UNIVERSITY OF EXETER

IMECHE (Wind Turbine User Group 2023)

FLOATING WIND OFFSHORE TURBINES - INSTALLATION ENGINEERING

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FOWT DEPLOYED

Deployed FOWT
- 2 barges
- 7 spars (10 more under construction)
- 9 semi submersibles
- 0 TLPs

Fixed bottom
- 4,000+ Monopiles   (limit 50m)
- 300+ Jackets (limit 70m)

Reasons for low deployment
- FOWT high capital costs (CAPEX)
- FOWT high operating costs (OPEX)
- Lack of ports for construction

FIXED ON BOTTOM AND FLOATING WIND Ref[15]

Monopile (<50m) Jackets (<70m) Semisubmersible (>60m) TLP (>100m) SPAR (>90m)

INSTALLATION CONSTRAINTS

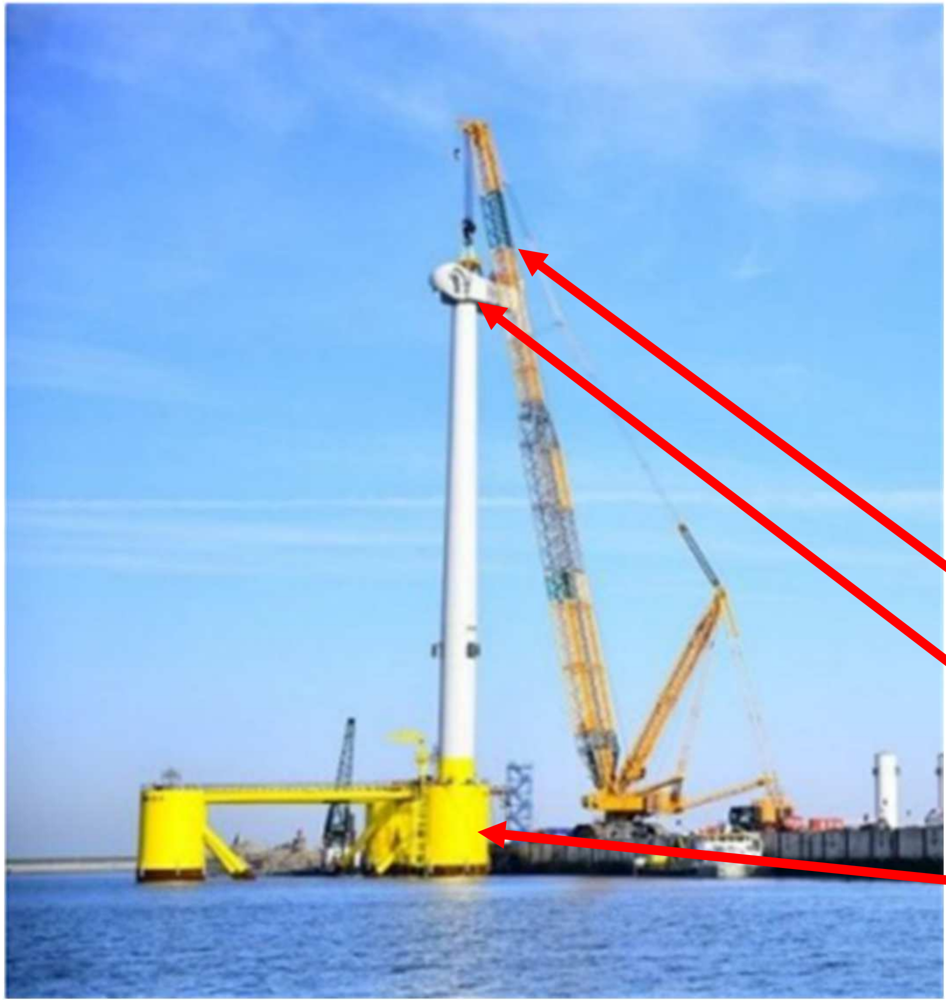
Barges:
- Low freeboards
- Tow out motions high

Semi submersible:
- High steel weight
- 10m to 15m water depth adjacent to fit out quay

Spars
- Deep sheltered water required for fit out
- Not possible to return to port for heavy maintenance

TLPs
- Low or negative intact stability during tow out
- Very complicated moorings, weather restricted during installation
- Not possible to return to port for heavy maintenance

SEMI SUBMERSIBLE



LIFTING NACELLE BY ONSHORE CRANE AT THE FIT OUT QUAY, Ref[5]

Large onshore crane

Nacelle

Substructure

LIFTING NACELLE BY ONSHORE CRANE AT THE FIT OUT QUAY, Ref[5]

People needed to make the connection between nacelle and tower

Lifting blades by onshore crane at the fit out quay, Ref[5]

Large onshore crane

Blade handling tool

Substructure

LIFTING BLADES BY ONSHORE CRANE AT THE FIT OUT QUAY, Ref[5]

May need temporary buoyancy or air bags to reduce draft

WET STORAGE, Ref[5]

Temporary
Mooring
Piles

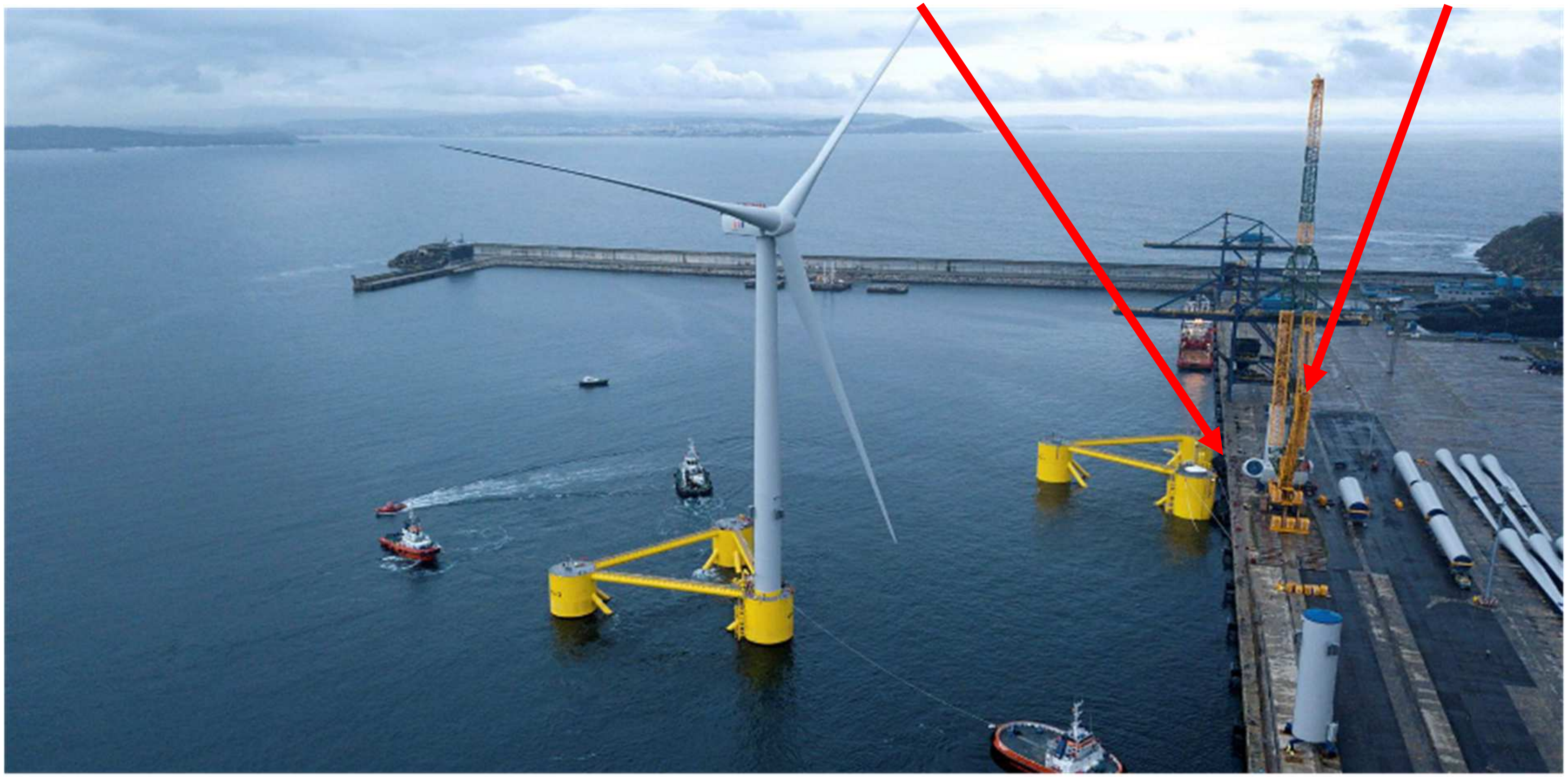
Harbour Tug

FOWT

WINDFLOAT, OFFSHORE PORTUGAL Ref[5],

Fender

Onshore crane for nacelle/blades



WINDFLOAT, OFFSHORE CROMARTY Ref[5],
Potential fit out port

PORT TALBOT PROPOSAL Ref[25]

WISON (China) SEMI SUBMERSIBLE, Ref[2]

Substructure
91m long
91m wide
31m depth

SPMT Trailers

Submersible
Barge

Harbour Tug

CONNECT MOORINGS   Ref[2]

Mooring lines
(3 per column)

Moorings being
tensioned

Tugger lines

SPAR

EQUINOR, TAMPEN Ref[4],

Equinor's 88MW Hywind Tampen project in Norway, which is to become the world's first floating wind farm supplying renewable power to offshore oil and gas installations. Loading solid ballast into the base.

HYWIND TAMPEN, Ref[4]

Onshore crane
Lifting blades

Wet storage
Of Spar

HYWIND TAMPEN, Ref[4]

Towing Tugs

Steering Tugs

BARGE

BARGE, Ref[11]

Concrete substructure

Crane for outfitting

TLP

Possible Installation Methods

TLP TEMPORARY BUOYANCY Ref [9]

Stiesdal TLP

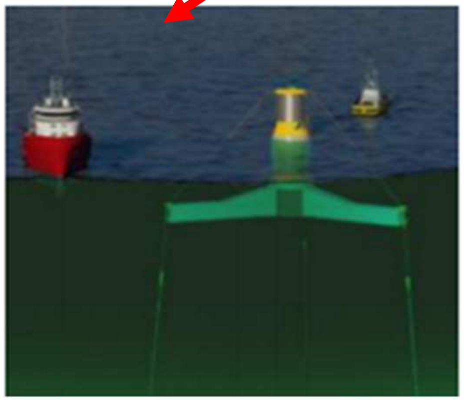
Tow out with temporary buoyancy

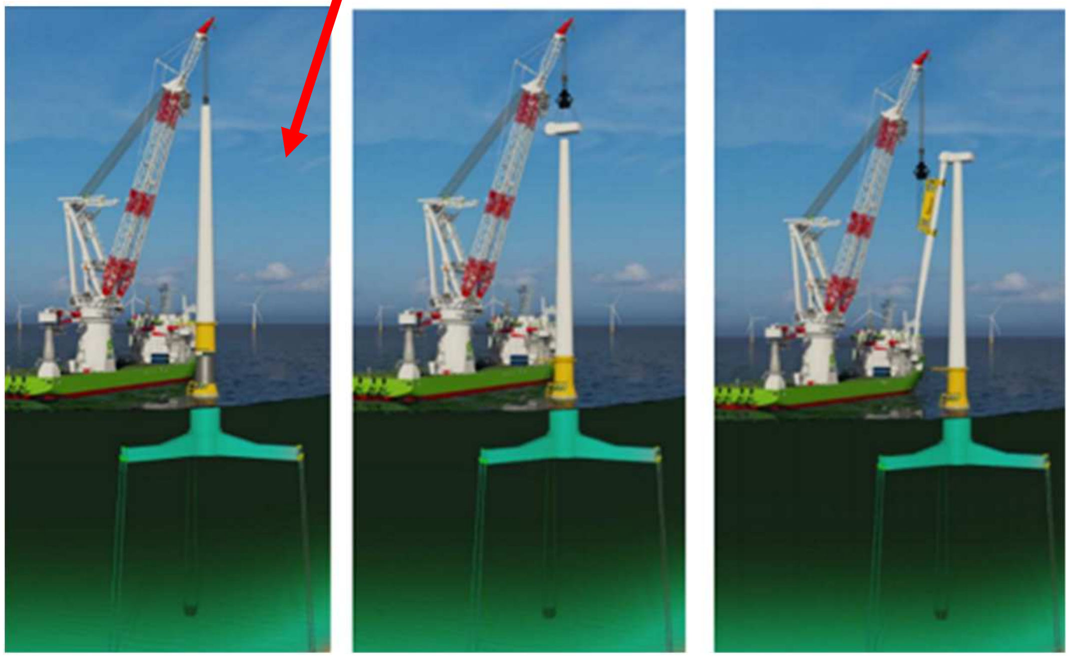
Remove temporary buoyancy after
Connecting tendons

TLP Install Crane Vessel

Ref [10]

Bluewater Tugs Active Heave Compensation Of Hook of DP2 crane vessel





SBM **Ref[23]** Tension Leg Platforms (TLPs)

PROVENCE GRAND LARGE, July 2022, Ref [23]

Eiffage Métal's site in Fos-sur-Mer, where the assembly of the structures is being carried out by the French company and Smulders, its Belgium-based subsidiary

SBM Ref[8]

Tow out shallow draft
Large 2nd moment of waterplane area

Tension (chain) tethers, ballast down and re-tension

BLUE SATH TURRET MOORING

BLUE SATH Ref[12]

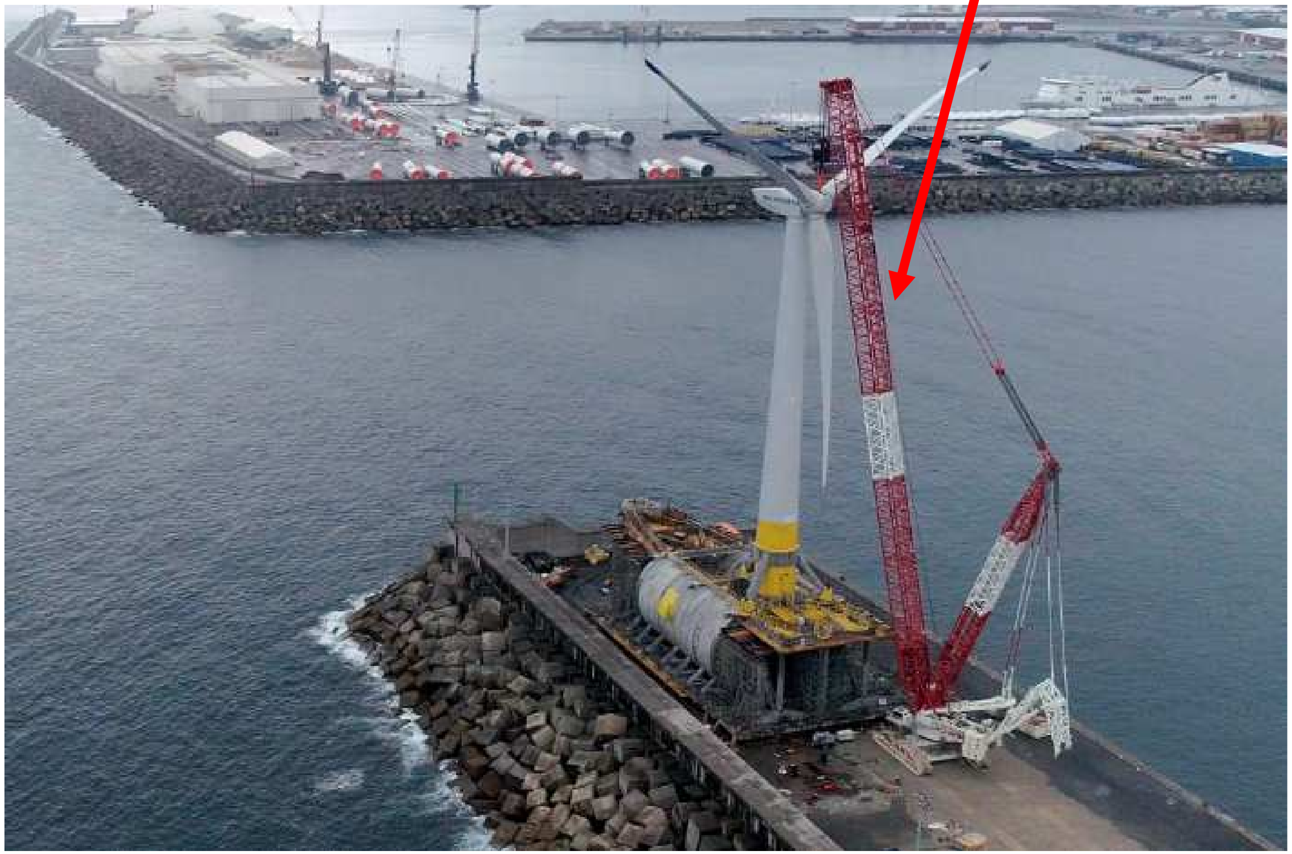
DemoSATH mooring, anchoring and quick connect solution is set for the 2MW turbine.

Maersk Supply Service completed the installation of six mooring lines (comprised by hybrid lines of chain and fibre rope) and six drag anchors with Maersk Mariner.

Once loaded, the vessel left the Port towards the installation site at test area where the elements’ connection and laying took place. The lines will be recovered from the seabed for a plug and play connection.

BLUE SATH Ref[12]

Large onshore crane

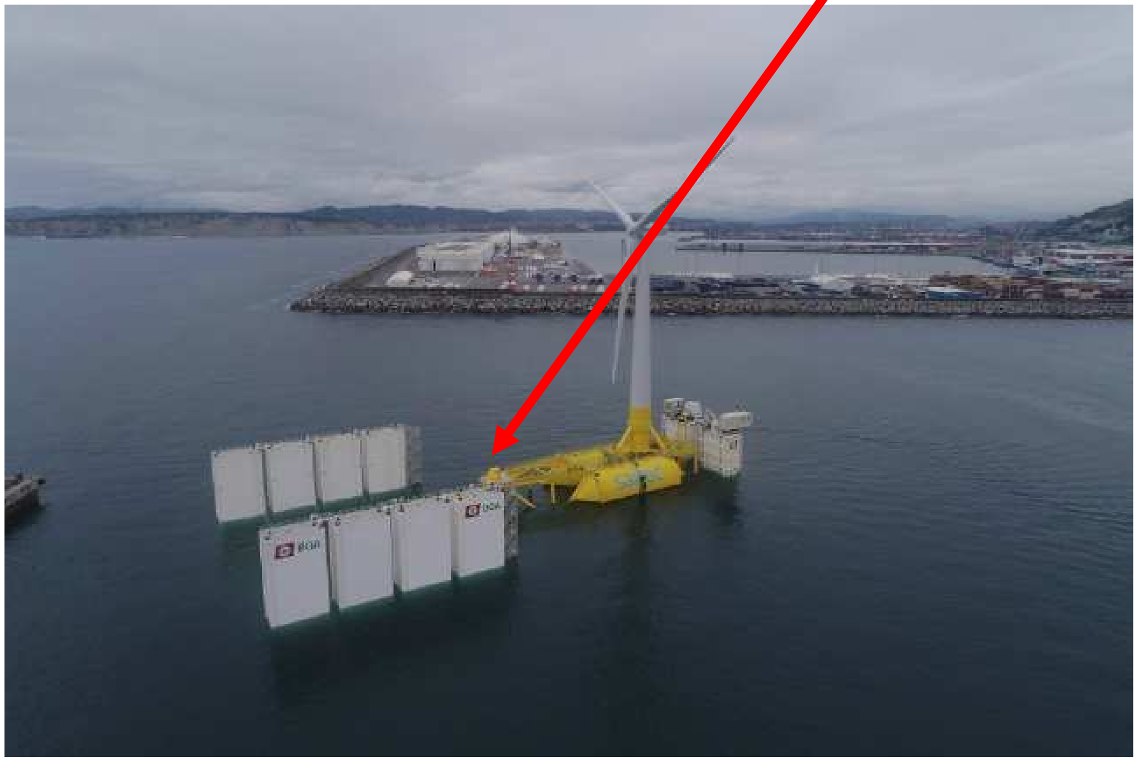


BLUE SATH **Ref[12]**

Submersible barge

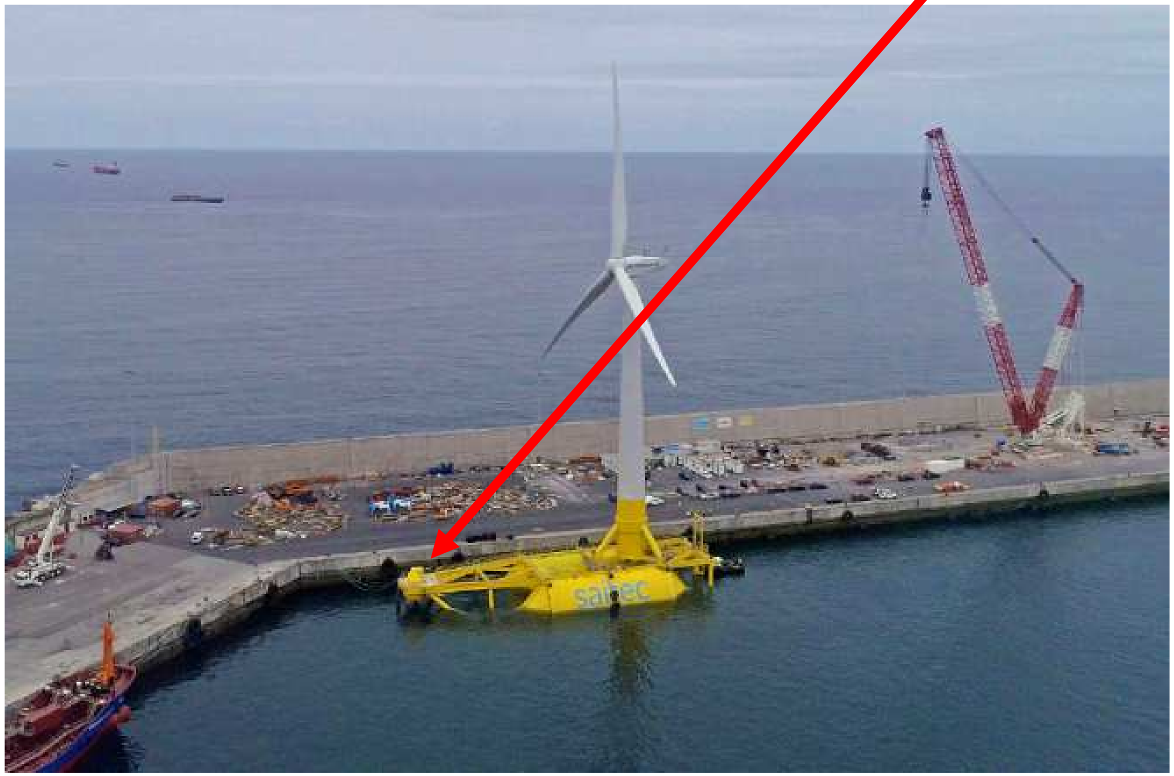
BLUE SATH **Ref[12]**

Turret mooring



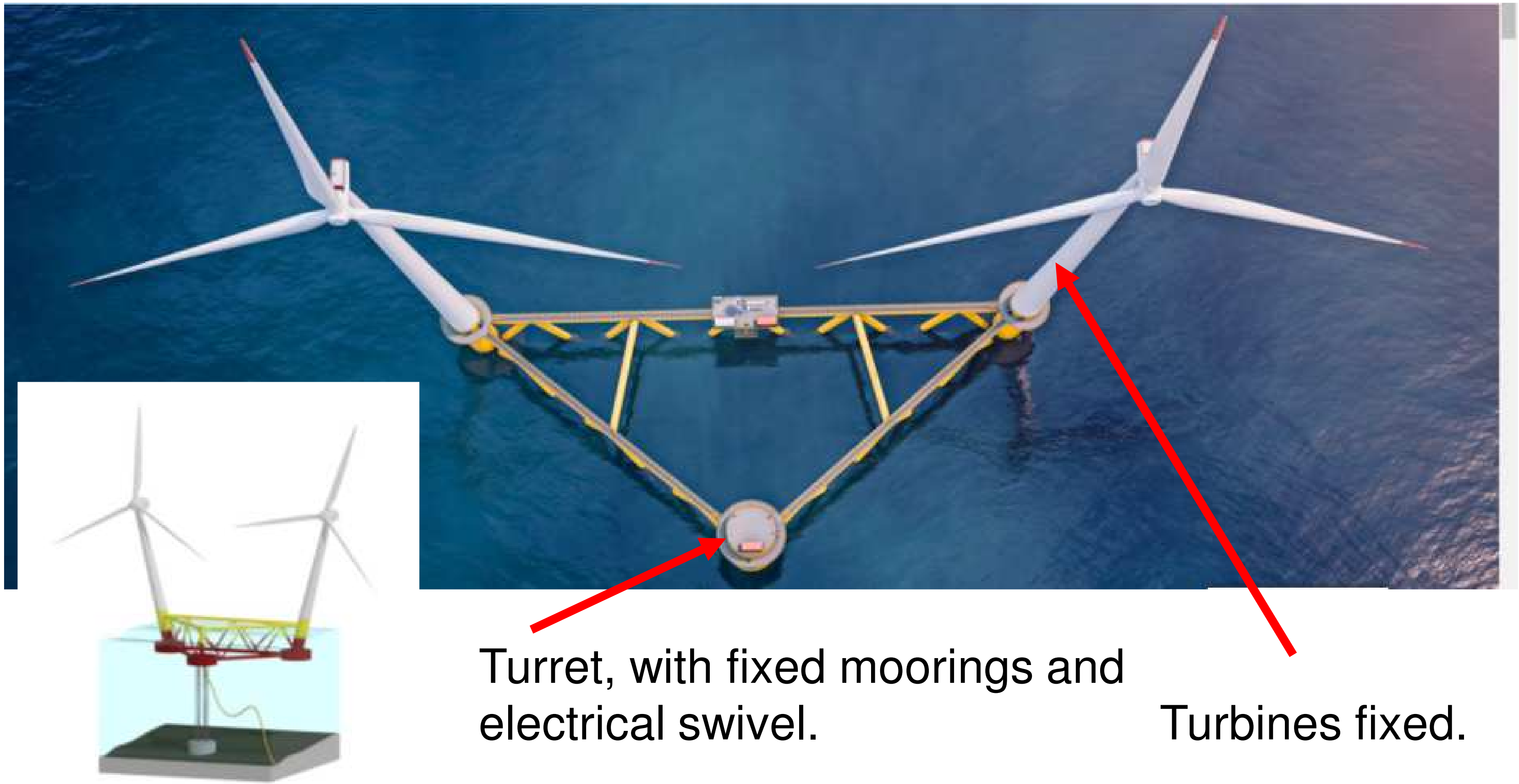
BLUE SATH Ref[12]

Turret mooring



TURRET

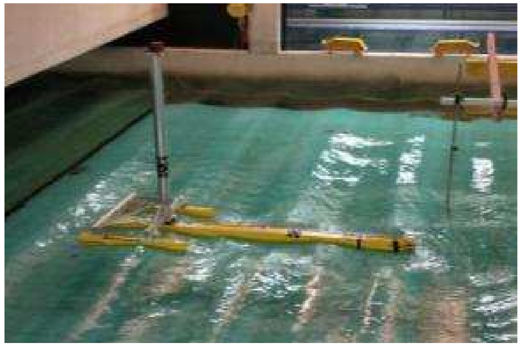
HEXICON TWIN FLOATER TURRET Ref[8]



Turret, with fixed moorings and electrical swivel.

Turbines fixed.

TRIVANE, TURRET MOORING   Ref[7]

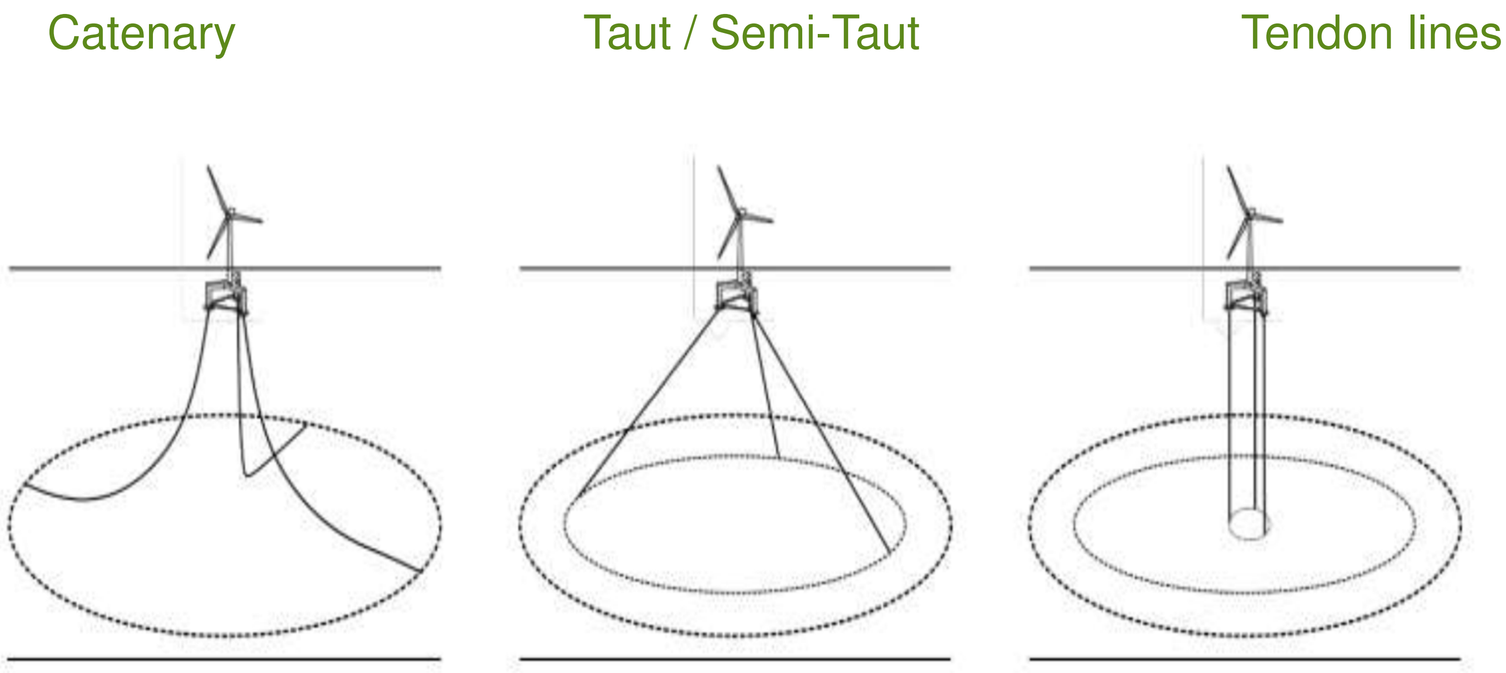


Model test University of Plymouth
scale 1/50

PIVOT BUOY (X1Wind) For Canary Islands Ref[8]

MOORING

MOORING TYPES, Ref [16]



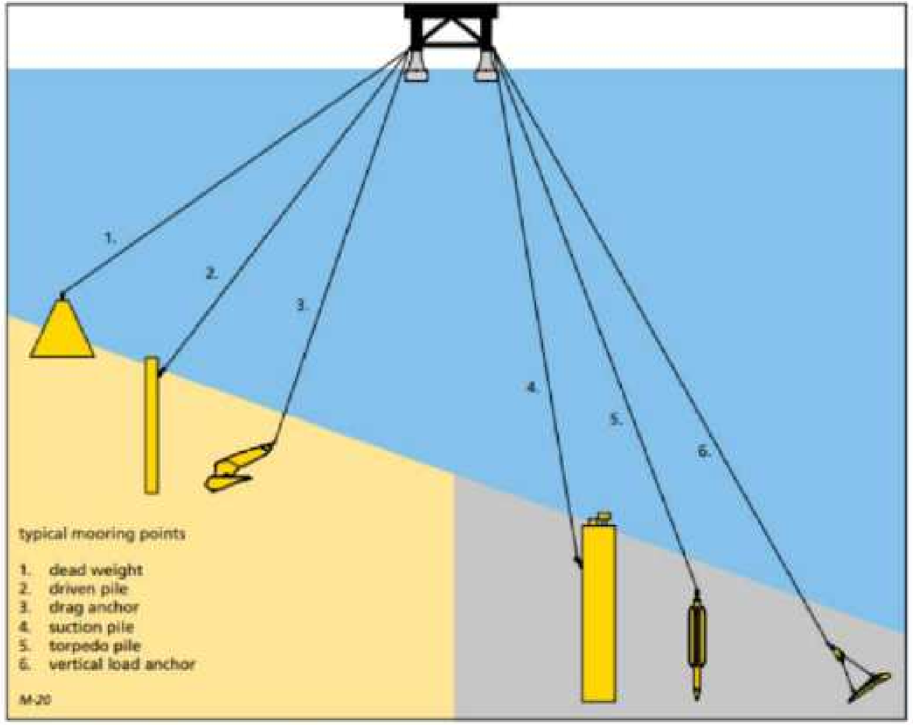
Source: Trubat Casal, P. (2020). Station keeping analysis and design for new floating offshore wind turbines.

ANCHOR TYPES, Ref [17]

Gravity

Driven piles

Drag embedded anchor



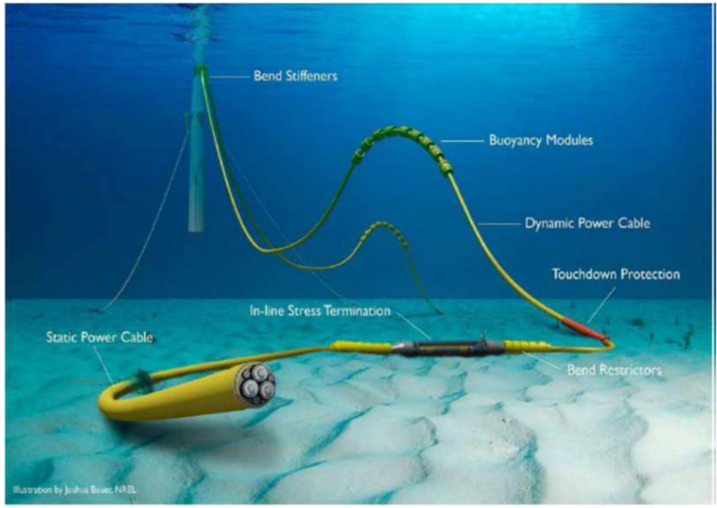
Suction

Free-fall

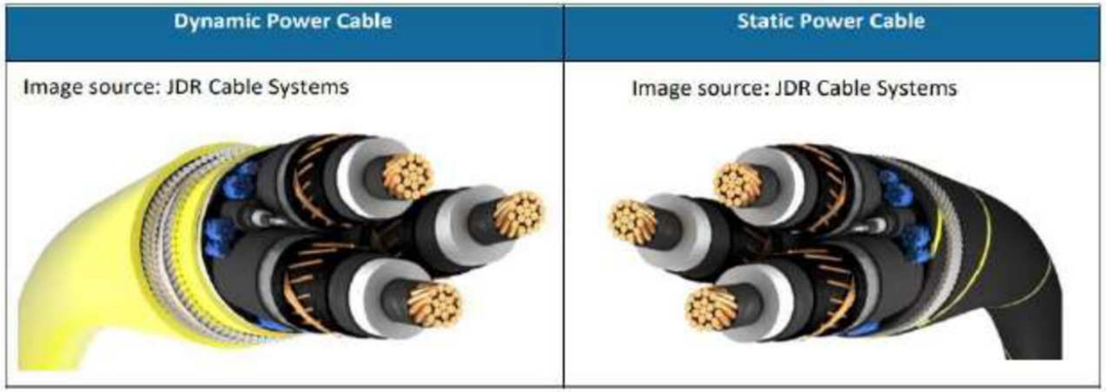
Plate anchor

CABLES, Ref [18]

Inter Array Cable (IAC)
- Between Wind Turbines
- MV 66kV
- 3-core AC
- Dynamic and Static cable



Export cable
- From substation to shore/O&G facilities
- HV 132 345 kV cables, 3-core AC
- HV320 kV single core DC

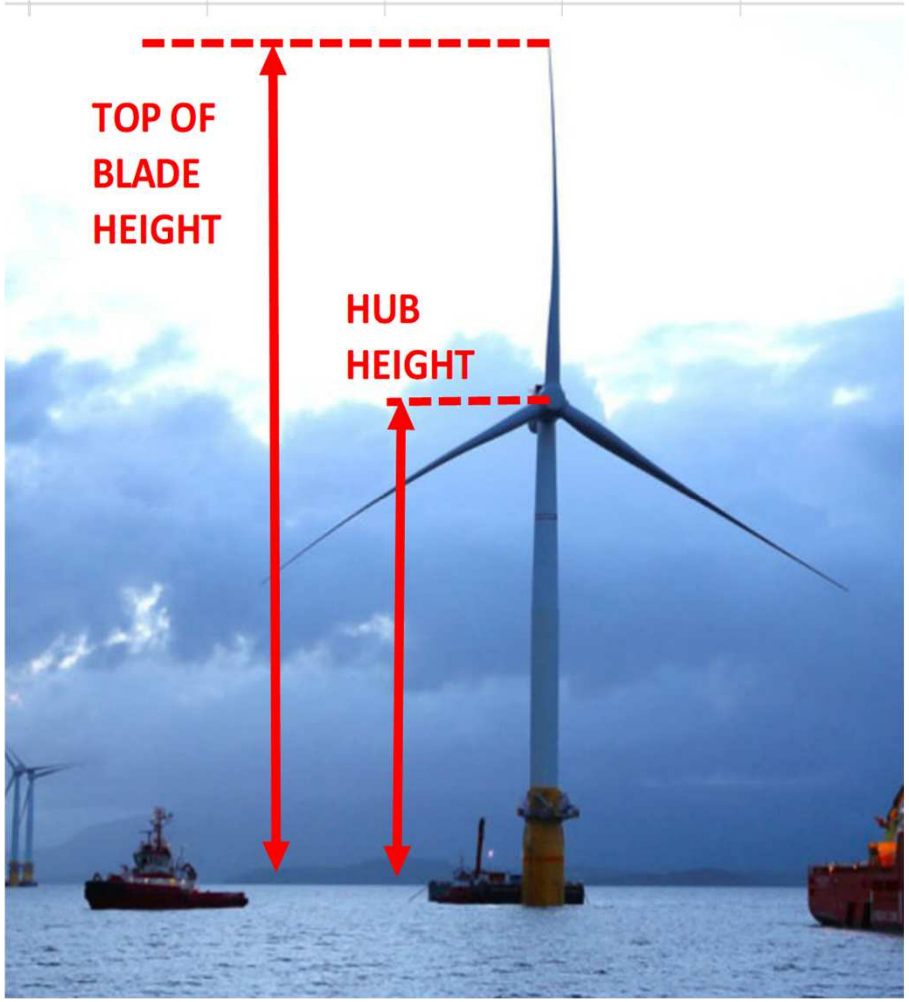


TURBINES

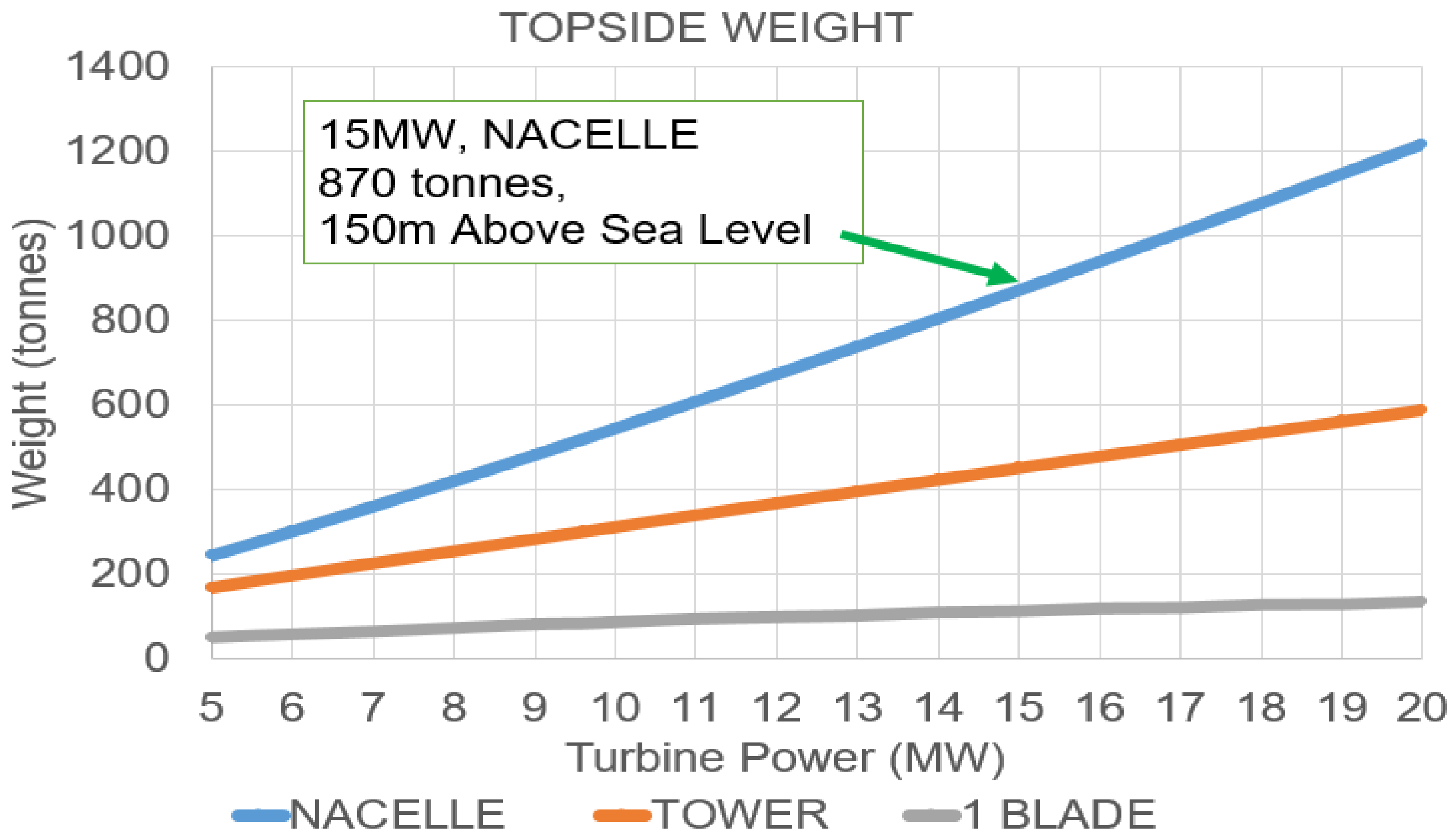
BLADE HANDLING, Ref[13]

AIR DRAFT Ref[13]

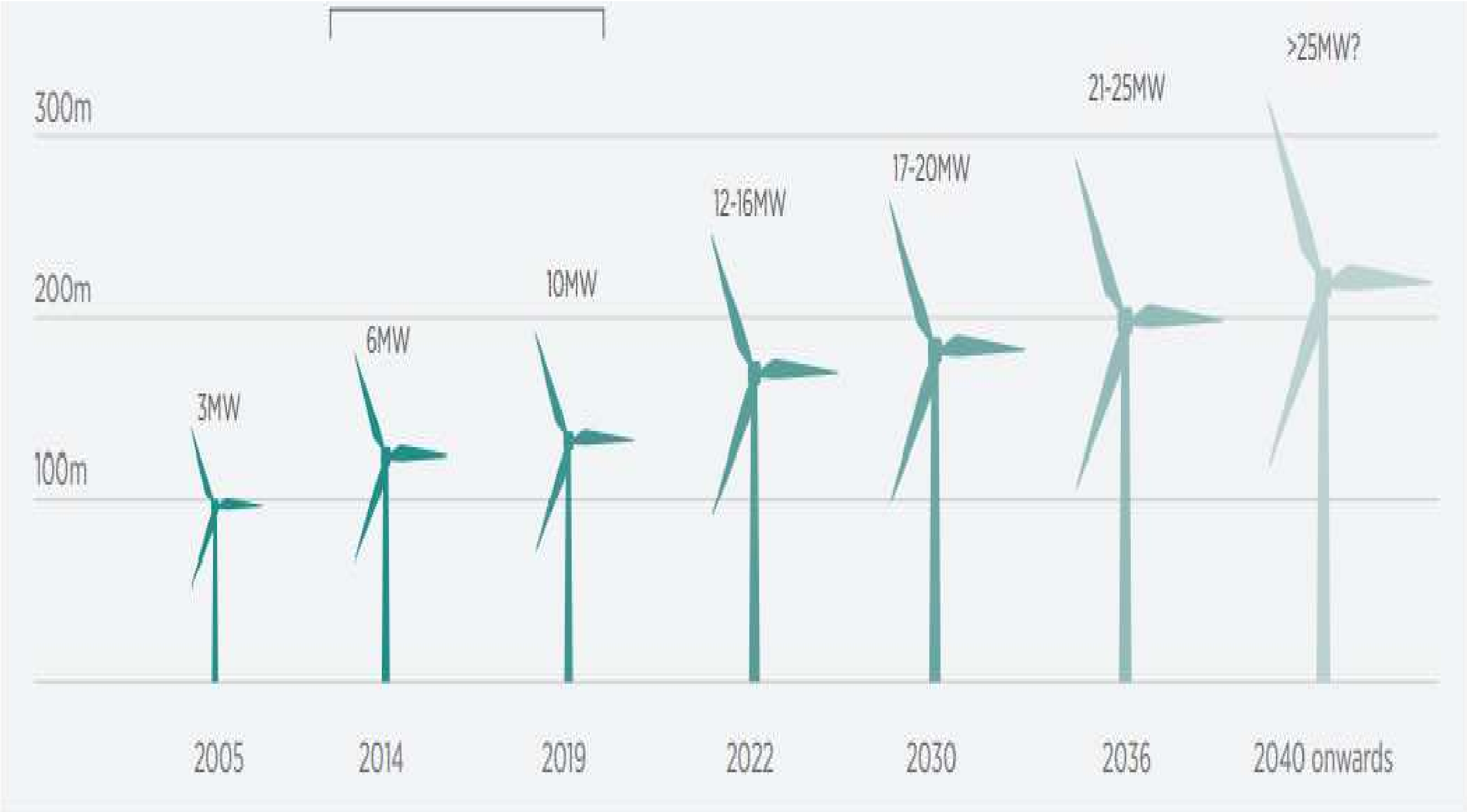
TURBINE CAPACITY	BLADE LENGTH	HUB HEIGHT	TOTAL HEIGHT	LOCATION
		ABOVE WATER		
MW	m	m	m	
2	43.3	68.8	113.2	
3	52.8	80.1	133.9	
5	67.6	97.4	166.2	
6	73.8	104.6	179.8	
8	84.9	116.3	202.6	Hywind Tampen
9.6	92.7	124.1	218.3	Kincardine
10	94.6	126.1	222.2	
11	99.1	130.6	231.2	
12	103.3	135.8	241.7	Dogger Bank
13	107.4	140.4	250.9	Dogger Bank
14	111.4	145.4	260.7	
15	115.2	150.2	270.3	Germany
16	118.8	154.3	278.6	China
17	122.4	157.9	285.7	
18	125.8	161.8	293.6	
19	129.1	165.1	300.3	
20	132.4	168.9	307.8	



TURBINE WEIGHTS Ref[13]



TURBINE SIZE   Ref[13]



FUTURE WORK

Floating wind will be an important component in the offshore wind industry’s future. In some markets – such as Spain, Japan, Norway, West Coast of the U.S. and island communities – there is limited shallow water and so floating wind is a potential solution.

In other markets, floating wind will be used more once we run out of sites that can accommodate fixed-bottom wind turbines.

It will take time to scale up production of floating wind components.

RESEARCH WORK

- Shipyard requirements for mass production
- Fit out quay requirements (strength of quay wall and water depth and available cranes)
- Tow out and installation of TLPs
- Heavy maintenance offshore of Spars and TLPs

CONCLUSIONS

To facilitate the installation process and minimize costs, the main installation aspects have to be considered:

> Floating offshore wind turbine type (substructures different)

> Shipyard location
> Distance from the shipyard to the fit out port distance
➢ Distance from fit out port to offshore wind farm site (3 day tow)

> Minimise weather downtime during installation
> Number of anchor handling vessels (3 or 4)
> Whether an offshore crane vessel is required (TLP)

THANK YOU FOR YOUR ATTENTION

ANY QUESTIONS

Email ac1080@Exeter.ac.uk

ABBREVIATIONS

FOWT	floating offshore wind turbine
HTV	heavy transport vessel
SPMT	self propelled modular transporter (trailer)

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Abstract

Floating offshore wind turbines are an emerging source of marine renewable energy. Installation engineering of these large floating structures is required to provide confidence to owners and insurers that they are constructed in a safe and cost effective manner. This paper covers the construction and installation of various substructure types including barges, Spars, semi submersibles and tension leg platforms.

This paper details the engineering requirements for installation vessels and large onshore cranes required for the construction of floating substructures that support offshore wind turbines. Each of the installation phases, such as load-out, fit out, tow out, mooring connection and cable laying poses challenges in the use of existing technology and the development of new installation techniques. The presentation will give an overview and comparative analysis of lessons learnt for offshore installation of floating offshore wind turbines.

3 key phrases

i. Floating wind turbines nearshore construction

ii. Requirements for installation vessels and onshore cranes for floating wind

iii. Technical advances for floating wind installation