engineering – wind turbine design

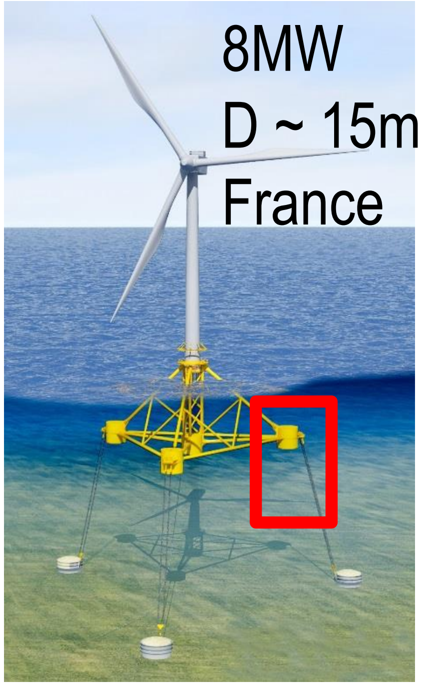
Example #1:
Universal Buoyancy Bodies

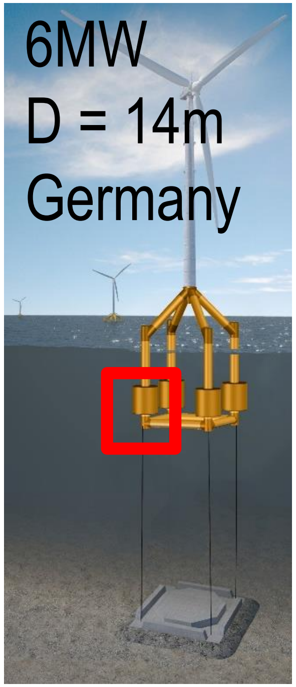

2MW
D = 10.7m


6MW
D = 14-15m


2MW
D = 9.5m


6MW
D = 14m
USA


8MW
D ~ 15m
France


6MW
D = 14m
Germany

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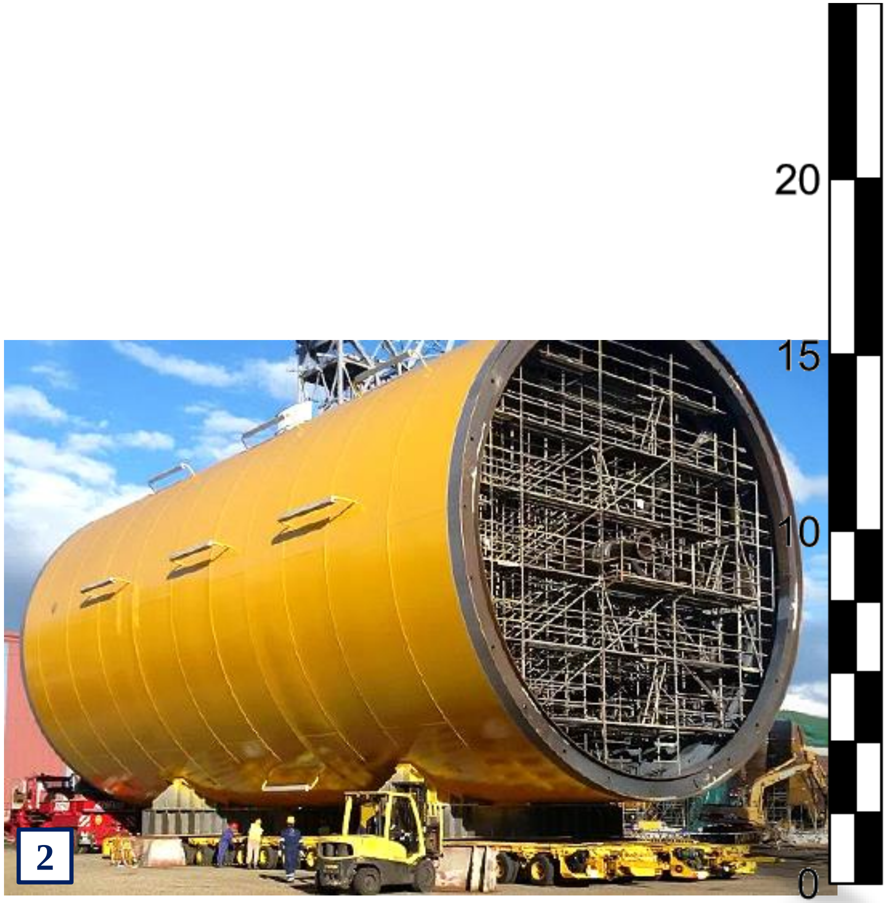
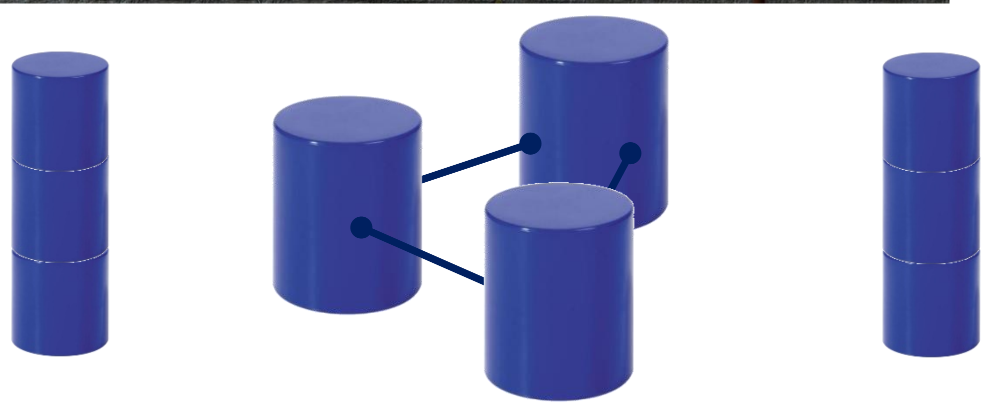
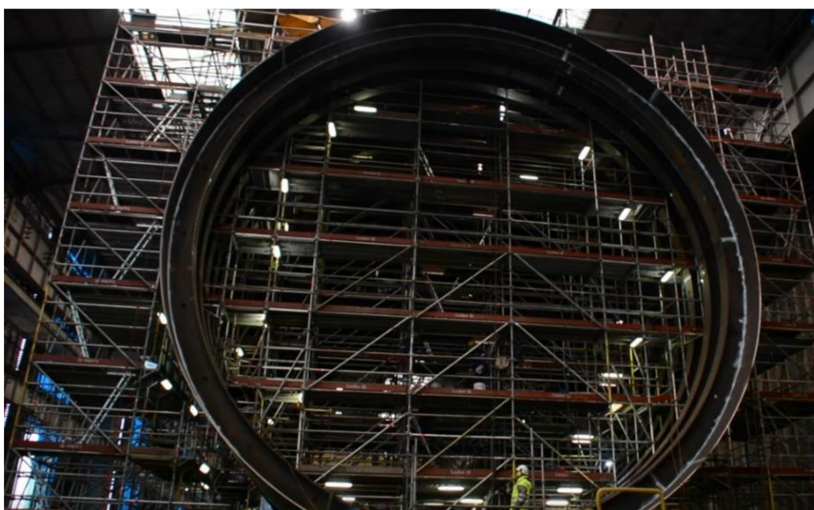
Universal buoyancy bodies:

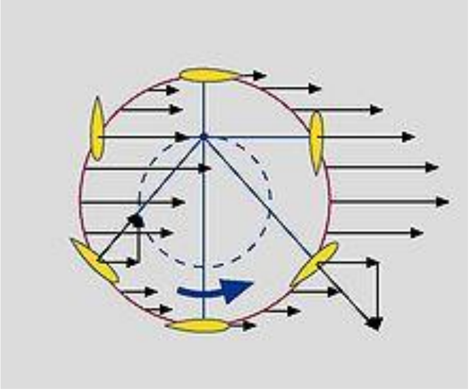
- Reduced costs
- Applicable for different floaters etc.
- D ~ 16.5m | H ~ 30m







Example #2:
Adapted gravity stabilized (Spar Buoy)

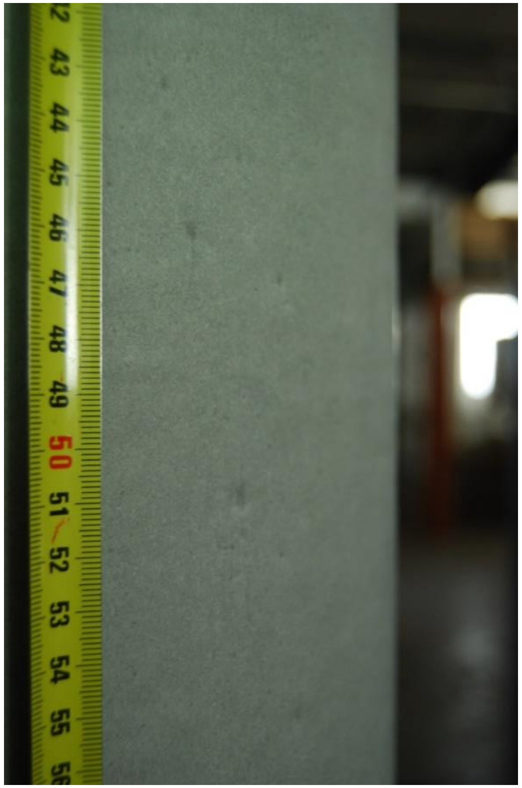


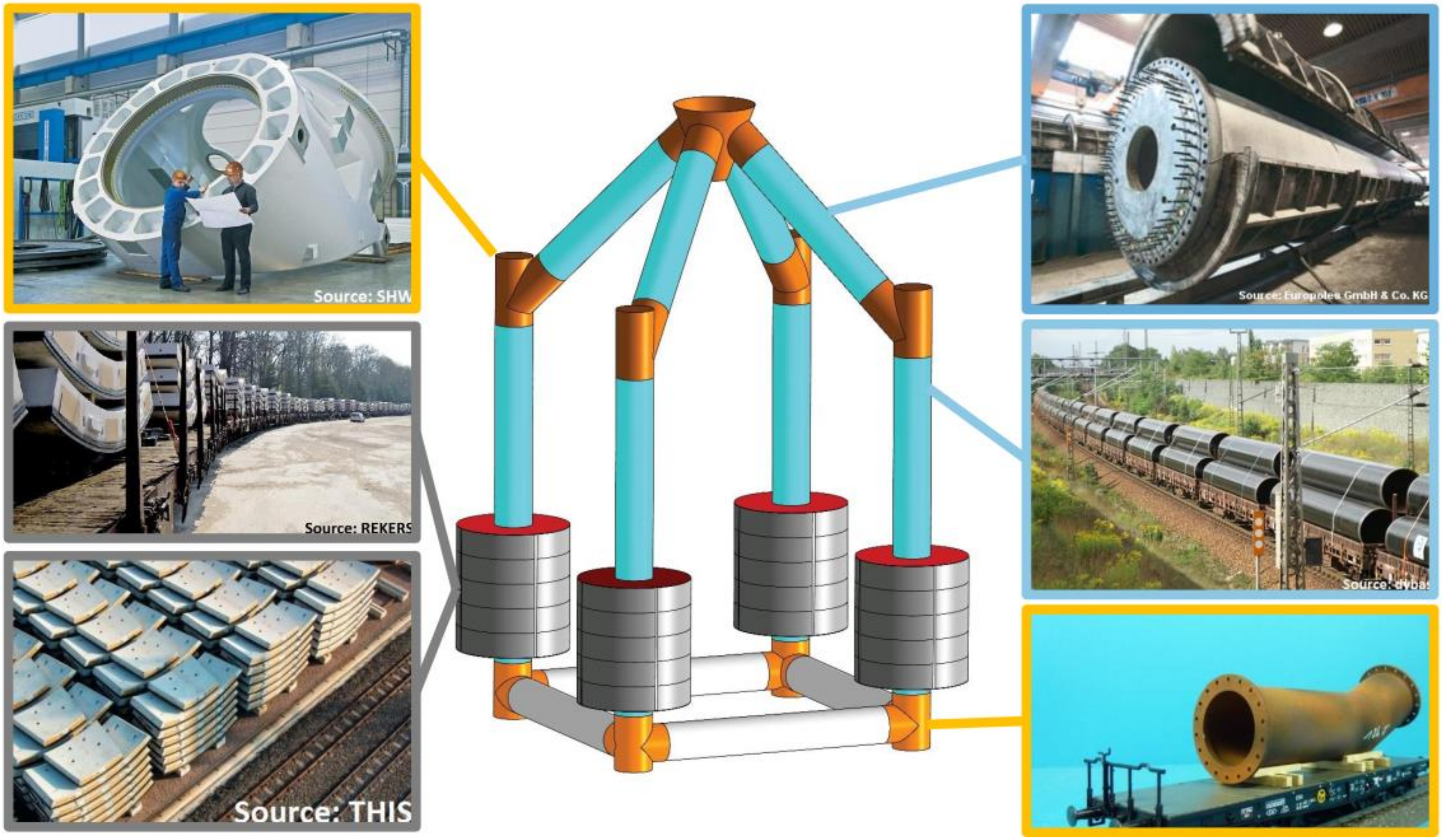
Example #3:
Optimized mooring line stabilized (TLP)

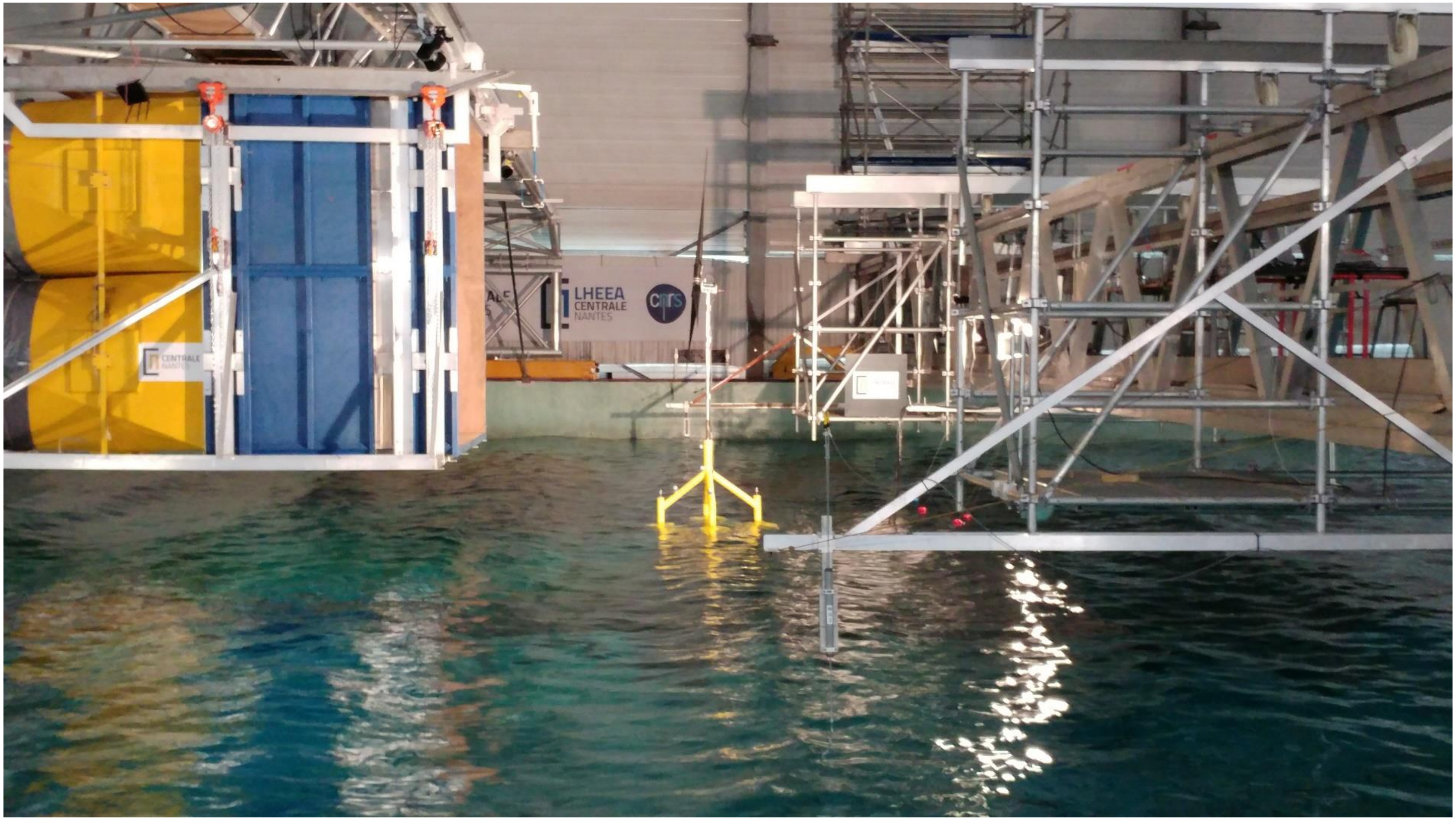
Ultra-High-Performance-Concrete (UHPC)

- Compressive strength: **80 - 500 Mpa**
- Tensile strength: **3 - 20 MPa**
- Flexural strength (reinforced): **5 - 75 MPa**
- Fracture energy: **50 - 90 kN/m**
- Crack width: **<< 0.1 mm**
- Carbonating: **1.5 mm after 3 years**
- Water pen. depth.: **not measurable**
- Chloride-diffusion: **not measurable**
- Weight: **1.5 - 2.7 t/m^3**

- **Cost: 400€/t (steel > 3000€/t)**




Source: SHW
Source: REKERS
Source: THIS
Source: Europoles GmbH & Co. KG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