DeepWind

tomorrow's concept for large offshore wind power

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Agenda

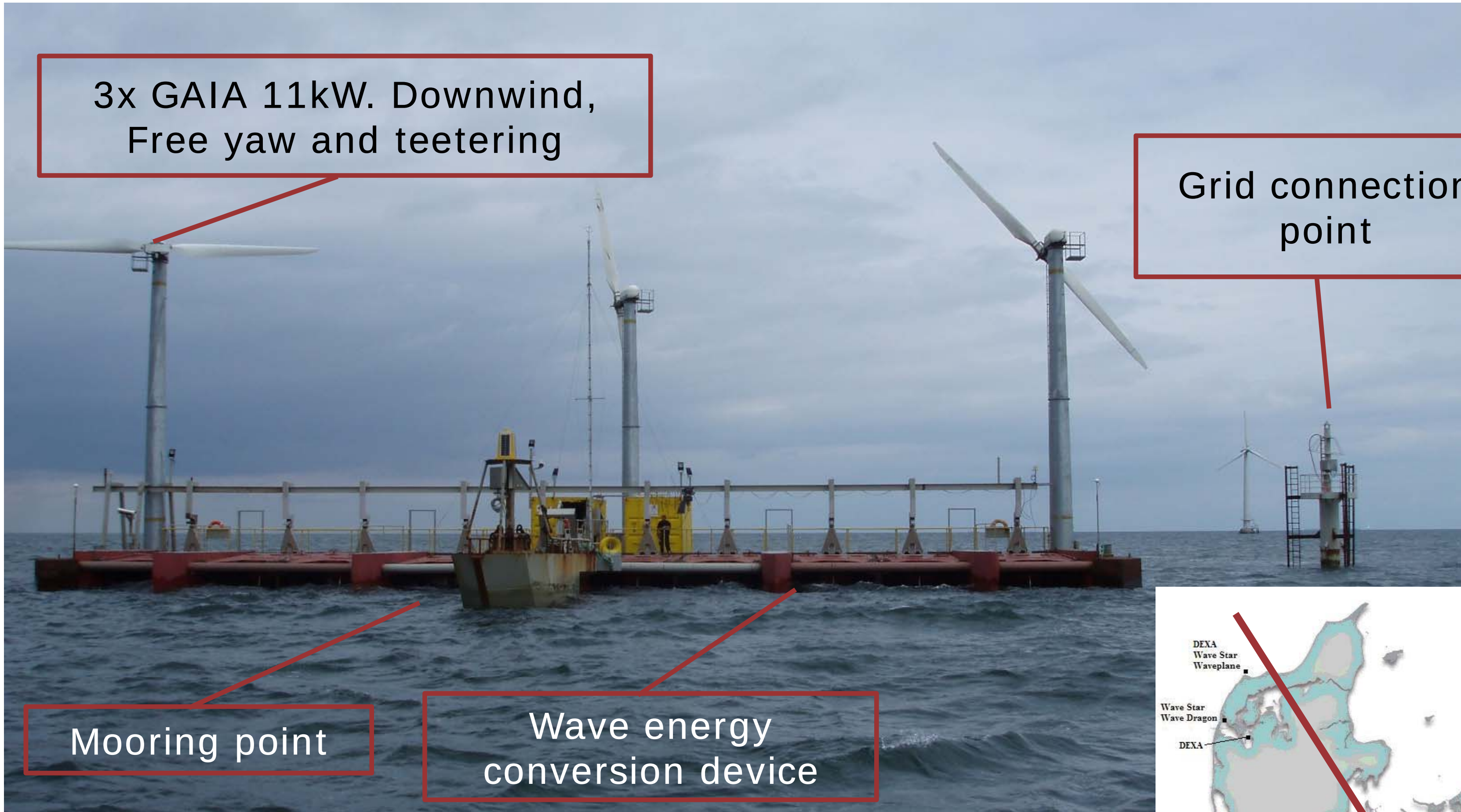
- Introduction
- DeepWind concept description
- Dimensions
- Challenges and results from first order investigations
- DeepWind project description and partners
- Conclusions

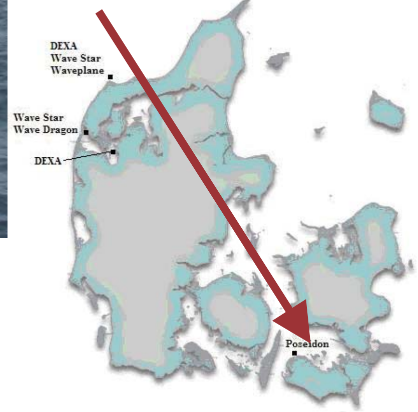
Research project overview nov. 2010

- EUDP Walney – wake and foundations measurements - TB 7 MDKK (6 my)
- EUDP Wave loads on offshore structures
- EUDP resonant wave
- TWENTIES – EU – Storm control– TB 56 M€ (8 my)
- HTF foundations – Cost efficient foundations – TB 80 MDKK (11 my)
- PSO Wake effects
- Wake effects of large offshore wind farms
- IEA Annex 30 – Code comparison
- HYWIND – Floating turbine
- MARINA
- Poseidon – Wind and wave concepts
- DeepWind – New offshore floating concept
- EU-Norsewind – Wind resources
- Radar@Sea – PSO - Wind resources
- ORECCA
- South Baltic offshore
- Wasp offshore

Poseidon: how it looks

PSO project, measurements and modeling: DONG, FPP, DHI and Risø DTU





Cost of onshore –offshore wind power

- Higher cost due to larger structures(volume and mass) and complexity of installing the tower
- Higher cost on foundations, constructions, grid connection
- Higher cost with distance from shore

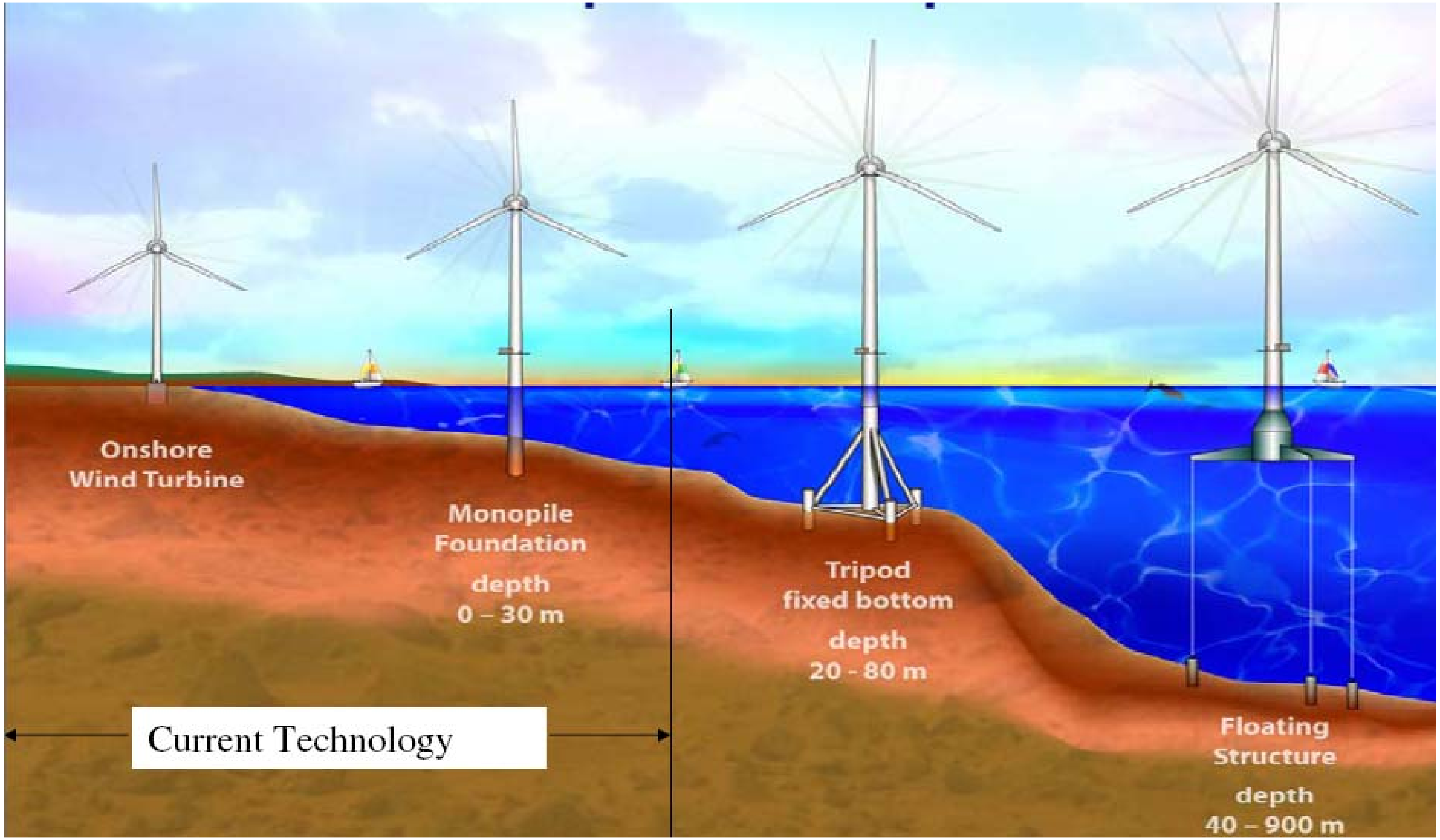
- **Tower and foundation +20%, all in all 2-2.5 times the cost on land**

Land based wind turbines, cost of electricity : 5-9 c€/kWh
Offshore wind turbines, cost of electricity : 6-10 c€/kWh

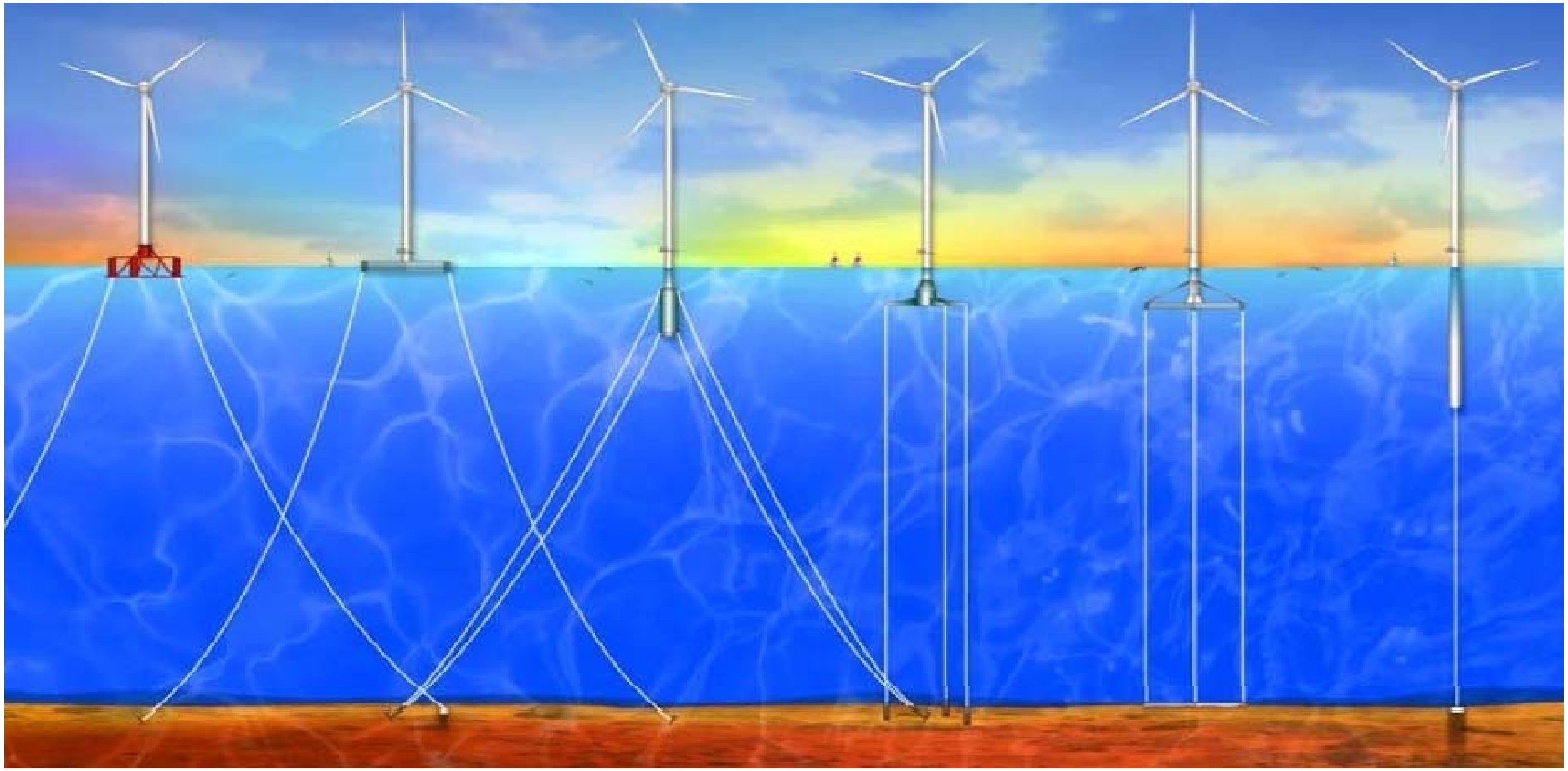
Table 8: Cost structure of a typical 2 MW wind turbine installed in Europe (year 2006 €)

	Investment (1000 €/MW)	Share (%)
Turbine (ex works)	928	75.6
Foundation	80	6.5
Electric installation	18	1.5
Grid-connection	109	8.9
Control systems	4	0.3
Consultancy	15	1.2
Land	48	3.9
Financial costs	15	1.2
Road	11	0.9
Total	1227	100

From shore to deep sea



From shore to deep sea



*from NREL and MIT (*Sclavounos*)*

DeepWind hypothesis

- So far, offshore wind energy has been mainly based on onshore technology moved in shallow waters

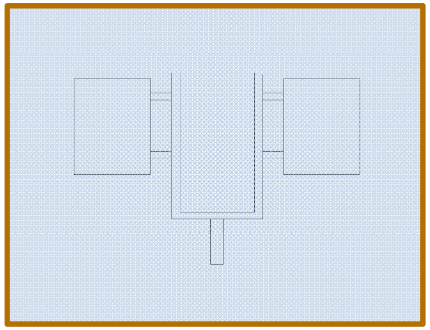
- In order to reduce the cost, offshore wind energy needs new concepts specifically designed for offshore conditions

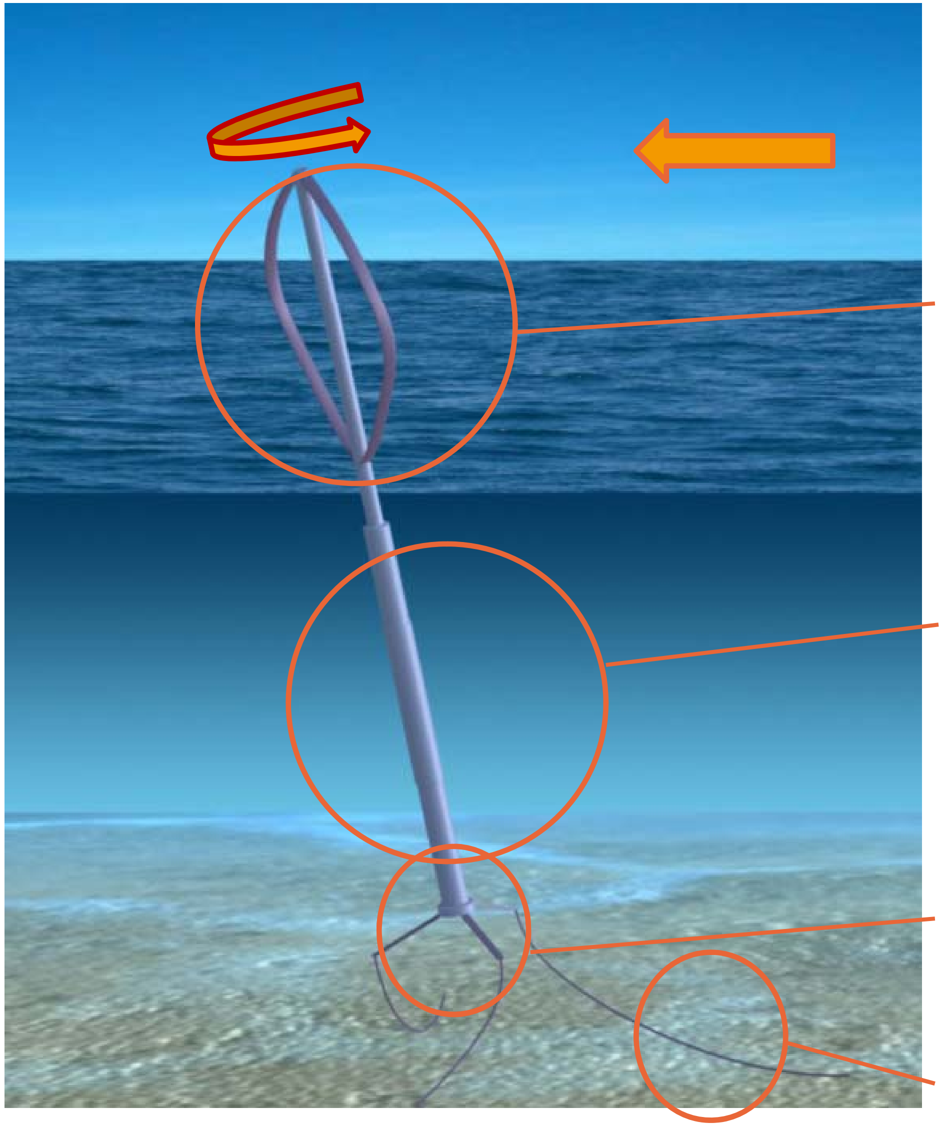
- Key issues for a successful offshore concept are:
  - ✓Simplicity
  - ✓Up-scaling potential
  - ✓Suitability for deep sites

- COE=f(technology, AEP) takes a leap. Both technology as well as large capacity through upscaling contributes to improving COE.

General concept description

- floating and rotating tube as a spar buoy
- No pitch, no yaw system
- C.O.G. very low –counter weight at bottom of tube
- Safety system

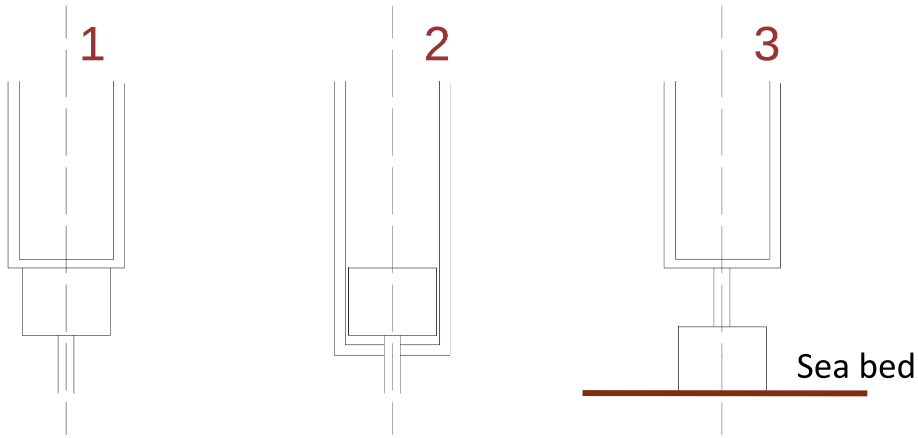


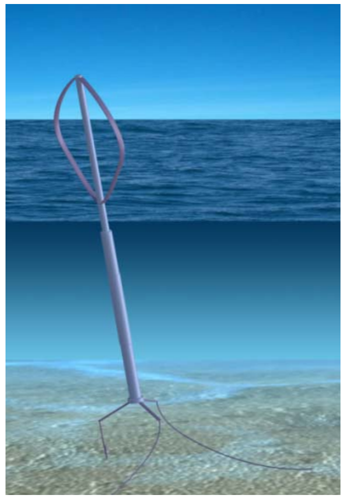


Components - Generator configurations

- The Generator is at the bottom end of the tube; several configuration are possible to convert the energy

- Three selected to be investigated first:
  1. Generator fixed on the torque arms, shaft rotating with the tower
  2. Generator inside the structure and rotating with the tower. Shaft fixed to the torque arms
  3. Generator fixed on the sea bed and tower. The tower is fixed on the bottom (not floating).





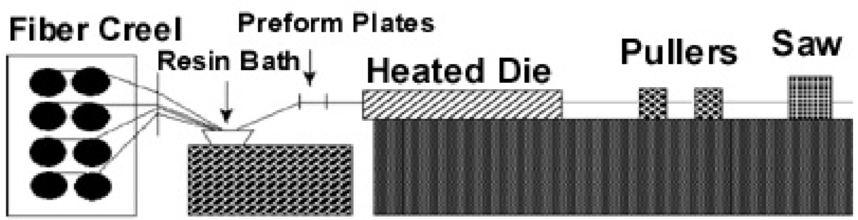
DeepWind concept description

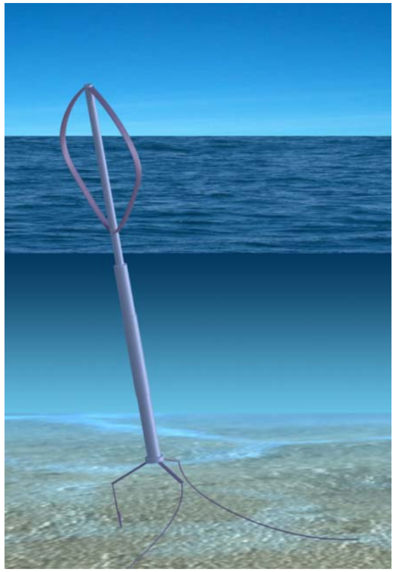
Components – Blades technology

- The blade geometry is constant along the blade length

- The blades can be produces in GRP

- Pultrusion technology:
 11 m chord, several 100 m long blade length



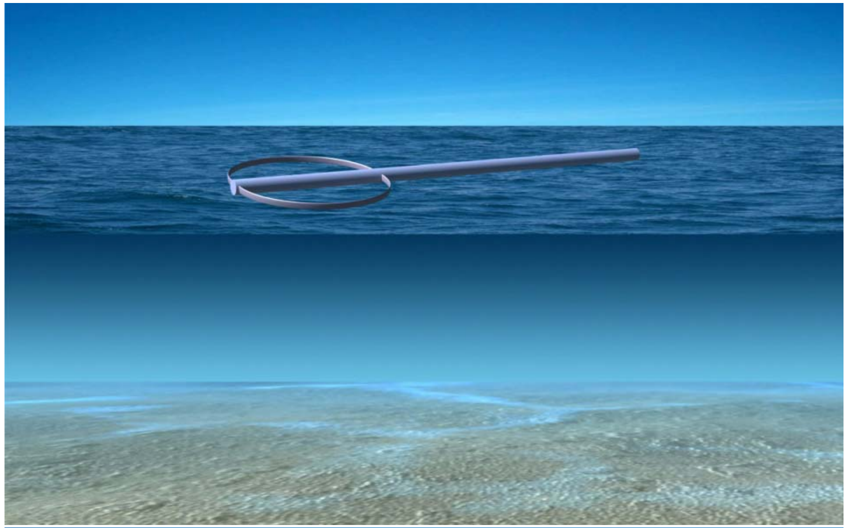


- Pultrusion technology could be performed on a ship at site

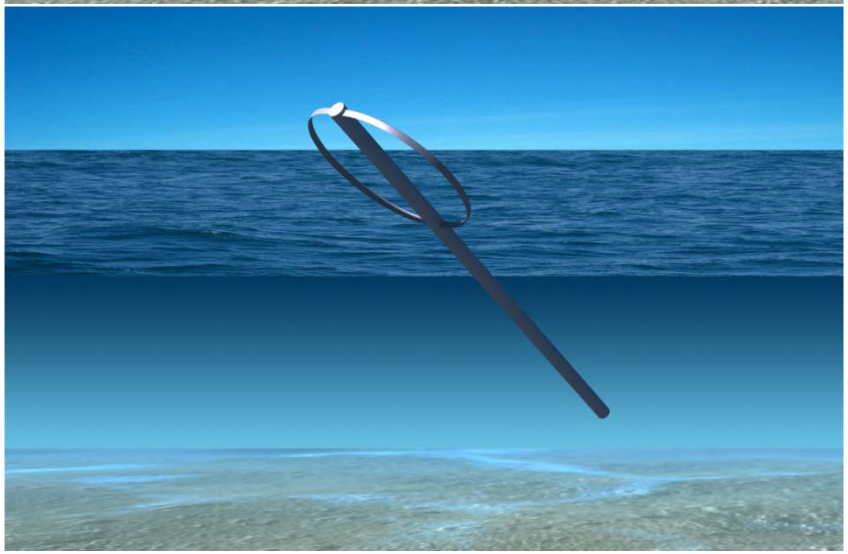
- Blades can be produced in modules

Installation, Operation and Maintenance

- INSTALLATION
  - ✓ Using a two bladed rotor, the turbine and the rotor can be towed to the site by a ship. The structure, without counterweight, can float horizontally in the water. Ballast can be gradually added to tilt up the turbine.



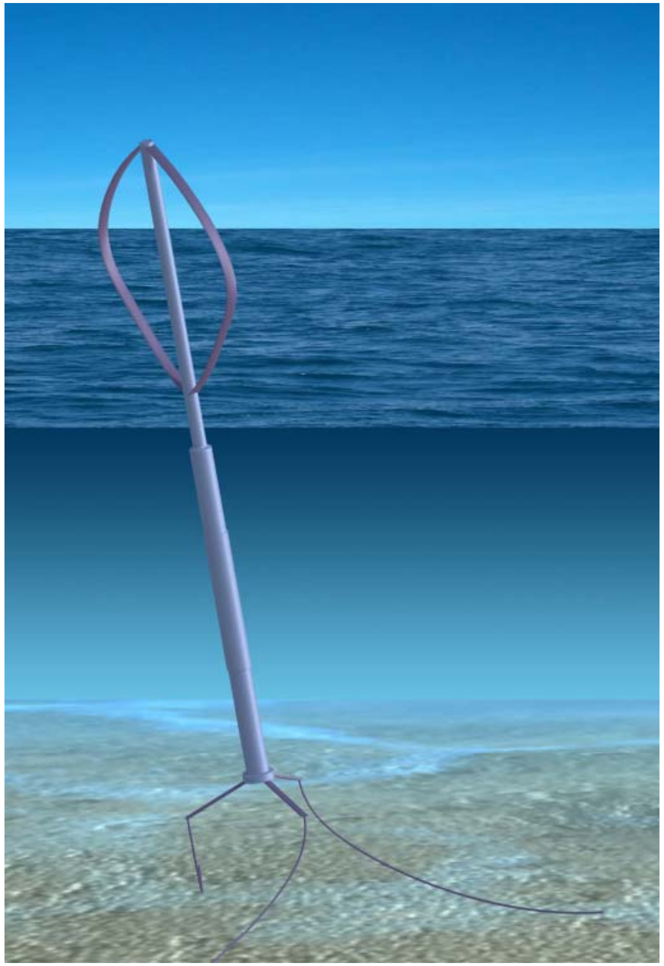
- O&M
  - ✓ Moving the counterweight in the bottom of the foundation is possible to tilt up the submerged part for service.
  - ✓ It is possible to place a lift inside the tubular structure.



Deep Wind Concept
Upscaling

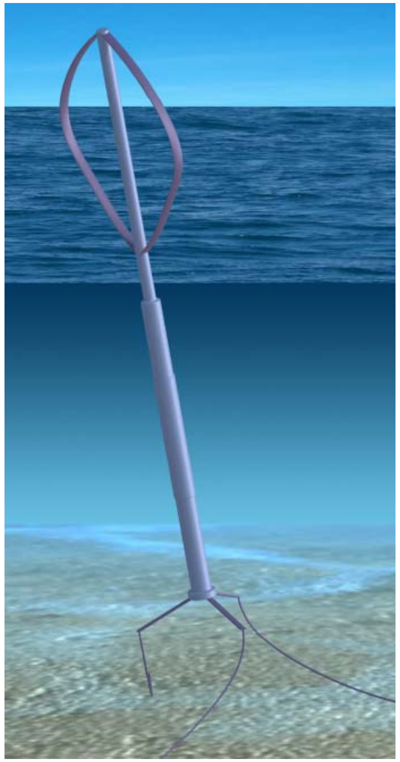
- Pultrusion technology allows for very long and fail-free manufactured blades
- Concept simplicity
- Few components with less down time failures

- Cost-effective different materials for large structure
- Specific requirements to maintain the underwater components



Dimensions

2MW VAWT vs HAWT

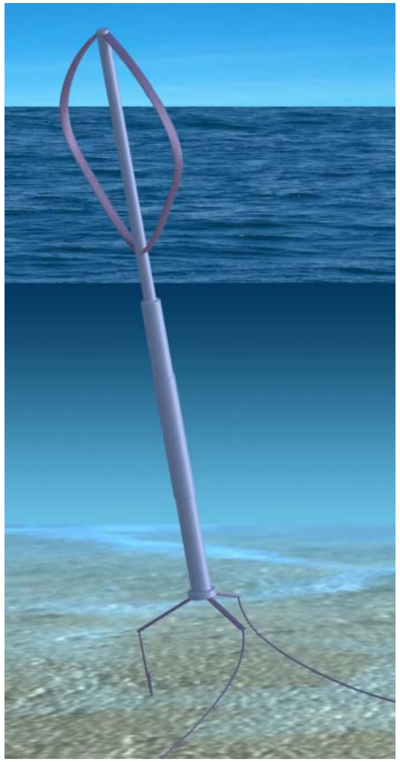


	Deep Wind	HyWind *
Power	2 MW	2.3 MW
Rotor Diameter	67 m	82.4 m
Reference rotor Height	75 m	65.0 m
Chord (blades number)	3.2 m (2)	(3)
Rotational speed at rated conditions	15.0 rpm	16 .0 rpm
Radius of the rotor tower	2.0 m	3.0 m
Maximum radius of the submerged part	3.5 m	4.15 m
Total tower length (underwater part)	183 m (93m)	165 (100)
Displacement	3000 tons	5300 tons

*"*HYWIND, Concept, challenges and opportunities* ", Statoil

Dimensions

20 MW outlook



	2 MW	20MW
Power	2 MW	20 MW
Rotor Diameter	67 m	240 m
Reference rotor Height	75 m	240 m
Chord (blades number)	3.2 m (2)	11.0 m(2)
Rotational speed at rated conditions	15.0 rpm	4.1 rpm
Radius of the rotor tower	2.0 m	3.0 m
Maximum radius of the submerged part	3.5 m	6.5m
Total tower length (underwater part)	183 m (93m)	340 (105)
Displacement	3000 tons	13000 tons

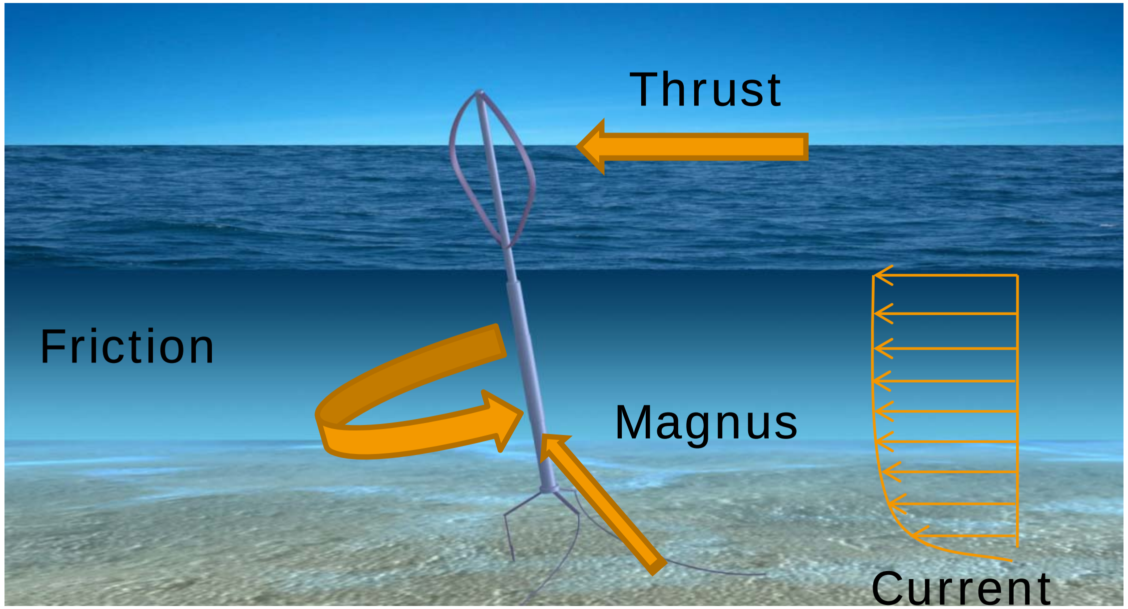
Fluid interaction investigation: loads on the tower and friction losses

$$L = L(\mathrm{Re}, \alpha)$$

$$\alpha = \frac{\omega R}{U}$$

U= 1m/s

R=3m

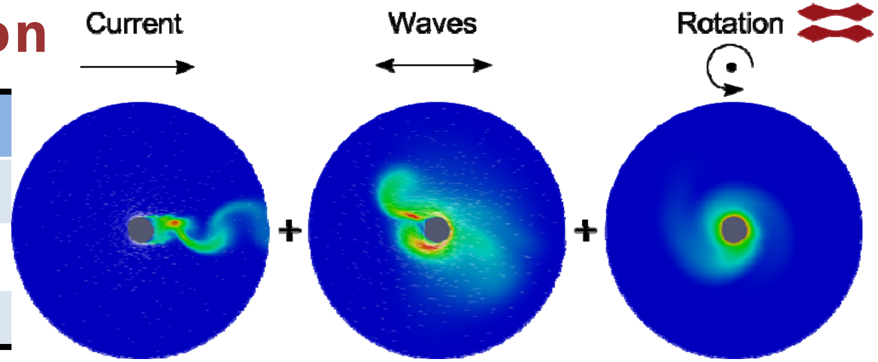


α	L per meter [kN/m]	Aerodynamic Thrust [kN]	Friction Power [kW]	Generated Power [kW]	Friction/Generated power
1.4 (5.5rpm)	9.950	65.81	3.71	0.0	/
2.9 (11rpm)	23.72	186.85	16.69	1050	0.012(1.2%)
3.9 (15rpm)	**25.15**	**239.65**	43.20	1960	**0.022(2.2%)**

Challenges and results from first order investigations

Selected configuration

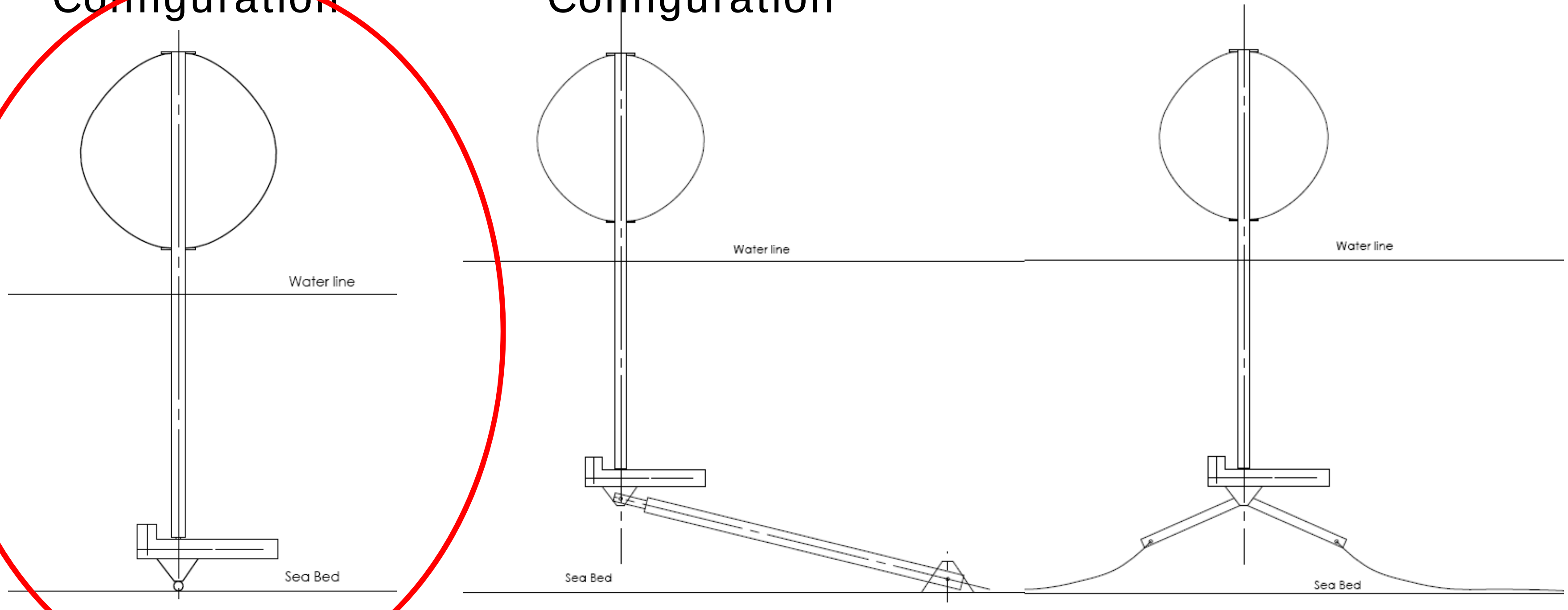
	Surge	Sway	Heave	Pitch	Roll
1st Configuration				X	X
2nd Configuration			X	X	X
3rd Configuration	X	X	X	X	X



1st Configuration

2nd Configuration

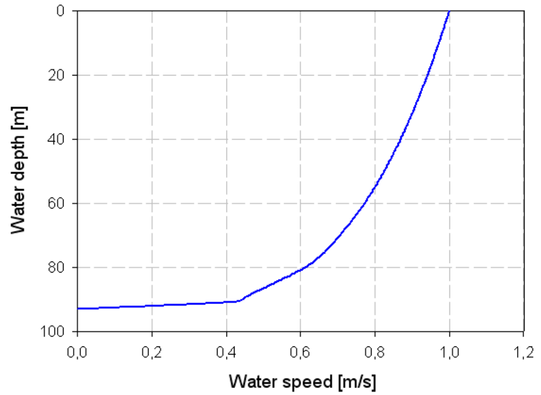
3rd Configuration

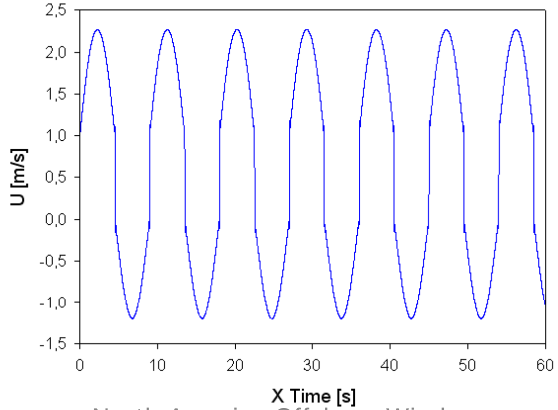


External conditions and load cases

- **Wind speed:**
  - ✓14m/s constant, no turbulence
  - ✓Direction: y axis
  - ✓Wind shear: power law, α=0.14
- **Water currents:**
  - ✓1m/s
  - ✓Direction x axis
- **Waves:**
  - ✓Regular waves
  - ✓Significant height 4.0m
  - ✓Wave Period 9.0s
  - ✓Direction: x axis

	Wind	Waves	Currents
Reference load case	X		
1st load case	X	X	
2nd load case	X		X
3rd load case	X	X	X





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	Wind	Waves	Currents
Reference load case	X		
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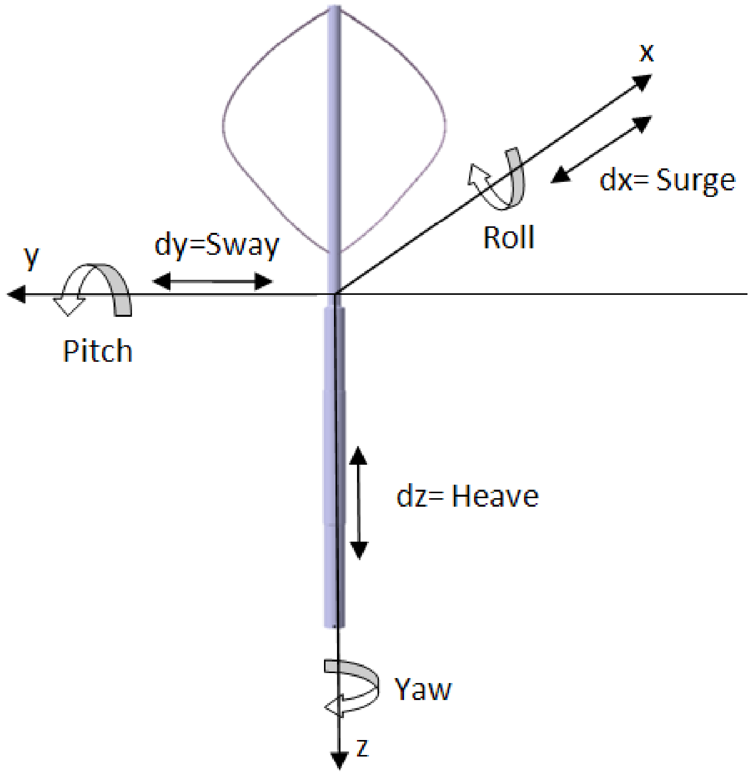
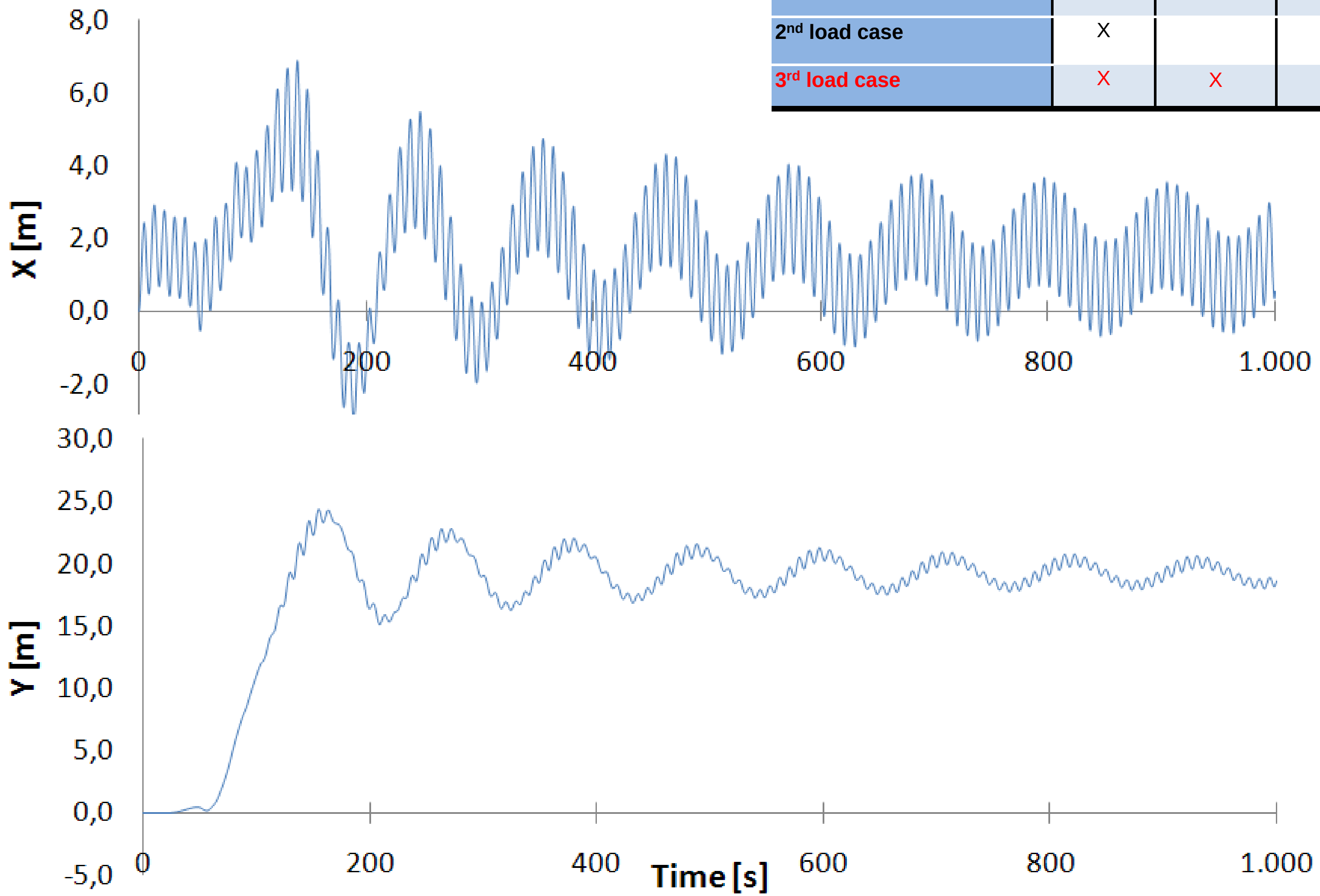
3rd load case	X	X	X



First order investigation
3rd load case

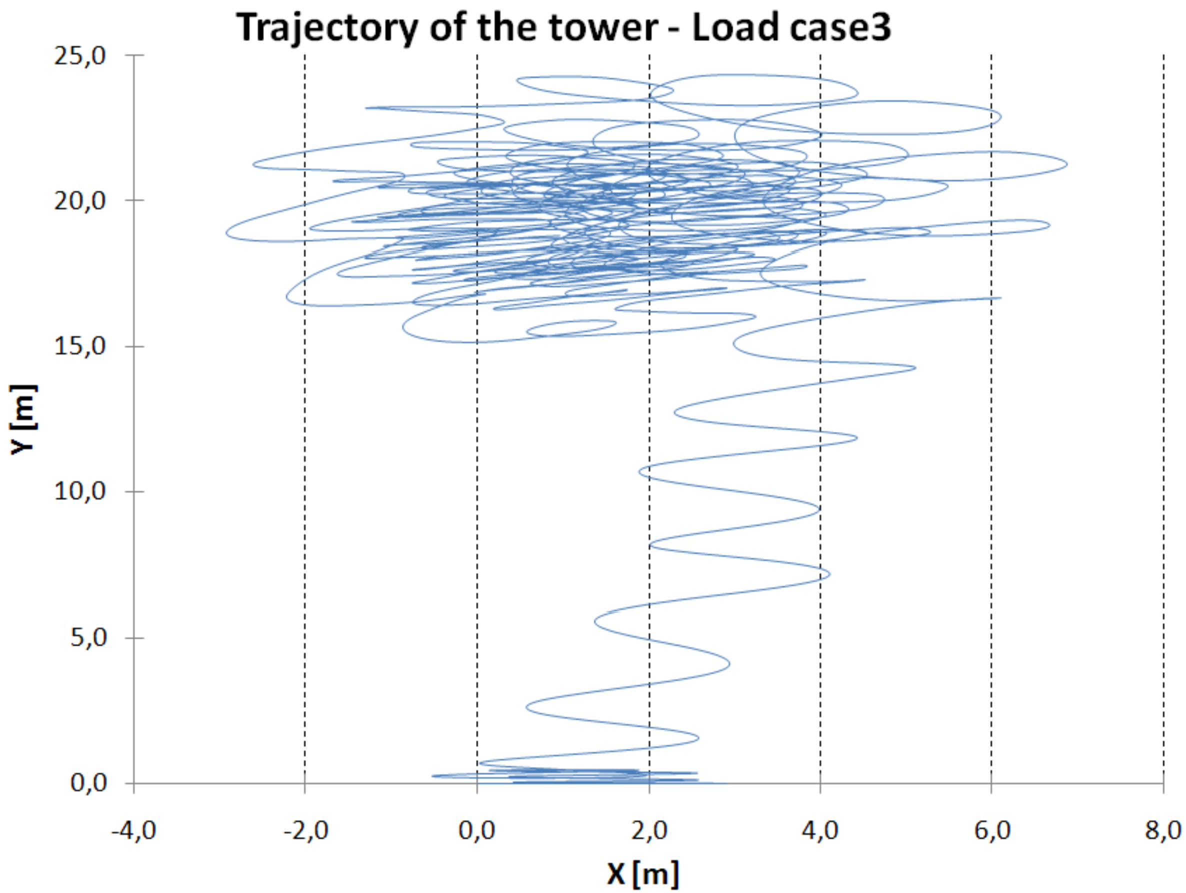
	Wind	Waves	Currents
Reference load case	X		
1st load case	X	X	
2nd load case	X		X
3rd load case	X	X	X



First order investigation
3rd load case

	Wind	Waves	Currents
Reference load case	X		
1st load case	X	X	
2nd load case	X		X
3rd load case	X	X	X

3rd load case:
•Max tilt angle 14.7 degrees



DeepWind project and partners

DeepWind, EU call FP7 Future Emerging Technologies for Energy Applications

- Duration: 4 years (October 2010-2014)
- Cost: 4.18 M€ (2.99 M€ financed by EU)
- Academic: 2PhD and 2 Post doc included
- Project objectives:
  - ✓ Investigation of the feasibility of the concept with a 1kW proof-of-principle turbine
  - ✓ Design of 5MW size including all the components (around 200m water depth)
  - ✓ Outlook for up-scaling possibility to larger sizes (20MW)

DeepWind project and partners

- Work Packages:
  1. Aero-elastic fully coupled code implementation and simulation
  2. Blade technology and blade design
  3. Generator concepts
  4. Turbine system controls
  5. Mooring, floating and torque absorption systems
  6. Exploration of torque, lift and drag on a rotating tube
  7. Proof-of-principle experiments
  8. Integration of technologies and upscaling
- Partners:
  - ✓Risø-DTU, MEK-DTU, TUDelft, Aalborg University, DHI, SINTEF, Marintek, Marin,Università di Trento, NREL
  - ✓Vestas, Nenuphar, Statoil
- Advisory board:
  - ✓L.O.R.C., DNV, Grontmij CarlBro, DS SM A/S, Vatenfall, Vertax Wind LtD

Preliminary conclusions and next steps

- DeepWind aim is to address a solution for offshore wind power at deep sea
- Hydrodynamics forces seem to be dominant in the analysis of the concept
- The choice of the site is crucial for DeepWind concept; a thorough investigation of the met-ocean data at the site is needed
- The simplicity of the design can allow some adaptation strategies to particular sites, if previously investigated
- DeepWind has potential for large up-scaling
- Specific challenges will be investigated in the WPs
- A first experimental study on a small demonstrator will be carried out at Risø fjord at the end of the year

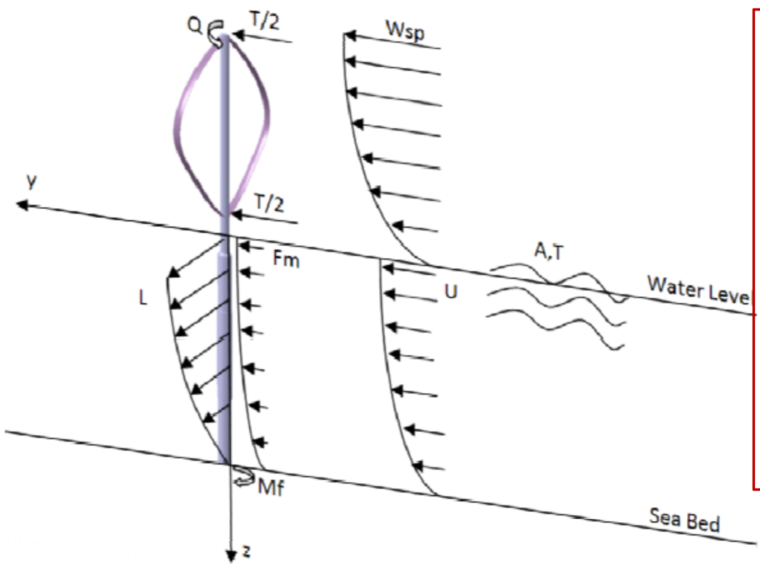
Questions and discussion

Contact:
uwpa@risoe.dtu.dk

Thanks to:
DeepWind consortium
EU

Main challenges connected with the concept

- Very large lateral forces on the underwater part of the rotating structure due to water currents
- Very large torque at the bottom of the structure
- Maintenance operation needed in very deep water



Wsp:	Wind speed
U:	Water current speed
A, T:	Significant wave height and wave period
T:	Aerodynamic force on the rotor
Q:	Aerodynamic torque
L:	Hydrodynamic side force
Fm:	Hydrodynamic forces in oscillatory flow as formulated by Morrison
Mf:	Friction Moment

First order investigation

Reference Load case

	Wind	Waves	Currents
Reference load case	X		
1st load case	X	X	
2nd load case	X		X
3rd load case	X	X	X

- **No waves**
- **No currents**

- **Wind speed:**

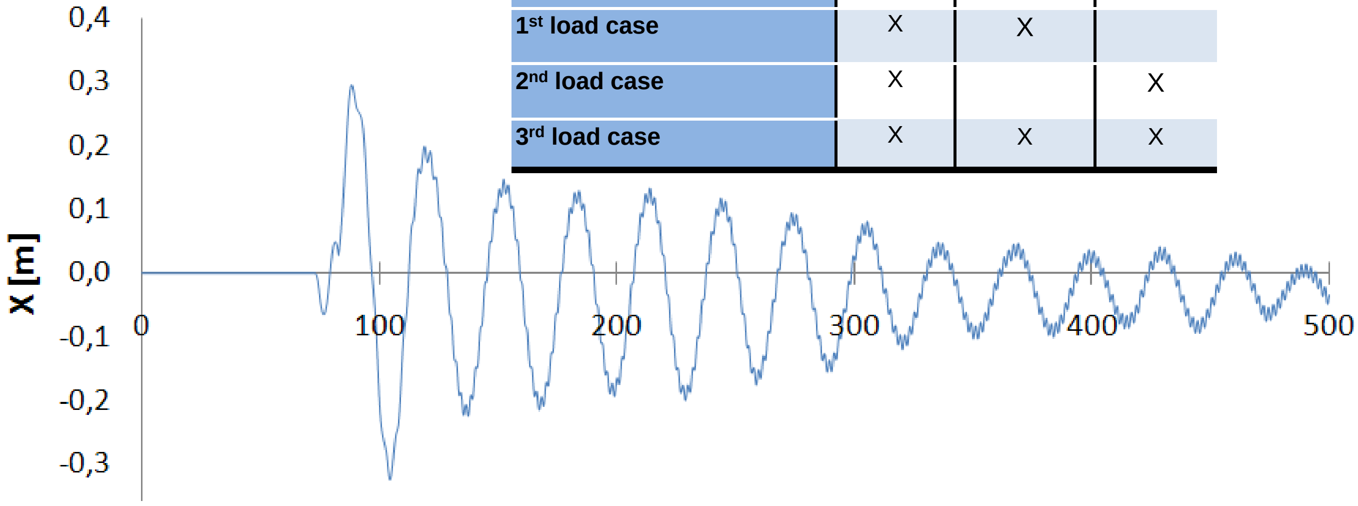
✓ 14m/s constant, no turbulence

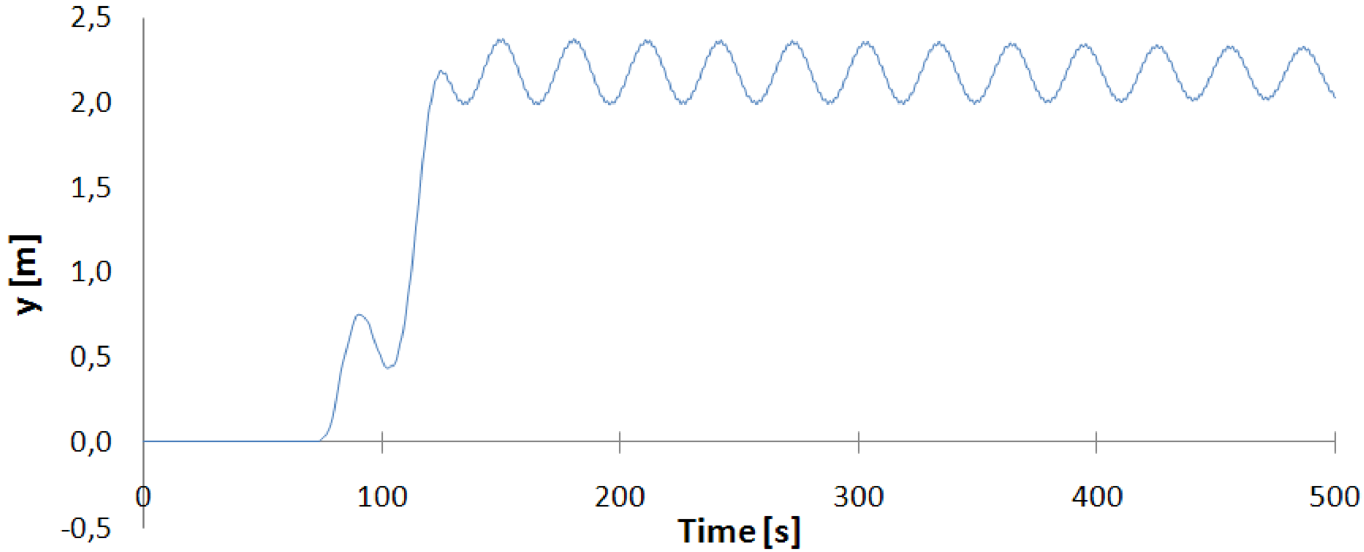
✓ Direction:

y axis

✓ Wind shear:

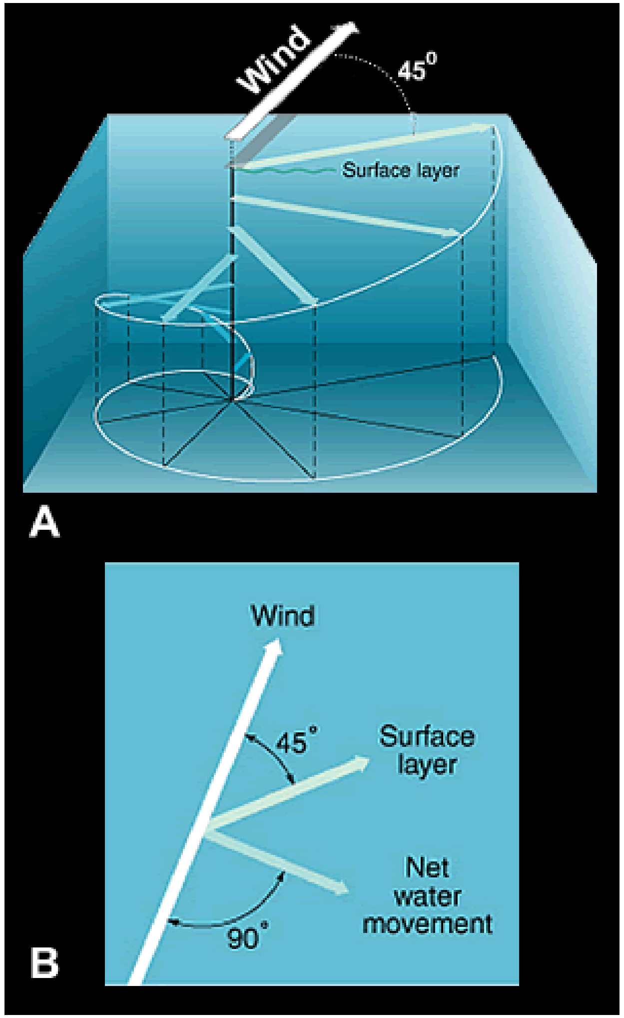
power law, $\alpha=0.14$





Challenges and results from first order investigations

Currents (in theory)



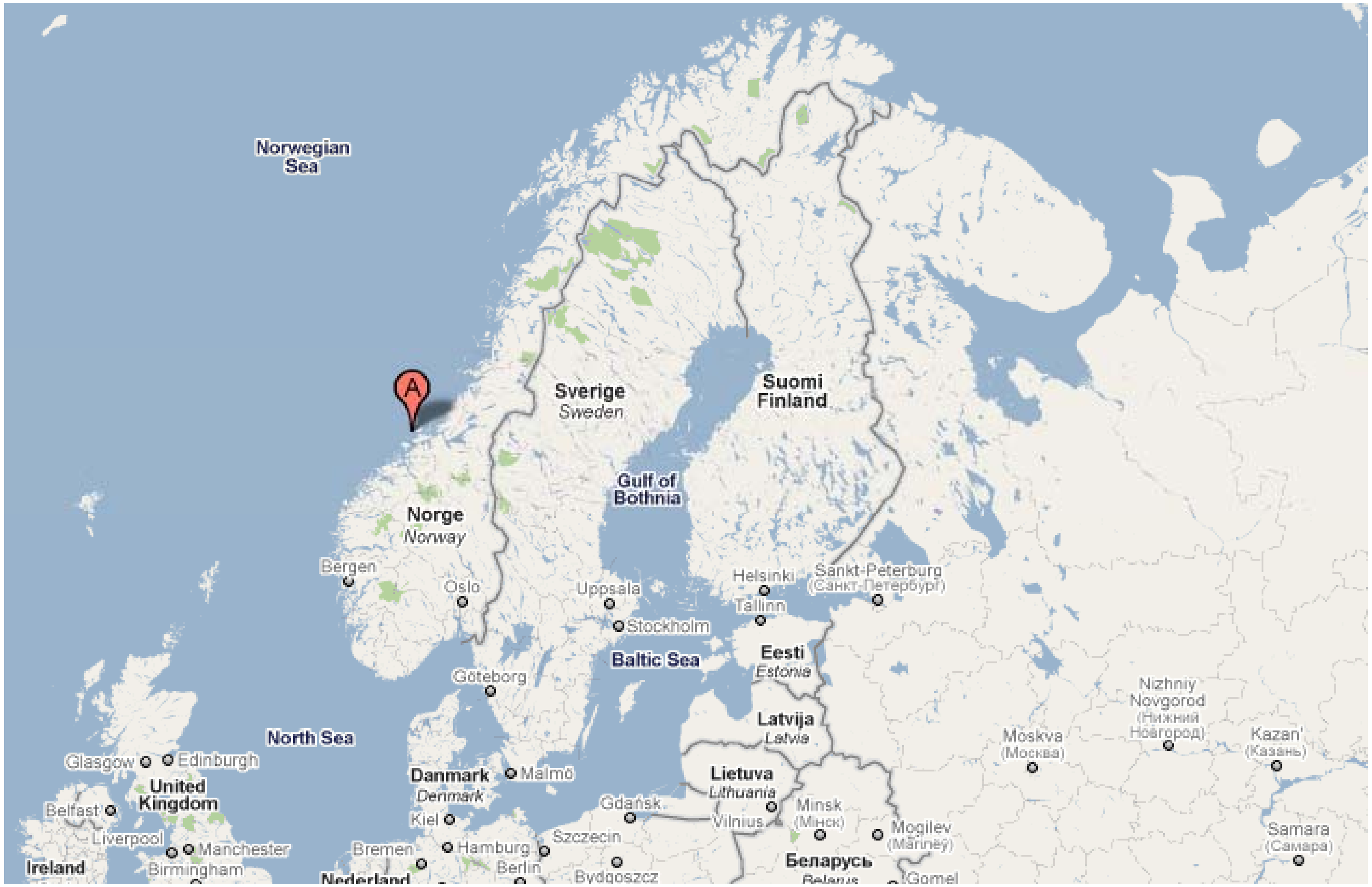
- Coriolis forces deflect each successive layer of water slightly more clockwise. Main water transport, the average of all speeds in all directions, is perpendicular to the wind, Surface flow is theoretically at 45 degrees to the wind.

- In practice, the layers of water are restricted in their flow, particularly near the coasts. Net flow is then in a direction no more than 30 degrees from the direction of the wind

- About 90% of oceanic water currents , below 400m is driven by thermohaline circulation(density driven)

Challenges and results from first order investigations
Currents (Real data)

Sletringen site (Thanks to Joachim Reuder and OCEANOR)



Challenges and results from first order investigations

Currents (Real data)