WPC WINDPOWER CONSTRUCTION GMBH

GICON® Firmengruppe

Development of a TLP substructure for a 6 MW wind turbine – use of steel concrete composite material

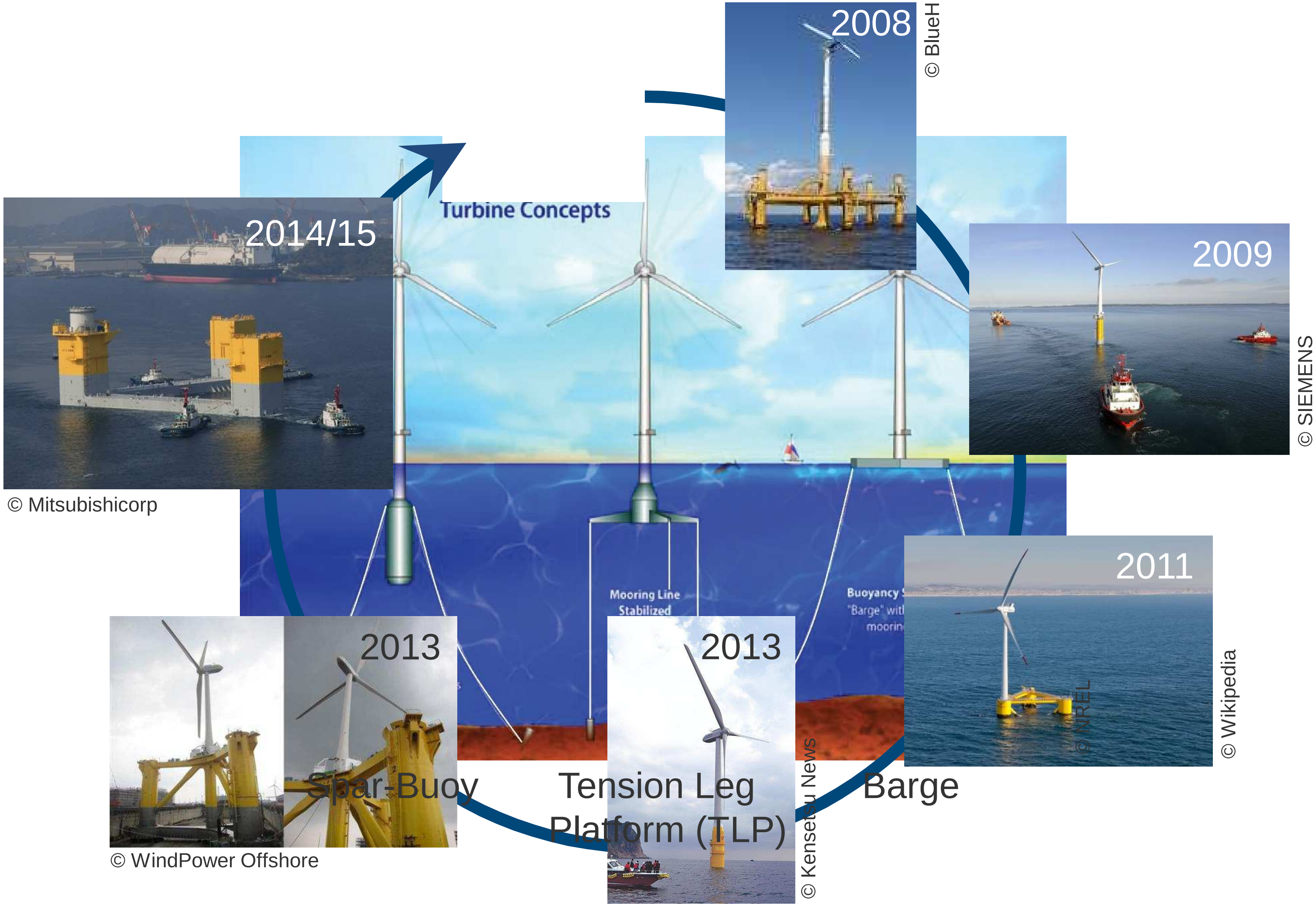
A cooperation between industry and research institutions

Frank Adam

EERA DeepWind'2016 – 20.01.2016 - Trondheim

LWET Stiftungslehrstuhl Windenergietechnik

Floating foundations for offshore - wind turbines



Preliminary GICON-TLP for wind turbines

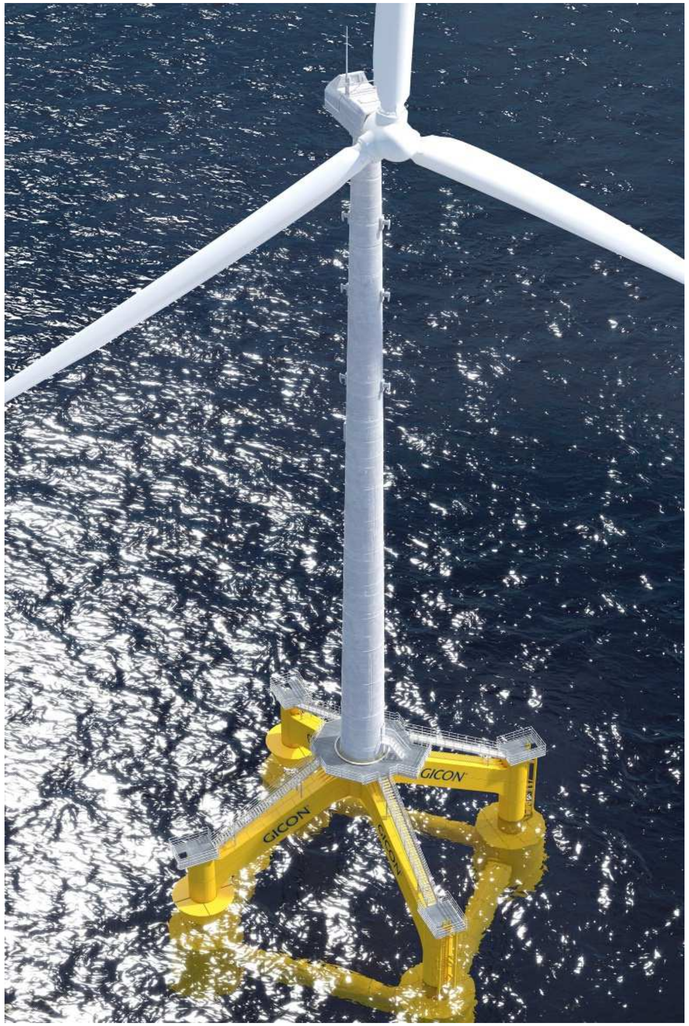
Components of the platform:

- Cylindrical buoyancy bodies (BB)
- Horizontal pipes (HP)
- Vertical pipes (VP)
- Cantilever beam (CB)
- Transition piece (TP)
- Ice-breaking Cone (IC)

Dimensions (L x B x H)	32 m x 32 m x 28 m
TLP Weight incl. sec. Steel	**≈ 742 t**
Total weight incl. WT	**≈ 1062 t**
min. # of Anchor points	4

Objectives for floating offshore wind sub-structures

- Economical solution
  → Mass as low as possible
- LCOE as low as possible
- Steel is not the cheapest material
- Steel-concrete composite material would be an alternitve:
  - Tension?
  - Life time?
  - Surface qualtiy?



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TLP for OWT

Steel-concrete components

Economical aspects

Pre-design 6 MW

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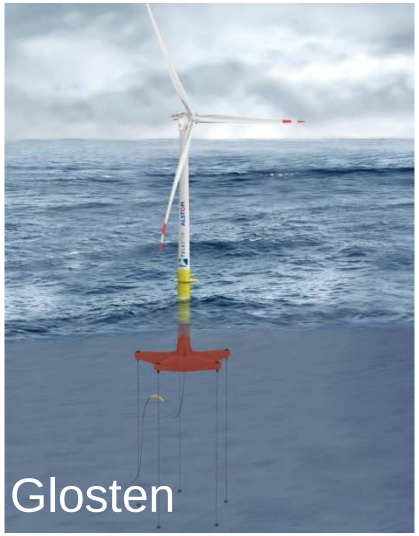
Examples for TLPs or TLBs

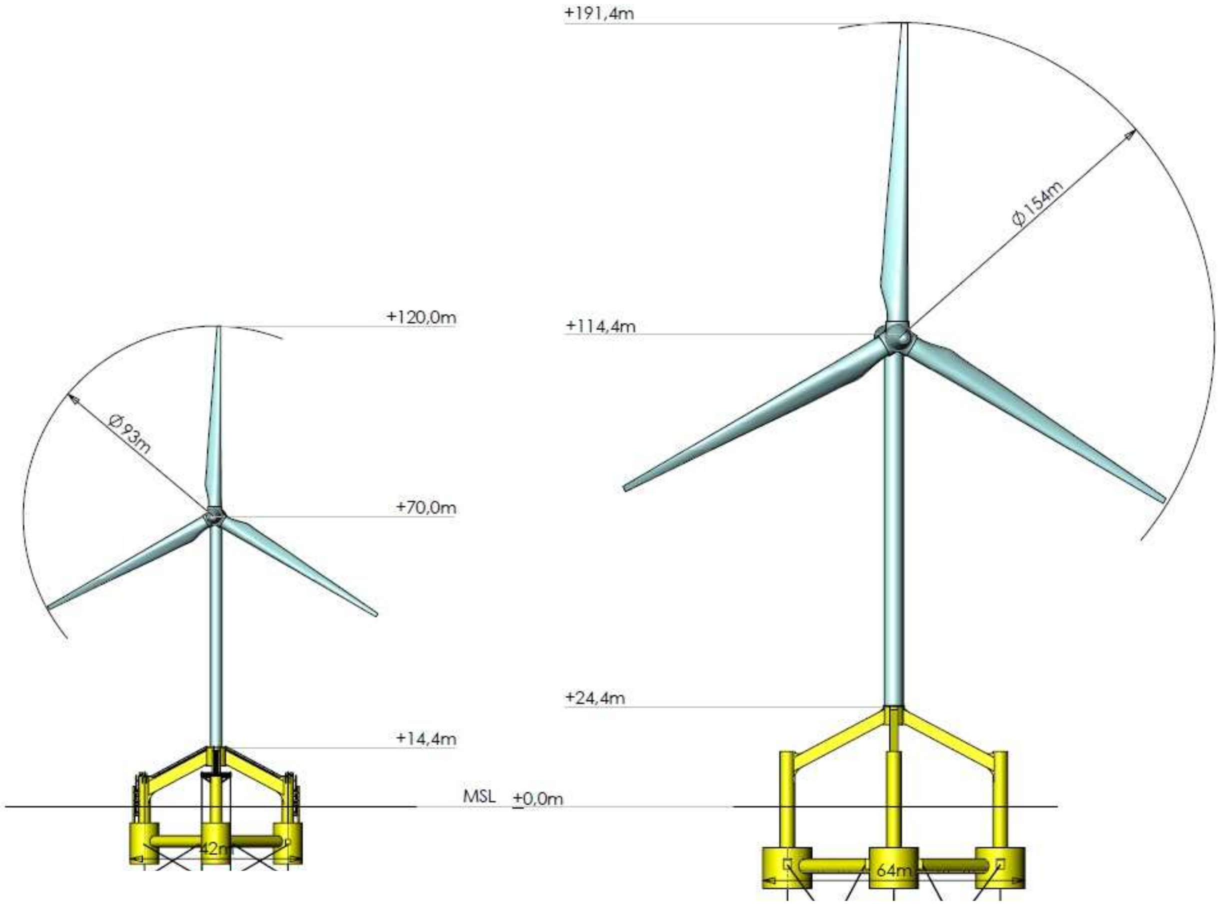
			
Tank tests 2012	Tank tests 2013	Tank tests 2013	Tank tests 2012-14
Vertical ropes	Angled ropes	Vertical ropes	Vertical and angled ropes
TRL 4	TRL 3	TRL 4	TRL 4

Path of development

Mass in t	ca. 2000	2214	1790	**742**
Width in m	70	68	50	**32**
High in m	25	24	39	**28**

→ These values are for a 2.3 MW wind turbine (~ 320 t/MW)

Preliminary Design of a 6 MW substructure



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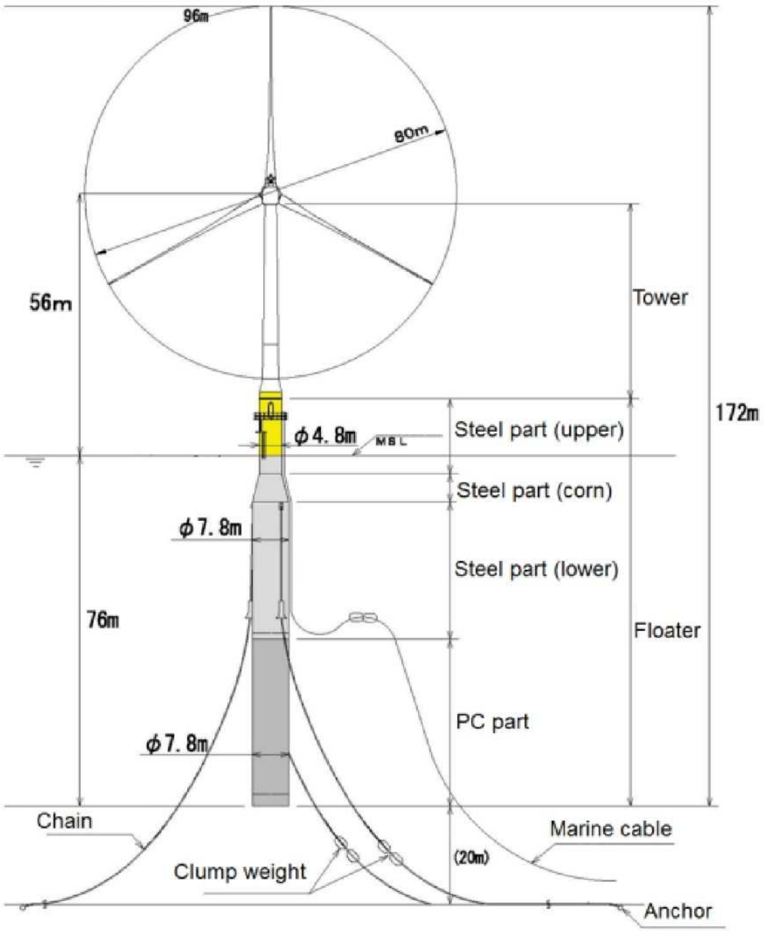


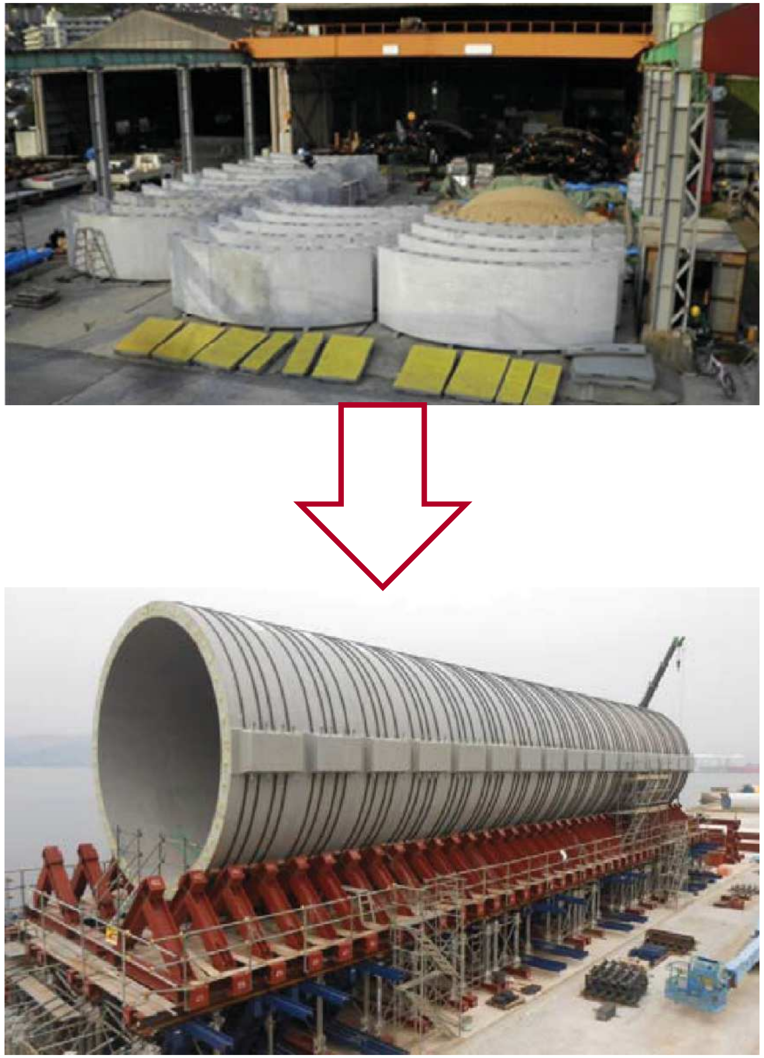
Source: T. Utsunomiya (2015). "Design and Installation of a Hybrid-Spar Floating Wind Turbine Platform". In: *Proc. OMAE2015*

Advantages:

- Modular system
- External fabrication – independently from the yard
- Transport via truck or ships

Challenges:

- Lifetime
- Tightening



Source: T. Utsunomiya (2015). "Design and Installation of a Hybrid-Spar Floating Wind Turbine Platform". In: *Proc. OMAE2015*

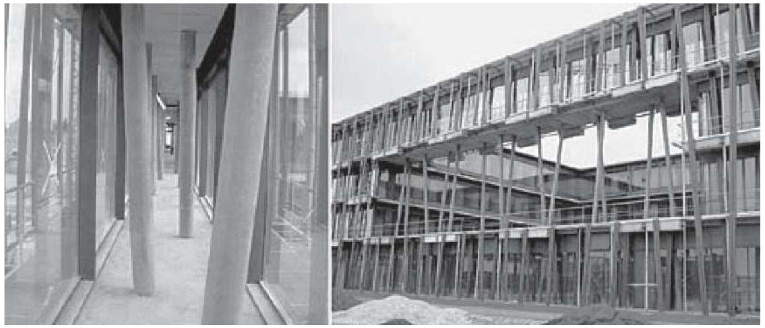
Centrifugally spun concrete pile

Advantages:

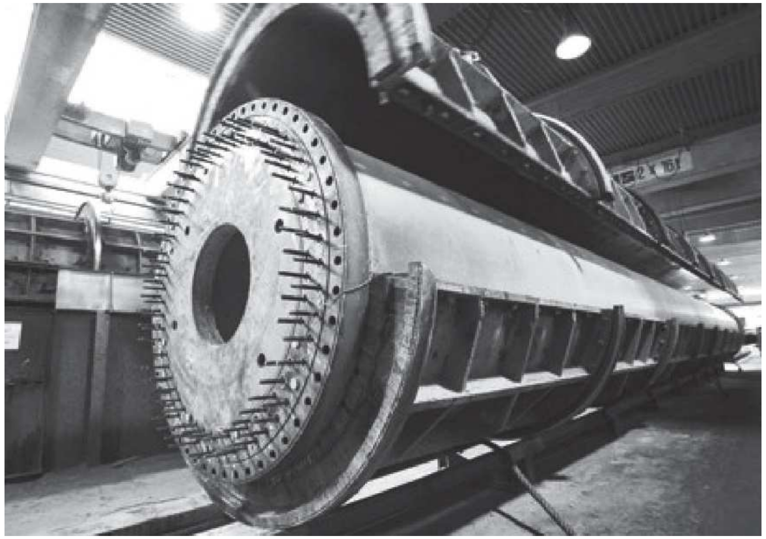
- Modular system
- External fabrication – independently from the yard
- Simple pre-fabrication
- Good surface via centrifugal force

Challenges:

- Lifetime
- Pre-tensioning
- Tightening



Source: DBZ Deutsche Bauzeitschrift



Source: Europoles

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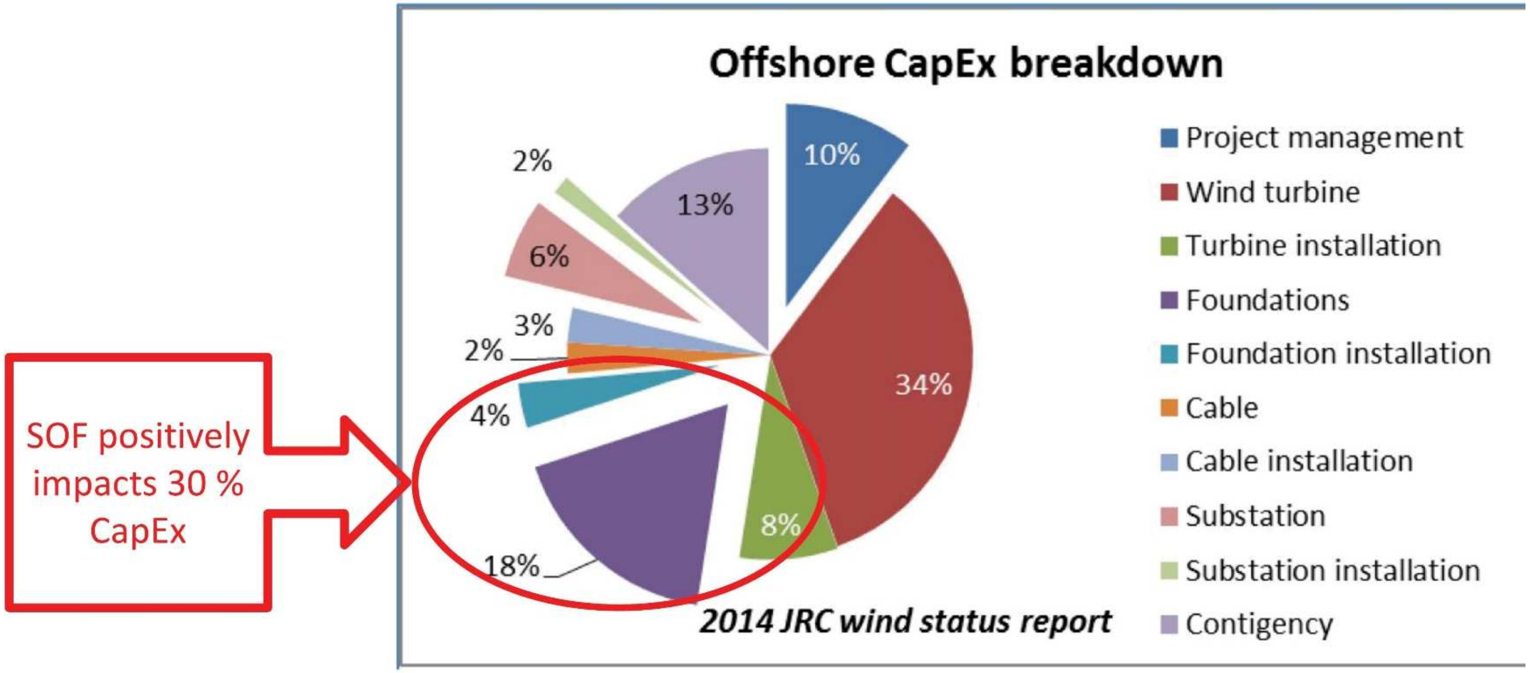
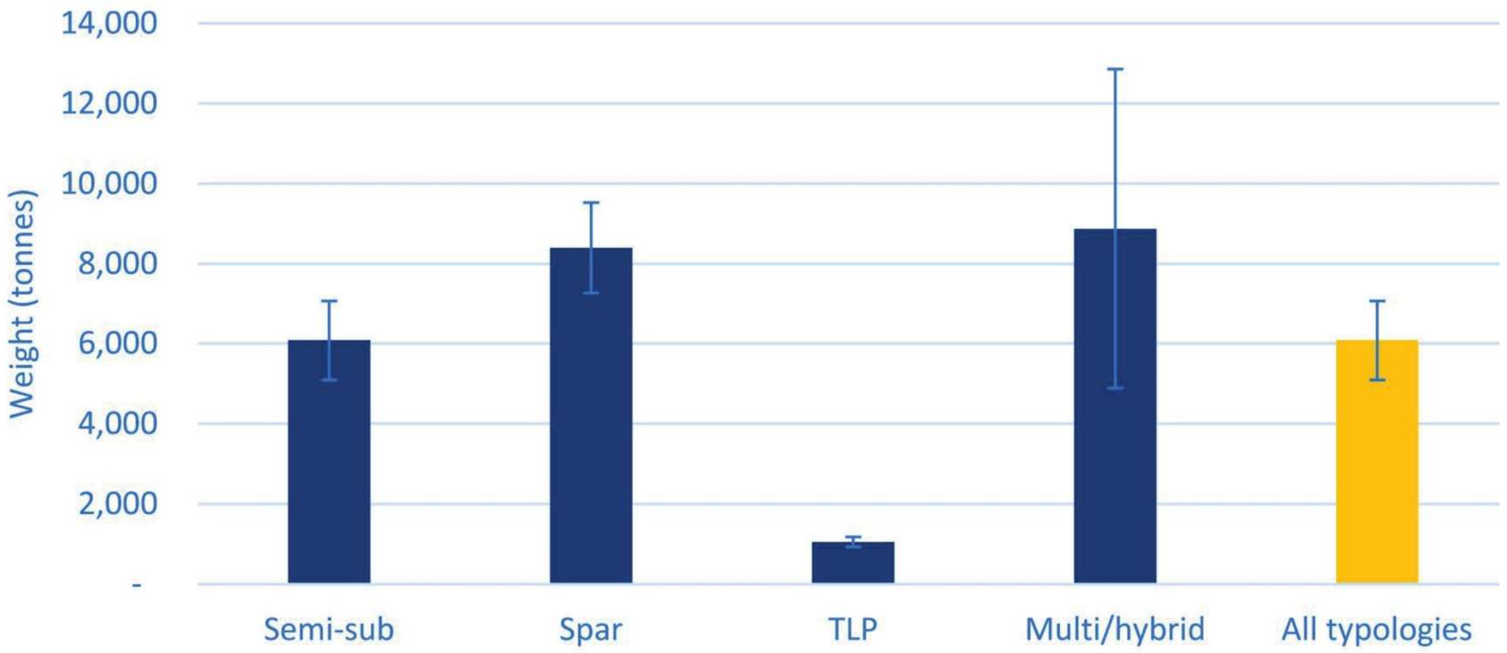
Offshore CapEx breakdown



Source: 2014 JRC Wind Status Report 'Technology, market and economic aspects of wind energy in Europe'

Platform weight, post-ballast, by typology (steel concepts only)

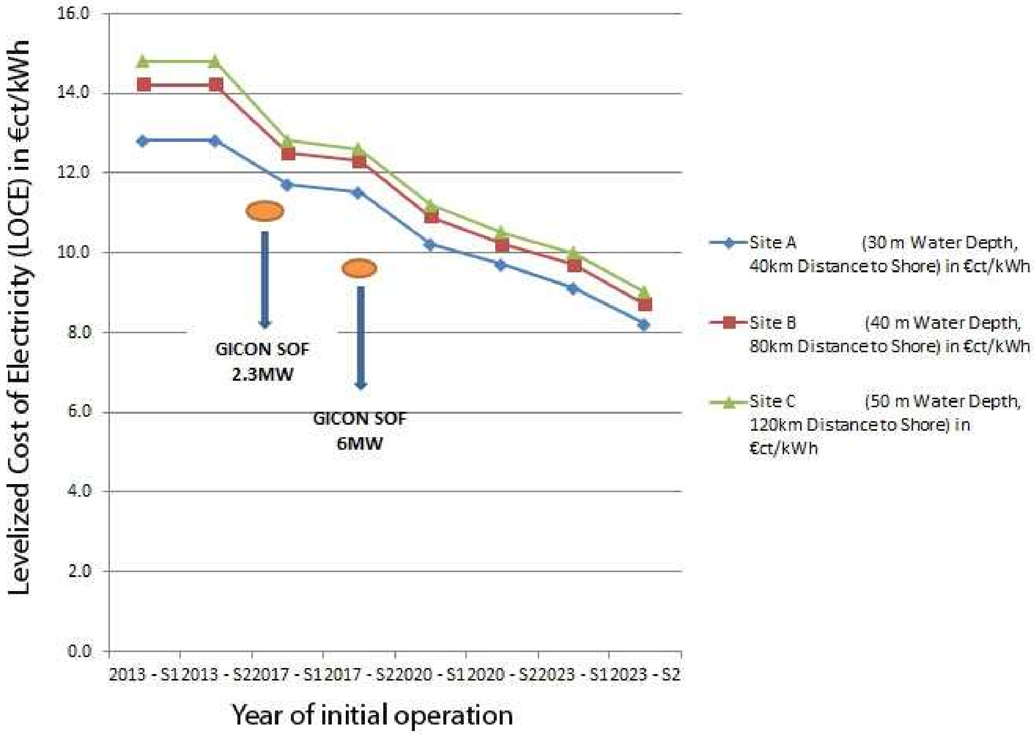


Source: 'Floating Offshore Wind: Market and Technology Review' Prepared for the Scottish Government. Carbon Trust, June 2015

LCOE for the presented design

- First results show the technical feasibility of the 6 MW system
- The system will be an economically viable solution

SOF - Economic Viability highlighted by estimated LCOE
(independent analysis by ECOVIS based on Prognos Fichtner Scenarios 2013)



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Requirements for the 6 MW sub-structure

Mass (incl. sec. steel) ≤ 1200 t

Floating stability for the sub-structure and anchor incl. wind turbine

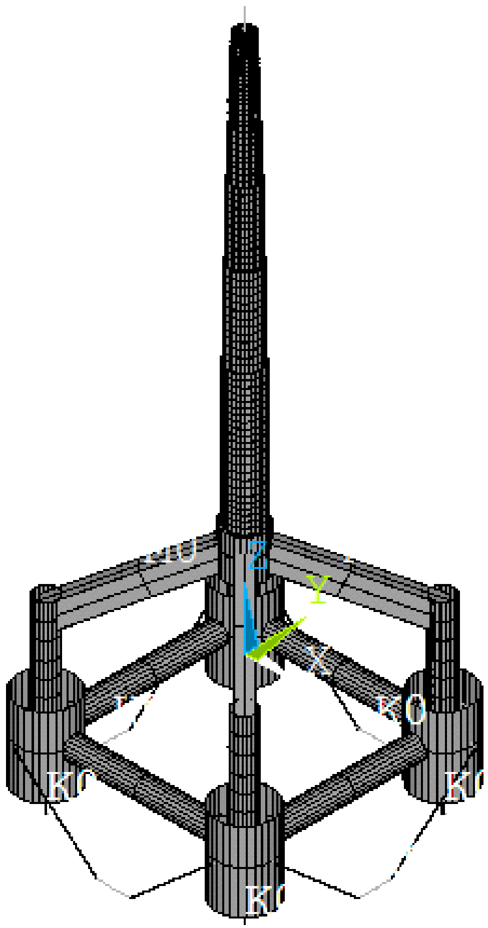
Fabrication – 1 ½ sub-TLPs/week

Aim: 80 TLPs/year

Economical solution for water depths ≥ 30/35 m – comparable with fixed sub-structures

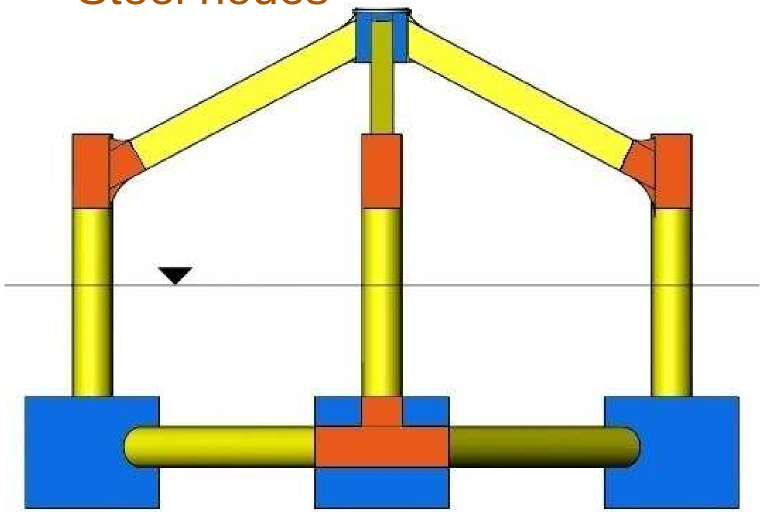
Calculation

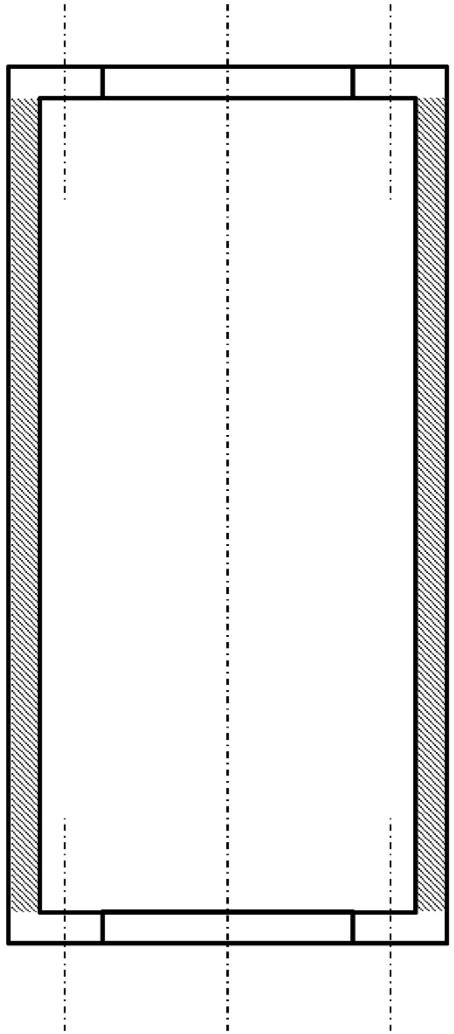
- ANSYS AQWA for the floating stability
- Analysis → FEM
- Using ULS interface forces for the pre-design (no coupled calculation):
  - Normal Force – 7300 kN
  - Shear Force – 2400 kN
  - Overturning Moment – 210000 kNm
  - Torsional Moment – 25000 kNm



Mass (incl. sec. steel) ≤ 1200 t

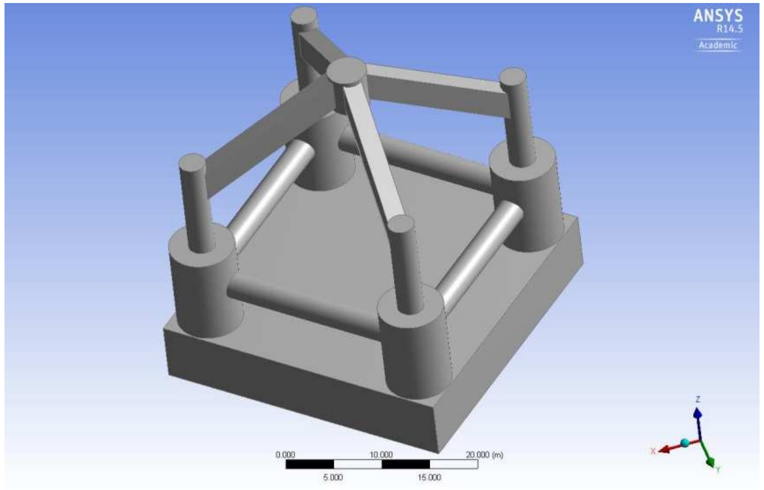
Concrete
Steel-Concrete-Composite
Pipes
Steel nodes





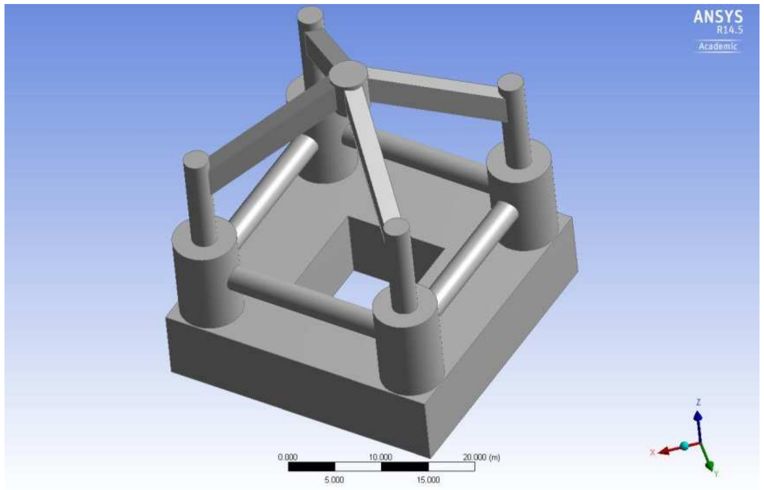
Floating stability incl. Wind Turbine

	DeviationMaximum				
	Acceleration (ms^-2)			Rotation(Degree)	
Angle ofAttack	X	Y	Z	RX	RY
180	-0,616	-0,155	-3,014	0,058	0,716
135	0,385	-0,495	-2,799	0,078	0,855
90	-0,017	-0,661	-2,716	0,164	-7,970
45	-0,384	-0,496	-2,801	0,040	0,736
0	0,617	-0,155	-3,017	0,098	4,268

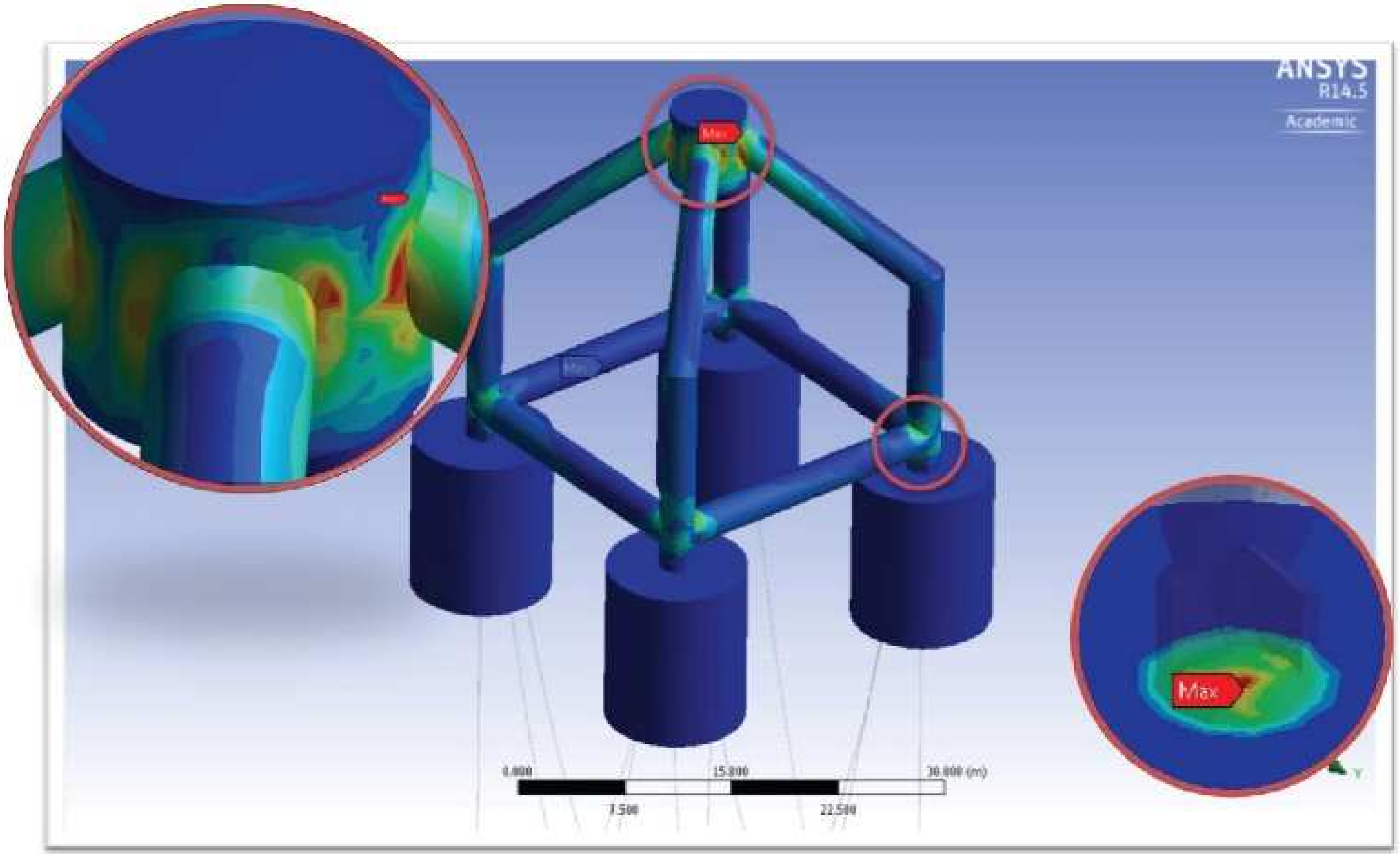


Mass	5000t
WaveFreq	0.1Hz
WaveHeight	2m

	DeviationMaximum				
	Acceleration (ms^-2)			Rotation(Degree)	
Angle ofAttack	X	Y	Z	RX	RY
180	-0,705	-0,101	-3,281	0,104	11,971
135	-0,411	0,590	-3,205	0,105	12,232
90	0,002	-0,717	-3,246	0,556	-0,487
45	0,408	0,591	-3,209	0,043	12,426
0	0,705	-0,101	-3,282	0,013	11,979



Pre-design Maximum von Mises

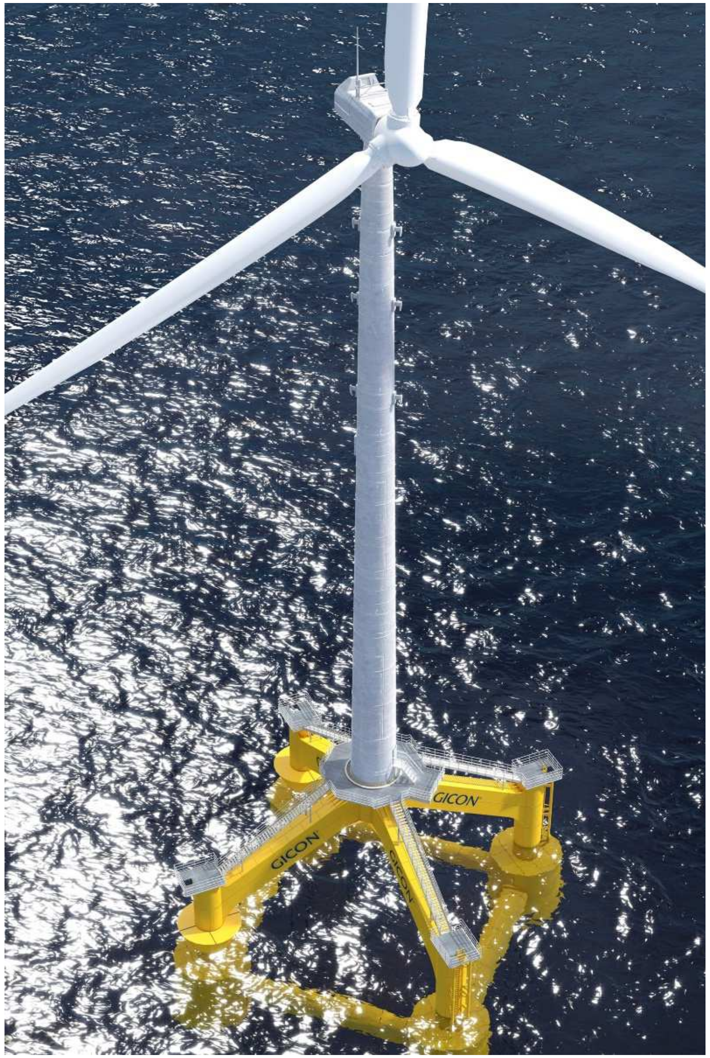


Eigen frequencies – mass participation factors

	Frequency	X	Y	Z	ROTX	ROTY	ROTZ
200m	1.15E-01	0.12607	-0.11983	-34.133	-50410	-53061	-0.03062
Angled	1.16E-01	0.11878	0.12509	0.87388	52733	-50095	-1.6672
and	2.47E-01	0.00236	0.003176	-0.04248	604.21	604.14	-0.00028475
Vertical	2.48E-01	0.01567	0.00492	0.001667	-602.1	601.81	1.9038
	2.55E-01	0.01821	-0.06862	5.2954	1648.7	1971.2	0.0094054
50m	0.01378	0.20017	0.20011	-3E-05	4779.2	-4779.2	21245
Angled	0.02611	12.456	-12.395	-0.00176	-739.34	-742.8	1.6528
and	0.02612	18.073	17.023	-0.0038	1029.4	-1091	-87.716
Vertical	0.20771	-0.00943	0.007796	39.867	43499	52694	0.92508
	0.20867	-0.00772	-0.00937	-3.82	-52443	43213	9.5983
	0.45705	0.010201	-0.00256	0.1162	-59.501	-237.26	0.16141
	0.45762	0.063893	-0.03888	0.94007	-905.67	-1488.7	0.5471
200m	0.0117	24.491	-24.131	-0.09312	-5291.2	-5370.5	4.6527
Vertical	0.01171	51.618	52.365	-0.00176	11321	-11160	916.54
	0.01172	57.685	-56.791	-0.23205	-12479	-12676	10.269
	0.08985	0.019853	-0.01897	38.706	47834	49990	0.00072706
	0.09103	0.018239	0.019105	-0.5743	-49329	47200	-0.16997
	0.42944	-0.00134	0.001261	-1439.6	-198.33	-480.87	-0.0096311
50m	0.17175	0.005659	-0.00497	36.067	45409	51583	-0.001375
Vertical	0.17267	0.004895	0.005579	-2.2369	-51298	45118	-0.029769

Conclusion

- Coupled simulations
- Basic design of the new steel-concrete components
- Solving logistical issues
- Development of high performance concrete
- Cooperation with the certification body



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