EMEC THE EUROPEAN MARINE ENERGY CENTRE LTD

White Paper | The need for a National Floating Wind Test Centre

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The energy opportunity

Located as we are on the east side of the large ocean basin, Britain and Ireland are blessed with a strong and consistent offshore wind resource.

With energy being the multiple of power and time – and where power is a cube law of wind-speed – it is no surprise that offshore wind developers look to the UK as one of the best locations globally to build offshore wind projects. Consistent strong winds mean good energy generation, dependable revenues, and the lowest risk of not being able to service the borrowing that funds large offshore projects.

Offshore wind is not without risk though, as technology and project developers have discovered over the twenty years or so since the first commercial offshore wind farms were built in Denmark and the UK. As with all major engineering projects the 'risk cascade' applies:

Engineer out the risk > Contract out the risk > Insure the risk > Bear the remaining risk

Engineering out the risk

'Engineering out the risk' is key because it means there is less risk down every subsequent part of the cascade. The less track record there is for a design, the less chance there will be for the projects to cost-effectively share the risk with third parties. Furthermore, risk appetites of suppliers, insurers, investors and markets can all change over time, both gradually with the benefit of experience, but also sharply and abruptly in response to some particular failure, or worse, the discovery of a serial defect within a fully deployed fleet of many tens or hundreds of units.

Insurers, for example, limit the scope of cover for serial losses, and exclude wear and tear and fatigue, while being able to review cover on an annual basis to potentially exclude defects that might have become apparent. The residual risk can therefore accelerate rapidly to the end of that cascade.

This 'engineering out the risk' phase is why, across all industries, we have research labs, crash test dummies, test centres, test pilots, asset monitoring sensors and algorithms, and regular inspections during normal operations.

At the same time, projects will naturally seek to engineer down cost, but some of these initiatives can actually increase risk – in the extreme necessitating the retrofitting of more robust protections for the project assets – which arguably has already been seen in fixed offshore wind with cable protection systems.

Limited understanding of the revised risk profile can therefore actually increase costs (and downtime) to the project, rather than affording cost savings.

Learning from fixed offshore wind

In the history of offshore wind this engineering evolution happened incrementally as onshore wind turbines were first marinized and deployed offshore, then scaled up, deployed further offshore, scaled up some more, and so on. It was ever and always a small step beyond where we were at the time. With 1 and 2 MW turbines to 3, to 5, to 7, to 9 MW, and so on, and from monopiles, to tripods, to jackets, to maxi-piles, to twisted jackets, etc.

At the same time blades got ever longer, hub-heights higher, nacelles heavier, towers wider and heavier, and the cranes and vessels required to lift the components ever larger, more capable, and more expensive. The benefit though was the ever lower and more competitive cost of energy produced, fuelled in countries like the UK by competitive auction processes that rewarded a 'how low can you go' bidding approach.

However, we've perhaps now gone too far with that. The 'arms race' for ever larger turbines and the lack of any bidders in the recent AR5 allocation round show that there is both a floor limit to price below which no-one can make a profit, and probably also an upper turbine size limit above which the engineering difficulty and risk of loss of revenue in the event of failure become excessive. It's not clear yet whether we've reached that limit, but if not, it's bound to be soon.

Each upscaling of turbine size pushes back the insurer's level of confidence through lack of long-term operating data around failure rates and associated costs. The ever-larger installation and maintenance vessels are rarer and therefore harder to contract on the spot market for one-off repairs – further increasing cost and crucially downtime, with the loss of more powerful turbines representing a greater revenue loss per day out-of-action. These risks are magnified even more dramatically if the few suitable vessels are based, or are already contracted out, thousands of miles from your project site.

50+ GW of technical risk

As we look ahead from this backdrop to the 50+ GW pipeline of bottom-fixed and floating offshore wind (FOW) projects destined for UK waters over the coming decades, we need always to consider that technical risk. Deploying large, innovative projects a long way from shore is not without risk, and we should be mindful of that. Developing and building a big offshore wind project is very different to popping down to the local car dealership to buy the latest model.

This is especially true for floating offshore wind, where we are combining multiple new risks all at once – bigger turbines, deployed further from shore, in deeper and more energetic waters, and all of it free to move in six degrees of freedom. Moorings and dynamic cables will be subjected to a regime of motion and stress not previously experienced even in oil and gas deployments, and these may be difficult to adequately physically inspect over time, for instance due to thick layers of marine growth. The forces involved in floating wind are bigger, the masses to resist those forces larger, and the environment to operate in likely to be much more challenging. That's not to say that these challenges cannot be overcome – give good engineers enough time and money and they can overcome more or less anything!

However, this is a competitive marketplace and clean energy needs to be affordable as well as dependable. This takes us back to 'engineering out the risk' and doing so cost-effectively at an early stage. In most engineering disciplines this means making maximum use of labs and test centres, and making sure that what goes into serial production is a proven product unlikely to fail in real life operations. Prevention is better (and cheaper) than cure, as several major players in the offshore wind industry have learned recently and in the past.

De-risking through demonstration

In floating wind we've achieved a good degree of de-risking by means of some early single turbine demonstrators at the 2 MW scale, then we've built on this with higher output turbines and small demonstration projects formed of a handful of turbine units, typically all below 10 MW each. From this we are about to launch an industry that in the UK alone needs around 2,500 floating turbines at an average of around 18 MW each. An alarming leap.

In fact, it's less like going to the car dealership to buy the latest model, and more like going to the dealership to ask for a model:

- that hasn't been made yet;
- that hasn't therefore been trialled on a "test track" over long distances to prove the body can handle the weight and the higher power from the engine;
- that floats;
- and by 'floats', we mean 50-100 kilometres offshore;
- when we say 'offshore' we mean in the North Sea, the Celtic Sea, and the North Atlantic, all of them ocean environments renowned for not being particularly 'gentle' on any kind of technology.

This is analogous to an 'Apollo Programme' of engineering innovation; a new challenge that stretches significantly beyond current engineering capabilities. Except that in this case we're not aiming to be the first country to walk on the moon, we're actually trying to rapidly industrialise a completely new energy source for the UK, and to put several thousand floating turbine units out into the ocean all within a few years of each other.

Sticking with the Apollo Programme analogy, NASA was made responsible for the US space programme by the US government, but it was Edwards Air Force Base that emerged as the epicentre for testing many of the technologies subsequently developed to get astronauts safely to the moon and back – i.e. during that programme's 'engineering out the risk' phase.

The UK needs its equivalent of that Edwards Air Force Base to de-risk floating offshore wind, and this white paper explains why an exposed and energetic spot 20 km directly west of Orkney should be the location for it.

UK floating offshore wind demonstration

Conceived initially around five years ago as a likely 'need' of the floating offshore wind sector, Orkney-based European Marine Energy Centre (EMEC) has been investigating and examining options for a national floating wind test centre since early 2020. More recently EMEC accepted a 60 MW grid connection offer to connect its proposed site into Orkney's soon-to-be-connected 220 MW cable to the Scottish mainland and the UK national grid.

EMEC has a twenty-year history in providing pre-consented test and demonstration berths to wave and tidal energy technologies and, as well as guiding other nations in how to set up their own test centres, also produced the first green hydrogen from offshore renewables in 2017. EMEC is no stranger to innovation and is well-practised in hosting novel clean energy technologies, and to this day is the only UKAS-accredited centre in the world for testing marine energy technologies to IEC standards.

Since EMEC was formed in 2003 many European countries have established their own equivalent marine energy test centres (see figure 1), almost all of them originally conceived as wave energy test sites, but now re-positioning themselves as capable of testing floating offshore wind technologies too. Like EMEC's grid-connected wave energy site at Billia Croo, this wave test site history means they're reasonably close to shore, in reasonably shallow water, and typically with grid connections that are adequate for nascent wave energy technologies and concepts, but generally inadequate for testing the large 15 MW and larger FOW turbines of the future, and certainly not for testing four or more different kinds at once – as would be the requirement for a national test centre. More than that, the wind resource is nothing like what we see in the UK, and certainly not what we see in Scottish and Atlantic-facing waters in particular.

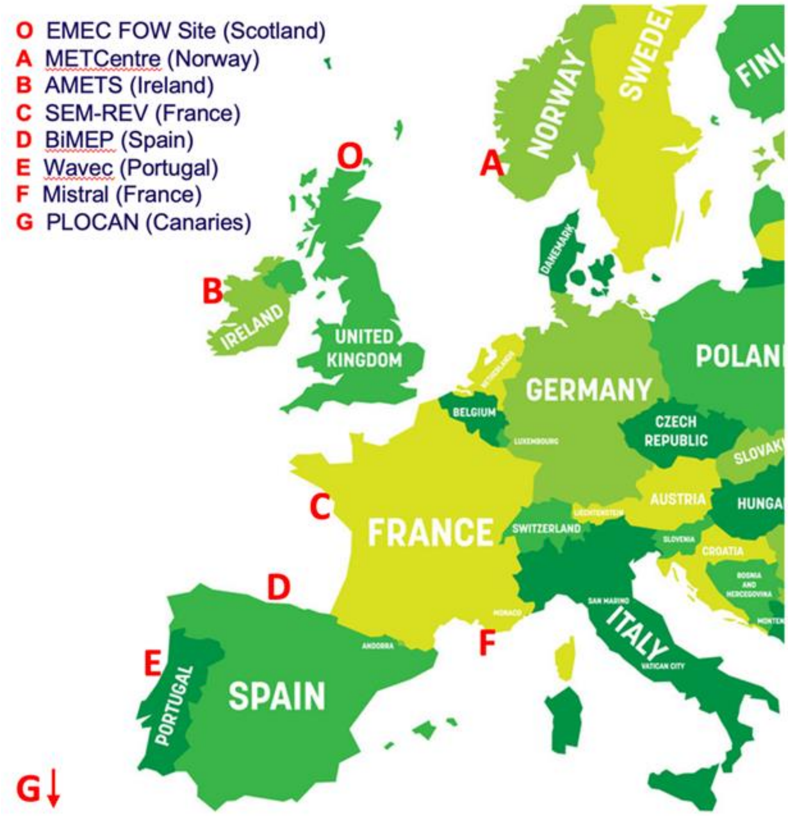

Figure 1 | European ocean energy test centre locations and countries

Why Orkney?

To put this claim into perspective, colleagues at EMEC carried out some comparison analysis using Copernicus data (see figure 2).

As might be anticipated given its exposed location with a 2,000 mile fetch across the North Atlantic to Canada and the USA, Orkney sees bigger winds and bigger waves than every other site in Europe. It's the reason why Orkney has some of the best wave energy potential in the world, and the reason why Orkney's onshore wind turbines achieve such high capacity factors, even though they'd be considered small by modern standards.

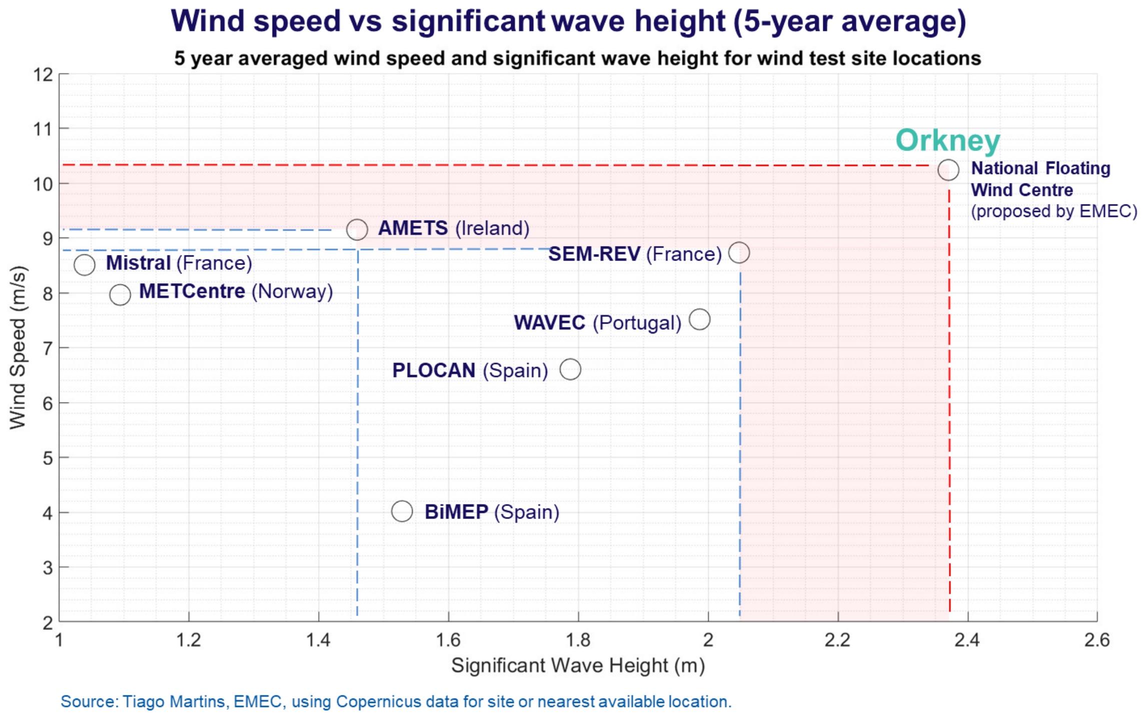

Figure 2 | Wind-speed and wave-height comparison of the European test centres – five year average

However, it is not really wind speed that breaks wind turbines, or wave height that damages shipping, but it's the power and energy in the wind and waves that is problematic. Since wind power is a cube factor of wind speed, the same chart plotting wind power and wave power against each other looks rather different (see figure 3).

In this we can see that Orkney is some long way beyond the other European test centres for both wind power and wave power, and in fact the area bounded by the dashed red line – that represents the typical metocean conditions 20 km west of Orkney on an average day – is nearly double the non-pink area bounded by the blue dashed line (which represents the metocean conditions of the 'next best' sites of SEM-REV in France's Bay of Biscay and the Atlantic-facing AMETS on the west coast of Ireland).

Beyond that, when we then overlay typical ScotWind, INTOG and Celtic Sea project locations modelled using the same process (figure 4), we see that none of the other European test sites have wind and wave climates that represent real project locations in UK waters. This is particularly important for certification bodies and insurers, who typically will be looking for an absolute minimum of 8,000 hours of normal operation 'in a representative environment' to provide project certification.

Representative environment for project certification

Insurers rely heavily on project certification - as opposed to more general type certification of individual components – because this project certification process will address the fitness for purpose for the designs given the particular metocean conditions at the project site. Data solely obtained from a less energetic test site will make this project certification far more problematic, and insurers are likely to be very uncomfortable with engineering calculations extrapolated from numbers they may see as non-representative.

The outcome of this is that if you test at an existing European test centre, this does not mean that your technology is considered proven and certifiable/bankable for deployment into a ScotWind or Celtic Sea project. You might choose to deploy anyway, you might even get though final investment decision (FID), but the scope of project insurance is likely to be reduced and/or premiums and deductibles increased, and the risk and consequence of failure is all on you.

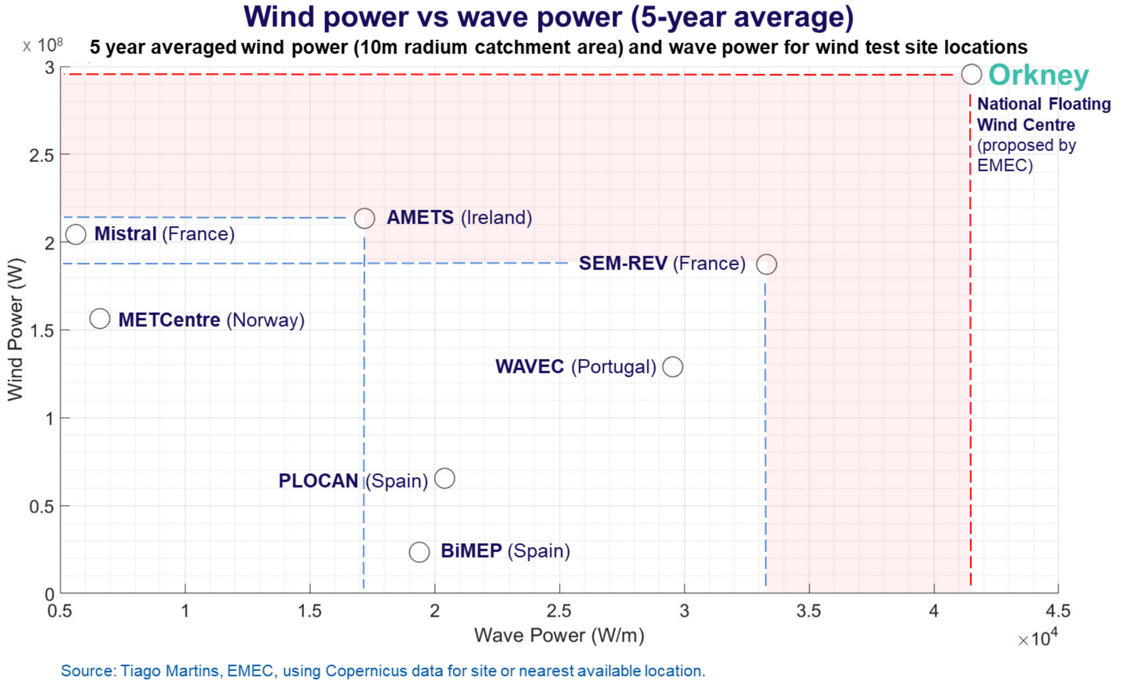

Figure 3 | Wind power and wave power comparison of the European test centres - five year average

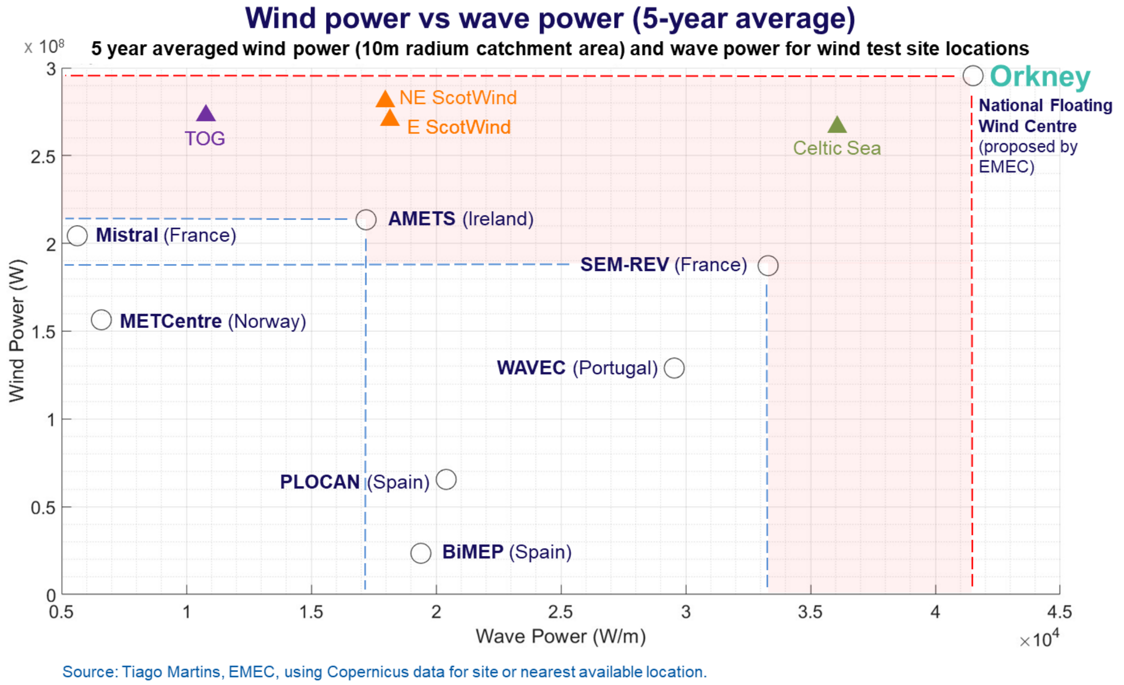

Figure 4 | Wind power and wave power overlay of FOW projects in UK waters - five year average

So far, the charts presented have all been about the five year average conditions – that's all very well for energy yield and for breaking capacity factor records, but what about the 100 year storm event? That's what insurers really care about, and what engineers have to design for.

Figure 5 shows this 100-year storm event data for European test centres charted along with our typical UK floating wind project locations. The difference between an Orkney FOW test site and the existing European test sites (as indicated by the shaded pink area) is not as prominent as in the previous charts. This seems slightly counter-intuitive at first, but is because 100-year storms are huge systems covering thousands of square kilometres. They are also persistent and track for hundreds of kilometres, and so encompass huge swathes of the European continent over the fullness of their duration.

Consequently, but depending on their exact path off the Atlantic and into Europe, their winds - and the waves blown up by those winds - will affect nearly all test sites to some degree or other. Even so, figure 5 still shows that UK projects in the North Sea, Celtic Sea, and the north and east coasts of Scotland, will all see more energetic storm events than the other European test centre locations.

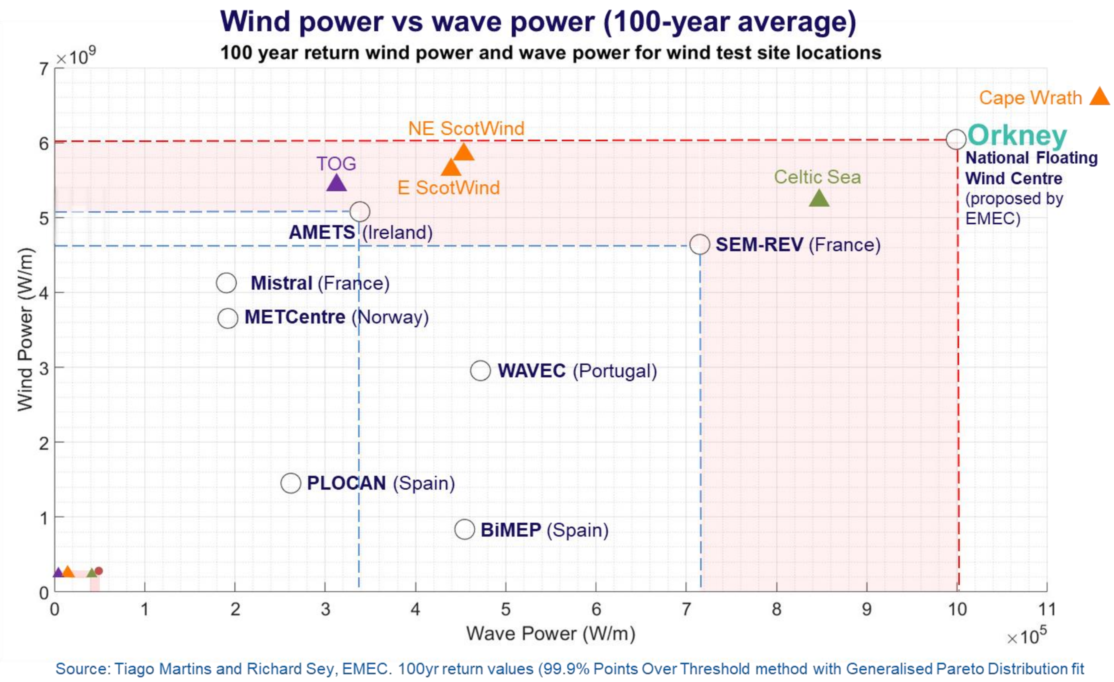

Figure 5 | UK floating projects and test centres - 100 year storm event

Storm event risk

Perhaps more important for developers and insurers is to recognise the difference in energy between the everyday 5-year average and the 100-year storm event (i.e. to compare the values on the x and y axes between the two charts). Right down in the bottom left-hand corner by the origin, the 100-year storm chart of figure 5 contains within it the 5-year average chart data of figure 4, plotted to the same scale. From this you can see that wind power during a 100-year storm event is ~20 times the 5-year average, and that wave power is ~25 times. Each taken alone would be a significant increase in forces and stress on the floating wind system, but in storms these both come simultaneously, and that is why storm events represent such a significant risk for floating offshore wind projects.

Such storm events are of course what insurance is for, but to put that into context, a total loss of a single floating turbine at the size we are now looking at would likely result in a loss of £50m to £100m, so the loss of several turbines and/or a floating sub-station would be insurance market-changing, i.e. it would be likely to result in a sustained period of tougher insurance terms for subsequent floating wind projects. Furthermore, even if remaining afloat, the failure of a platform to hold station by breaking loose from its moorings would constitute a massive threat, not just of damage to the rest of the array, but to other users of the sea.

This is very significant difference that will be crucial for engineers to incorporate in their designs if they are to adequately 'engineer out the risk' and keep certification bodies, insurers and lenders satisfied. Demonstrating and proving new and scaled-up existing designs at a representative test centre will be critical to learning and confidence, and to achieve the certifications that will be required by multiple parties prior to design freeze and FID.

The consequence of failing to achieve these certifications is likely to lead to significant delay and cash burn in the project, so ensuring that Tier 1 contractors and others dedicate adequate time to de-risking and proving their designs in the representative environment will be key. Ideally you would have tested a full-scale unit at EMEC for at least the insurer absolute minimum of 8,000 operating hours to generate confidence from all parties *before* rolling out an array at scale.

National Floating Wind Test Centre

The national floating wind test centre proposed by EMEC to enable this is a four-berth grid-connected test site, that can be extended to up to 8 berths if there proves to be sufficient demand. The site location is 20 km to the west of Orkney (see figure 6), and, as well as ideal water depths of 85-100 metres, that position gives sufficient distance from shore to consent floating turbines up to 20 MW, with tip heights in the order of 300 to 350 metres. Furthermore, being orientated directly across the predominant wind direction means clean wind for testing for the majority of the time, whilst also being able to replicate the 'middle of the windfarm' wake condition when the wind is from the SSE and blows along the line of turbines at the test site.

Beyond that, the very consistent wave direction allows technologies that weather-vane to the wind on a single-point mooring to fully test how the balance of wind and wave forces play out, including their effect on floater movement and energy yield if the wind and wave directions are mis-aligned (e.g. waves from the west but wind from the SSE). Evidencing this in the real-world environment at full scale will be crucial in achieving bankability, especially where digital and tank-scale physical modelling are suspected/known to be incomplete or uncertain.

Importantly for FOW developers, as well as having strong and consistent winds at the test site, the entrance to the sheltered waters of Scapa Flow – the largest deep water natural harbour in the northern hemisphere - is just 24 km from the test site (see figure 6). Scapa Flow has the potential for wet-storage of many tens of FOW units, and will include the Scapa Deep Water Quay development proposed by Orkney Islands Council. This facility will have significant FOW-specific port-side infrastructure and supply-chain, including a suitably sized quayside ring crane for full turbine-floater integration.

Proximity to such assets, and the wider pool of FOW O&M assets that will develop across Scotland and Norway over time, will allow reduced mobilisation costs and delay should they ever be required for regular O&M activities, or for an insurance event. For the latter, ready availability, reduced delays, quicker return to normal operation, and reduced payouts for loss of generation revenue, will all help to reduce the cost of a claim and therefore the cost to the windfarm owner.

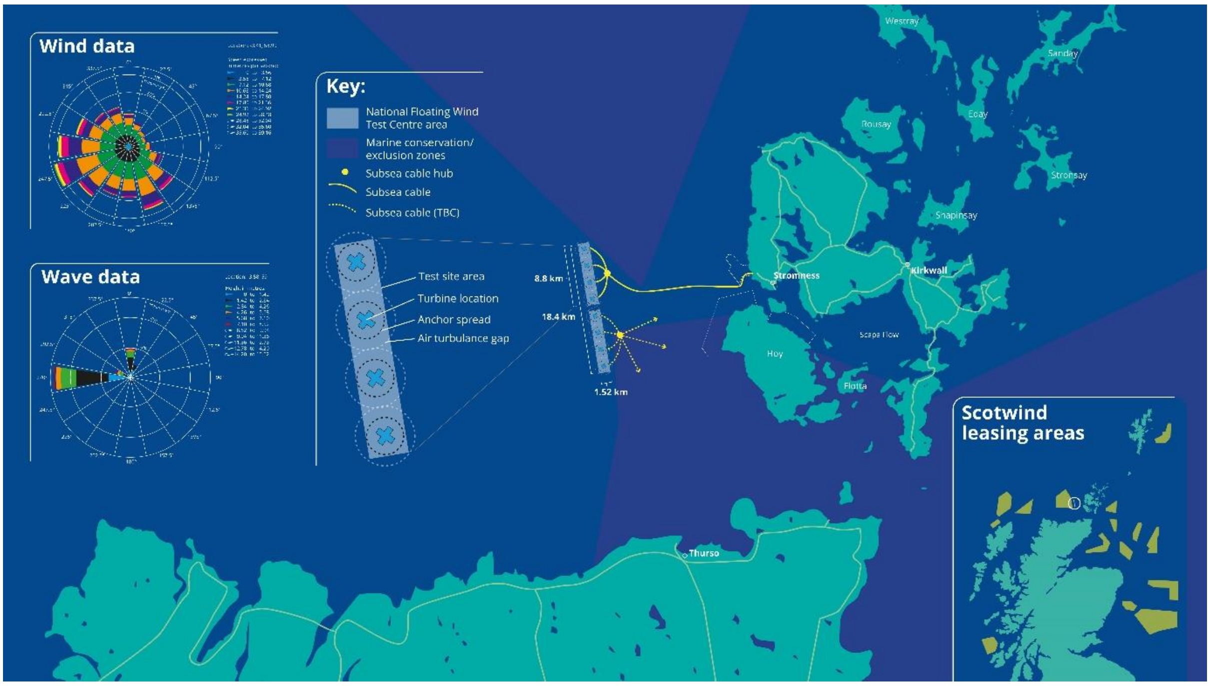

Figure 6 | Proposed floating wind test centre location and wind and wave roses

Phased approach for 'fleet leaders'

In terms of the test site layout the expectation is to consent for up to 8 berths, but deploy in two phases. The first phase being for four individual berths, which can potentially be followed by a further four berths should demand dictate.

The first four berths would be connected by 66 kV dynamic cable and standard wetmate connector to a subsea connection hub, and from there via a single 66 kV export cable directionally drilled under the beach to EMEC's existing Billia Croo wave test site. EMEC's substation will step-down the voltage to the island distribution voltage of 33 kV, and power will be transmitted across the island to the grid connection point at Finstown.

The grid connection offer for that onshore cable has already been accepted, and the clock is running towards a 2028 energisation date. Having a defined energisation date puts EMEC's test centre ahead of almost all of the large commercial floating projects in the UK, and ensures that there is sufficient opportunity to test, de-risk and scale-up technologies in time for these first project deployments.

Looking further ahead, keeping a device on test at EMEC for longer than is strictly necessary just for proving and certification also allows developers to have a 'fleet leader' turbine that can accumulate operational hours and harsh weather events at a faster rate than any commercially deployed units. As a kind of real-world 'accelerated life testing', this provides the opportunity

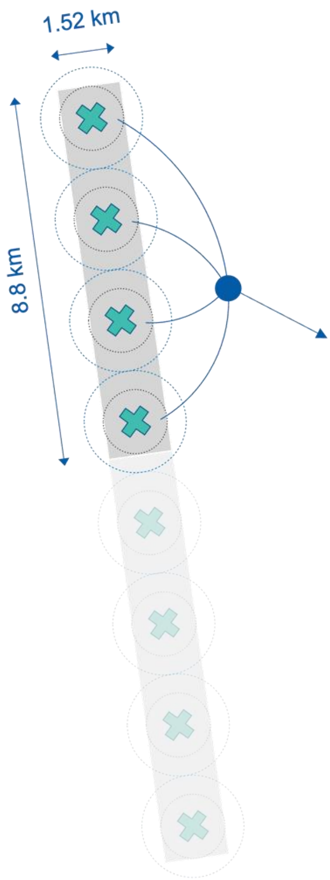

Figure 7 | EMEC test site layout

to identify and develop solutions for any emerging fatigue or issues at an early stage, and to roll them out to the wider commercial fleet before they are encountered by regular owners. This obviously helps with ensuring contractual availability obligations are met and/or exceeded, and further reduces the risk of failure events that might lead to an insurance claim.

Harnessing export potential

Beyond that, there is a strong commercial case because a successful test and certification deployment at EMEC's FOW test site off Orkney is likely to be valid for many other project locations around the world. (i.e. if it works in the energetic waters off Orkney it will work anywhere). This means that once a technology is proven at Orkney it should be possible to avoid re-testing for local conditions elsewhere to achieve insurability and bankability there, saving both time and money for developers with global project ambitions.

Conclusions

In summary, this white paper argues:

1. that the UK needs its own dedicated 'National Floating Wind Test Centre' to properly and believably test and prove floating technologies in the metocean conditions that are truly representative of the actual locations into which they will be deployed;
2. that the best location for this is the high energy site EMEC has identified 20 km west of Orkney;
3. that this site can be ready and energised in time to meet the needs of UK floating offshore wind projects anticipated for ScotWind, INTOG, and the Celtic Sea; and
4. this site is ideal for more reasons than just wind speed and wave climate because it both addresses the very particular needs of insurers and certification bodies, and provides valuable export benefits for project and technology developers looking to build global FOW portfolios.