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Reducing Carbon Footprint of Wind Turbine Floaters

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Delivered by the Cornwall FLOW Accelerator

Agenda

- Examine the current state-of-art technology for offshore wind floating foundations
  - To be carried out by going over different types of structures
  - Provide a comparison between different structures and a summary of some ongoing projects
- Compare materials used for floating wind foundations
- Define a reference floater based on prior findings

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Project

Research opportunities for reducing the carbon footprint of floating wind turbine foundations

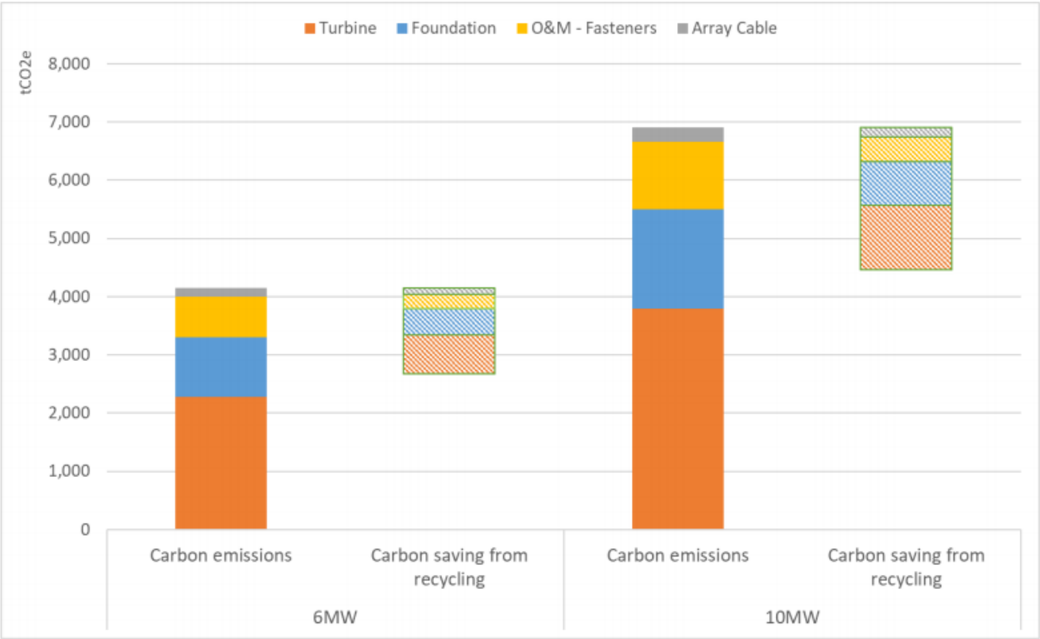
1) Carry out a literature review to highlight trends in industry and academia to identify opportunities

2) Define a reference tower with a view for engaging industry and local supply chains in order to identify manufacturing facility requirements

Problem Statement

Floating wind possesses huge potential with regards to the offshore wind energy sector.

For example; ScotWind will produce over 14,000MW of floating wind projects.



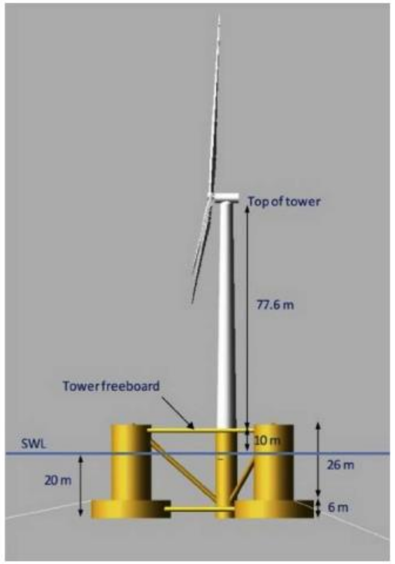
Emissions and savings when recycling windfarm components. [1]

However, the floating industry is still young with plenty of opportunities for improvements.

One key area is environmental impact, GHG emissions (CO_2) and sustainability.

Current State-of-art: Semi-submersible

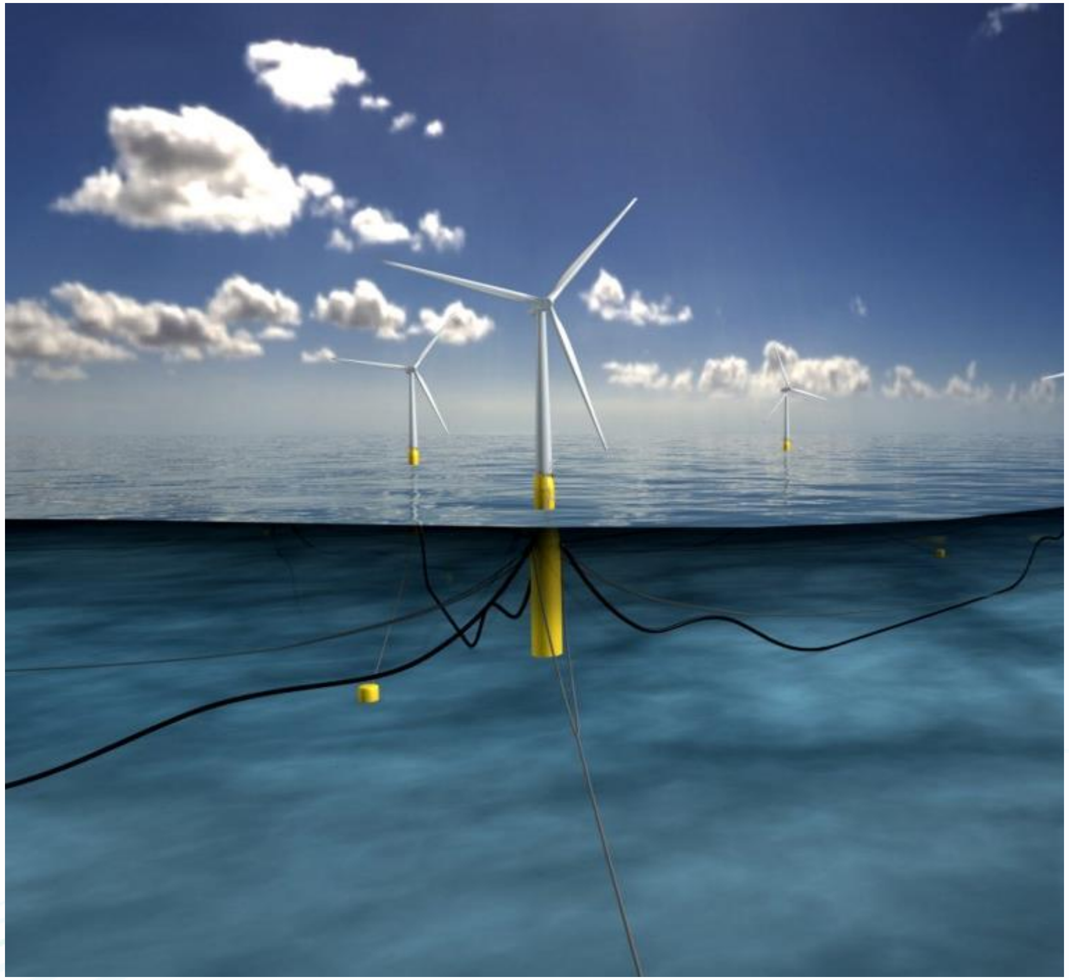
- The most commonly used structure
- Consists of a series of columns and pontoons
- Possesses poorer stability than other foundations
- Can be applied at a range of depths (typically above 40m)
- Turbine can be installed on the floater dockside and towed to the site, simplifying installation.



Top:Diagram of a semi-submersible FOWT concept [2]
Bottom: Windfloat installation [3]

Current State-of-art: Spar

- Consist of a vertical cylinder buoyant cylinder with a ballasted deep draft at the end for stability
- More stable than the semi-sub concept
- Simpler than other concepts
- Due to the height of the spar, it can only be used in deeper water (>100m)
- More challenging to transport, installation often applied offshore.



Equnior's Hywind Spar Concept [4]

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Current State-of-art Barge

- Uses an ocean-going barge
- Allows the turbine to be installed at port.
- Can be used in deep water without taking up “real estate”
- Heavier structure that is well suited to larger wind turbines

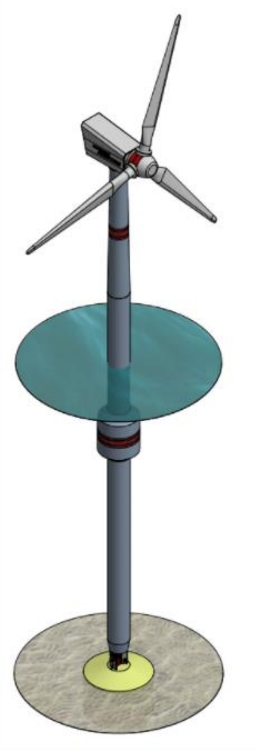
BW Ideol Floatgen Barge [5]

Current State-of-art
TLP

- Consists of columns and pontoons, like that of the semi-sub
- Concept is made more unique due to its tensioned mooring system
- This mooring system makes it one of the most stable structures
- Thanks to this, it is also one of the lightest concepts
- Can be installed in a high depth range but cannot be applied in shallower water
- Susceptible to high-frequency dynamic loads

SBM TLP Floater [6]

Current State-of-art
Other



Left: A 3D model of the Offshore Kinematics WTSS concept design. [7] Right: A model of the Trivane concept. [8]

Industrial Project Summary

Project breakdown (57 total):

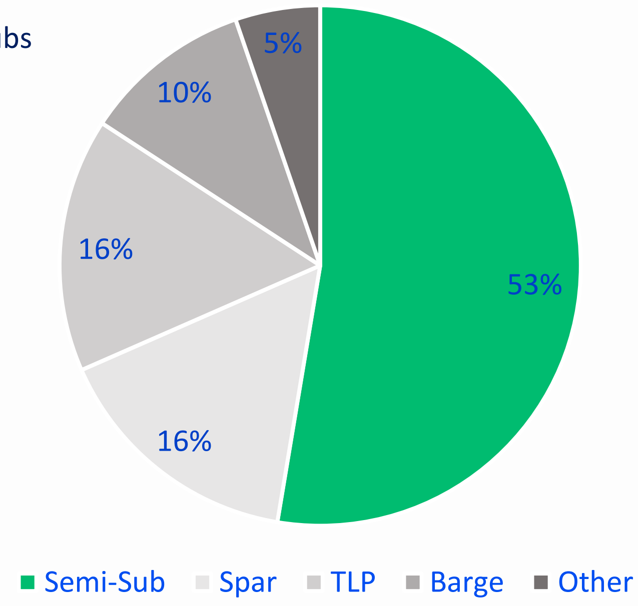
30 semi-subs

9 spars

9 TLPs

6 Barges

3 Other



Project/ Owner	Structure Type	Material	Weight (t)	Dimensions. (m)	Min Water Depth (m)	Tested Turbine Output (MW)	Tons/ MW Est	TRL
Hywind Tampen/ Equinor	Spar	Concrete	5000	14.5 x 14.5 x 110	N/A	8	571	7
Hywind Scotland/ Equinor	Spar	Steel	2300	14.5 x 14.5 x 91	75	6	310	8
Floatgen/ Ideol	Barge	Concrete	4360	36 x 36 x 9.5	26	2	2230	8
Hibiki/ Ideol	Barge	Steel	10560	45 x 45 x 10	28	3	3586	8
Windfloat/ Principle Power	Semi-sub	Steel	2750	75 x 75 x 30	40	9.6	298	8
EOLINK / EOLINK	Semi-sub	Hybrid	1900 (steel) mass of concrete not known	66 x 59 x 50	50	15	N/A	6
TLPWind/ Iberdrola	TLP	Steel	940	50 (length)	60	5	188	5
GICON SOF GICON	TLP	Hybrid	75 (steel), 600 (concrete)	32 x 32 x 26	45 - 350	6 - 8	214	5

Material Comparison

Only two materials have been applied in floating structures

1) Steel

Advantages	Disadvantages
Well established in offshore wind and energy sectors	Will produce components with larger dimensions.
Fast assembly provided components have been pre-fabricated	Expensive and is subject to fluctuating prices
Lighter than concrete	Requires specialised equipment (such as large scale welding machines and heavy-duty cranes)

2) Concrete

Advantages	Disadvantages
Concrete supply is adaptable to local conditions and project requirements	Limited overall usage within wind industry
Local content is ensured (workforce, supply chain)	Large dimensions require large construction areas
No specialised equipment required	High weight
Low costs	Manufacturing will require other procedures such as pre-tensioning
Easy to make adjustments due to casting process	Can be restricted by weather conditions during construction
Less storage required (no raw material needs to be stored)	Will require higher levels of quality assurance due to a potentially inaccurate mixing process

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Initial LCA Results

Assumptions and Limitations:

1) Project Life:30 years

2) Standard CTV O&M strategy adopted

3) 1 HVAC offshore substation on a monopile foundation included

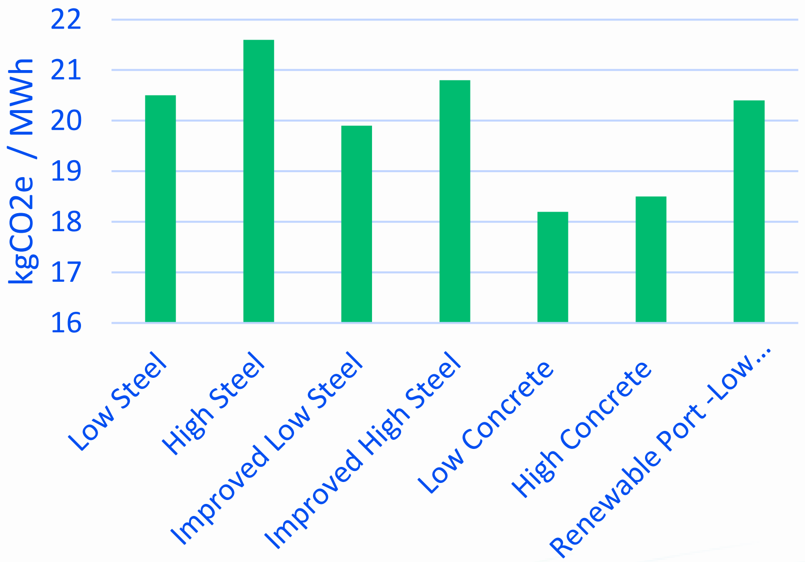
4) 66kV array cables used

5) Hub height set at 150m (for 15MW Semi-sub floating wind turbine)

6) Comparative study used to find representative UK carbon emissions

7) Transportation emissions of materials ignored

8) Construction time set as a constant for all substructures



		Low Steel	High Steel	Improved Low Steel	Improved High Steel	Low Concrete	High Concrete	Renewable Port -Low Steel
Single Substructure Carbon Cost	tonnesCO2e	7700	9752	6425	8151	3032	3660	7588
LCA	kgCO2e / MWh	20.5	21.6	19.9	20.8	18.2	18.5	20.4

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Future Opportunities

- Redesigning structures to minimise mass/ materials
- New materials: composites?
- Improving manufacturing processes
  - Improved techniques
  - Better heat recovery
  - Making use of technology such as Carbon Capture Storage (CCS), hydrogen, etc
- Improving general efficiency
  - Reducing port distance
  - Improving O&M practices
  - Improved installation and assembling

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Reference Floater Definition

- For the remainder of this ongoing project, it'll be essential to define a floating substructure.
- Based on prior research, it has been identified that concrete is a good choice of material with regards to emissions reductions.
- Additionally, it has been identified that the semi-sub structure is one of the lightest floaters and is also one of the best studied lending itself better for further development

Conclusion

- Examined the current state-of-art technologies for floating wind foundations.
- Performed a simple comparison between each of the core structures
- Looked at steel and concrete floaters
- Looked at an LCA result comparing materials
- Identified some potential opportunities
- Defined a reference floater for further project work

References

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