Offshore wind
floating futures

Part 1

Globally, some 80% of potential offshore wind power resources are said to lie in waters more than 60 metres deep. These deeper water sites often offer stronger and more continuous wind, but probably cannot be exploited with conventional "fixed bottom" wind turbine units. So the industry, following a path previously charted by offshore oil and gas, is developing floating turbine foundation units.

Expectations of floating technology are high. At the end of 2019, only 66MW had been installed worldwide but, by some estimates, this could grow a hundredfold by 2030 (implying a rate of growth about 10 times faster than fixed bottom offshore wind capacity achieved between 2008 and 2018).[1]

This is the first of a series of articles about floating offshore wind projects, and how far existing contractual and regulatory frameworks may need to be modified for them. Although there are still a number of technical risks to be addressed in relation to floating projects, it seems likely that mitigating the commercial risks will be key to allowing the technology to achieve its full potential.[2]

In this article, we look at: some further background; what floating offshore wind projects consist of; some general preliminary legal issues; and how the construction contract packages, and operation and maintenance (O&M) arrangements, for such projects are likely to compare with what is found in the fixed bottom market. We close with some suggestions of next steps and where the industry might do best to start in scaling up the deployment of this promising technology. Future articles will include analysis of transmission, offtake, governance and finance issues.

Why floating offshore wind?

A large percentage of the capital cost (and subsequent value) of any wind farm is found in the wind turbines and foundations. Currently, the generating assets of offshore wind farms consist almost entirely of wind turbines mounted on a fixed foundation driven into, or resting on, the seafloor.

The costs of offshore wind projects using fixed bottom technologies have fallen significantly and it has become feasible to build them much further from the shore than was once the case. However, as noted above, they cannot readily be deployed

1 Global Wind Energy Council, Global Offshore Wind Report 2020.

2 A conclusion reached in Offshore Renewable Energy (ORE) Catapult, An Introduction to Risk in Floating Wind (2017), which still holds good today, notwithstanding technical progress in the intervening three years and estimates that floating offshore wind may reach levelised cost of electricity (LCOE) parity with fixed bottom installations sooner than previously expected.

in waters more than 60 metres deep.[3] Even in shallower seas, the condition of the seabed sometimes makes them impracticable, and the areas where the industry has expanded to date have been determined in part by where seabed conditions are most conducive to development. Although some UK and French projects have started to push the boundaries of the kind of conditions in which fixed bottom foundations can be installed, it may be that once floating offshore wind has become cheaper, they will be deployedin shallower depths as well.[4]

In countries with steeply shelving coasts, it may be impossible to realise the commercial potential of offshore wind to any significant extent without floating technology. However, even in the UK, which has been a leading market for offshore wind partly because of its relatively wide range of suitable shallow water sites, there are compelling reasons to move to deeper waters with floating turbine platforms. On the one hand, government policy and expert opinion propose multiple tens of GW of offshore wind power in the UK's future "net zero carbon" generating mix.[5] On the other hand, as the industry grows, and more capacity is built or planned in the available areas of shallower water with relatively easy seabed conditions, the potential for cumulative adverse impacts on the environment and other users of the sea in those areas increases. This may pose problems under nature conservation legislation, weaken the public consensus in favour of offshore wind, and make it harder for new fixed bottom projects to be developed.[6]

The obvious solution to the limited range of fixed bottom offshore wind farms is to open up a much wider range of potential sites by developing a floating alternative which can operate in far deeper waters and more challenging seabed conditions. This would use floating substructures and moorings, and dynamic cable connections, based on designs and engineering that draw on experience from the offshore oil and gas sector, which should have less of a negative environmental impact both during installation (e.g. less need for piling activities that disturb sea life) and operation (e.g. reduced scour effects). A small number of models have already been successfully deployed in arrays of 10-50MW. Over the next two or three years, more are expected to reach this stage, and one or two others are expected to reach "pre-commercial" (50-200MW) deployment. Now that proof of concept has been demonstrated and (with floating offshore technology now being regarded as having reached a high technology readiness level) a useful quantity of operational data has been gathered from such schemes, the technology should soon be ready to progress to full-scale commercialisation.

In addition to the UK and France, other jurisdictions identified as potentially promising floating offshore wind markets (at least in terms of wind resource and demand for power on or reasonably close to the coast) include Ireland, Portugal, Norway, Spain (the Canary Islands), Japan, China, Taiwan, South Korea and the US (particularly the west coast and Hawaii).

Floating technology is currently considerably more expensive per MW than fixed bottom, but it is hoped that, as with fixed bottom, larger projects will lead to cost reduction through economies of scale and other efficiencies. The first floating projects can use similar turbines to fixed bottom ones, so that floating projects can benefit from cost reductions that the fixed bottom offshore wind industry has already achieved through high-volume production, leading to economies of scale, as well as technical progress in turbine design and manufacture. At present, the same turbine may not generate as efficiently when mounted on all forms of floating

3 For a useful collection of statistics on the depth and distance from shore of existing offshore wind farms (to the end of 2018), including commentary on foundation types, see S. Sánchez, J-S. López-Gutiérrez, V. Negro and M. Dolores Esteban, Foundations in Offshore Wind Farms: Evolution, Characteristics and Range of Use. Analysis of Main Dimensional Parameters in Monopile Foundations. Journal of Marine Science and Engineering, (2019), 7, 441 (available here).

4 Fixed foundation projects in the southern North Sea have benefited not only from relatively shallow water, but also from deep consolidated sand and clay on the seabed. Even with these conditions, careful consideration has to be given to boulders and protruding rock units, resulting in occasional "refusal" during piling operations. Examples of developments in more challenging conditions include projects like Inch Cape, Neart na Gaoithe, and Saint Brieuc. It is known that the seabed near the surface is so weak, in some new areas, outside the southern North Sea, that 80m piles have been driven, even to support a 4-legged jacket. It is not hard to imagine locations like those of these more "marginal" projects (which are currently using 3-leg or 4-leg jackets) being suitable candidates for floating platforms in the future.

5 See the March 2020 UK government consultation on possible amendments to the Contracts for Difference (CfD) subsidy regime for renewables and Dentons' article on it here, as well as the Committee on Climate Change's 2019 Net Zero report, which contemplates a near-tenfold increase in offshore wind capacity by 2050, to 75GW (see, for example, the accompanying technical report). See also related Lloyd's Register commentary on UK government's 40GW by 2030 aspirations here.

6 There is also the possibility of new consents being revisited or made subject to additional conditions as cumulative environmental impacts change (for example, as a result of new projects). See the recent UK government review of consents in the southern North Sea, available here.

substructure as it would on a fixed bottom foundation. However, the technology can be adapted to deal with these issues and they may in any event be offset by the access to areas of higher wind capacity factor that floating technology can provide.[7] In this and other technical areas, learning by doing will be essential to bring down the costs of floating substructures.

Just as special subsidies for the electricity generated by floating offshore wind in France and Scotland have helped to stimulate a number of pilot projects, so public financial support may also help to scale up the new technology and bring down costs. However, at present, floating projects will struggle to win in a competitive tender or subsidy allocation process against fixed bottom projects. It therefore makes sense to hold separate tender processes, or effectively to ring-fence some subsidy budget, for floating projects, until floating projects become competitive with fixed bottom ones.[8] France[9] and Japan[10] have already adopted this approach and the UK is considering doing so.[11]

Another factor that may help to scale up deployment of floating technologies more quickly is the number of deep-pocketed oil and gas companies increasingly committed to net zero goals which are keen to exploit, in the offshore wind context, the expertise that they have gained over decades building offshore oil and gas platforms. Oil majors have already been involved in some fixed bottom offshore wind projects, but the move to floating technology brings offshore wind closer to the core skills of companies that – as well as being experts at building and operating floating offshore structures – have recently achieved very significant reductions in the costs of their installations, for example through greater standardisation. They (and oilfield services companies) are starting to buy up, or take stakes in, floating offshore wind technology companies.[12]

In the UK, there is an additional incentive to get involved in the sector in the form of regulatory encouragement for upstream electrification with low carbon power, both for existing oil and gas platforms (brownfield electrification) and greenfield electrification of new platforms in deeper waters beyond the reach of fixed bottom technology. Increasing carbon prices (from which the upstream sector has to some extent been shielded to date) may make even relatively expensive floating offshore wind cheaper than the default option of on-platform fossil-fuel generated power supplies.[13]

Historically, oil and gas companies are used to larger and more complex installations than even a large floating offshore wind turbine array, with correspondingly larger budgets. However, in order for the new technology to develop rapidly, they (and perhaps also the oil and gas services sector) will need to bring to bear not only their financial muscle and offshore engineering expertise, but the cost reduction know-how that they have gained in recent periods of dramatically reduced oil prices. On some estimates, floating offshore wind technology is expected to develop fast enough for full-scale commercial projects to become feasible in the second half of the 2020s, and to bring the cost of floating offshore wind electricity level with electricity from fixed-bottom projects in or soon after 2030. This is not a small challenge, as it means moving from €140/MWh to €40/MWh.

7 At present, on some (though not all) floating substructures, it is necessary to reduce power output or shut down when motions, tower angular inclination or accelerations exceed certain limits in order to ensure that the rotor and drivetrain operate according to design assumptions. There are also possibilities for active control of the platform by means of the wind turbine blade pitch controller, but this penalises the energy capture. On the other hand, for an example of the increased wind speeds and generally better wind resource potentially accessible by floating projects, see the capacity factors at Hywind Scotland over 55% (with active control adapted to include stabilisation of spar buoy).

8 This may happen at different times in different markets, depending on the extent to which local seabed conditions favour the cheaper forms of fixed bottom installation. Floating technology is likely to start to be competitive with the more expensive forms of fixed bottom foundation.

9 See https://www.ecologie.gouv.fr/eolien-en-mer-0.

10 See http://jwpa.jp/page_295_englishsite/jwpa/detail_e.html.

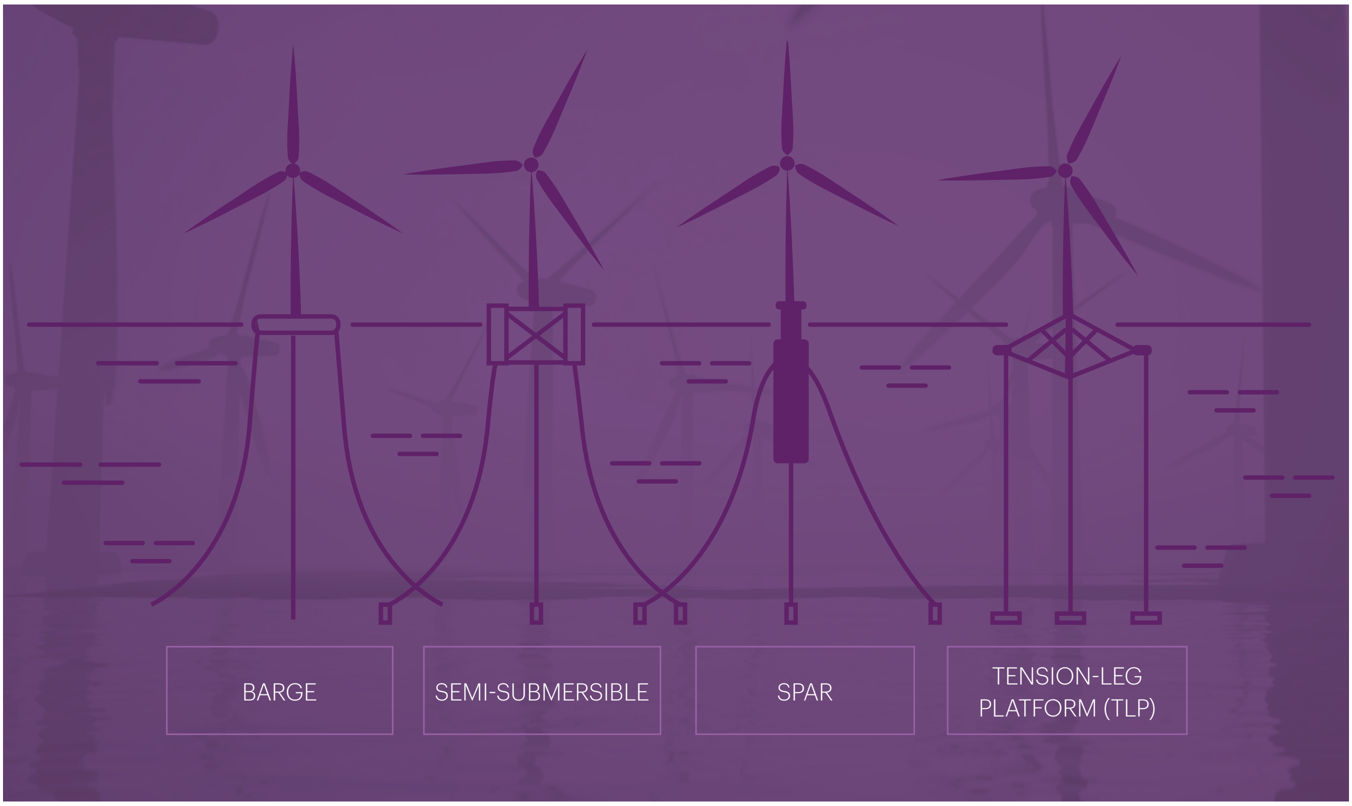
11 See the UK government's March 2020 CfD consultation and Dentons' article on it (note 6 above). The reference to special subsidies in Scotland relates to a special "banding" rate under the Renewables Obligation subsidy scheme, which is now no longer available to new projects.

12 See, for example, the 2019 acquisition of EOLFI by Shell and Aker Solutions' increasing stake in Principle Power and Shell's earlier investment in the TetraSpar demonstration project. As well as oil majors, major utilities such as Iberdrola and RWE have invested in floating technology.

13 See Dentons' article, Offshore wind and renewables in the UK: synergies on the way to Net Zero? (August 2020) and the OGA publications referenced there.

What exactly is floating offshore wind?

In a fixed bottom offshore wind installation, everything is typically fixed to the bottom of the sea: the turbine itself, via the substructure and any intermediate support structure; the cables that gather the power generated by individual turbines to an offshore substation; the offshore substation itself; and the export cable that links the wind farm to the onshore transmission grid. In a floating project, only the export cable need be fixed in this way. However, the biggest difference is in the substructure. Fixed bottom installations have a monopile, multi-pile, jacket, or gravity-based foundation fixing the turbine to the sea floor and, in some cases, involve driving piles some distance into the seabed. All result in a structure that is more or less like an onshore wind turbine, but with a taller tower, which may or may not broaden out at its base or penetrate a fair distance into the seabed. Floating wind substructures, unsurprisingly, do not go down so far, but are held in place by mooring links that attach them to the seabed. It is conventional to divide them into four main types (although some substructures combine elements of more than one type), which are illustrated schematically below.[14]



14 For more detailed diagrams of the three main substructure technologies, which include illustrations of some of the different anchoring systems used, see https://www.energyfacts.eu/floating-wind-structures-and-mooring-types/.

A key question for any floating offshore wind turbine, and the key distinction between these different technology types, is what stops the turbine toppling over in rough conditions. A simplistic analogy might be to imagine that you want a vase of flowers to float on the surface of a swimming pool. A **barge** works in the same way as keeping the vase afloat by sticking it to a tea tray. With a **semi-submersible**, it is more as if you were to take three or four large, sealed tin cans, partly filled with water, and put a triangular or square frame on top, with the cans at the corners and the vase on top of one of them. A **spar** would be like having an extremely long, thin vase, sealed, with air at the top and a weight at the bottom, so that it floats on its own in the water with the flowers protruding.

A **tension-leg platform (TLP)** is like a version of a semi-submersible in which the tin cans are full of air only, and taut chains secure them vertically to the bottom of the pool so that the whole structure can move a bit from side to side, but not up and down, with the motion of the water around it.[15]

What are the main pros and cons of each of these substructure technologies?

- For most purposes, barge and semi-submersible substructures can be considered together. Although barges have an advantage in having the shallowest draft of all the technologies, which may be an advantage in some locations, they are also heavier, and may cover a wider area. Even if their dimensions are similar to those of a semi-submersible, they have a greater water-plane area, so that they interact more with the water surface and waves, leading to increased loading (by contrast, most of the semi-submersible structure is either above or below the surface). In general, they seem to be the least popular design approach, but Ideol's "damping pool" technology has been successfully deployed in France and Japan. Capable of being made of concrete or steel, it can be manufactured locally in many different parts of the world. (With our earlier analogy in mind, think of a very thick tea tray from which almost everything apart from the edge has been cut out, with the turbine mounted on one side: this dampens the wave motion.[16])
- One attraction of floating technologies is the possibility of putting the turbine on the substructure in port and towing the complete unit to its moorings in one piece, reducing the amount of construction work to be done at sea. How far this opens up a longer season for the construction of offshore wind farms will presumably depend on the extent to which it is possible to tow completed units, and connect them to offshore electrical infrastructure, in weather windows that are longer and more frequent during a typical year, than those in which fixed foundations can currently be built and turbine units attached to them. Although assembly in port is not without potential challenges, such as negotiating bridges and other obstructions as the assembled unit moves towards the installation site, it also opens up the prospect of more onshore employment, in less hazardous conditions.[17] Accordingly, one potentially important differentiator between the substructure types is how possible, or easy, it is to assemble and install them in this way.
- Broadly speaking, **semi-submersible** substructures lend themselves to being assembled in dry dock (although other, more efficient techniques may emerge for assembling some designs); are likely to be the easiest to tow (using conventional tugs); and their moorings are cheaper than those of TLPs. However, building them may be more labour –and material-intensive than the othertechnologies. Turbines installed on them will be affected more by wave motion (which may mean that they require more robust mooring cables), although this can be mitigated to some extent by the incorporation of "heave plates" in the structure. It should be possible to deploy them in any depth, regardless of the composition of the seabed. To date, semi-submersible technology has produced the greatest number of different designs.

15 That is why, in our diagram, its cables appear as vertical straight lines and the cables of the other substructures appear as curves: their function is more to keep the unit in place than to keep the turbine upright. For a more technical description of the substructure technologies and a literature review, see M. Leimester, A. Kolios and M. Kollu, Critical review of floating support structures for offshore wind farm deployment (2018). For more information about the considerable variety of anchoring systems in current use, see Vryhof Manual: The Technical Guide to Anchoring, available here (although this publication is not specifically focused on floating offshore wind).

16 See https://www.ideol-offshore.com/en/technology.

17 See Crown Estate Scotland and Offshore Renewable Energy (ORE) Catapult, Macroeconomic Benefits of Floating Offshore Wind in the UK (2018). This report estimates a potential "value capture" by the UK supply chain of £2.3 billion per year between 2031 and 2050.

- **Spar substructures** cannot be attached to the turbine in port and towed out as a single unit. This potentially detracts from one of the generic advantages of floating installations. Putting the turbine on the substructure requires special heavy-lift vessels and must be done in relatively sheltered, deep water. Spars also may be less suitable for shallower sites. However, there are exceptions, particularly in relation to certain designs that combine elements of semi-submersible and spar technology.[18] Moreover, they have the benefit of being a simple design and share with semi-submersibles a cost advantage over TLPs in moorings, but they are likely to have longer mooring lines, and thus a larger seabed footprint than TLPs. On the other hand, although they are less susceptible to wave motion and, potentially, corrosion than the other substructure types, spars are also likely to have relatively high fatigue loads at the base of the turbine tower.
- Once on-station and moored, **TLPs** are the substructures least susceptible to wave motion and, like semi-submersibles, can be assembled onshore or in dry dock. However, they may be significantly less stable during assembly at the quayside and whilst being towed to site. Special vessels are likely to be required for installation, which in the short term may add to costs,[19] but if their mooring installation and technology costs are currently higher than those of the other technologies, they at least have shorter cables and the smallest seabed footprint of all the substructure types. Unlike the other types, they are not suitable for all seabed conditions. They are the lightest substructure type, with the lowest material costs, and the lowest life-cycle carbon impact, since steel manufacture is the main contributor to offshore wind's CO_2 emissions.[20]

It should be emphasised that these are very general comments, since many different versions of each technology have been proposed. Some of these aim to overcome the generic drawbacks of their type, as do several hybrid designs. Multi-turbine platforms aim to spread the cost of supporting infrastructure over the revenues of more than one turbine. A number of publications compare these variants or showcase the models used in particular projects.[21] Inevitably, not all will be taken up by the market: one concern that has been expressed is that not all potentially promising designs have had access to collaboration with wind turbine manufacturers and their expertise relating to matters such as loads and control, posing a risk that future market standard designs may be suboptimal.

Another view is that perhaps focusing exclusively on substructures fails to take account of the possibilities that floating technology may offer to reduce the costs,

18 See, for example, the Stiesdal Tetraspar (with video here), the Saipem Hexafloat and Floating Energy Systems' drop-keel concept.

19 See, for example, this presentation on the PelaStart TLP foundation by Glosten Associates and C. Dymarski, P. Dymarski and J. Żywick, Technology concept of TLP platform towing and installation in waters with depth of 60m, Polish Maritime Research Special Issue 2017 S1 (93) 2017, Vol. 24 pp. 59-66, available here. As special vessels are deployed over the installation of many units, the overall life-cycle cost may turn out to be lower.

20 See also J-I.Bang, C. Ma, E. Tarantino, A. Vela and D. Yamane, Life Cycle Assessment of Greenhouse Gas Emissions for Floating Offshore Wind Energy in California.

21 See, for example, M. Hannon, E. Topham, J. Dixon, D. McMillan and M. Collu, Offshore wind, ready to float? Global and UK trends in the floating offshore wind market (2019) and the Phase II Summary Report (2020) from the Carbon Trust's Floating Wind Joint Industry Project, which also identifies some of the key "technology and innovation needs" that need to be met to enable the industry to grow.

and improve the efficiency, of offshore wind. In the longer term, it may turn out that there is more to optimising floating offshore wind design than finding the best floating platform on which to install what is essentially a larger version of an onshore wind tower and turbine. Some of the more innovative designs abandon the single tower structure, or even the basic notion of a three-bladed turbine that the rest of the structure aims to keep more or less at right angles to the surface of the water.[22] However, the wider industry is now familiar with wind turbines that have certain basic features, and may be slow to embrace radical change.

If optimal solutions require a holistic approach to the design of platforms and turbines, the best outcomes may be obstructed by a chicken-and-egg problem: turbine manufacturers will not commit significant resources to working with novel designs until the market for them is comparable in size to those for conventional designs – which will not happen without their co-operation. Turbine manufacturers are used to working in the fixed bottom context, where they can effectively dictate the loads, deflections, inclinations and accelerations at the interface between foundation and superstructure. The foundation type is then selected to accommodate the needs of the turbine and seabed conditions, and adjustments are made to the wind turbine controller on a site-by-site basis.

By contrast, floating platforms can be designed to be capable of deployment regardless of seabed conditions, which means the same wind turbine/platform combination may be suitable for multiple sites, as long as they have similar wind and oceanographic conditions. Such an approach would support the standardised, centralised, industrialised and modular construction of platforms, which should reduce costs in the future. Indeed, TLPs have been described as wind turbine-agnostic, enabling standardisation of the platform not only for multiple sites but also for multiple turbine designs, bringing down even further the costs of engineering, fabrication, infrastructure and the supply chain.

Floating turbines: structures or ships?

A distinctive feature of floating offshore wind units is the possibility of being able to assemble them in port and tow them in one piece to the project location. In a later article, we will discuss the further possibility of using them to supply power to offshore oil and gas platforms, even moving from one location to another over the course of their operational lives as individual upstream assets cease production of oil or gas.[23] In any event, the potential (and, in some cases, actual[24]) mobility of floating offshore wind units forces us to consider a fundamental legal question about floating offshore wind platforms: should they be treated as ships and, if so, for what purposes?

Why does it matter if floating offshore wind units are considered to be ships?

Ships are treated differently, in national and international law, from other kinds of machinery or most other floating objects. Their ownership and the security interests of mortgagees in respect of them are recorded in public registers.[25] The register in which a ship is entered determines its home or flag state, and aspects of the law to which it and its operation are subject, regardless of where it is located in the world at a given time. Ships can be subject to claims against the ship itself (actions "in rem") in respect of maritime liens and other rights that do not exist in relation to other floating objects.[26] In the context of construction, shipbuilding contracts follow different standard forms, and are a different kind of contract from a contract for the construction of an offshore installation such as a wind farm – the former being in English law partly a contract for the sale of goods in a way that the latter is not.[27]

22 What might be classed as second or third generation floating concepts include the designs proposed by X1 Wind, Eolink and, perhaps most radically, TouchWind.

23 See also Dentons' earlier article, cited in note 13 above.

24 For example, the substructure of the first turbine to be installed on the Kincardine floating offshore wind farm in Scotland travelled some 1,400 miles from Portugal, where it had previously formed part of another project.

25 In some jurisdictions, registration of ships is voluntary. For example, in the UK, persons entitled to register a ship as a UK ship because the criteria for such registration set out in the Merchant Shipping Act 1995 are met are not obliged to do so. They may find it advantageous to register the ship under the flag of another state because they prefer its regulatory regime. However, no prudent commercial owner will fail to register their ship somewhere, as an unregistered ship is like a stateless person. Equally, a mortgagee is not obliged to register their security interest in a ship under the 1995 Act, but given that doing so provides them with a statutory power of sale and priority over subsequently registered mortgagees and all unregistered mortgagees (see section 16 and Schedule 1, paragraphs 7 to 13), they have an extremely powerful incentive to do so. Whether such an incentive will also apply to lenders to floating offshore wind projects may depend on whether the units comprising them are likely to move between jurisdictions.

26 See the Senior Courts Act 1981, section 21.

27 See McDougall v. Aeromarine of Emsworth Ltd [1958] 2 Lloyd's Rep 345, Hyundai Heavy Industries Co v. Papadopoulos [1980] 2 Lloyd's Rep 1, Stocznia Gdanska SA v. Latvian Shipping Co [1998] 1 Lloyd's Rep 609, Dalmare SpA v. Union Maritime Ltd (The Union Power) [2010] EWHC 3537 (Comm), Neon Shipping v. Foreign Economic and Technical Co-operation [2016] EWHC 399 Comm.

Another distinctive feature of the regulation of ships is the work done by classification societies. These independent, private bodies, such as Lloyd's Register, play a key role in the context of the distinct body of safety rules that apply to ships. However, they also assess wind turbines and projects under other regimes. At present, there are different approaches that are being advocated for checking that floating offshore wind turbines and projects, in particular, comply with relevant standards – notably "classification" and "certification". We explore these in more detail in the Annex to this paper. The debate over which approach to take is bound up with the "ships or structures" question, because classification is the process most familiar in the shipping context.

What is a ship?

Given that it makes such a difference in legal terms whether or not something is a ship, it is perhaps surprising that there is not more clarity and consistency in the rules about what is and is not a ship.

The definition in s.313 of the Merchant Shipping Act 1995 is important because it determines what kinds of thing can be registered as a UK or British ship. It tells us that "'ship' includes every description of vessel used in navigation". Similar wording has appeared in predecessors to the 1995 Act since 1854. More than a century of case law has established that, in order to be a ship, an object does not have to be capable of moving on its own, to be a particular shape, or to have a rudder, a keel or a crew (although, in some cases, the presence of a crew seems to be a factor in favour of an object being a ship).[28] An object may also be a ship if it performs its most distinctive functions when secured in one place and resting on the seabed, although there is also authority that suggests that very infrequent movement may tell against an object being a ship. Almost 100 years ago, the Court of Appeal referred in this context to "the position of the gentleman who dealt with the elephant by saying he could not define [it], but he knew what it was when he saw one".

On that basis, we recommend an experiment: do a Google image search for "floating offshore wind turbine" and ask yourself whether most of the pictures that come up are of things that, even if capable of "navigation" in a broad sense, can reasonably be described as "vessels". In ordinary language at least, it is arguable that the inherent concept of a vessel is that of a container in which other things (or people) are carried. If actual floating offshore wind units were more like large versions of the tea tray or vase of flowers we referred to by way of illustration earlier, they might more easily be described as vessels but, in fact, many of them are frame-like structures in which the turbine and the thing that keeps it afloat are highly integrated. (For comparison, search "oil platform" and "buoy": the former are more easily seen as vessels than the latter, and floating offshore wind units perhaps resemble the latter more in this respect – but then search for images of "floating substations", which any floating offshore wind farm will also need, and which perhaps resemble the former more, even including crew quarters.)

The table below sets out a sample of other significant and potentially relevant regulatory definitions.

28 See Perks v. HM Inspector of Taxes [2001] EWCA Civ 1228. In itself, this case is not perhaps an ideal precedent, in that it is ultimately about the treatment of seafarers' wages and fairness of treating differently those employed on different kinds of vessel (see the judgment of Sir Robert Walker at paragraphs 69-73). However, it does usefully review the authorities.

Instrument	Relevant provisions and observations
United Nations Convention on the Law of the Sea, 1982 (UNCLOS)	UNCLOS, the most general in scope of the UN maritime treaties, codifies basic propositions about ships and navigation, such as the freedom of the high seas and the international law basis of the registration/flagging system, but it does not define a "ship". However, it also provides for coastal states to establish exclusive economic zones (EEZs) where they can exercise (article 56(1)) "sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living, of the waters superjacent to the seabed and of the seabed and its subsoil, and with regard to other activities for the economic exploitation and exploration of the zone, such as the production of energy from the water, currents and winds"; and "jurisdiction…with regard to…the establishment and use of artificial islands, installations and structures". There is a clear, if implicit, distinction between "ships" and "installations and structures". Many existing fixed bottom offshore wind farms established in EEZs clearly fall into the latter category. It is not obvious why future floating offshore wind developments should not also.
International Convention for the Safety of Life at Sea, 1974 (SOLAS)	SOLAS does not define a "ship". It defines a "passenger ship" as "a ship which carries more than twelve passengers" and a "cargo ship" as "any ship which is not a passenger ship". Unlike UNCLOS, it is not concerned with "structures" (other than those that are part of ships). It generally applies only to ships on international voyages (that is, voyages "from a country to which the present Convention applies to a port outside such country, or conversely" (Chapter I, Regulations 1 and 2)). It is full of provisions that are self-evidently not appropriate to a structure that is not designed to move more than a few times in its life, and is not intended to carry either people, or goods that are not part of it, on the occasions when it does move.
Merchant Shipping (Cargo Ship Construction) Regulations 1997	These Regulations implement parts of SOLAS in the UK. As its name suggests, it is concerned with cargo ships. It defines a cargo ship slightly differently from SOLAS, as "a mechanically propelled ship which is not a passenger ship, troop ship, pleasure vessel or fishing vessel" (regulation 2). Clearly, the criterion of being "mechanically propelled" (in the sense of being able to navigate under its own power) is not one that is ever likely to apply to floating offshore wind units, to which the legislation therefore does not apply.
International Convention for the Prevention of Pollution from Ships (MARPOL)	MARPOL is concerned with pollution arising from oil, noxious liquids or harmful substances carried by ships leaking into the sea, as well as from sewage, garbage and air pollution caused by ships. It defines a "ship" as "a vessel of any type whatsoever operating in the marine environment", including "hydrofoil boats, air-cushion vehicles, submersibles, floating craft and fixed or floating platforms". It is clear from the references that it makes to "platforms", that these are thought of in terms of the offshore oil and gas industry, with specific mention of drilling rigs, floating production storage and offloading facilities (FPSOs) and floating storage units (FSUs) as being platforms. All relate to the fact that such platforms have a crew, carry harmful substances or generate air pollution.
International Convention on Salvage, 1989	The Salvage Convention (incorporated into UK law as Schedule 11 to the 1995 Act) refers to "vessels" rather than "ships", a "vessel" being "any ship or craft, or any structure capable of navigation". It is clear that this could apply to oil and gas platforms as in the case of MARPOL. However, it does not apply to "fixed or floating platforms or…mobile offshore drilling units when such platforms or units are on location engaged in the exploration, exploitation or production of seabed mineral resources".
International Convention on Load Lines, 1966	The Load Lines Convention is about the draft of ships and the maximum extent to which they can be loaded in particular conditions. The concept of a "ship" is not defined. It is also not defined in the Merchant Shipping (Load Line) Regulations 1998 that implement the Convention in the UK.
Convention on Limitation of Liability for Maritime Claims, 1976 (LLMC)	LLMC (incorporated into UK law as Schedule 7 to the 1995 Act) provides for shipowners (charterers, managers, operators, etc.) and salvors to be able to limit their liability for various maritime claims related to the operation of a ship (including loss of life or personal injury and loss or damage to property) to an amount calculated on the basis of the tonnage of the ship. It does not define what a "ship" is. The related EU Directive 2009/20/EC, which requires shipowners to hold insurance up to the amount of the LLMC limitation also does not define "ship", but it does so only in respect of registered ships. LLMC does not apply to "floating platforms constructed for the purpose of exploring or exploiting the natural resources of the seabed or the subsoil thereof", but wind is not a resource of the seabed, even if floating offshore wind turbine units can reasonably be considered "platforms".

Instrument	Relevant provisions and observations
International Regulations for preventing Collisions at Sea, 1972 (COLREGS)	The COLREGS are concerned with "vessels", and these are defined to include "every description of water craft, including non-displacement craft...and seaplanes, used or capable of being used as a means of transportation on water".[29] They are implemented in the UK by the Merchant Shipping (Distress Signals and Prevention of Collisions) Regulations 1996 and a related Merchant Shipping Notice. It is clear from their provisions that they are concerned with ships in the most obvious or narrow sense, rather than other structures that sometimes move from one place to another over the sea.
EU Ship Recycling Regulation (1257/2013)	Potentially relevant in the decommissioning context, the Regulation obliges registered shipowners to have their ships recycled only in facilities that appear on an approved list. For these purposes, a "ship" is "a vessel of any type whatsoever operating or having operated in the marine environment, and includes submersibles, floating craft, floating platforms, self-elevating platforms, Floating Storage Units (FSUs), and Floating Production Storage and Offloading Units (FPSOs), as well as a vessel stripped of equipment or being towed".[30]

The following points emerge from case law and the above sample of regulatory definitions.

- What counts as a ship or vessel in any given context is more often than not either left undefined, or defined in such terms that a fact-specific judgment is required to determine whether things that are not ships or vessels in the most obvious or colloquial sense fall within it.
- A number of the regulatory regimes depend on the ship or vessel having been registered, which brings us back to the somewhat unsatisfactory case law (although in fact most of the reported judgments have not been attempts to construe the 1995 Act or its predecessors).[31]
- The breadth or narrowness of what is covered by the key international rules, and the national rules that implement them, is closely related to their regulatory purposes. This probably accounts for the broader scope of those rules that have an environmental or purely economic, rather than a "traditional shipping" focus on the safety of human life.
- Some of the regimes that are clearly intended to cover floating objects other than those that are obviously or colloquially ships make specific reference to structures and installations used in the offshore oil and gas industry. These regimes vary in the extent to which they cover matters likely to be relevant to, or use language that arguably includes, floating offshore wind units as well. The more specific to oil and gas is the language that brings other floating objects within scope, the less justification there may be for assuming that they would cover floating offshore wind units, unless there is other evidence that this is so. Moreover, although a wide range of upstream oil and gas installations and structures are clearly covered by some of the international rules, it is far from being the case that all such objects are invariably registered by their owners in a national register of ships. For example, some national shipping registers, such as those of Singapore and Norway, expressly allow for such floating platforms to be registered, although not always for all purposes.

29 See Merchants Marine Insurance Co Ltd v. North of England Protecting and Indemnity Association (1926) 25 Lloyd's List Rep 446, per Scrutton LJ, and the first instance judgment of Ferris J, (1926) 26 Lloyd's List Rep 201. For a modern US comparison, see the judgment of the Supreme Court in Lozman v. City of Riviera Beach, Florida (No. 11-626 (US 15 January 2013), on the question whether an idiosyncratic floating home was a vessel. This is of some interest because the legislative definition of "vessel" that was under consideration has similarities with some of the regulatory definitions reviewed later in this article.

30 The Regulation implements the Hong Kong International Convention for the safe and environmentally sound recycling of ships, 2009 (available here).

31 The United Nations Convention on Conditions for Registration of Ships, 1986 is not in force and many countries (including the UK) are not parties to it (see here). In the course of setting out some basic propositions about registration, it defines a "ship" as "any self-propelled seagoing vessel used in international seaborne trade for the transport of goods, passengers, or both with the exception of vessels of less than 500 gross registered tons". However, by its own terms it would not exclude the registration of vessels not matching this definition even if it was in force.

Finally, it is worth asking whether, at least in the UK context, regulatory regimes focused on ships need to be applied to floating offshore wind units in order to fill a legislative vacuum. Nobody would claim that fixed bottom offshore wind turbines are ships, although their installation and maintenance obviously involves ships. Accordingly, the development of the UK offshore wind industry has required the Health and Safety Executive and the Maritime and Coastguard Agency to learn to apply, respectively, onshore safety legislation (which has been specially extended to apply to relevant areas of the UK's territorial waters and EEZ) and maritime safety rules in a way that avoids duplication or gaps in coverage in respect of offshore wind projects.[32] At the same time, although the (onshore, extended) legislation that governs the construction of offshore wind farms pre-dates the current high level of interest in floating offshore wind, it has been drafted in terms that include floating units – as long as they are not "vessels" – which in this context means "capable of being navigated".[33]

Regulation and the growth of the floating offshore wind sector

What, then, can we conclude about the regulatory position of floating offshore wind units? Are they "ships" or "vessels", or merely non-ship floating structures? And what is the relationship likely to be between finding a regulatory way forward and the growth of the floating offshore wind sector?

It is questionable how helpful it would be to treat floating offshore wind turbine units as ships in the near term. Existing offshore wind players and project structures are not necessarily attuned to dealing with ships or vessels and the legal implications of developing, constructing, financing and operating a project made up of a large number of them. Equally, the world of shipping is not, on the whole, used to dealing with offshore wind or the sectoral regulation of renewable power projects more generally. At both the international convention and the national implementing legislation levels, there would need to be a fair amount of change to adapt the regulation of different points in a ship's life-cycle to the life of a floating offshore wind turbine, and to ensure that such turbines were subject to a version of current ship regulation that fairly reflected the potential risks associated with them without adding unnecessary compliance costs to projects. All this would take time to accomplish, potentially delaying commercialisation of floating technology while the necessary regulatory changes were processed. On the other hand, bringing floating offshore wind turbines into the world of ship regulation could make it easier to establish some commercial and legal norms for the sector on a global basis. For example, the application of LLMC rules could be a significant benefit of registering floating offshore wind turbines as ships.

As we have seen, there is, at least in the UK, already a template for developing floating offshore wind projects within the same contractual and regulatory frameworks that have been used for fixed bottom projects for a number of years. Those frameworks would benefit from some refinement, but the changes required would be an order of magnitude smaller and quicker to deliver than the work needed to create versions of the international maritime convention obligations that are well adapted to the floating offshore wind context. The potential for a standard international approach would be reduced, because the existing fixed bottom frameworks owe less to international conventions, although this has not proved a barrier to the development of such frameworks in the (admittedly fairly small number of) jurisdictions that already have mature offshore wind sectors. Whether the sector would have developed more quickly in any of the theoretically promising jurisdictions where it has been slow to take off if floating technology had been commercially available sooner is another question.

It is possible that, without going fully down the route of the "ship" approach, the position of classification societies can be used to help grow the market by establishing non-statutory forms of certification that will build the confidence of floating offshore wind industry stakeholders without imposing unduly onerous burdens on them.[34] This could be done

32 See RenewableUK, Offshore Wind and Marine Energy Health and Safety Guidelines (2014), available here.

33 See the Health and Safety at Work etc Act 1974 (Application outside Great Britain) Order 2013, article 9 and the Construction (Design and Management) Regulations 2015, regulation 3. Note the reference in article 9(2) of the 2013 Order to "a fixed or floating structure or machine, **other than a vessel**, which is, or is to be, or has been, used for producing energy from water or wind" (emphasis added: "vessel" is defined in article 2, as including "a hovercraft and any floating structure which is capable of being navigated").

34 There are already moves in this direction: see DNV GL, Service Specification for Certification of Floating Wind Turbines (2018), available here. Although not presented as a classification process, the approach outline here does involve periodic inspections to ensure that the relevant standards are still met. Classification can only take place once the flag state has put a label on the type of vessel. There would be some flexibility if they were classed as "special purpose vessels", but would still be subject to SOLAS, many provisions of which, as we have seen, are not relevant.

initially in support of the existing, non-ship-based approach (mirroring what has already happened with fixed bottom offshore wind, as noted above), but adapted over time to support a ship-based approach as appropriate. There may be merit in testing these propositions in a public and transparent way with a wide and global body of industry stakeholders, along with other possible viewpoints on the underlying "ship or structure" questions, as soon as possible. If the ship-based approach finds favour, changes at the international convention level may be appropriate.[35]

Construction contracts

Fixed bottom offshore wind presents a number of engineering challenges. Floating projects will present similar challenges, with some complicating factors – most obviously, the fact that the units will move around (i.e. dynamically), and do so more than a floating offshore oil and gas platform. (Indeed, a basic difference between oil and gas platforms and floating offshore wind units is that, at least when the wind is blowing, the wind unit is principally subject to horizontal load, whereas on oil or gas platforms, the main load is always vertical.) That has implications for risk, and for the need for additional robustness in, for example, the electrical cable connections, mooring lines, anchors and access vessels. In some circumstances, there will also be implications for other vessels and structures using the same parts of the sea.

In what follows, we assume an evolution of the current offshore wind construction contracting model rather than a revolutionary departure in favour of a "ship-based" model for floating offshore wind.

The construction of fixed bottom offshore wind projects is typically procured on a multi-package basis. Like upstream oil and gas joint ventures, offshore wind developers do not (as the developers of some other types of generating facility often do) typically enter into a single contract with an engineering, procurement, construction and installation (EPCI) contractor that takes responsibility for managing all the contracts for the constituent elements of the project, including foundations, turbine supply agreement (TSA), inter-array cables, substations, vessels, export cable etc, and charges a premium for doing so.

Not taking the wrapped EPCI approach requires the developer to have considerable procurement and project management capabilities and leaves it managing overall project risk. It represents a trade-off between lower upfront costs and higher interface and integration risks (as well as potential joint and several liability issues in a consortium: for example, a turbine supplier would be less willing to take risk on works outside turbine-related issues). Interface risks include the failure of one contractor causing delays and disruption to others, resulting in a ripple effect in terms of both delay and cost across the project as a whole; integration risks arise if what is produced in one work package does not meet the requirements of another package, with the result that the full performance output is not achieved. Both kinds of risk scenario have, on occasion, occurred in the offshore wind sector. On the other hand, it has been found that large, over-arching EPCI contracts do not always address issues with sufficient rigour or technical subtlety to drive down costs.

In the medium to longer term, as floating technology is more widely deployed, and larger corporate groups move in to buy the smaller companies who have developed the technology, there could be a transition to a model with fewer packages. For example, a critical issue for the construction of a fixed-bottom offshore wind turbine is the availability of installation vessels: if the relevant vessel is not available in the "weather window" when the turbines need to be installed, the negative impacts on the schedule of the project as a whole can be profound (for example, in terms of requirements to meet construction milestones in order to secure public funding). This risk is usually taken by the project developer, because the turbine supplier (not having control of vessel availability) would be unwilling to do so.

Once floating technology is more proven, turbine suppliers may accept responsibility for integration of their turbine with the foundations, especially where this can be done in the less risky context of a yard rather than at sea, and, as noted above, at least with some substructure types, there is less

35 It is only fair to point out that the history of past concerted efforts to introduce consistent treatment of oil and gas installations through an international convention does not necessarily encourage optimism in this regard. See, for example, M. White, "Offshore craft and structures: a proposed international convention" (1999) 18 AMPLJ available here, written after more than 20 years of inconclusive efforts towards such a convention. As the definitions cited earlier show, in practice, the body of modern international maritime conventions has grown up with a piecemeal (but functional) approach to oil and gas installations.

need for specialised installation vessels. On the other hand, it is possible that a project may face a capacity constraint not in respect of the availability of installation vessels, but in terms of capacity to make enough units available on time in the ports where turbines and substructures are to be combined – although this could be overcome by having units fabricated and assembled in different yards or ports (potentially at the cost of increased towage risk).

Whilst it is difficult to envisage the floating offshore sector moving generally to a single EPCI basis, it might at least be feasible as the technology matures to reduce the number of separate construction contracts or packages to between two and four contracts, with the balance of plant (BoP) effectively being on an EPC delivery basis:

- turbines – turbine supply and floating foundations;
- vessels – likely to be separate but possibility for it to be wrapped into BoP;
- BoP – surveys, cable supply and installation, offshore/onshore substations and electrical works, mooring;
- commissioning – elements could be included in turbines and BoP packages.

This may change again as truly integrated designs of turbine and platform become available. In the long term, it is possible to imagine a commoditised floating offshore wind sector in which single companies or consortia supply large portfolios of similar wind farms at multiple locations around the world. In the meantime, developers may hope that, for those elements of floating offshore wind units that are different from fixed bottom structures, manufacturers may be persuaded to offer greater completion and warranty support than has become customary for fixed bottom projects, in order to support the growth of the market for the new technology.

Turbines

The turbines used in the fixed bottom and floating offshore wind projects are very similar – both use adapted onshore machines, and modifications are made to the blade pitch control algorithms for floating turbines. Care may need to be taken to ensure that these modifications do not invalidate the manufacturer's warranty. More generally, there is a risk that uncertainties about the harsher and novel operating conditions in which units will be operating may lead to reduced periods of warranty cover when turbines are mounted on floating substructures, and limitations of liability, particularly around cable connection to the substation.

Operation and maintenance

O&M accounts for about two-thirds of the operating costs of the UK's current fleet of offshore wind farms.[36] In fixed bottom offshore wind projects, the O&M function is contracted out using the multi-contract approach. For instance, the turbine manufacturer or supplier maintains the turbine in accordance with a long-term service agreement (LTSA) which includes warranty protection for certain defects. Other O&M agreements may include specific maintenance contracts, such as the foundations and array cables (the transmission assets will be maintained by the OFTO in the UK, but typically contracted out to the generator who bids a nominal sum to ensure that it has control over the availability of the OFTO assets).

In practice, the maintenance of fixed bottom offshore wind may involve the use of jack-up vessels, crew vessels and helicopters. While not desired, exchange of major turbine components, such as blades, gearbox and transformers, is often inevitable. Heavy maintenance procedures in fixed bottom offshore wind are well defined and have been practised at commercial scale. The jack-up vessels and cranes used for these projects may also be able to undertake blade and gearbox exchange for floating projects, although there will be limits to the depths in which jack-ups are suitable for this work.

The same approaches may translate to floating offshore wind projects. Alternatively, it is possible that a plug-and-play strategy may develop, that enables floating units to be disconnected and towed back to port for work but, due to the costs involved, this would probably only be for major component exchanges, involving parts such as blades, gearboxes, main bearings or nacelle bedplates.

This tow-to-port maintenance approach would mitigate the need for expensive heavy-lift floating vessels, as well as potential risks of undertaking operations in harsh offshore environments. It would rely on the development of electrical connections between the turbine units and inter-array cabling that could be repeatedly disconnected and

36 See Offshore Wind Innovation Hub, Operations & Maintenance: Cost Drivers, p.6 (available here).

reconnected whilst still remaining effective and watertight. Developing technology for rapid and reliable disconnection and reconnection of mooring lines and the kind of electrical cables involved is challenging and, at this stage, a work in progress.

Modelling carried out by the UK's Offshore Wind Innovation Hub (OWIH) suggests that, for any work that would require a jack-up or heavy-lift vessel if carried out on a fixed bottom offshore wind farm, "offsite" approaches have a cost advantage over "onsite" repair across all substructure types and a range of distance between the project and the offsite repair location.[37]

However, the OWIH modelling also highlights a number of sensitivities, including weather conditions, availability of space at the offsite repair facility, and the extent to which the fixed costs of an offsite repair campaign can be spread over a large number of units. One potential risk of an offsite approach is that of losing more potential generating time than current maintenance approaches as a result of unexpected delays (for example, as a result of waiting for suitable towing weather or capacity in port, or as a result of port blockage). It is possible that, at some stage, it may become possible to mitigate this by installing a replacement turbine unit on a temporary basis while the original unit is undergoing maintenance elsewhere. While in port, turbines may also pose an unwelcome risk for lenders in the event that they wish to enforce security over a floating offshore wind farm's assets, since units that are in port undergoing maintenance may be the subject of a possessory lien in favour of the O&M contractor (under the Torts (Interference with Goods) Act 1977), which would have priority over a mortgagee's interest.

Automation and digitalisation

Research by OWIH suggests that, like other complex industries, the offshore wind sector could make significant efficiency gains by exploiting the potential of automation and digitalisation.[38] For example, in a study that does not specifically reference floating projects, automated servicing was highlighted as being able to save up to £3,850/MW/year in the

current fleet and £2,640/MW/year in the "next generation fleet". Data generated by sensors installed on units can be used to anticipate the need for maintenance, as well as monitoring and being used to improve performance. These innovations will not be unique to floating projects but, if floating projects embrace them, they may well help to reduce O&M costs more rapidly and therefore accelerate deployment of floating technology. The contractual arrangements for construction and O&M would need to take this into account, both in their overall allocation of risk and in provision for matters such as data sharing and cyber security.

What happens if things go wrong?

As with any complex engineering, sometimes things go wrong in the construction of offshore wind farms. Reported offshore wind cases in UK courts include the failure of foundations constructed in accordance with a flawed technical standard that did not meet a separate contractual requirement that they would last for 20 years;[39] a defective export cable that was found to have been suffering from unseen corrosion for some time before the offshore transmission assets were sold to a new owner;[40] and defective shipments of steel for turbines (where it was initially unclear whether they were defectively manufactured or had suffered as a result of subsequent testing).[41]

37 See OWIH, Floating Wind: Cost modelling of major repair strategies (available here).

38 See OWIH, Operations & Maintenance: Cost Drivers (cited above) and Data & Digitalisation: Cross Sector Lessons for Offshore Wind (available here).

39 MT Højgaard A/S v. E.On Climate & Renewables UK Robin Rigg East Limited and another [2017] UKSC 59. However, it is on balance helpful that the fixed bottom standard in question in that case (J101) has a floating offshore wind counterpart (J103), already in its second edition.

40 Gwynt y Môr OFTO plc v. Gwynt y Môr Offshore Wind Farm Ltd and other companies [2020] EWHC 850 (Comm).

41 Fluor Ltd v. Shanghai Zhenhua Heavy Industries Ltd [2016] EWHC 2062 (TCC).

What lessons do these cases have for the new technology? Two of them show the importance of careful contractual drafting, and how it is easy, in a negotiated agreement, to come close to including, unintentionally, words that would give it a meaning that was the opposite of what at least one of the parties intended. In one, the court says, in effect, that a contractor ought to have checked whether the calculations in an industry standard were correct and not have taken them for granted. Another simply shows the challenges of establishing responsibility for a defect when components have undergone a number of processes.

Perhaps the key point (if a trite one) is that given the problems that have arisen on some fixed bottom projects, while dealing with a fairly mature technology, those involved in floating offshore wind projects will need to be particularly careful to allocate risk correctly and to make sure that the contractual documents are unambiguous. If liabilities are incorrectly allocated to those with less understanding of, control over, or ability to bear risks, contractual frameworks may not deal adequately with potential issues and costs will increase – if not in the construction phase itself, then later on as technical problems manifest themselves over the lifetime of projects.[42]

At the same time, while a number of the floating wind technology providers (notably substructure manufacturers) are still relatively small companies, there may be heightened concerns about insolvency risk. We will address some of the other key finance and operational risks, such as turbine units or substations breaking from their moorings, in subsequent articles in this series.

Regulation

We have noted above that the potential choice to be made between treating floating offshore wind turbine units as ships or treating them as floating versions of fixed bottom installations has implications for the health and safety related aspects of the regulation of their construction. In the UK, broadly speaking, this amounts to a choice between a regime based on international conventions, particularly SOLAS, and a regime based on the Health and Safety at Work etc. Act 1974 and associated regulations. Existing regimes are already accommodating pilot projects.

It has been reported that the UK government is to review the national policy statements (NPSs) for energy infrastructure that form the policy basis for determining consenting applications for large offshore renewable energy projects in English and Welsh waters or parts of the EEZ.[43] While the scope and timing of this review remain unclear, there would clearly be merit in taking the opportunity to update the parts of the NPSs that relate to offshore wind so as to address the different issues raised by the new technology as compared with fixed bottom projects. In this context, it would be important to learn from the experience of the Scottish consenting authorities, who have already had occasion to consider some floating offshore wind projects under their separate but similar regime.[44]

It is, of course, possible that in individual cases, floating projects will still encounter stakeholder pressures as they navigate the consenting regimes. For example, the standard approach is for consenting authorities to set a "safety zone" of 500 metres around each turbine during construction and decommissioning, into which most other users of the sea must not enter. The safety zone typically reduces to 50 metres during operation, but may increase again in respect of "major maintenance"

42 It may be inevitable that, in the early stages of the new technology, some parties will want to rely more heavily on insurance, if the insurance market can provide cover that is more cost-effective than existing self-insurance and cost-sharing arrangements.

43 See press release by the Good Law Project dated 2 October 2020, attaching a brief email from the Department for Business, Energy and Industrial Strategy, available here.

44 Notably in the case of the Kincardine offshore wind farm project: see the consent documents available here.

periods. Fishermen and others sometimes object to wide exclusion zones being set around offshore wind farms during their operational phases (or argue over what should count as "major maintenance"). If the proximity of mooring line and power cables to the surface of the water is considered to expose floating offshore wind projects to a greater risk of damage from fishing nets, for example, it is possible that developers may seek wider exclusion zones throughout the operational life of a project (as is standard for oil and gas installations), with adverse consequences for maritime stakeholder management.[45] Unlike fixed bottom units, floating barge or semi-submersible platforms secured by catenary mooring systems may themselves also move position by up to 50 metres, and large projects will involve complex mooring spreads covering potentially very large areas of sea in a more exclusive way than the largest fixed bottom projects yet proposed. This may make consenting harder to achieve without relying on as yet untried technology, such as shared anchors, which may carry other risks due to the loss of redundancy.

However, the areas where regulation can do most to help or hinder the development of floating offshore wind technology are not those that directly regulate their construction or maintenance, but those that relate to other aspects of offshore wind projects, such as the offshore transmission system and financial support for renewables under the CfD regime. We will address these in future articles.

Conclusion and next steps

There is a finite number of sites where fixed bottom installations can be developed cost-effectively without unacceptable negative environmental impacts and, if floating technology does not make the use of deeper waters and areas of more challenging seabed conditions accessible to offshore wind, the development of the sector – at least in certain markets, and possibly as a whole – could stall. Floating offshore wind technology has great potential, but faces some significant challenges if it is to realise that potential. As with other technologies that could help unlock the timely achievement of a net zero greenhouse gas emissions economy – notably low carbon hydrogen – the question is how to scale up the deployment of what is already a more or less proven technology, and reduce its costs.

Construction and O&M are key to reducing the costs of floating offshore wind units. While this cost reduction is mostly an engineering challenge, project design and the development of regulatory frameworks also have an important part to play.

From a project design point of view, steps that could bridge the gap between today's fairly small-scale floating projects and a mature, deep water floating offshore wind subsector include:

- **Shallower water projects:** As noted above, floating units have advantages over fixed bottom turbines in areas of shallower water where the seabed conditions are difficult for fixed foundations (which become more expensive to deploy there). Shallower water should reduce O&M and other costs, making this potentially a good model for scaling up to the hundreds of MW level before attempting a project in deep water.
- **Hybrid projects:** The currently higher costs of floating units could be spread by adding a number of them to the deeper edge of a fixed bottom development (either existing or new, perhaps up to 25-30% of the fixed bottom turbines' combined capacity). Moreover, the revenues from floating units could be enhanced by at least 50% by attaching underwater wave-power units to their substructures. Generation from these tends to peak at different times from when peak wind generation occurs and they also contribute to platform stability by dampening the impact of wave motions on the platform.[46]
- **Experimenting with mooring configurations:** Including, in a development where most of the floating units have their own independent mooring systems, a number of units with shared moorings and anchors, so as to test the risks and redundancy over a typical operational life-cycle.

These approaches, of course, would raise some contractual and regulatory issues of their own. However, they could be addressed on a case-by-case basis, whilst the industry and its stakeholders take time to consider some of the more fundamental legal questions, including contract package structure and "ship or structure" type regulatory issues which we have highlighted as being an indispensable part of developing the best models for this new technology.

45 See, for example, the Secretary of State's 2019 decision in relation to the safety zone for Triton Knoll offshore wind farm. The current legislation is sufficiently flexible to allow for larger exclusion zones throughout the life of a floating offshore wind farm. The Kincardine floating offshore wind project, off Aberdeen, has to date only requested a 500 metre exclusion zone for its operational phase outside of major maintenance periods.

46 For an example of the kind of wave-power units we have in mind, see https://www.bomborawave.com/.

ANNEX: CLASSIFICATION, CERTIFICATION AND CONFORMITY ASSESSMENT

For those unfamiliar with the work of classification societies, their distinctive contribution can perhaps be highlighted by comparing their role with that of notified bodies under EU Directives and Regulations that lay down safety or performance requirements for machinery and other complex products.

In that case, the legislation prescribes certain "essential requirements" in generic terms, which must be met in order for the product to be declared in conformity with them, "CE" marked as such, and therefore capable of being lawfully placed on the market. The task of conformity assessment may be performed by "notified bodies" (testing houses approved by national authorities to carry out conformity assessment under particular legislation).

Alongside the legislation, however, certain "harmonised standards" are referenced, that have been developed by the appropriate European Standardisation Organisation (ESO).[47] The standards offer manufacturers and others responsible for placing products on the market with a ready-made route to compliance with the essential requirements: so much so that, in some cases, where a harmonised standard is being followed, there is no need to involve a notified body in the conformity assessment process. Compliance with such a standard is not the only route to compliance with the requirements set out in the EU legislation, but it creates a presumption of conformity with them.[48]

In the world of ships, the role of classification societies is partly analogous to that of the notified body and partly analogous to that of the ESO. National authorities are ultimately responsible for maintaining the compliance of ships that carry their flags with safety and environmental rules that are set out in international conventions to which they are parties. However, they can and do delegate the assessment of ships to classification societies, acting as "recognised organisations" on their behalf.

Classification societies maintain their own registers of the ships they have certified, so that there is an up-to-date public record of their class status. As a consequence of all this, maintaining a valid class certificate during a ship's working life is of prime importance for many commercial purposes, such as chartering, finance or insurance. Indeed, rules of classification may be adopted by a society that go beyond the requirements of the conventions or national legislation, or provide a set of standards in an area or for a category of equipment that is not the subject of equivalent statutory regulation, and, because of the society's expertise and reputation, those private rules may become a market standard. Some classification societies offer classification, as well as certification services in respect of fixed bottom and floating offshore wind units.

The societies (or national authorities) issue "statutory certificates" to indicate that the convention requirements are met, but the basis on which they do so is typically by reference to the societies' own rules and procedures. Their "class certificates" certify that a ship is fit for a particular use or service, and are referred to in, and in one case even required by, the international conventions.[49]

In contrast to the EU conformity assessment process, sampling techniques can be employed in some cases, and manufacturers are never left to do all the checking themselves. Moreover, unlike in the case of EU product legislation, which is only concerned with the initial marketing of products, ships are required to continue to meet the requirements that apply to them. Classification societies are therefore closely involved not just at the shipbuilding stage, but in periodic inspections to ensure that they continue to meet those requirements – or, as it is generally expressed, given the central role of their societies and their own rules and procedures, that they remain "in class".

This can be a distinction between "classification" and "certification", where the latter refers to checking against, for example, a relevant standard of the

47 The status and role of the ESOs is briefly described here. See also the sections on harmonised standards in the publication referred to in note 48 below.

48 See generally European Commission notice 2016/C 272/01, The "Blue Guide" on the implementation of EU products rules 2016, available here.

49 See generally the international conventions referred to in the table later in the article. An explicit normative reference appears at Chapter II-1, Regulation 3-1 of the International Convention for the Safety of Life at Sea 1974 (SOLAS): "In addition to the requirements contained elsewhere in the present regulations, ships shall be designed, constructed and maintained in compliance with the structural, mechanical and electrical requirements of a classification society which is recognized by [national authorities] in accordance with the provisions of regulation XI-1/1, or with applicable national standards of the [national authorities] which provide an equivalent level of safety.".

International Electrotechnical Commission,[50] but not during the operational life of an installation. Certification in this sense is more closely analogous to conformity assessment under EU product legislation, but is often undertaken to give assurance to a commercial counterparty as a contractual requirement rather than in order to comply with legislation.

However, in some cases, commercial counterparties will require that checks be carried out during a project's operational life to ensure that it continues to meet the criteria for certification, and some classification societies provide this service (for example, within the framework of the IEC System for Certification to Standards relating to Equipment for use in Renewable Energy applications (IECRE)).[51]

The UK's Offshore Wind Innovation Hub has a project on the application of standards, regulation, project certification and classification, and expects to publish a summary report on this subject in Q2 2021 which should be of use to the floating offshore wind supply chain.

Finally, in these debates that in some ways reflect historic legal and institutional frameworks, it is important not to lose sight of the bigger picture. Like the rest of the world, the shipping and energy industries are getting to grips with the game-changing potential of digitalisation. In the digital world, where data from sophisticated sensors embedded within complex engineering systems can be monitored remotely in real time, the idea of choosing between just checking at the manufacturing or installation stages and periodic physical inspections during the operational phase, or between different intervals between such inspections, may begin to look archaic. Of course, there will be a cost to those remote data feeds and, in some cases, there may be no adequate substitute for physical inspection by a human being, but the information that comes from embedded sensors will also serve other purposes beyond the evolution of certification and classification.

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50 For example, IEC TS 61400-3-2:2019, Wind energy generation systems – Part 3-2: Design requirements for floating offshore wind turbines (available here).

51 See here (section 7.17 of the document).

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