# PORT AND SHIPYARD REQUIREMENTS FOR THE INSTALLATION OF FLOATING WIND TURBINES

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# Abstract

As the floating offshore wind turbine industry continues to develop and grow, the capabilities of established port facilities need to be assessed as to their ability to support the expanding installation requirements. This presentation assesses current infrastructure requirements and projected changes to port facilities that may be required to support the floating offshore wind industry. Understanding the infrastructure needs of the floating offshore renewable industry will help to identify the port-related requirements.

The naval architecture aspects of port development include loadout ballasting and mooring, intact stability during floatout from a drydock and fit out of turbine components. The capabilities of established port facilities to support floating wind farms are assessed by evaluation of size of substructures, height of wind turbine with regards to onshore cranes for fitting of blades, distance to offshore site and offshore vessel characteristics. In addition large areas are required for laydown of mooring equipment, turbine blades and nacelles. The floating offshore wind industries are in early stages of development and port facilities are required for substructure fabrication, turbine manufacture, turbine construction and maintenance support. The presentation discusses the potential floating wind substructures to provide a snapshot of the requirements at the present time, and potential technological developments required for commercial development. Scaling effects of demonstration-scale projects will be addressed, however the primary focus will be on commercial-scale (30+ units) device floating wind energy farms.

# SUMMARY

- Floating offshore wind turbines are an emerging renewable technology
- Prototype and demonstration projects are being installed
- Floating wind farms offer access to wind resources of water too deep for conventional, bottom-fixed wind farms.
- Spar, barge, TLP and semisubmersible types have been deployed as demonstration units.
- Pre commercial units have been installed off the coasts of Portugal (3) and the east coast of Scotland(10).
- This presentation will explain the port and shipyard requirements for floating offshore wind turbines.

# INDEX

- Summary
- Types
- Moorings
- Windfloat Semi submersible
- Hywind Spar
- Damping Barge
- Chinese Semi submersible
- Topside laydown
- Cable loadout

# PORTS AND LOGISTICS FOR FOWT

- Ports are for assembly, installation and operations support.
- Shipyards need to  construct several FOWT at one time
- Substructure dry transport so no limits on shipyard location
- Weather forecasts are more accurate within 72 hours and this sets the tow time from the fit out quay to offshore.
- Different types of substructures have different port requirements:
- Port capability is likely to influence substructure design choices. Semisubmersibles, barges large quayside areas (80m x 80m).
- Spars require deep-water,(80m) sheltered area for turbine fitout
- TLPs have a small water plane area and will probably have low stability during towing, so final assembly may take place offshore

# ABP PORT TALBOT (Ref [17])

Fabrication Assembly Loadout onto submersible barge

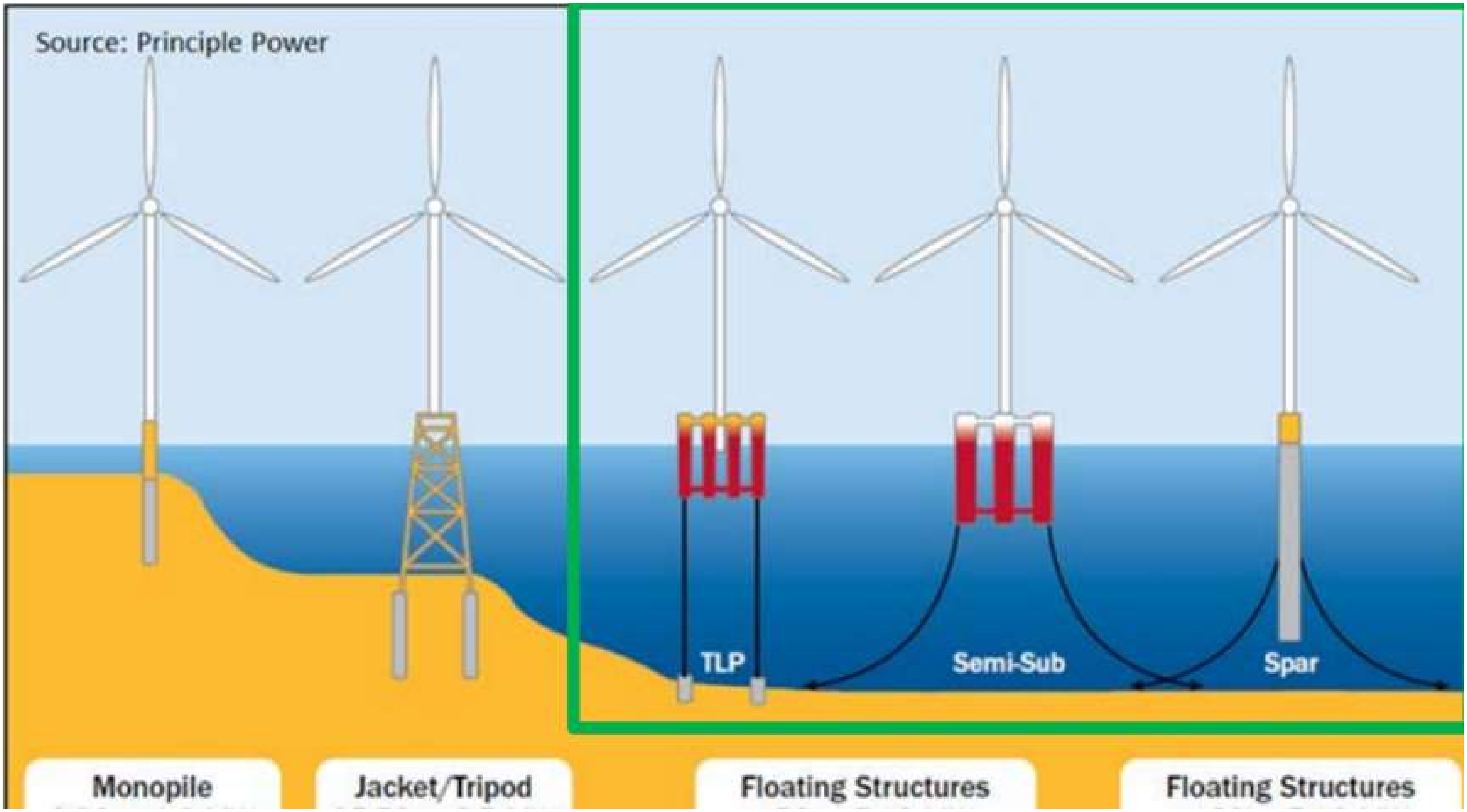
Towers, Nacelles Blades Out-fit Wet-Storage Tow-out

# FIT OUT PORTS

- A fit out port looking will need access to a large laydown area to store nacelles, blades, towers.
- For turbine assembly, a port will need a lifting capacity of 700+ tonnes for the nacelle, the heaviest lifting operation.
- Mobile cranes with sufficient lifting and reach capability are limited in global availability and mobilisation costs are high as it is transported in sections and needs to be assembled for use.
- After turbine assembly in port, touch-up work including bolt tensioning checks, electrical circuits and safety system checks are carried out.

# TYPES

# SUMMARY



Source: Principle Power
TLP
Semi-Sub
Spar
Monopile
Jacket/Tripod
Floating Structures
Floating Structures

# MOORING TYPES

CATENARY (MAYBE TAUT MOORINGS)

Semi-submersible examples: Windfloat (courtesy: Principle Power), Eolink (courtesy: Eolink) & OO Star (courtesy: Dr. techn. Olav Olsen)

VERTICAL TENDON TLP

WEATHER VANING TURRET

Multi-Turbine example: SCD Nezzy2 (courtesy:

Barge examples: BlueSATH (courte

# LIMIT ON WATERDEPTH

LIMIT FOR FIXED WIND TURBINES

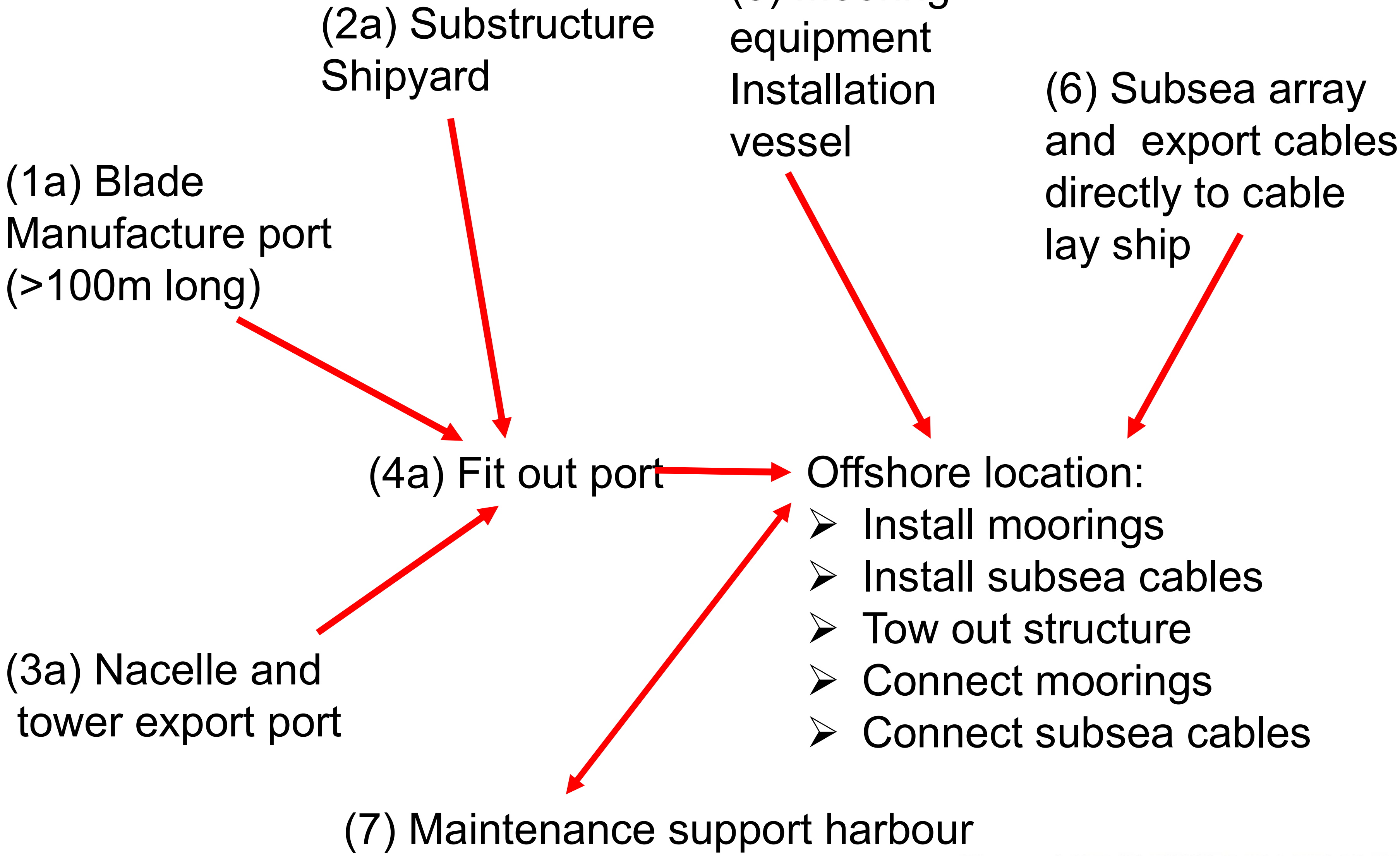
WATER DEPTH FOR WIND TURBINE INSTALLATION VESSEL

EXISTING = 60m
FUTURE = 80m

# JAPAN DEMONSTRATION

# PORTS REQUIREMENTS

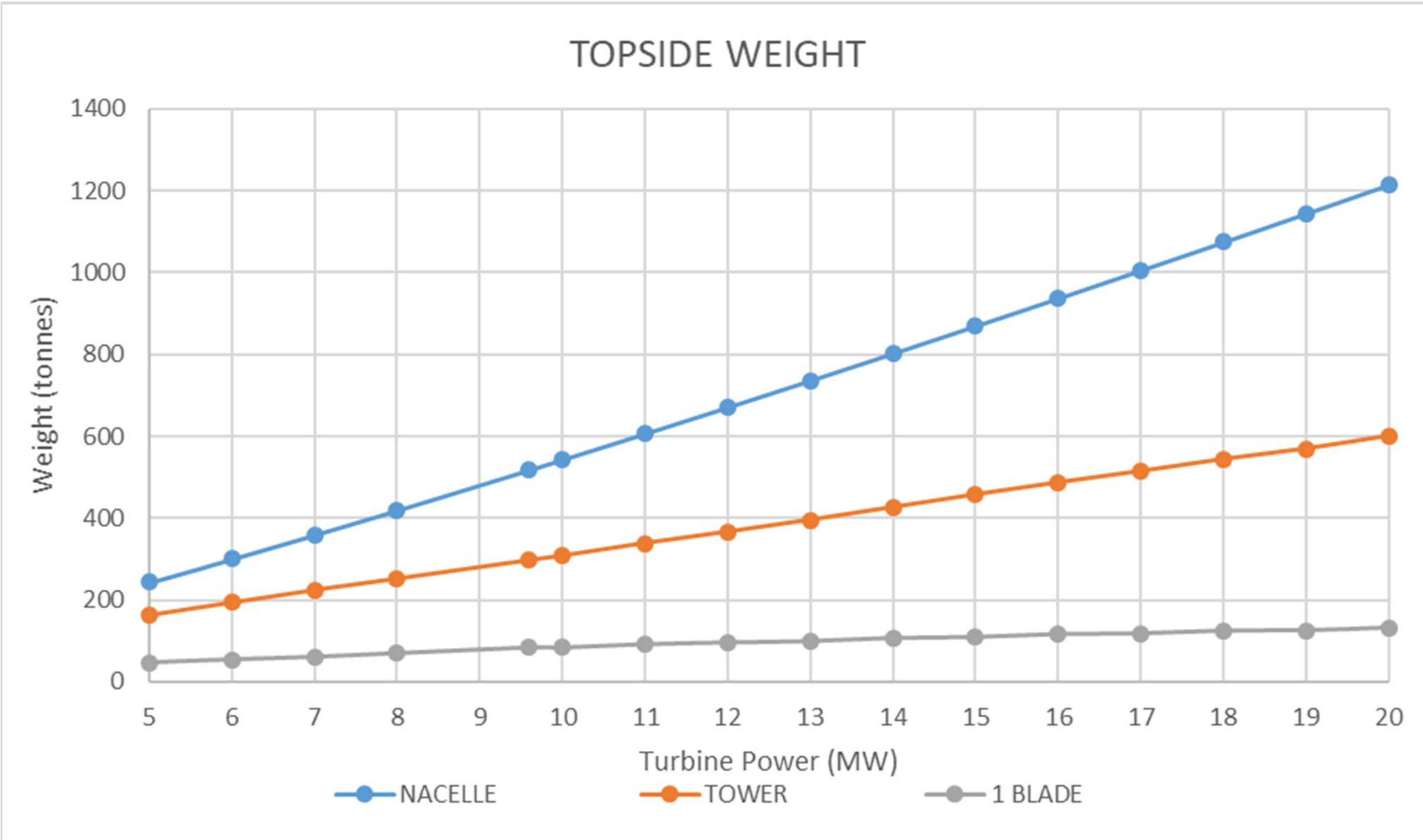
# PORTS


(1a) Blade Manufacture port (>100m long)
(2a) Substructure Shipyard
(5) Mooring equipment Installation vessel
(6) Subsea array and export cables directly to cable lay ship
(4a) Fit out port
Offshore location:
➢ Install moorings
➢ Install subsea cables
➢ Tow out structure
➢ Connect moorings
➢ Connect subsea cables
(3a) Nacelle and tower export port
(7) Maintenance support harbour

# AIR DRAFT

| 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 | |

# TOPSIDE WEIGHTS (FIT OUT QUAY LIFTING)



# SHIPYARD AND FIT OUT QUAY

| PRIMARY CRITERIA | SEMI-SUB | SPAR | TLP |
|---|---|---|---|
| Navigation channel width | 100-135m | 60-90m | 90-135m |
| At fit out quay FOWT to navigation channel offset | 30m | 30m | 30m |
| Navigation channel depth | 10-12m | 90m in sheltered | 10-12m, if fitted with temporary |
| Area for substructure shipyard | 4-6hectare | 3-5hectare | 4-6hectare |
| Area for fit out | 4-6hectare | 5-8hectare including temporary moorings | 4-6hectare |
| Shipyard bearing capacity | 10 tonnes/m2 | 10 tonnes/m2 | 10 tonnes/m2 |
| Fit out quay bearing capacity | 15 tonnes/m2 | 15 tonnes/m2 | 15 tonnes/m2 |
| Crane for 5MW turbine | 1,000 tonne | 1,000 tonne | 1,000 tonne |

# MOORINGS STORAGE IN PORT

Mooring and anchor systems can be stored in a separate port but do not need particularly high lifting capability. There is potential to use drums to store synthetic rope, which would require less space.

# SUCTION PILES


# WINDFLOAT MOORINGS

# MOORING CHAIN LAYDOWN

# WINDFLOAT SEMI SUBMERSIBLE

# WINDFLOAT LOADOUT FROM FLAT QUAY

Heavy transport vessel    Semi submersible substructure SPMT

# SEMI SUBMERSIBLE IN DRYDOCK

Temporary buoyancy for even draft of semi submersible floatout from a drydock

Drydock

Heave damping plates under columns

# WINDFLOAT FLOATOFF - HEAVY TRANSPORT VESSEL

# SEMI SUBMERSIBLE FIT OUT

Onshore mobile crane

Turbine Topsides

Substructure, turbine
Column close to quay

Quay Moorings

# FIT OUT QUAY FOR SEMI SUBMERRSIBLE

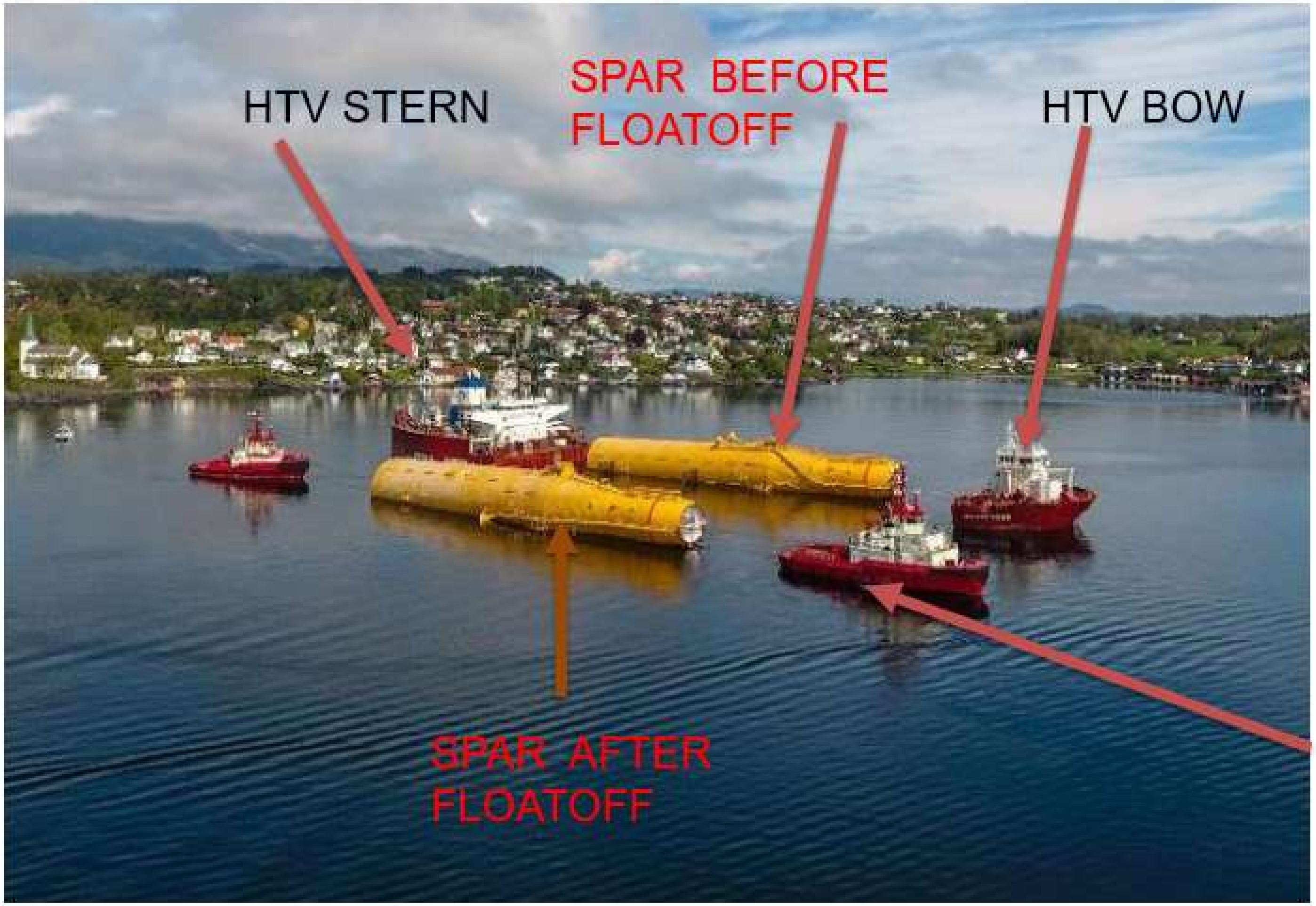
In addition to the heavy lifting requirements, the larger cranes, turbines and foundations have changed the requirements of the carrying capacity. The pre-assembly port storage area has a minimum overall surcharge load of 15 t/m2 as a uniform distributed load (UDL) and 12-16 ha for 10 MW wind turbines.

Areas assigned for heavy lifting crane operations must accommodate a minimum surcharge load of 30-40 t/m2 (UDL) which increases to a maximum surcharge of 50-80 t/m2 by operation of the main crawler crane when lifting a large nacelle.

## EQUINOR HYWIND SPAR

# SPAR SIDE LOADOUT

# SPAR OFFLOADING SHELTERED HARBOUR



# SPAR UPENDING SHELTERED FJORD

Spare during upending, with water ballast
solid ballast added to base after upending

# HYWIND TOWERS ON THE WAY TO NORWAY

# SPAR TOPSIDES ONSHORE FIT OIUT

# SPAR TOP SIDE LIFT IN FJORD

# SPARs ON TEMPORARY INSHORE MOORINGS

# DAMPING BARGE

# STEEL DAMPING BARGE DRYDOCK AND TOPSIDES

Steel Substructure
Built In Drydock

Floating Sheer Leg
Installs Turbine

# CONCRETE BARGE SUBSTRUCTURE AND FIT OUT

Concrete Substructure
Built On Pontoon

Fit Out Of Turbine

# CONCLUSION

# CHINESE SEMI SUBMERSIBLE

# WISON 91m*91m*32m,  5.5MW turbine

# STIESDAL

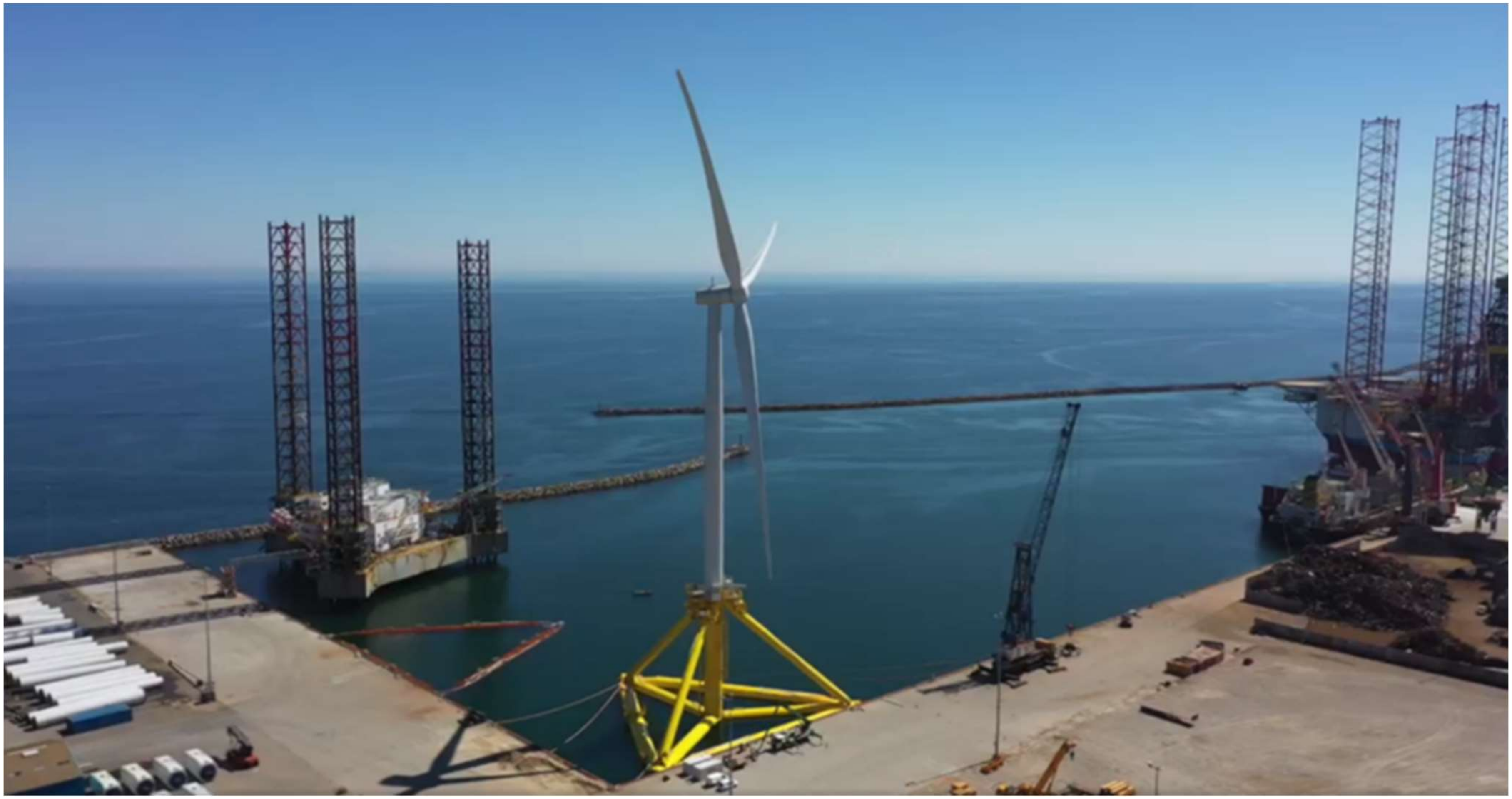
# TUBULAR CONSTRUCTION

# NODE CONNECTORS

# ASSEMBLY

# SUBSTRUCTURE AND KEEL

# TURBINE FIT OUT



# TOPSIDE LAYDOWN

# TOPSIDE LAY DOWN

Marshalling ports, large waterside sites with the acreage and weight-carrying capacity necessary to assemble, house and deploy the huge wind turbines ready to ship out into the ocean, will be critical to meeting this current and committed demand for floating offshore wind

# BLADE UNLOADING

# NACELLE

## SUBSEA CABLES

> Export cable
> Export cable protection
> Dynamic cables

# CABLE LOADOUT

## Direct from factory onto cable lay ship


# CONCRETE MATS FOR SUBSEA CABLE PROTECTION

# TURBINE LAYDOWN

# GE BLADE FACTORY TEESIDE Ref [15]

Dedicated to the production of its 107m- long offshore wind turbine blades, a key component of GE's Haliade-X turbine.

# VESTAS ISLE OF WIGHT

Vestas recently announced its next-generation turbine, the V236-15.0 MW turbine, which is due to be powered by 115.5m blades, a world-leading blade length.

**GB OFFSHORE WIND TURBINE**

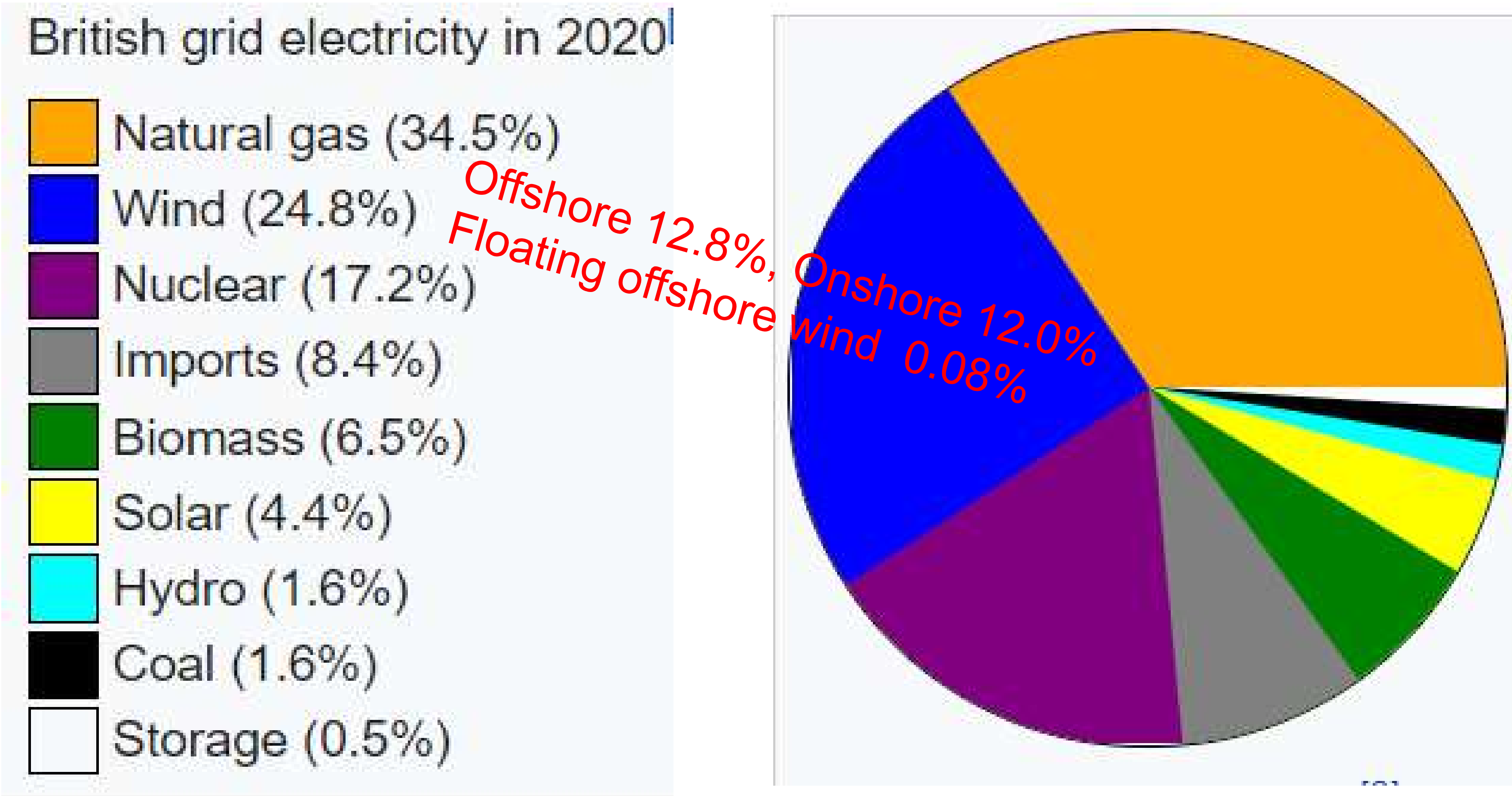
Installed Capacity September 2021:
- Offshore Installed Wind 10.400 GW
- Of Which Floating Wind 0.080 GW

*Expectation GB floating wind 1.000 GW by 2030*

Wind Turbine Size
- Largest fixed wind turbine 12.0 MW (15MW on order)
- Largest floating wind turbine 9.6 MW

*Expectation future floating wind 15.0 MW each*

# MAINLAND GB ELECTRICAL POWER IN 2020




Wind ranges from 3% to 45% of the total

# CONSIDERATIIONS

Fit out port

- Transport channel width and depth
- No height restrictions
- Size of components – blades, nacelles
- Safe harbour for wet storage of substructure
- Crane capacity and strong foundations
- Quayside space
- Skilled workforce
- Road/rail connections

# CONCLUSION

Functions required:

- Shipyard for substructure
- Loadout of anchors and chains, delivery to mooring port
- Mooring storage close to offshore site
- Cable loadout direct onto cable lay vessels
- Blade manufacture on quay
- Tower manufacture on quay
- Storage and loadout of nacelle at fit out quay
- Fit out quay also needs moorings and crane space
- Wet storage
- Operation and Maintenance port

Issues

- Ports are the current pinch point for floating wind
- No single port currently has the capability to do all the functions
- Long term investment required

# REFERENCES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THANK YOU FOR YOUR TIME

ANY QUESTIONS ?

**Email: ac1080@exeter.ac.uk**

# QUESTIONS

1. UK manufacturing capability? = There are plans to develop Port Talbot and Port of Nigg for substructure shipyards and fitout ports.
2. TLP installation? = Use crane vessels with DP2/DP3 and an active heave compensation on the carne hook.
3. 33KV cables? = Dynamic array cables are 33kv. Export cables > 200kv, so need a substation (floating, fixed, subsea) to convert voltage.
4. Anchors moving? = Drag anchors need to be pre-tensioned to get them to the required penetration depth, which needs to be done prior to substructure installation. Suction piles, driven piles and drilled piles are tensioned after substructure installation.
5. Build in pieces inland? = All items are of large dimensions and need to be built close to the quay edge.
6. FOWT design and construction? = UK is good at project management.

Windfloat semi submersible designed in USA, constructed in Spain and fit out in Netherlands

Equinor steel spar designed in Norway, constructed in Spain and fit out in Norway

7. FOWT costs? = In 70m water depth FOWT is 10% more expensive than fixed bottom.

FOWT costs need large scale commercialisation to reduce costs.