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# The benefits of hybrid bottom-fixed and floating wind sites

## EXECUTIVE SUMMARY

A large portion of the asset requirements for floating offshore wind is common with bottom-fixed offshore wind. A site with sufficiently deep water which can accommodate both bottom-fixed (e.g. less than 60 m) and floating turbines (e.g. greater than 50 m) can allow sharing of common assets across a hybrid site, allowing the floating part of the project to benefit from procurement scale and reduce the cost of deployment of pre-commercial technology in comparison to standalone sites. This paper analyses the feasibility of bottom-fixed / floating offshore wind hybrid sites in Scottish waters.

- Hybrid bottom-fixed / floating projects provide an opportunity to accelerate deployment of floating wind in Scottish waters at a cost close to current wholesale prices, as shown in the ScotWind lease zone N1 case study.
- The shared grid connection provides the largest cost impact of the co-location. This enables more efficient use of infrastructure and a bottom-fixed offshore substation allows export of electricity without the need for yet to be developed higher voltage (132kV +) dynamic cables.
- The site conditions in the hybrid site are not optimal for either floating wind or bottom-fixed. The bottom-fixed turbines have a high substructure cost due to the water depth. The floating structures would be more economic at deeper water sites, with potentially higher wind speeds as well as less complex mooring line configurations.
- A pathway of increasing capacity projects enables supply chain and developers to prove skills on smaller projects before advancing on to larger projects, accelerating technology maturity and bringing the costs of future projects below the base case modelled in this analysis.
- Regulatory bodies such as Marine Scotland and Crown Estate Scotland should be engaged early to minimise the risk of delay due to planning or environmental issues.
- Scottish National Investment Bank provides an opportunity for Scottish companies looking to invest in the sector at an early stage. The opportunity for attractive financing terms may encourage supply chain to accelerate investment in scaling up facilities.

## INTRODUCTION

The purpose of this report is to analyse the feasibility of bottom-fixed / floating offshore wind hybrid sites in Scottish waters. A large portion of the asset requirements for floating offshore wind is common with bottom-fixed offshore wind. A site with sufficiently deep water which can accommodate both bottom-fixed (e.g. less than 60 m) and floating turbines (e.g. greater than 50 m) can allow sharing of common assets across a hybrid site, allowing the floating part of the project to benefit from procurement scale and reduce the cost of deployment of pre-commercial technology in comparison to standalone sites.

## SITUATION

### Industry Background

With increasingly ambitious targets for offshore wind deployment in the UK, floating wind will undoubtedly constitute a significant portion of future installed capacity. Large-scale deployment of floating wind will be imperative if the UK is to realise Committee on Climate Change ambitions for 75GW by 2050. ORE Catapult expects that floating wind will contribute significantly, with a large portion in Scottish waters.

Floating wind has made significant advances in recent years and is set to become a major contributor to global offshore wind capacity over the coming decades. Today, the UK leads the world in deployment of floating wind and has the opportunity to develop a sustainable industry supporting large-scale employment, exports and Gross Value Add (GVA).

The Challenge

### Hybrid Sites in Scotland

A large portion of the asset requirements for floating offshore wind is common with bottom-fixed offshore wind, including transmission assets (provided the substation can be sited in suitable water depth) and turbines. A site with sufficiently deep water which can accommodate both bottom-fixed (e.g. less than 60 m) and floating turbines (e.g. greater than 50 m) can allow both solutions to be deployed in different locations within the same site. This will allow the sharing of common assets across a hybrid site, allowing the floating part of the project to benefit from procurement scale (e.g. large volume turbine order, central procurement of steel (if desired)) and avoiding the need to construct transmission assets and have separate port leases specific to the relatively small floating part of the project.

## HYBRID SITE CASE STUDY

It is expected that floating offshore wind could contribute 50% of the 10GW offshore wind capacity available through Scotwind lease zones. Figure 1 shows the ScotWind lease zones and the bathymetry of Scottish waters. It is wholly feasible for site developers to choose a site with seabed suitable for both bottom-fixed and floating offshore wind. Outwith these lease zones, there is also an opportunity for existing bottom-fixed offshore wind farms to extend into adjacent deeper waters.

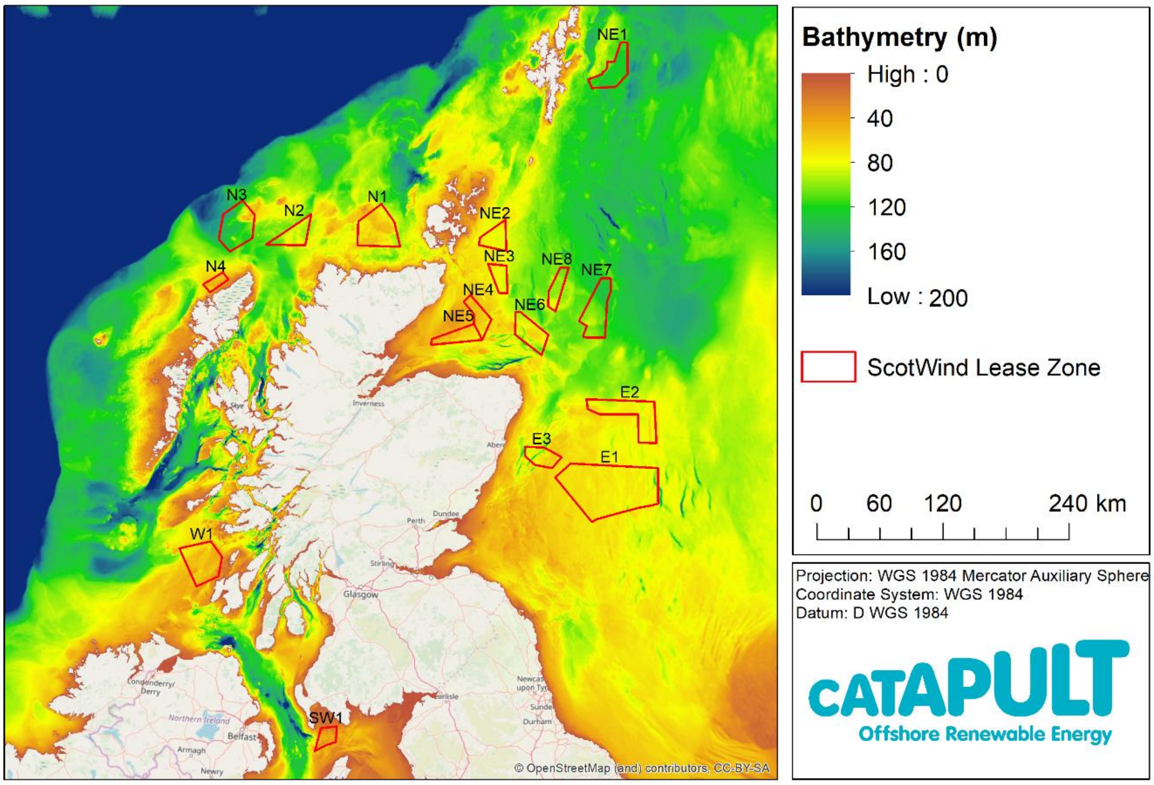


*Figure 1: ScotWind Lease Zones © 2019 EMODnet Bathymetry. Contains information from Crown Estate Scotland*

A geographical information system (GIS) tool was used to analyse the bathymetry, seabed sediment type and existing infrastructure surrounding the lease zones. These factors influence the site location within the lease zone, choice of substructure for both technologies and the appropriate substructure mooring system. Zone N1 was selected to demonstrate a hypothetical case study for a hybrid site.

## Site Assumptions

Table 1 shows the parameters used in the N1 lease zone site. The average water depth for bottom-fixed structures is assumed to be 53 metres, using jacket foundations and for floating structures is 65 metres. The floating wind substructure is modelled as a generic semisub.

Floating wind turbine technology will mirror developments in bottom-fixed wind. Paramount to this is the expectation that future projects will use larger turbines. 15MW turbines have been modelled with a 220m rotor diameter and a combined tower, nacelle and blade mass of 1,770 tonnes.

| N1 Lease Zone | | Bottom-fixed zone (90%) | Floating Zone (10%) |
|---|---|---|---|
| Foundation type | | Jacket | Semisub |
| Bottom-fixed wind capacity | *MW* | 900 | 105 |
| Turbine rating | *MW* | 15 | 15 |
| Number of turbines | | 60 | 7 |
| Average water depth | *m* | 53m | 65m |
| Distance from shore | *Km* | 60 - 80km | 60 - 80km |
| Mean wind speed | *m/s* | 10 | 10 |
| Net capacity factor | *%* | 49.1% | 49.1% |

*Table 1: Project parameters for N1 Lease Zone*

## Cost Assumptions

The cost modelling in this analysis is consistent with the methodology used in the report 'Macroeconomic benefits of floating offshore wind in the UK'[1], using an ORE Catapult in-house Excel-based economic model and reviewed by industry stakeholders. Project costs have been estimated using bottom up analysis based on the site and technology parameters outlined in section 0.

Table 2 shows the cost assumptions for the site broken into four components: a standalone floating site, a standalone bottom-fixed site, the effective cost of the floating 'zone' in a hybrid site and the average cost across a hybrid site. The main areas where the floating wind project benefits from shared infrastructure are highlighted in green and detailed in the following points:

- The development cost for the 105MW standalone site is particularly high, driven by the small scale of the project rather than the maturity of the technology.
- The standalone 105MW floating site uses two 66kV cables to connect the turbines to shore. This is expensive as the site is far from shore, requiring 150 kilometres of cables in total. By sharing the offshore substation with the bottom-fixed site, cable length per MW is reduced significantly, partly offset by additional cost of offshore substations and export cables.
- Most vessel operations during construction are distinct due to different installation processes. Cable installation vessels and crew transfer vessels may be used across both areas of the site dependent on project phasing. There are more synergies during the operating life of the site, through a combined maintenance strategy and shared use of onshore facilities.

[1] https://www.crownestatescotland.com/maps-and-publications/download/219

- Floating turbines may return to port to undertake major repairs (e.g. blade replacement). Bottom-fixed turbines are maintained on-site using jack-up vessels which cannot operate in deeper waters.
- All types of floating sites will benefit from innovation driving cost reduction in bottom-fixed offshore wind sites, such as increasing automation and use of remote inspection.
- The floating zone of the project retains a higher contingency (held within 'other capex') to allow for any issues relating to the newer technology, such as needing to replace dynamic cables after 10 – 15 years as these are considered to be a relatively unproven technology.
- The weighted average cost of capital (WACC) remains higher for the floating zone of the project as it remains a higher risk investment while the technology is still being developed versus the bottom-fixed zone which has a WACC estimated to be representative of the most recent UK contract for difference (CfD) auction round.
- By bringing the 105MW floating wind development zone adjacent to the 900MW bottom-fixed site, LCOE reduces from £98 per MWh to £74 per MWh for the floating zone in a hybrid site. The total hybrid site has an average LCOE of £50 per MWh. All LCOE is reported in 2012 terms consistent with UK CfD auction announcements.

| Capex | | Floating Standalone 105MW | Bottom-Fixed Standalone 900MW | Floating "Zone" 105MW | Hybrid 1,005MW |
|---|---|---|---|---|---|
| Project Development | £/kW | 195 | 90 | 195 | 101 |
| Site Capex | £/kW | 2,924 | 1,921 | 2,430 | 1,971 |
| Transmission Capex | £/kW | 975 | 325 | 380 | 325 |
| Annual Opex | £/kW/year | 88 | 68 | 79 | 69 |
| Decommissioning | £/kW | 844 | 190 | 118 | 183 |
| WACC | % | 7.5% | 4.5% | 7.5% | 4.8% |
| Total LCOE (2012 real) | £/MWh | 98 | 48 | 74 | 50 |

*Table 2: Cost assumptions for 105MW floating / 900MW bottom-fixed site*

## Sensitivity Analysis

If a 50:50 ratio were used instead of the 90:10 ratio, with otherwise consistent site parameters, the LCOE of the floating standalone site is estimated at £74 per MWh as the larger scale of the project brings efficiencies in the use of ports and vessels both in construction and operation, and offshore electrical infrastructure. However, at £57 per MWh, the average LCOE of the hybrid site is higher.

If the scale of the project were increased from a hybrid site of 1GW to 1.5GW, with a 33% proportion of floating wind, the hybrid site has an average LCOE of £54 per MWh. This is still higher than the base case, which has a lower proportion of floating wind.

## PROJECT FEASIBILITY

As a new technology, floating wind still faces a number of challenges. Development zones provide an opportunity to test new innovation at a smaller scale. Hybrid projects give further risk reduction by hedging the new technology against tried and tested methods. This section considers areas where floating wind requires further development, both in the technology and the surrounding regulation and legislation.

### Technical Feasibility

Much of the technology used in floating offshore wind has a proven track record. Turbines will benefit from the same advances in increasing turbine rating as bottom-fixed technology. Many substructure, mooring and anchoring systems are adapted from the marine industry or oil and gas and retain the same design standards.

There are areas where new technology is required, or established technology is working in new ways, with new interfaces. These are listed below:

- Dynamic cables have been proven up to 66kV, however the long-term fatigue impact due to increased movement and dis/re-connection for major repair during the operating life is unknown. In addition, dynamic cables at the voltage commonly used for export (132kV +) have not yet been developed. This makes hybrid sites which can connect into a bottom-fixed offshore substation a good interim opportunity.
- The installation process for floating turbines relies more heavily than bottom-fixed projects on suitable port facilities. Portside lifting capability upwards of 600 tonnes is required. In the near term, floating foundations may use jack-up vessels in portside locations to install turbines. Ultimately, floating wind turbine assembly and installation may be cheaper than on-site bottom-fixed processes which are more susceptible to adverse weather conditions.

### Economic Feasibility

As a less mature technology, floating wind will attract a different class of investors, willing to take a higher risk in a less proven technology to potentially make a higher return. Green Giraffe expect early projects in the UK will have a lower leverage, in the order of 60 – 70%, and will command a small premium on debt rates[2] above bottom-fixed wind. The UK, with decades of experience in bottom-fixed offshore wind, stands out as a low risk market to enter when compared to other emerging floating wind markets with less experience.

[2] https://green-giraffe.eu/sites/green-giraffe.eu/files/190611_2019_green_giraffe_fow_seminar.pdf

Higher cost of financing has a big impact on the LCOE of a project. As an example, if a more conservative estimate of pre-tax real WACC is used on the case study, such as 9%, this would increase the LCOE of the 105MW standalone site from £91 per MWh to £106 per MWh.

This investment will be dependent on the technical risks outlined in section 0 being mitigated satisfactorily. Specific due diligence will be necessary for new technology, availability guarantees, design certification and ample contingency.

## Commercial Feasibility

There are several areas of commercial risk associated with both the bottom-fixed and floating offshore wind markets in Scotland in terms of consenting, revenue support, and grid connection cost and availability.

### Consenting

Floating wind technology requires new regulation as the mooring lines and anchors may interact differently than bottom-fixed structures with the marine environment. Given the inherent uncertainty in deploying demonstration projects in the water, Marine Scotland has introduced the Survey, Deploy and Monitor Policy, which aims to provide a risk-based approach to help address uncertainties in licensing for offshore renewables development, taking into consideration environmental sensitivity, device type and scale of development. Project operators closely monitor sites, which is used to inform licensing and consenting of future projects.

### Grid connection

Grid connection charges include a transmission network use of system (TNUoS) charge which is dependent on where in the country a generator is connecting to the grid, and charges are consistently higher in Scotland. This is not specific to floating wind but is an issue that is relevant to the types of site required for a hybrid site that are most often in Scottish waters.

### Revenue support

The current revenue support mechanism, in the form of competitive auction rounds, has been very successful in bringing down the cost of electricity, from £119.89 per MWh at the first auction round in 2015, to £39.65 per MWh at auction round three in 2019.

Over an estimated 25-year lifetime, at a strike price of £100 per MWh, the 105MW standalone floating wind development site would cost £262m[3] in revenue support over 15 years. On an average annual basis, this equates to £17.5m which only represents 3% of the previously allocated £557m CfD allocation. The hybrid project combining the 105MW floating wind with 900MW bottom-fixed wind could potentially accept a strike price around £50 per MWh. Whilst this isn't as low as the most recent auction prices, it is below current forecasts for future wholesale prices and could be considered subsidy free.

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[3] Using BEIS reference scenario wholesale price projection – www.gov.uk/government/collections/energy-and-emissions-projections

The proposed amendment to CfD Auction Round 4 to re-define the pot structure to remove direct competition between bottom-fixed offshore wind and floating wind is a positive step for the commercial deployment of floating wind, however it may have the impact that a hybrid site will fall between the two available mechanisms, making a project of this type less attractive.

### Opportunities for Scottish supply chain

There is an opportunity to develop a local supply chain for Scotland that is well equipped to provide the foundation for, and then benefit from, the long-term opportunities associated with the build-out of floating offshore wind, both in Scotland and more globally. By gradually increasing the scale of projects, the supply chain can prove their capability on smaller projects before investing in larger facilities to support commercial scale sites. In this context, hybrid projects may act as the next step of technology demonstration to prepare the UK supply chain for larger commercial projects.

As the projects increase in size, fabrication moves from being bespoke pieces to requiring assembly line style methods beyond the current capability and scale of the regional supply for some components. To build this capability, the region will need to invest in facilities to secure a large share of supply chain, as well as unlocking the opportunity to export these skills to projects elsewhere.

## CONCLUSIONS

Hybrid bottom-fixed / floating projects provide an opportunity to accelerate deployment of floating wind in Scottish waters at a cost close to current wholesale prices. The cost reduction in grid connection stands out as the largest impact of the co-location. As well as enabling more efficient use of infrastructure, a bottom-fixed offshore substation is a technical enabler to export electricity without the need for larger voltage (132kV +) dynamic export cables which are yet to be developed.

Over an estimated 25-year lifetime, at a strike price of £50 per MWh (2012 real), the N1 project is below some current forecasts for future wholesale prices and could be considered subsidy free.

However, the site conditions in the hybrid site are not optimal for either floating wind or fixed. The bottom-fixed turbines have a high substructure cost due to the water depth. The floating structures would be more economic at deeper water sites, with potentially higher wind speeds as well as less complex mooring line configurations.

There are limited sites in Scottish water where that hybrid sites are suitable for and this type of project is a tool alongside other innovative developments to accelerate floating wind cost reduction and technology maturity. The barrier of a clear revenue pathway for a hybrid site is a potential challenge in the near term. There are several developers focused on commercial scale sites and with the right type and level of support mechanism in place, this is many stakeholders' preferred route.

# Appendices

## AUTHOR PROFILE

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