Fixed vs Floating Foundations

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In the deep end – where does the transition from fixed to floating foundations really lie?

Monopiles are the most widely installed type of offshore wind foundation, currently installed in water depths up to around 30m. Beyond depths suitable for monopiles, bulkier jacket foundations have been used. It is generally accepted in the offshore wind industry, that the limiting water depth for commercial viability of jacket foundations lies around 50-60m. Beyond these depths, floating foundations should become technically viable options.

The offshore wind industry is maturing, and the low-hanging fruit of easily accessible shallow water sites have been built up. Sites now under consideration are deeper and further from shore. However, the potential for greater windspeeds further out at sea could balance the increased installation costs of projects in deeper waters. BEIS recently announced changes to the CfD scheme to allow for a separate strike price for floating wind projects at water depths greater than 60m[1]. This shows that the government is committed to supporting floating wind and sees 60m as a fixed to floating turning point. The change will undoubtedly incentivise development, but does a floating project represent good value for money for the consumer at water depths around 60m?

With many of the Scotwind sites situated in deeper waters than the generally accepted limit for jacket foundations, it can be tempting to assume floating will play a key role in the leasing round. However, technoeconomic modelling is fundamental to understanding the true economic balance of deeper water sites.

Xodus conducted internal modelling of offshore wind projects in sites of varying bathymetry, yielding interesting results in terms of the economic viability of jackets and floating foundations at water depths beyond 60m. In the analysis, a semi-submersible platform was compared to jacket foundations, both sized for the same site using corresponding met-ocean and geotechnical data. The turbine size considered was 12MW and the project capacity 1GW.

With only a few demonstrator projects in the water, floating offshore wind is still at very early stages of deployment. However, there is a huge amount of interest in the technology with numerous concepts for floating platforms under development at various technical readiness levels. Currently, the costs associated with floating wind remain high. Uncertainty also exists in defining the optimum installation and maintenance strategies and related costs.

As larger projects are erected, it is expected that supply chains will become streamlined and economies of scale will reduce floating costs. The Carbon Trust state in their Floating Offshore Wind Market & Technology Review that a 48% reduction in capital expenditure could be possible as technologies mature from demonstrator to commercial scale[2]. The announcement regarding the changes to the CfD scheme will likely accelerate development, and learning rates will be at the higher end of previous predictions.

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[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/869778/cfd-ar4-proposed-amendments-consultation.pdf *Contracts for Difference for Low Carbon Electricity Generation, BEIS, March 2020*

[2] https://prod-drupal-files.storage.googleapis.com/documents/resource/public/Floating%20Offshore%20Wind%20Market%20Technology%20Review%20-%20REPORT.pdf *Floating Offshore Wind: Market and Technology Review, Carbon trust, 2015*

Learning rates & economies of scale

The steep learning curve expected for floating will bring down installation, operation and procurement costs. This was taken into account in the analysis conducted. For a fair comparison, in the 2030 case, a learning rate was applied to both floating and jacket foundations. As jackets are considerably more established than floating, the learning rate applied to jackets was only a third of that applied for floating. This accounts for research and innovations in novel maintenance strategies, improved design and development of supply chains.

Results

Xodus completed a comparative analysis of floating and fixed wind for generic sites on the Scottish east coast. Water depth at the sites considered varied from 40m-90m. The analysis was done with current costs and predicted cost reductions for 2030. The results of the analysis are graphed below as CAPEX/MW against water depth. The greatest cost differences arise from installation and procurement; in our high-level comparison energy yield was widely similar for the two technologies. On the other hand, OPEX costs are highly dependent on-site conditions, distance to port and the type of floating foundation considered. Hence, CAPEX is visualised here to provide a more transparent and general comparison of the two foundation types. The overall LCOE results were reasonably consistent with the CAPEX trends. The analysis was also repeated for the west coast, yielding similar results. It is worth noting jacket and floating platform sizing was only carried out at a high level and not detail design was undertaken at this point.

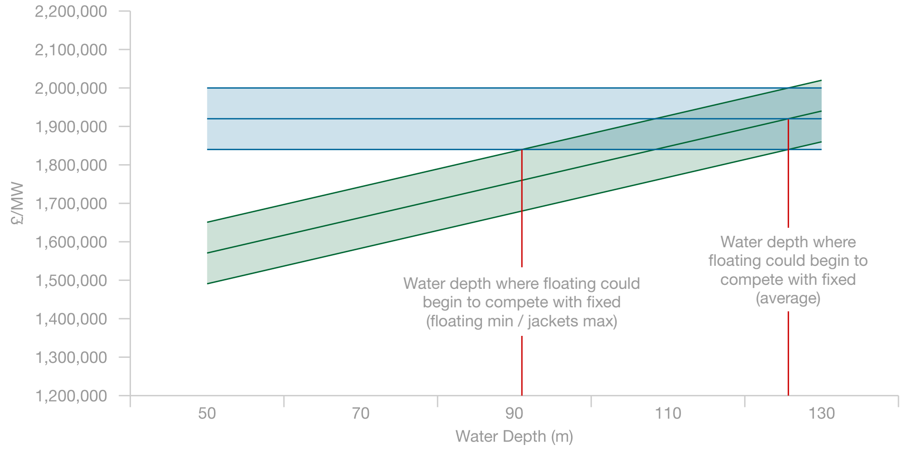

Figure 1

Current floating vs fixed project CAPEX costs for varying water depths

East Coast 2020

- 🟦 *Floating*
- 🟩 *Jackets*

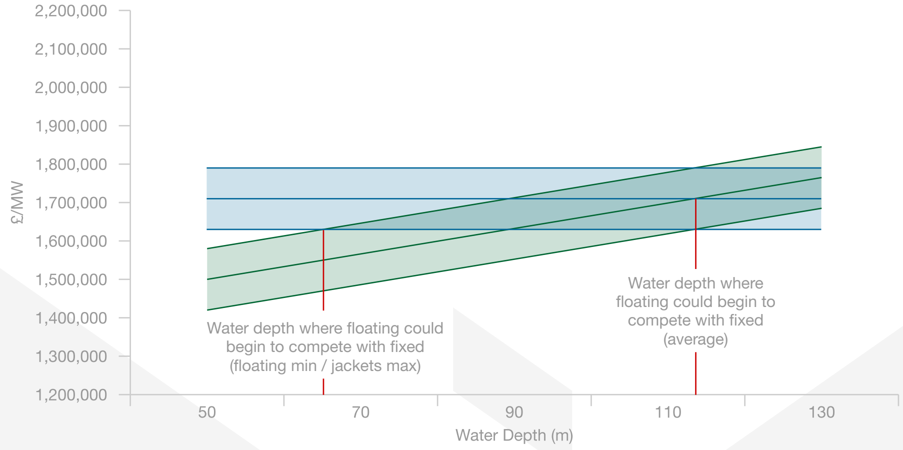

Figure 2

Expected floating vs fixed project CAPEX costs for varying water depths

East Coast 2030

- 🟦 *Floating*
- 🟩 *Jackets*

The results show that fixed foundation CAPEX increases almost linearly with depth, whereas floating costs remain quasi-static. Floating remains significantly more expensive even at water depths considerably beyond the 60m threshold. The 2020 plot shows the uncertainty ranges first crossing at around 90m, implying that this is the minimum water depth floating could start competing on a purely cost basis with fixed. In the 2030 graph, this minimum threshold has decreased to 65m. The average value lines cross only at 115m, and the extreme ranges beyond the scale of the graph, indicating a large range for the actual location of the cross-over point. The uncertainty range in the 2030 graph is wider because of the greater uncertainty in learning rates used in the analysis.

Running the model for floating and fixed cases for several different sites supported the trend. The results were surprising, inviting a more detailed analysis of the cost drivers. Even with the expected cost reductions applied, 60m seems low for the generally accepted transition point.

Cost drivers

The following site-related factors were identified as examples of CAPEX cost drivers differentiating between floating and fixed.

VARIABLE COST DRIVER	FIXED JACKETS		FLOATING	
Water depth	Jacket size increases with water depth, increasing fabrication and steel base costs.	Significant effect on jacket CAPEX	Length of mooring lines increases with water depth. Platform size is unaffected.	Small effect of floating CAPEX (from a certain water depth)
Met-ocean conditions	Harsh met-ocean conditions increase required jacket weight and increase the probability waiting on weather disruptions.	Moderate effect on jacket CAPEX	Harsh met-ocean conditions considerably increase floating platform weight and increase the probability of weather disruptions. However, floating installation is less affected by waiting on weather than fixed.	Significant effect on floating CAPEX
Distance to shore & installation vessel rates	Longer transit times equate to higher vessel costs. Fixed installation vessels are more expensive than those required for floating.	Moderate effect on jacket CAPEX	Longer transit times equate to higher vessel costs, however floating installation vessels are less expensive than those for fixed.	Moderate effect on floating CAPEX

The key parameter in the analysis is foundation weight. It dominates over all other criteria, and the cross-over depth is only achieved when the weight of the fixed jackets equates that of the floating platform. For fixed foundations, the jacket weight is defined by water depth and wind, wave and current loading. The floating platform weight is unaffected by water depth, except for a relatively small change in mooring line length. Instead, met ocean conditions define the size of the floating platform required to maintain tower tilt, natural period and loading within acceptable limits. Two conclusions relating to the cross-over water depth can be drawn from this. Firstly, the cross-over water depth is likely to be lower for a platform design lighter than the semi-submersible, such as a TLP. Secondly, the cross-over water depth will vary depending on site met-ocean conditions.

There are other challenges related to floating wind that are not quantified in this analysis and that can have a significant penalty on installation costs. For example, the construction port selection available in Scotland will be very restricted due to the required float-out draft and drydock size. Due to limited experience, installation and maintenance techniques for floating are still highly conceptual and unexpected costs are likely to arise as these operations move through a learning curve. However, extreme water depths also create new challenges for jacket installation. Large footprint jackets face storage space constraints at installation ports, are likely to require complex split lift operations due to limited crane lift capacity and will have an increased installation duration as less units will fit onboard the installation vessel per trip. These effects have been quantified in the model as increased operation durations and greater vessel costs, however it is likely that once a certain jacket size is reached, installation is no longer feasible or safe with current technology and infrastructure.

Conclusions

The results should not be taken to mean that floating will only ever be competitive with fixed at extreme depths. Xodus believes commercialisation of floating offshore wind will be a case of when rather than if. The gradient of the learning curve will depend on progress of research, successes of demonstrator projects and amount of investment into required infrastructure. What the results do show us, is that the tipping point between commercial viability of fixed and floating foundations could be at a greater water depth than previously expected. Furthermore, the decision between floating and fixed is not dictated merely by water depth, but by a combination of factors. Identifying the most suitable project concept option should be done through detailed techno-economic analysis, and fixed jackets could potentially be seen in unexpectedly deep waters.

Notes (model assumptions)

As the purpose of the modelling was comparative, identifying costs that differentiate fixed from floating was key. The main differences in floating and fixed costs are detailed below. For the sites in question, only offshore installation was more expensive for jackets than floating. The same turbine size and wind farm capacity were assumed for both fixed and floating.

COST BREAKDOWN	FIXED JACKETS	FLOATING
Procurement costs	The foundation procurement costs are calculated from jacket weight and consist of a steel base cost and a fabrication cost.	The floating foundation procurement costs are calculated from platform weight and consist of a steel base cost and a fabrication cost. Weight based costs are also added for mooring lines, anchors and ballast.
Onshore installation	Onshore installation operations included tower assembly only.	Onshore installation operations included tower assembly as well as platform and turbine assembly in a drydock.
Offshore installation	Offshore installation operations included piling, jacket installation, turbine lift, and grouting. Installation costs were calculated from required vessel day rates, using operation durations per turbine to define total durations.	Offshore installation operations included mooring line and anchor installation, turbine float-out and hook-up.